USER'S MANUAL FOR

LRFD ABUTMENT AND RETAINING WALL ANALYSIS AND DESIGN (ABLRFD)

pennsylvania

DEPARTMENT OF TRANSPORTATION

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USER'S MANUAL FOR
COMPUTER PROGRAM ABLRFD
LRFD ABUTMENT AND RETAINING WALL
ANALYSIS AND DESIGN
Version 1.20.0.0

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Imbsen & Associates, Inc. for
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LRFD ABUTMENT AND RETAINING WALL ANALYSIS AND DESIGN

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SUMMARY OF JUNE 1999 REVISIONS - VERSION 1.2

This release of ABLRFD Version 1.2 contains the following error corrections and enhancements:

1. All dates have been modified to display a 4 digit year in the output file.

2. The default value for reinforcement grade in SI units has been changed to 420 MPa and the upper limit for reinforcement grade has been changed to 450 MPa.

3. The program now uses soft metric reinforcement (the dimensions and data of US units bars converted to SI units) as per PennDOT standard drawing BC-736M-1-A. The true SI units reinforcement that was allowed in the previous version has been disabled.

The program has been converted to the Digital Visual Fortran Version 6.0B compiler as a Win32 application. It will run on Windows 95, Windows 98 and Windows NT Version 4.0 operating systems. It will NOT run under the DOS 6.22 or below operating systems.

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SUMMARY OF MARCH 2001 REVISIONS –VERSION 1.3

Since the release of ABLRFD Version 1.2 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.3 corrects the following known problems and provides enhancements. The following list describes the changes made to the program.

ABLRFD Version 1.3 contains the following revisions:

1. Revised the moment calculation to properly take into account the effect from changing the “Bearing Location Y” on the AT1 and AT2 commands.

2. Changed the ARE and SRA commands for the upper limit of Area per Unit Width parameter to 8500 $mm^2$to be consistent with the US unit upper limit.

3. Revised the program so that foundations with battered piles or caissons can be run without entering the strength and service lateral capacities.

4. Revised output messages, for a spread footing on rock run that fails to obtain a design, to clarify that sliding is not checked when “N” is entered for the Sliding Resistance on the RCK command.

5. Revised to make the program to run when the user-input minimum footing width is exactly equal to the sum of the user-input toe plus the user-input heel plus the stem width at the top of the footing.

6. Revised the default values of Toe End Cover and Heel End Cover to 2” (50mm) for the CVR command in accordance with BD-631 and BD-632M.

7. Enhanced the program so input files do not have to reside in the same directory as the executable file.

8. Revised the program so it can run under Windows 2000. It should also run under Windows 9x, and Windows NT.

9. Revised the program to use unfactored horizontal and vertical loads when computing the inclination factors and use B’ and L’ when determining if the footing is continuous.

10. Revised the default for the Top Width parameter for the AWB and RWL commands to 1'-5.25" in accordance with BD-624M.

11. Revised the program to work properly for parameter 4 of the EQL command.

12. Clarified several error messages.

13. Several pages of the User's Manual have been revised including a new Chapter 9.

14. The parameter definition file is now named as ABLRFD.PD. Previously it was using the .PDF file extension that would cause confusion with the Acrobat Adobe file.

SUMMARY OF SEPTEMBER 2003 REVISIONS - VERSION 1.4

Since the release of ABLRFD Version 1.3 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.4 contains the following revisions and enhancements.

1. A user input horizontal live load has been added to be applied on the Backwall (Request 10)

2. The output routines have been revamped to decrease program size and to allow easier modification. A blank page that appears when no warnings are present at the end of the input echo has been removed (Request 11).

3. The program does not stop with an error if the height of backfill is zero at the analysis point for a design run (Request 27).

4. Two new user inputs have been added to the FTG command that allows the user to control the increments that the program uses to increase the footing width and thickness. These can be used to speed up the program for a design run (Request 29).

5. Significant modifications have been made as to how settlement is calculated for foundations on cohesive soil and a "Detailed Consolidation Settlement" report has been added to the output. (Requests 30, 112).

6. A copyright notice has been added to the program output for use during beta testing (Request 31).

7. The pile selection process has been modified to utilize all possible pile patterns (Request 32).

8. The bearing capacity routine has been modified so that if at least one soil layer has no cohesion, but has an internal angle of friction, the N_{cq} does not have to be entered on the SOI card (Request 34).

9. A user input horizontal wind load acting on the substructure has been added to the program (Request 35).

10. Additional compiler settings in Visual Fortran have been activated to trap divide by zero errors (Request 36).

11. The Average Load Factor is now being shown in the Foundations section of the Factored Load Table in the output (Request 40).

12. The program now calculates the area of reinforcement correctly for backwalls (Request 42).

13. The water pressure part of the saturated backfill is now factored as a water load and it is no longer considered as a component of the horizontal earth pressure. The horizontal earth pressure equations have been modified to better model the application of the forces upon the structure (Request 53).

14. The program now checks the height difference between the front and back water levels to assure that it complies with DM-4 3.11.3. Also, the program will verify that the back water level depth does not fall below the bottom of soil layer(s) for spread footings, or bottom of footing for all foundation types on rock. (Request 56).

15. The footing moment calculation for final surcharge has been corrected when temporary surcharge is entered as zero. This applies to Live Load and Earth Surcharge (Request 71).

16. The minimum water differential between the front and back water levels for US units is now considered as 3’-0” instead of 3’-3”. (Request 98)

17. The User's Manual Chapter 5 description of the MRD Parameter 2 (Development Length Correction Factor) was modified to exclude reference to epoxy coating. Epoxy coating is already considered for development length calculations in the program and should not be entered by the user (Request 101).

18. The metric values for moist and saturated density of backfill have been updated to be in accordance with DM-4 Section 3.11.5.5 (Request 108)

19. The bearing capacity routines now consistently use the absolute value of eccentricity when calculating effective footing width. For the case of negative eccentricity, this prevents the effective footing width from exceeding the actual footing width. (Request 111).

20. The program has been revised to use the height of stem measured to the top of footing when computing stem forces and moments. Previously the height of stem measured to the bottom of footing was used. For retaining walls the program reports results for both Temporary and Final Construction Stages. Because the Temporary Construction Stage will not control for Retaining Walls, the lateral earth pressure (EH) is computed only for the Final Construction Stage. This lateral earth pressure is then applied to the Temporary Construction Stage (Request 113).

21. For retaining walls, the method of computing lateral earth pressure for broken backfills has been revised to use a backfill soil with an internal friction angle $\varphi = 33^{\circ}$ and the broken backfill calculations have been documented in the User's Manual. Input items have been added to the Materials (MAT) input command for "Backfill Friction Angle", "Backfill Unit Weight Dry ", "Backfill Unit Weight Saturated ", and "Minimum Equivalent Fluid Pressure". The Active Earth Pressure Coefficient (Ka) is now calculated separately for

Stem and Foundation earth pressure calculations, and a "Lateral Earth Pressure Intermediate Values" report has been added to the output (Request 114).

22. A tolerance has been added to the front and back water height check to eliminate a false warning message (Request 117).

23. The program has been revised to assign the proper soil category when computing Soil Bearing Capacity for Category 3 (sand over clay) when the shear zone is less than the soil height. (Request 118)

This is a list of error corrections and or enhancements that are known but will be implemented in a later version:

1. A minimum value of tension will be allowed in caissons and piles. (Request 13)

2. The backfill material properties will become user input items. They are currently hard coded in as system parameters (Request 43).

3. The J-bars protruding from footings in to the stem will be epoxy coated regardless of whether the user specifies epoxy coated bars or not as per DM-4 Section 5.4.3.6P (Request 44).

4. The concrete density will become a user specified input item. The user will have to specify two concrete densities. One will be used for calculating the Modulus of Elasticity, the other will be for load considerations (Request 45).

5. The following revisions will be made to conform to DM-4 2000 specifications and standards.

    a. Increase the maximum value for the Temp. ES on LDC card by 10 ft (3.05m). Update pp. 3-25 and 3-26 of manual to be consistent with nomenclature of 2000 DM-4 (Request 47).

    b. Use equations for active earth pressure coefficient rather than table of values (Request 48, 49).

    c. Revise elastic settlement for foundations on stiff cohesive soils - refers back to Eq. D10.6.2.2.3b-1. Update p. 3-40 of manual to reflect the use of equation D10.6.2.2.3b-1 for the case of stiff cohesive soils. Add μ_o from equation D10.6.2.2.3b-1 to input under SOI or CNS input commands (Request 50)

    d. Update manual (Section 3.5.2.9) and program to accommodate new equation for d_v. If Eqn. A5.7.3.3.1 is satisfied for the section, it is under reinforced or balanced and d_v should be computed when no prestressing is present (as in abutments) (Request 52).

6. The reinforcement modification factors will conform to AASHTO Article 5.11.2.1.3 and 5.11.2.4.2. (Request 55, 82)

7. Reinforcement design algorithm will be optimized and the design reinforcement output will be clarified (Request 57, 99)

8. Increment width before thickness in footings for a design run to speed up execution. (Request 60)

9. The program will be revised to correct unit conversion errors for input items in the LAB, LRT, DLL, SLL, and EQL commands. (Request 61)

10. The Wind Load Factor (WL) will be modified to 1.0 for both service and strength limit states. (Request 66)

11. A negative 2” eccentricity will be applied at the bearings for the minimum load case. Currently the positive 2” eccentricity is applied for both the maximum and minimum load cases (Request 69).

12. The program will calculate moment resistance based on Temperature and Shrinkage steel when a negative moment is detected in the stem. (Request 80)

13. Pile Group Resistance will be shown as “kips(kN)/unit length” versus the current output which is “resistance per unit width of structure”. (Request 83)

14. A new Friction Force Input item will be added. The friction force will be applied at the bearings. (Request84)

15. The program will be revised to only apply the Development Length Reduction Factor once. Currently, the factor located on the MRD card Parameter 2 is applied twice. To apply a correction factor correctly, the user should enter the square root of the Correction Factor to be used. (Request 101)

16. The maximum shear in a footing on piles/caissons will be evaluated at various points of interest within piles located in the toe/heel projection. Similarly the maximum shear in a spread footing will be evaluated at incremental points along the toe/heel projection Currently the program assumes the critical shear location at the back face of the stem or an effective depth away from the stem depending on the sign of the moment. Until this revision is implemented, the user must perform hand computations to check the maximum shear in the heel/toe projection. Refer to PennDOT e-Notification ABLRFD No. 1 for further details. (Request 110)

17. The program will be revised, for piles, to check that the ratio of unfactored vertical load to horizontal load is not be less than 3.5 (excluding seismic forces) as specified in Section 6.15.1P of DM-4 (Request 115).

SUMMARY OF NOVEMBER 2004 REVISIONS - VERSION 1.4.0.3

Since the release of ABLRFD Version 1.4 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.4.0.3 contains the following revisions and enhancements.

1. The 1.4 top footing bar development length correction factor is now only applied to footing bars which have 12 in (300 mm) of concrete beneath them. The user entered development length correction factor is now only being applied once in the program. The cover for stem J-bar development length calculations is now using the correct stem clear cover value (Request 55).

2. The program has been modified to use an optimized design process for all foundation types. The optimization has decreased the amount of trial footing sizes required to find an economical design (Request 60).

3. The User's Manual has been modified to reflect the proper units for loads applied to abutments and retaining walls. The new unit conveys that the force is applied per unit of width (Request 61,128).

4. The program has been enhanced to compute shear in the heel at multiple locations to enable it to detect the maximum shear in the heel and corresponding location for both spread and pile foundation types. Also, the vertical component of the Lateral Earth Pressure is now considered a partial force being applied to the side of the footing (Request 110).

5. The unfactored vertical force to horizontal force ratio check, from DM-4 Section 6.15.1P, has been added to the program to check the Service loads on battered pile foundations. A warning will now be printed if the ratio check is violated (Requests 115).

6. The User’s Manual has been modified to indicate that the Saturated Soil Density must be entered for all soil types (Request 127).

7. The Temporary Stage Horizontal Earth Pressure calculations have been restored in the program for retaining walls (Request 129).

8. The maximum bar diameter is now being correctly utilized for pile foundation analysis runs where reinforcement is specified as area per width. This revision only affects crack control spacing calculations. Also, the spacing during an area per width analysis run is now being calculated rather than using the design width as the spacing for crack control calculations (Request 130).

9. A typographical error has been corrected for a Backfill related input check warning messages (Request 131).

10. The User's Manual has been revised to better document the direction of the "Wind On Substructure" load that is applied to the substructure (Request 132).

11. Chapter 6 of the User's Manual has been revised to correct the typical range limits on the Concrete Rock Friction Angle parameter (Request 134).

12. When the bearing pressure lies entirely within the toe projection of a foundation, the program has been modified to resize the foundation during a design run, and provide a more meaningful warning message during an analysis run (Request 142).

13. The program is now choosing the optimum footing size with the smallest toe projection rather than the largest toe projection. Also, a range of acceptable toe projections is now shown in the Footing Geometry output table during design runs (Request 146).

14. Original Ground Slope input check warning messages have been revised to provide a more informative message. Also, duplicate messages have now been eliminated (Request 154,155).

15. The User's Manual has been modified to show the correct Equation 4 in Section 3.6.1(Request 157).

16. The load factors in Section 3.3.4 Tables 1 and 2 of the User's manual have been corrected to match the program (Request 161)

17. The upper limit of the Live Load Upward force on the DLL command has been changed to error if a value above zero is entered. This change was made to prevent the force from being improperly applied by the program (Request 162).

18. The water differential warning messages have been enhanced to more clearly indicate that 3 ft (1 m) is the typical value used for design when the differential is greater than 3 ft (1 m) (Request 165)

SUMMARY OF APRIL 2006 REVISIONS - VERSION 1.4.0.4

Since the release of ABLRFD Version 1.4.0.3 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.4.0.4 contains the following revisions and enhancements.

1. The program was revised to allow the top of rock layer to be equal with the top of the footing. Previously the program would halt with an error for this condition (Request 196).

2. The angle (s_r) of the partial earth pressure applied to the heel (P_{a1}), used in the internal Footing EH-V calculations from User's Manual Section 3.3.2.5.2, was corrected for the Coulomb failure method. Previously, for the Coulomb method the program would calculate a lesser Internal Footing EH-V force due to the use of the incorrect angle which could lead to unconservative perpendicular heel reinforcement. The Rankine method is unaffected by this revision (Request 196).

3. The program has been modified to use the correct Ka value for the Internal Footing EH-V force calculation for the temporary stage. Previously the program would use the final Ka value for both the temporary and final stage Internal Footing EH-V calculations (Request 202).

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SUMMARY OF JULY 2006 REVISIONS - VERSION 1.5.0.0

Since the release of ABLRFD Version 1.4.0.4 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.5.0.0 contains the following revisions and enhancements.

General Revisions

1. The program now supports long file names (Request 125).

2. The program has been enhanced so temporary files are now created on the local drive for network compatibility (Request152).

3. The wind on live load and Extreme-I earthquake load factors have been modified to match DM-4 (Request 66,138,161,167).

4. The number of heel shear analysis points has been changed from a fixed number of 50 point to dynamic amount based on the footing geometry in an effort to reduce the program processing time (Request 200)

Input Revisions

5. Two new inputs for concrete density have been added to the program to store a density for self weight calculations and a second density for modulus of elasticity calculations (Request 45, 87).

6. A new friction force has been added to the program and is applied at the bearings (Request 84).

7. The Ductility, Redundancy and Operational Importance Limit State factors found on the LDC card have been modified so the default values are 1.0 as per DM4-2000 Section 1.3 (Request 88).

Output Revisions

8. The pile pattern output table has been relocated in the output to follow the footing geometry table (Request 86).

9. The footing volume units on the Pile Pattern output table have been changed to ft^3 (m^3) from piles/foot (piles/m) (Request 168).

10. The program has been modified to use more descriptive headers in the output tables for Factored Forces and Controlling Forces (Request 58).

11. The program has been modified to output an intermediate bearing resistance values output table (Request 77).

Reinforcement Revisions

12. The main stem bars entering the footing are now always considered as epoxy coated for design runs as per DM-4 2000 Section 5.4.3.6P (Request 44).

13. The backwall calculations have been modified to work properly when reinforcement is entered as areas per width (Request 79).

14. Temperature and Shrinkage reinforcement in the front face of the stem is now considered for moment resistance when the applied moment in the stem is negative (Request 80).

15. An informative error message is now shown when a stem reinforcement bar cannot be developed within the footing during a design run. Previously the program would crash. (Request 133,140).

16. The program has been modified so the minimum spacing check considers the clear spacing between bars (Request 164).

17. The program has been modified so the user may specify an allowable minimum spacing and bar spacing requirement (Request 186).

18. The #10 SI reinforcement bar is no longer considered during design runs (Request 187).

Development Length Revisions

19. The program has been enhanced to consider hooked bars for the perpendicular reinforcement in the footing during a design run if selected by the user (Request 185a).

20. The program has been enhanced to show development length information for perpendicular footing bars during analysis runs when a bar size and spacing are used. Previously analysis runs did not produce output for development length information (Request 185b).

21. The program has been enhanced to allow users to specify if hooked reinforcement bars are used in the perpendicular direction of a footing during analysis runs (Request 185c).

22. The 0.8 limitation on the Area of Steel Ratio factor used for development lengths has been removed (Request 185d).

23. The program has been enhanced to display a status code when the design spacing has been modified to meet development length requirements during a design run (Request 185g).

24. The program User's Manual has been enhanced to provide a more detailed description of the Development Length Correction factor on the MRD command for Chapter 5 (Request 185h).

25. The program has been modified to provide the area of steel required and the area of steel provided so the user can more easily verify the development length calculations (Request 185i).

Settlement Revisions

26. The length of the footing used for the second soil layer has been stored and is now used for settlement calculations (Request 72).

Footing Revisions

27. The footing volume units on the Lateral Loads / Pile Group Lateral Resistance Table have been changed to indicate the force is per unit width (Request 83).

28. The correct angle is now used in calculation of the partial EH-V force for footings. The angle is now based on the ratio of K_{av} over K_{ah} rather than the backfill slope angle. Also the top of rock layer height can now be set equal to the top of the footing. (Request 171).

Pile Revisions

29. The program has been modified so the minimum footing width for pile/caisson foundations is based on the minimum layout dimensions along with the normal footing minimum dimensions (Request 136,195).

30. The program has been modified so the lateral capacity of pile/caisson input is only required for an all vertical pile/caisson foundation (Request 177).

31. The program has been modified to correct an insufficient battered pile/caisson layout selection (Request 181)

32. The program has been modified to provide a warning message when over 50% of the piles/caissons in the last row of an analysis run have been specified as battered (Request 182).

Stem Cutoff Revisions

33. A note for the Reinforcement Design Details tables has been modified to clarify that the theoretical cutoff is when every other bar is no longer required (Request 184b).

34. The Reinforcement Design Details tables has been modified to include a code to indicate which extension length criteria controls (Request 184d).

35. The program has been modified to provide crack control information for each bars cutoff location (Request184e).

36. The program was modified so factors shear resistance for the stem cutoff locations will now appear in the Shear Results table and rather than the Reinforcement Design Details table (Request 184g).

User's Manual Revisions

37. The variable notation used for active earth pressure coefficients have been changed to match notation used in DM-4 (Request 47).

38. The default value for the Minimum Equivalent Fluid Pressure in Chapter 5 Section 5.17 has been changed to match the default value the program is currently using (Request 174).

39. The example input files have been modified so warning messages will not appear in the program output. Chapter 8 of the User's manual is now formatted to match the Input Summary table from the output (Request 175).

40. The program User's Manual has been modified to correct a typographical error in Section 3.6.1 (Request 170).

41. The program User's Manual has been modified to define delta as the rock/friction angle (Request 144).

42. The program User's Manual has been modified to indicate that a minimum water differential is still required when the water level is below the bottom of the footing for the Back Water Level input value on the AT1, AT2, AWB, and RWL cards (Request 213).

Engineering Assistant Revisions

43. The Engineering Assistant figures have been modified to include descriptive captions (Request 158).

44. The correct figures have been inserted for the LYD command in the Engineering Assistant configuration files (Request 183).

Programming Revisions

45. The program has been converted to be a Windows DLL (Request 126).

46. The program has been modified so blank information is returned as output if the ABLRFD DLL is used with the APRAS run option (Request 179).

47. The program has been converted to Intel Visual Fortran (Request 190).

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SUMMARY OF JANUARY 2007 REVISIONS - VERSION 1.5.0.1

Since the release of ABLRFD Version 1.5.0.0 several revision requests have been received. This release of ABLRFD Version 1.5.0.1 contains the following revisions.

1. The heel shear at the face of the stem has been corrected to use the partial Vertical component of the Horizontal Earth Pressure (EH-V) force. Previously, the program was incorrectly using the EH-V force calculated from the full height of the abutment or wall (Request 233).

2. The program has been modified to prevent debug messages from being displayed while the program is running (Request 231).

3. The program has been revised so 50 points of analysis are now used to determine the maximum shear within the heel of the footing (Request 239).

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SUMMARY OF APRIL 2007 REVISIONS - VERSION 1.6.0.0

Since the release of ABLRFD Version 1.5.0.1 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.6.0.0 contains the following revisions and enhancements.

Input Revisions

1. An input check has been added to the program for pile/caisson foundation analysis runs which ensures that the parallel reinforcement cover entered on the CVR command will not cause interference with the adjacent perpendicular reinforcement. (Request 238)

2. An input check has been added to the program for pile/caisson foundations which checks the distance between the face of the pile and the footing edge to ensure the minimum distance from DM-4 is not violated. The program will continue with a warning message for analysis runs and halt with an error message for design runs. (Request 242)

Output Revisions

3. The program has been modified to correct an erroneously displayed status code in the crack control tables. The “spacing less than minimum allowed” status code was being displayed at all times. (Request 225)

4. The program has been modified to indicate which stem locations have cracked in the “Crack Control – Analysis/Design” output table. When this occurs the message provides instructions on how the user should proceed. (Request 237)

5. The “Footing Stability On Pedestal” table has been revised to show all Service load cases and stages for the pedestal sliding check. Previously only the maximum case final stage was checked. (Request 243)

Reinforcement Revisions

6. The crack control equations have been modified in the program to conform to DM-4. The exposure input parameters on the MRD card have been changed from Normal to Class 1 and from Severe to Class 2 to comply with DM-4. Input files created before v1.5.1.0 will require modification. (Request 199)

7. The program has been modified to calculate a spacing for use with serviceability checks when the reinforcement is entered as an area per width. (Request 197)

Footing Revisions

8. The moment assumption criteria has been replaced with a moment direction criteria in the “Internal Footing Forces” table. Previously, the moment assumption defined a positive moment as causing the bottom steel in the toe and the top steel in the heel to be in tension and was indicated by an “OK” or “NG” in the output. The “NG” could be confused with a design or analysis failure. Now, the moment direction criteria define moment direction as a number which indicates whether the top or bottom of the toe or heel is in tension. Also the program has been revised to determine if a negative moment will control for the perpendicular reinforcement check in a footing. (Request 172,173)

9. The program has been modified to perform an analysis of a footing without a toe or heel projection. Previously the program would crash if the toe or heel projection had a zero dimension. Also the program can now perform a design of a footing without a heel. (Request 193)

10. The program has been revised to use a tolerance when checking minimum pile edge distances. This prevents a warning message from appearing under certain conditions when the measurements are close. (Request 198)

Load Factor Revisions

11. The program has been modified so the correct load factors for LLDD, LLDU, LLBW, LLBH for the Extreme-I limit state are now being used by the program in accordance with DM-4. (Request 066)

User's Manual Revisions

12. The User's Manual has been revised to indicate that the program assumes the connection between a pedestal and the footing is integral through the use of transverse shear keys and dowels. (Request 188)

13. The User's Manual has been revised to remove the reference to keyed footings in Section 6.19.4. (Request 189)

LRFD ABUTMENT AND RETAINING WALL ANALYSIS AND DESIGN

SUMMARY OF FEBRUARY 2008 REVISIONS - VERSION 1.7.0.0

Since the release of ABLRFD Version 1.6.0.0 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.7.0.0 contains the following revisions and enhancements.

Input Revisions

1. A new input has been added to the OUI command to show the Factored Forces and Moment Axial Interaction Forces for each designed stem bar at the cutoff location. Previously the program would only show these forces for the largest cutoff stem bar. (Request 184k)

2. The program has been revised to allow up to 512 characters to be entered on an input command line. (Request 194)

3. The program has been revised so a warning message is shown if the Datum is set on the CTL command for an analysis run. (Request 221)

4. New input items for the “Loads on Retaining Wall (LRT)” command have been added to the program. The new loads allow for the addition of dead load due to a noise wall and wind on an external structure. (Request 224)

5. The upper limit of the DC load on the LAB command has been increased to accommodate higher loads. (Request 246)

6. The program has been revised to properly calculate the default minimum footing width when the toe and/or heel projection inputs on the FTG command are left blank for pile/caisson design runs. Previously, under certain conditions, the calculated minimum footing width could be incorrect which would cause the program to stop with an error. (Request 262)

Output Revisions

7. The program has been revised so cutoff information will not be shown in the “Reinforcement Design Details” Table for stem bars which cannot be cutoff. (Request 184j)

8. The “Reinforcement Summary for Design” output table for pedestal foundations has been restored in the program. This output table was accidentally disabled starting with ABLRFD Version 1.4. (Request 191)

9. A Specification Check Warning and Specification Check Error Table have been added to the ABLRFD program. (Request 222)

10. The program has been enhanced so the eccentricity check will now be shown in the output tables as an allowable eccentricity and an eccentricity performance ratio. (Request 223)

11. An error message relating to footing width in the output has been revised so the message will not be truncated. (Request 226)

Stem Cutoff Changes

12. The program has been modified so the Type II Abutment will now set stem locations at quarter points using the seat level as the top of stem. Previously the program would set Stem Location A at the stem notch and then set the remaining stem locations at third points. (Request 184h)

13. The program has been enhanced to consider the weight of stem bars including cutoffs when determining the most economical bar size and spacing during a design run. (Request 184i)

User's Manual Changes

14. A typographical error has been fixed in User's Manual Section 3.4.1.3.1 to correct a referenced DM-4 Article. (Request 234)

15. Documentation has been added to User's Manual to describe the Footing Stem Increment parameter on the FTG Command. (Request 250)

16. The DM-4 and AASHTO Section 10 references in the ABLRFD program have been updated. (Request 261)

SUMMARY OF DECEMBER 2008 REVISIONS - VERSION 1.8.0.0

Since the release of ABLRFD Version 1.7.0.0 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.8.0.0 contains the following revisions and enhancements.

Input Revisions

1. The program has been revised to calculate a minimum cover value for parallel reinforcement in the footing for design runs. The calculated value is compared to the user entered cover with the larger value being shown in the “Input Summary” Table and used in all design calculations. Previously, the program would permit the perpendicular and parallel bars to be in the same plane. The program was also incorrectly displaying the default cover values for parallel reinforcement during a design run on the “Input Summary” Table while continuing to use the user entered value for all deign calculations. (Requests 252, 268)

2. The program has been revised so stem batter values can be left blank or set to zero without causing the program to halt processing. Previously, entering a zero for a batter component would cause the program to crash. (Request 230)

3. The program has been revised to allow for the design of a substructure without a toe projection. Previously the program would only allow a design with a 1 foot minimum toe projection. (Requests 100, 266)

4. The Y distance to Wind Load on External Structure parameter on the LRT command has been revised so the program upper limit now matches the value documented in the User's Manual. (Request 279)

5. The upper limit of the Downward Live Load parameter on the DLL command has been increased to 10 kip/ft (150 kN/m). (Request 280)

Output Revisions

6. The Footing Flexure table has been revised to indicate which minimum reinforcement condition controlled for a design run if minimum reinforcement controls. (Request 059)

7. The program has been revised to eliminate the soft classification for rock foundations and to now report the maximum bearing pressures for all rock foundations. Previously, the program would report uniform bearing pressures if the Modulus of Elasticity of the Concrete exceeded the Modulus of Elasticity of the rock. (Request 109)

8. The headings for the “Specification Check” table have been revised to correctly reflect with verbiage when errors or warnings have been found. Previously, the program had fixed headers which would cause confusion with verbiage not matching the presence or lack of errors/warnings. (Request 271)

Loading Revisions

9. A new load has been added to the program to account for the weight of an Architectural Treatment placed on the front face of an abutment or wall. (Request 253)

Serviceability Revisions

10. The program has been revised to properly indicate when a section is cracked on the “Crack Control” table for analysis runs. Previously, under certain circumstances, the program would indicate a section was not cracked even when an actual stress was being reported. (Request 247)

11. The program has been revised to prevent an erroneous status flag for allowable spacing from appearing in the “Crack Control” table for analysis runs when a stem section has cracked. Previously, under certain conditions, the program would report a spacing failure even when the actual spacing was less than the allowable. (Request 273)

General Changes

12. The program has been modified so the effective footing width cannot be less than zero. Previously, for certain input files, the effective footing width could become less than zero leading to a program crash. (Request 248)

13. The program has been modified to print to the screen the range of B’ values for a footing width which causes an L’ over B’ < 1 warning during a design run. This change greatly reduced the amount of warning messages printed to the screen. Previously, the program would print one line to the screen for each iteration of a footing width design (Request 263)

14. The program has been modified to allow a zero length toe/heel projection in the water force calculation routine. Previously, if a zero projection was encountered, the program would output a cryptic warning message. (Request 264)

User's Manual Changes

15. Chapter 3 of the User's Manual has been modified so all effective consolidation stresses are annotated with a prime character. (Request 123)

16. The contact information in Chapter 9 has been updated to reflect the new organizational name changes at PennDOT. (Request 270)

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SUMMARY OF FEBRUARY 2010 REVISIONS - VERSION 1.9.0.0

Since the release of ABLRFD Version 1.8.0.0 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.9.0.0 contains the following revisions and enhancements.

Input Revisions

1. An input check has been added to the program to check if the bottom of the footing is located above the top of the rock layer. If it is, then an error message is printed in the output to provide a recommendation for how this issue can be corrected. Previously, a cryptic error message was displayed indicating a negative embedment depth. (Request 254)

2. An input check has been added to the program to ensure that parallel reinforcement information has not been added for a spread footing analysis run. Previously, the program would provide a cryptic warning message and terminate. (Request 276)

Output Revisions

3. The program has been revised to now list the title and page number in the Specification Check Warning and Error tables for each occurrence of a warning found in the Moment Axial Interaction table. Previously, the program would only display the title and page number for the last stem location even when no problem occurred at the location. (Request 277)

4. The program has been enhanced to generate a PDF file for each output file. When possible, the PDF file contains bookmarks for easier navigation of the output. The PDF file also makes it easier to print and paginate the program output. (Request 284)

5. The program has been modified to pass a crack control warning for analysis runs to the specification check output when applicable. Previously, the program was not reporting this warning. (Request 292)

Loading Revisions

6. The Wind on Substructure force has been revised to distribute the user entered force vertically along the face of the wind area. For stem locations, the program will determine the applicable wind area and use the magnitude of the calculated distributed force to determine the wind load. The Wind on Substructure force is now applied for both the Temporary and Final stages and can be applied in both the positive or negative direction. Previously, the program would incorrectly calculate the Wind on Substructure moment for the Stem Locations. (Request 286)

Settlement Revisions

7. The program has been revised to prevent maximizing the H/B' ratio when calculating the Elastic Settlement Factor in Figure 3.4.1.3.1-1 for a Strong over Weak Layer soil condition. Previously, the program would maximize this ratio which could lead to large calculated settlement values for Strong over Weak Layer soil conditions (Request 287)

Serviceability Revisions

8. The program has been modified to account for 1 inch of foundation unevenness at the bottom of the footing when calculating the crack control spacing. Previously the program would use the entire cover dimension when calculating the crack control spacing. (Request 291)

General Changes

9. The ABLRFD program has been revised to no longer support SI unit input files. This is based on a decision by AASHTO Subcommittee on Bridges and Structures to no longer publish updates to the SI unit version 2007 AASHTO LRFD Bridge Design Specifications. (Request 290)

Pile Foundation Changes

10. The pile pattern design algorithm was investigated to determine why changing the percent battered piles in the last row for a design run would cause the program to change from a 2 row pattern to a 4 row pattern. It was determined that including battered piles in the last row increased the calculated pile spacing in row 1 which caused the pile pattern to fail for punching shear and meant the program rejected the pattern. A future revision to ABLRFD will attempt to reduce the pile spacing in row 1 when a reinforcement failure is detected in an effort to generate a good design for the pattern. The workaround is to make two design runs, one with 0% battered piles in the last row, and one with 50% battered piles in the last row, and to use the design with the least number of pile rows. (Request 288)

11. The program has been revised to now resize a pile foundation design if the ratio of the unfactored vertical and horizontal service loads is less than 3.5. Previously, the program would only provide an output message that the criteria had failed without changing the foundation design. Also revised program to perform ratio check for caisson foundations during analysis runs. (Request 115)

SUMMARY OF MARCH 2011 REVISIONS - VERSION 1.10.0.0

Since the release of ABLRFD Version 1.9.0.0 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.10.0.0 contains the following revisions and enhancements.

Input Revisions

1. An input check has been added to the program to check if the back water level is above the backfill at the stem/backfill interface. Previously, a cryptic error message was displayed stating that the back water level was above exposed stem. (Request 296)

Output Revisions

2. The program output has been revised to properly indicate the absence of a toe or heel during an analysis run and to prevent specification check flags from being set erroneously. (Request 267)

Loading Revisions

3. The program has been revised to apply a 2 inch eccentricity towards the heel for vertical bearing loads when designing or analyzing the stem for the minimum load case. Previously, the program would always apply a 2 inch eccentricity towards the toe for vertical bearing loads for both the maximum and minimum load case when designing or analyzing the stem. The eccentricity towards the toe is still applied for the maximum load case (Request 69)

Pile Foundation Changes

4. The pile pattern design algorithm has been revised to now reanalyze a pile pattern at a reduced row spacing if the pattern was found to fail due to punching shear. Previously, the program would just increment to the next pile pattern which cause large increases in the number of pile rows when the Last Row % Batter parameter was increased on the LYD command. (Request 288)

User's Manual Changes

5. The Elastic Modulus parameter on the RCK command has been renamed to Intact Elastic Modulus for consistency with DM-4 and for clarification of which elastic modulus to enter in the program. (Request 306)

6. The description of the Soil Level at Toe parameter on the SOI command in Chapter 5 has been expanded to include a description of how the program uses the input value. (Request 307)

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LRFD ABUTMENT AND RETAINING WALL ANALYSIS AND DESIGN

SUMMARY OF AUGUST 2012 REVISIONS - VERSION 1.11.0.0

Since the release of ABLRFD Version 1.10.0.0 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.11.0.0 contains the following revisions and enhancements.

General

1. The ABLRFD program has been updated to the AASHTO LRFD Bridge Design Specifications Fifth Edition 2010 and the 2012 PennDOT Design Manual Part 4.

2. The program has been revised to prevent a design run with all vertical pile/caisson foundation from getting stuck in an infinite loop when punching shear controls during the footing design. (Request 345)

Input Revisions

3. Addition information has been added to the existing error message when the layout of piles is outside the footing width. The new information includes the footing width, the distance from the front of the footing to the first pile row and the distance from the last pile row to the end of the footing. Previously, a cryptic error message was displayed stating layout of piles was outside the footing width with no additional information. (Requests 297)

4. The Number of Pile Rows parameter on the LYA command has been revised so a minimum 2 rows of piles are required. Previously, the program would allow for entry of 1 row of piles but would result in errors. (Request 311)

5. The input check for back water level above the backfill has been revised so the check is not performed when the back water level is left to default. Previously, the program would perform this check when the backwater level was left to default and would stop with an error. (Request 314)

Loading Revisions

6. The Horizontal Earth Pressure load (EH) has been revised to apply the resultant at 1/3 times height of the soil. Previously, the program would apply the resultant at 0.4 times the height of the soil. (Request 321)

7. The program has been revised to issue a warning when ETA factors other than 1.0 are entered. (Request 324)

8. The program has been revised to no longer apply Live Load Surcharge in the Extreme I limit state. (Request 327)

Backwall Revisions

9. The program has been revised to correctly calculate the backwall section depth when the paving notch height extends below the mid-height backwall location. (Request 341)

Flexural Revisions

10. The Flexural Phi factor has been revised to comply with the 2010 AASHTO LRFD Specifications. The phi factor now varies linearly based on the strain in the section. Also, the moment axial interaction envelope has been revised to include the tension controlled strain point and the point based on $0.1A_{gross}f'_c$. has been removed.(Request 319)

11. The shrinkage and temperature reinforcement calculations for Serviceability have been revised to comply with new shrinkage and temperature reinforcement specifications In the 2012 DM-4 Article 5.10.8 and the 2010 AASHTO LRFD Specifications. (Request 320)

Spread Foundation Revisions

12. The elastic settlement of foundations on rock has been revised to meet the specifications in the 2010 AASHTO Article 10.4.6.5. The program will now calculate the elastic settlement based on either the Rock Mass Rating (RMR) or the Elastic Modulus Reduction Factor (E_m/E_i) and Joint condition. Previously the program would only use the Rock Quality Designation (RQD) with an assumed joint condition for elastic settlement. (Request 322)
    NOTE: this change requires that any previously existing input files using the Rock Data Command be updated because of additional input now required.

Development Length Revisions

13. The program has been revised to remove the bar cover and spacing development length extension factor to be compliant with the 2010 AASHTO Article 5.11.2.1.2. (Request 325)

Program Source Revisions

14. The ABLRFD program has been updated to the Intel Fortran Composer XE 2011 Compiler. (Request 312)

User's Manual Revisions

15. The equation for cohesion used in the calculation of sliding resistance on clayey-sandy soils, per 2012 DM-4 Article 10.6.3.4, has been revised to correct for the units. (Request 326)

16. The Load Factor Table 3.3.4.2-2 in Chapter 3 has been revised to indicate that the Earthquake and Collision Force loads are applied for both the minimum and maximum cases. Previously, the table indicated that the forces were only applied for the maximum case. (Request 328)

17. The detailed description in Section 6.12.4, for the PIL command Service Axial Capacity parameter, has been revised to clarify the input for piles supported on bedrock. (Request 348)

Engineering Assistant Revisions

18. The Wind on Substructure parameter on the Loads on Abutment card in Engineering Assistant has been revised to allow for entry of negative values. (Request 302)

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LRFD ABUTMENT AND RETAINING WALL ANALYSIS AND DESIGN

SUMMARY OF APRIL 2013 REVISIONS - VERSION 1.12.0.0

Since the release of ABLRFD Version 1.11.0.0 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.12.0.0 contains the following revisions and enhancements.

Input Revisions

1. The program has been modified to produce an error when a Backfill Slope is defined and the Backfill Slope Height is set equal to zero on the RWL command. Previously, the program would calculate a Broken Backfill lateral earth pressure rather than the intended continuous slope lateral earth pressure. (Requests 304)

2. An input check has been added to the program to ensure the Backfill Slope does not exceed 1:1.5 when the Backfill Slope Height is entered on the RWL command. Previously, the program would allow the slope to exceed the specified maximum slope of 1:1.5. (Request 329)

3. The SLL Load Factor application has been revised to correctly apply the user input load factors for all the applicable load types. Previously, the program was using default load factors rather than the input factors from the SLL command. (Request 334)

4. The program has been revised to treat a pile as a vertical pile when both the horizontal and vertical pile batter values are entered as zero for pile batter on the LYA and LYD commands. Also, input checks have been added to ensure that a battered pile has both horizontal and vertical batter component values that are greater than zero. Previously, the program would stop execution with a cryptic error message when one or both of the batter component values was zero. (Requests 356)

5. The default value for the Stem Notch Width on the AT2 command has been revised to 20 inches. Previously the default value was 21 inches. (Request 359)

6. The upper limit of the Effective Friction Angle on the SOI command has been revised to be 45 degrees. Also, the upper limit for the $N_{\gamma q}$ input value has been revised to produce an error if exceeded. Previously, the Effective Friction Angle upper limit was 60 degrees and the program would issue a warning if the upper limit of the $N_{\gamma q}$ was exceeded. (Request 360)

Output Revisions

7. The $N_{\gamma q}$ value format in the Intermediate Bearing Resistance Values table has been revised to accommodate values up to 999.9. Previously the format field was limited to 99.99. (Request 330)

8. The units for Actual Stress on the Gravity Wall Stress Check Table have been revised to show ksf. Previously, the units were incorrectly shown as ksi. (Request 335)

Flexural Revisions

9. The program has been revised to provide over-reinforced warning messages for the stem and backwall locations and to also issue a warning in the Specification Check tables. Previously, the program would only show warnings for the footing only without indicating there was an issue in the Specification Check tables (Request 332)

Backwall Revisions

10. A new check has been added to the backwall calculations for analysis and design runs to verify that a lap splice with the stem bars has adequate room to develop within the backwall. Additionally, for a design run, the program will now set the spacing of the backwall reinforcement to either the optimum stem bar spacing or a multiple thereof. The new bar alignment option is activated by a new input on the AT1 and AT2 commands. Previously, the spacings for backwall and stem bars were always calculated independently. (Request 337)

Development Length Revisions

11. The calculation of the Actual Development for the Toe and Heel in the footing has been revised to include a tolerance. Previously, for certain input files, the program would not find a valid development length due to significant digits. (Request 318)

Engineering Assistant Revisions

12. The Engineering Assistant lower limit for the Void Ratio and Compression Index on the Consolidation Command has been revised to now allow zero to be entered. Previously, the lower limit was set at 0.1 and 0.001 respectively even though the descriptions said to enter zero for certain soil conditions. (Requests 351)

Pile Revisions

13. The limit on the ratio specified in DM-4 Section 6.15.1 of vertical load to horizontal load at the service limit state for pile foundations has been revised from 3.5 to 2.4. (Request 352)

14. The minimum pile spacing for H piles has been revised to be 2.0 times the diagonal dimension of the pile. Previously, the program would calculate the minimum spacing of H piles as 2.5 times the depth or width of the pile cross-section. (Request 357)

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LRFD ABUTMENT AND RETAINING WALL ANALYSIS AND DESIGN

SUMMARY OF JANUARY 2014 REVISIONS - VERSION 1.13.0.0

Since the release of ABLRFD Version 1.12.0.0 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.13.0.0 contains the following revisions and enhancements.

Input Revisions

1. The program has been modified to produce a warning when the rear face batter slope of abutments and retaining walls is greater than a 1:3 ratio of horizontal to vertical ratio. (Requests 317)

2. The program has been revised to exit with error messages when errors are found upon reading the input. Previously, for certain input files the program would read in the input with errors and crash when the input checks are performed. (Request 347)

3. A new parameter was added to the SOI command to either include or omit the inclination factors when calculating the bearing resistance for soil. Previously, the program would always apply the inclination factors. (Request 361)

Output Revisions

4. The Crack Control – Analysis output table has been modified for footings to display the allowable crack control spacing for bars when the minimum bar spacing has been violated. Previously, the program would always display an allowable crack control spacing of zero when the minimum bar spacing was violated for footings. (Request 339)

5. The headings on the Footing Stability tables have been revised to indicate that the loads are factored. Previously, the table headings did not explicitly state whether loads were factored on not. (Request 340)

6. The Moment Axial Interaction tables have been revised to now provide the section thickness and the effective depth at each design location. Previously, the program did not explicitly display the section thickness and the effective depth for each design location. (Request 349)

7. The Factored Forces and Moment Axial Interaction output tables with Stem Cutoff Location information have been revised to prevent empty table headers with no numbers from appearing for bars that cannot be cutoff. Previously, the program would print an empty table for those bars that could not be cutoff. (Request 358)

Loading Revisions

8. For certain input files with a short stem height, the height of the Partial EH-V force triangle would sometimes

be taller than the stem height leading to a cryptic error message. The program has been corrected so that when this condition occurs, the height of the Partial EH-V force triangle is set equal to the stem height. (Request 301)

9. Approach Slab Loads have been added as a user input to the program in accordance with BD-628M, Sheet 2, Note 14. When the Approach Slab Loads are entered using the new ASL command, the approach slab is modeled as a simple span between the abutment and the sleeper slab, and the Earth Surcharge and Live Load Surcharge loads are not included for the Final stage. In order to implement Note 14, two separate runs of ABLRFD are required. One run with the ASL command and one without the ASL command. Previously, approach slab loads could only be accounted for through the Earth and Live Load Surcharge input parameters. (Request 303)

Settlement Revisions

10. A check has been added to the settlement routines to prevent a divide by zero error when calculating Secondary Consolidation. Previously, the program would crash when the divide by zero was encountered. (Request 350)

Crack Control Revisions

11. When performing the crack control calculations for the bottom footing reinforcement, the calculation of the d_c value has been revised to prevent the program from subtracting the 1 inch foundation unevenness thickness more than once. Previously, the program could potentially subtract more than 1 inch of foundation unevenness for the bottom footing reinforcement. (Request 378)

User's Manual Revisions

12. The description of Concrete/Rock Friction Angle parameter on the RCK command has been revised to provide more complete information and guidance on how the parameter should be set. (Requests 342)

13. The User's Manual Section 3.6 has been revised to clarify how the section thickness at design locations within the stem are calculated for a Type II abutment. (Request 353)

Engineering Assistant Revisions

14. The lower limits of the Void Ratio and Compression Index on the CNS command have been changed to 0.0. Previously, the lower limits were set at 0.1 for the Void Ratio and 0.001 for the Compression Index. (Requests 351)

SUMMARY OF MAY 2014 REVISIONS - VERSION 1.13.0.1

Since the release of ABLRFD Version 1.13.0.0 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.13.0.1 contains the following revisions and enhancements.

General Program Revisions

1. The method of calling the engineering program DLL from the Engineering Assistant has been changed for compatibility with EngAsst v2.5.0.0 which uses Microsoft's .NET Framework, version 4.5. Because of this, ABLRFD will no longer work with EngAsst v2.4.0.6 or v2.4.0.9 unless the EngAsst "Edit / Run EXE – Command Window" option is selected. ABLRFD will no longer work with EngAsst v2.4.0.0 and earlier. (Request 379)

2. The ABLRFD program has been updated to compile with Intel Fortran XE 2013 SP1 Update 1 using Visual Studio 2012 Update 4. (Request 367)

Input Revisions

3. The program has been revised to correctly apply a default dry unit weight for the second soil layer on the SOI command when the user has not entered a value. Previously, the program would apply the default when the user had already provided a value. (Requests 380)

4. The program has been revised to issue a warning message if one the of the back face batter components on the AT2,AWB or RWL command is either set to zero or left blank when the other component has a value greater than zero. Previously, there would be no warning message for this condition. (Request 381)

User's Manual Revisions

5. The User's Manual Section 6.12.4 has been revised to clarify how the service axial capacity value is determined. (Request 365)

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LRFD ABUTMENT AND RETAINING WALL ANALYSIS AND DESIGN

SUMMARY OF APRIL 2015 REVISIONS - VERSION 1.14.0.0

Since the release of ABLRFD Version 1.13.0.1 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.14.0.0 contains the following revisions and enhancements.

Input Revisions

1. For Analysis runs the Footing Datum parameter on the CTL command should be left blank. But if it was entered the program would print a warning that it should be left blank and then it would proceed to use the input value causing confusion. To resolve this, the program has been revised to internally set the footing datum to top of footing for Analysis runs when the Footing Datum parameter on the CTL command is entered by the user. (Request 369)

Output Revisions

2. For pedestal footings a new footnote has been added to the Flexural Strength output table for Design and Analysis runs, and to the Reinforcement Design Details / Footing output for Analysis runs, stating that the program does not analyze perpendicular direction reinforcement for pedestal footings because the program assumes the footing and pedestal are made integral using transverse shear keys and dowels per DM-4 10.6.5.2P. (Request 192)

3. The page layout of the output file has been enhanced to allow for more characters per page width and more lines per page in the PDF output file. The new layout has 102 characters per page width and 83 lines per page. The Table of Contents now includes a second level which is converted to a second level of bookmarks to assist in navigating the PDF file. (Request 388)

4. The FACTORED FORCES output table has been revised to show the Vertical over Horizontal Load Ratio for the Service limit states for pile and caisson foundation types. Previously, the program would only output a flag and footnote during an analysis run if the ratio check was violated. (Request 392)

Loading Revisions

5. The program has been revised to prevent a divide by zero error when the calculated area for the Wind on Substructure is less than or equal to zero. Previously, the program would populate portions of the output reports with a Not a Number (NaN) output value and produce incorrect results. This issue was rare and would only occur for certain input files. (Request 383)

Stem Revisions

6. The program has been revised to correctly consider the capacity of the minimum temperature and shrinkage reinforcement in the front face of a stem if a negative moment is encountered during a design run. Previously, the program would attempt to compare the positive calculated capacity for the temperature and shrinkage reinforcement to the negative applied load resulting in errors. (Request 362)

7. A new geometry check has been added to the design loop to prevent the backwall for a Type 2 Abutment from overhanging the end of the heel when the toe projection is being increased. Previously, the program would stop with an error indicating the backwall overhangs the end of the heel. (Request 373)

8. The calculation of the Stem Thickness at Location D during the design loop has been revised to be consistent with the calculations performed in the stem routines. Previously, the discrepancy in the calculation would sometimes cause the program to halt with a geometry check error. (Request 374)

Bearing Resistance and Stability Revisions

9. The equations and documentation for bearing resistance of spread footings on two sand layers, Soil Condition 6 and 7, have been revised to be consistent with the methodology in the *Principles of Geotechnical Engineering, Third Edition by Braja Das*. Previously, the equations and documentation were inconsistent with methodology in the Das textbook resulting in an overestimation of the bearing resistance. This request fixes the issues documented in e-Notification 018. (Request 385)

10. The bearing resistance phi factor for the Service Limit states has been revised to be 1.0. Previously, the program would apply the same bearing resistance phi factor to all limit states. (Request 371)

11. The program has been revised to increase the allowable kern for stability checks for the Extreme Limit state to 2/3rds the footings base width per AASHTO 10.6.4.2 and 11.6.5. This revision affects spread footings and pedestal footings. (Request 375)

12. The allowable kern for the Final Stage stability checks has been revised for all limit states, except the Extreme Limit State, to be in accordance with 2014 AASHTO 11.6.3.3. This revision affects spread footings and pedestal footings. (Request 391)

Pile/Caisson Revisions

13. The program has been revised to no longer consider the Service Limit State when checking the Factored Axial Resistance and Factored Lateral Resistance for pile/caisson foundation design and analysis runs. Previously, the program would resize a pile/caisson pattern or footing size if the Factored Axial Resistance or the Factored Lateral Resistance was insufficient for the Service Limit State. (Request 366)

14. The pile/caisson design loop has been revised to allow for increasing the footing thickness when the Service Load Ratio check controls a design iteration. Per DM-4 6.15.1P the Service Load Ratio is the ratio of the SERVICE-I limit state unfactored vertical load to horizontal load and this ratio much be greater than 2.4. Previously, when the Service Load Ratio was less than 2.4, the program would increase the footing width without first trying to increase the footing thickness, causing some designs to be inefficient. (Request 372)

User's Manual Revisions

15. The default value for the Inclination Factor parameter on the SOI command in the ABLRFD User's Manual has been changed to “Y” to be consistent with the program and the Engineering Assistant configuration files. (Request 384)

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SUMMARY OF MARCH 2016 REVISIONS - VERSION 1.15.0.0

Since the release of ABLRFD Version 1.14.0.0 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.15.0.0 contains the following revisions and enhancements.

Output Revisions

1. For analysis runs a new Minimum Reinforcement Check output table has been added to provide detailed information related to the calculation of minimum area of steel based on rho-min and temperature and shrinkage requirements. (Request 338)

Minimum Reinforcement Revisions

2. The Crack Control spacing calculation has been revised to limit the calculated tensile stress in the reinforcement to be no greater than 0.6*fy based on the 2014 AASHTO LRFD A5.7.3.4. Previously, the program would use the computed tensile stress in the calculation of the Crack Control spacing without limitation. (Request 405)

3. The calculation of Cracking Moment has been revised to use a new equation from the 2015 DM-4 Section 5.7.3.3.2 which applies multiple factors. Previously, the program would calculate the Cracking Moment using a constant 1.2 factor. (Request 407)

Backwall Revisions

4. When the Backwall/Stem Bar Alignment input is set to ‘Y’ during a design run and no valid backwall bar can be designed at the stem spacing with cutoffs, the program has been enhanced to set the backwall reinforcement spacing to the stem spacing without cutoffs and the backwall bar design process is repeated to try to find a valid design. Previously the program would end processing without finding a valid backwall reinforcement design. (Request 395)

5. The program has been modified to check the front face temperature and shrinkage steel for adequate moment capacity when negative moment is found in the backwall. Previously, the program would only report a negative moment condition and the user would have to perform hand calculations. (Request 396)

Settlement Revisions

6. The calculation of Elastic Settlement on Rock has been revised to use a new Elastic Modulus input added to the RCK command. This was done because of updates to the 2014 AASHTO LRFD 10.4.6.4. Previously, the program would calculate the Elastic Modulus based on the Elastic Modulus Reduction Factor or the Rock Mass Rating input values on the RCK command. (Request 399)

User's Manual Revisions

7. The ABLRFD User's Manual has been revised to state that unfactored wind load should be entered for wind on substructure on the LAB command in the ABLRFD program. (Requests 398)

8. The assumption that the ABLRFD program does not consider Blast Loading has been added to the ABLRFD User's Manual. (Requests 400)

9. The Assumption and Limitation section of Chapter 2 has been revised to condense topics and update wording of some items. (Request 409)

The following is a list of enhancements from the 2014 AASHTO LRFD Specifications that are not included in this version but will be implemented in a later version:

1. The 2014 AASHTO LRFD Specifications include the variation of the resistance factor, φ, for sections in the transition zone between tension-controlled and compression-controlled defined by the net tensile strain in the extreme tension steel and the compression-controlled and tension-controlled strain limits. Previously, the variation in the resistance factor was expressed in terms of the ratio dt/c. (Request 406)

SUMMARY OF JANUARY 2017 REVISIONS - VERSION 1.16.0.0

Since the release of ABLRFD Version 1.15.0.0 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.16.0.0 contains the following revisions and enhancements.

Input Revisions

1. The lower limit of the Pile Embedment on the PIL command has been revised to be 12.0 inches, according to DM-4 10.7.1.2. The 12" minimum caisson embedment specification check has been removed, according to DM-4 10.8.1.2. (Request 430)

Output Revisions

2. The Extreme-I limit state output results for the horizontal EQ effects on the abutment footing have been removed from the “Footing W/O Foundation Pressure” output report because the horizontal earthquake loading applied to the footing (see AASHTO Figure 11.6.5.1-1) causes a negligible bending moment in the footing. (Request 163)

3. For design runs, the cracking moment Mcr and 4/3 * Mu calculated values have been added to the bottom of the MOMENT AXIAL INTERACTION and FLEXURAL STRENGTH output tables. (Request 408)

4. For certain Analysis run input files, a specification check error appeared in the Stem - Crack Control – Analysis table indicating that the provided area of steel is less than minimum area required for shrinkage/temperature control or rho min, even though area of steel provided is far greater than the minimum area required. ABLRFD was incorrectly comparing the area of steel provided against the area of steel required for maximum applied moment. The check has been updated to compare the area of steel provided to the minimum area required for the minimum area for shrinkage/temperature or rho min. (Request 422)

5. A problem preventing a valid design has been corrected when the user-input minimum footing width was very nearly equal to the user-input minimum toe + user-input minimum heel + ABLRFD-computed stem width at the top of footing. A tolerance factor has been added to the footing width comparison, allowing the design to now run to completion. (Request 428)

6. The error messages displayed in the output file have been enhanced when the top of soil/rock is located above the top of footing/pedestal or when the top of soil/rock is located below the bottom of the footing/pedestal. Previously, a cryptic error message was displayed. (Request 429)

Phi Calculation Revisions

7. The calculation of ϕ factor has been revised to use the new strain-based equation from AASHTO Section 5.5.4.2 for the situations where loading causes the strain in the section to be between the tension-controlled and compression-controlled regions. Also, calculations for computing and considering the moment resistance and axial load resistance for the compression-controlled strain condition of the section have been added to ABLRFD moment axial interaction calculations. (Request 406)

Pile Revisions

8. A specific input file for a design run with battered piles that have uplift forces was found to result in a valid design but with a performance ratio less than 1.0. An error was found in ABLRFD in which the pile spacing required to resist uplift was incorrectly being calculated using the pile's axial capacity for battered piles. ABLRFD was updated to consider only the vertical component of the pile's axial capacity (Pile Uplift Capacity) for battered piles when calculating the pile spacing to resist the uplift. (Request 390)

Sliding Resistance Revisions

9. An input item has been added to the SOI soil data command for specifying the type of concrete footing to be analyzed / designed. In addition to the current 'cast-in-place' option, 'precast' footings may now be selected. Selecting 'Precast' will reduce the sliding resistance of the footing by 20% for footings on sand or clayey-sandy "C-Phi" soils per A10.6.3.4-2 and D10.6.3.4. (Request 403)

User's Manual Revisions

10. The ABLRFD User's Manual Assumptions and Limitations section has been revised to state that micropiles are not supported. (Request 412)

11. The ABLRFD User's Manual Assumptions and Limitations section has been revised to clarify that the ABLRFD program calculates the shear in the perpendicular direction for spread footings, pile footings, gravity type abutments and gravity retaining walls, but only compares the perpendicular direction shear force to the shear resistance for spread footings and pile footings. (Requests 410)

12. The ABLRFD User's Manual Section 3.3.2.22 EQ has been enhanced to include additional information on the earthquake load calculations in ABLRFD. Also, Section 3.3.7 Earthquake Loading has been added. (Request 376)

13. Incorrect figure references in the ABLRFD User's Manual Section 3.3.2.6 EH were corrected. (Request 425)

14. The ‘Allowable Caisson Uplift’ parameter on the CAI command and the ‘Allowable Pile Uplift’ on the PIL command have been revised to ‘Caisson Uplift Capacity’ and ‘Pile Uplift Capacity’ respectively and these parameter descriptions have been updated to emphasize that the uplift capacity is measured in the axial direction. (Request 427)

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LRFD ABUTMENT AND RETAINING WALL ANALYSIS AND DESIGN

SUMMARY OF NOVEMBER 2019 REVISIONS - VERSION 1.17.0.0

Since the release of ABLRFD Version 1.16.0.0 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.17.0.0 contains the following revisions and enhancements.

Input Revisions

1. An input check has been added to the program to ensure that the user input value for retaining wall / abutment height is greater than the maximum footing thickness. This check only occurs for design runs where the footing datum is set to the bottom of footing (Request 424).

2. The lower limit for Pile Embedment on the PIL command has been increased to 12 inches from 1 inch (Request 432).

3. The program has been updated to accommodate the Type 4 Approach Slabs which were revised in the 2010 BD-628M, Change 1 standards to move the location of the drain trough for Type 4 to be integral and attached to the abutment. Input has been added to the APPROACH SLAB (ASL) command to fully define the support pedestals and drain trough for the Type 4 Approach Slab. The program will now calculate all loads and load effects from the Type 4 Approach Slab, support pedestals and drain trough (Request 438).

Output Revisions

4. The description "Backwall Height" on the ABUTMENT BACKWALL AT SEAT LEVEL output has been revised to "Available Height in Backwall" to accurately describe the value reported (Request 417).

5. Several output reports in the ABLRFD INPUT SUMMARY have been revised so that the output values are in the same order as they are in the input file and User's Manual (Request 421).

6. Chief Bridge Engineer warnings are now much more obvious in the program output with the inclusion of "%WARNING: **THIS MUST BE APPROVED BY CHIEF BRIDGE ENGINEER**" as part of the warning message (Request 423).

7. The FOOTING REINFORCEMENT DETAILS output report for the stem now shows the reinforcement as entered by the user. Previously, a single effective bar size and spacing were calculated, equivalent to the bars entered by the user. In addition, the "Area / Width" column heading for both stem and footing was revised to "Total Area / Design Width" to more accurately describe the values in the column (Request 435).

8. The input consistency check for the attempted design of a gravity wall has been moved earlier in the program so that the program stops with an error stating that a gravity wall cannot be designed before other input checks.

A sentence has been added to the "Type of Run" parameter on the CTL command to advise the user that gravity walls cannot be designed (Requests 436 and 448).

Design Optimization Revisions

9. ABLRFD designed a larger footing size, for a specific input file with a water level significantly below the bottom of footing, compared to a design without water. The larger footing size design was then converted into an Analysis run (with water) and the footing size was entered as the smaller size (from the design without water) and the smaller footing size was found to be acceptable with water present. This confirmed that ABLRFD was not designing the optimum footing size for this specific input. The ABLRFD design optimization process was revised to fix this issue (Request 450).

Phi Calculation Revisions

10. The program no longer considers sections to be under-reinforced or over-reinforced. Previously, sections having a “c/de” ratio greater than 0.42 were considered to be over-reinforced as defined in AASHTO Article 5.7.3.3.1. AASHTO Article 5.7.3.3 notes that Article 5.7.3.3.1 was deleted in 2005. The ϕ factor is now computed by the program to determine if the reinforcement is sufficient and the calculated phi factor has been added to the MOMENT AXIAL INTERACTION output reports (Requests 416 and 462).

Pile Revisions

11. For a specific design run with piles, it was observed that the pile factored axial loads to pile factored axial resistance was slightly less than 1.0 for a few of the limit states. To fix this issue, an additional check has been added to the program to ensure that the controlling pile spacing calculated by the program is not greater than the spacing required to resist the compressive vertical load (Request 431).

Specification Checking Revisions

12. The calculation of the Bearing Resistance, $q_{ult,}$ for Soil Types 6 and 7 has been revised in the program to match the equations shown in the User's Manual section 3.4.1.4.2.1. Previously, the program was using the gamma value from Soil Layer 1 for both soil layers.This was fixed to use the gamma value for each soil layer separately. Also, additional information regarding gamma used in the q_{ult} calculation has been added to the program output on the INTERMEDIATE BEARING RESISTANCE VALUES report (Request 446 and 463).

13. The calculation of the punching shear diameter for piles has been revised to use d_v, the effective shear depth. Previously, the program was incorrectly using the effective depth, d. The User's Manual section 3.5.2.10 has been revised, as well (Request 454).

User Manual Revisions

14. For a specific output file, the REINFORCEMENT DESIGN DETAILS output report showed that two bar sizes could be cutoff and the optimum bar size could not be cutoff. Below this output table was a note stating “STEM BARS CANNOT BE CUT OFF FOR THE DESIGN”. This was confusing because two of the bars could be cutoff. This note has been revised to “Optimum stem bars cannot be cutoff for this design” (Request 413).

15. User's Manual Section 4.4 has been revised to correctly describe the Windows Start Menu group for the installed program (Request 415).

16. Section 3.4.1.1 of the User's Manual has been revised to match the program functionality with respect to the location of the load resultant for footings on rock and soil. Previously, the program calculations had been revised, but the User's Manual was inadvertently not revised to reflect the program functionality (Requests 437 and 464).

17. Clarification was added to the User's Manual sections 5.12.5, 5.12.7, 6.12.5 and 6.12.7 explaining that DM-4 6.15.1 is used for the pile design procedure, but only one of the five conditions are check by the program to determine if Chief Bridge Engineer approval is required. It is up to the user to determine if Chief Bridge Engineer approval is required for the other four specific pile conditions (Request 439).

18. Additional documentation was added to User's Manual sections 3.5.2.6 and 5.23.5 concerning the minimum reinforcement spacing and how it is calculated. The lower limit on minimum spacing on the SPD command has been set to 1 inch to match the way the program works (Request 442).

19. The Engineering Assistant field help for the CNS command has been revised to add a missing image for Figure 1 and correct a previously added image for Figure 2 (Request 443).

20. Units of ksi have been added to the User's Manual Section 5.19.14 description of the rock mass modulus on the RCK command (Request 445).

21. The descriptions of Strength Axial Capacity and Strength Lateral Capacity in User's Manual section 5.12 and Strength Lateral Capacity in User's Manual section 6.12.7 have been updated to state that the capacities are factored capacities. Also, the FACTORED LATERAL LOADS / PILE GROUP FACTORED LATERAL RESISTANCE output report has been updated to show units of "kips / ft" for FACTORED LATERAL LOAD and FACTORED LATERAL RESIST (previously, the units were shown as "kips / unit width" (Request 451).

22. The contact information and revision request forms in Chapter 9 of the User's Manual have been revised. Users are also advised to submit sample input files via e-mail attachment (Requests 453 and 460).

23. The sample SRA command in the User's Manual section 6.27 has been revised to the correct the end location to 7 feet. Also, the example bar size has been revised to the correct value of #8 (Request 459).

Programming Revisions

24. ABLRFD has been revised to use Visual Studio 2017 and Intel Parallel Studio XE 2017 Fortran Update 5 for compilation and linking (Request 433).

25. Intermediate footing design files are now written to the same directory as the program input file. The intermediate file name will also start with the input file name, making it reasonably distinctive. Previously, the intermediate footing design files were written to the Windows TEMP folder (Request 434).

SUMMARY OF JANUARY 2022 REVISIONS - VERSION 1.18.0.0

Since the release of ABLRFD Version 1.17.0.0 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.18.0.0 contains the following revisions and enhancements.

Input Revisions

1. Two new input values are available on the SOI command, Layer 1 Reduction Coefficient, RC_{BC}, and Layer 2 Reduction Coefficient RC_{BC} to calculate the Bearing Resistance for Soil Near a Slope. These values allow the user to enter values from LRFD Specifications Table 10.6.3.1.2c-1 or 10.6.3.1.2c-2 for spread footings on or near a slope. The previously used values for footings on or near a slope, Layer 1 N_{cq}, Layer 1 N_{gq}, Layer 2 N_{cq}, and Layer 2 N_{gq} are no longer used by the program and should be removed from input files (Request 476).

2. The lower limits for reinforcment area on the ARE command have been changed to 0.01 in^2/ft in order to prevent a program crash when the areas are entered as 0.0 in^2/ft (Request 482).

Output Revisions

3. The units for applied loads (LAB, LRT, DLL, SLL, and EQL commands) in the program output have been changed to report the loads as kip/ft rather than just kip. The magnitude of the loads entered by the user will not change because the program has always assumed that the loads entered into the program are per unit width of the abutment. This output change is to make the program output consistent with the User's Manual, and to more clearly indicate that the loads should be entered as load per unit width (Request 490).

4. The phi factors reported in the Moment Axial Interaction Output Table have been corrected. Previously, the phi factors were always reported as 0.900. The correct phi factor was being used to compute resistance values so there are no changes to the computed resistance values (Request 492).

Pile Revisions

5. Minimum edge distance errors in the program output have been revised to refer to DM-4 Section 10.7.1.2 rather than 10.7.1.5 (Request 475).

Specification Checking Revisions

6. The methods for calculating the elastic modulus of concrete and the modular ratio between the concrete and reinforcement have been revised to match the LRFD Specifications, 8th Edition, and the tables of values in the 2019 DM-4 Sections 5.4.2.1 and 5.4.2.4. Along with these changes, the MAT command has been enhanced with additional input checks, and upper and lower limits changed for consistency with the LRFD Specifications and DM-4 (Request 472).

7. The concrete density modification factor (λ) has been added to shear resistance calculations, as specified in the 8th Edition LRFD Specifications (Request 473).

8. The reinforcement development length is now computed based on AASHTO LRFD Specifications 8th Edition. Also, the lap length is based on Class B splice with a splice factor of 1.3. Previously, the splice factor was 1.7 based on a Class C splice. The AASHTO LRFD Specifications 8th Edition eliminated Class C splices (Request 474).

9. The calculation for the modulus of rupture of concrete has been revised to include the concrete density modification factor, and to now use a single equation for both lightweight and normal weight concrete. Also, the Minimum Reinforcement Check output table headers have been changed from “4/3*M(u)” to “1.33*M(u)” (Request 477).

10. For the implementation of the spread footing Christian and Carrier Settlement equations for soil, set μ1 to 0.0 when the value LOG(H/B') is less than -1.0. Refer to User Manual Figure 3.4.1.3.1-1. Previously, the program would incorrectly calculate a negative μ1 resulting in a negative settlement (Request 483).

11. The calculations of the shape correction factors for bearing resistance of soil have been revised to be consistent with Table 10.6.3.1.2a-3 for the condition where the friction angle is equal to zero (Request 485).

12. The load factors for wind loads for the Service-I, Strength-III, Strength-V limit states have been revised to match the current LRFD Specifications. The DC and DW load factors for Extreme-I and Extreme-II limit states have been revised, as well. New inputs have also been added to the LAB and LRT commands for the limit state-specific wind loads specified by the LRFD Specifications (Request 486).

13. The minimum spacing of caissons has been increased to 4*caisson diameter to correspond with the requirements of the LRFD Specifications Section 10.8.1.2 (Request 498).

User Manual Revisions

14. The User Manual and Engineering Assistant help, and documentation files now reference DM-4/AASHTO specifications using the 8th Edition section numbers.Many of the 7th Edition section numbers for Section 5 changed in the 8th Edition (Request 470).

15. References to DM-4 were added to the maximum bar spacing requirements documented in User Manual Section 3.5.2.6 (Request 478).

16. Chapter 7 of the User's Manual was reviewed against the current program output and revised, where necessary, to allow the User's Manual to match the program output (Request 488).

17. Cross-references in chapters 3 and 5 of the User's Manual were reviewed and updated due to new sections being inserted in chapter 3 (Request 495).

18. Context has been added to the definition of B'_1 in Section 3.4.1.3.1 of the User's Manual (Request 499).

Programming Revisions

19. ABLRFD has been revised to use Visual Studio 2019 and the Intel Fortran Compiler Classic OneAPI version 2021.4.0 for compilation and linking (Requests 461 and 496).

20. An incorrect error condition check has been removed from the PHIBVAR routine so that the program does not prematurely stop with a confusing error message (Requests 468 and 481).

SUMMARY OF OCTOBER 2023 REVISIONS - VERSION 1.19.0.0

Since the release of ABLRFD Version 1.18.0.0 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.19.0.0 contains the following revisions and enhancements.

Input Revisions

1. Invalid combinations of Cohesion and Effective Friction Angle are now reported as an error during the processing of the SOI command. Previously, entering the cohesion as zero and leaving the effective friction angle blank would result in an invalid soil type error message without indicting corresponding valid input for cohesion and effective friction angle. (Request 414)

2. An input warning message has been added for the Top Width dimension on the AT1, AT2, or AWB command being less than the minimum from the BD Standards. Also, failures to solve the quadratic equation for the required area of steel now reports values for the variables used for the quadratic equation. (Request 440)

3. Warning messages are now given when the Minimum Footing Thickness on the FTG command is less than the minimum required by DM-4. For spread footings on soil or rock the minimum footing thickness is 2'-0". (DM-4 11.6.4.1P) For pile/caisson footings the minimum footing thickness is 2'-6". (DM-4 10.7.1.2) No minimum footing thickness is checked for Footings on Pedestals. (Request 471)

4. Input data for Type I and Type II Abutments (AT1 and AT2 commands) are now checked for minimum stem width dimension at the bearing seat. Also, for Type II Abutments the standard Stem Notch Width and Stem Notch Height dimensions are now checked and the minimum stem width at the stem notch is now checked. The minimum dimensions are specified on Bridge Design Standard BD-621M. (Request 521)

5. Input data checks are now made for the ratio of the horizontal and vertical components of the batter for the LYA and LYD commands. Per DM-4 section 10.7.1.4 the batter is limited to 1 Horizontal on 3 Vertical. For design runs an error message is given when the batter exceeds 1 Horizontal on 3 Vertical (or 1/3). For analysis runs a warning message is given when the limit is exceeded. (Request 523)

Output Revisions

6. An internal programming error that resulted in erroneous warning messages for "Invalid break distance." for retaining walls with a broken backfill has been corrected. (Request 300)

7. Service I Limit State has been removed from the eccentricity and bearing resistance checks for spread footings and pedestal footings. (Request 441)

8. The initial steel area used to design the backwall is now set to a small positive value to allow the iteration process to converge. Previously, when the first load case had a negative applied moment, the iteration process would fail to converge, and the program would stop. (Request 457)

9. Computation of the area and centroid of the stem for Type 2 Abutments have been revised to use coordinates defining the stem. This corrected an issue that resulted in multiple warning messages for a "Negative vertical distance" when the Backwall Height was equal to the sum of the Corbel Height, Corbel Slope Height, and the Seat Face Height. Additionally, this corrected the applied vertical load from the stem self-weight for design locations located within the Stem Notch Height. (Request 458)

10. The Stem Bar Development error message has been enhanced to include information for the footing thickness, available development length, and required development for each bar. (Request 469)

11. Factored Forces output, the Moment/Axial Interaction output, the Reinforcement Summary – Analysis output, and the Shear Results output for analysis runs at rebar cutoff locations defined by the SRB command have been added to the output. Previously, this information was only provided for design runs. (Requests 497, 480)

12. Development length for hooked and straight bars at stem location D have been added to the Reinforcement Summary Report for Analysis runs. Also, the required reinforcement area and the splice length have been added to the report for stem location D. (Request 489)

13. The crack control design results have been corrected for stem locations where only some of the factored loads result in cracking the section. Previously, the incorrect controlling moment and axial forces were reported with the incorrect allowable spacing for some bar sizes. (Request 513)

Settlement Revisions

14. The consolidation settlement influence factor has been revised to use the effective footing width based on the Consolidation and Secondary Settlement Limit State. Previously, the effective width for Elastic Settlement was being used. (Request 447)

Loading Revisions

15. Horizontal loads that could be applied in opposite directions are now considered as a positive force and as a negative force. These horizontal forces are Braking Force (BR Design or Special LL), Wind on Live Load (WL), Thermal Force (TU), Friction Force (FR), Wind on Superstructure (WSUP1, WSUP3, WSUP5), and Wind on Substructure (WSUB1, WSUB3, WSUB5). Two additional Load Cases are considered to maximize the effects of the negative horizontal loads: Maximum Vertical with Minimum Horizontal (MxVMnH) and Minimum Vertical with Minimum Horizontal (MnVMnH). The negative horizontal loads are only considered for the foundation. (Request 505)

User Manual Revisions

16. The ABLRFD User Manual is now consistent with DM-4 in that load modifiers other than 1.0 are not permitted by PennDOT. Previously, the User Manual stated load modifiers other than 1.0 required Chief Bridge Engineer (CBE) approval. A standard CBE warning message is now reported for piles with vertical load to horizontal load ratio less than 2.4 at the service limit state. Previously, a non-CBE warning message was reported. (Request 465)

17. The tables in sections 6.36, 6.37, and 6.38 of the User's Manual now have table captions and the table names appear in the List of Tables. (Request 500)

18. Windows 8.1 operating system has been removed from the User's Manual as a supported operating system. (Request 520)

Programming Revisions

19. For each new pile pattern tried for a given footing configuration, the count of punching shear failures is reset to zero. Previously, on rare occasions, a design run on pile footing would stop with an error message of "Final spacing controls mismatch". (Request 466)

8th Edition Revisions

20. The compression-control strain limit used to determine the factored resistance of concrete components for reinforcement with yield strengths, fy, less than or equal to 60 ksi is now the minimum of 0.002 and fy/Es. Previously, the compression-control strain limit for yield strengths less than or equal to 60 ksi was 0.002. (Request 493)

21. The Moment-Interaction Diagram is now based on six data points: 1) Pure Tension, 2) Pure Flexure, 3) Tension Control Strain, 4) Balanced Strain, 5) Allowable Compression, and 6) Pure Compression. Previously, the seventh point was based on the Compression Control Strain, but the compression control strain is now the balanced strain. (Request 494)

SUMMARY OF APRIL 2025 REVISIONS - VERSION 1.20.0.0

Since the release of ABLRFD Version 1.19.0.0 several revision requests and user requested enhancements have been received. This release of ABLRFD Version 1.20.0.0 contains the following revisions and enhancements.

Input Revisions

1. **Having entered both a non-zero friction force and a non-zero temperature force on the LAB command now results in an error message. (Request 510)**

Output Revisions

2. **For design runs that have failed to find a solution, the smallest footing width with the most passing checks are reported. When no footing configurations have passed at least one check, no footing dimensions are reported. Previously, sometimes the footing with the most passing checks was not being reported. (Request 426)**

3. **For spread and pedestal footings an Intermediate Settlement Data output report has been added to provide values used to compute the elastic settlement. (Request 484)**

4. **The CFG command parameters have been processed to set global output variables before any output has been written to the output file. Previously, the global output variables affected by the CFG command were not set until the Input Summary was printed. (Request 504)**

5. **The Input Parameter Names, reported in the Input Commands Output, has been increased to allow longer names to be used. This will allow the Parameter Names to more closely match the names used in Chapter 5 and in the tab pages for Engineering Assistant. (Request 507)**

6. **Average Load Factors have been removed from the Foundation Force output results for spread footings and footing on piles. (Request 511)**

7. **The PED Command input parameter, DESIGN OPTIMIZATION, has been added to the Input Summary output. For analysis runs, the DESIGN OPTIMIZATION parameter is left blank. Added a check to print "none" for this case. For design, print the user input value of "D" or "V". Previously, the DESIGN OPTIMIZATION input was not printed in the output. (Request 516)**

8. **The acceptable range of toe projections given in the ADDITIONAL INFORMATION Report now clarifies that range is for the given footing geometry. For footings on pedestals a second acceptable range of toe projections has been added that applies for both the footing geometry and the pedestal geometry. For footings on piles or caissons a second acceptable range of toe projections has been added that applies for both the footing geometry and the pile or caisson pattern. An issue that on very rare occasions resulted incorrect ranges has been corrected. (Request 518)**

User Manual Revisions

9. **The Revision Request Forms (User Manual and Word Template) do not refer to a PennDOT fax number. (Request 503)**

10. **Nomenclature has been updated in Chapter 3 to reflect the variables and information currently used. (Request 487)**

Design Revisions

11. **Design Permit Loads have been added to the DLL command. This allows all relevant limit states to be considered in a single run of ABLRFD. Previously, separate runs were required for the PHL-93 Design live load and the Permit live load (Controlling P-82 or P2016-13). Note that no design live load is considered for Strength V based on DM-4 Table 3.4.1.1P-3 – Load Factors and Live Load Vehicles for Abutment/Retaining Walls. (Request 201)**

12. **Wind on substructure input parameters have been added to the Loads on Retaining Walls (LRT) Command to allow horizontal wind loads on the stem of retaining walls. (Request 509)**

13. **Design optimization for minimum footing volume has been enhanced to only consider trial footings with volumes less than the current minimum footing volume. (Request 515)**

Engineering Assistant Revisions

14. **The figure names in Engineering Assistant's tabs and descriptions have been updated to be consistent with the figure names used in the User Manual. The User Manual has also been updated to include additional figures in Chapter 6. (Request 514)**

Programmer Revisions

15. **The program has been made compatible with the forthcoming release of Engineering Assistant v3.0.0.0. Changes include:**
    1) **switching image formats from Enhanced Metafile (.emf file) to Portable Network Graphic (.png file) required by the new Engineer Assistant,**
    2) **associating a Tab Name with the current 3 letter tab abbreviation,**
    3) **resolving issues when setting floating-point precision on 64-bit systems. (Request 530)**

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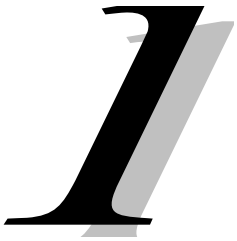

GENERAL DESCRIPTION

1.1 PROGRAM IDENTIFICATION

Program Title: LRFD Abutment and Retaining Wall Analysis and Design

Program Name: ABLRFD

Version: 1.20.0.0

Subsystem: Substructure

Authors: Pennsylvania Department of Transportation,
Imbsen and Associates, Inc., and
Modjeski and Masters, Inc.
Michael Baker International

ABSTRACT:

The LRFD Abutment and Retaining Wall Analysis and Design program (ABLRFD) performs an analysis and specifications check in accordance with the AASHTO LRFD Bridge Design Specifications and the Pennsylvania Department of Transportation Design Manual Part 4, for cast-in-place reinforced concrete abutment and retaining wall structures. As a result of a decision by the AASHTO Subcommittee on Bridges and Structures to no longer publish SI unit specifications, the program only supports US customary (US) units.

The program can perform an analysis or design for a variety of abutment configurations including geometries with or without backwalls and with either straight or notched stems. Retaining walls may have battered front and back faces, and either sloped or level backfills. Spread, pile, caisson, and pedestal footings may be evaluated.

The loads applied to the structure are based on the LRFD limit state combinations that have been adjusted to incorporate PennDOT policies. The limit state combinations include strength, service, and extreme limit states for both temporary and final construction stages.

The program computes and performs specifications checking of the reinforcement at selected locations in the stem, backwall and footing. The program also performs specifications checking of the structures for overturning, sliding, settlement, and bearing capacity whenever applicable.

1.2 ABBREVIATION

This section provides definitions of abbreviations that are commonly used throughout this User's Manual

AASHTO	-	American Association of State Highway and Transportation Officials.
ABLRFD	-	LRFD Abutment and Retaining Wall Analysis and Design Program.
DM-4	-	Design Manual Part 4, December 2019 Edition, published by the Pennsylvania Department of Transportation. This publication can also be downloaded free of charge from PennDOT's website.
LRFD specifications	-	AASHTO LRFD Bridge Design Specifications, Eighth Edition, 2017, published by: American Association of State Highway and Transportation Officials 444 North Capitol Street, N.W., Suite 249 Washington, D.C. 2001
PennDOT	-	Pennsylvania Department of Transportation.

Other references used in chapter 3:

[FDNHBK] - Winterkorn, H.F., and Fang, N.Y., Foundation Engineering Handbook, Van Nostrand Reinhold Company, New York, New York, 1975.

[CC1978] - Christian, John T., and Carrier III, W. David, "Janbu, Bjerrum and Kjaernsli's Chart Reinterpreted", Canadian Geotechnical Journal, Vol. 15, 1978.

[BOWLES] - Bowles, J.E., Foundation Analysis and Design, McGraw-Hill Book Company, New York, New York, 1988.

[DAS] - Das, B. M., Principles of Geotechnical Engineering 3rd edition, PWS Publishing, Boston, MA, 1994.

PROGRAM DESCRIPTION

2.1 GENERAL

The purpose of the LRFD Abutment and Retaining Wall Analysis and Design Program (ABLRFD) is to provide a tool for bridge engineers to analyze and design cast-in-place, reinforced concrete abutments and retaining walls. ABLRFD performs an analysis and specification check in accordance with the AASHTO LRFD Bridge Design Specifications and the Pennsylvania Department of Transportation Design Manual Part 4. As a result of a decision by the AASHTO Subcommittee on Bridges and Structures to no longer publish SI unit specifications, the program only supports US customary (US) units.

The program can either analyze an existing substructure or design a new substructure, based on the values of the input parameters entered by the user.

The program assumes a typical 1 ft strip (parallel direction) of the substructure for the structural analysis and design. The program and documentation use the terms “perpendicular” (to the stem) and “parallel” (to the stem) as shown in Figure 2.1-1.

2.2 SUBSTRUCTURE TYPES

The program can be used to perform an analysis or design of one of four substructure types summarized below.

Abutment Type I is an abutment with a backwall and a straight stem. The stem thickness is constant below the seat such that the front and back face of the stem are completely vertical. Abutment Type I is shown in Figure 2.2-1.

Abutment Type II is an abutment with a backwall which may be offset from the stem. The front and back face of the stem below the seat may be battered. Abutment Type II is shown in Figure 2.2-2.

Abutment without backwall is an abutment that resembles a retaining wall while providing a seat for the bridge superstructure at the top of the stem. The front and back face of the stem may be battered. This abutment type may be used to describe a gravity abutment which assumes that the stem and footing are not reinforced. Gravity abutments may be analyzed only and they may not be designed. Gravity abutment toe and heel projections are small or non-existent. Abutment without backwall is shown in Figure 2.2-3.

A Retaining Wall stem may have a battered front and back face. Sloped or level backfills may be specified. The retaining wall may be used to describe a gravity wall which assumes that the stem and footing are not reinforced. Gravity wall toe and heel projections are small or non-existent. Retaining wall is shown in Figure 2.2-4.

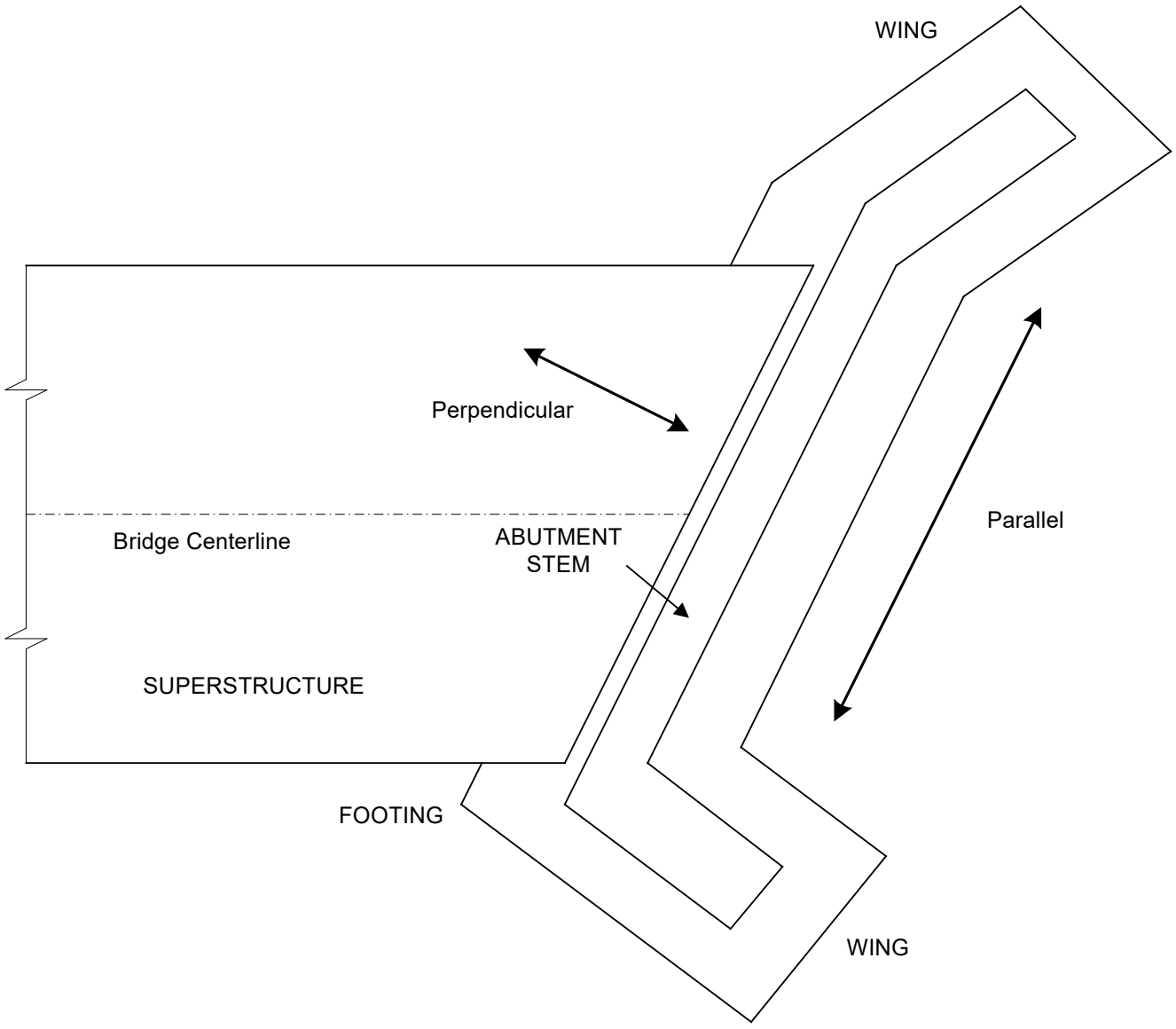

Figure 2.1-1 Directions

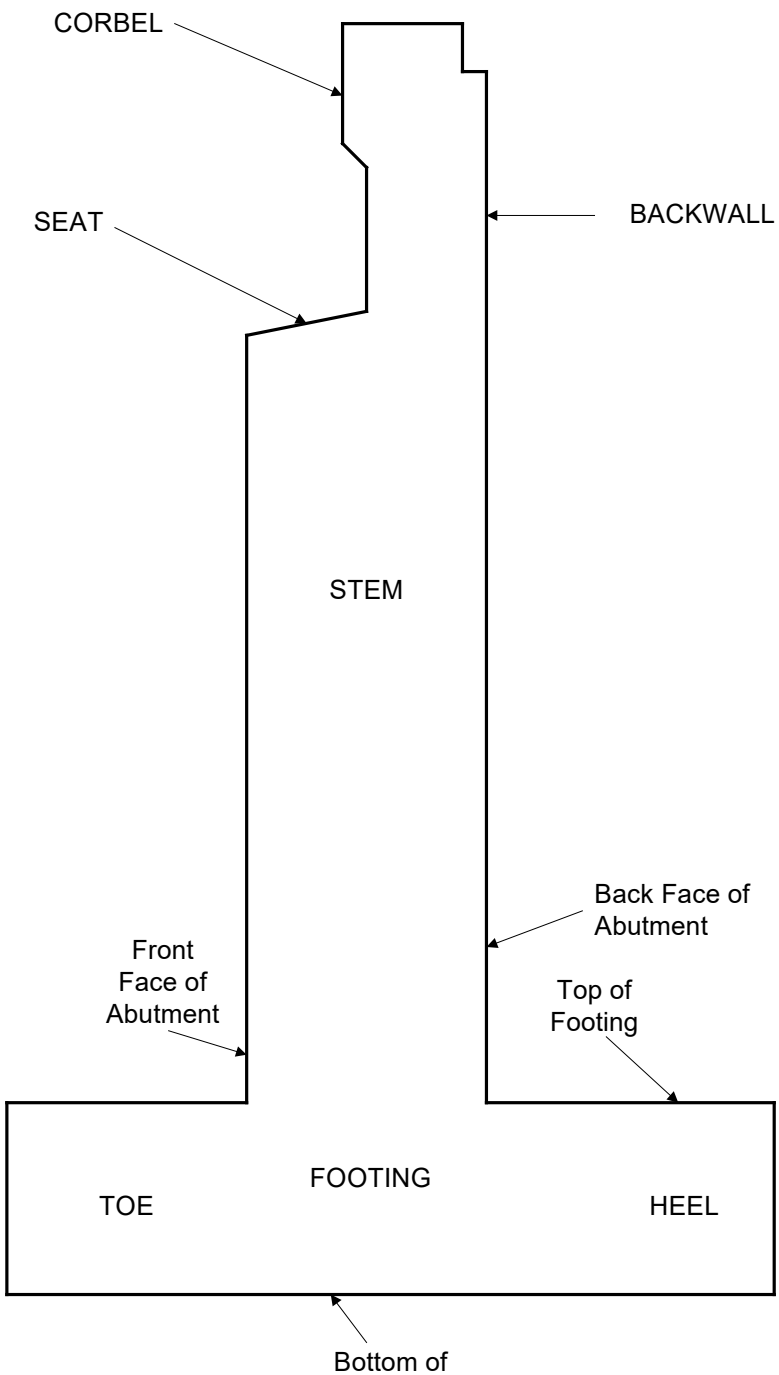

Figure 2.2-1 Abutment Type I

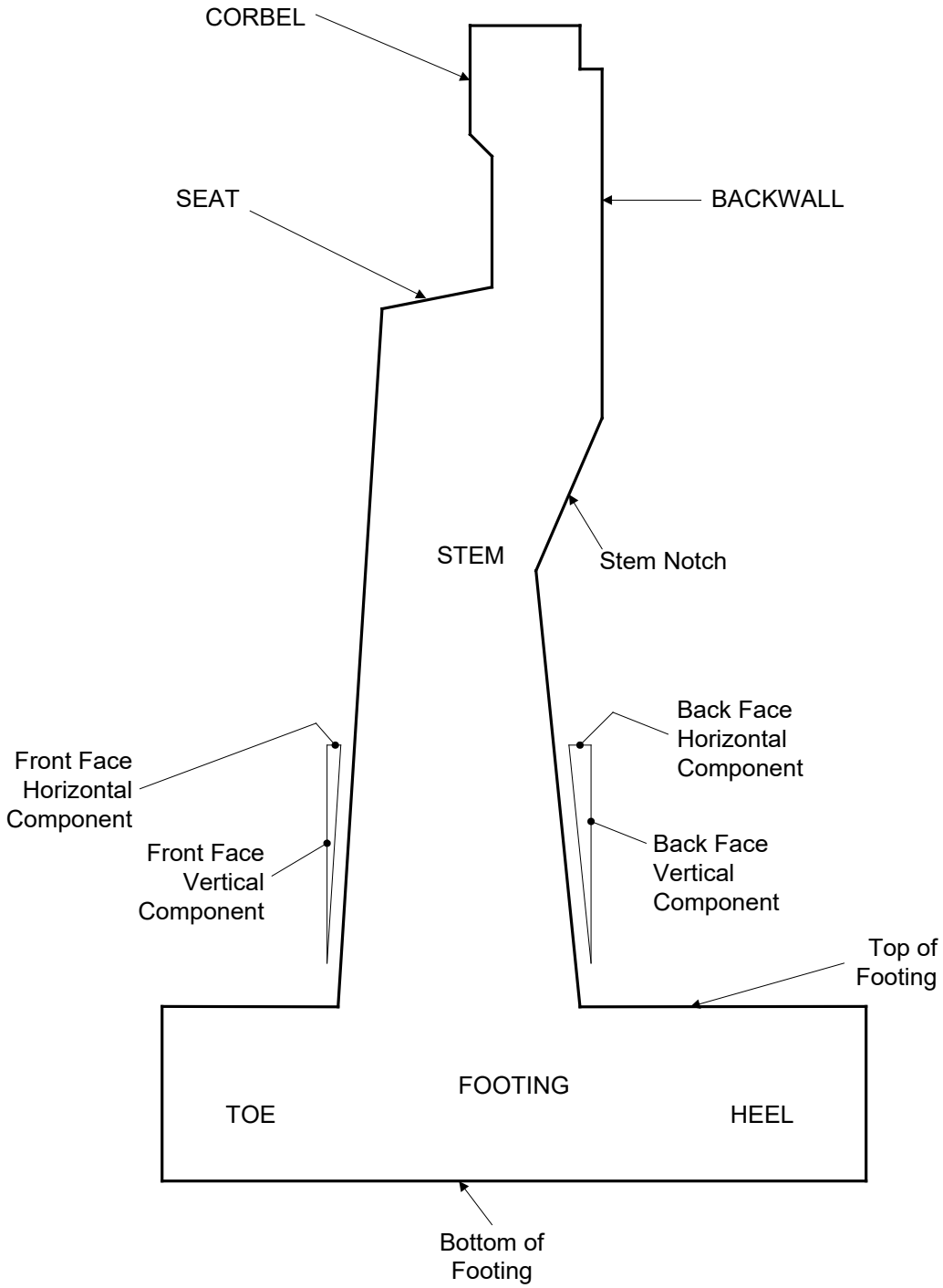

Figure 2.2-2 Abutment Type II

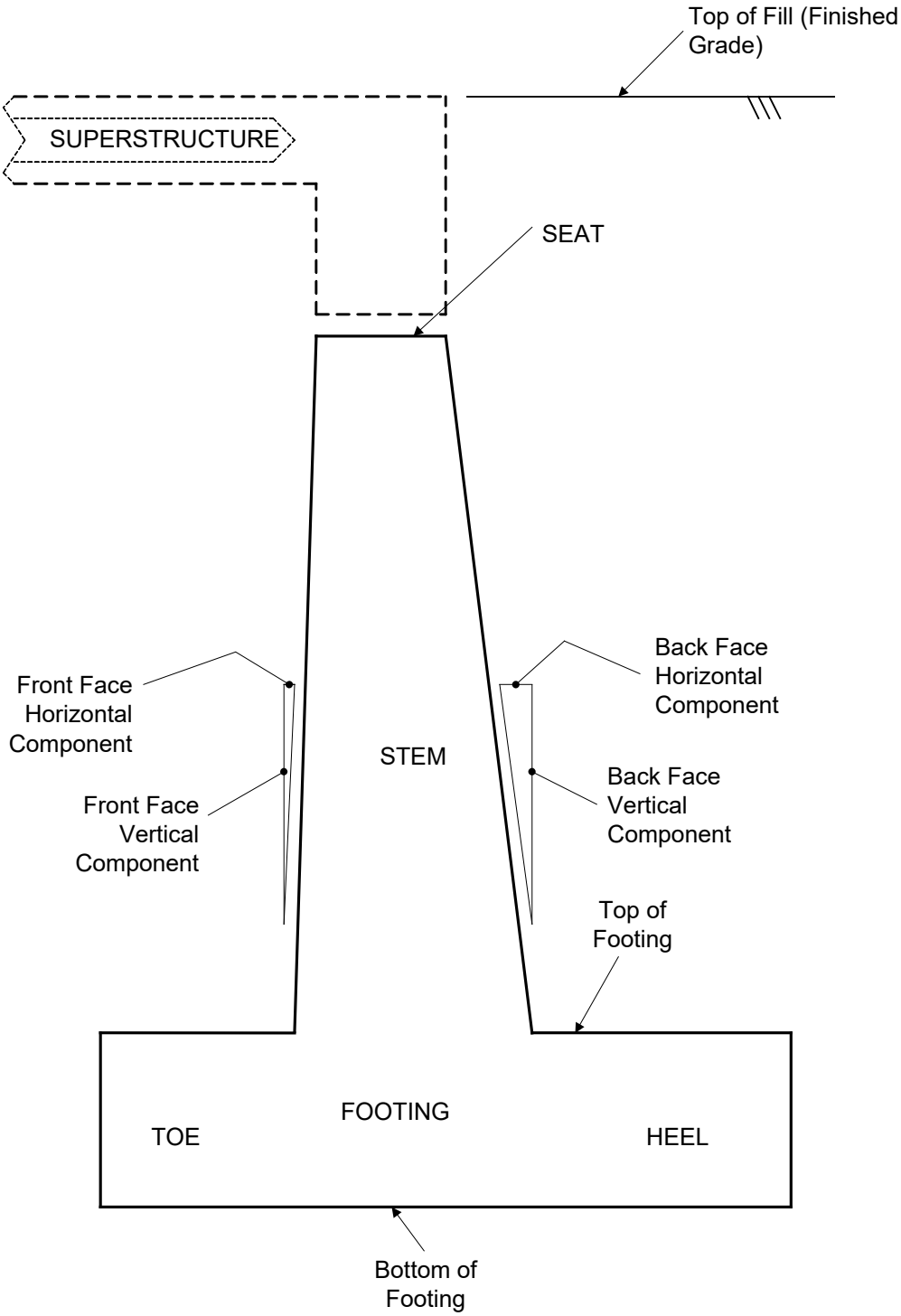

Figure 2.2-3 Abutment without Backwall

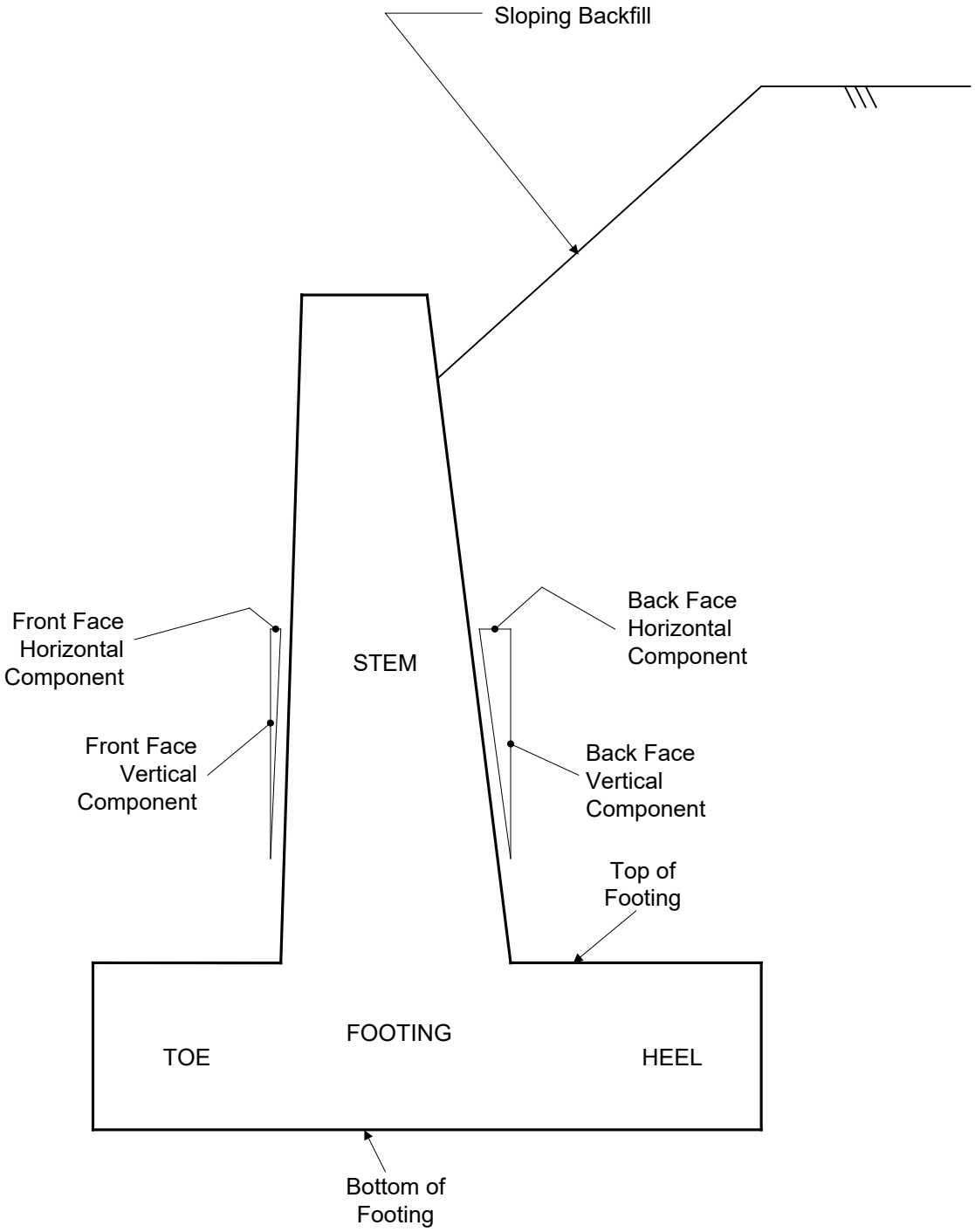

Figure 2.2-4 Retaining Wall

2.3 FOOTING TYPES

The program can be used to perform an analysis or design of one of the four footing types summarized below:

Spread footings are cast-in-place reinforced concrete footings founded on either soil or rock. Gravity abutments and walls may only be described using the spread footing type.

Pile footings are cast-in-place reinforced concrete footings supported on piles embedded in the footing. The individual pile capacity, both vertical and horizontal (lateral), must be entered by the user.

Caisson footings are cast-in-place reinforced concrete footings supported on caissons. The individual caisson capacity, both vertical and horizontal (lateral), must be entered by the user.

Pedestal footings are cast-in-place reinforced concrete footings supported on cast-in-place concrete pedestals founded on rock. Both the footing and the pedestals are analyzed and/or designed by this program.

2.4 PROGRAM FUNCTIONS

ABLRFD performs the functions listed below:

1. Input Processing - The program prompts the user for the name of the input file and output file and then processes the input. The program checks the user-entered input values and compares them with lower and upper limits stored in the program. If the user value is less than the lower limit, or greater than the upper limit, an error or warning is issued. If an error is detected, the program will stop processing, otherwise the program will continue on to the calculations involving the geometry.

2. Define Geometry - The program processes the input data to establish the geometry of the abutment or retaining wall. This geometry is used to calculate the dead loads, earth pressure, and other loads acting on the substructure and foundation. For analyses, the geometry of the stem and footing is not altered. For design, the geometry of the stem is not altered, but the program considers various combinations of footing width, thickness and toe projection.

3. Apply Loads - The program applies the loads that are applicable for a given substructure type for the two construction conditions that are described in Section 2.5. The effects of these loads are combined according to the limit states as specified in the LRFD Specifications. The resulting forces and moments are used to evaluate stability of the substructure.

4. Check Stability - The program evaluates the overall stability of each substructure type by examining: overturning, sliding, bearing capacity, and settlement as applicable. Overturning is satisfactory if the location of the resultant force falls within the kern area of the footing. The kern area depends on the foundation material (soil or rock). Sliding is checked by comparing the horizontal forces to the resistance force. The bearing capacity of the foundation is evaluated by considering: the bearing resistance based on the entered properties for soil or as entered for rock; the distribution of applied loads at the footing base; and, the geometry of the footing. The settlement of spread footings is evaluated on the properties of the foundation material and the applied load. Consolidation and secondary settlements are considered for soils with cohesion.

5. Modify Footing Dimensions - For design problems, if the substructure is unstable, the program will revise the footing geometry. The modifications to the geometry include, where applicable: changes in footing size (width, thickness, stem location); variations in the number of piles and/or pile pattern; and, changes in the pedestal geometry (width, thickness, back offset, front projection). For analysis problems, the stability conditions that were violated are reported in the output, but the program does not adjust the geometry.

6. Footing Reinforcement Design - The program evaluates the reinforcement requirements at the toe and heel locations within the footing. Flexural reinforcement is considered for both strength (moment capacity) and serviceability (crack control) conditions. For a design problem, the program determines the area of steel required for the strength limit state. This area is used to compute the bar spacing for each bar size. The spacing

is reduced as necessary to satisfy the serviceability requirements. At least one bar size and a corresponding bar spacing are needed to satisfy the design criteria. If a solution cannot be found, the program modifies the footing geometry and returns to function 2. The shear capacity is based on the concrete strength only (i.e., an unreinforced section). If the shear resistance is inadequate, the design procedure is re-evaluated with a thicker footing. For analysis problems, the resistance calculated using the user specified reinforcement is compared to the applied loads.

7. Stem Reinforcement Design - For design, the program computes the reinforcement in the stem based on the reinforcement area required for strength at the quarter points. Moment and axial load interaction is considered for both strength (flexure) and serviceability (crack control) criteria. The procedure for evaluating the reinforcement required (bar size and spacing) is similar to that used in the footing. The bar size and spacing for each bar size are determined at the base of the stem. The program then tries to find one "cutoff" point for each bar size at which every other bar may be terminated, in which case consideration will be given to the development and embedment length requirements of the bar. The optimum solution is then indicated as the bar size and spacing that satisfy all design criteria and provide the least reinforcement area. For analysis problems, the reinforcement specified by the user in the stem is checked for conformance to the specifications.

2.5 LOADINGS

The program applies the Dead Loads (DC, DW, EV), Live Loads (LR, BR, CE, PL), Water and Wind Loads (WL, WSUP,WSUP1,WSUP3,WSUP5,WSUB1,WSUB3,WSUB5,WA-E), Earth Pressure (EH, ES, LS), Temperature Force Effect (TU), Friction Forces (FR), Earthquake Effect (EQ) and Collision Force (CT) to the substructure as defined in the LRFD Specifications. Some of these loads are entered as input by the user and others are calculated by the program.

The program applies the above loads as two construction conditions; the temporary construction condition and the final construction condition. The temporary construction condition is a structure constructed and backfilled to the seat level of an abutment or to the top of a retaining wall. For temporary construction conditions, the bridge superstructure loads are not being applied, but a live load surcharge and an earth surcharge may be applied to the backfill. The final construction condition includes all loads.

2.6 ASSUMPTIONS AND LIMITATIONS

The following is a list of the basic assumptions and limitations used by ABLRFD:

1. The bearing capacity of rock foundations is not calculated by the program and must be supplied by the user.
2. Pedestals must be founded on rock. For design, the clear spacing between pedestals remains constant as specified by the user. Pedestal footing reinforcement is considered in the parallel direction only. Pedestal footing reinforcement is not analyzed in the perpendicular direction (toe and heel locations) because the footing and pedestal are assumed to be made integral using transverse shear keys and dowels as per DM-4 Section 10.6.5.2P.
3. Spread footing reinforcement is considered in the perpendicular direction only.
4. Shear in spread footings and pile footings for cantilever type abutments and cantilever type retaining walls is considered in the perpendicular direction only. Shear in the footings of gravity type abutments and gravity type retaining walls is calculated in the perpendicular direction only but not checked.
5. Only backface vertical reinforcement is designed in the stem. Minimum temperature and shrinkage reinforcement (#4's @ 12 inches) in the front face is only considered for negative moment conditions in the stem.
6. Foundations may consist of one or two soil layers or of only one rock layer. Soil and rock layers may not be mixed.
7. The material under the lowest soil layer is assumed to be infinitely stiff.
8. For design, the footing thickness is increased in one direction only; upward when the footing bottom elevation is fixed, or downward when the footing top elevation is fixed.
9. The gravity wall substructures are considered to be unreinforced.
10. Only the effective friction angle of soil is considered in the computations.
11. Horizontal loads applied to the abutment are assumed to be acting toward the center of the bridge. Refer to Tables 3.3.2-1 through -5 and Figure 5.30-1.
12. A one foot strip (in the parallel direction) of the abutment or wall is considered for analysis and design.
13. For the computation of self weight, the density of reinforced concrete is assumed to be 150 lbs/ft^3.
14. The modulus of elasticity of reinforcement, E_s, is assumed to be 29,000 ksi.
15. For footings on rock, the thickness of rock layer is assumed to be very large. It is inherent in the settlement calculations and it is not entered as an input value.
16. Punching shear is checked for single piles only. Effects due to overlapping shear planes should be checked by the engineer if piles are closely spaced.
17. The weight of fill above the toe is not included for overturning calculations.
18. A 2 inch eccentricity is applied to all vertical bearing load moment calculations for the design and analysis of the stem only. The 2 inch eccentricity offsets the load closer to the toe for the maximum case and closer to the heel for the minimum case.
19. Blast Loading defined in LRFD Specifications Section 3.15 is not considered by the ABLRFD program. Blast Loading is not shown in the DM-4 Load Factor table for Abutments which indicates that it should not be considered, even though the AASHTO section for Blast Loading was not deleted in DM-4.

20. Micropiles are not supported by ABLRFD. Analysis runs using the PIL command can be made to obtain the foundation loads, which can then be used to design the micropiles using other software or hand calculations.
21. When Type 4 Approach Slabs are input:
    - The contribution of the drain trough box and drain trough pedestals to the strength of the abutment stem and backwall will be conservatively ignored.
    - Loading from the Type 4 Approach Slab/drain trough support pedestals is transmitted directly to the abutment footing - no loading from the Type 4 Approach Slab is transmitted to either the abutment backwall or stem.
    - Type 4 drain trough support pedestals will never overhang the footing heel. For abutments with a Type 4 Approach Slab, the minimum allowable heel projection is assumed to be the maximum of the Minimum Heel Projection input value and the Type 4 drain trough support pedestal length (drain trough width + drain trough wall thickness).
    - The approach slab is assumed to act as a simple span between the sleeper slab and the drain trough pedestal. One half of the Type 4 Approach Slab total weight is assumed to be transferred to the drain trough pedestal.
    - The deck slab thickness above the drain trough is assumed to be 1'-6".

Additional assumptions and limitations, including parameter lower limits, and defaults, are presented with the input descriptions in Chapter 5.

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METHOD OF SOLUTION

The primary purpose of this program is to analyze and design cast-in-place, reinforced concrete, abutment and retaining wall structures. The structural analysis and specifications checking are performed in accordance with the LRFD Specifications and DM-4. This chapter provides detailed information regarding the method of solution used in this program.

In the analysis and design of abutment and retaining wall structures used for highway bridges, the following steps are generally required:

1. Define the geometry of the structure.
2. Calculate the applied load effects.
3. Check the structure stability regarding overturning, sliding, settlement and bearing capacity.
4. Calculate structure section resistance.
5. Perform specifications checking.
6. Adjust footing size and foundation configuration for design.

The program performs the above calculations using classical methods of structural and foundation analysis, and following the specifications provided in the LRFD Specifications and DM-4.

For the purposes of this program, the analysis and design runs are defined as follows:

For an analysis, the structure type and size and the applied loads are known, and the program performs all calculations mentioned above except for Step 6. For a design run, all calculations mentioned above are performed.

The following sections describe the above calculations in detail. Refer to any standard text book on structural and/or foundation analysis, and the appropriate sections of this manual, for calculations performed in Steps 1, 2 and 3. Refer to the LRFD Specifications and DM-4 for calculations performed in Steps 4 and 5. Refer to the appropriate sections in this manual for the calculations performed in Step 6.

Chapter 3 Method of Solution

3.1 NOTATION

The following are the meanings of equation notations used in various expressions throughout this document. Definitions of abbreviations can be found in Section 1.2.

a = depth of concrete stress block in a reinforced concrete section (in)

a_{mb} = maximum moment between pedestal for bottom steel (k-ft)

a_{mbs} = service moment between pedestals (k-ft)

a_{mo} = maximum moment over the pedestal for top steel (k-ft)

a_{mos} = service moment over pedestals (k-ft)

A = area of cross section (ft^2)

A_g = gross area of cross section (ft^2)

A_{gross} = gross area of reinforced concrete section (in^2)

A_s = area of mild steel reinforcement (in^2)

A_{st} = area of reinforcement (in^2)

A_{sbar} = area of steel for a given bar (in^2)

A_{sprov} = area of steel provided (in^2)

A_{sprov_new} = area of steel needed so splice will fit within the backwall (in^2)

A_{sprov_old} = area of steel provided in backwall for specified bar size (in^2)

A_{sreqd} = area of steel required (in^2)

A_{tr} = area of transverse reinforcement within spacing, s, and crossing the potential splitting plane (in^2)

b = width of concrete cross section (in) **(3.5.2.1)**

b = least width of the component (in) (3.5.2.7.1)

b_c = Beta factor for punching shear around piles **(dim)**

b_o = shear perimeter around the piles - used for punching shear calculations (ft)

bw = base width used for **overturning** calculations **(in)**

B = footing width (in)

B' = effective width used for sliding resistance and settlement calculations (in)

B'_1 = effective width used for settlement calculations for upper layer of soil (in)

B'_2 = effective width used for the settlement calculation for lower layer of soil (in)

Base = contact length between footing and pedestal (ft)

BH = backwall height minus the backwall cover and minus the paving notch, if one is present (in)

BR = horizontal braking force from live load acting on the superstructure (k/ft)

c = neutral axis depth **from extreme compression fiber** (**in**) **(3.5.2.1)**

c = cohesion of soil taken as undrained shear strength (ksf)

c_1 = undrained shear strength of the top layer of soil (ksf)

c_2 = undrained shear strength of the lower layer of soil (ksf)

c_a = **adhesion between footing and soil (ksf)**

c_b = the smaller of the distance from center of bar or wire being developed to the nearest concrete surface and one-half the center-to-center spacing of the bars or wires being developed (in)

ccp = center to center spacing of pedestals (ft)

c_i = distance of the ith row to the centroid of the pile group (ft)

c_i = cohesion of soil taken as undrained shear strength (soil layer i) (ksi)

C = concrete compressive strength (ksi)

C_{624} = lateral capacity of a pile in an all vertical pile foundation (kip)

CAP_A = axial capacity for a pile (kip)

CAP_H = axial pile capacity horizontal component for a battered pile (kip)

CAP_V = vertical component of axial capacity for a battered pile (kip)

C_c = compression index used for computing the consolidation settlement based on void ratio definition **(dim)**

C_{cr} = recompression index based on strain definition **(dim)**

C_d = settlement adjustment factor for elastic settlement **(dim)**

CE = horizontal centrifugal force from the live load acting on the superstructure (k/ft)

CF = elastic settlement factor used in the Christian and Carrier method **(dim)**

CG = centroid of the pile group relative to the toe (ft)

CT = vehicle collision force acting on top of a parapet on a retaining wall (k/ft)

C_α = coefficient of secondary compression based on void ratio definition **(dim)**

d = effective depth of concrete section (in)

d_b = diameter of a reinforcing bar (in)

d_c = thickness of concrete cover measured from tension fiber to center of bar (in)

d_h = effective depth of heel (ft)

diam = diameter of piles - used for punching shear calculations (ft)

ds = distance from extreme compression fiber to the centroid of the nonprestressed tensile reinforcement (in)

d_t = effective depth of toe (ft)

d_v = depth of section for shear capacity computation (in)

D = shear zone for bearing resistance calculations (ft)

D = effective shear depth (ft) (3.4.1.4.2)

D = maximum depth where bearing is effective (ft) (3.4.1.4.2.1)

DC = dead load due to the weight of the abutment (including backwall) or retaining wall (k/ft)

DC-A = dead load due to abutment components (k/ft)

DCAP = dead load due to weight of drain trough (k/ft)

DCAS = dead load due to approach slab (k/ft)

DCAT = dead load due to the weight of an architectural treatment applied to the front face of an abutment or retaining wall (k/ft)

DC-S = dead load due to superstructure components (k/ft)

D_f = footing embedment depth (ft)

D_{f1} = depth to base of footing measured from soil layer directly above toe point (ft)

D_{f2} = depth to top of second soil layer measured from the soil layer directly above the toe (ft)

D_i = distance of the ith row of the pile group from the toe of the footing (ft)

DW = dead load due to the weight of utilities, wearing surfaces, and future overlays (k/ft)

DW-A = dead load due to future wearing surface (k/**ft**)

DWAS = dead load due to the utilities, wearing surface, and future overlays resting upon either the backwall, beam notch, corbel, or drain trough pedestal on an abutment (k/ft)

DW-S = dead load due to wearing surface and utilities from superstructure (k/**ft**)

e = distance from the vertical load to the centroid of the pile group (in)

e_B = eccentricity of load in the B direction (in)

ecc = eccentricity of load resultant; used for stability and pressure calculations (ft)

eccp = eccentricity of the load resultant relative to center of pedestal (ft) **(3.4.2.5)**

eccp = eccentricity for pedestal stability calculations (ft)

e_L = eccentricity of load in the L direction (in)

e_o = void ratio at initial effective stress (dim)

E = **Young's** modulus (ksf)

E_1 = Young's modulus of soil layer 1 (ksf)

E_2 = Young's modulus of soil layer 2 (ksf)

E_c = modulus of elasticity of concrete (ksi)

EH = lateral earth pressure computed by considering the active condition of the backfill (ksf)

EH_1 = lateral earth force for backfill above height of water in backfill (k/ft)

EH_2 = lateral earth force for backfill below height of water in backfill (k/ft)

EH_3 = lateral net force for backfill and water below height of water (k/ft)

EH-V = overall force effects of the horizontal earth pressure in the vertical direction (ksf)

$EH\text{-}V_1$ = vertical component of earth force for backfill above height of water in backfill (k/ft)

$EH\text{-}V_2$ = vertical component of earth force for backfill below height of water in backfill (k/ft)

$EH\text{-}V_3$ = vertical component of net force for backfill and water below height of water (k/ft)

E_i = modulus of elasticity of intact rock (ksf)

E_m = rock mass modulus (ksf)

$E_{m(input)}$ = user input rock mass modulus (ksf)

EQ = total earthquake force applied in the final stage (k/ft)

E_s = modulus of elasticity of steel (ksi)

E_s = Young's modulus for soil (ksi) (3.4.1.3.1)

ES = uniform earth surcharge load applied to the surface of backfill, expressed as an equivalent height of backfill soil (ft)

ES_h = horizontal force component of ES load (kip)

ES_v = vertical force component of ES load (kip)

EV = dead load due to the weight of the backfill soil with vertical component only (k/ft)

EV = soil vertical load between approach slab pedestal and end of the heel (k/ft) (3.5.1.1)

EV_a = soil vertical load between approach slab pedestals (k/ft)

ExtFor = input Horizontal External Earthquake Force (k/ft)

f'_c = compressive strength of concrete (ksi)

f_c = compressive stress in concrete (ksi)

f_{ps} = factor for punching shear calculations (dim)

f_r = rupture stress in concrete (ksi) (3.5.1.4)

f_s = tensile stress in rebar **(ksi)**

f_{sact} = actual stress in reinforcement due to applied loads (ksi)

f_{ss} = tensile stress in rebar for crack control (ksi)

f_{suncr} = tensile stress based on uncracked section properties (ksi)

f_u = ultimate tensile strength of steel (ksi)

f_y = yield strength of steel (ksi)

FR = horizontal force on the abutment induced by friction in sliding type expansion bearings (k/ft)

F_t = footing thickness (ft)

h = section thickness of gravity wall at given location (in) **(3.6.5)**

h = footing thickness – pile/caisson embedment (ft) (3.5.2.10)

h = least height of component (in) (3.5.2.7.1)

h = overall thickness or depth of the component (in)

h_{ES} = height of ES load input by user (ft)

$h_{ES\text{-}tmp}$ = height of ES load input by user for final stage(ft)

hlfp = horizontal force including pedestal effects (kip)

hlmp = horizontal moment applied to pedestal footing (k-ft)

$hlpr_p$ = pressure at heel for pedestal stability calculations (ksi)

h_{LS} = height of LS load input by user (ft)

$h_{LS\text{-}tmp}$ = height of LS load input by user for final stage (ft)

hmp = pedestal overturning moment due to applied horizontal loads (k-ft)

htb = total height of pedestal (ft)

H = height of stem (ft) **(3.6.1)**

H = height of backfill (ft) **(3.3.2.8)**

H = height of soil above the analysis point (broken backfill) (ft) (3.3.2.8)

H = height of soil at end of heel from bottom of footing or top of rock layer (internal footing forces) (ft) (3.3.2.9.2)

H = height of concrete cross section (in) (3.6.1)

H_1 = depth of soil layer 1 (upper layer) used for settlement calculations (in) **(3.4.1.3.1)**

H_1 = depth of soil layer 1 (upper layer) used for bearing resistance calculations (ft) (3.4.1.4.2)

H_1 = height of soil above the point of analysis to the backfill break point (ft) (3.3.2.8)

H_1 = distance from bottom of footing to top of the second soil layer (ft) (3.4.1.4.2.2)

H_2 = depth of soil layer 2 (lower layer) used for settlement calculations (in) **(3.4.1.3.1)**

H_2 = depth of soil layer 2 (lower layer) used for bearing resistance calculations (ft) **(3.4.1.4.2.3)**

H_2 = difference in height between H and H_3 (internal footing forces) (ft) (3.3.2.9.2)

H_3 = height of internal pressure acting on the heel (ft) (3.3.2.9.2)

H_{crit} = critical height of soil where two soil layers may be considered as one soil layer (ft)

H_{final} = height of surcharge loading in horizontal direction for final stage (ft)

H_{ftg} = lateral load (per unit length) applied to the pile group (kip)

H_i = depth of soil layer i; used for settlement calculations (in) and bearing resistance (ft)

HLF = horizontal force determined from the minimum load case for all limit states except the service load limit state (kip) **(k/ft for pedestals)**

HLM = overturning moment (about the toe) generated by applied horizontal loads (k-ft)

HMF = moment from footing based on horizontal loads (k-ft) **(k-ft/ft for pedestals)**

H_p = heel projection (ft)

H_{pe} = effective pressure at heel (heel pressure - pore water pressure) (ksf)

H_{stem} = height of stem (ft)

H_{temp} = height of surcharge loading in horizontal direction for temporary stage (ft)

H_U = unfactored horizontal force (k/ft)

H_w = height of water in backfill (ft)

H_{w1} = height of water above center of sublayer in Layer 1 (ft)

H_{w2} = height of water above center of sublayer in Layer 2 (ft)

H_{WH} = height of water table (heel) (ft)

H_{WT} = height of water table (toe) **(ft)**

i_c, i_γ, i_q = load inclination factors for evaluating bearing resistance of soils **(dim)**

I = moment of inertia (ft^4)

I_g = moment of inertia in pile group (in^4)

IN_{max} = maximum input spacing of piles (ft)

I_p = influence coefficient to account for rigidity and dimensions of footing (dim)

jd = distance between resultant compression and tension forces (in)

k = fraction of effective depth that represents the location of neutral axis **(dim)**

kd = depth to the neutral axis from extreme compressive fiber (in)

k_{tr} = transverse reinforcement index (dim)

K_1 = correction factor for source of aggregate, BXLRFD uses a value of 1.0 (dim)

K_a = active earth pressure coefficient (dim)

K_{ah} = horizontal component of K_a (dim)

K_{av} = vertical component of K_a (dim)

K_s = punching shear coefficient for computing the bearing resistance of cohesionless soils (category 4) **(dim)**

l_{bact} = actual length available to develop a given bar (ft)

l_d = development length - after consideration of all applicable factors (ft)

l_{db} = development length required for a given bar (**in**)

l_{dh} = modified hooked bar development length (in)

l_{d_old} = old development length for the specified bar size (in)

l_{hb} = basic hooked bar development length (in)

l_{spt} = splice length (in)

l_{spt_old} = old splice length for the specified bar size (in^2)

L = length of the footing (in)

L' = effective length of the footing (in)

L' = effective length of foundation (in)

L'_1 = effective length used for settlement calculations for upper layer of soil (in)

L'_2 = effective length used for settlement calculations for lower layer of soil (in)

Lap = lap length (ft)

L_{dact} = available space for a bar to develop in the component (in)

L_{dbar} = development length of a bar (in)

L_{dratio} = ratio of available length to develop versus the required bar development length (dim)

L_{fact} = influence factor for consolidation settlement of clays (dim)

L_{foot} = footing length measured parallel to the front of the abutment (user input) (ft)

LL = vertical live load acting on the structure (k/ft)

LLAS = live load due to approach slab (k/ft)

LLBH = horizontal live load applied to the top of the backwall, including effects due to impact, only considered in backwall analysis (k/ft)

LLBW = vertical live load on the backwall applied along the front edge of the corbel, including effects due to impact, only considered in backwall analysis (k/ft)

LLDD = design live load reaction applied in downward direction and does not include effects due to impact (k/ft)

LLDU = design live load reaction applied in upward direction and does not include effects due to impact (k/ft)

LLIM = live load including dynamic load allowance (kip)

LS = live load surcharge applied when a vehiclular load acts on the surface of the backfill, expressed as an equivalent height of backfill soil (ft)

LS_H = horizontal force component of LS load (ft)

LS_V = vertical force component of LS load (**ft**)

m = parameter for elastic settlement calculations for soil layer (dim) (3.4.1.3.2)

M = applied moment (k-ft)

M_{app} = net applied moment at gravity wall section (k-ft)

M_{calc} = internal moment from equilibrium of axial load and strain compatibility (**k**-ft)

M_{cap} = moment capacity (k-ft)

M_{cr} = moment required to crack the section (k-ft)

M_n = nominal moment resistance of the section (k-ft)

MRD = user input development correction factor on the MRD command (dim)

$M_{service}$ = applied moment from service limit state; used for crack control (k-ft)

M_u = ultimate applied factored moment (k-ft)

M_x = applied moment to a pile group (k-ft)

n = modular ratio of mild steel reinforcement and concrete - rounded to the nearest integer **(dim) (3.5.1.4)**

n = number of piles - used to compute the force in a given pile **(dim) (3.4.3.1)**

n = parameter for elastic settlement calculations for soil layer **(dim) (3.4.1.3.2)**

n = load inclination factor multiplier for i_c **(dim) (3.4.1.4.2.1)**

n = number of bars or wires developed along plane of splitting (dim) (3.5.2.4)

nsub = number of sub layers **(dim)**

N = applied axial load (kip)

N_c = bearing capacity factor for cohesion **(dim)**

N_m = soil bearing capacity factor **(dim)**

NP_{cum} = cumulative number of battered piles for rows 1 to i (dim)

NP_i = number of piles in ith row from the pile group pattern definition (dim)

NP_{max} = most piles in a row (first row) (dim)

NP_{min} = least piles in a row (last row) (dim)

NP_{tot} = total number of piles from pile group pattern definition (dim)

N_q = bearing capacity factor for surcharge (dim)

N_γ = bearing capacity factor for unit weight (footing width) term (drained loading) (dim)

p = parameter for elastic settlement calculations for soil layer (dim)

p_{back} = pressure at the back of the pedestal (ksf)

pf = horizontal projection of the sloping portion of the front of the pedestal (ft)

p_{front} = pressure at the front of the pedestal (ksf)

p_m = pedestal moment about the toe i.e. pedw acting at centroid (k-ft)

pt = projection of the top of the pedestal from the footing toe (ft)

pw = pedestal width (ft)

p_{wt} = pedestal self weight (area*thickness*conc density) vertical force (kip)

P = applied vertical load (kip)

P_a = axial pile force (kip)

P_{a1} = internal force acting on the heel (k/ft)

P_{app} = applied axial load (kip)

P_{cap} = axial load capacity (kip)

P_h = horizontal component of axial pile force (kip)

PL = vertical live load due to pedestrians acting on the superstructure (k/ft)

P_{max} = bearing resistance of the pedestal concrete **(ksi) (3.4.2.2)**

P_{max} = maximum axial load (ksi) (3.6.1)

P_o = axial compressive strength of a reinforced concrete section (kip)

P_v = vertical component of axial pile force (kip)

q = parameter for elastic settlement calculations for soil layer **(dim) (3.4.1.3.1)**

q_1 = applied bearing pressure for settlement calculations for layer 1 (ksf) **(3.4.1.3.1)**

q_1 = **norminal bearing resistance of footing supported in the upper layer of a two-layer system, assuming the upper layer is infinitely thick (ksf) (3.4.1.4.2.3)**

q_2 = applied bearing pressure for settlement calculations for layer 2 (ksf) **(3.4.1.3.1)**

q_2 = **nominal bearing resistance of a fictitious footing of the same size and shape as the actual footing but supported on surface of the second (lower) layer of a two-layer system (ksf) (3.4.1.4.2.3)**

q_n = **nominal bearing resistance (ksf) (3.4.1.4.2.1)**

q_o = bearing pressure for elastic settlement calculations (ksf) **(3.4.1.3.1)**

q_{ult} = ultimate bearing resistance of soil (ksf) **(3.4.1.4.2)**

r = reinforcement ratio **(dim)**

ratio = ratio of applied axial load to axial capacity **(dim)**

Ratio = ratio used to increase A_{sprov_old} so a splice will fit within the backwall (dim)

R = nominal resistance of section - used for pedestal bearing calculations (ksf)

R = sliding resistance of footing (k/ft)

R_a = axial resistance of pile (kip)

RC_{BC} = reduction coefficient for bearing resistance due to slope effects for single soil layer (dim)

RC_{BC1} = reduction coefficient for bearing resistance due to slope effects for soil layer 1 **(dim)**

RC_{BC2} = reduction coefficient for bearing resistance due to slope effects for soil layer 2 **(dim)**

ResFact = input Response Modification Factor (dim)

R_h = horizontal (lateral) resistance of **an individual battered** pile (kip)

R'_h = horizontal (lateral) resistance of vertical pile (kip)

R_{ped} = load resultant in pedestal (kip)

R_τ = nominal resistance for sliding for foundations on frictional and cohesive shear strength soils (k/ft)

s = maximum center-to-center spacing of transverse reinforcement within l_d (in)

s = spacing of reinforcement in the layer closest to the tension face for crack control (in) (3.5.2.8)

s_c, s_γ, s_q = footing shape factors for bearing resistance calculation (dim)

s_{new} = new suggested spacing for bar development (in)

s_{new} = bar spacing needed so splice will fit within the backwall (in)

s_{orig} = original bar spacing (in)

s_r = angle of internal force acting on heel to horizontal (β for Rankine, δ + β for Coulomb) (deg)

s_u = undrained shear strength of soil (ksf)

sudl = service limit state uniform distributed load applied to pedestal footing (k/ft)

S = bar spacing **(in)**

S = pedestal clear spacing **(ft)**

S = section modulus (ft^3)

S_b = bottom section modulus, non-composite, non-transformed (in^3)

S_{BPHL} = pile spacing in the ith row (piles are battered) (ft)

S_c = consolidation settlement (in)

S_{ci} = consolidation settlement for each sublayer i (in)
S_e = elastic settlement (in)
S_{iBPVL} = pile spacing in the i^{th} row (piles are battered) (ft)
S_{iVPVL} = pile spacing in the i^{th} row (piles are vertical) (ft)
S_{max} = maximum spacing for a reinforcement bar (in)
S_{max} = maximum spacing of piles in the first row (ft) (3.7.3.1)
SoiFact = input soil pressure factor (dim)
S_p = maximum Pile Spacing (ft)
S_s = secondary settlement (in)
S_t = total settlement (in)
SupFor = input horizontal superstructure force (k/ft)
S_{VPHL} = pile spacing (ft)
t = structural thickness of the member (in)
t_1, t_2 = arbitrary time interval for secondary settlement calculation (years)
t_e = depth of embedment into rock (when applicable for foundations on rock) (ft)
t_h = pedestal thickness (ft)
$topr_p$ = pressure at toe for pedestal stability calculations (ksi)
T = tensile strength of reinforcement (kip)
T_p = toe projection (ft)
T_{pe} = effective pressure at toe (toe pressure - pore water pressure) (ksf)
TU = horizontal force on the abutment induced by thermal expansion or contraction of the superstructure (k/ft)
udl = maximum uniform distributed load applied to pedestal footing (k/ft)
v_{fact} = constant for shear capacity **(dim)**
vlfp = vertical force for a given combination that also includes the pedestal (kip)
vmf = moment from footing based on vertical loads (k-ft) **(k-ft/ft for pedestals)**
vmp = vertical moment for a given combination that also includes the pedestal (k-ft)
vmp = pedestal overturning moment due to applied vertical loads (k-ft)
vped = maximum applied shear force for pedestal footing (kip)
V = vertical force used in sliding resistance equations (kip)
V_c = shear capacity of the section (kip)
V_{ftg} = vertical load (per unit length) acting at the footing bottom (k/ft)
V_i = vertical load on a pile in the i^{th} row (k/ft)
VLF = vertical force for a given load combination (kip) (k/ft for pedestals)
VLM = overturning moment (about the toe) generated by applied vertical loads (k-ft)
V_{pr} = punching shear resistance (kip)
V_U = unfactored vertical force (k/ft)
w_c = unit weight of concrete **(kcf)**
W = width of footing (ft) (3.3.2.11)

WA = **three forces consisting of the buoyant force acting under the footing, the downward force equal to the weight of water over the toe of the footing, and the horizontal force due to water pressure on the front face of them stem (k/ft) (3.3.2.13)**

WA-E = **application of the horizontal component of the water load (k/ft)**

W_{bf} = **horizontal distance from back face of stem to vert. plane at the heel used in LS, ES calculations (ft)**

WL = **horizontal force acting on the bearing due to wind acting on the superstructure live load (k/ft) (3.3.2.17)**

WS = **Wind Superstructure (either horizontal or vertical) (k/ft)**

WSUB1 = **horizontal force from wind acting normal to the face of the abutment on the substructure, Service-I Limit State (k/ft) (3.3.2.16)**

WSUB3 = **horizontal force from wind acting normal to the face of the abutment on the substructure, Strength-III Limit State (k/ft) (3.3.2.16)**

WSUB5 = **horizontal force from wind acting normal to the face of the abutment on the substructure, Strength-V Limit State (k/ft) (3.3.2.16)**

WSUP = **vertical force from wind acting on a superstructure (k/ft)**

WSUP1 = **horizontal force acting normal to the face of the abutment or noise wall on a retaining wall from wind acting on a superstructure or external structure attached to a retaining wall, Service-I Limit State (k/ft) (3.3.2.15)**

WSUP3 = **horizontal force acting normal to the face of the abutment or noise wall on a retaining wall from wind acting on a superstructure or external structure attached to a retaining wall, Strength-III Limit State (k/ft) (3.3.2.15)**

WSUP5 = **horizontal force acting normal to the face of the abutment or noise wall on a retaining wall from wind acting on a superstructure or external structure attached to a retaining wall, Strength-V Limit State (k/ft) (3.3.2.15)**

W_u = pseudo uniform load **(k/ft)**

x = ratio of **effective** length to effective width **(dim) (3.4.1.3.1)**

x = **drain trough length (ft)**

x_{resp} = distance of the load resultant (applied to pedestal) relative to the toe (ft)

X_r = distance of resultant measured from toe (in)

y = **drain trough pedestal width (in)**

z = **distance between the end of heel and end of the drain trough support pedestal (in) (3.5.2.11)**

z_w = **depth of water table relative to base of footing (in)**

Z = depth to center of soil sublayer used for settlement (in)

α = **elastic distortion** settlement factor **(dim)**

α = angle of soil wedge, used for EH calculations (deg)

α = **unacceptable eccentricity location from toe or heel of footing (ft)**

β = angle of fill to the horizontal (deg)

β = **shear capacity factor (2.0) (dim)**

β = acceptable eccentricity range at center of footing (ft)

β_1 = ratio of the depth of the equivalent uniformly stressed compression zone to the depth of the actual compression zone (dim)

β_m = punching index of soil (dim)

β_s = crack width factor used in crack control calculations (dim)

β_z = factor to account for footing shape and rigidity (dim)

γ = density of soil (kcf)

γ' = effective soil unit weight (kcf)

γ_1 = density of soil layer 1 (kcf)

γ_{1f} = unit density of upper loose sand layer used to compute nominal bearing resistance of lower layer (kcf)

γ_D = unit weight of dry soil (kcf)

γ_{DC} = load factor for dead load component (dim)

γ_e = exposure factor used in crack control calculations (dim)

γ_{im} = input moist unit weight of soil (single layer) (kcf)

γ_{im1} = input moist unit weight of soil for layer 1 (kcf)

γ_{im2} = input moist unit weight of soil for layer 2 (kcf)

γ_{is} = input saturated unit weight of soil (single layer) (kcf)

γ_{is1} = input saturated unit weight of soil for layer 1 (kcf)

γ_{is2} = input saturated unit weight of soil for layer 2 (kcf)

γ_m = unit weight of moist soil (kcf)

γ_s = unit weight of saturated soil (kcf)

γ_w = unit weight of water (kcf)

Δh = thickness of soil sub-layer used for settlement and bearing calculations (in)

ε = angle tolerance to avoid cotangent of zero (deg)

ε = component of soil wedge angle based on backfill slope angle and internal friction angle (deg) (3.3.2.8)

ε_c = strain in concrete at extreme compression fiber (in/in)

ε_{cl} = compression-controlled strain limit (in/in)

ε_{cu} = crushing concrete strain (in/in)

ε_s = strain in tensile reinforcement (in/in)

ε_t = tensile strain in the extreme tensile steel at nominal resistance (in/in)

ε_{tl} = tension-controlled strain limit (in/in)

δ = friction angle between backfill and wall, assumed one-half of the backfill friction angle (deg) (3.3.2.8)

δ = user entered concrete/rock friction angle (deg) (3.4.1.2.1)

θ = angle of backface of wall to the vertical (deg)

θ = angle between pile axis and the vertical (deg)

κ = **shear strength ratio (c_2/c_1) for two layered cohesive soil systems below footing (dim)**

λ = concrete density modification factor **(dim)**

λ_{cf} = **reinforcement coating factor (dim)**

λ_{cw} = **reinforcement coating factor (dim)**

λ_{er} = **excess reinforcement factor (dim)**

λ_{rc} = **reinforcement confinement factor (dim)**

λ_{rl} = **reinforcement location factor (dim)**

μ_1 = elastic settlement influence factor **(dim)**

μ_2 = elastic settlement influence factor **(dim)**

μ_c = **reduction factor taken as specified in Figure 3.4.1-6 (dim)**

υ = **Poisson's ratio (dim)**

ρ = **reinforcement ratio (dim)**

ρ_{min} = minimum reinforcement ratio **(dim)**

σ'_b = **effective bearing pressure at the bottom of the footing using effective footing dimension B'1 (ksi)**

σ'_f = **Final effective stress at center of soil sublayer (ksi)**

σ'_{ft} = Final effective stress at top of soil layer (ksi)

σ'_o = Initial effective stress at center of soil sublayer (ksi)

σ'_{ot} = Initial effective stress at top of soil layer (ksi)

σ'_p = Maximum past effective stress at center of soil sublayer (ksi)

$\sigma'_{p\ bottom}$ = Maximum past effective stress at bottom of soil layer (ksi)

$\sigma'_{p\ top}$ = Maximum past effective stress at top of soil layer (ksi)

φ = **strength reduction factor (dim)**

φ' = **effective angle of internal friction within backfill (deg)**

φ_f = **soil friction angle (deg)**

φ_{f1} = friction angle for soil layer 1 (deg)

φ_{f2} = **friction angle for soil layer 2 (deg)**

φ_{if} = **input soil friction angle (deg)**

φ_{if1} = **input soil friction angle for layer 1 (deg)**

φ_{if2} = **input soil friction angle for layer 2 (deg)**

φ_τ = **resistance factor for sliding resistance between soil and footing (dim)**

3.2 GEOMETRY

The substructure type, size, backfill slope, other substructure and foundation dimensions, and geotechnical parameters are input by the user. These dimensions and values are used to calculate the applied load effects and the structural analysis solution. The abutment backwall and stem or retaining wall stem are defined by various dimensions as shown on Figures 5.6-1, 5.7-1, 5.8-1, and 5.9-1. The footing is defined by its type as shown on Figures 5.6-1, 5.7-1, 5.8-1, 5.9-1, 5.12-1, 5.14-1, 5.14-2, 5.15-1, and 5.16-1.

A design run is viewed as a series of analysis runs for a variety of footing geometry. Essentially, all of the specification checks that would be applicable in an analysis run are considered in a design run. In an analysis run, the program simply evaluates each applicable specification check given one user-defined specified footing geometry. In a design run, the user specifies a range of values for the footing geometry. The program will check all configurations of footing geometry within that range of values, discarding those configurations that do not satisfy any of the checks. Satisfactory configurations are evaluated for their economy based on criteria selected by the user. The most economical configuration is deemed to be the optimal design solution.

The design description is organized into the following sections. Section 3.2.1 identifies how the footing geometry can be modified. It has a detailed description of the iteration scheme used within the program. Section 3.7 addresses the special considerations for design. The ‘design’ algorithms and criteria for selecting the optimal design solution are described for spread footings in Section 3.7.1, pedestal footings in Section 3.7.2, and, pile footings in Section 3.7.3.

Sections 3.5.3 and 3.6.3 describe the checks that are performed for each footing and stem cross section. They specifically address the design algorithms that are applied for the rebar checks in the footing and stem. Shear checks for design are described in Section 3.7.4.

3.2.1 Footing Design Iteration

The scope of the footing geometry configurations that will be checked by the program is defined by user-specified maximum and minimum values for the footing thickness, footing width, toe projection, and, heel projection. These values are entered by using the FTG command (see Section 5.10). Refer to Section 6.10 for further information concerning the limitations of this input.

Figure 3.2.1-1 illustrates how the footing dimensions are reconfigured. The footing thickness may be increased upwards or downwards. The width extends incrementally towards the heel side, and the stem moves incrementally from the toe side to the heel side. The following incremental values are used by default in the program:

- Footing thickness is increased by 2 inches.
- Footing width is increased by 3 inches.

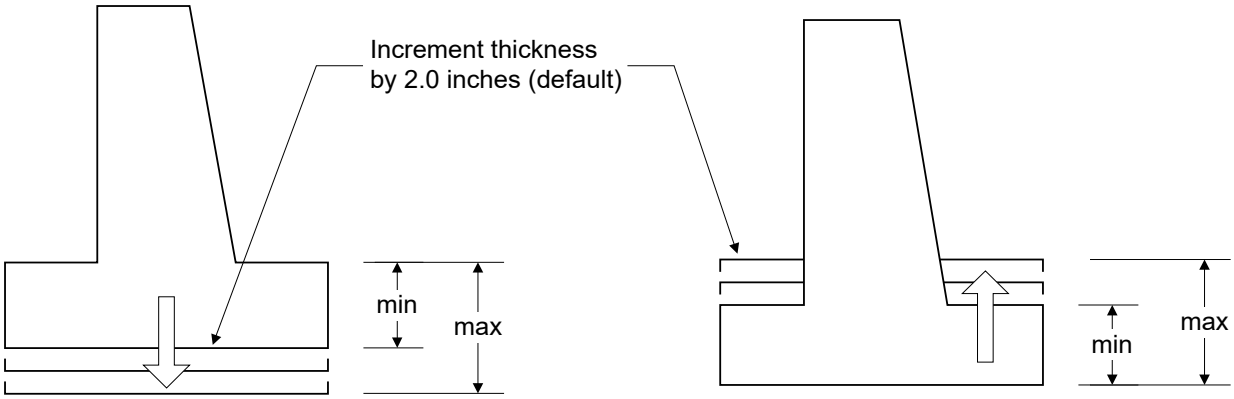
- Stem location is moved by 1 inch.

If applying an incremental value causes a footing dimension to fall outside the user-specified limiting values, then the dimension is adjusted to the limiting value. For example, if the user specifies a minimum thickness of 2 ft. and a maximum thickness of 2.4 ft., the program will check footing thickness configurations of 2.0 ft, 2.17 ft, 2.33 ft, and 2.4 ft. Since 2.50 ft. exceeds the limit imposed by the user, the program will use 2.4 ft instead.

Conceptually, the footing iteration algorithm consists of combinations of width and thickness while looping through the stem positions. The description that follows is based on Figure 3.2.2-2. The figure illustrates a typical iteration scheme.

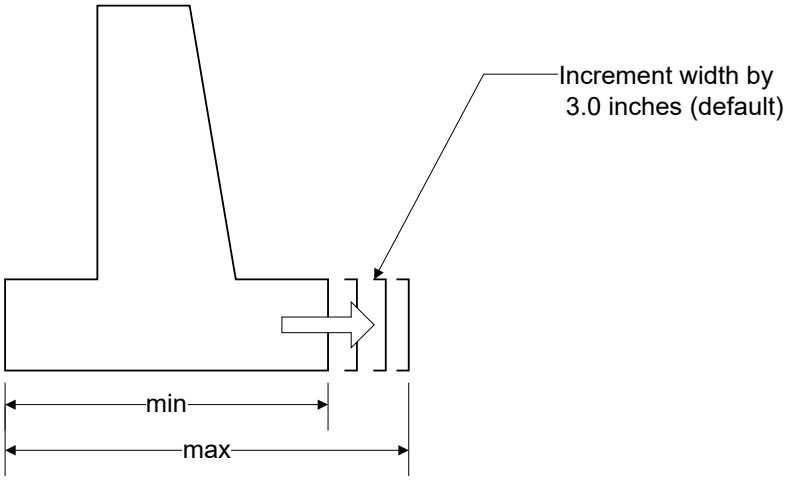
The program applies a design optimization algorithm that provides efficient footing dimension selection. The program begins by initializing the footing geometry with the minimum toe projection, maximum thickness, and minimum width. For any selected footing configuration, the applied loads are evaluated and combined as described in Section 3.3, and the applicable stability checks are evaluated, as described in Section 3.4. At this point, footing-specific designs, i.e. pile pattern layouts or pedestal geometry configurations, are evaluated as described in Section 3.7. After all of the applicable specification checks have been evaluated and are satisfied, the program determines the cost of the configuration as described in Section 3.7.

The next step is to determine if another footing configuration can be evaluated. The set of configurations is defined as: minimum and maximum toe projections; minimum heel projection; and stem position incremental value (see Figure 3.2.1-1(d)). The first parameter to be considered is the stem position. For a given footing thickness and width, the program checks a finite set of configurations of the stem location. Each stem position increment that is applied will move the stem closer to the heel. If the stem position does not reach the limit imposed by the minimum heel or maximum toe projection, the stem is repositioned by an increment and the program returns to the load evaluation stage. If the stem position reaches the minimum heel or maximum toe limit, then the design algorithm determines whether to increase the thickness or width of the footing.

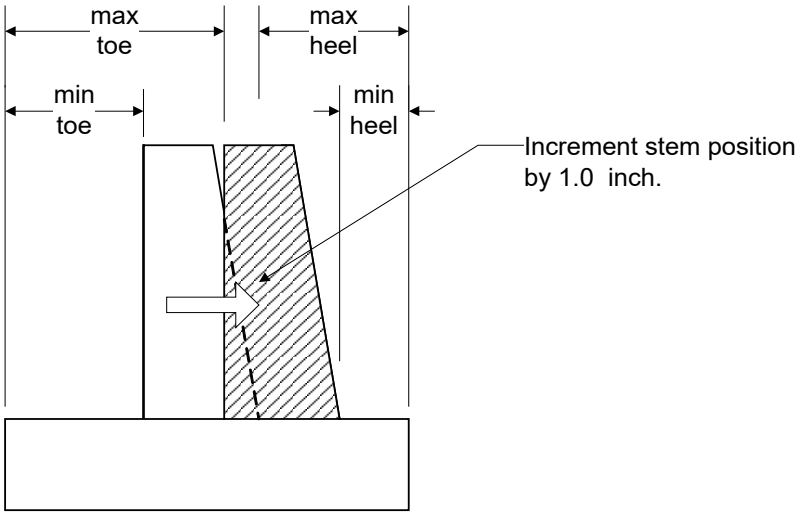


(a) footing thickness variation - downward

(b) footing thickness variation - upward



(c) footing width variation



(d) toe and heel projections

Figure 3.2.1-1 Incremental Positions of the Footing Geometry

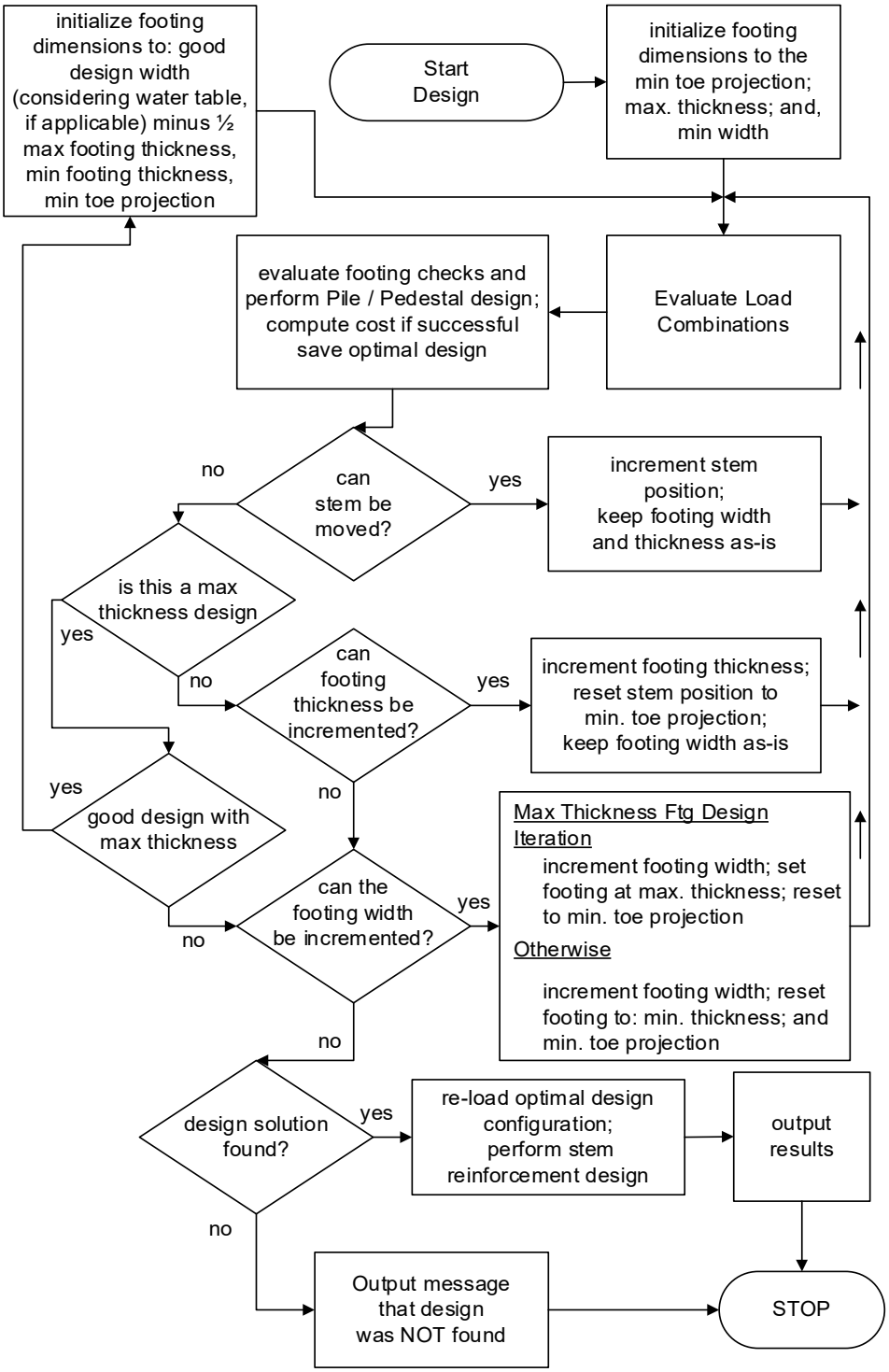


Figure 3.2.1-2 Design Algorithm for Footing Iteration Scheme

The program begins the design by using the maximum footing thickness and iterating the footing width by the width increment until a valid design is found. When the valid design is found, the program then sets the thickness to the minimum footing thickness and reduces the footing width by one half the maximum footing thickness. However, if the water table is close enough to the footing bottom to affect bearing capacity (D10.6.3.1.2gP-2), then the thickness is reduced to the minimum footing thickness input and the footing

width is reduced to the point at which the water table will not be considered in the footing design minus one half the maximum footing thickness. The footing width reduction will not reduce the footing width to less than the minimum footing width. The program then begins to check the load evaluation and increase the thickness. Refer to Figure 3.2.1-3.

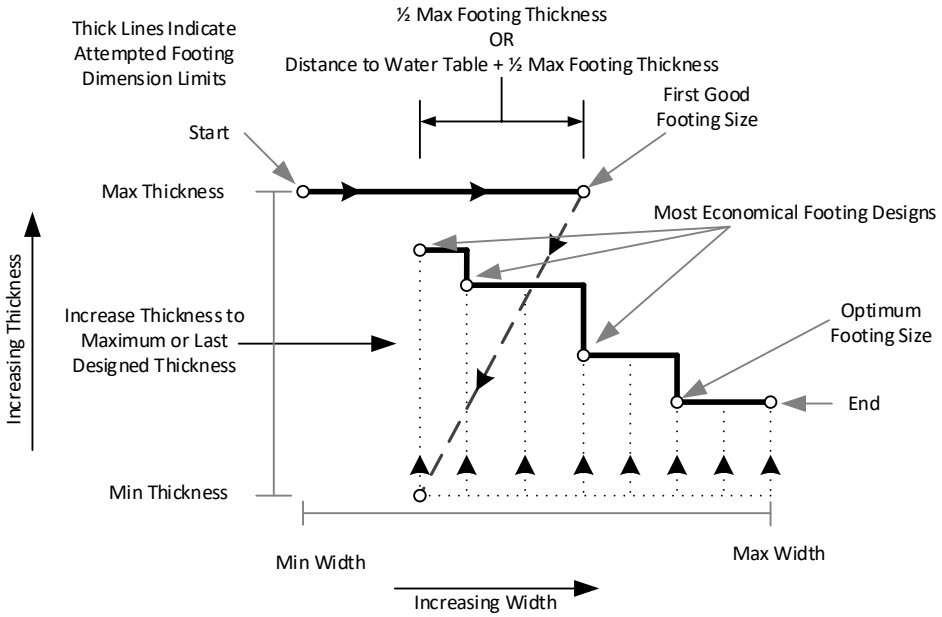


Figure 3.2.1-3 Typical Attempted Footing Design Dimensions

The set of footing thickness configurations to be examined is based on the: minimum thickness, maximum thickness or last designed thickness, and thickness incremental value (Figure 3.2.1-1(b)). If the footing thickness has not reached the maximum or last designed thickness value, then the stem position is reset to the minimum toe projection and the footing thickness is incremented. The program returns to the load evaluation step with the new footing dimensions.

After the program has looped through all iterations of the footing thickness, the footing width is examined. The set of footing width positions is defined by the: minimum width, maximum width, and width incremental value (Figure 3.2.1-1(c)). Each time the footing width is incremented, the footing thickness is reset to the minimum thickness and the stem position is reset to the minimum toe projection. The program then returns to the loads evaluation step. As the footing width increases, more stem positions are examined because the toe and heel projections are defined relative to the width. The following example illustrates this.

Consider a footing with the following parameters:

- Stem thickness at the base is 4 ft.
- Minimum footing thickness is 2 ft. and maximum footing thickness is 2.25 ft.
- Minimum footing width is 8.0 ft. and maximum footing width is 10.0 ft.

- Minimum toe projection is 2 ft. and the minimum heel projection is 1 ft.
- Maximum toe and heel projections are not specified.

Table 1 shows a sample of the configurations that are checked. Configurations that are checked but not shown (for sake of brevity) in the table are widths of 8'-3"; 8'-6", 8'-9", 9'-3", 9'-6" and 9'-9".

During a design run, the progress of the program can be examined by reviewing the design status information that is displayed on the monitor. Two examples are shown in Figure 3.2.1-3.

The status information will indicate the current iteration value of the footing thickness and width. The maximum values are also shown. Furthermore, the status will indicate if a solution was found. In case (a) above, a solution has not been found; note that the footing width is 7.083 ft. In case (b), the status indicates that the current width is 8.083 ft and the program will iterate until the width is 10.917 ft. A solution was found when the footing width was 7.417 ft and the footing thickness was 2.5 ft. Section 6.10.8 describes how the program can dynamically change the maximum value of the footing width.

In summary, the program will iterate through all combinations of footing geometry as defined by the limits and incremental values. For any footing, the program will evaluate:

1. loads (individual and combinations - as described in Section 3.3).
2. footing stability checks (e.g. eccentricity, bearing pressure, sliding ... see Section 3.4).
3. footing flexural strength checks (e.g. moment capacity, development length; see Section 3.5.2).
4. footing serviceability checks (e.g. crack control, spacing ... see Section 3.5.2).
5. footing shear check (see Section 3.5.2.9).

If the program cannot find a solution, the program will notify the user and then terminate. If one or more solutions has been found, the optimal footing configuration (as defined in Section 3.7) is re-evaluated, then the program will design the stem rebar by evaluating:

1. stem and backwall (if applicable) strength checks (Sections 3.6.2.1 through 3.6.2.1.3).
2. stem and backwall (if applicable) serviceability checks (Section 3.6.2.4).
3. stem shear checks (Section 3.6.2.5).
4. stem cutoff locations and optimal stem rebar (Section 3.6.3).

Table 3.2.1-1 Sample Footing Configurations

Footing Width	Footing Thickness	Toe Projections	Comments
8’-0”	2’-3”	2’-0”, 2’-1”, 2’-2”, ... 2’-10”, 2-11”, 3’-0”	Maximum footing thickness design
9'-0"	2’-3”	2’-0”, 2’-1”, 2’-2”, ... 2’-10”, 2-11”, 3’-0”	
10'-0"	2’-3”	2’-0”, 2’-1”, 2’-2”, ... 2’-10”, 2-11”, 3’-0”	Found good design for maximum footing thickness
9’-0”	2’-0”	2’-0”, 2’-1”, 2’-2”, ... 2’-10”, 2-11”, 3’-0”, 3’-1”, 3’-2”, ... 3’-10”, 3-11”, 4’-0”	Reduce width, try minimum thickness
	2’-2”	2’-0”, 2’-1”, 2’-2”, ... 2’-10”, 2-11”, 3’-0”, 3’-1”, 3’-2”, ... 3’-10”, 3-11”, 4’-0”	New Thickness
	2’-3”	2’-0”, 2’-1”, 2’-2”, ... 2’-10”, 2-11”, 3’-0”, 3’-1”, 3’-2”, ... 3’-10”, 3-11”, 4’-0”	New Thickness
10’-0”	2’-0”	2’-0”, 2’-1”, 2’-2”, ... 2’-10”, 2-11”, 3’-0”, 3’-1”, 3’-2”, ... 3’-10”, 3-11”, 4’-0”, 4’-1”, 4’-2”, ... 4’-10”, 4-11”, 5’-0”	Increase width, try minimum thickness
	2’-2”	2’-0”, 2’-1”, 2’-2”, ... 2’-10”, 2-11”, 3’-0”, 3’-1”, 3’-2”, ... 3’-10”, 3-11”, 4’-0”, 4’-1”, 4’-2”, ... 4’-10”, 4-11”, 5’-0”	New Thickness

Performing Footing Design ...

Current Thickness	Maximum Thickness	Designed Thickness	Current Width	Maximum Width	Designed Width
2.833	3.500	--?--	7.083	45.600	--?--

(a) A design solution has not been found yet as indicated by “---?----“

Performing Footing Design ...

Current Thickness	Maximum Thickness	Designed Thickness	Current Width	Maximum Width	Designed Width
2.500	3.500	2.500	8.083	10.917	7.417

(b) Current width is 8.083 ft. A solution was found when the width was 7.417 ft.

Figure 3.2.1-4 Design Status of Footing Iteration Scheme Displayed on Monitor

3.3 APPLIED LOAD EFFECTS

Section 2.5 briefly described the load types and combinations that are considered by the program. This section provides information about the assumptions and details associated with the loads that are computed by the program and the factors that are applied for each limit state.

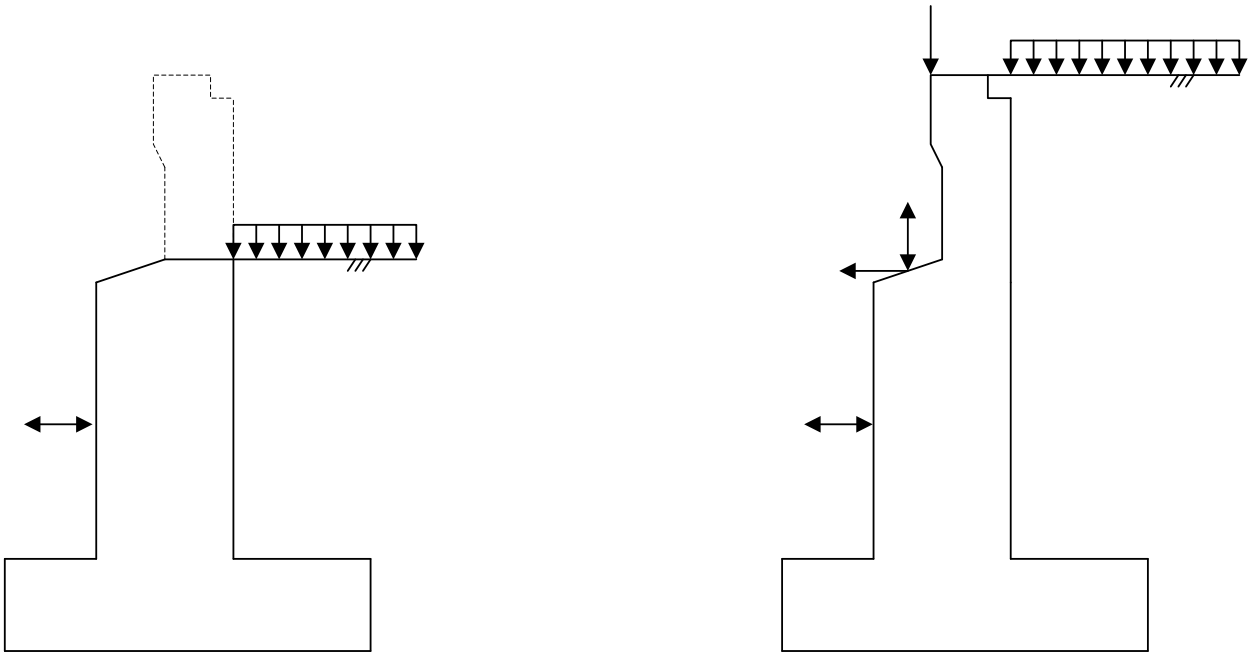
3.3.1 Construction Stages

Loading is based on two construction stages of the abutment or retaining wall:

- Temporary (construction) stage
- Final stage

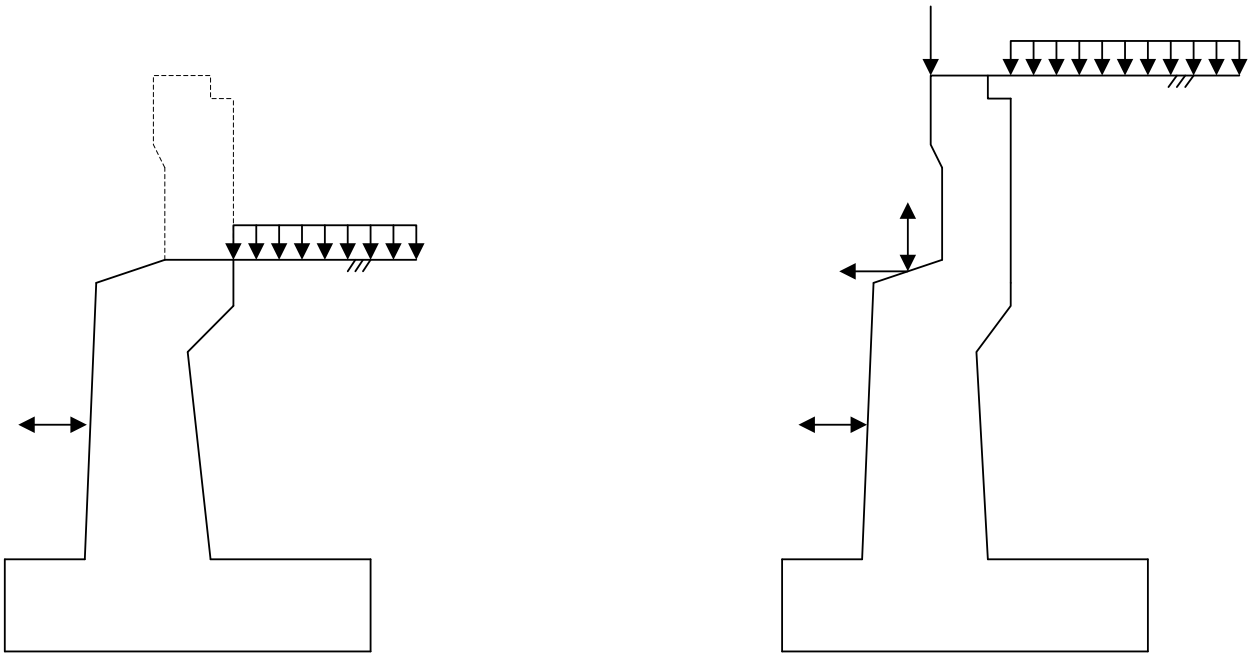
The temporary (construction) stage simulates an abutment or retaining wall that is still under construction. The abutment is considered to be constructed and backfilled to the seat level. Bridge superstructure loads are non-existent at this stage, but a live load and earth surcharge may be applied to the backfill. Retaining walls are considered to be completely constructed with a level backfill at a point where the top of backfill meets the walls. The construction stages for abutments and retaining walls are shown in Figure 3.3.1-1(a-d), with a representation of the applicable loads.

The final stage includes all loads, backfill and abutment dimensions that the user specifies. The final stage for abutments and retaining walls are shown in Figure 3.3.1-1(a-d), with a representation of the applicable loads.



Temporary Stage　　Final Stage

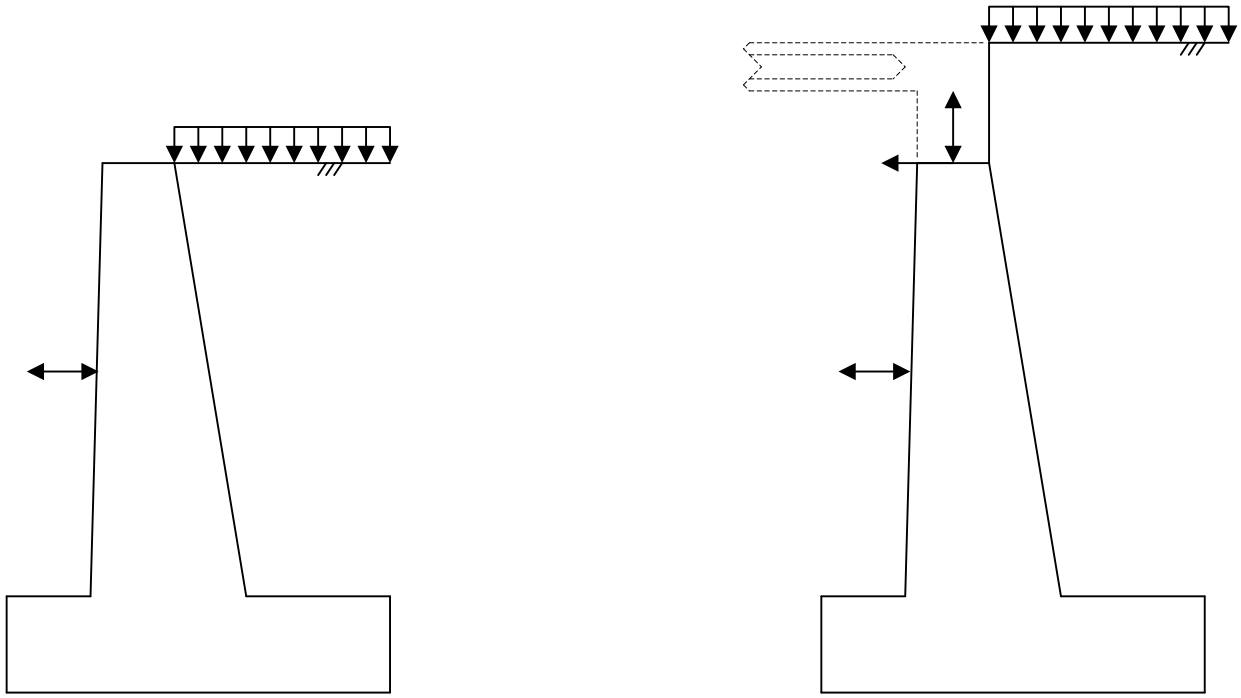
(a) Abutment Type I



Temporary Stage　　Final Stage

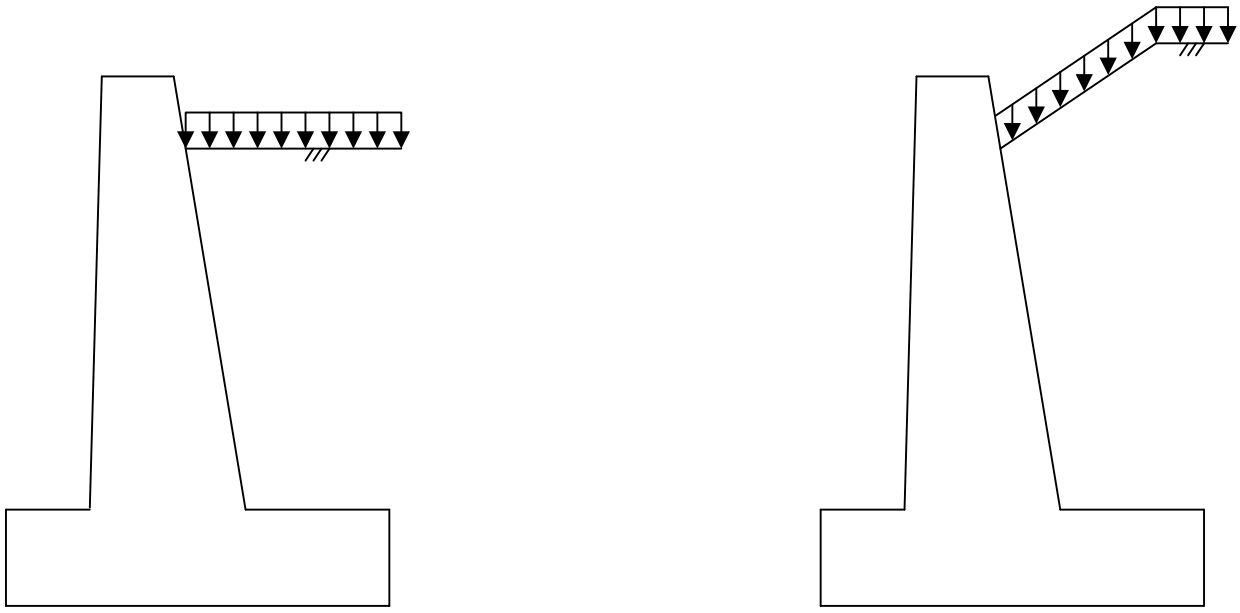
(b) Abutment Type II

Figure 3.3.1-1　Construction Stages



Temporary Stage　　Final Stage

(c) Abutment without Backwall



Temporary Stage　　Final Stage

(d) Retaining Wall

Figure 3.3.1-1 Construction Stages (Cont.)

3.3.2 Applied Loads

LRFD applied loads are based on both user-specified data and calculated values. Applied loads depend on the stage that is being considered. The LRFD applied loads used in the abutment and retaining wall program may be grouped into the following categories:

- Dead Loads (DC, DW, EV, DCAT, DCAP, DCAS, DWAS)
- Live Loads (LL, BR, CE, PL, LLAS)
- Water Loads (WA, WA-E)
- Wind Loads (WL, WSUP, WSUP1, WSUP3, WSUP5, WSUB1, WSUB3, WSUB5)
- Earth Pressure (EH, ES, LS)
- Temperature Force Effects (TU)
- Friction Force Effects (FR)
- Earthquake Effects (EQ)
- Collision Force (CT)

Some of the applied loads are specified by the user and others are determined by the program, as shown in Table 1. Positive horizontal loads are directed toward the bridge superstructure, except in the case of water pressure at the front of the stem. Negative horizontal loads are directed away from the bridge superstructure. Vertical loads are directed downward toward the footing except for the vertical wind on superstructure load (WSUP) and the upward live load forces. The following sections describe the LRFD applied loads in more detail. Tables 1-5 provide a summary of the applied loads considered for the foundation analysis, footing analysis, stem analysis, and backwall analysis.

3.3.2.1 DC

DC is the dead load due to the weight of the abutment (including backwall) or retaining wall. It is computed using the area of the structure above the point of interest and the concrete density. For the final stage of an abutment, DC includes the weight of the superstructure. For the final stage of a retaining wall, DC includes the weight of a parapet and noise wall if present.

3.3.2.2 DW

DW is the dead load due to the weight of utilities, wearing surfaces, and future overlays. DW is only applicable for the final stage of an abutment, and includes DW from the superstructure and the future wearing surface.

For abutments without approach slabs (no ASL command (Section 5.31) has been entered), the program calculates DW effects assuming a load of 30 psf over the backwall, stem, and backfill over the heel of the abutment. The calculated DW load effects are shown in the program output as the DW-A load.

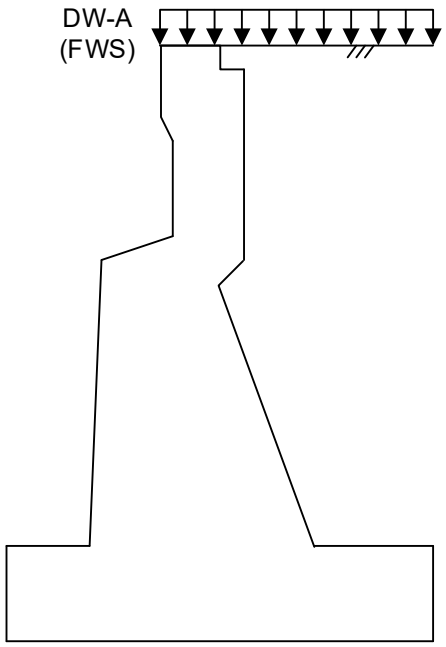


Figure 3.3.2-1 DW-A Load Applied by the Program (no Approach Slab)

For abutments with Type 1, 2, or 3 Approach Slabs (ASL command has been entered, but Type 4 input values have not been entered), the program does not calculate any additional DW-A load. The user enters all DW load acting on the approach slab with parameter 5 of the ASL command, "Approach Slab DW".

For abutments with Type 4 Approach Slabs (ASL command has been entered, with all Type 4 dimensions entered), the user enters the DW load from the approach slab on parameter 5 of the ASL command. The program also calculates effects due to a DW load over the drain trough, and potentially over the abutment heel, assuming a load of 30 psf. The effects due to the DW load over the backfill over the heel are only calculated by the program if there is flexible pavement adjacent to the tooth dam (parameter 6 of the ASL command). The calculated DW load effects are shown in the program output as the DW-A load. The limits of the DW-A load calculated by the program for Type 4 Approach Slabs are shown in Figures 5.31-5 and 5.31-6.

3.3.2.3 DCAT

DCAT is the dead load due to the weight of an architectural treatment applied to the front face of an abutment or retaining wall. The following figure shows a typical application of an architectural treatment on the front face of a stem.

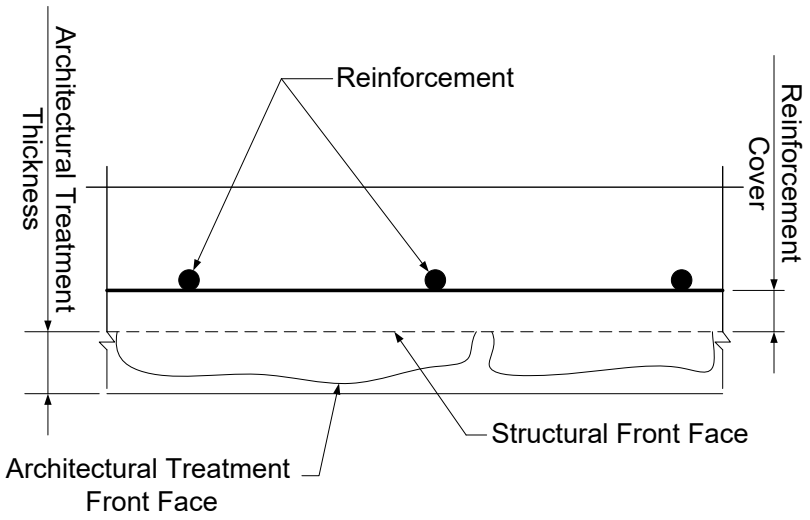


Figure 3.3.2-2 Architectural Treatment Detail

The area of the architectural treatment is computed using the height of the front face of the stem times the thickness of the architectural treatment as specified by the user on the structure type input command. The architectural treatment area is then multiplied by the density of the architectural treatment which is also specified by the user on the MAT command to determine the architectural treatment load. The architectural treatment density input allows the user to account for the irregularities of the architectural treatment by entering an averaged density for the entire thickness. The dead load due to the weight of an architectural treatment is applied for both the temporary and final stages of an abutment/retaining wall design or analysis.

3.3.2.4 DCAS

When the ASL command is entered, the approach slab is usually considered to be simply supported by the sleeper slab on the highway side and by the end of the beam, backwall, corbel, or Type 4 Approach Slab drain trough pedestal on the bridge side. DCAS is the dead load due to the weight of an approach slab resting upon either the backwall, beam notch, corbel, or drain trough pedestal on an abutment. It is entered by the user and is applied in the final stage of an abutment run. When the DCAS load is specified, the final Earth and Live Load Surcharge loads are not included for the final stage.

If the ASL command is used to specify a Type 4 Approach Slab, the user also has the option to specify flexible pavement adjacent to the drain trough. If flexible pavement is specified, the user is not permitted to specify a DCAS load, and the final Earth Surcharge load will be applied beyond the drain trough.

3.3.2.5 DWAS

When the ASL command is entered, the approach slab is considered to be simply supported by the sleeper slab on the highway side and by the end of the beam, backwall, corbel, or drain trough pedestal on the bridge side. DWAS is the dead load due to the utilities, wearing surface, and future overlays resting upon

either the backwall, beam notch, corbel, or drain trough pedestal on an abutment. It is entered by the user and is applied in the final stage of an abutment run. When the DWAS load is specified, no program-calculated DW load is applied above the heel of the footing for the final stage.

3.3.2.6 DCAP

For abutments with Type 4 Approach Slabs, DCAP is the dead load due to the weight of the drain trough, the portion of the deck slab between the drain trough and the approach slab, and drain trough support pedestals. The shaded areas in the following figures indicate the concrete extents used in calculating the DCAP loading for Type I and Type II abutments. DCAP is assumed to act only on the footing and piles, pedestals, rock, or soil below the footing, if they exist.

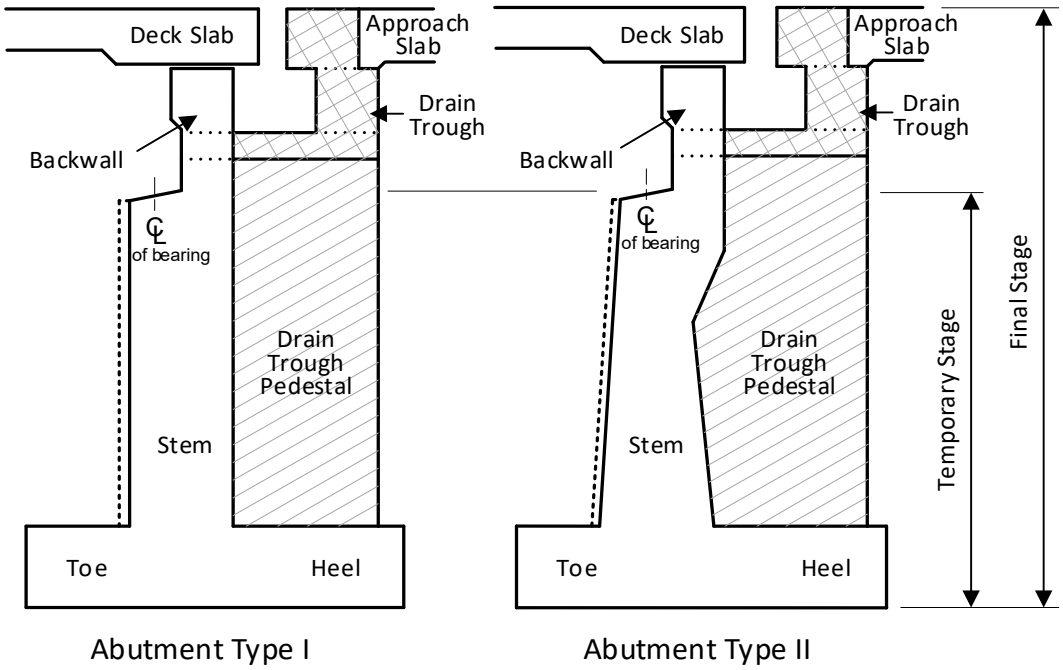


Figure 3.3.2-3 Type 4 Drain Trough and Drain Trough Pedestals

The volume of the drain trough and drain trough pedestals is computed using the dimensions entered on the ASL command. The volume is computed between two drain trough pedestals using the Drain Trough Support Pedestal Spacing distance. The volume is then multiplied by the density of the abutment concrete weight for DL which is also specified by the user on the MAT command to determine the DCAP load. The DCAP load computed is then divided by the Drain Trough Support Pedestal Width to determine the weight on the abutment design section. The dead load due to the weight of the drain trough and drain trough pedestals is applied for both the temporary and final stages of an abutment design or analysis.

3.3.2.7 EV

EV is the dead load due to the weight of the backfill soil. This load has a vertical component only. EV is a vertical load that is applied to the heel of the footing and to an inclined stem back face. For backfill soil above the water level, the moist unit weight of soil (entered on MAT input card) is used. The saturated unit weight of soil (entered on MAT input card) is used for backfill soil below the water level. Soil above the toe is neglected for force calculations due to unreliable front soil height conditions due to erosion, scour, etc.

3.3.2.8 EH

EH is the lateral earth pressure computed by considering the active condition of the backfill soil. ABLRFD determines whether to use Rankine or Coulomb procedures for calculation of the active earth pressure coefficient (K_a). The procedure chosen is a function of where the soil's failure surface intersects the stem. For retaining walls with a broken backfill slope, empirical curves (see DM-4) are used to determine the active earth pressure coefficient.

EH is computed using the following general equation. The corresponding pressure distributions are illustrated in Figure 3.3.2-4. For spread footings embedded in rock, the soil wedge begins at the embedment point along the heel face. For all other cases, the soil wedge begins at the bottom of the footing heel. The wedge extends towards the structure as illustrated in Figure 3.3.2-5.

For spread footings embedded in rock, the height H, is measured to the top of the rock layer. For all other cases, it is measured to the bottom of the footing.

$$EH = EH_1 + EH_2 + EH_3$$

Where:

$$EH_1 = + 0.5 (K_{ah}) (\gamma_D) (H-H_w)^2$$

$$EH_2 = + (K_{ah}) (\gamma_D) (H-H_w) (H_w)$$

$$EH_3 = + 0.5 (K_{ah}) (\gamma_S - \gamma_W) (H_w)^2$$

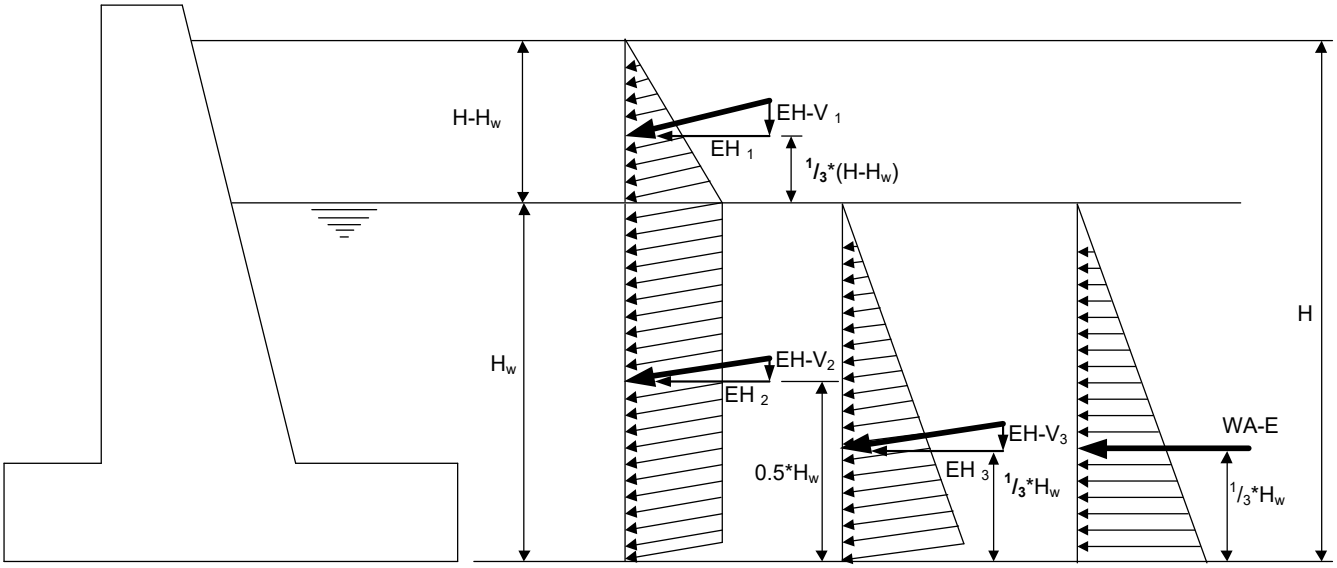


Figure 3.3.2-4 Illustration of EH and WA-E Loads

When computing the horizontal component of EH, K_{ah} is used for K_a in the above equations. For the vertical component, K_{av} is used for K_a, H is the height of the backfill soil and H_w is the height of the water.

The remainder of this section describes how the coefficient of active earth pressure (K_a) is evaluated. Coulomb Theory is used to compute K_a if the structure is a gravity wall. For all other structures, the program computes the angle of a soil failure wedge (See Figure 3.3.2-5). Coulomb Theory is used to compute K_a if the soil wedge intersects the back face of the stem. For structures with a large heel projection where the soil wedge may not intersect the stem, Rankine Theory is used to compute K_a.

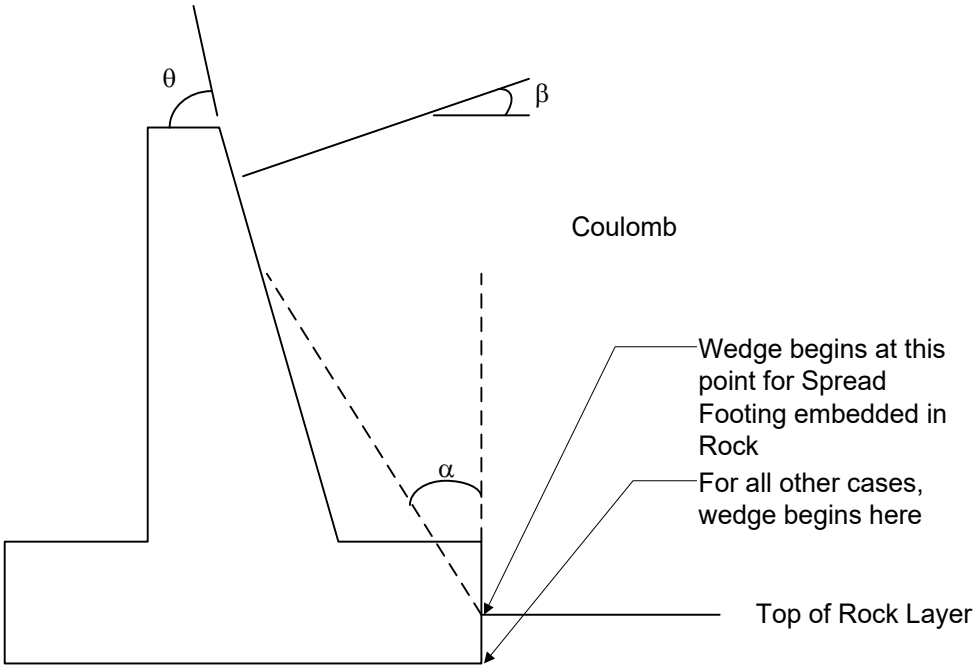


Figure 3.3.2-5 Illustration of Soil Wedge

The angle of the soil wedge is computed according to the following equation:

$$\alpha = \frac{1}{2}(90^{\circ} + \beta - \varphi' - \varepsilon)$$

Where: $\varepsilon = \sin^{-1}\left(\frac{\sin\beta}{\sin\varphi'}\right)$

α = angle of the soil wedge measured from the vertical

β = backfill slope angle measured from the horizontal

φ' = backfill internal friction angle

For spread footings embedded in rock, the soil wedge begins at the embedment point along the heel face. For all other cases, the soil wedge begins at the bottom of the footing heel. The wedge extends towards the structure as illustrated in Figure 3.3.2-5. If the soil wedge intersects the back face of the stem at a point that is backfilled, Coulomb Theory is used to compute K_a. For example, if the soil wedge intersects the back face of a retaining wall stem, but the intersection occurs at the exposed back face of the stem, Rankine Theory would be applicable. A typical soil wedge is illustrated in Figure 3.3.2-5.

Once the failure mode is determined, K_a is computed and broken into horizontal and vertical components using the equations that follow:

Coulomb Theory (LRFD Specifications Equation 3.11.5.3-1):

$$K_a = \frac{\sin^2(\theta + \varphi')}{\Gamma \sin^2(\theta)\sin(\theta - \delta)}$$

Where (LRFD Specifications Equation 3.11.5.3-2):

$$\Gamma = \left[1 + \sqrt{\frac{\sin(\varphi'+\delta)\sin(\varphi'-\beta)}{\sin(\theta-\delta)\sin(\theta+\beta)}}\right]$$

$\delta = \frac{1}{2}\varphi'$ Wall Friction Angle

θ = Angle of back face of wall to the vertical

$K_{ah} = K_a \cos(\delta + 90 - \theta)$

$K_{av} = K_a \sin(\delta + 90 - \theta)$

Rankine Theory (DM-4 Equation 3.11.5.8.1-2):

$$K_a = \cos(\beta)\frac{\cos(\beta) - \sqrt{\cos^2(\beta) - \cos^2(\varphi')}}{\cos(\beta) + \sqrt{\cos^2(\beta) - \cos^2(\varphi')}}$$

Where: $K_{ah} = K_a \cos(\beta)$

$K_{av} = K_a \sin(\beta)$

Broken Backfill:

If the backfill on a retaining wall is broken, the program will derive the vertical and horizontal Ka values from Figure 3.3.2-6 below. The figure is based on the 1993 LFD DM-4 Figure 5.5.2(B) Type 2 Soil which assumes a soil unit weight of 120 pcf and an effective angle of friction of 33^{O}.

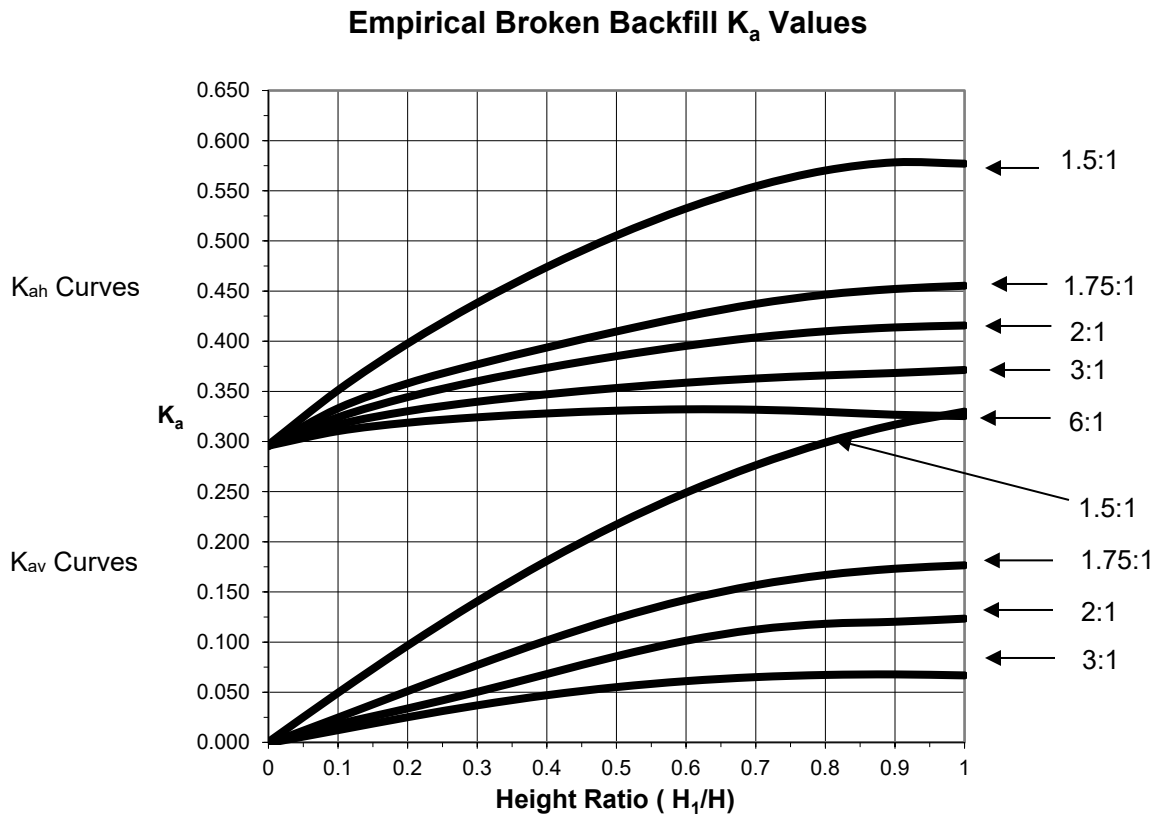


Figure 3.3.2-6 Broken Backfill K_a Values

Note: The values obtained from Figure 3.3.2-6 are not to be less than the User Inputted Equivalent Fluid Pressure from the MAT input card.

The height ratio is the vertical distance from the height of soil above the point of analysis to the break, divided by, the height of soil above the analysis point. Below is a figure depicting this ratio.

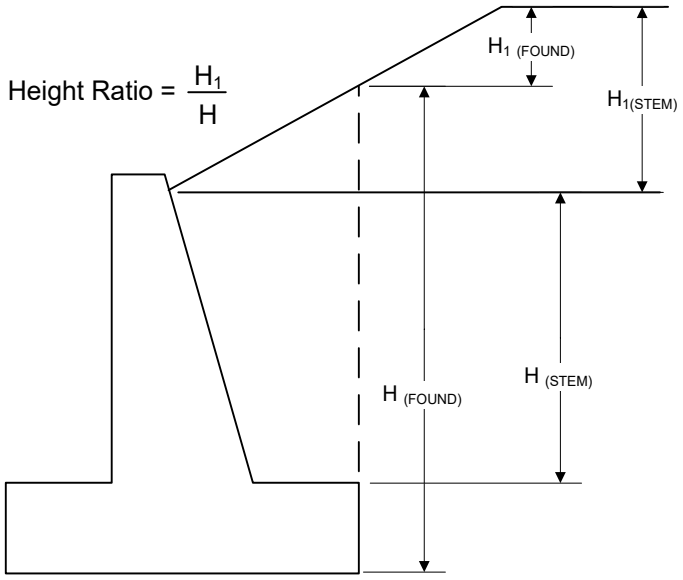


Figure 3.3.2-7 Broken Backfill Soil Height Ratio

3.3.2.9 EH-V

The EH-V force occurs when the EH force has a vertical component, i.e. when K_{av} is non-zero. The calculation of this vertical force is shown below. The first section shows how the force is calculated for the overall structure while the second section shows the method to calculate the force for internal footing use. For methods of Ka calculation, refer to Section 3.3.2.8. Refer to Figure 3.3.2-4.

3.3.2.9.1 Overall EH-V Equations

The following equations are used when the program is calculating the overall force effects of the horizontal earth pressure in the vertical direction.

$$EH\text{-}V = EH\text{-}V_1 + EH\text{-}V_2 + EH\text{-}V_3$$

Where:

$$EH\text{-}V_1 = +0.5\,(K_{av})\,(\gamma_b)\,(H-H_w)^2$$

$$EH\text{-}V_2 = +\,(K_{av})\,(\gamma_b)\,(H-H_w)\,(H_w)$$

$$EH\text{-}V_3 = +0.5\,(K_{av})\,(\gamma_s - \gamma_w)\,(H_w)^2$$

3.3.2.9.2 Internal Footing EH-V Equations

The following equations for EH-V are used for computing internal footing forces, specifically the internal shear and moment in the heel of the structure. The force calculations are based on the partial force as described in the "Foundation Engineering Handbook" ({FNDHBK} Section 12.7.2).

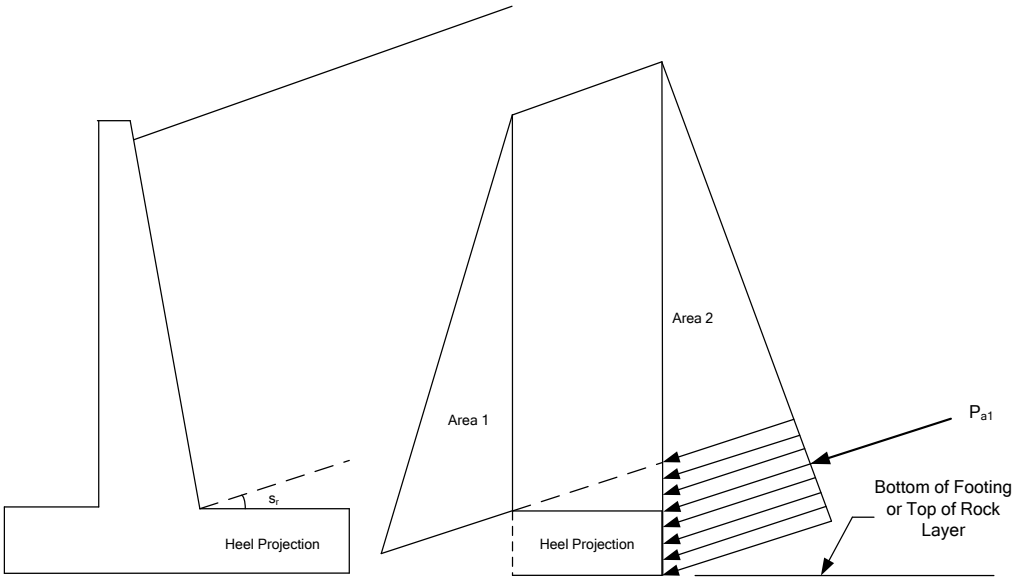


Figure 3.3.2-8 Partial EH-V Force Diagram

Figure 3.3.2-8 shows that when the internal forces of the heel projection are being considered, the horizontal earth pressure from Area 2 is acted upon equally by the resistance of the stem in Area 1, hence the only force considered on the heel is P_{a1}. Below are the three cases based on the location of backwater which are used to calculate the partial EH-V force for internal footing forces. The following general equations apply to the three sets of equations below.

$$H_3 = F_t - t_e + H_p\left(\frac{K_{av}}{K_{ah}}\right)$$

$$H_2 = H - H_3$$

Where:

F_t = Footing Thickness

H_p = Heel Projection

s_r = β (for Rankine) or $\delta+\beta$ (for Coulomb)

t_e = Depth of embedment into rock (when applicable for foundations on rock)

Case 1 - No back water / water below footing

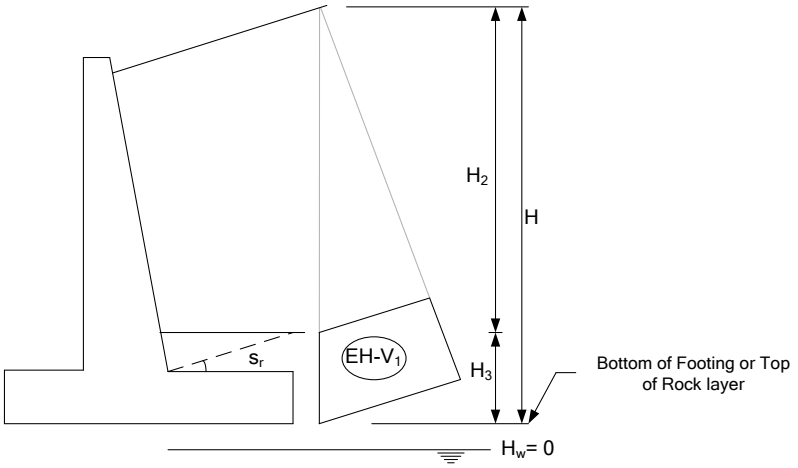


Figure 3.3.2-9 Case 1 Area Diagram - Water Below Footing

Equations to calculate EH-V for Case 1:

$$\text{EH-V}_1 = 0.5\left(K_{av}\right)\left(\gamma_d\right)\left(H\right)^2 - 0.5\left(K_{av}\right)\left(\gamma_d\right)\left(H_2\right)^2$$

EH-V = EH-V1

Case 2 - Back water above affected area

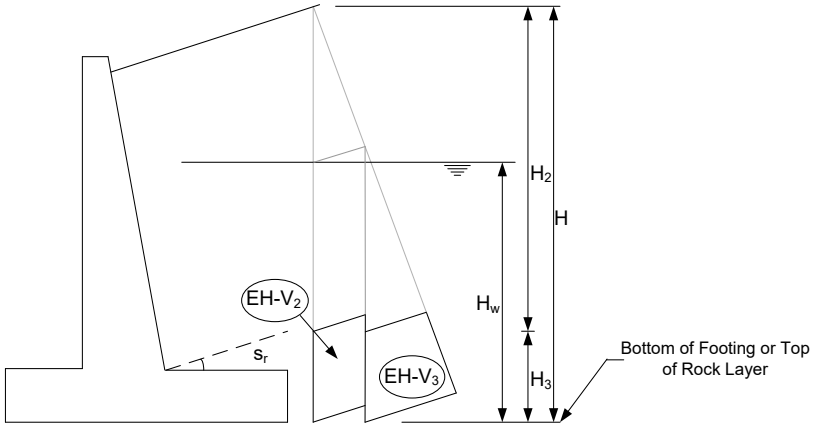


Figure 3.3.2-10 Case 2 Area Diagram - Water Above Affected Area

Equations to calculate EH-V for Case 2:

$$\text{EH-V}_2 = \left(K_{av}\right)\left(\gamma_d\right)\left(H - H_w\right)\left(H_3\right)$$

$$\text{EH-V}_3 = 0.5\left(K_{av}\right)\left(\gamma_s - \gamma_w\right)\left(H_w\right)^2 - 0.5\left(K_{av}\right)\left(\gamma_s - \gamma_w\right)\left(H_w - H_3\right)^2$$

EH-V = EH-V2 + EH-V3

Case 3 - Back water within affected area

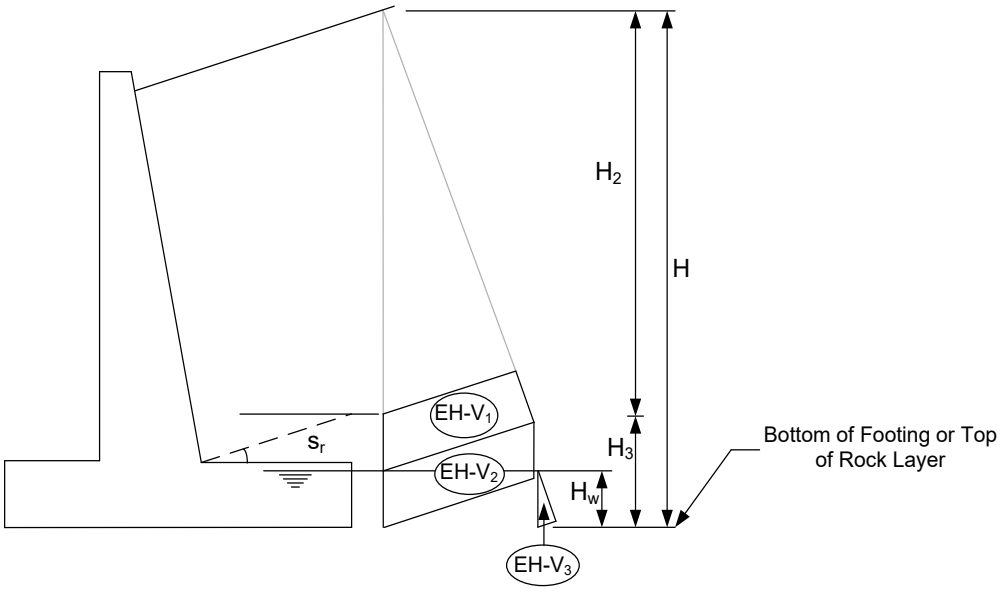


Figure 3.3.2-11 Case 3 Area Diagram - Water Within Affected Area

Equations to calculate EH-V for Case 3:

$$\text{EH-V}_1 = 0.5\left(K_{av}\right)\left(\gamma_d\right)\left(H - H_w\right)^2 - 0.5\left(K_{av}\right)\left(\gamma_d\right)\left(H_2\right)^2$$

$$\text{EH-V}_2 = \left(K_{av}\right)\left(\gamma_d\right)\left(H - H_w\right)\left(H_w\right)$$

$$\text{EH-V}_3 = 0.5\left(K_{av}\right)\left(\gamma_s - \gamma_w\right)\left(H_w\right)^2$$

$$\text{EH-V} = \text{EH-V}_1 + \text{EH-V}_2 + \text{EH-V}_3$$

3.3.2.10 WA-E

WA-E is the application of the horizontal component of the water load. The horizontal component is computed by the following equation:

$$WA - E = 0.5(\gamma_W)H_w^2$$

It is applied at one third of the height as illustrated in Figure 3.3.2-4.

Note: H_w is the depth of water from the top of the water level to the point of analysis on the structure, i.e., base of stem, bottom of footing, etc.

3.3.2.11 LS

LS is the live load surcharge applied when a vehicular load acts on the surface of the backfill, refer to Figure 3.3.2-12 and 3.3.2-13. LS is expressed as an equivalent height of backfill soil. The value of LS between

may differ between the temporary stage and final stage. If approach slab loads are included in an abutment run using the ASL command, the Final LS load is not included for the final stage. LS has components in the horizontal and vertical direction. In the vertical direction, LS is computed as a uniformly distributed load on the backfill:

$$LS_v = h_{LS}\, \gamma_D\, W_{bf}$$

In the horizontal direction, the pressure due to LS is computed as follows:

$$LS_h = h_{LS}\, \gamma_D\, K_{ah}\, H$$

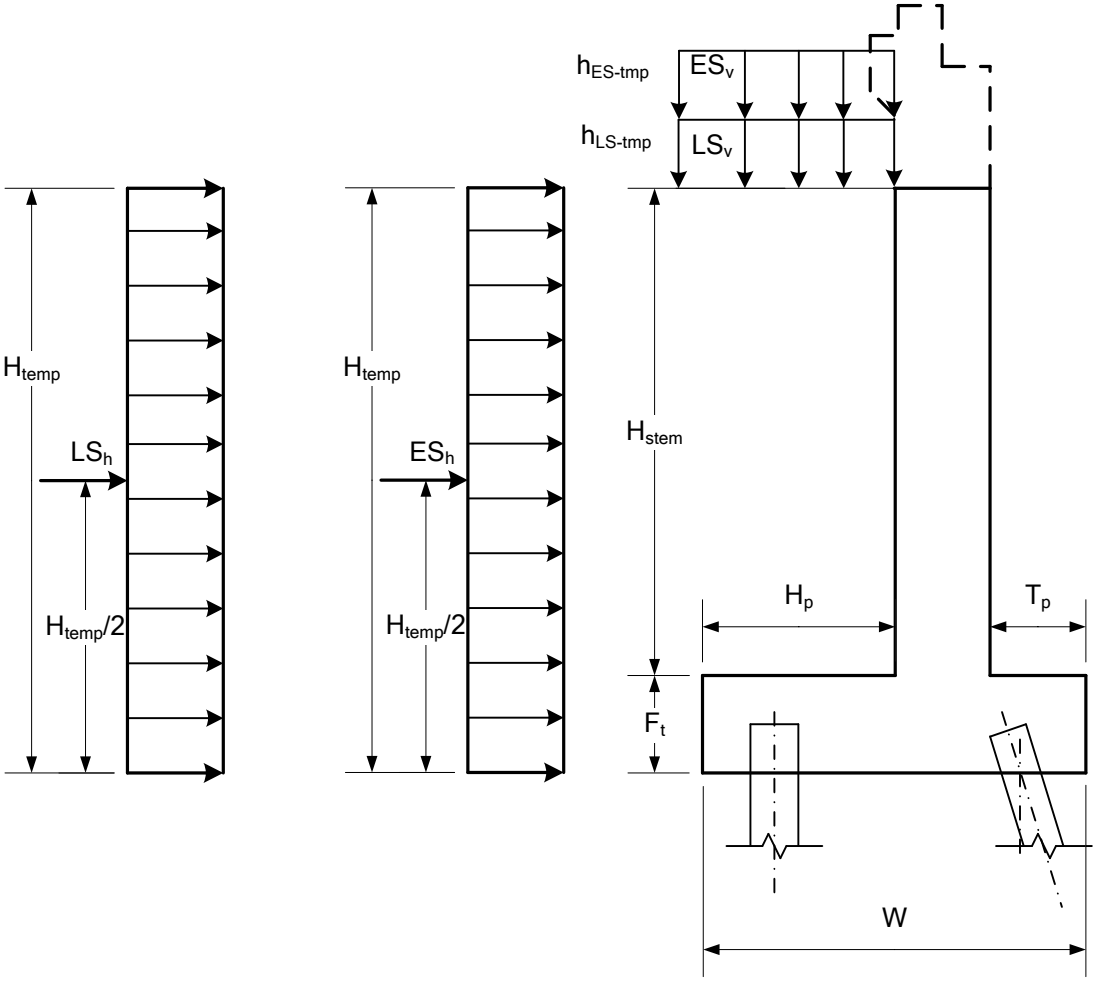


Figure 3.3.2-12 Temporary Stage - Live Load and Dead Load Surcharge Loading

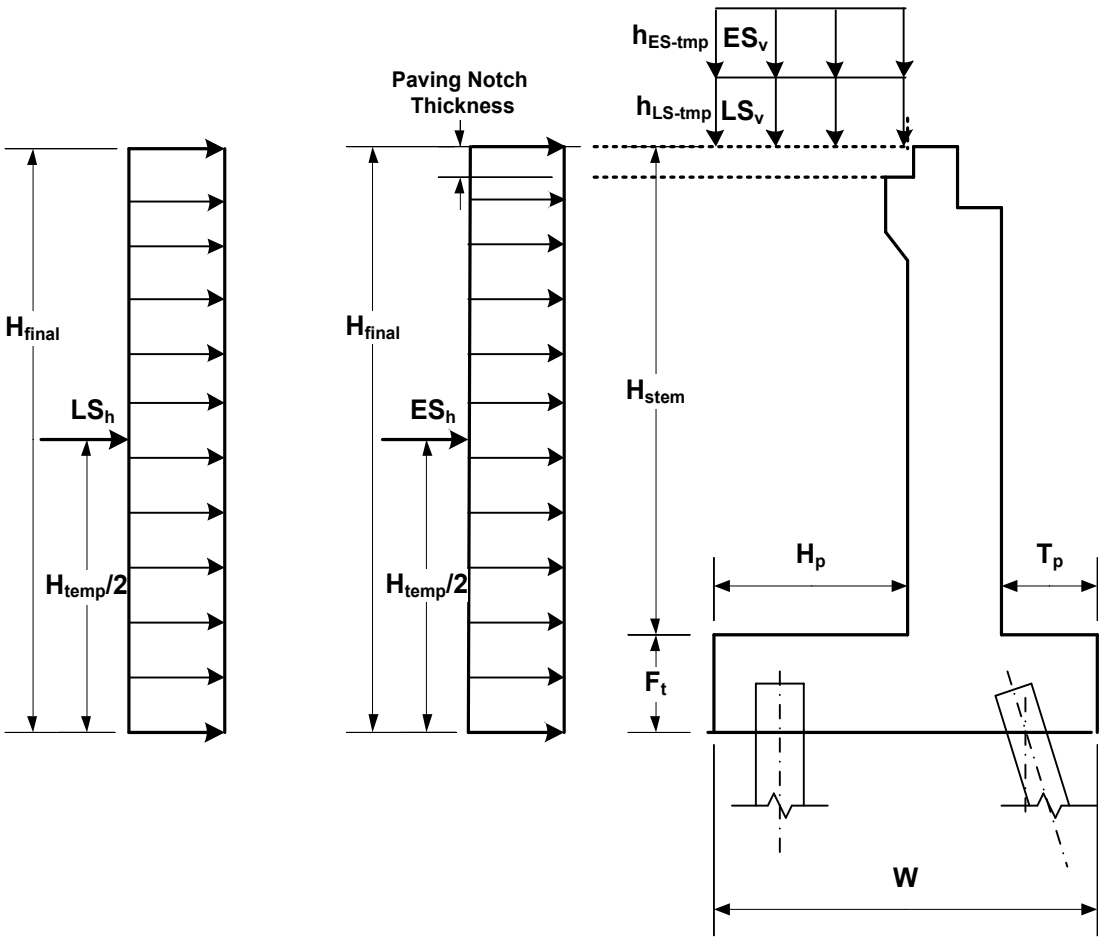


Figure 3.3.2-13 Final Stage - Live Load and Dead Load Surcharge Loading

3.3.2.12 ES

ES is a uniform earth surcharge that may be applied to the surface of the backfill, refer to Figures 3.3.2-12 and 3.3.2-13. ES is expressed as an equivalent height of backfill soil. The value of ES may differ between the temporary stage and final stage. For Approach Slab Types 1, 2, 3, and 4 (with no flexible pavement), if approach slab loads are included in an abutment run using the ASL command, the Final ES Load is not included for the final stage. For Type 4 Approach Slab (with flexible pavement), the Final ES load is only placed beyond the end of the drain trough. The user is not allowed to enter an ASL DCAS load for the Type 4 Approach Slab (with flexible pavement) case. ES has components in the horizontal and vertical direction. In the vertical direction, ES is computed as a uniformly distributed load on the backfill:

$$ES_v = h_{ES}\gamma_D W_{bf}$$

In the horizontal direction, the pressure due to ES is computed as follows:

$$ES_h = h_{ES}\gamma_D K_{ah} H$$

3.3.2.13 WA

WA consists of three forces, the buoyant force acting under the footing, the downward force equal to the weight of water over the toe of the footing, and the horizontal force due to water pressure on the front face of the stem. When computing buoyancy, the water levels at the front and back of the structure are considered. For a design run, when the front water level is not entered, the program will calculate this value based on the back water level and DM-4 Section 3.11.3. For analysis, if the front water level is left blank, the program places the front water level at the bottom of the footing. The program computes an area of buoyant effect below the footing as shown in Figure 3.3.2-14. The buoyant force is then determined by multiplying the area of buoyant effect by the unit weight of water.

Note: The buoyant force is not applied for spread footings on rock.

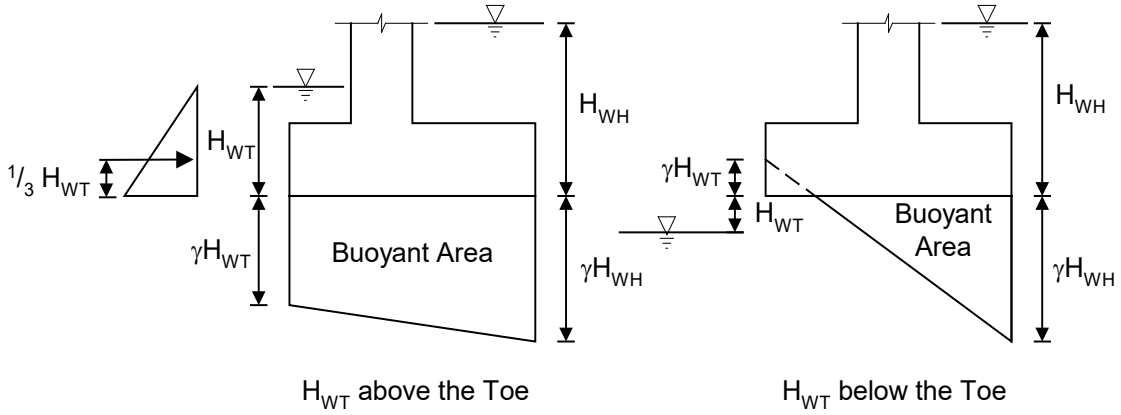


Figure 3.3.2-14 Illustration of WA Load

The horizontal water pressure on the front face of the stem is computed according to the following equation:

$$WA = ½ (\gamma_w) H_w^2$$

It is applied at one third of the height as illustrated in Figure 3.3.2-14.

Note: H_w is the depth of water from the top of the water level to the point of analysis on the structure, i.e., base of stem, bottom of footing, etc.

3.3.2.14 WSUP

WSUP is the vertical force from wind acting on a superstructure. This force is only applicable to abutments in the final stage, is only considered for the Strength-III limit state, and is assumed to be transmitted to the abutments through the bearings. The vertical force typically acts in an upward direction. This force applies only for WSUP3 wind taken perpendicular to the longitudinal axis of the bridge.

3.3.2.15 WSUP1, WSUP3, WSUP5

WSUP1, WSUP3, and WSUP5 are horizontal forces acting normal to the face of the abutment or noise wall on a retaining wall from wind acting on a superstructure or external structure attached to a retaining wall. For abutments, the transverse and longitudinal components of the wind load applied to the superstructure must be resolved into forces acting normal to the face of the abutment accounting for the skew of the abutment and fixed or expansion bearing conditions. These forces are only applicable to abutments in the final stage and is assumed to be transmitted to the abutments through the bearings. For retaining walls, the force is applied in the final stage and is transmitted to the top of the stem by a user specified vertical distance. Each load is considered for a specific limit state: WSUP1 is included in the Service-I limit state, WSUP3 is included in Strength-III, and WSUP5 is included in Strength-V. Each load must be calculated by the user with the corresponding design 3-second gust wind speed specified in LRFD Specifications Table 3.8.1.1.2-1 and input into the program. Each horizontal force is considered to act in two opposite directions. For abutments the positive direction is towards the superstructure and the negative direction is towards the abutment. For retaining walls the positive direction is the same as the vehicle collision force and the negative direction is opposite of that force. The positive forces are indicated with a plus sign (+), WSUP1+, WSUP3+, and WSUP5+. The negative forces are indicated with a minus sign (-), WSUP1-, WSUP3-, and WSUP5-.

3.3.2.16 WSUB1, WSUB3, WSUB5

WSUB1, WSUB3, and WSUB5 are the horizontal forces from wind acting normal to the face of the abutment **or retaining wall** on the substructure. This force is applicable to abutments **and retaining walls** for both the temporary and final stage. The force is transmitted into the stem from the centroid of the exposed wind area. The force is applied as a positive value or as a negative value to produce maximum force effects in the substructure. Positive forces are indicated with a plus sign (+), WSUB1+, WSUB3+, and WSUB5+. Negative forces are indicated with a minus sign (-), WSUB1-, WSUB3-, and WSUB5-. A positive value contributes to overturning. A negative value contributes to maximum pile loads in the footing heel. If a water level is specified, the exposed stem area is located between the water line and the bearing seat **or top of stem**. If no water level is specified, then the exposed stem area is located between the top of footing and the bearing seat **or top of stem**. Each load is considered for a specific limit state: WSUB1 is included in the Service-I limit state, WSUB3 is included in Strength-III, and WSUB5 is included in Strength-V. Each load must be calculated by the user with the corresponding design 3-second gust wind speed specified in LRFD Specifications Table 3.8.1.1.2-1 and input into the program.

For wind directions taken skewed to the abutment **or retaining wall**, the transverse and longitudinal wind loads shall be resolved into components perpendicular to the front face of the abutment **or retaining wall**.

For the application of the wind load on the stem, the program calculates a distributed force based on the exposed wind area then determines the applicable force and moment for each stem location. Figure

3.3.2-15 illustrates the application of the wind on substructure load at the stem locations. The force entered corresponds to the force for Stem Loc D.

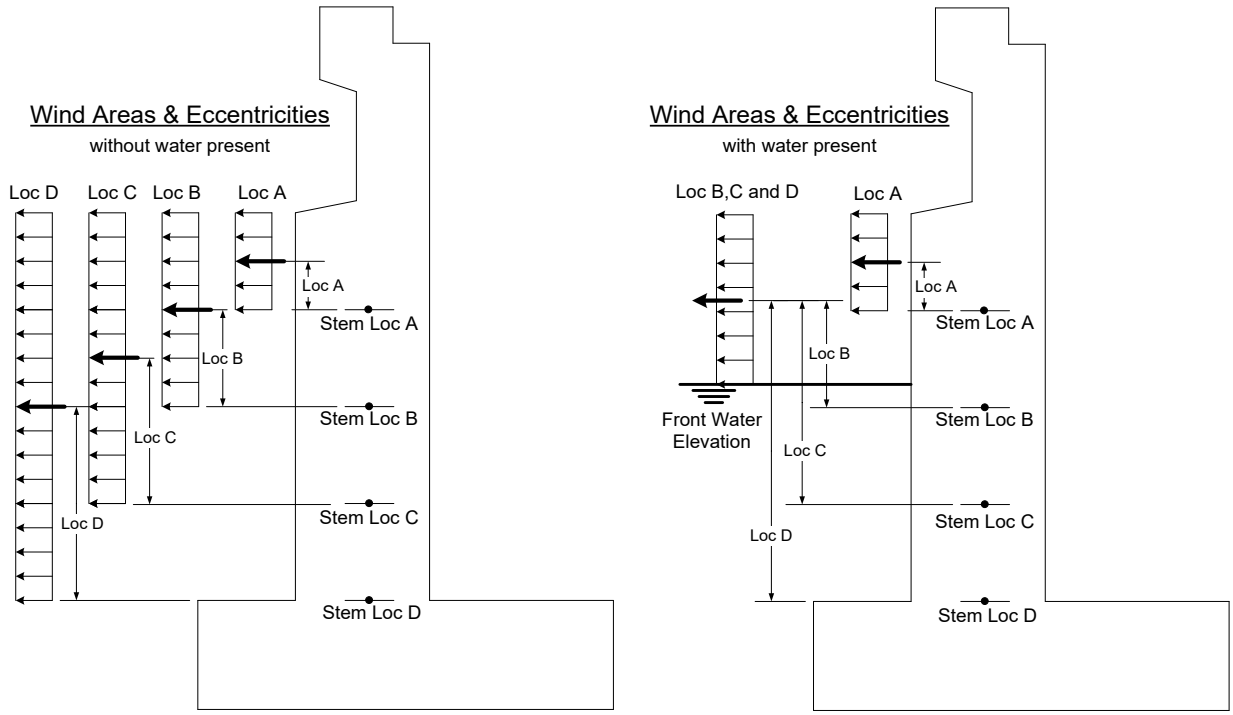


Figure 3.3.2-15 Application of Wind at Stem Locations

3.3.2.17 WL

WL is the horizontal force acting on the bearing due to wind acting on the superstructure live load. Transverse and longitudinal wind load components are applied to the live load with the skew angle measured from the perpendicular to the longitudinal axis of the bridge. These components must be resolved into longitudinal components normal to the face of the abutment accounting for the abutment skew and bearing conditions. The force is applied as a positive value or as a negative value to produce maximum force effects in the abutment. Positive values are indicated with a plus sign (+), WL+. Negative values are indicated with a minus sign (-), WL-. This force is only applicable to abutments in the final stage and is assumed to be transmitted to the abutments through the bearings.

3.3.2.18 PL

PL is the vertical live load due to pedestrians acting on the superstructure. This force is only applicable to abutments in the final stage and is assumed to be transmitted to the abutments through the bearings.

3.3.2.19 LL

LL is the vertical live load acting on the structure. Live load is only applicable to abutments in the final stage and as assumed to be transmitted to the abutments through the bearings. A downward live load may be

applied to the front top corner of the backwall as shown in Figure 5.30-1. A horizontal live load may be applied to the top of the backwall as shown in Figure 5.30-1. The backwall live load is only applied to the backwall and is not used in evaluating the loads applied to the stem or footing. A design live load acting on the superstructure and applied at the abutment bearing seat, may be specified in the upward and downward direction. **A permit design live load is applied in the same way as the design live load, but is only used the Strength II limit state.** A special live load is applied in the same way as the design live load, but the special and design live loads are mutually exclusive (i.e., both may not be specified) in the same run.

3.3.2.20 LLAS

When the ASL command is entered, the approach slab is usually considered to be simply supported by the sleeper slab on the highway side and by the end of the beam, backwall, corbel, or Type 4 Approach Slab drain trough pedestal on the bridge side. LLAS is the live load acting on an approach slab either resting upon the backwall, beam notch, corbel, or drain trough on an abutment. It is entered by the user and is applied in the final stage of an abutment run. When the LLAS load is specified, the final Earth and Live Load Surcharge loads are not included for the final stage.

If the ASL command is used to specify a Type 4 Approach Slab, the user also has the option to specify flexible pavement adjacent to the drain trough. If flexible pavement is specified, the user is permitted to specify an LLAS load for the live load directly over the drain trough wall, and the final Live Load Surcharge load will be applied beyond the drain trough.

3.3.2.21 BR

BR is the horizontal braking force from the live load acting on the superstructure. This force is only applicable to abutments in the final stage and is assumed to be transmitted to the abutments through the bearings. Braking force for the design**, permit design,** or special live load may be applied, but **special live load** may not be specified in the same run **with design or permit design live load**. The force is applied as a positive value or as a negative value to produce maximum force effects in the abutment. Positive values are indicated with a plus sign (+), BR+D**, BR+P,** or BR+S. Negative values are indicated with a minus sign (-), BR-D**, BR-P,** or BR-S. This force must be resolved into a component normal to the face of the abutment to account for the abutment skew.

3.3.2.22 CE

CE is the horizontal centrifugal force from the live load acting on the superstructure. This force is only applicable to abutments in the final stage and is assumed to be transmitted to the abutments through the bearings. Centrifugal force for the design**, permit design,** or special live load may be applied, but **special live load** may not be specified in the same run **with design or permit design live load**.

3.3.2.23 TU

TU is the horizontal force on the abutment induced by thermal expansion or contraction of the superstructure. TU is only applicable for abutments, is only considered in the final stage, and is assumed to be transmitted to the abutments through the bearings. The force is applied as a positive force for thermal expansion and as a negative force for thermal contraction. Positive values are indicated with a plus sign (+), TU+. Negative values are indicated with a minus sign (-), TU-. This force must be resolved into a component normal to the face of the abutment to account for the abutment skew.

3.3.2.24 FR

FR is the horizontal force on the abutment induced by friction in sliding type expansion bearings. FR is only applicable for abutments, is only considered in the final stage, and is transmitted to the abutment at the bearings. The force is applied as a positive force for expansion and as a negative force for contraction. Positive values are indicated with a plus sign (+), FR+. Negative values are indicated with a minus sign (-), FR-. This force must be resolved into a component normal to the face of the abutment to account for the abutment skew.

3.3.2.25 EQ

EQ is the total earthquake force acting on the structure. EQ is applicable for all structure types. It is applied in the final stage only. This load is only considered in the Extreme Event I limit state. EQ is composed of earth pressure due to earthquake force and, for abutments only, a user-specified Horizontal Superstructure Force from the superstructure for abutments and user-specified Horizontal External Structure Force for retaining walls. In calculating the EQ forces, the earth pressure due to earthquake force is initially set by the program to be the same as EH (see Section 3.3.2.8 above), but may be modified by a user input values for Response Modification factor (see Section 6.35.1) and Soil Pressure Factor for abutments and retaining walls (see Section 6.35.2).

The program calculates the earthquake load (EQ) as follows:

$$EQ = \frac{(EH)\ SoiFact + SupFor}{ResFact} \qquad (Abutments)$$

$$EQ = \frac{(EH)\ SoiFact + ExtFor}{ResFact} \qquad (Retaining\ Walls)$$

Where:

- The lateral earth pressure (EH), the input Horizontal Superstructure Force (SupFor) and the input Horizontal External Earthquake Force (ExtFor) are divided by the input Response Modification Factor (ResFact) to obtain the EQ force.
- Only the lateral earth pressure (EH) is multiplied by the input Soil Pressure Factor (SoiFact) to

obtain the EQ force.

The vertical component of the earth pressure force (EV and EH-V) is not considered in the calculation of the EQ forces (LRFD Specifications Section 3.10.1).

3.3.2.26 CT

CT is the vehicle collision force acting on top of a parapet on a retaining wall. This force is only applicable for retaining walls in the final stage and is only applied in the Extreme Event II limit state. The user may specify the vertical distance to this force from the top of the retaining wall as shown in Figure 5.32-1.

Table 3.3.2-1 User or Program Applied Loads

User Specified		Program Calculated		Description
Vert.	**Horiz.**	**Vert.**	**Horiz.**	
		DC		Substructure weight
DC				Superstructure weight
DC				Parapet weight on retaining wall
DCAS[3]				Approach slab weight
DWAS[3]				DW load on the approach slab
		DCAP[3]		Type 4 Approach Slab drain trough/trough pedestal weight
DCAT				Architectural Treatment weight
		DW		Wearing surface on backfill
DW[3]				Wearing surface on superstructure
		EV		Earth weight of backfill soil
		EH	EH	Earth pressure of backfill soil
ES[1]		ES[1]	ES[1]	Earth surcharge
LS[1]		LS[1]	LS[1]	Live load surcharge
			WA	Water pressure on front of stem
			WA-E	Water pressure due to backfill soil
		WA		Buoyancy
WSUP[3]	WSUP1 WSUP3 WSUP5			Wind on superstructure (abutments) Wind load on external structure (retaining walls)
	WSUB1[3] WSUB3[3] WSUB5[3]			Wind on substructure
	WL[3]			Wind on live load
	TU[3]			Thermal force from superstructure
	FR[3]			Friction force from superstructure
LL[2,3]				Live load from superstructure
LL[3]				Live load for backwall only
LLAS[3]				Live load on the approach slab
PL[3]				Pedestrian live load
				(table continues on next page)

Notes: [1] The actual surcharge force applied to the structure are determined by the program, based on user input and geometry.

[2] These loads are specified for a design**, permit design,** or special live load.

[3] Applied to abutments only.

Table 3.3.2-1 User or Program Applied Loads (continued)

User Specified		Program Calculated		Description
Vert.	**Horiz.**	**Vert.**	**Horiz.**	
	BR[2,3]			Live load braking force
	CE[2,3]			Live load centrifugal force
	EQ[3]			Earthquake force from superstructure
			EQ	Earthquake force due to earth pressure
	CT			Collision force applied to the parapet on top of retaining wall

Notes: [1] The actual surcharge force applied to the structure are determined by the program, based on user input and geometry.

[2] These loads are specified for a design**, permit design,** or special live load.

[3] Applied to abutments only.

Table 3.3.2-2 Foundation Applied Loads

Vertical		Horizontal		Description
Temp.	**Final**	**Temp.**	**Final**	
DC[1]	DC			Substructure weight
	DC			Superstructure weight
DCAT	DCAT			Architectural Treatment weight
	DC			Parapet weight on retaining wall
	DCAS[3]			Approach slab weight
	DWAS[3]			DW load on the approach slab
DCAP[1,3]	DCAP[3]			Type 4 Approach Slab drain trough/pedestal weight
	DW			Wearing surface on backfill
	DW[3]			Wearing surface on superstructure
EV[1]	EV			Earth weight of backfill soil
EH[1]	EH	EH[1]	EH	Earth pressure of backfill soil
ES[1]	ES	ES[1]	ES	Earth surcharge
LS[1]	LS	LS[1]	LS	Live load surcharge
		WA	WA	Water pressure on front of stem
		WA-E	WA-E	Water pressure due to backfill soil
WA	WA			Buoyancy
	WSUP[3]		WSUP1 WSUP3 WSUP5	Wind on superstructure (abutments) Wind load on external structure (retaining walls)
		WSUB1[3] WSUB3[3] WSUB5[3]	WSUB1[3] WSUB3[3] WSUB5[3]	Wind on substructure
			WL[3,4]	Wind on live load
			TU[3,4]	Thermal force from superstructure
			FR[3,4]	Friction force from superstructure
	LL[2,3]			Live load from superstructure
	LL[3]			Live load for backwall only
	LLAS[3]			Live load from approach slab
	DC			Parapet weight on retaining wall
	PL[3]			Pedestrian live load
				(table continues on next page)

Notes: [1] Temporary stage considers concrete and soil up to seat level
[2] Design**, permit design,** or special live load, depending on user input
[3] Applied to abutments only.
[4] Both positive and negative directions.

Table 3.3.2-2 Foundation Applied Loads (continued)

Vertical		Horizontal		Description
Temp.	**Final**	**Temp.**	**Final**	
			BR[2,3,4]	Live load braking force
			CE[2,3]	Live load centrifugal force
			EQ[3]	Earthquake force from superstructure
			EQ	Earthquake force due to earth pressure
			CT	Collision force applied to the parapet on top of retaining wall

Notes: [1] Temporary stage considers concrete and soil up to seat level
[2] Design**, permit design,** or special live load, depending on user input
[3] Applied to abutments only.
[4] Both positive and negative directions.

Table 3.3.2-3 Footing Applied Loads

Heel		Toe		Description
Temp.	**Final**	**Temp.**	**Final**	
DC	DC	DC	DC	Toe or heel projection weight
	DCAS[2]			Approach slab weight
	DWAS[2]			DW load on the approach slab
DCAP[1,2]	DCAP[2]			Type 4 Approach Slab drain trough/pedestal weight
	DW			Wearing surface on backfill
EV[1]	EV			Earth (backfill soil) weight
EH[1]	EH			Earth pressure (vertical) of backfill soil
EH[1]	EH			Earth pressure (horizontal) of backfill soil
ES[1]	ES			Earth surcharge
LS[1]	LS			Live load surcharge
WA	WA			Buoyancy
	LLAS[2]			Live load from approach slab

Notes: [1] Temporary stage considers concrete and soil up to seat level.

[2] Applied to abutments only. These loads are only applied to the footing when specified in conjunction with a Type 4 Approach Slab.

Table 3.3.2-4 Stem Applied Loads

Axial		Moment		Shear		Description
Temp.	**Final**	**Temp.**	**Final**	**Temp.**	**Final**	
DC[1]	DC	DC[1]	DC			Substructure weight
	DC[3]		DC[3,4]			Superstructure weight
DCAT	DCAT	DCAT	DCAT			Architectural Treatment weight
	DC		DC			Parapet weight on retaining wall
	DCAS[3]		DCAS[3]			Approach slab weight
	DWAS[3]		DWAS[3]			DW load on the approach slab
	DW		DW			Wearing surface on backfill
	DW[3]		DW[3,4]			Wearing surface on superstructure
EV[1]	EV	EV[1]	EV			Earth weight of backfill soil
EH[1]	EH	EH[1]	EH	EH[1]	EH	Earth pressure of backfill soil
ES[1]	ES	ES[1]	ES	ES[1]	ES	Earth surcharge
LS[1]	LS	LS[1]	LS	LS[1]	LS	Live load surcharge
		WA	WA	WA	WA	Water pressure on front of stem
		WA-E	WA-E	WA-E	WA-E	Water pressure due to backfill soil
	WSUP[3]		WSUP[4] WSUP1 WSUP3 WSUP5		WSUP1 WSUP3 WSUP5	Wind on superstructure (abutments) Wind load on external structure (retaining walls)
		WSUB1[3] WSUB3[3] WSUB5[3]	WSUB1[3] WSUB3[3] WSUB5[3]	WSUB1[3] WSUB3[3] WSUB5[3]	WSUB1[3] WSUB3[3] WSUB5[3]	Wind on substructure
			WL[3,5]		WL[3,5]	Wind on live load
			TU[3,5]		TU[3,5]	Thermal force from superstructure
			FR[3,5]		FR[3,5]	Friction force from superstructure
	LL[3]		LL[3,4]			Live load from superstructure
	LLAS[3]		LLAS[3]			Live load from approach slab
	LL[3]		LL[3]			Live load for backwall only
	PL[3]		PL[3,4]			Pedestrian live load
						(table continues on next page)

Notes: [1] Temporary stage considers concrete and soil up to seat level
[2] Design**, permit design,** or special live load, depending on user input.
[3] Applied to abutments only
[4] Moments are calculated in the vertical direction with a 2 inch positive eccentricity (towards the toe) for the maximum load case and a 2 inch negative eccentricity (towards the heel) for the minimum load case, from the centerline of the bearings.
[5] Only positive direction.

Table 3.3.2-4 Stem Applied Loads (continued)

Axial		Moment		Shear		
Temp.	**Final**	**Temp.**	**Final**	**Temp.**	**Final**	**Description**
			BR[2,3,5]		BR[2,3,5]	Live load braking force
			CE[2,3]		CE[2,3]	Live load centrifugal force
			EQ[3]		EQ[3]	Earthquake force from superstructure
		EQ[3]	EQ		EQ	Earthquake force due to earth pressure
			CT		CT	Collision force applied to the parapet on top of retaining wall

Notes: [1] Temporary stage considers concrete and soil up to seat level
[2] Design**, permit design,** or special live load, depending on user input.
[3] Applied to abutments only
[4] Moments are calculated in the vertical direction with a 2 inch positive eccentricity (towards the toe) for the maximum load case and a 2 inch negative eccentricity (towards the heel) for the minimum load case, from the centerline of the bearings.
[5] Only positive direction.

Table 3.3.2-5 Backwall Applied Loads (Final Stage Only)

Axial		Moment		Shear		Description
Temp.	**Final**	**Temp.**	**Final**	**Temp.**	**Final**	
	DC		DC			Substructure section weight
	DCAS[1,2]		DCAS[1,2]			Approach slab weight
	DWAS[1,2]		DWAS[1,2]			DW load on approach slab
	DW[1,]		DW[1,]			Wearing surface on superstructure
	EV		EV			Earth weight (pavement/backfill soil)
			EH		EH	Earth pressure of backfill soil
			ES		ES	Earth surcharge
			LS		LS	Live load surcharge
	LL		LL			Live load for backwall only
	LLAS[2]		LLAS[2]			Live load for approach slab
			EQ		EQ[1]	Earthquake force from earth pressure

Notes: [1] Applied to Abutments only
[2] Applicability of load is based on “Approach Slab on Beam Notch” parameter on the ASL command

3.3.3 Load Cases

Extreme force effects are determined for each limit state by applying maximum or minimum load factors to the applied loads. Limit state load cases are formed this way.

Use of the maximum or minimum load factor depends on the applied load direction under consideration. For example, if the vertical force acting on the abutment is to be minimized, the component dead load (DC) of the superstructure would be factored by the minimum load factor. Some applied loads have components in both the vertical and horizontal directions. These applied loads are multiplied by the maximum load factor because the horizontal force is always maximized and both components of force must be multiplied by the same factor. An example of this situation is the live load surcharge (LS).

3.3.4 Limit States and Load Combinations

There are eight limit states considered by the program, namely: Service I, Strength I, Strength IP, Strength II, Strength III, Strength V, Extreme I, and Extreme II.

In addition, the program uses load factors for checking secondary and consolidation settlement (CSS).

Load combinations are performed in accordance with the LRFD specifications and superseded by the DM-4 specifications. Tables 1 and 2 identify the loads and corresponding load factors that are combined for

each limit state of the temporary stage and final stage respectively. When two load factors are presented, the first load factor is the maximum load factor and the second load factor is the minimum load factor.

The applicability of a given limit state load combination is a function of the:

1. Construction condition (temporary stage or final stage).
2. Load case (maximum, minimum, MaxVert MinHorz, or MinVert MinHorz).
3. Component (stem, footing, or backwall).
4. Structure type (abutment or retaining wall).

The description of the construction condition can be found in Section 2.8.1. Vehicular type loads (LL, BR, CT...) and superstructure loads (DC) are not considered in the temporary stage load combinations because the superstructure is not constructed.

The maximum load case refers to the situation when the objective of the load combination is to maximize the downward vertical load. Similarly, the minimum load case refers to the situation when the objective of the load combination is to minimize the downward vertical force. For both the maximum and minimum load case, the horizontal load is maximized. The maximum vertical, minimum horizontal load case refers to the situation when the objective of the load combination is to maximize the downward vertical load with the horizontal load minimized by using reverseable horizontal loads in the opposite direction. The reverseable loads are wind (WL, WSUP1, WSUP3, WSUP5, WSUB1, WSUB3, and WSUB5), thermal (TU), braking force (BR), and friction (FR). The minimum vertical, minimum horizontal load case refers to the situation when the objective of the load combination is to minimize the downward vertical force with the horizontal load minimized by using reverseable horizontal loads in the opposite direction. These two load cases are considered for foundations of all types. The effects of reversing the horizontal loads are most apparent when finding the maximum loads in each pile row, depending on the abutment geometry and the pile pattern. For load types that have components in both the horizontal and vertical directions (LS, ES, EH and EQ), the load is maximized in both directions.

The program incorporates the following “rules” in the application of load combinations.

1. If the earthquake command (Section 5.35) is not specified by the user, the Extreme I limit state is not applied.
2. If the collision load (see Section 5.32) is not specified by the user, the Extreme II limit state is not applied.
3. If the pedestrian live load (see Section 5.30) is not specified by the user, the Strength IP limit state is not applied.
4. The backwall live load is only applicable for the final stage of Abutment Types I and II.

5. The following load cases are not applicable for retaining walls:
    - DC - Superstructure
    - DW - Superstructure and Abutment
    - Bearing Line Loads (LLIM, PL, WS, WL, BR, FR, CE, and parts of EQ)
    - Substructure Wind Loads (WSUB1, WSUB3, WSUB5)
    - Approach slab loads (DCAS, DWAS, LLAS, DCAP)

Table 3.3.4-1 Load Factor/Load Combination Table: Temporary Stage

Type of Load	Service I	Strength I	Strength IP	Strength II	Strength III	Strength V	Extreme I	Extreme II	CSS
DC-A	1.00/1.00	1.25/0.90	1.25/0.90	1.25/0.90	1.25/0.90	1.25/0.90	--	--	--
DC-S	--	--	--	--	--	--	--	--	--
DCAS	--	--	--	--	--	--	--	--	--
DCAP	1.00/1.00	1.25/0.90	1.25/0.90	1.25/0.90	1.25/0.90	1.25/0.90	--	--	--
DW-A	--	--	--	--	--	--	--	--	--
DW-S	--	--	--	--	--	--	--	--	--
DWAS	--	--	--	--	--	--	--	--	--
EV	1.00/1.00	1.35/1.0	1.35/1.0	1.35/1.0	1.35/1.0	1.35/1.0	--	--	--
EH	1.00/1.00	1.50/1.50	1.50/1.50	1.50/1.50	1.50/1.50	1.50/1.50	--	--	--
EH-V	1.00/1.00	1.50/1.50	1.50/1.50	1.50/1.50	1.50/1.50	1.50/1.50	--	--	--
ES	1.00/1.00	1.50/1.50	1.50/1.50	1.50/1.50	1.50/1.50	1.50/1.50	--	--	--
LS	1.00/1.00	1.75/1.75	1.50/1.50	1.50/1.50	--	1.50/1.50	--	--	--
LLDD	--	--	--	--	--	--	--	--	--
LLDU	--	--	--	--	--	--	--	--	--
LLBW	--	--	--	--	--	--	--	--	--
LLBH	--	--	--	--	--	--	--	--	--
LLAS	--	--	--	--	--	--	--	--	--
PL	--	--	--	--	--	--	--	--	--
WSUP	--	--	--	--	--	--	--	--	--
WSUP1	--	--	--	--	--	--	--	--	--
WSUP3	--	--	--	--	--	--	--	--	--
WSUP5	--	--	--	--	--	--	--	--	--
WSUB1	1.00/1.00	--	--	--	--	--	--	--	--
WSUB3		--	--	--	1.00/1.00	--	--	--	--
WSUB5		--	--	--	--	1.00/1.00	--	--	--
WL	--	--	--	--	--	--	--	--	--
WA	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0	--	--	-
BR	--	--	--	--	--	--	--	--	-
CE	--	--	--	--	--	--	--	--	--
TU	--	--	--	--	--	--	--	--	--
FR	--	--	--	--	--	--	--	--	--
EQ	--	--	--	--	--	--	--	--	--
CT	--	--	--	--	--	--	--	--	--

Table 3.3.4-2 Load Factor/Load Combination Table: Final Stage

Type of Load	Service I	Strength I	Strength IP	Strength II	Strength III	Strength V	Extreme I	Extreme II	CSS
DC-A	1.00/1.00	1.25/0.90	1.25/0.90	1.25/0.90	1.25/0.90	1.25/0.90	1.00/1.00	1.00/1.00	1.0/1.0
DC-S	1.00/1.00	1.25/0.90	1.25/0.90	1.25/0.90	1.25/0.90	1.25/0.90	1.00/1.00	1.00/1.00	1.0/1.0
DCAS	1.00/1.00	1.25/0.90	1.25/0.90	1.25/0.90	1.25/0.90	1.25/0.90	1.00/1.00	1.00/1.00	1.0/1.0
DCAP	1.00/1.00	1.25/0.90	1.25/0.90	1.25/0.90	1.25/0.90	1.25/0.90	1.00/1.00	1.00/1.00	1.0/1.0
DW-A	1.00/1.00	1.50/0.65	1.50/0.65	1.50/0.65	1.50/0.65	1.50/0.65	1.00/1.00	--	1.0/1.0
DW-S	1.00/1.00	1.50/0.65	1.50/0.65	1.50/0.65	1.50/0.65	1.50/0.65	1.00/1.00	--	1.0/1.0
DWAS	1.00/1.00	1.50/0.65	1.50/0.65	1.50/0.65	1.50/0.65	1.50/0.65	1.00/1.00	--	1.0/1.0
EV	1.00/1.00	1.35/1.0	1.35/1.0	1.35/1.0	1.35/1.0	1.35/1.0	1.35/1.0	1.35/1.0	1.0/1.0
EH	1.00/1.00	1.50/1.50	1.50/1.50	1.50/1.50	1.50/1.50	1.50/1.50	--	1.50/1.50	1.0/1.0
EH-V	1.00/1.00	1.50/1.50	1.50/1.50	1.50/1.50	1.50/1.50	1.50/1.50	--	1.50/1.50	1.0/1.0
ES	1.00/1.00	1.50/1.50	1.50/1.50	1.50/1.50	1.50/1.50	1.50/1.50	1.50/1.50	1.50/1.50	1.0/1.0
LS	1.00/1.00	1.75/1.75	1.35/1.35	1.35/1.35	--	1.35/1.35	--	0.50/0.50	--
LLDD	1.00/--	1.75/--	1.35/--	1.35/--	--	1.35/--	--/--	--	--
LLDU	--/1.00	--/1.75	--/1.35	--/1.35	--	--/1.35	--/--	--	--
LLPD	**--**	**--**	**--**	**1.35/--**	**--**	**--**	**--**	**--**	**--**
LLPU	**--**	**--**	**--**	**--/1.35**	**--**	**--**	**--**	**--**	**--**
LLBW	1.00/--	1.75/--	1.35/--	1.35/--	--	1.35/--	--/--	--	--
LLBH	1.00/--	1.75/--	1.35/--	1.35/--	--	1.35/--	--/--	--	--
LLAS	1.00/--	1.75/--	1.35/--	1.35/--	--	1.35/--	--/--	--	--
PL	--	--	1.75/--	--	--	--	--	--	--
WSUP	--	--	--	--	1.00/1.00		--	--	--
WSUP1	1.00/1.00	--	--	--	--	--	--	--	--
WSUP3	--	--	--	--	1.00/1.00	--	--	--	--
WSUP5	--	--	--	--	--	1.00/1.00	--	--	--
WSUB1	1.00/1.00	--	--	--	--	--	--	--	--
WSUB3	--	--	--	--	1.00/1.00	--	--	--	--
WSUB5	--	--	--	--	--	1.00/1.00	--	--	--
WL	1.00/1.00	--	--	--	--	1.00/1.00	--	--	--
WA	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0
BR	1.0/1.0	1.75/1.75	1.35/1.35	1.35/1.35	--	1.35/1.35	--/--	--	--
CE	1.0/1.0	1.75/1.75	1.35/1.35	1.35/1.35	--	1.35/1.35	--/--	--	--
TU	1.0/1.0	0.50/0.50	0.50/0.50	0.50/0.50	0.50/0.50	0.50/0.50	--	--	--
FR	1.0/1.0	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00	--
EQ	--	--	--	--	--	--	1.0/1.0	--	--
CT	--	--	--	--	--	--	--	1.0/1.0	--

3.3.5 Eta Factor

The Eta (η) factor is the consideration of the ductility, redundancy and operational importance of the structural component with respect to the margin of safety of the bridge. The application of the Eta factor as per DM-4 differs from the AASHTO LRFD implementation. DM-4 states that the application of load modifiers other than 1.0 have been found to have a detrimental effect on economical bridge designs without a corresponding increase in comfort level. As per PennDOT DM-4 Section 1.3.2.1, Eta factors other than 1.0 are not permitted by PennDOT.

The program applies the Eta factor based on each applied load rather than applying one factor to all of the loads for the given limit state. If the applied load was factored by the maximum load factor, the load contribution to the limit state response is multiplied by η. If the applied load was factored by the minimum load factor, the load contribution to the limit state response is divided by η, so as to reduce the response.

3.3.6 Earthquake Loading

The earthquake loads applied to the abutment emanate from three sources: the abutment mass-inertia effect; the inertia effect of the soil; and, the forces transmitted from the superstructure.

It is typically acceptable to ignore the mass-inertia effect of the abutment (assuming that it is not important). This effect is ignored in ABLRFD.

The unfactored earthquake loads (EQ) are calculated as per Section 3.3.2.25. The EQ loads are then factored using the load factors specified in User's Manual Table 3.3.4-2 for the Extreme I limit state.

For pile/caisson foundations, the Phi Factor Foundation input value from Section 6.35.3 is multiplied by the pile/caisson lateral and axial resistance for Extreme Event I limit state only.

For spread footings on rock or soil, the Phi Factor Foundation input value from Section 6.35.3 is multiplied by the bearing resistance for Extreme Event I limit state only.

Earthquake loads are not considered during the analysis of the Footing.

3.4 STABILITY

Each footing type has a unique set of checks for stability. The following sections identify the stability checks that are evaluated for each footing type: spread, pedestal and pile.

3.4.1 Spread Footing Stability

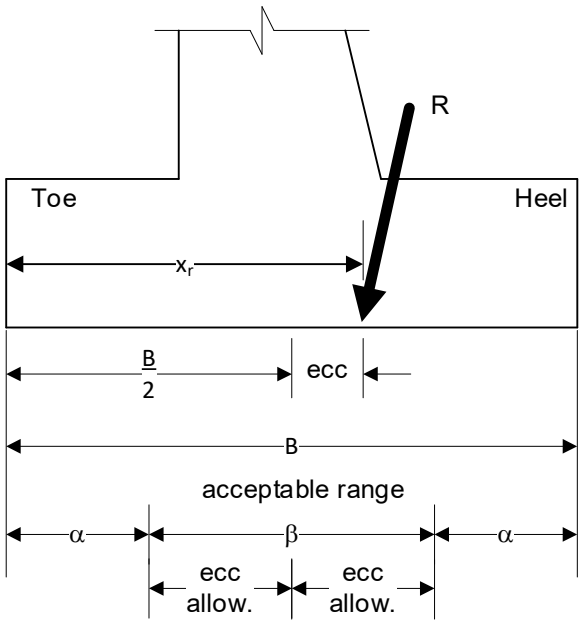
The stability of spread footings considers: overturning, sliding, settlement, and bearing capacity. Each type of check is described in the sections that follow.

3.4.1.1 Overturning (Eccentricity Check)

The eccentricity check examines the location of the resultant force relative to the toe of the footing. The distance from the toe to the resultant, X_r, is calculated by dividing the net overturning moment (from both horizontal and vertical loads) by the net vertical force as illustrated in the equation below:

$$X_r = \frac{VLM + HLM}{VLF}$$

For spread footings on rock foundations, the resultant (R) should be situated in the middle nine-tenths of the footing base width for the Final Stage. For spread footings on soil foundations, the resultant (R) should be situated in the middle two-thirds of the base width for the Final Stage as shown in Figure 3.4.1-1. The program calculates an allowable eccentricity and verifies the eccentricity does not exceed the allowable by providing a performance ratio based on these values.



Strength Limit States

Temporary Stage

Footing on Rock or Soil Foundations: α = B/6; β = 2B/3 (DM-4 Section 11.6.3.3)

Final Stage

Footing on Rock Foundations: α = B/20; β = 9B/10
Footing on Soil Foundations: α = B/6; β = 2B/3 (LRFD Specifications Section 11.6.3.3)

Extreme Limit States I and II

Temporary and Final Stage

Soil and Rock Foundations: α = B/6; β = 2B/3 (LRFD Specifications Section 11.6.5.1)

Figure 3.4.1-1 Stability Check for Spread Footing

3.4.1.2 Sliding Check for Spread Footings

The sliding check consists of comparing the factored sliding resistance to the applied horizontal force. Sliding is not a problem if the factored resistance ($\phi_\tau R$) is greater than the applied horizontal force (HLF) as shown in the following equation:

$$\varphi_\tau R \geq HLF$$

The horizontal force is determined from the minimum load case for all limit states and stages except for the service limit state. The resistance factor ϕ_τ is specified by the user in the SOI command. The resistance is a function of the material in the top-most foundation layer and the concrete type of the footing. The following sections identify how the sliding resistance is evaluated.

3.4.1.2.1 Sliding Resistance of Rock Foundations

The resistance is a function of the applied vertical force (VLF) and the friction angle (user-specified) of the rock layer, as shown below:

$$R = (VLF) \tan \delta$$

3.4.1.2.2 Sliding Resistance of Sand Foundations

The value of the cohesion of the soil layer is used to distinguish Sands from Clays. Sands have no cohesion. The following from LRFD Specifications Equation 10.6.3.4-2 is used for sands:

$$R = (VLF) \tan \delta$$

Where:

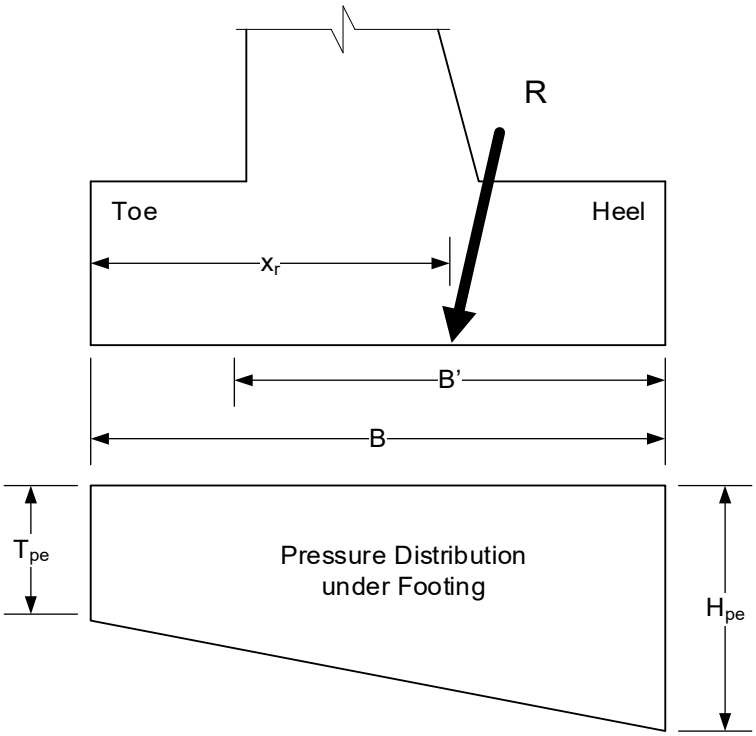
$\tan \delta = \tan \varphi_f$ for cast-in-place concrete

$\tan \delta = 0.8 * \tan \varphi_f$ for precast concrete footing

3.4.1.2.3 Sliding Resistance of Clay Foundations

The sliding resistance for clays (i.e., when cohesion > 0.0 and $\phi_f = 0.$) is based on the relative values of : the undrained shear strength (s_u); the effective bearing pressures in the footing at the toe (T_{pe}) and the heel (H_{pe}) locations due to applied loads; and the location of the resultant applied force (x_r). Table 3.4.1-1 identifies the equations used to compute the unfactored sliding resistance of the soil.

Figure 3.4.1-2 illustrates the variables referenced in Table 3.4.1-1. To find the equation that defines the sliding resistance (defined in the third column); find the row in which x_r satisfies the condition in column 1; and s_u satisfies the condition(s) in column 2. Start at the first row and work downwards to find the applicable case.



Note: Variables referenced in Table 3.4.1.2.3-1

Figure 3.4.1-2 Illustration of Pressure Distribution Under Spread Footing

Table 3.4.1-1 Unfactored Sliding Resistance for Clays

Location of Resultant	Shear Strength Condition	Sliding Resistance
--	$s_u < \frac{H_{pe}}{2}$ & $s_u < \frac{T_{pe}}{2}$	$R = s_u B$
$x_r < \frac{B}{3}$	$s_u > \frac{T_{pe}}{2}$	$R = \frac{3}{4} T_{pe} x_r$
$x_r < \frac{B}{3}$	$s_u \leq \frac{T_{pe}}{2}$	$R = s_u(3x_r - D) + \frac{1}{2} s_u D$ where: $D = \frac{6 x_r s_u}{T_{pe}}$
$x_r > \frac{2B}{3}$	$s_u > \frac{H_{pe}}{2}$	$R = s_u(3(B - x_r) - D) + \frac{1}{2} s_u D$ where: $D = \frac{6(B - x_r) s_u}{H_{pe}}$
$x_r > \frac{2B}{3}$	$s_u \leq \frac{H_{pe}}{2}$	$R = \frac{3}{4}(H_{pe} + T_{pe})B$
$\frac{B}{3} \leq x_r \leq \frac{2B}{3}$	$s_u > \frac{H_{pe}}{2}$ & $s_u > \frac{T_{pe}}{2}$	$R = \frac{1}{4}(H_{pe} + T_{pe})B$
$\frac{B}{3} \leq x_r \leq \frac{2B}{3}$	$s_u > \frac{H_{pe}}{2}$	$R = s_u(B - D) + \frac{1}{2}\left(s_u + \frac{1}{2} H_{pe}\right) D$ where $D = \frac{\left(s_u - \frac{1}{2} H_{pe}\right) B}{\frac{1}{2}(T_{pe} - H_{pe})}$:
$\frac{B}{3} \leq x_r \leq \frac{2B}{3}$	$s_u \leq \frac{H_{pe}}{2}$	$R = s_u(B - D) + \frac{1}{2}\left(s_u + \frac{1}{2} T_{pe}\right) D$ where $D = \frac{\left(s_u - \frac{1}{2} T_{pe}\right) B}{\frac{1}{2}(H_{pe} - T_{pe})}$:

Legend:
T_{pe}, H_{pe} = Effective pressure at Toe and Heel; x_r = load resultant; s_u = shear strength; B = footing width as illustrated in Figure 3.4.1-2. x_r is measured from the Toe towards the Heel.

3.4.1.2.4 Sliding Resistance of Clayey-Sandy "C-Phi" Soils

For soils that have a non-zero cohesion and a non-zero friction angle, the sliding resistance is computed as shown below using DM-4 Equation 10.6.3.4-3:

$$R_\tau = V \tan\delta + c_a B'$$

Where (DM-4 Section 10.6.3.4):

$$c_a = c\left(0.21 + \frac{0.54}{c} \leq 1.0\right)$$

c in units of ksf

tan δ = tan φ_f for cast-in-place concrete

tan δ = 0.8 * tan φ_f for precast concrete footing

The effective width, B', is computed as (variables as shown in Figure 3.4.1-2):

$$B' = B - 2\left(\left|\frac{B}{2} - x_r\right|\right)$$

3.4.1.3 Settlement of Spread Footings

There are three components to the total settlement of spread footings, namely: elastic, consolidation, and secondary. The total settlement for Rock and Sand foundations consists of the elastic settlement only; the consolidation and secondary settlements are computed for clay and c-phi soil foundations only. Clays and c-phi soils are distinguished from sands by their non-zero cohesive (or undrained) strength.

If the undrained shear strength (s_u) of clay is less than 4.35 psi the clay is considered to be too soft to be used as a foundation material and the program will exit after printing an error message. A c-phi soil is considered to be too soft to be used as a foundation material if the cohesive strength is less than 4.35 psi and the friction angle is less than 20 degrees.

The uniform bearing pressure (q) used for the elastic settlement equation is determined from the service limit states only. The bearing pressure is computed using the effective width (please refer to the previous section for a definition of effective width). This width is also used to compute the pressure for the consolidation and secondary settlement calculations.

The consolidation settlement uses a bearing pressure that is also based on the service limit states. However, in this case, the live load and LS load are not considered in the load combinations.

The following section describes how each component of the total settlement is calculated.

3.4.1.3.1 Elastic Settlement

The elastic settlement for a single layer of soil or rock is computed as described below. Two values used by the elastic settlement calculations are B'_1 and L'_1 (also defined in LRFD Specifications Section 10.6.1.3). B'_1 is the effective footing width to be used with rock or the top layer of soil, and is defined as:

$$B'_1 = B - 2\left(\left|\frac{B}{2} - x_r\right|\right)$$

where: B = total footing width (as shown in Figure 3.4.1-2)

x_r = distance from the face of the toe to the load resultant (see Figure 3.4.1-2)

Since ABLRFD does not consider eccentricity of load parallel to the face of the abutment, L'_1 is always equal to the "Footing Length (Parallel)" entered on the SOI or RCK command

For a rectangular footing on rock:

The program uses the lesser of the input rock mass modulus and input intact elastic modulus.

The following equations are based on LRFD Specifications Equations 10.6.2.4.4-3 and 10.6.2.4.4-4 and Table 10.6.2.4.2-1.

$$E_m = MIN\left(E_{m(input)}, E_i\right)$$

$$x = \frac{L'_1}{B'_1}$$

$$\beta_z = -0.0005x^2 + 0.0438x + 1.0271$$

$$I_p = \frac{\sqrt{x}}{\beta_z}$$

$$CF = B'_1(1 - \upsilon^2)I_p$$

$$S_e = (CF)\frac{q_0}{E_m}$$

Where:

E_m is in units of ksf (LRFD Specifications Equation is in units of ksi).

For a rectangular footing on a single layer of soil:

The following equations are based on DM-4 Equation 10.6.2.4.2-1:

$$E_s = E$$

$$CF = \mu_0\mu_1 B'_1$$

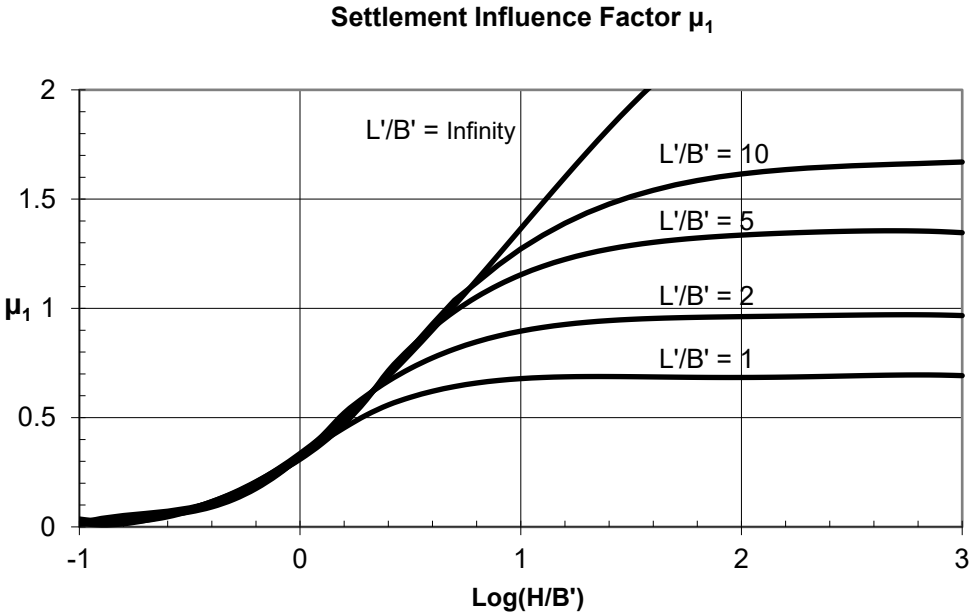
$$S_e = (CF)\frac{q_0}{E_s}$$

Where: μ_o and μ_1 are the influence factors based on Christian and Carrier's work (Figure 3.4.1-3).

μ_1 includes the elastic effects of a Poisson's Ratio of 0.5

μ_o is set to 1.0. Reference DM-4 Section 10.6.2.4.2

E_s is in units of ksf (DM-4 Equation is in units of ksi).



DM-4 Figure 10.6.2.4.2-2

Figure 3.4.1-3 Settlement Influence Factor based on Christian and Carrier

The elastic settlement for two layers of soil as computed based on one of the following three scenarios:

Scenario 1: If soil layer 2 (lower layer) is much stiffer than the soil layer 1 (top layer), i.e., if $E_2 > 10E_1$, the settlement is calculated as a single layer using the properties of soil layer 1 (top layer). The depth of soil layer 1 is only considered for elastic settlement. The settlement adjustment factor used (shown below) is the same as for a single soil layer.

$$CF = \mu_0 \mu_1 B_1'$$

Scenario 2: If the lower layer (soil layer 2) is softer than the upper layer (soil layer 1), i.e. $E_2 < E_1$, the settlement is calculated using the properties of the lower layer (soil layer 2) and the adjustment factor (CF) is based on the properties of the top layer (soil layer 1) as shown in the equation below:

$$CF = \alpha C_d \mu_0 \mu_1 B_1'$$

Where: α is interpolated from Table 3.4.1-2.

C_d is interpolated from Table 3.4.1-3.

μ_o is set to 1.0.

μ_1 is a function of: the ratio of depth of soil layer 1 (top layer) to the effective width (H/B'_1); and the ratio of the length of the footing to the effective width (L'_1/B'_1) of the footing. (Note: For scenario 2, H **is the total thickness of the two soil layers** for calculation of μ_1 **and** α.

The alpha factor used in the Adjustment Factor (CF) for the Scenario 2 is based on a round footing. The Cd factor is based on a rectangular footing and is used as an approximate correction between the round and rectangular footing. This may lead to exaggerated settlement values under certain conditions.

Table 3.4.1-2 Elastic Distortion Settlement Factor – α (From Table 4.4 of {FDNHBK})

	E_1/E_2					
H_i/B'		1	2	5	10	100
	0.0	1.000	1.000	1.000	1.000	1.000
	0.1	1.000	0.972	0.943	0.923	0.760
	0.25	1.000	0.885	0.779	0.699	0.431
	0.5	1.000	0.747	0.566	0.463	0.228
	1.0	1.000	0.627	0.399	0.287	0.121
	2.5	1.000	0.550	0.274	0.175	0.058
	5.0	1.000	0.525	0.238	0.136	0.360
	∞	1.000	0.500	0.200	0.100	0.010

Table 3.4.1-3 Shape and Rigidity Factor – C_d (From Table 4.1 of {FDNHBK})

C_d for settlements at center of rectangle	
L'/B' = 1.0	1.12
L'/B' = 1.5	1.36
L'/B' = 2.0	1.52
L'/B' = 3.0	1.78
L'/B' = 5.0	2.10
L'/B' = 10	2.53
L'/B' = 100	4.00
L'/B' = 1000	5.47
L'/B' = 10000	6.90

Scenario 3: If neither scenario described above applies, then the elastic settlement is equal to the sum of the settlement for each layer. The settlement for each layer is calculated by applying the properties of each layer in the formulation of the single layer soil described earlier. However, the thickness of the lower layer

of soil will be the lesser of H_2 and (6B - H_1). For the lower layer, the pressure and effective width of the footing used in the settlement equation are determined by the following relations:

$$B_2' = B_1' + H_1$$

$$q_2 = q_1 \left(\frac{B_1'}{B_2'}\right)\left(\frac{L_1'}{L_2'}\right)$$

$$L_2' = L_1' + H_1$$

The relationship between B'_1 and B'_2 is illustrated in Figure 3.4.1-4. Since the loads entering the footing are always perpendicular to the length of the foundation, the L'_1 length is equal to the total length of the footing due to lack of eccentricity in the length plane.

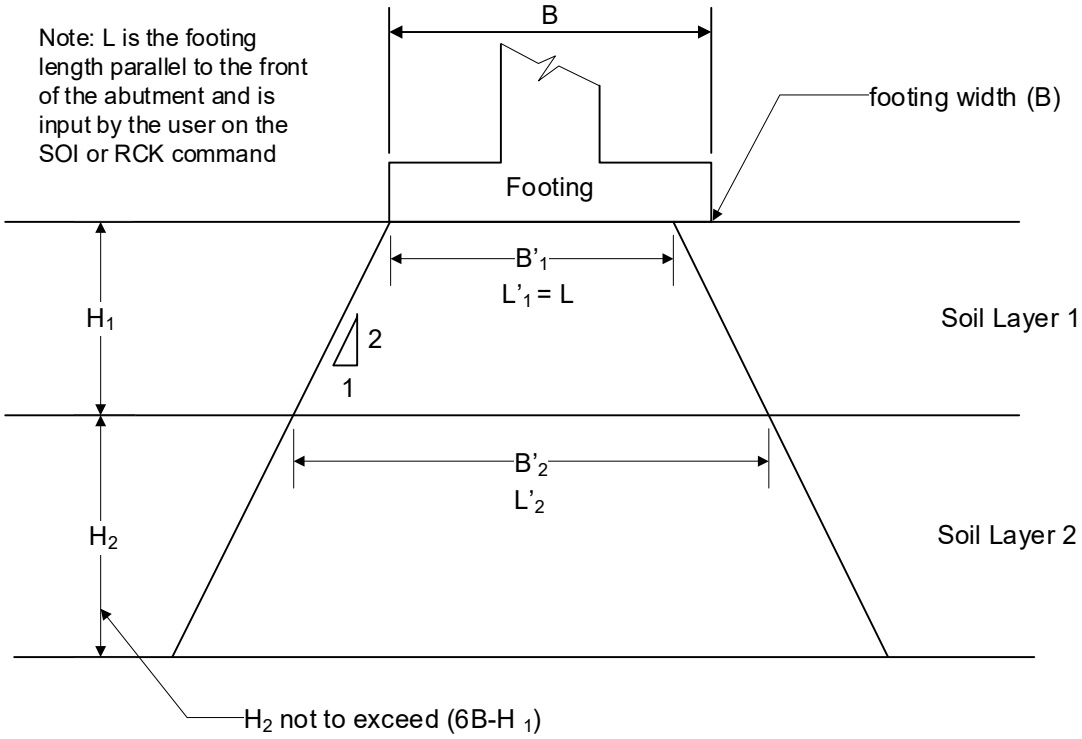


Figure 3.4.1-4 Considerations for Settlement for Two Layers of Soil

3.4.1.3.2 Consolidation Settlement of Clays (and C- φ Soils)

Consolidation Settlement is calculated for clay soils when water is present in the soil layer(s). This settlement is a result of the excess water being forced out of the layer, allowing the soil to increase in density. The program however, always assumes the soil layer(s) are saturated and will consider the entire layer for consolidation regardless of water presence. It is possible to exclude the effects of primary consolidation for a layer by setting C_c and C_{cr} to zero for that layer. Also it is important to note that the settlement calculations performed by the program do not consider effects of an adjacent embankment (for more information refer to Section 6.20). The consolidation settlement is calculated by subdividing each clay

and (and C - φ soil) layer. The number of sublayers is calculated by dividing the layer thickness by 5 ft (1.5m) and rounding to the nearest integer. The consolidation settlement (Sc) is equal to the sum of the consolidation settlement (Sc_i) for each sublayer.

NOTE: the solution employed in the program ignores the effect of soil removed by excavation to construct the footing. This is conservative, if a more detailed analysis considering this effect is required the user should perform independent calculations.

$$S_c = \sum_{i=1}^{nsub} S_{ci}$$

The depth of soil considered for the settlement is restricted to the lesser of: the depth of the lower soil layer or 6 * B below the bottom of footing.

The Final Effective Stress of each soil sublayer is computed using the Boussinesq Equation (equation 5-8 of [BOWLES]) based on the corner of a rectangular region.

Initial Effective Stress

Layer 1

$$\sigma'_{o1} = \sigma'_{o1t} + \gamma_{s1} Z - \gamma_w H_{w1}$$

Layer 2

$$\sigma'_{o2} = \sigma'_{o2t} + \gamma_{s2}(Z - H_1) - \gamma_w H_{w2}$$

Maximum Past Effective Stress

Layer 1

σ'_{p1} = The interpolated value between $\sigma'_{p1\ Top}$ and $\sigma'_{p1\ Bottom}$ at Z

Layer 2

σ'_{p2} = The interpolated value between $\sigma'_{p2\ Top}$ and $\sigma'_{p2\ Bottom}$ at Z

Final Effective Stress

Layer 1

$$\sigma'_{f1} = 4\sigma'_b L_{fact(Z)} + \sigma'_{o1}$$

Layer 2

$$\sigma'_{f2} = 4\sigma'_b L_{fact(Z)} + \sigma'_{o1t} + \gamma_{s1} H_1 - \gamma_w H_{w1} + \gamma_{s2}(Z - H_1) - \gamma_w H_{w2}$$

NOTE: this form of the final effective stress equation is used to accommodate special cases as described in section 6.20.6

Where: Z = Distance from the bottom of footing to center of sublayer (Figure 3.4.1-5).

H_1	=	**Depth of soil layer 1 (upper layer) used for settlement calculations**
H_{w1}	=	Height of water above center of sublayer in Layer 1 (Figure 3.4.1-5)
H_{w2}	=	Height of water above center of sublayer in Layer 2 (Figure 3.4.1-5)
		H_{w1} and H_{w2} are limited to the maximum height of the soil layer.
L_{fact}	=	**influence factor**
γ_s	=	**unit weight of saturated soil (kcf)**
γ_w	=	**unit weight of water (kcf)**
σ'_{o1} & σ'_{o2}	=	Initial effective stress at center of soil sublayer (ksi)
σ'_{p1} & σ'_{p2}	=	Maximum past effective stress at center of soil sublayer (ksi)
σ'_{f1} & σ'_{f2}	=	Final effective stress at center of soil sublayer (ksi)
σ'_{o1t} & σ'_{o2t}	=	Initial effective stress at top of soil layer (input) (ksi)
$\sigma'_{p1\ top}$ & $\sigma'_{p2\ top}$	=	Maximum past effective stress at top of soil layer (input) (ksi)
$\sigma'_{p1\ bottom}$ & $\sigma'_{p2\ bottom}$	=	Maximum past effective stress at bottom of soil layer (input) (ksi)
σ'_{f1t}	=	Final effective stress at top of soil layer 1 (ksi)
σ'_b	=	the effective bearing pressure at the bottom of the footing calculated using effective footing dimension B'_1 (Figure 3.4.1-4)

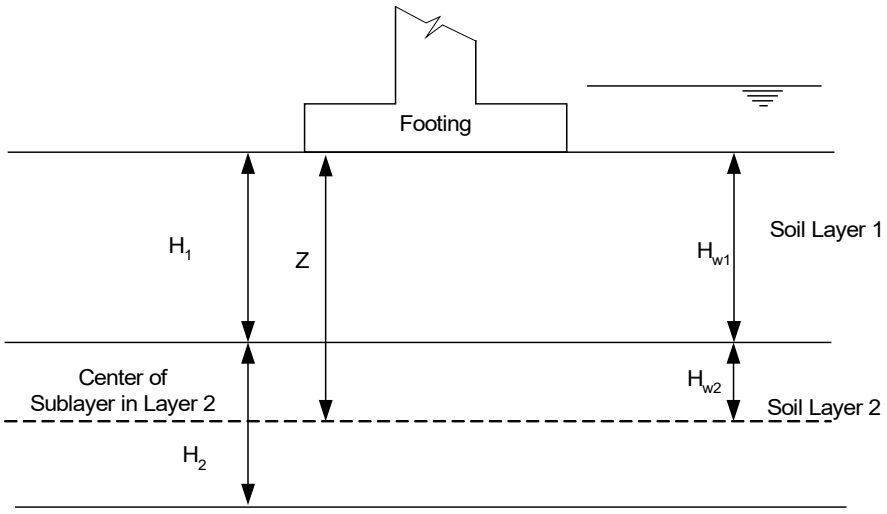


Figure 3.4.1-5 Description of Z and H_w values

The influence factor used in the equation is calculated as per equation 5-8 of [Bowles]. The influence factor is based on the geometry of the footing and always uses the effective dimensions of the foundation at the bottom of the footing. The factor is a function of the footing geometry and the depth of the soil layer as shown below:

$$L_{fact} = \frac{1}{4\pi}\left[\frac{2p\sqrt{q}}{p^2+q}\left(\frac{q+1}{q}\right) + \tan^{-1}\left(\frac{2p\sqrt{q}}{q-p^2}\right)\right]$$

Arc Tangent is in Radians

Where:

$$n = \frac{0.5L'_1}{Z}$$

$$m = \frac{0.5B'_1}{Z}$$

$$p = mn$$

$$q = m^2 + n^2 + 1$$

When $p^2 > q$, the $\tan^{-1}$ term is negative and it is necessary to add π.

The effective soil pressure is evaluated for each sub-layer. It is used with the compression index (C_c), recompression index (C_{cr}), and void ratio (e_o) at initial vertical effective stress to compute the consolidation settlement for the *I th* sub-layer as show below. The Ccr and Cc values used by the program are based on the void ratio definition.

For Over-Consolidated Soils $\left(\sigma'_p > \sigma'_o\right)$

$$S_{ci} = \frac{\Delta h}{1+e_o}\left[C_{cr}\log\frac{\sigma'_f}{\sigma'_p} + C_c\log\frac{\sigma'_f}{\sigma'_p}\right] \text{ if } \sigma'_f > \sigma'_p$$

$$S_{ci} = \frac{\Delta h}{1+e_o}\left[C_{cr}\log\frac{\sigma'_f}{\sigma'_p}\right] \text{ if } \sigma'_f \le \sigma'_p$$

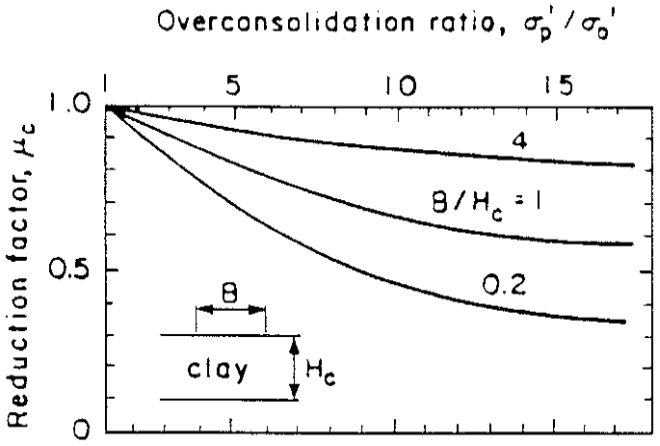
For Normally-Consolidated Soils $\left(\sigma'_p = \sigma'_o\right)$

$$S_{ci} = \frac{\Delta h}{1+e_o}\left[C_c\log\frac{\sigma'_f}{\sigma'_p}\right]$$

For Under-Consolidated Soils $\left(\sigma'_p < \sigma'_o\right)$

The ABLRFD program does not consider settlement for Under-Consolidated soil. If Under-consolidation is encountered, the input file should be checked for errors. Hand calculations are required along with approval from the Chief Bridge Engineer. If Under-Consolidation is detected during a design run, a warning will be issued and primary consolidation settlement will be calculated assuming a normal consolidation condition.

For the total settlement of the first layer of soil only, a settlement factor based on the average over consolidation ratio (OCR) is applied. The OCR is computed for each sublayer and the average is then applied to the figure below. This factor is based on LRFD Specifications Figure 10.6.2.4.3-3



LRFD Specifications Figure 10.6.2.4.3-3

Figure 3.4.1-6 Consolidation Settlement Reduction Factor

$$S_{c1} = S_{c1}\mu_c$$

If the total settlement is less than zero, the program will provide a secondary calculation for total settlement which combines the elastic and secondary settlement values for the total settlement.

$$S_{t1} = S_e + S_c + S_s$$

$$S_{t2} = S_e + S_s$$

3.4.1.3.3 Secondary Settlement of Clays (and C-φ Soils)

The secondary settlement is calculated using the same sublayers as for the consolidation settlement. The secondary settlement (S_s) is equal to the sum of the secondary settlement (S_{si}) for each sublayer. This settlement starts at the end of primary consolidation settlement.

$$S_s = \sum_{i=1}^{nsub} S_{si}$$

The secondary settlement is a function of the: coefficient of secondary compression (C_α); the time interval (t_2, t_1) for which the settlement is being computed; and, the thickness of the sub-layer. The Coefficient of Secondary Compression used by the program is based on the Strain definition:

$$S_{si} = \Delta h \left[C_\alpha \log \frac{t_2}{t_1} \right]$$

3.4.1.3.4 Allowable Settlement

The acceptable total settlement is set by the program to a default value of 1 inch. The user may override this value (See the SOI and RCK commands in Chapter 5). However, a warning message is still issued if the total settlement exceeds the program default value of allowable settlement.

3.4.1.4 Bearing Capacity Check

The bearing capacity check consists of comparing the factored bearing resistance of the soil (or rock) foundation to the factored applied loads at the bottom of footing level. The check is evaluated for all applicable limit states / stages / load cases. The applied pressure due to the factored applied loads depends on several factors and is described in Section 3.4.1.4.3.

3.4.1.4.1 Bearing Capacity of Rock Foundations

The user is responsible for specifying the bearing capacity of rock foundations. The capacity is specified using the RCK command in Chapter 5.

3.4.1.4.2 Bearing Capacity of Clay and Sand Foundations

The bearing capacity of soft soils is not computed. The definition of a soft soil can be found in Section 3.4.1.3 (discussion of settlement).

The factored bearing capacity of the soil is the lesser value of ϕq_{ult} and $[(0.7)(0.85)(f'_c)]$. For multi-layer soils, q_{ult} is typically calculated using properties based on a “weighted average” of the soil layers, except when a multi-layer capacity is used.

The effective footing width and length values are used in the bearing capacity calculations as defined in LRFD Specifications Section 10.6.1.3

The depth to the ground water level from the bottom of the footing (z_w) is used in the bearing capacity calculations and is based on the back water level entered on the AT1, AT2, AWB, or RWL command cards. This value will be less than zero when the water level is above the bottom of the footing.

The program classifies all soil into one of 4 Soil Classifications. Three of the soil classifications contain 3 Soil Conditions. The table below lists the categories and conditions for soil typing.

Table 3.4.1-4 Soil Categories and Conditions

Soil Category	Soil Condition	Number of Layers	Clay ϕ_f=0 & c=0 & s_u>0	Sand 20<ϕ_f<60 & c=0 & s_u=0	Mixed ϕ_f>0 & c>0 & s_u=0	Condition	Description *
1	1	1	Clay, Sand, or Mixed Layer			One layer of clay, sand, or mixed	Single Layer
2	2	2	Two Layers			$c_1 < c_2$	Weak Clay over Strong Clay
	3	2	Two Layers			$c_1 > c_2$	Strong Clay over Weak Clay
	9	2	One Layer		One Layer	One Layer Clay One Layer Mixed	Mixed Soil with Clay - Undrained
3	4	2	One Top Layer	One Bottom Layer	One Top Layer	$D > H_1$	Clay or Mixed Soil over Sand
			One Bottom Layer	One Top Layer	One Bottom Layer	$D > H_1$	Sand over Clay or Mixed Soil ($\phi_{f1} < 25^O$ or $\phi_{f1} > 50^O$)
					Two Layers	$D > H_1$	Mixed Soil over Mixed Soil
	5	2	One Top Layer	One Bottom Layer	One Top Layer	$D \le H_1$	Clay or Mixed Soil over Sand
			One Bottom Layer	One Top Layer	One Bottom Layer	$D \le H_1$	Sand over Clay or Mixed Soil ($\phi_{f1} < 25^O$ or $\phi_{f1} > 50^O$)
					Two Layers	$D \le H_1$	Mixed Soil over Mixed Soil
	8	2	One Bottom Layer	One Top Layer	One Bottom Layer	Top Layer Sand over a Bottom Layer of Clay or Mixed Soil	Sand over Clay or Mixed Soil ($25^O \le \phi_{f1} \le 50^O$)
4	6	2		Two Layers		$H_1 < 2B'$ & $\phi_{f1} > \phi_{f2}$	Dense Sand over Loose Sand
	7	2		Two Layers		$H_1 < 2B'$ & $\phi_{f1} < \phi_{f2}$	Loose Sand over Dense Sand
	10	2		Two Layers		$H_1 \ge 2B'$	Two Sand Layers

* To better clarify the calculations, the categories will be sub-divided into Soil Conditions below. The calculations are displayed in reverse order meaning the main bearing equation is listed first, then all secondary equations used to determine the main equation are listed after.

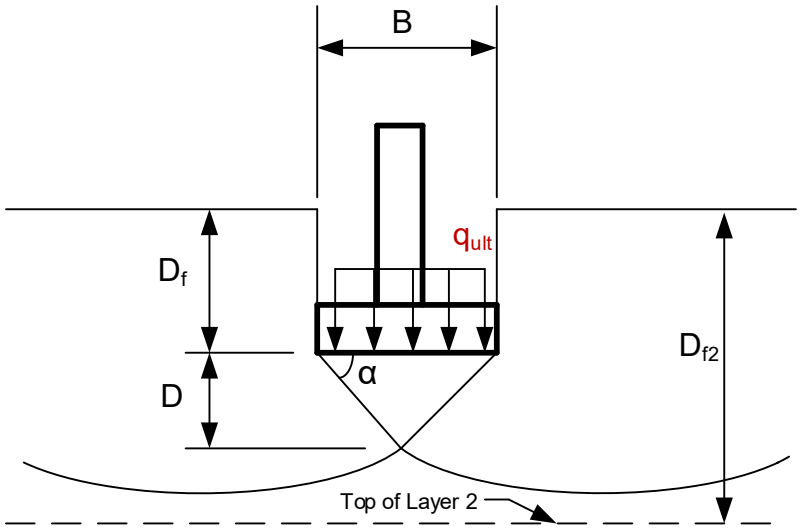


Figure 3.4.1-7 D_{f1} and D_{f2} definitions (from Bowles Second Edition Figure 4-3)

Category Independent Calculations

The following shows calculations for values generally used by most Categories and Soil Conditions

Bearing Resistance = q_{ult}*ϕ , where ϕ is the strength reduction factor applied to bearing resistance

$$D = 0.5B' \tan\left(45 + \frac{\phi_f}{2}\right)$$

Effective Shear Depth

DM-4 Equation 10.6.3.1.2gP-6

$$\phi_f = \tan^{-1}\left(\frac{H_1 \tan\phi_{if1} + (D - H_1)\tan\phi_{if2}}{D}\right)$$

Average Soil Friction Angle for Multiple Layers

(Bowles Section 4-8, Fourth Edition)

$$N_q = e^{\pi \tan\phi_f} \tan^2\left(45 + \frac{\phi_f}{2}\right)$$

DM-4 Equation C10.6.3.1.2a-1

$$B' = B - 2e_B$$

LRFD Specifications Equation 10.6.1.3-1

$$L' = L - 2e_L$$

LRFD Specifications Equation 10.6.1.3-1

Where:

If e_B or e_L are < 0 then; e_B = |-e_B| and e_L = |-e_L|

Note: L' = L since e_L is always 0

3.4.1.4.2.1 Category 1 - Soil Condition 1: Single Soil Layer

For bearing resistance the equations used are shown below.

$$q_n = cN_c s_c i_c + 0.5\gamma B' N_\gamma s_\gamma i_\gamma + \gamma D_f N_q s_q i_q$$ DM-4 Equation 10.6.3.1.2a-10

D_f in the equation above may be either D_{f1} or D_{f2}, depending on the soil category and soil condition. The following sections specify which value, D_{f1} or D_{f2}, to use as D_f.

For footings on or near a slope, the embedment term ($\gamma D_f N_q s_q i_q$) is neglected. As per the LRFD Specifications Section C10.6.3.1.2c, the RC_{BC} factors used to correct for footings on or near a slope are based on no footing embedment. Also, for footings on or near a slope, q_{ult} is multiplied by the adjustment factor (entered by the user), RC_{BC}:

$$q_n = RC_{BC}\left(cN_c s_c i_c + 0.5\gamma B' N_\gamma s_\gamma i_\gamma\right)$$ NOTE: Used only for footings on or near a slope

Input for Condition 1 - Single Layer

$\gamma_m = \gamma_{im}$

$\gamma_s = \gamma_{is}$

$\phi_f = \phi_{if}$

$c = c_i$

$D_f = D_{f1}$

$RC_{BC} = RC_{BC1}$

Calculation of Gamma (γ)

$$\gamma' = \gamma_s - \gamma_w$$

If $z_w \leq 0$

$$\gamma = \gamma'$$ DM-4 Equations 10.6.3.1.2gP-3,7

If $0 < z_w < B'$ and $\phi_f < 37°$

$$\gamma = \gamma' + \frac{z_w}{B'}(\gamma_m - \gamma')$$ DM-4 Equation 10.6.3.1.2gP-2

Where γ_m is the moist unit weight of soil

If $z_w \geq B'$ and $\phi_f < 37°$ and $z_w \geq D$

$$\gamma = \gamma_m$$ DM-4 Equations 10.6.3.1.2gP-1,4

If 0< z_w < B' and $\phi_f \geq 37°$ and z_w <D

$$\gamma = (2D - z_w)\frac{z_w \gamma_m}{D^2} + \frac{\gamma'}{D^2}(D - z_w)^2$$ DM-4 Equation 10.6.3.1.2gP-5

Calculation of N_c, N_q, and N_γ

$$N_q = e^{\pi \tan(\phi_f)} \tan\left(45° + \frac{\phi_f}{2}\right)$$ DM-4 Equation C10.6.3.1.2a-1

$$N_\gamma = 2(N_q + 1)\tan\phi_f$$ DM-4 Equation C10.6.3.1.2a-4

If $\phi_f \neq 0$

$$N_c = (N_q - 1)\cot\phi_f$$ DM-4 Equation C10.6.3.1.2a-2

If $\phi_f = 0$

$$N_c = 5.14$$ DM-4 Equation C10.6.3.1.2a-3

Calculation of s_c, s_q, and s_γ

If L' > 5B'

$$s_c, s_\gamma, and\ s_q = 1.0$$ DM-4 Section 10.6.3.1.2a

If L' ≤ 5B'

LRFD Specifications Table 10.6.3.1.2a-3:

Friction Angle	Cohesion Term (s_c)**	Unit Weight Term (s_γ)	Surcharge Term (s_q)
$\phi_f = 0$	$1 + \frac{B'}{5L'}$	1.0	1.0
$\phi_f > 0$	$1 + \frac{B'N_q}{L'N_c}$	$1 - 0.4\frac{B'}{L'}$	$1 + \frac{B'}{L'}\tan\phi_f$

**NOTE: If ϕ_f > 0 and c (cohesion) = 0, s_c is set to 1.0. When c equals 0, the entire first term of DM-4 Equation 10.6.3.1.2a-10 will equal zero, so the value of s_c does not ultimately matter.

Calculation of i_c, i_q, and i_γ

If H_u = 0.0

i_c, i_q, and i_γ = 1

If $H_u \neq 0.0$

$\theta = 90^{O}$ Based on LRFD Specifications Figure C10.6.3.1.2a-1

$$n = \frac{2+\frac{L'}{B'}}{1+\frac{L'}{B'}}cos^2(\theta) + \frac{2+\frac{B'}{L'}}{1+\frac{B'}{L'}}sin^2(\theta)$$ LRFD Specifications Equation 10.6.3.1.2a-9

ε = 0.01 degrees = Angle tolerance

$$i_q = \left[1 - \frac{H_u L_{foot}}{V_u L_{foot} + B'L'c\,cot(\phi_f + \varepsilon)}\right]^n$$ LRFD Specifications Equation 10.6.3.1.2a-7

$$i_\gamma = \left[1 - \frac{H_u L_{foot}}{V_u L_{foot} + B'L'c\,cot(\phi_f + \varepsilon)}\right]^{n+1}$$ LRFD Specifications Equation 10.6.3.1.2a-8

If $\phi_f = 0$

$$i_c = 1 - \frac{nH_U L_{foot}}{B'L'cN_c}$$ LRFD Specifications Equation 10.6.3.1.2a-5

If $\phi_f \neq 0$ and c = 0

$$i_c = 0$$

If $\phi_f \neq 0$ and $c \neq 0$

$$i_c = i_q - \frac{1-i_q}{(N_q - 1)}$$ LRFD Specifications Equation 10.6.3.1.2a-6

NOTE: The H_U and V_U values used in the equations above are calculated in units of kips/ft and must be multiplied by the full length of the footing (L_{foot}, entered by the user on the SOI command) to obtain the full footing load.

3.4.1.4.2.2 Category 2 - Two Clay layers or Undrained Two Layer Mixed Soil

Equation for bearing resistance for footings NOT on or near a slope:

$$q_n = c_1 N_m + \gamma D_f$$ (Eq 3.4.1.4.2.2-1) DM-4 Equation 10.6.3.1.2e-4

Equation for bearing resistance for footings on or near a slope (embedment neglected due to LRFD Specifications Section C10.6.3.1.2c:

$$q_n = RC_{BC1}(c_1 N_m)$$ (Eq 3.4.1.4.2.2-2)

Equations needed for N_m (both equations use these values)

$$\kappa = \frac{c_2}{c_1}$$

If $\kappa < 0.6$, the soil is undesirable and the program will stop with an error.

$$\beta_m = \frac{B'L'}{2(B'+L')H_1}$$ LRFD Specifications Equation 10.6.3.1.2e-2

The average ϕ_f

$$\phi_f = \tan^{-1}\left(\frac{H_1 \tan\phi_{if1} + (D-H_1)\tan\phi_{if2}}{D}\right)$$ (Bowles Section 4-8)

N_c, N_q, and N_γ are computed using equations from Category 1

The average moist soil γ_m

$$\gamma_m = \frac{H_1\gamma_{im1} + (D-H_1)\gamma_{im2}}{D}$$

The average saturated soil γ_s

$$\gamma_s = \frac{H_1\gamma_{is1} + (D-H_1)\gamma_{is2}}{D}$$

γ is computed using equations from Category 1

s_c is computed using equations from Category 1

$D_f = D_{f1}$

Category 2: Soil Condition 2 - Weaker clay over stronger clay - Undrained

Soil Correction Factor for use in Equation 3.4.1.4.2.2-1:

$$N_m = \frac{\kappa N_c(N_c+\beta_m-1)[(\kappa+1)N_c^2 + (1+\kappa\beta_m)N_c + \beta_m - 1]}{[\kappa(\kappa+1)N_c + \kappa + \beta_m - 1][(N_c+\beta_m)N_c + \beta_m - 1] - (\kappa N_c + \beta_m - 1)(N_c+1)}$$

(Eq 3.4.1.4.2.2-3)

(Winterkorn and Fang 3.37)

Category 2: Soil Condition 3 - Stronger clay over weaker clay - Undrained

Soil Correction Factor for use in Equation 3.4.1.4.2.2-1

$$N_m = \frac{1}{\beta_m} + \kappa s_c N_c \leq s_c N_c$$ (Equation 3.4.1.4.2.2-4)

LRFD Specifications Equation 10.6.3.1.2e-1

Category 2: Soil Condition 9 - Mixed Soil with Clay - Undrained

When $c_1 \leq c_2$

Use Equation 3.4.1.4.2.2-3 for N_m

When $c_1 > c_2$

Use Equation 3.4.1.4.2.2-4 for N_m

3.4.1.4.2.3 Category 3 – Sand over Clay or Mixed Soil / Clay or Mixed Soil over Sand

Category three uses 3 conditions to determine the bearing pressure: Conditions 4, 5 and 8.

Category 3: Soil Condition 4 - Clay or Mixed Soil over Sand / Sand over Clay or Mixed Soil - D > H1

The Sand over Clay or Mixed condition will only occur when the ϕ_{if1} is between 20^O and 25^O or greater than 50^O. A Mixed soil over Mixed soil case may also occur for this condition.

The following values are used in the Single layer equation. The values of the soil properties are averaged.

The Maximum Depth that bearing is effective to

$$D = \frac{B'}{2}\tan\left(45 + \frac{\phi_{if1}}{2}\right)$$

Three Conditions Control Δh

$H_1 > D,\ \Delta h = 0$

$H_1+H_2 > D,\ \Delta h = D - H_1$

$H_1+H_2 \leq D,\ \Delta h = H_2$

The average cohesion value is calculated

$$c = \frac{c_1 H_1 + c_2(\Delta h)}{H_1 + \Delta h}$$ (Bowles Section 4-8)

The average ϕ_f

$$\phi_f = \tan^{-1}\left(\frac{H_1 \tan\phi_{if1} + (\Delta h)\tan\phi_{if2}}{H_1 + \Delta h}\right)$$ (Bowles Section 4-8)

The average moist soil γ_m

$$\gamma_m = \frac{H_1\gamma_{im1} + (\Delta h)\gamma_{im2}}{H_1 + \Delta h}$$

The average saturated soil γ_s

$$\gamma_s = \frac{H_1\gamma_{is1} + (\Delta h)\gamma_{is2}}{H_1 + \Delta h}$$

$$D_f = D_{f1}$$

$RC_{BC} = RC_{BC1}$

Compute Bearing Resistance following procedure for Soil Condition 1, neglecting the embedment term for footings on or near a slope.

Category 3: Soil Condition 5 - Clay or Mixed Soil over Sand / Sand over Clay or Mixed Soil - D ≤ H1

The Sand over Clay or Mixed condition will only occur when the ϕ_{if1} is between 20^O and 25^O or greater than 50^O. A Mixed soil over Mixed soil case may also occur for this condition.

The following values are used in the Single layer equation. The values of the soil properties for use in the single layer equation are shown below. These values are used to calculate q_n for the first layer

$$c = c_1$$
$$\phi_f = \phi_{if1}$$
$$\gamma_m = \gamma_{im1}$$
$$\gamma_s = \gamma_{is1}$$
$$D_f = D_{f1}$$
$$RC_{BC} = RC_{BC1}$$

Compute bearing resistance "q_1" following procedure for Soil Condition 1

The following values are used in the Single layer equation. The values of the soil properties for use in the single layer equation are shown below. These values are used to calculate q_n for the second layer

$$c = 0.67c_2$$ LRFD Specifications Equation 10.6.3.1.2b-1

$$\phi_f = \tan^{-1}\left(0.67\tan\left(\phi_{if2}\right)\right)$$ LRFD Specifications Equation 10.6.3.1.2b-2

$$\gamma_m = \gamma_{im2}$$
$$\gamma_s = \gamma_{is2}$$
$$RC_{BC} = RC_{BC2}$$

For footings on or near a slope:

$$D_f = H_1$$

otherwise,

$$D_f = D_{f2}$$

Compute bearing resistance "q_2" following procedure for Soil Condition 1. For footings on or near a slope, include the embedment term using the reduced D_f value shown above.

Then the critical Height is calculated

$$H_{crit} = \frac{3B' ln\left(\frac{q_1}{q_2}\right)}{2\left(1+\frac{B'}{L'}\right)}$$ LRFD Specifications Equation 10.6.3.1.2d-1

If $H_1 > H_{crit}$ Then

$$q_n = q_1$$

If $H_1 \leq H_{crit}$ Then q_n is calculated using the equation below

$$K = \frac{1-\sin^2 \phi_{if1}}{1+\sin^2 \phi_{if1}}$$ LRFD Specifications Equation 10.6.3.1.2f-2

$$q_n = \left[q_2 + RC_{BC1}\left(\frac{1}{K}\right)c_1 \cot(\phi_{if1}+\varepsilon)\right] e^{2\left(1+\frac{B'}{L'}\right)K \tan(\phi_{if1})\frac{H_1}{B'}} - RC_{BC1}\left(\frac{1}{K}\right)c_1 \cot(\phi_{if1}+\varepsilon)$$

LRFD Specifications Equation 10.6.3.1.2f-1

Where:

$\varepsilon = 0.01$ **degrees**

RC_{BC1} = 1.0 if footing is not on or near a slope

RC_{BC1} = reduction coefficient for bearing resistance due to slope effects for soil layer 1 if footing is on or near a slope

If $q_n > q_1$

$$q_n = q_1$$

Category 3: Soil Condition 8 - Sand over Clay or Mixed Soil – 20 ≤ ϕ_{if1} ≤ 50

The following values are used in the Single layer equation. The values of the soil properties for use in the single layer equation are shown below. Then the q_n for layer one is calculated based on the following values:

$c = c_1$

$\phi_f = \phi_{if1}$

$\gamma_m = \gamma_{im1}$

$\gamma_s = \gamma_{is1}$

$D_f = D_{f1}$

Compute bearing resistance "q_1" following procedure for Soil Condition 1, neglecting the embedment term for footings on or near a slope.

These values are used to calculate q_{ult} for the second layer

$$c = 0.67c_2$$ LRFD Specifications Equation 10.6.3.1.2b-1

$$\phi_f = \tan^{-1}\left(0.67\tan\left(\phi_{if2}\right)\right)$$ LRFD Specifications Equation 10.6.3.1.2b-2

$$\gamma_m = \gamma_{im2}$$

$$\gamma_s = \gamma_{is2}$$

For footings on or near a slope:

$$D_f = H_1$$

otherwise,

$$D_f = D_{f2}$$

Compute bearing resistance "q_2" following procedure for Soil Condition 1. For footings on or near a slope, include the embedment term using the reduced D_f value shown above.

Then the q_n is calculated using the equation shown below:

$$q_n = q_2 e^{0.67\left(1+\frac{B'}{L'}\right)\frac{H_1}{B'}}$$ LRFD Specifications Equation C10.6.3.1.2f-1

Then the critical height is calculated:

$$H_{crit} = \frac{3B' ln\left(\frac{q_1}{q_2}\right)}{2\left(1+\frac{B'}{L'}\right)}$$ LRFD Specifications Equation 10.6.3.1.2d-1

If $H_1 > H_{crit}$ or $q_n > q_1$ Then

$$q_n = q_1$$

3.4.1.4.2.4 Category 4 - Loose over Dense Sand or Dense over Loose Sand

Category four uses three conditions to determine the bearing pressure. Conditions 6 and 7 are used when the effective depth of bearing reaches the second layer of soil. Condition 10 is reserved for when the effective depth of bearing does not reach the second layer.

The following values are used in the Single layer equation. The values of the soil properties for use in the single layer equation are shown below. These values are used to calculate q_n for the first layer:

$$c = c_1$$
$$\phi_f = \phi_{if1}$$
$$\gamma_m = \gamma_{im1}$$
$$\gamma_s = \gamma_{is1}$$
$$D_f = D_{f1}$$
$$RC_{BC} = RC_{BC1}$$

Compute bearing resistance "q_1" following the procedure for Soil Condition 1, neglecting the embedment term for footings on or near a slope.

Retain γ_1 from q_1 for use in q_2

$$\gamma_{1f} = \gamma_1$$

If $H_1 >= 2B'$

Category 4: Soil Condition 10 - Two Sand Layers where $H_1 \geq 2B'$

Then $q_n = q_1$

If $H_1 < 2B'$

Then compare ϕ_{if1} to ϕ_{if2} to determine if **Soil Condition 6 or 7** controls

Category 4: Soil Condition 7 – Loose over Dense Sand where $H_1 < 2B'$ and ($\phi_{f1} < \phi_{f2}$)

The following values are used to calculate q_{ult2}.

$$\phi_f = \phi_{if2}$$
$$\gamma_m = \gamma_{im2}$$
$$\gamma_s = \gamma_{is2}$$

The γ_2, $N_{\gamma 2}$, $s_{\gamma 2}$, $i_{\gamma 2}$, N_{q2}, s_{q2} and i_{q2} values are computed following procedures in Section 3.4.1.4.2.1.

$$q_2 = 0.5\gamma_2 B' N_{\gamma 2} s_{\gamma 2} i_{\gamma 2} + \gamma_{1f} D_{f1} N_{q2} s_{q2} i_{q2}$$

For footings on or near a slope,

$$q_2 = RC_{BC2}\left(0.5\gamma_2 B' N_{\gamma 2} s_{\gamma 2} i_{\gamma 2} + \gamma_{1f} D_{f1} N_{q2} s_{q2} i_{q2}\right)$$

These equations are derived from DAS equation 11.55 except the unit weight of the top layer is used to determine the overburden.

The following equation is used to calculate q_{ult}:

$$q_n = q_1 + (q_2 - q_1)\left(1 - \frac{H_1}{2B'}\right)^2 \qquad \text{(DAS 11.54)}$$

Category 4: Soil Condition 6 - Dense over Loose Sand where $H_1 < 2B'$ and ($\phi_{f1} \geq \phi_{f2}$)

The following equations are used in the q_{ult} calculation

$$N_{q1} = e^{\pi \tan(\phi_{if1})} \tan^2\left(45 + \frac{\phi_{if1}}{2}\right) \qquad \text{DM-4 Equation C10.6.3.1.2a-1}$$

$$N_{\gamma 1} = 2\left(N_{q1} + 1\right)\tan\left(\phi_{if1}\right) \qquad \text{DM-4 Equation C10.6.3.1.2a-4}$$

$$N_{q2} = e^{\pi \tan(\phi_{if2})} \tan^2\left(45 + \frac{\phi_{if2}}{2}\right) \qquad \text{DM-4 Equation C10.6.3.1.2a-1}$$

$$N_{\gamma 2} = 2\left(N_{q2} + 1\right)\tan\left(\phi_{if2}\right) \qquad \text{DM-4 Equation C10.6.3.1.2a-4}$$

$$\gamma_1' = \gamma_{is1} - \gamma_w$$

$$\gamma_2' = \gamma_{is2} - \gamma_w$$

The following chart is used to determine K_s. The chart is from Figure 11.18 from *Principles of Geotechnical Engineering* by Braja M. Das, Third Edition.

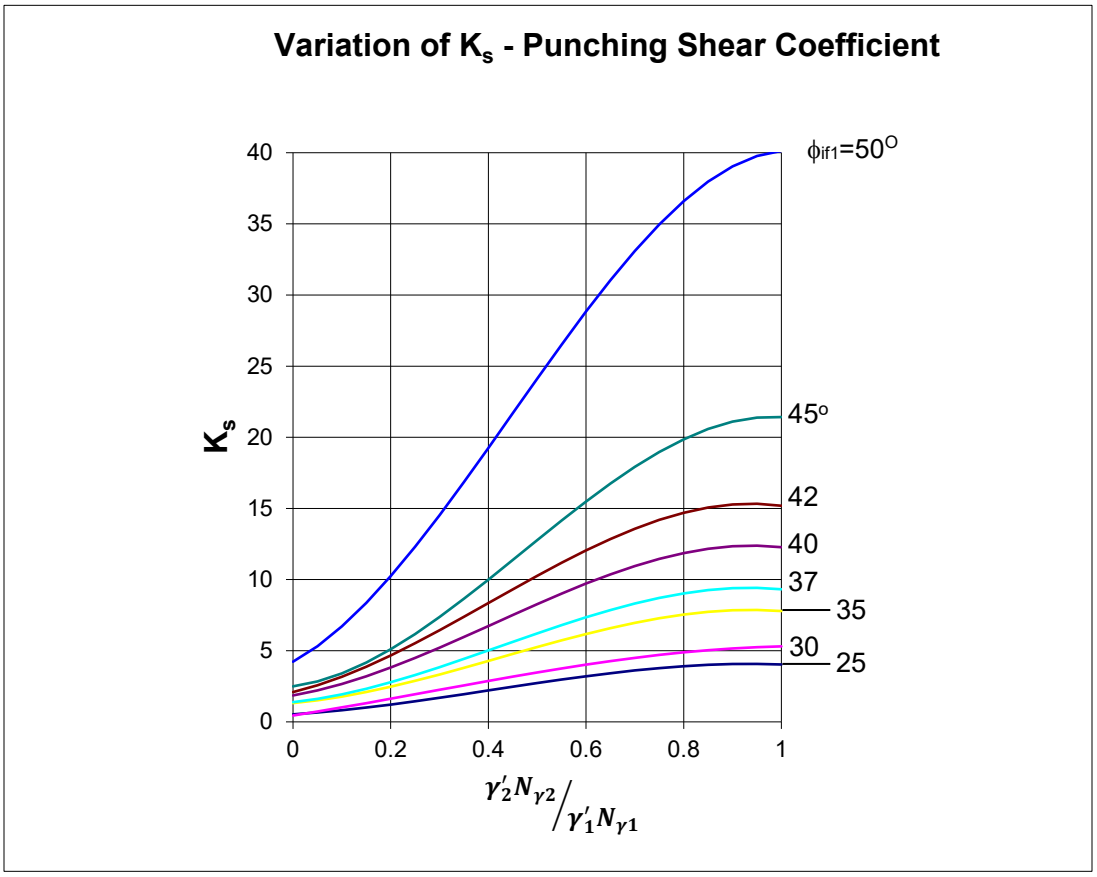


Figure 3.4.1-8 Punching Shear Coefficient Graph (K_s)

Then the bearing equation is determined by looking at the L'/B'

The following equation is used to calculate q_{ult2}.

$$\phi_f = \phi_{if2}$$

$$\gamma_m = \gamma_{im2}$$

$$\gamma_s = \gamma_{is2}$$

For footings on or near a slope:

$$D_f = H_1$$

otherwise,

$$D_f = D_{f2}$$

The γ_2, $N_{\gamma 2}$, $s_{\gamma 2}$, $i_{\gamma 2}$, N_{q2}, s_{q2} and i_q are computed following procedures in Section 3.4.1.4.2.1.

If the footing is not on or near a slope:

$$q_2 = 0.5\gamma_2 B' N_{\gamma 2} s_{\gamma 2} i_{\gamma 2} + \gamma_{1f} D_f N_{q2} s_{q2} i_{q2} \qquad \text{(DAS 11.48)}$$

If the footing is on or near a slope:

$$q_2 = RC_{BC2}\left(0.5\gamma_2 B' N_{\gamma 2} s_{\gamma 2} i_{\gamma 2} + \gamma_{1f} D_f N_{q2} s_{q2} i_{q2}\right) \quad \text{(DAS 11.48)}$$

If L' >5*B' then the following equations are used to calculate bearing resistance:

If the footing is not on or near a slope:

$$q_n = q_2 + \gamma_1'(H_1)^2\left(1+\frac{2D_{f1}}{H_1}\right)\frac{K_s tan(\phi_{if1})}{B'} - \gamma_1' H_1 \leq q_1 \quad \text{(DAS 11.44)}$$

If the footing is on or near a slope:

$$q_n = q_2 + RC_{BC1}\left(\gamma_1'(H_1)^2\frac{K_s tan(\phi_{if1})}{B'} - \gamma_1' H_1\right) \leq q_1 \quad \text{(DAS 11.44)}$$

If L' ≤ 5*B' the following equations are used to calculate bearing resistance:

If the footing is not on or near a slope:

$$q_n = q_2 + \left(1+\frac{B'}{L'}\right)\gamma_1'(H_1)^2\left(1+\frac{2D_{f1}}{H_1}\right)\frac{K_s tan(\phi_{if1})}{B'} - \gamma_1' H_1 \leq q_1 \quad \text{(DAS 11.46)}$$

If the footing is on or near a slope:

$$q_n = q_2 + RC_{BC1}\left(\left(1+\frac{B'}{L'}\right)\gamma_1'(H_1)^2\frac{K_s tan(\phi_{if1})}{B'} - \gamma_1' H_1\right) \leq q_1 \quad \text{(DAS 11.46)}$$

3.4.1.4.3 Applied Bearing Pressure

The applied bearing pressure due to the factored applied loads for rock foundations is the greater of the toe ($topr_p$) and heel ($hlpr_p$) pressure is used.

For all soils (sands, clays, and C-φ), the applied bearing pressure due to the factored applied loads is based on a uniform distribution so that it is equal to VLF/B'.

3.4.2 Pedestal Footing Stability

The footing on pedestal is checked for overturning (eccentricity), bearing pressure, and sliding. The pedestal itself is checked for overturning (eccentricity), bearing pressure and settlement.

3.4.2.1 Pedestal Footing Overturning / Eccentricity Check

The eccentricity of the load resultant is compared to the acceptable range in DM-4. All load combinations except for SERVICE-I and EXTREME-I limit states and the temporary stage construction condition for retaining walls is checked.

The eccentricity check is very similar to that of a spread footing on a rock foundation. The base width (instead of the footing width) is used for footings situated on pedestals. The base width is that portion of the

footing width that is in contact with the pedestal i.e. it is equal to footing width minus the back offset. Hence the eccentricity is measured relative to the center of the footing contact length (i.e. base width).

Figure 3.4.2-1 illustrates the acceptable range for the location of resultant (R). The resultant must lie in the middle three-quarters of the footing contact length for the final stage and in the middle two-thirds of the footing contact length for the temporary stage. The following are acceptable values for α and β shown in Figure 3.4.2-1.

Strength Limit States

$\alpha = \frac{bw}{20}$ and $\beta = \frac{9bw}{10}$ *(Final Stage)* LRFD Specifications Section 11.6.3.3

$\alpha = \frac{bw}{6}$ and $\beta = \frac{2bw}{3}$ *(Temporary Stage)* DM-4 Section 11.6.3.3

Extreme Limit States

$\alpha = \frac{bw}{6}$ and $\beta = \frac{2bw}{3}$ *(Temporary and Final Stage)* LRFD Specifications Section 11.6.5.1

The program calculates an allowable eccentricity and verifies the eccentricity does not exceed the allowable by providing a performance ratio based on these values.

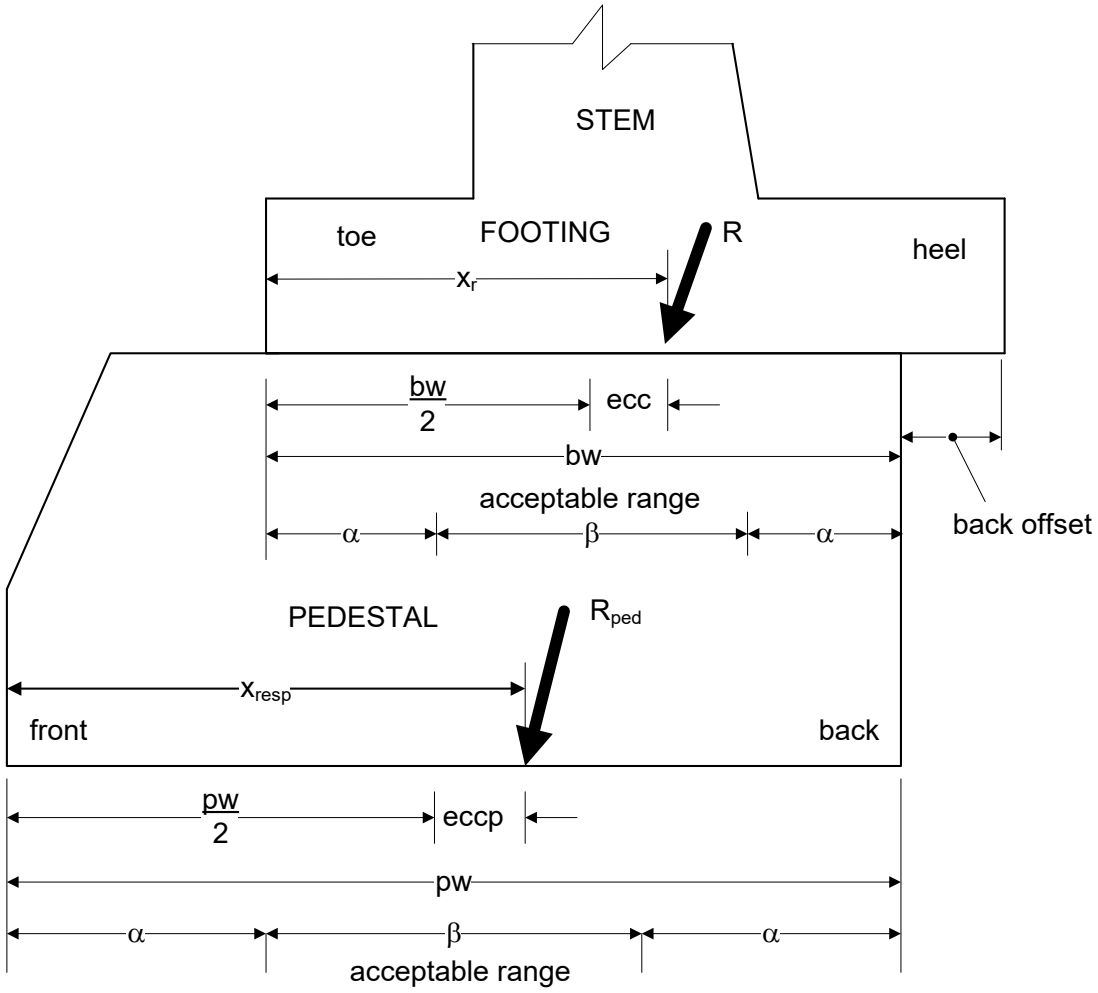


Figure 3.4.2-1 Stability Check for Pedestal Footing and Pedestal

3.4.2.2 Pedestal Footing Bearing Pressure Check

The bearing pressure check of the footing consists of comparing the bearing resistance of the pedestal concrete (P_{max}), to the maximum applied pressures (maxpr) at the toe and heel locations. The applied pressure is adjusted by the pedestal center-to-center spacing (ccp) and thickness (th), as shown in the following equation. The pedestal footing bearing pressures that appear in the program output are shown on a per unit width basis.

$$Maximum\ Pressure = \left(\frac{ccp}{th}\right) \mathrm{MAX}\,(topr_p, hlpr_p)$$

Where the maximum resistance of the pedestal concrete (P_{max}) is computed by the equation below:

$$P_{max} = \phi 0.85 f_c'$$

Where:

ϕ = 0.7

Toe ($topr_p$) and heel ($hlpr_p$) pressures are computed assuming that a linear pressure distribution exists under the footing. The pressure is a function of the location of the load resultant (see previous section). The maximum pressure at the toe and heel locations is determined from the final stage of all applicable load combinations.

If the load resultant is within the toe side of one third of the base width, the pressures are:

$$topr_p = \frac{2VLF}{3X_r}$$

$$hlpr_p = 0.0$$

If the load resultant is situated in the heel side of one third of the base width, the pressures are:

$$topr_p = 0.0$$

$$hlpr_p = \frac{2VLF}{3bw - X_r}$$

If the load resultant is within the center middle third of the base width, the pressures are:

$$topr_p = \frac{VLF}{bw}\left(1 + \frac{6ecc}{bw}\right)$$

$$hlpr_p = \frac{VLF}{bw}\left(1 - \frac{6ecc}{bw}\right)$$

3.4.2.3 Pedestal Footing Sliding Stability

Sliding of the footing on the pedestal is checked by evaluating the ratio of the Vertical Force to Horizontal Force. A ratio greater than or equal to two (2.0) is acceptable as shown in the equation below. The forces are determined from the service limit state, final stage.

$$\frac{VLF}{HLF} \geq 2.0$$

Sliding of the pedestal on the rock foundation is not checked because only the vertical force, due to the weight of the pedestal, will increase, thus increasing the value of the ratio.

3.4.2.4 Pedestal Overturning / Eccentricity Check

For pedestal foundations, the resultant (R) must lie in the middle two-thirds of the pedestal width for the temporary stage. The following are acceptable values for α and β shown in Figure 3.4.2-1.

Strength Limit States

$\alpha = \frac{pw}{20}$ and $\beta = \frac{9\,pw}{10}$ *(Final Stage)* LRFD Specifications Section 11.6.3.3

$\alpha = \frac{pw}{6}$ and $\beta = \frac{2pw}{3}$ *(Temporary Stage)* DM-4 Section 11.6.3.3

Extreme Limit States

$\alpha = \frac{bw}{6}$ and $\beta = \frac{2bw}{3}$ *(Temporary and Final Stage)* LRFD Specifications Section 11.6.5.1

The program calculates an allowable eccentricity and verifies the eccentricity does not exceed the allowable by providing a performance ratio based on these values.

3.4.2.5 Pedestal Bearing Pressure Check

Pedestals are assumed to bear on rock only. The bearing capacity of the foundation is a function of the pressure distribution under the pedestal. The type of pressure distribution (uniform, linear variation) is determined by the strength of the rock foundation. The terms “front” and “back” refer to the front and back of the pedestal (they are analogous to the toe and heel locations in the footing). The weight of the pedestal is considered in the bearing pressure check calculations. The bearing pressure check is not evaluated for the temporary stage.

The bearing pressure check of the pedestal is evaluated by computing the pressure distribution under the pedestal for each load combination and comparing the front and back pressures to the bearing capacity of the rock foundation. If the factored resistance is greater than the applied pressure, the pedestal is considered to be satisfactory:

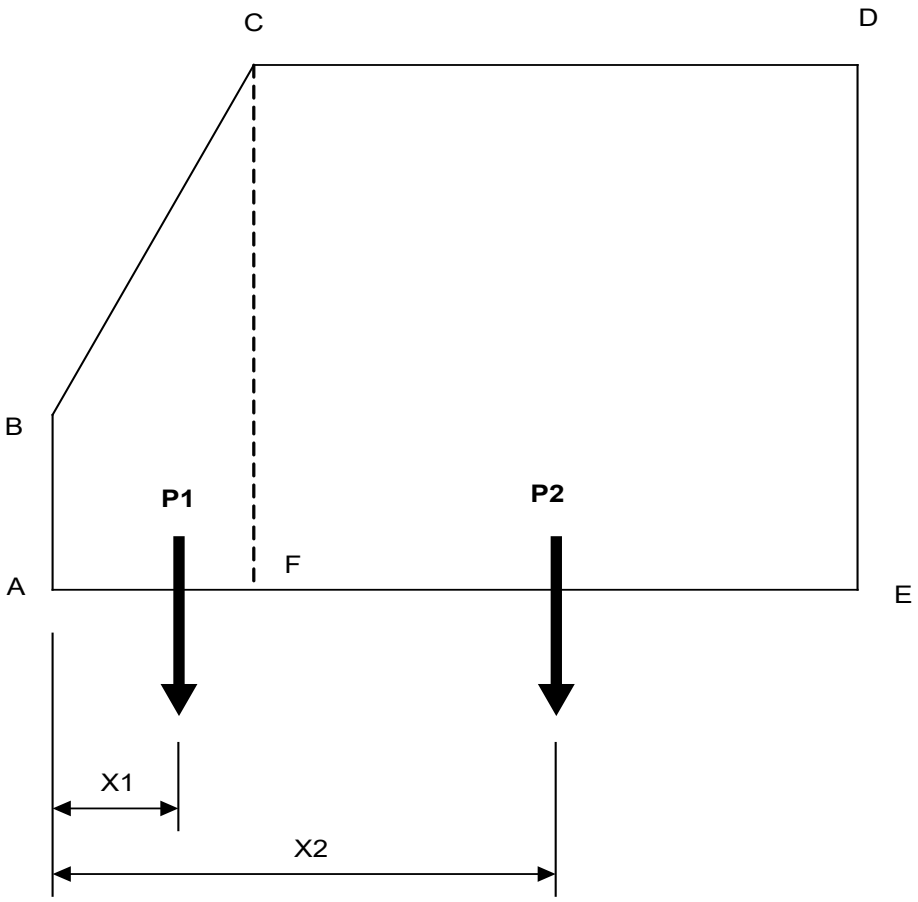
$$\varphi R > p_{front}$$
$$\varphi R > p_{back}$$

The LRFD resistance factor ϕ is specified by the user and is used for all limit states except Extreme I. A separate value exists for the Extreme I (earthquake) limit state. The bearing capacity is specified by the user (see RCK command, Chapter 5). The remainder of this section describes how the front and back pressures are evaluated.

The pedestal front (p_{front}) and back (p_{back}) pressures include the effects of the pedestal weight and the moment generated about the toe of the pedestal by the weight of pedestal as shown in Figure 3.4.2-2. The pedestal force and moment are modified by the dead load factor of the given combination as shown in the equations below.

$$vlfp = VLF\,(ccp) + \gamma_{DC}\,p_{wt}$$

$$vmp = ccp[vmf + VLF(pf + pt)] + \gamma_{DC}\, p_m$$



X1 = lateral distance to centroid of ABCF

X2 = lateral distance to centroid of CDEF

P1 = weight of pedestal portion ABCF

P2 = weight of pedestal portion CDEF

p_{wt} = P1 + P2

p_m = P1*X1 + P2*X2

Figure 3.4.2-2 Pedestal Weight (p_w) and Moment (p_m)

The horizontal force and moments are adjusted to account for the pedestal spacing as follows:

$$hlfp = HLF(ccp)$$

$$hmp = ccp[HMF + HLF(htb)]$$

The location of the resultant is determined by dividing the net moment (vmp-hmp) by the vertical force (vlfp). The eccentricity (eccp) is the distance from the location of the resultant (xresp) to the center of the pedestal as illustrated in Figure 3.4.2-1. The equations are:

$$xresp = \left(\frac{vmp + hmp}{vlfp} \right)$$

$$eccp = \left(\frac{pw}{2} \right) - xresp$$

If the pedestal is situated on rock, the front and back pressures are computed assuming a linear variation in the pressure distribution under the pedestal. The following equations are applied using pedestal width (pw) and pedestal thickness (th):

Rock:

If the resultant lies within the back third of the pedestal

$$p_{front} = \frac{2vlfp}{(3\,xresp)\,th}$$

$$p_{back} = 0.0$$

If the resultant is in the front third of the pedestal

$$p_{front} = 0.0$$

$$p_{back} = \frac{2vlfp}{(3\,pw - xresp)\,th}$$

If the resultant lies within the center middle third of the pedestal

$$p_{front} = \frac{vlfp}{pw \times th}\left(1 + \frac{6\,eccp}{pw} \right)$$

$$p_{back} = \frac{vlfp}{pw \times th}\left(1 - \frac{6\,eccp}{pw} \right)$$

3.4.2.6 Pedestal Settlement

The settlement of the pedestal is evaluated using the same algorithm as the settlement of a spread footing on rock, i.e. only the elastic settlement is considered (see Section 3.4.1.3).

3.4.3 Pile Footings

The stability of pile footings is checked by examining the vertical and lateral forces in the piles. Unlike the spread footing, the bearing capacity, settlement, and sliding checks are not applicable. The analysis is based on the properties of the pile group. Caisson footings are handled similarly.

3.4.3.1 Pile Group Properties

Pile group properties are based on a unit width of the structure and includes the distance from the toe to the centroid of the pile group and the moment of inertia of the pile group. When determining the moment of inertia and centroid, the area of a single pile is assumed to be unity, while the moment of inertia of a single pile is assumed to be negligible. Once the properties have been computed, the vertical load, P_v, on any pile can then be calculated using the following equation based on elastic theory:

$$P_v = \frac{P}{n} + \frac{xM}{I}$$

When the vertical load on each pile is known, axial and lateral loads can then be computed and the axial loads can be compared against the axial pile resistance. Vertical loads are computed for each applicable limit state, load case, and stage.

3.4.3.2 Vertical Load Stability

Vertical pile loads are used to compute the axial pile loads. When the pile is vertical, the axial load is equal to the vertical pile load, P_V. When the pile is battered at an angle θ, as shown in Figure 3.4.3-1, the axial pile load is computed as follows:

$$P_a = \frac{P_v}{\cos\theta}$$

Where: θ = Angle between the pile axis and the vertical

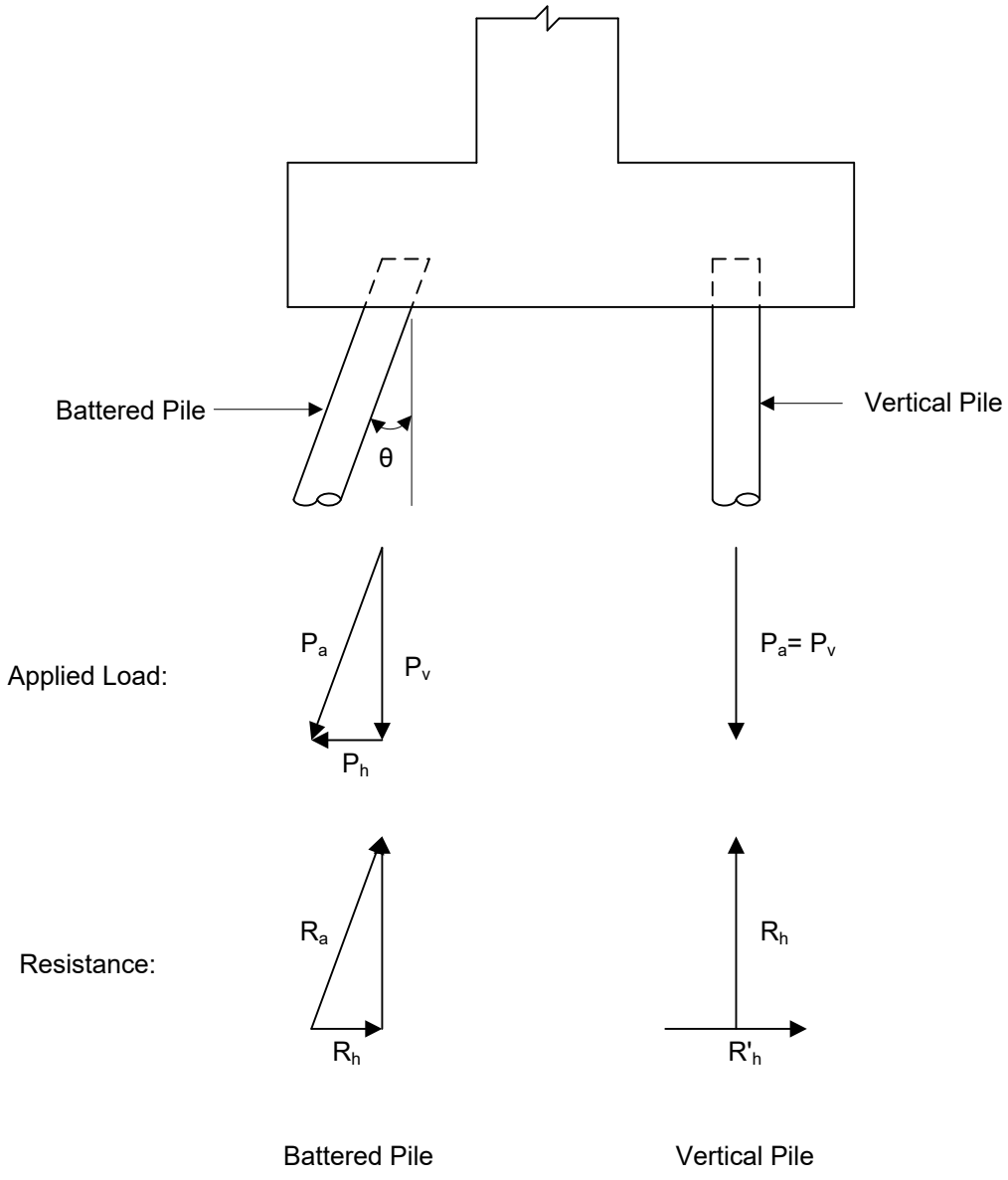


Figure 3.4.3-1 Force Relationships for Vertical & Battered Piles

3.4.3.3 Lateral Load Stability

The program computes the lateral load acting on the pile footing and determines whether the pile footing can resist the load. The user may specify a lateral resistance for an individual vertical pile. However, this resistance is only applicable when all piles are vertical. If any pile is battered, the lateral resistance for the pile footing is based on the lateral resistance of the battered piles and neglects any lateral capacity of the vertical piles. The lateral resistance for an individual battered pile, R_h, is based on the axial pile resistance, R_a, using the following equation:

$$R_h = R_a \sin \theta$$

For a pile footing analysis, the footing lateral load is compared to the lateral pile resistance of the pile group as computed by the program.

3.5 FOOTING

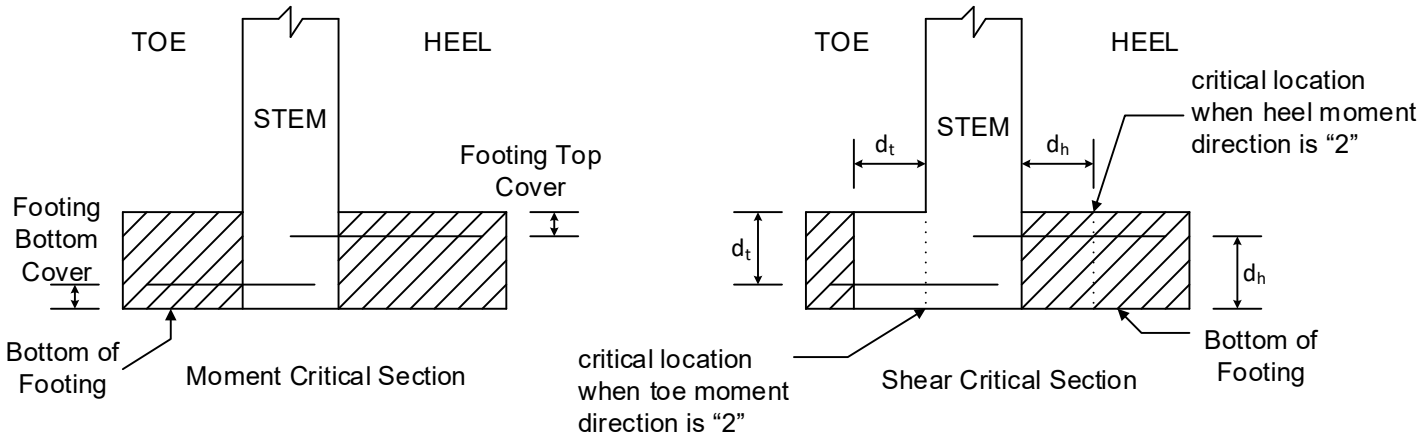
3.5.1 Structural Analysis

Each footing type is checked for flexure and shear. The critical location and direction within the footing depends on the footing type as shown in Figure 3.5.1-1. Spread footings are analyzed in the perpendicular direction only. Pile footings are analyzed in both the perpendicular and parallel directions. Pile/Caisson footings use typical sections at maximum moment location. Bar details are illustrated in Figure 5.22-1. The user should ensure that the cover for the bottom reinforcement is sufficient to accommodate the pile/caisson embedment when applicable. Pedestal footings are analyzed in the parallel direction only (see Figure 2.1-1) because the footing and pedestal are assumed to be made integral using transverse shear keys and dowels as per DM-4 Section 10.6.5.2P. The critical location for shear may vary depending on the direction of the applied moment. The following sections identify the idiosyncrasies of each footing type.

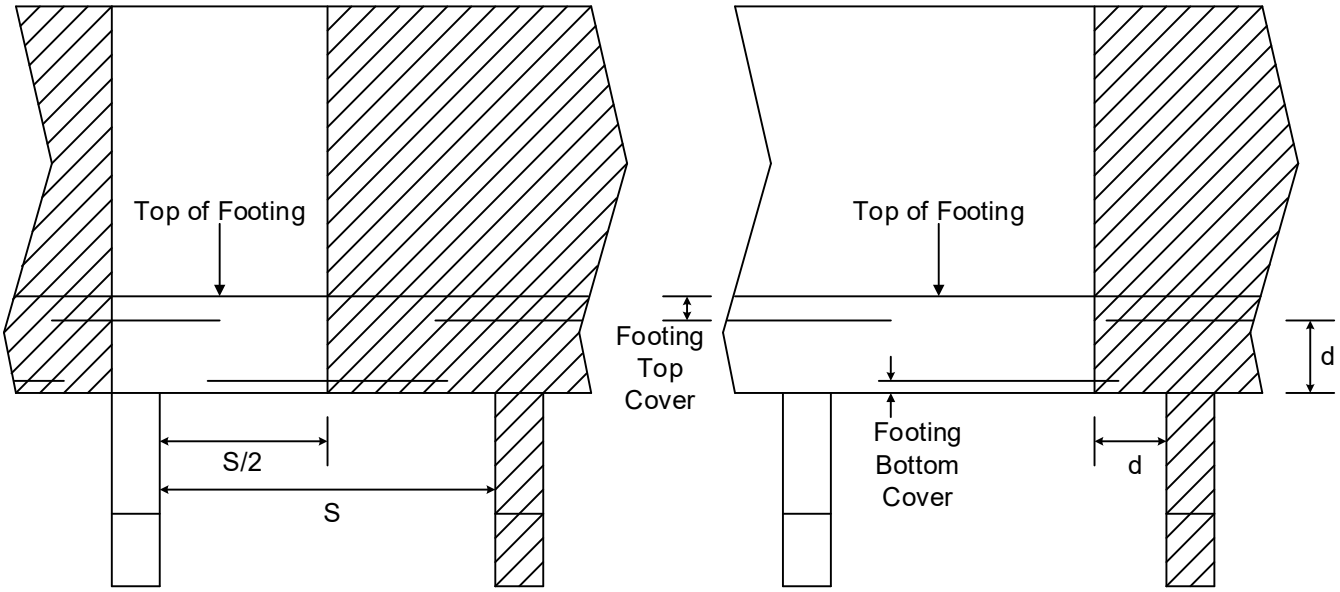
Loads from the service limit state are used to evaluate the moment that will determine the stresses in the reinforcement for the crack control check. Loads from all limit states are used to evaluate the maximum moment that must be resisted by the section.

A separate section identifies how the stress in the rebar is evaluated under the service limit state. This generic description can be applied to all singly reinforced sections where the applied axial load is zero.

The Moment direction within the footing is used to determine the critical shear locations in the footing as well as where the controlling moment used for perpendicular reinforcement analysis originates. For a Condition ”1” moment direction the moment induces tension in the bottom perpendicular reinforcement within the toe and tension in the top perpendicular reinforcement within the heel. For a Condition “2” moment direction the moment induces tension within the top perpendicular reinforcement for the toe and tension within the bottom perpendicular reinforcement within the heel.



Spread, Pile and Caisson Footings (perpendicular direction)



Moment Critical Section

Shear Critical Section

Pedestal Footing (parallel direction)

Figure 3.5.1-1 Critical Location for Footing Analysis

3.5.1.1 Spread Footing

The internal moment and shears are evaluated at the critical locations as shown in Figure 3.5.1-1. The moment at the toe critical location is assumed to create a tensile stress at the bottom face of the footing and is referred to as Condition “1”. The moment at the heel critical location is assumed to create tension at the top face of the footing also referred to as Condition “1”. The critical sections for flexure are always situated at the face of the stem. The toe critical shear location is typically situated at a distance ‘d’ from the face of the front stem. If the toe moment direction is Condition “2” , the shear is evaluated at the front face of the stem. The heel critical shear location is typically situated at the back face of the stem, or if the heel moment direction is condition “2”, the critical shear location is situated at a distance ‘d’ from the back face of the stem. In addition to these critical heel shear locations, the heel shear is calculated at fifty points along the heel projection to detect where the maximum shear is located. Below is a diagram showing the 50 analysis locations.

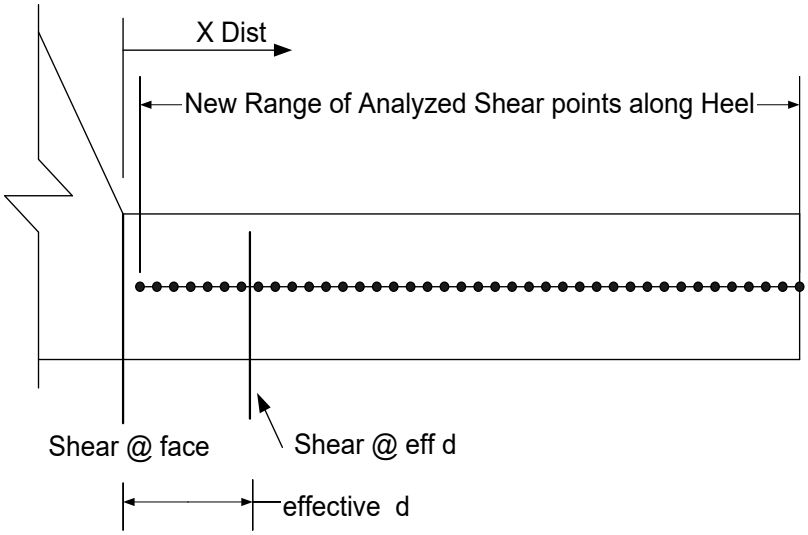


Figure 3.5.1-2 Heel Shear Analysis Points Locations

The internal forces are determined by examining the loads applied to the free-body diagrams of the toe and heel sections. The internal moment and forces are evaluated by considering the net effects of the applied loads (directly above the toe or heel) and the actual bearing pressure below the footing. For abutments with Type 4 Approach Slabs, the applied loads also include the loading due to the approach slab and the drain trough and drain trough pedestals; soil vertical loads vary depending upon whether the section is between approach slab pedestals, EV_a, or between the approach slab pedestal end and the end of the heel, EV.

The bearing pressure distribution under the footing is determined by applying the overturning moment and vertical force to the footing. This pressure distribution is not the same as that considered for the bearing capacity check, and will always be triangular or trapezoidal in shape. The following is a diagram showing a typical soil pressure distribution including applied loads and shear diagram.

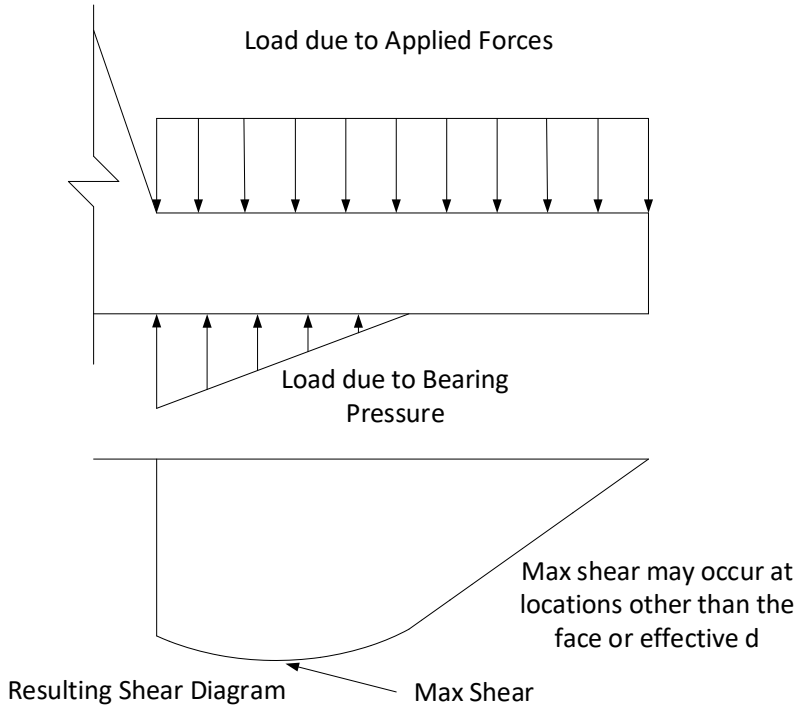


Figure 3.5.1-3 Spread Footing Heel - Applied Load and Shear Diagram (Not Type 4 Approach Slab)

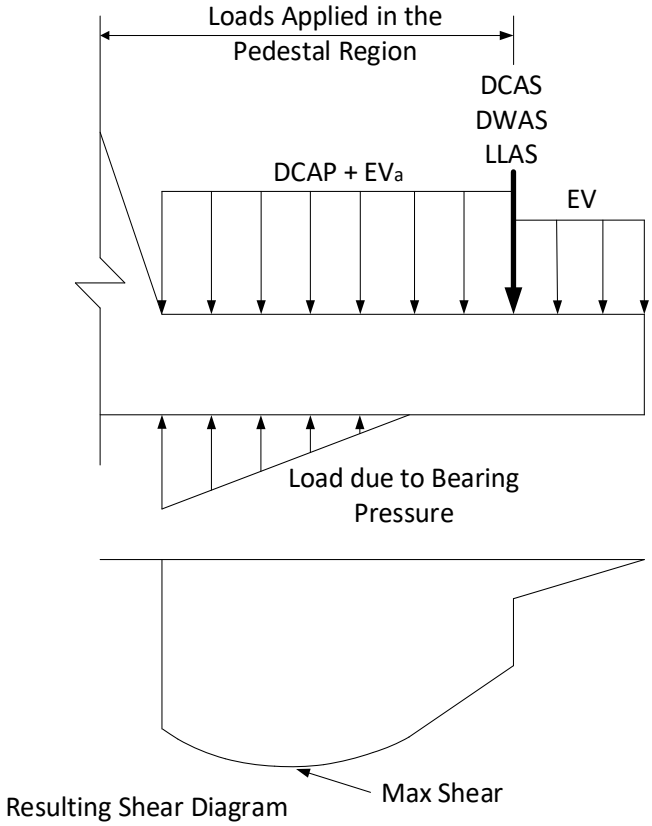


Figure 3.5.1-4 Spread Footing Heel - Applied Load and Shear Diagram (Abutments with Type 4 Approach Slab)

3.5.1.2 Pile Footings

For a pile footing analysis, axial pile loads are compared against the axial pile resistance given by the user. Axial pile loads must be compressive; an exception is made for the Extreme Event I limit state (earthquake). The tensile pile resistance may be specified by the user (CAI and PIL commands); it is only applicable for the Extreme Event I limit state.

The pile or caisson footing is analyzed in the perpendicular and parallel directions.

3.5.1.2.1 Perpendicular Direction

The analysis of loads in the perpendicular direction of the pile footing is similar to that of the spread footing except that the pile forces are used in lieu of the actual soil pressure. Internal moments and shear are evaluated for strength and serviceability checks.

The internal forces are determined by computing the net effects of the loads applied to the free-body diagrams of the toe and heel critical sections. Applied loads include footing weight, soil loads and surcharges, resisted by buoyancy and loads from contributing piles determines if the pile moment will be considered in the capacity. For abutments with Type 4 Approach Slabs, applied footing loads also include the loading due to the approach slab and the drain trough and drain trough pedestals. Soil vertical loads vary depending upon whether the section is between approach slab pedestals, EVa, or between the approach slab pedestal end and the end of heel, Ev. The shear force is proportioned according to the area of the pile on either side of the critical location. In addition to the critical heel shear locations, the heel shear is calculated at fifty points along the heel projection to detect where the maximum shear is located. The following is a diagram showing the typical pile reactions including applied loads and the shear diagram.

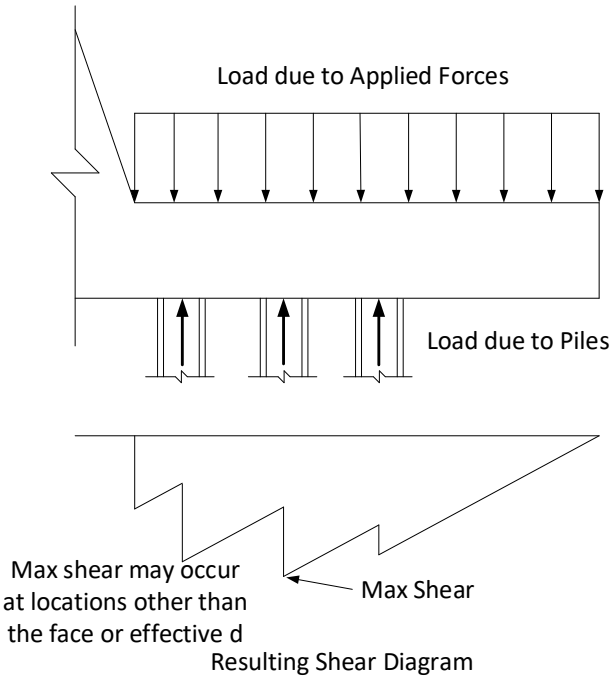


Figure 3.5.1-5 Pile Footing Heel - Applied Load and Shear Diagram (Not Type 4 Approach Slab)

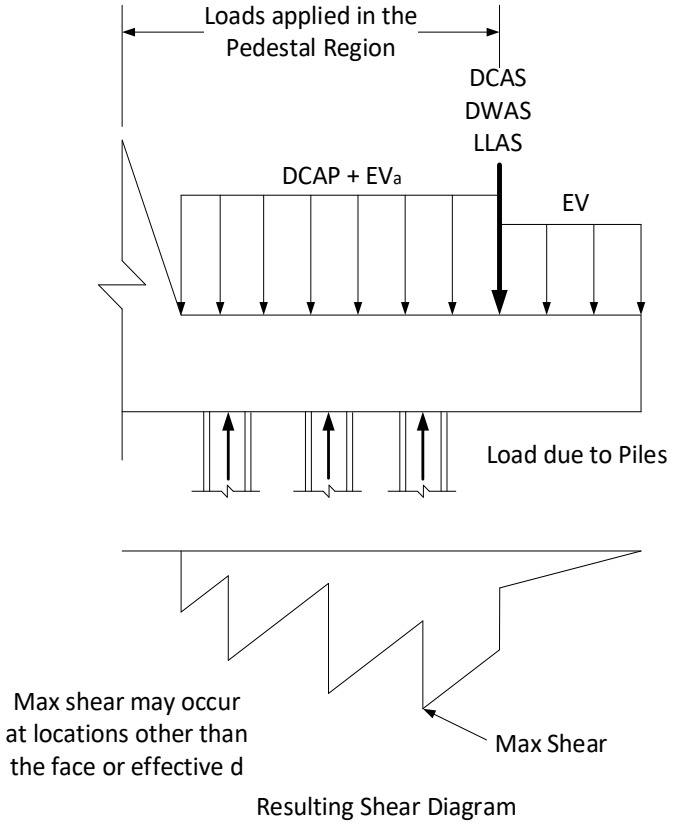


Figure 3.5.1-6 Pile Footing Heel - Applied Load and Shear Diagram (Type 4 Approach Slab)

For moment calculations, a pile contributes when its centroid falls within the free-body diagram. If the moment critical section intersects a pile, but the pile's centroid falls outside the critical section, the pile does not contribute to the internal moment, as illustrated in Figure 3.5.1-7.

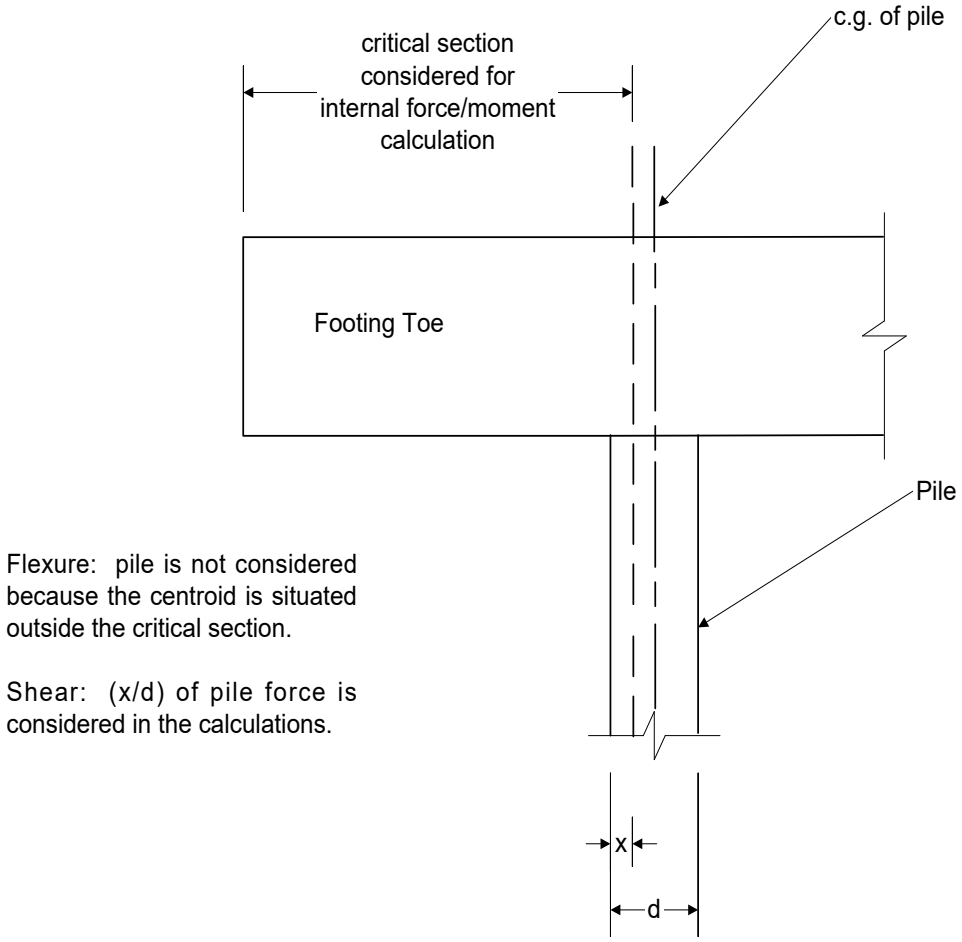


Figure 3.5.1-7 Contribution of Pile to Moment and Force Calculations

For shear calculations, a pile contributes as a percentage of that portion that falls within the free body diagram. For example, if the shear critical section intersects a pile, the contributing force is computed as a percentage of the dimension that falls within the free body diagram, as illustrated in Figure 3.5.1-7.

3.5.1.2.2 Parallel Direction

Parallel moments for the pile footing are computed using the maximum vertical load on the footing and assume that only 50% bending occurs in the longitudinal direction. A pseudo uniform load (Wu) is derived by dividing the maximum vertical load (VLF) by the footing width (B). The parallel moment (M) is then computed based on the pseudo uniform load (Wu) and the maximum pile spacing (S_p), as shown in the following equations:

$$M = \frac{1}{2}\left(\frac{WuS_p^2}{10}\right)$$

where:

$$Wu = \frac{VLF}{B}$$

Analysis of loads over the heel in pile footings in the parallel direction are computed as follows for abutments with Type 4 Approach Slabs.

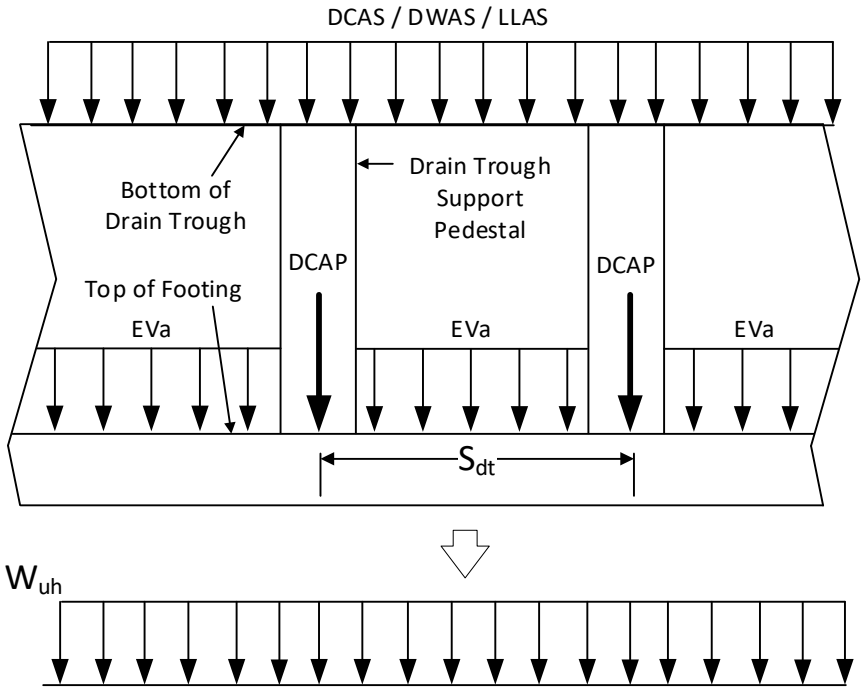


Figure 3.5.1-8 Pile Footing Parallel Loading Type 4 Approach Slabs

The total load over the heel that is distributed between two drain trough pedestals is computed by summing the DCAP, DCAS, DWAS, LLAS loads and EV load between two pedestals and then dividing by Sdt, the drain trough pedestal spacing, to compute the uniform load W_{uh}. The W_{uh} load over the heel is then added to the other vertical footing loads to compute a total VLF for the footing design section, which is used to compute the moment in the parallel direction.

This parallel moment is used in the analysis check of the top and bottom parallel reinforcement. The maximum vertical force is used for the strength limit states check. The maximum vertical force from the service limit state is used to evaluate the moment for the serviceability (crack control) checks.

3.5.1.3 Pedestal Footings

Pedestal footings are checked for: the relative values of the vertical and horizontal forces; the bearing pressure under the footing; the location of the footing resultant force; the flexural capacity of the footing (parallel direction); the shear capacity (parallel direction) of the footing; the bearing capacity under the

pedestal; and the serviceability of reinforcement (crack control). Pedestal footing reinforcement is not analyzed in the perpendicular direction (toe and heel locations) because the footing and pedestal are assumed to be made integral using transverse shear keys and dowels as per DM-4 Section 10.6.5.2P. The critical locations are shown in Figure 3.5.1-1. Each item is described in more detail under a separate sub-section.

3.5.1.3.1 Footing Flexural Loads (parallel direction)

The applied flexural loads of the footing are evaluated in the parallel direction only. The applied moments are computed assuming that a uniform distributed load is applied over a continuous span structure. The uniform load is computed for two situations, namely: strength (maximum) and service conditions. The uniform load is determined by dividing the applicable vertical force (VLF) by the footing width (B) as shown in the equations below:

$$udl = \frac{VLF}{B}$$

Where: VLF = the maximum vertical force from “strength limit state combinations”.

$$sudl = \frac{VLF}{B}$$

Where: VLF = the maximum vertical force from service limit state combinations.

For abutments with Type 4 Approach Slabs, the uniform loads udl and sudl are derived by distributing the DC_{AP}, DC_{AS}, DW_{AS}, LL_{AS}, and EV loads uniformly over the top surface of the footing heel as documented in Section 3.5.1.2.2.

The moment between the pedestals is used in the computations involving the bottom steel in the footing. The maximum moment between pedestals is:

$$a_{mb} = 3udl\,\frac{s^2}{40}$$

The service moment between pedestals is:

$$a_{mbs} = 3sudl\,\frac{s^2}{40}$$

The maximum moments over the pedestals are used in the computations of the top steel in the footing. The maximum moment over the pedestal is:

$$a_{mo} = udl\,\frac{s^2}{10}$$

The service moment over pedestals is:

$$a_{mos} = sudl\,\frac{s^2}{10}$$

For a design run, the flexural reinforcement required (as described in Section 3.5.2.2) in the parallel direction is evaluated using a_{mo} and a_{mb}. The flexural reinforcement oriented in the perpendicular direction is not considered by the program.

For a design run, the moment capacity of the section is evaluated using the procedure described in Section 3.5.2.1 The capacity is compared to the applied moments a_{mo} and a_{mb}.

The service moments, a_{mbs} and a_{mos}, are used to compute the service load stresses as described in Section 3.5.1.4.

3.5.1.3.2 Shear Loads (parallel direction)

The maximum applied shear force is computed at a distance 'd' from the face of the pedestal. The following equation is used:

$$vped = udl\left(\frac{s}{2} - d_t\right)$$

The shear capacity of the footing section is evaluated as described in Section 3.5.2.9 and compared to vped computed above.

3.5.1.4 Service Load Stresses

This section describes how the stress in the rebar is evaluated. It can be applied to all singly reinforced sections experiencing flexural loads only, i.e., both toe and heel critical sections and any point in the parallel direction.

The program will compute the stress at the extreme tensile fiber of the cross section. The stress is computed using gross section properties. The following equations are used:

$$f_{suncr} = -\frac{P}{A} + \frac{M}{S}$$

where: $A = bh$

$$S = \frac{bh^2}{6}$$

The axial load is assumed to be compressive. In footing sections, the axial load is zero. Compressive stresses are negative by the program's definition. The rupture stress is defined as follows for lightweight concrete with f'c <= 10 ksi and for normal weight concrete with f'c <= 15 ksi:

$$f_r = 0.24\,\lambda\sqrt{f'_c}$$ (f'c in ksi) LRFD Specifications Section 5.4.2.6

Where: λ = concrete density modification factor (LRFD Specifications Section 5.4.2.8)

If the stress is compressive or the tensile stress is less than 80% of the rupture stress, the program sets the applied steel stress, f_s, to zero.

The actual stress is based on the reinforced concrete theory based on a cracked section under service limit states. The actual stress f_{sact} is computed as follows:

$$f_{sact} = \frac{M_{service}}{A_s\, jd}$$

where:

$$j = 1 - \frac{k}{3}$$

$$k = \sqrt{2\rho n + (\rho n)^2} - \rho n$$

$$\rho = \frac{As}{bd}$$

$$n = \frac{E_s}{E_c}$$

The solution is obtained by solving for the neutral axis depth such that the tensile force is equal to the compressive force and the strain compatibility is maintained.

3.5.1.4.1 Modulus of Elasticity and Modular Ratio

The program computes the concrete elastic modulus, E_C, based on the Concrete Unit Weight for E (w_C; parameter 13 of the MAT command) and the concrete strength input by the user (f'_C; parameters 1, 2, and 3 of the MAT command). The modular ratio, n, is then calculated as the ratio of the steel elastic modulus, E_S, to E_C.

The program assumes that concrete is normal weight when it has a w_C greater than or equal to 0.135 kcf. Lightweight concrete has a w_C less than 0.135 kcf.

Several steps are followed for the determination of the concrete elastic modulus (E_c) and the modular ratio (n) used by the program. In all of these steps, the steel elastic modulus (E_S) is assumed to be equal to 29,000 ksi.

1. DM-4 Sections 5.4.2.1 and 5.4.2.4 specify values for n and E_C based on specific f'_c and w_C values. The concrete densities are specified as either normal weight, with a density of 0.145 kcf, or lightweight, with a density of 0.110 kcf. If the user enters a w_C value of exactly 0.145 kcf or 0.110 kcf, along with

an f'_C value of exactly 4.0, 3.5, 3.0, or 2.0 ksi, the E_C and n values will be set to the values shown in DM-4 Sections 5.4.2.1 and 5.4.2.4.

2. If the user enters a w_C value of exactly 0.145 kcf or 0.110 kcf, along with an f'_C value between 4.0 ksi and 2.0 ksi (and not 4.0, 3.5, 3.0, or 2.0 ksi), the E_C and n values will be interpolated between the values shown in DM-4 Sections 5.4.2.1 and 5.4.2.4. The E_C value will be rounded to the nearest 100 ksi, and n will be rounded to the nearest integer value.

3. If the user enters a w_C value of exactly 0.145 kcf, along with an f'_C value greater than 4.0 ksi and less than or equal to 10.0 ksi, the E_C value will be calculated with LRFD Specifications Equation C5.4.2.4-2:

$$E_c = 33{,}000 w_c^{1.5} \sqrt{f_c'}$$

where:
- E_C = Concrete elastic modulus
- w_C = Concrete density for Ec
- f'_C = Compressive strength of concrete

The E_C value will be rounded to the nearest 100 ksi. The rounded E_C value is then used to calculate n, which will be rounded to the nearest integer value.

4. If the user enters a w_C value of exactly 0.145 kcf, along with an f'_C value greater than 10.0 ksi, the E_C value will be calculated with LRFD Specifications Equation 5.4.2.4-1:

$$E_c = 120{,}000 K_1 w_c^{2.0} (f_c')^{0.33}$$

where:
- E_C = Concrete elastic modulus
- K_1 = Correction factor for source of aggregate. BXLRFD uses a value of 1.0.
- w_C = Concrete density for E_C
- f'_C = Compressive strength of concrete

The E_C value will be rounded to the nearest 100 ksi. The rounded E_C value is then used to calculate n, which will be rounded to the nearest integer value.

5. If the user enters a w_C value of exactly 0.110 kcf, along with an f'_C value greater than 4.0 ksi, the E_C value will be calculated with LRFD Specifications Equation 5.4.2.4-1, shown in step 4.

6. If the user enters a w_C value other than 0.110 kcf or 0.145 kcf, along with any f'_C value, the E_C value will be calculated with LRFD Specifications Equation 5.4.2.4-1 shown in step 4.

3.5.2 Specification Checking

A given section is checked for flexural strength, crack control (serviceability) and shear. The capacity is based on a section that has a unit width and is considered to be singly reinforced. The reinforcement is assumed to be situated in the tensile zone. Perpendicular and parallel bar details are illustrated in Figure 5.22-1. The program does not check if the bottom reinforcement interferes with the piles or caissons. Hence the user should provide an adequate cover in such circumstances.

The flexural strength considers the minimum area of steel and bar spacing. For design problems, the flexural strength check evaluates the area of reinforcement required to resist the applied moment, then, an appropriate spacing value is determined for each bar size. For analysis problems, the flexural strength check evaluates the resisting moment based on the area of reinforcement specified by the user. The resisting moment is compared to the applied moment. In the pile footing, the flexural reinforcement is placed in both the perpendicular and parallel directions. Hence the reinforcement is checked in both directions.

The crack control check considers the stress in the reinforcement under service limit states. Bar spacing requirements are also considered. For design problems, the program may decrease the bar spacing required for flexural strength to satisfy the crack control specifications. This would result in increasing the area of reinforcement within the section.

The shear check ensures that the thickness of the section is adequate to resist the applied shear. Shear reinforcement is not considered. For design problems, the section thickness will be increased incrementally if the shear check fails.

The following sub-sections describe the details of each type of check.

3.5.2.1 Strength Check – Analysis

The user may specify the reinforcement in terms of bars and spacings (BAR and SPA commands) or in terms of developed area of reinforcement (ARE command). If the bar-and-spacing option is used, the development length of the bar is evaluated to determine the area of developed reinforcement. There are three cases that may apply:

1. If the actual length available to develop a given bar, l_{bact}, is greater than or equal to the development length, l_d, all of the reinforcement is considered to be fully developed.

2. If l_{bact} over l_d ratio is less than $0.8(l_d)$, none of the reinforcement is considered to be developed.

3. If l_{bact} over l_d ratio is greater than 0.8(l_d) and less than l_d, then none of the area of reinforcement is considered to be developed and an informative message containing a spacing that would develop the bar is shown. The spacing is calculated with the following equation

$$s_{new} = s_{orig} * \left(\frac{l_{bact}}{l_d} \right)$$

Where: s_{new} = new suggested spacing
s_{orig} = original bar spacing
l_d = Development length of bar
l_{bact} = Available space for bar to develop in the component

The procedure for evaluating the development length is described in Section 3.5.2.3.

The moment capacity, ϕM_n, is evaluated given the developed area of reinforcement and ϕ computed as shown in Section 3.5.2.5. The value of ϕ is initially set equal to the ϕ limit and the stress in the reinforcement steel, f_s, is assumed to be equal to the specified minimum yield strength, f_y.

The net tensile strain and the stress in the reinforcement is computed from the following:

$$c = \frac{A_s f_s}{0.85 f_c' \beta_1 b}$$

$$\varepsilon_t = \frac{0.003 (d - c)}{c}$$ LRFD Specifications Equation C5.6.2.1-1

$$f_s = \min (\varepsilon_t \cdot E_s, f_y)$$

If the mild steel stress, f_s, is less than the yield strength, f_y, then the initial assumption was incorrect and the nominal flexural capacity is determined based on conditions of equilibrium and strain compatibility. The resistance factor ϕ is computed with the net tensile strain using the equations shown in Section 3.5.2.5. The equation to compute the moment capacity derived below is based on a generic cross section of unit width shown in Figure 3.5.2-1.

From internal equilibrium (Tension = Compression):

$$A_s f_y = 0.85 f_c' a b$$

Nominal moment capacity (M_n) is equal to tensile force multiplied by the internal lever arm:

$$M_n = A_s f_y \left(d - \frac{a}{2} \right)$$

Solving the internal equilibrium equation for a and substituting a in equation for nominal moment capacity results in the following:

$$M_n = A_s f_y \left(d - \frac{A_s f_y}{2(0.85) f_c' b} \right)$$

The factored resistance moment is compared to the factored applied moment.

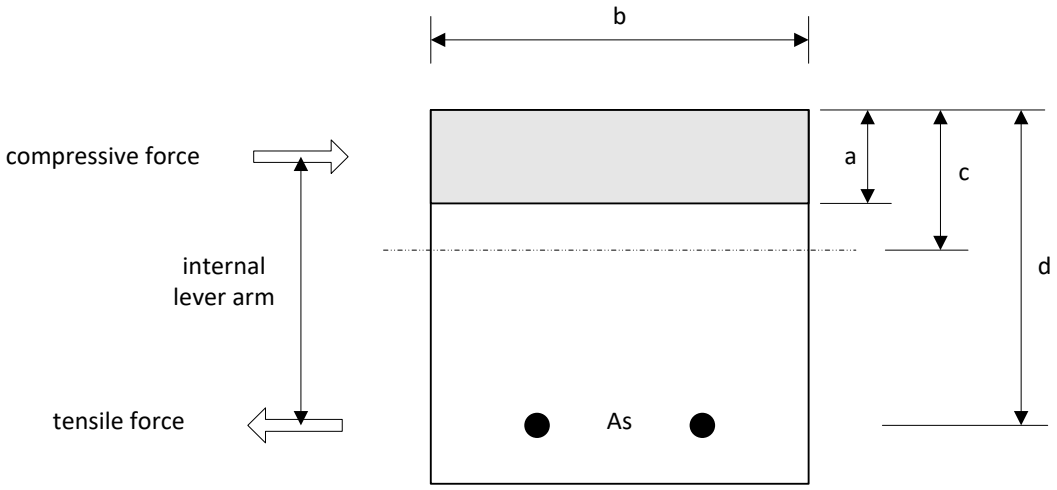


Figure 3.5.2-1 Singly Reinforced Section

Finally, the factored flexural capacity is computed by multiplying the nominal flexural capacity by ϕ. If the computed ϕ factor is less than 0.90, then the process is repeated with ϕ assumed to be 0.75 and a second moment capacity is computed. Using the second moment capacity a new factored flexural capacity is computed. If the second moment capacity is less than the applied factored moment then the cross section is considered inadequate; otherwise, the ϕ factor is iterated until the assumed ϕ factor is equal to the computed ϕ factor. For analysis, the inadequate resistance is reported.

3.5.2.2 Strength Check – Design

When the program is designing reinforcement, the development length is checked to ensure that the selected bar size and spacing will be able to develop within the actual geometry of the concrete component. If the bar does not develop, the program will then reduce the spacing by multiplying by a ratio of the actual length available to the calculated development length, not less than 80%, and then check the development again. If the reduced spacing requires a development length that is greater than the actual geometry available then the program will indicate that the bar cannot be developed.

For perpendicular footing bars, if the Hooked Footing Bars parameter on the SPD card is set to “Y”, the program will check if hooked bars would work when a straight bar does not. In this case the program will then calculate the hooked development length of bar at its original spacing. If the hooked bar cannot be developed in the actual geometry, the program will then reduce the spacing by a ratio of the actual length available to the development length, not less than 80%, and then recalculate the development length. If the reduced spacing requires a development length that is greater than the geometry available then the program will indicate that the bar cannot be developed.

The method of reducing the spacing is shown below with accompanying equations:

When the $L_{dbar} > L_{dact}$

$$L_{dratio} = MAX\left(\frac{L_{dact}}{L_{dbar}}, 0.8\right)$$

$$s_{new} = s_{orig} * L_{dratio}$$

Where:
- L_{dbar} = Development length of a bar
- L_{dact} = Available space for bar to develop in the component
- L_{dratio} = Ratio of available length to develop versus the required bar development length
- s_{orig} = Selected bar spacing
- s_{new} = New reduced bar spacing

The 0.8 in the above equation is the limit on the spacing reduction. For example, if a 9 inch spacing does not work, then the spacing is reduced but to no less than 7.2 inches which rounds to 7 inches. This technique allows the program to inform the user of the spacing required for the selected bar that would allow the bar to develop within the space available.

The procedure for evaluating the development length is described in Section 3.5.2.3.

For a design run when the required area of reinforcement, A_s, can be developed to resist applied moment, M_u, is calculated by solving the following quadratic equation:

$$\left[\frac{f_y^2}{2(0.85)f'_c b}\right] A_s^2 - [f_y d]\, A_s + \frac{M_u}{\varphi} = 0$$

The area of reinforcement calculated using the above equation is based on a theory of singly reinforced rectangular concrete section.

The derivation of the above equation is shown below: Refer to Figure 3.5.2-1.

From internal equilibrium (Tension = Compression)

$$A_s f_y = 0.85 f'_c ab$$

From external equilibrium:

$$M_u = \varphi M_n = \varphi A_s f_y \left(d - \frac{a}{2}\right)$$

Solve for ‘a’ above:

$$M_u = \varphi A_s f_y \left[d - \frac{A_s f_y}{2(0.85) f'_c b} \right]$$

Simplifying the above equation results in the quadratic equation shown above.

For a design run the program assumes ϕ to be 0.90 and solves the area of steel for all limit states, all flexure maximum effect cases, and all points-of-interest.

The nominal moment resistance is computed with the assumption that f_s is equal to f_y in the following equations:

$$c = \frac{A_s f_s}{0.85 f_c' \beta_1 b}$$

$$a = \beta_1 c$$

$$M_n = A_s f_s \left(d - \frac{a}{2} \right)$$

where: c = distance from the extreme compression fiber to the neutral axis (in)

As = area of tension reinforcement (in2)

fs = stress in mild steel tension reinforcement at nominal flexural resistance (ksi)

fc' = Concrete design strength (ksi)

β_1 = ratio of the depth of the equivalent uniformly stressed compression zone to the depth of the actual compression zone

b = width of the compression face of the member (in)

a = depth of equivalent rectangular stress block (in)

Mn = nominal flexural resistance (in-kips)

d = distance from compression face to centroid of tension reinforcement (in)

The net tensile strain and the stress in the reinforcement is computed from the following:

$$\varepsilon_t = 0.003 \left(\frac{d_s}{c} - 1 \right)$$

$$f_s = min\left(\varepsilon_t \cdot E_s, f_y \right)$$

where: ε_t = net tensile strain in extreme tension steel at nominal resistance (in/in)

ds = distance from extreme compression fiber to the centroid of the nonprestressed tensile reinforcement (in)

Es = modulus of elasticity of reinforcing bars (ksi)

fy = specified minimum yield strength of reinforcing bars (ksi)

If the mild steel stress, f_s, is less than the yield strength, f_y, then the initial assumption was incorrect and the nominal flexural resistance is determined based on conditions of equilibrium and strain compatibility.

The resistance factor ϕ is computed with the net tensile strain using the following equation:

$$0.75 \leq \phi = 0.75 + \frac{0.15\,(\varepsilon_t - \varepsilon_{cl})}{(\varepsilon_{tl} - \varepsilon_{cl})} \leq 0.9$$

where: ε_{cl} = compression-controlled strain limit, 0.002

ε_{tl} = tension-controlled strain limit, 0.005 (for $f_y \leq 75.0$ ksi)

ε_{tl} = $0.005 + \frac{(f_y - 75.0)(0.003)}{25.0}$ (for 75.0 ksi < $f_y \leq$ 100.0 ksi)

Finally, the factored flexural resistance is computed by multiplying nominal flexural resistance by ϕ. If the computed ϕ factor is less than 0.90, then the process is repeated with ϕ assumed to be 0.75 and a second steel area is computed from the quadratic equation. Using the second area a new factored flexural resistance is computed. If the new factored flexural resistance is less than the applied factored moment then the cross section is considered inadequate and the section depth is incremented and the process is repeated. Otherwise, an iterative procedure is used to find an area of steel that results in a factored flexural resistance that equals (within a tolerance) the applied factored moment.

The program will use the smallest positive root as the solution. If both roots are negative, the area cannot be evaluated because of the incompatible relationship between the applied moment, material strengths and the given geometry of the section, i.e., stronger materials properties and/or a deeper section are required.

3.5.2.3 Tension Development Length

The modified tension development length of a reinforcing bar depends on several factors including: bar size; geometry (straight or hooked); function and the user specified correction factor (see MRD command, Chapter 5).

Straight Bars

The modified tension development length (ℓ_d) is calculated from the basic development length (ℓ_{db}) by adjusting for correction factors (λ_{rl}, λ_{cf}, λ_{rc}, λ_{er}, and λ), which are described further in the next sub-section. The correction factors consider the location of the reinforcement, epoxy coating on the bar, confinement of the reinforcement, excess reinforcement and a value specified by the user.

$$\ell_d = max\left(12.0",\ \ell_{db} * \left(\frac{\lambda_{rl}\,\lambda_{cf}\,\lambda_{rc}\,\lambda_{er}}{\lambda}\right) * MRD\ Factor\right)$$

$$\ell_{db} = 2.4\,d_b\left(\frac{f_y}{\sqrt{f'_c}}\right)$$ LRFD Specifications Equation 5.10.8.2.1a-2

Where: ℓ_d = modified bar development length (in) (LRFD Specifications Equation 5.10.8.2.1a-1)

ℓ_{db} = basic development length required for a given bar (in)

λ_{rl} = reinforcement location factor

λ_{cf} = coating factor

λ_{rc} = reinforcement confinement factor

λ_{er} = excess reinforcement factor

λ = concrete density modification factor (LRFD Specifications Section 5.4.2.8)

d_b = nominal diameter of reinforcing bar or wire (in)

f_y = specified minimum yield strength of reinforcement (ksi)

f'_c = compressive strength of concrete (ksi)

MRD Factor = User input development correction on the MRD Command

Note: The concrete compressive strength, f'_c, and steel yield stresses, f_y, are specified in ksi, the bar diameter, d_b, is specified in inches, and the development length has the units of inches.

Hooked Bars

The following equations apply for computing the modified development length (ℓ_{dh}) for a hooked bar. The basic development length is adjusted by the correction factors (λ_{rc}, λ_{cw}, λ_{er}, and λ), which are described further in the next sub-section. The basic development length considers the yield strength of the reinforcement and concrete, while the correction factors consider the confinement of the bar, epoxy coating on the bar, and the area of reinforcement.

$$\ell_{dh} = max\begin{pmatrix} 8.0 * d_b \\ 6.0" \\ \ell_{hb} * \left(\frac{\lambda_{rc}\lambda_{cw}\lambda_{er}}{\lambda}\right) * MRD\ Factor \end{pmatrix}$$

$$\ell_{hb} = \frac{38.0\ d_b}{60.0}\left(\frac{f_y}{\sqrt{f'_c}}\right) \qquad \text{LRFD Specifications Equation 5.10.8.2.4a-2}$$

Where: ℓ_{dh} = modified hooked bar development length (in) (LRFD Specifications Equation 5.10.8.2.4a-1)

ℓ_{hb} = basic hooked development length required for a given bar (in)

λ_{rc} = reinforcement confinement factor

λ_{cw} = coating factor

λ_{er} = excess reinforcement factor

λ = concrete density modification factor (LRFD Specifications Section 5.4.2.8)

d_b = nominal diameter of reinforcing bar or wire (in)

f_y = specified minimum yield strength of reinforcement (ksi)

f'_c = compressive strength of concrete

MRD Factor = User input development correction on the MRD Command

3.5.2.4 Development Length Correction Factors

The basic development length for straight bars is multiplied by the following factors (LRFD Specifications Sections 5.10.8.2.1b and 5.10.8.2.1c):

- λ_{rl}*, reinforcement location factor is 1.3 for horizontal reinforcement footing bars, placed such that more than 12.0 in. of fresh concrete is cast below the reinforcement, otherwise 1.0, including for vertical stem and backwall reinforcement.
- λ_{rc}, reinforcement confinement factor is defined as follows:

$$0.4 \leq \lambda_{rc} \leq 1.0$$

In which:

$$\lambda_{rc} = \frac{d_b}{c_b + k_{tr}}$$

$$k_{tr} = 40\,A_{tr}/(sn)$$

where:

c_b = the smaller of the distance from center of bar or wire being developed to the nearest concrete surface and one-half the center-to-center spacing of the bars or wires being developed (in).

k_{tr} = transverse reinforcement index

A_{tr} = total cross-sectional area of all transverse reinforcement which is within the spacing s and which crosses the potential plane of splitting through the reinforcement being developed (in.^{2})

Note: A_{tr} is conservatively taken as zero which results in k_{tr} also being zero and reduces the the reinforcement confinement factor equation to d_b/c_b with the limits of 0.4 and 1.0.

s = maximum center-to-center spacing of transverse reinforcement within l_d (in.)

n = number of bars or wires developed along plane of splitting

- λ_{cf}*, coating factor is 1.5 for epoxy-coated bars with less than $3d_b$ cover or with clear spacing between bars less than $6d_b$, and 1.2 for other epoxy-coated bars, and 1.0 for plain bars.
- λ_{er}, excess reinforcement factor adjusts the length by the ratio:

$$\lambda_{er} = \frac{(A_s\ required)}{(A_s\ provided)}$$

* The product of λ_{rl} x λ_{cf} need not be taken greater than 1.7.

The basic development length for hooked bars is multiplied by the following factors (LRFD Specifications Section 5.10.8.2.4b):

- λ_{rc}, reinforcement confinement factor for #11 bars and smaller is 0.8 and 1.0 for other bars.

- λ_{cw}, coating factor is 1.2 if epoxy coated and 1.0 for plain
- λ_{er}, excess reinforcement factor adjusts the length by the ratio:

$$\lambda_{er} = \frac{(A_s\ required)}{(A_s\ provided)}$$

3.5.2.5 Resistance Phi Factor

The relationships that apply are based on the section illustrated in Figure 3.5.2-1 and the equations shown below.

The current LRFD Specifications now reduces the phi factor based on the strain condition at the cross-section. A reduction in the phi factor for compression-controlled sections is used to compensate for decreased ductility in comparison to tension-controlled sections. The variant resistance phi factor is computed by the following equation:

$$c = \frac{A_s f_s}{0.85 f_c' \beta_1 b}$$

$$\varepsilon_t = \frac{0.003(d-c)}{c}$$ LRFD Specifications Figure C5.6.2.1-1

The resistance factor ϕ is computed with the net tensile strain using LRFD Specifications Equation 5.5.4.2.1-2:

$$0.75 \leq \emptyset = 0.75 + \frac{0.15(\varepsilon_t - \varepsilon_{cl})}{\varepsilon_{tl} - \varepsilon_{cl}} \leq 0.9$$

where: ε_τ = net tensile strain in the extreme tension steel at nominal resistance (in./in.)
ε_{cl} = compression-controlled strain limit in the extreme tension steel (in./in.)
ε_{tl} = tension-controlled strain limit in the extreme tension steel (in./in.)
c = distance from the extreme compression fiber to neutral axis (in.)
d = distance from the extreme compression fiber to the centroid of the extreme tension steel (in.)

3.5.2.6 Spacing Requirements

The minimum clear distance between parallel bars in a layer for the serviceability check is the greatest of:

- 2.5 in. DM-4 Section 5.10.3.1.1
- 1.5 times the nominal bar diameter LRFD Specifications Section 5.10.3.1.1
- 1.5 times the maximum size of the coarse aggregate (entered on the MRD command) LRFD Specifications Section 5.10.3.1.1

The minimum bar spacing limit is the clear distance between bars plus the bar diameter. This check is performed for both design and analysis runs. If the reinforcement is entered as a developed area of reinforcement for an analysis run, the program will calculate a bar spacing based on the entered area of reinforcement and the entered maximum bar diameter. This calculated spacing will be used for spacing requirement checks.

The maximum spacing for a #4 bar is:

$$S_{MAX} = min(1.5t, 12\ in)$$ DM-4 Section 5.10.3.2 and DM-4 Section 5.10.6.1P

The maximum spacing for bar sizes #5 or larger is:

$$S_{MAX} = min(1.5t, 18\ in)$$ DM-4 Section 5.10.3.2 and DM-4 Section 5.10.6.1P

Where "*t*" is the structural thickness of the member.

3.5.2.7 Minimum Area of Reinforcement

The minimum area of reinforcement that is required is determined by the following relationships:

3.5.2.7.1 Minimum Based on Temperature and Shrinkage Requirements

$$A_{s1} = \frac{1.3bh}{2(b+h)f_y}\ (\text{in}^2/\text{ft})$$ LRFD Specifications Equation 5.10.6-1

If $A_{s1} < 0.11$ Then

$A_{s1} = 0.11\ \text{in}^2/\text{ft}$

If $A_{s1} > 0.6$ Then

$A_{s1} = 0.6\ \text{in}^2/\text{ft}$

A_{s2} = #4's @ 12 in = 0.2 in^2/ft DM-4 Section 5.10.6.1P

$A_s = MAX\ [A_{s1}, A_{s2}]$

Where:

h = least height of the component (in)

b = least width of the component (in)

ABLRFD sets the least width of the component equal to the height for backwall/stem or the width of the footing as illustrated in Figures 3.5.2-2 and 3.5.2-3.

The 0.12 in^2/ft requirement from DM-4 Section 5.10.6 does not control over DM-4 Section 5.10.6.1P and is not considered by the ABLRFD program.

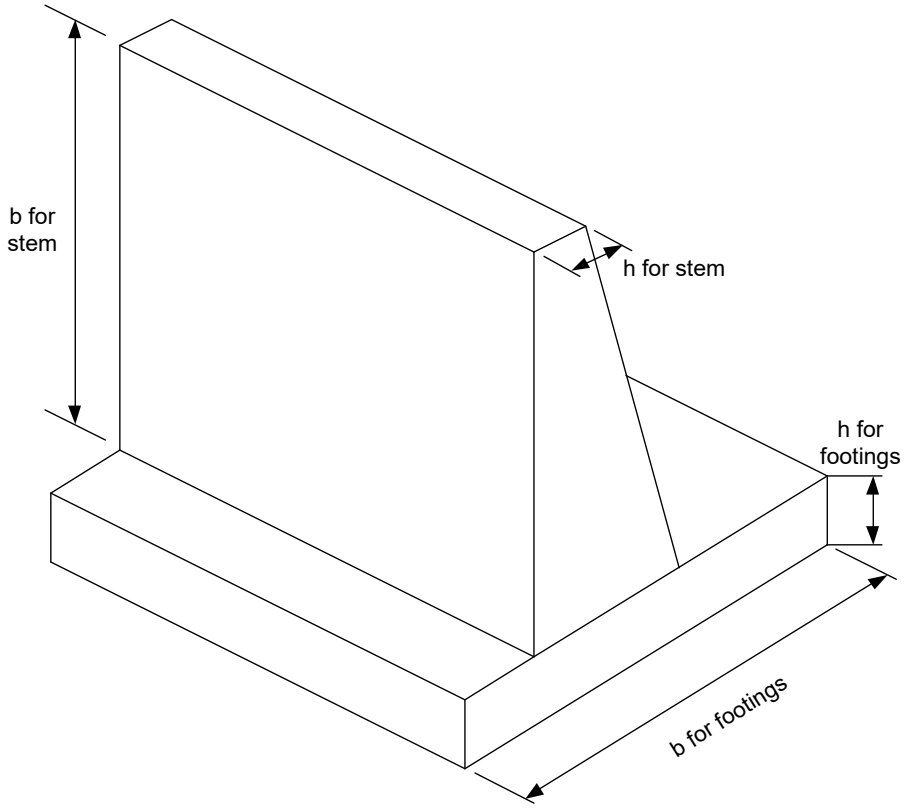


Figure 3.5.2-2 Temperature and shrinkage dimension location RWL, AWB

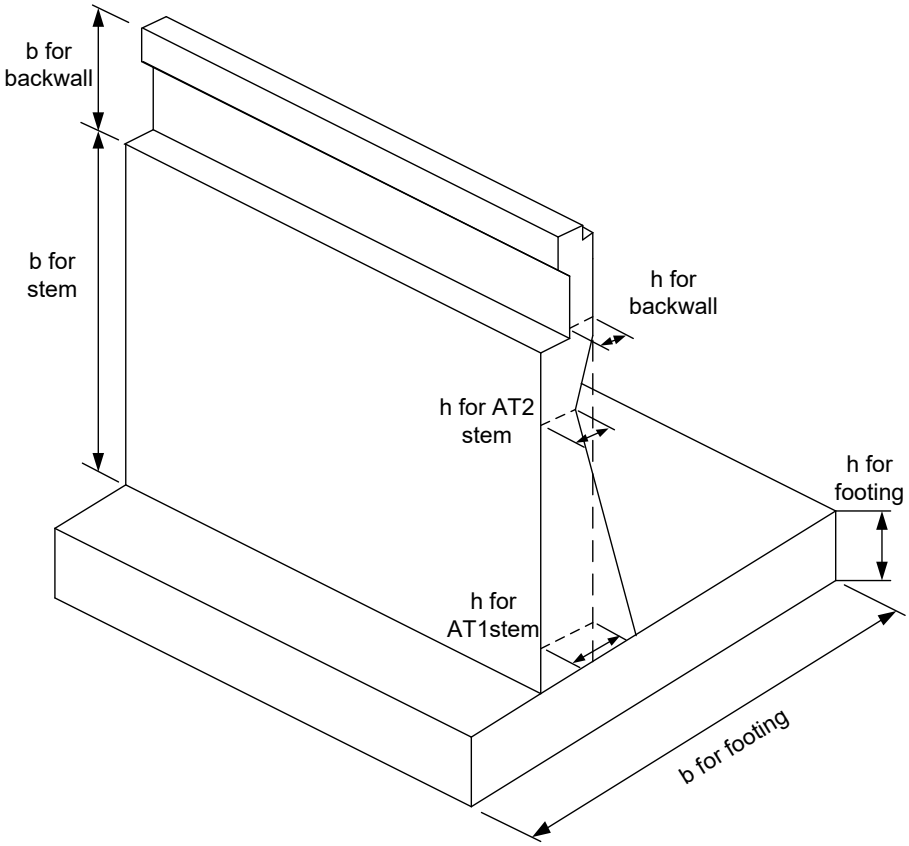


Figure 3.5.2-3 Temperature and shrinkage dimension locations AT1, AT2

3.5.2.7.2 Minimum Based on Flexural Requirements

The strength limit state requirements (i.e. moment capacity related) are based on the ρ_{min} criteria which evaluates the reinforcement ratio for a section that will resist an applied moment (M_{app}) that is the lesser of 1.33 M_u or M_{cr} (DM-4 Section 5.6.3.3).

$$M_{cr} = \gamma_3(\gamma_1 f_r S_b)$$

Where γ_1 = 1.6 for non prestressed concrete DM-4 Section 5.6.3.3

γ_3 = f_y/f_u DM-4 Section 5.6.3.3

The value of ρ is obtained from the following equation:

$$\rho = \frac{A_s}{bd} = 0.85\left(\frac{f'_c}{f_y}\right) - \frac{\sqrt{-b(0.85f'_c)\varphi\left(2M_{app} - \varphi bd^2(0.85f'_c)\right)}}{\varphi bd(f_y)}$$

This equation is based on the singly reinforced section illustrated in Figure 3.5.2-1. It is based on the solution to the quadratic equation identified in Section 3.5.2.2.

The cracking moment, M_{cr}, referenced above, is the moment applied to the section that will produce the rupture stress of concrete at the extreme tension fiber of an uncracked section.

3.5.2.8 Serviceability Crack Control

The crack control is checked as per DM-4 Section 5.6.7 where the spacing of the main tensile reinforcement is checked against the result of LRFD Specifications Equation 5.6.7-1. For bottom perpendicular reinforcement (toe) the program subtracts 1 inch of cover to account for foundation unevenness when calculating the allowable crack control spacing.

$$s \le \frac{700\gamma_e}{\beta_s f_{ss}} - 2d_c$$

Where γ_e = 1.00 for Class 1 Exposure

0.75 for Class 2 Exposure

f_{ss} = MIN(f_s , 0.6*f_y)

$$\beta_s = 1 + \frac{d_c}{0.7(h - d_c)}$$

3.5.2.9 Shear

The shear resistance of the section does not consider shear reinforcement. It is based on the strength of the concrete and the shear depth. The shear depth (d_v) is a function of: the Whitney stress block depth (a); the effective depth (d); and the height (h) of the section as shown below:

$$d_v = \mathrm{MAX}(d - \frac{a}{2}, 0.9d, 0.72h)$$ LRFD Specifications Section 5.7.2.8

The depth of the Whitney stress block, 'a', is calculated by evaluating the flexural capacity of the section as described in Section 3.5.2.1.

The shear capacity, V_c, is evaluated by the following:

$$V_c = v_{fact}\ \beta\ b\ d_v\ \lambda \sqrt{f'_c}$$ LRFD Specifications Equation 5.7.3.3-3

Where: v_{fact} = 0.0316

β = 2.0 LRFD Specifications Section 5.7.3.4.1

λ = concrete density modification factor (LRFD Specifications Section 5.4.2.8)

The maximum shear is considered from all of the limit state cases.

3.5.2.10 Punching Shear (Pile/Caisson Footings)

For both piles and caissons for design and analysis, the punching shear check begins by computing the depth of the Whitney stress block (see Section 3.5.2.1), based on the effective depth for the reinforcement in the top perpendicular direction of the footing. The shear depth is then computed using the equation in Section 3.5.2.9.

$$d_v = \mathrm{MAX}(d - \frac{a}{2}, 0.9d, 0.72h)$$ LRFD Specifications Section 5.7.2.8

Where: d = top perpendicular bar effective depth – pile/caisson embedment

h = footing thickness – pile/caisson embedment

A shear perimeter around the pile, **b_o,** is then computed based on the pile cross sectional dimension and the shear depth, d_v.

$b_o = 2\ (a + d_v) + 2\ (b + d_v)$ for rectangular piles

$b_o = \pi\ (diam + d_v)$ for circular piles

A beta factor (b_c) is then computed for rectangular piles by taking the bigger dimension and dividing it by the smaller dimension. The beta factor is 1 for circular piles. A punching shear factor is then computed using LRFD Specifications Equation 5.12.8.6.3-1 based on the beta factor:

$$f_{ps} = 0.063 + \frac{0.126}{b_c}, \text{ but not greater than } 0.126$$

The punching shear resistance is computed using LRFD Specifications Equation 5.12.8.6.3-1 and compared against the maximum vertical pile load:

$$V_{pr} = \varphi\, f_{ps}\, \lambda \sqrt{f'_c}\; b_o\, d_v$$

Punching shear is checked for single piles only. Effects due to overlapping shear planes should be checked by the engineer if piles are closely spaced.

3.5.2.11 Punching Shear (Type 4 Approach Slab Pedestals)

For design and analysis, the punching shear check begins by computing the depth of the Whitney stress block (see Section 3.5.2.1), based on the effective depth for the reinforcement in the top perpendicular direction of the footing. The shear depth is then computed using LRFD Specifications Section 5.7.2.8:

$$d_v = \mathrm{MAX}\left(d - \frac{a}{2}, 0.9d, 0.72h\right)$$

Where: d = top perpendicular bar effective depth
h = footing thickness

A shear perimeter around the drain trough pedestal is then computed based on the drain trough length, x, and width, y, and the effective shear depth:

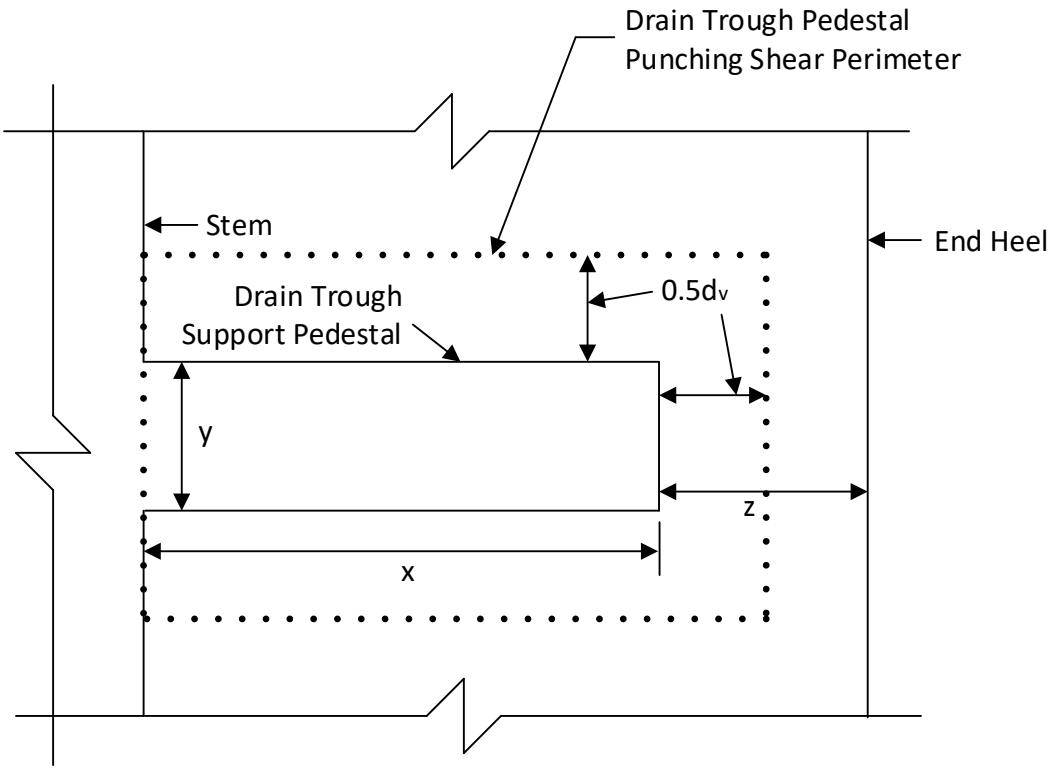


Figure 3.5.2-4 Punching Shear Perimeter Around Drain Trough Pedestal

$$b_o = 2\,(\,x + 0.5d_v) + 2\,(\,y + d_v)$$

If the distance between the end of heel and the end of the drain trough support pedestal, z, is less than $0.5d_v$ then the punching shear perimeter is reduced:

$$b_o = 2\,(\,x + z) + y + d_v$$

A beta factor (b_c) is then computed by taking the maximum of the drain trough pedestal length and the drain trough pedestal width and dividing it by the minimum of the drain trough pedestal length and the drain trough pedestal width. A punching shear factor is then computed using LRFD Specifications Equation 5.12.8.6.3-1 based on the beta factor:

$f_{ps} = 0.063 + \dfrac{0.126}{b_c}$, but not greater than 0.126

The punching shear resistance is computed using LRFD Specifications Equation 5.12.8.6.3-1 and compared against the maximum vertical loading transferred from the drain trough pedestal to the footing.

$$V_{pr} = \varphi\, f_{ps} \lambda \sqrt{f'_c}\, b_o\, d_v$$

3.5.3 Design of a Footing Section

The algorithm that follows is for a footing on piles. Pile footings contain rebar in both the parallel and perpendicular directions. The reinforcement in the parallel direction is not considered in spread footings, and the reinforcement in the perpendicular direction (toe and heel locations) is not considered for pedestal footings because the footing and pedestal are assumed to be made integral using transverse shear keys and dowels as per DM-4 Section 10.6.5.2P. Perpendicular and parallel bar details are illustrated in Figure 5.22-1. The program does not check if the bottom reinforcement interferes with the piles or caissons. Hence, the user should provide an adequate cover in such circumstances.

The design algorithm evaluates the area of steel required based on the strength requirements first. Hence, the area of reinforcement in the toe, the heel and the parallel (top and bottom) direction is computed to resist the maximum moment in each direction (parallel and perpendicular). The area of steel cannot be less than that defined by the minimum reinforcement ratio.

For each bar size, the program computes the spacing required to satisfy the area of reinforcement required. The bar spacing is rounded down to the nearest user entered increment. For example, if the area of reinforcement required (per ft) is 1.1 in^2, a #8 bar should be spaced at (12.0 in. x 0.79 (in^2/bar) / 1.1 (in^2)) = 8.618 in. If the requested minimum spacing is 6 inches and the increment is 3 inches then this value is rounded to 6.0 inches since it is the closest value within the increment and it does not exceed the theoretical bar spacing. A #9 bar would be spaced at 9.0 in (10.909 in. theoretical spacing). If the reported spacing during design runs is less than the User Requested Minimum Spacing or the LRFD Specifications spacing, the program will not report design values for the bar (See Chapter 7) and the spacing shown is the un-rounded design spacing shown for information purposes.

For each bar size and the corresponding spacing, the program then checks the serviceability requirements. These checks include:

- Minimum and maximum spacing requirements (Section 3.5.2.6); and,
- Allowable tensile stress in the rebar that incorporates crack width criteria (Section 3.5.2.8).

If the tensile stress exceeds the allowable stress, the bar spacing is reduced until a satisfactory solution has been obtained. If the required bar spacing violates the minimum spacing requirements, then that bar is rejected. If all the bar sizes are rejected, a solution cannot be obtained for the given footing configuration.

The footing configuration is considered acceptable if at least one bar size and its corresponding spacing satisfies the strength and serviceability requirements.

The program will compute the development length for each bar size as described in Section 3.5.2.3. The bar spacing may be further reduced to satisfy the development length criteria. This may occur for the larger bar sizes which require longer development lengths. For example, if the actual available length for developing a bar in the toe (toe projection - end cover) is shorter than the required development length, then the actual steel area provided may be increased by reducing the bar spacing in order to reduce the required development length as described in Section 3.5.2.4.

Development lengths can be computed for straight and hooked bars. Footing bars are assumed to be straight. Stem bars are assumed to be hooked in the footing, but straight in the stem.

Note that, reducing the spacing automatically satisfies the allowable tensile stress check (serviceability check).

3.6 BACKWALL AND STEM

The backwall is checked at two locations, namely: the middle of backwall and the seat level. The stem is examined at the quarter point locations. These points are shown in Figure 3.6-1. The cross sections are considered to be singly reinforced. Only the back face reinforcement is considered in the calculations.

Each point is checked for shear, service load stress in the rebar and the strength capacity. The strength capacity calculations consider the effect of the moment-axial load interaction.

The “Structural Analysis” section that follows briefly explains how the shear force, axial load and moments are evaluated. The section primarily focuses on how the stress in the rebar is evaluated considering axial and flexural loads. The “Specification Checking” section refers to the description for the footing section since the checks are very similar. The section primarily focuses on how the capacity is evaluated when the moment and axial load interaction is considered.

Stem and backwall bars are situated at the back face of the section as illustrated (see vertical reinforcement) in Figure 5.22-1. Figures 5.27-1 and 5.28-1 illustrate variations of how the stem reinforcement can be specified.

For the Type II abutment the assumption is made that the rear face vertical reinforcement extends parallel to the stem back face batter, as shown in Figure 3.6-1, up to the bearing seat. When an analysis point is located above the stem notch, the thickness of the design section is limited to the horizontal distance between the front face of the stem and the projected line from the stem back face batter.. Figure 3.6-1 illustrates how the section thickness for stem analysis locations above the stem notch is determined.

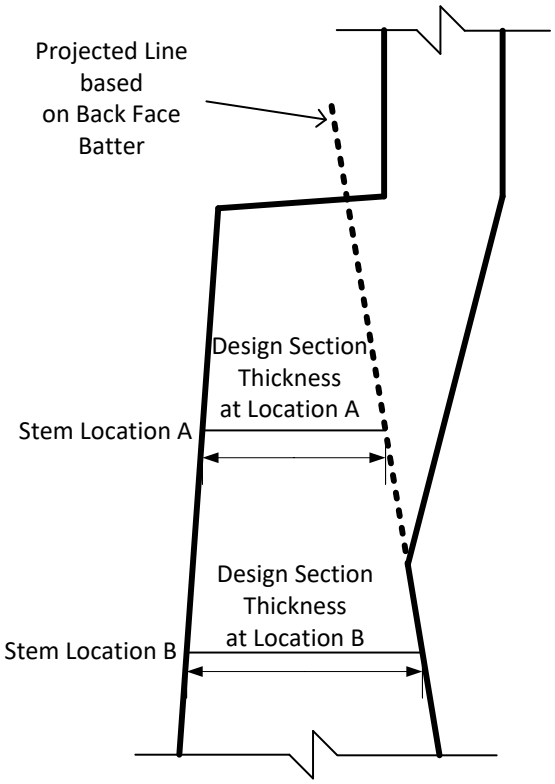


Figure 3.6-1 Type II Abutment Section Height at Stem Points of Analysis Above Stem Notch

3.6.1 Structural Analysis

The shear force, axial force and moment values at a given section are determined from a static analysis of the loads (horizontal and vertical) acting on the stem and backwall above the section under consideration. The calculation of the actual stress in the stem and backwall reinforcement is more complex than that in the footing because it considers the axial load. The procedure to compute that actual stress depends on the relative value (ratio) of the applied axial load (N) to the maximum axial load (P_{max}), the applied moment (M) and the geometry of the section as shown below:

$$P_{\max} = \frac{M}{\left(\frac{d}{6} + \frac{c}{2}\right)}$$

$$ratio = \frac{N}{P_{\max}}$$

If the ratio is less than 0.003, the section is considered to behave as a flexural member. Hence, the stress in the reinforcement, f_s, is computed using the procedure described in Section 3.5.1.4 for the footing (i.e., the axial load is neglected).

If the ratio is greater than 0.003 and less than or equal to 0.5, the solution is determined by iterating on the value of the concrete strain so that the equilibrium equations for the moment and axial values are satisfied. Refer to Figure 3.6.1-1 for the formulation of the equations that are checked and followed.

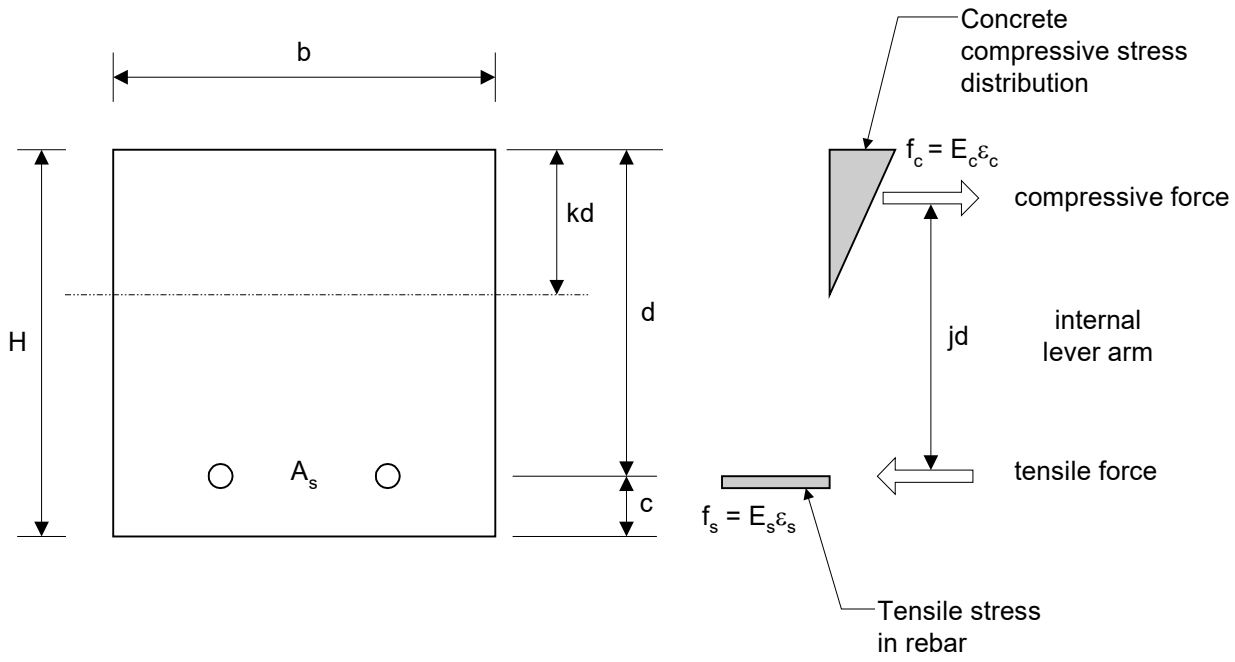
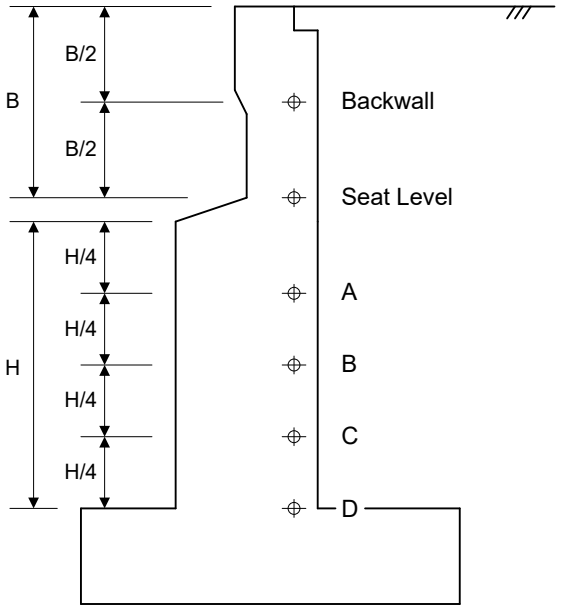
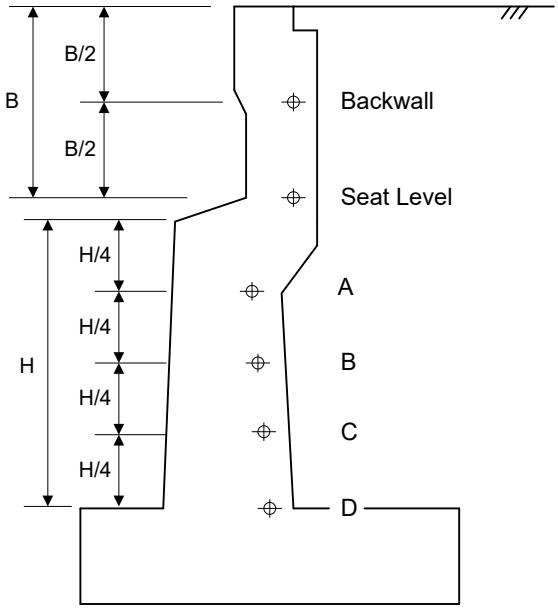


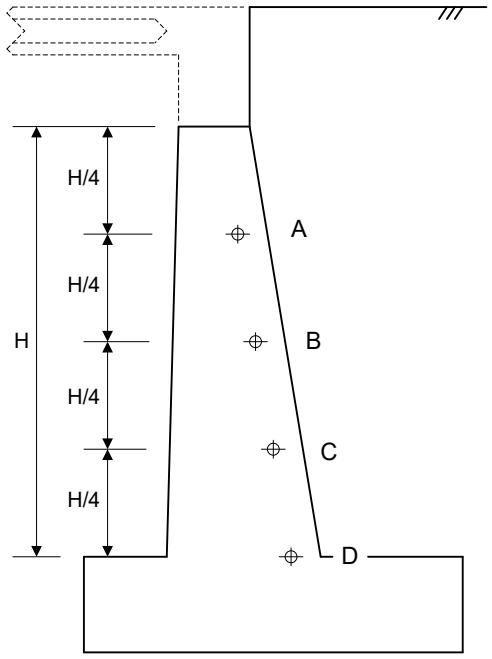
Figure 3.6.1-1 Lateral Forces of Cross Section



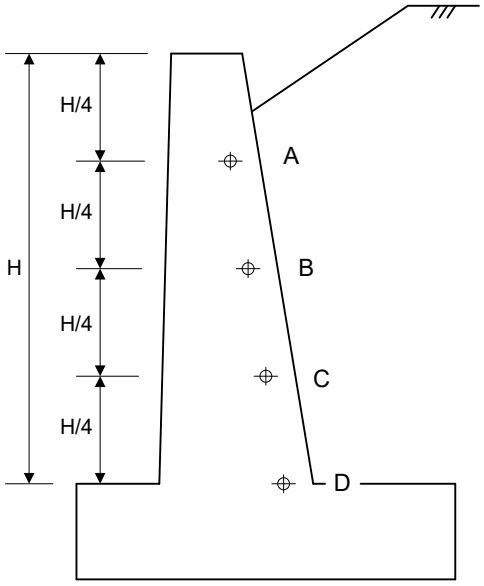
(a) Abutment Type I



(b) Abutment Type II



(c) Abutment without backwall



(d) Retaining Wall

⊕ Analysis Locations

Figure 3.6.1-2 Stem and Backwall Points of Analysis

From internal equilibrium of axial load and strain compatibility:

$$N = C - T \tag{1}$$

$$C = \frac{E_c \varepsilon_c bkd}{2} \tag{2}$$

$$T = E_s \varepsilon_s A_s = \frac{1 - k}{k} \varepsilon_c E_s A_s \tag{3}$$

Where:

kd = depth to neutral axis from extreme compressive fiber

ε_c *= strain in concrete at extreme compressive fiber*

ε_s *= strain in tensile reinforcement*

N = axial load

C = concrete compressive strength

T = tensile strength of reinforcement

A_s *= area of mild steel reinforcement*

Substitute (2) and (3) into (1) and simplify for k to get:

$$k^2 \left[\frac{E_c \varepsilon_c bd}{2N} \right] + k \left[\frac{\varepsilon_c (A_s) E_s}{N} - 1 \right] - \left[\frac{\varepsilon_c (A_s) E_s}{N} \right] = 0 \tag{4}$$

From strain compatibility:

$$f_s = \varepsilon_s E_s = \frac{1 - k}{k} \varepsilon_c E_s \quad ; \text{ and } \quad j = 1 - \frac{k}{3} \tag{5}$$

From moment equilibrium: (6)

$$M_{service} = Cjd - N \left(\frac{H}{2} - c \right) \tag{7}$$

Solution: Initialize concrete strain ε_c to 0.008, solve for k using equation (4), and check moment equilibrium (7). If M_{calc} is not within 0.1% of $M_{service}$, perform new calculations with revised strain.

The assumed concrete strain value is used to compute the neutral axis depth based on the equilibrium equation for the axial load (equation 4). The neutral axis depth and concrete strain are used to compute the internal moment of the section (equation 7). The moment is compared to the applied moment. If the comparison is not within an acceptable tolerance (0.1%), the concrete strain value is revised. The program will stop after 50 iterations if convergence has not occurred and print out an error message.

When the ratio is greater than 0.5, the program iterates on the depth of the neutral axis so that the equilibrium equations for the moment and axial values are satisfied. The formulation of the equations that are checked include:

From internal equilibrium of axial load and strain compatibility:

$$N = C - T \tag{1}$$

$$C = \frac{E_c \varepsilon_c bkd}{2} \tag{2}$$

$$T = E_s \varepsilon_s A_s = \frac{1 - k}{k} \varepsilon_c E_s A_s \tag{3}$$

Where: *kd = depth to neutral axis from extreme compressive fiber*

ε_c *= strain in concrete at extreme compressive fiber*

ε_s *= strain in tensile reinforcement*

N = axial load

C = concrete compressive strength

T = tensile strength of reinforcement

A_s *= area of mild steel reinforcement*

Substitute (2) and (3) into (1) and simplify for ε_c to get:

$$\varepsilon_c = \frac{2Nk}{E_c bdk^2 - 2A_s E_s (1 - k)} \tag{4}$$

From moment equilibrium:

$$M_{service} = Cjd - N\left(\frac{H}{2} - c\right) \tag{5}$$

Solution: Start iterating with k = 0.3; solve for ε_c using equation (4); then evaluate concrete compressive strength (2) given k and ε_c; check moment equilibrium (5). If M_{calc} is not within 0.1% of $M_{service}$, perform new calculations with revised neutral axis depth, k. Iterate for a maximum of 50 iterations.

The assumed neutral axis depth is used to compute the concrete strain at the extreme compressive fiber of the cross section (equation 4). The neutral axis depth and concrete strain are used to compute the internal moment of the section (equation 5). The moment is compared to the applied moment. If the

comparison is not within an acceptable tolerance (0.1%), the concrete strain value is revised. The program will stop after 50 iterations if convergence has not occurred and print out an error message.

3.6.2 Specification Checking

The specification checks of the stem locations are similar to those of the spread footing locations. The difference between the two is the presence of the axial force component. The subsections below describe the details of the checks.

3.6.2.1 Strength Considerations - Moment/Axial Capacity

The strength check consists of evaluating the Moment and Axial capacity of the section based on a singly reinforced section where the reinforcement of the back face is considered the tensile steel. If the moment in the section is negative the program will then calculate the capacity of the section using the front face temperature and shrinkage steel as the tensile steel. If the temperature and shrinkage steel is being used for capacity, a message is shown in the output. The capacity values are compared to the actual values as determined by analysis.

Figure 3.6.2-1 presents the moment-axial interaction curve used by ABLRFD to calculate the factored moment resistance, M_B, and factored axial resistance, P_B (represented by Point B in the diagram below). The interaction curve is defined by 6 discrete points -- Point 7 ($0,\varphi P_{o,ten}$), Point 8 ($\varphi M_o,0$), Point 9 ($\varphi M_t,\varphi P_t$), Point 10 ($\varphi M_b,\varphi P_b$), Point 12 ($0,0.8\ \varphi P_{o,comp}$). Point 11 is found by computing the intersection of two lines.

Figure 3.6.2-1 shows the nominal capacity (dashed line) and the factored capacity (solid line) that incorporates the phi factor (ϕ).The phi factor varies from 0.75 for compression-controlled sections to 0.90 for tension controlled sections (See Section 3.5.2.5).

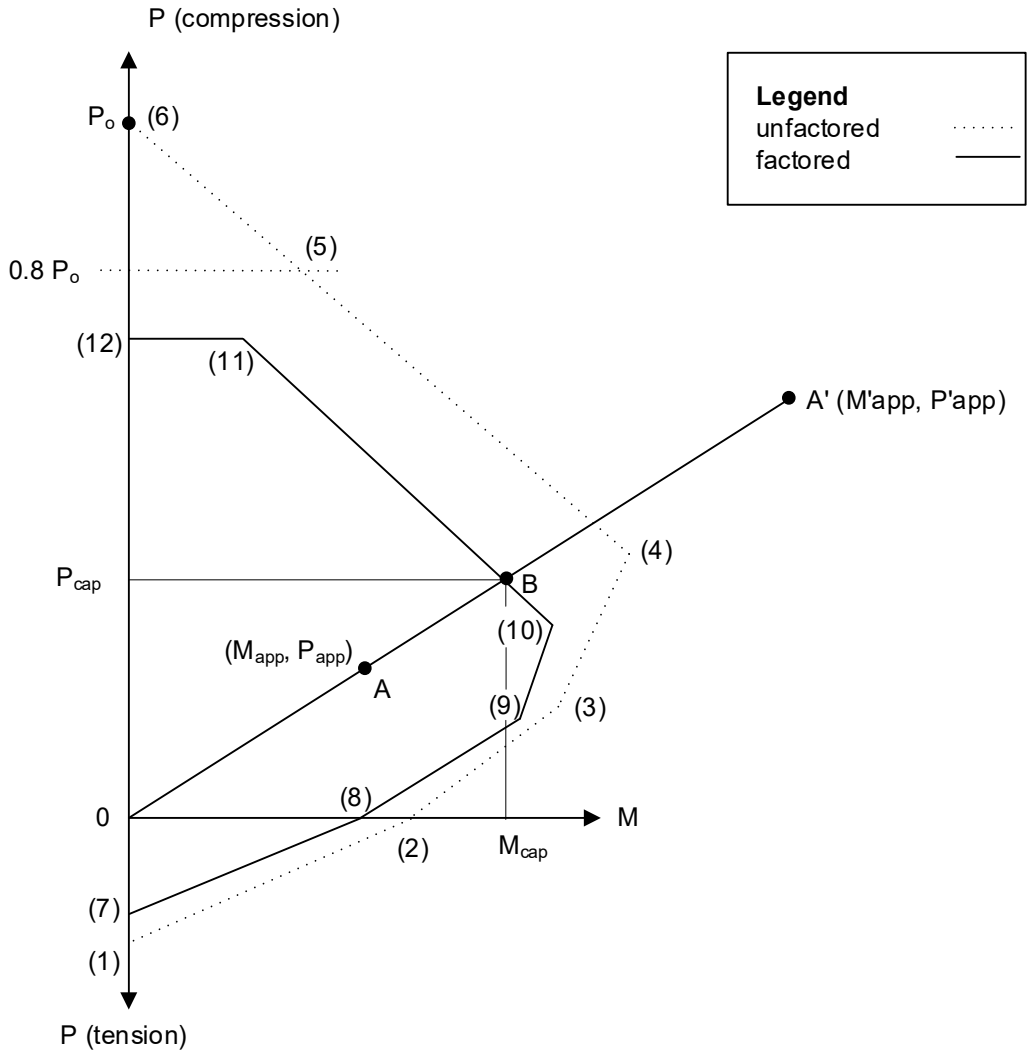


Figure 3.6.2-1 Moment-Interaction Diagram of a Singly Reinforced Section

The six points, (7) to (12), correspond to the following factored conditions, as shown in Figure 3.6.2-1:

7. Pure axial tensile strength (based on reinforcement only)

   $\phi = 0.9$ For cast-in-place

   $P_{(7)} = \phi A_{st} f_y$

   $M_{(7)} = 0$ (eccentricity of tensile force is ignored)

8. Pure flexural strength (axial capacity = 0.0)

The resistance factor, ϕ, is computed considering strain compatibility when appropriate, as shown below. The ϕ limit is 0.9 for cast-in-place.

$$P_{(8)} = 0$$

$$M_{(8)} = \phi \left\{ A_{st}\, f_s \left[d - \frac{A_{st}\, f_s}{2\,(0.85\, f_c'\, b)} \right] \right\}$$

With the known area of steel the quadratic equation is solved for the moment resistance, $M_{(8)}$, with ϕ equal to the ϕ limit and assuming the stress in the reinforcement steel, f_s, is equal to the specified minimum yield strength, f_y.

The net tensile strain and the stress in the reinforcement is computed from the following:

$$c = \frac{A_{st}\, f_s}{0.85\, f_c'\, \beta_1\, b}$$

$$\varepsilon_t = 0.003 \left(\frac{d}{c} - 1 \right)$$

$$f_s = \min\left(\varepsilon_t \cdot E_s, f_y\right)$$

If the mild steel stress, *fs*, is less than the yield strength, *fy*, then the initial assumption was incorrect and the nominal flexural resistance is determined based on conditions of equilibrium and strain compatibility.

The resistance factor ϕ is computed with the net tensile strain using the equation:

$$0.75 \le \phi = 0.75 + \frac{0.15\,(\varepsilon_{t(10)} - \varepsilon_{cl})}{(\varepsilon_{tl} - \varepsilon_{cl})} \le 0.9 \qquad \text{(for cast-in-place)}$$

where: ε_{cl} = compression-controlled strain limit, 0.002

ε_{tl} = tension-controlled strain limit, 0.005 (for $f_y \le 75.0$ ksi)

$\varepsilon_{tl} = 0.005 + \frac{(f_y - 75.0)(0.003)}{25.0}$ (for 75.0 ksi < $f_y \le 100.0$ ksi)

Finally, the factored flexural resistance is computed by multiplying the nominal flexural resistance by ϕ. If the computed ϕ factor is less than 0.90 (Cast-in-Place), then the process is repeated with ϕ assumed to be 0.75 and a second moment resistance is computed. Using the second moment resistance a new factored flexural resistance is computed. If the second moment resistance is less than the applied factored moment then the cross section is considered inadequate; otherwise, the ϕ factor is iterated until the assumed ϕ factor is equal to the computed ϕ factor. For analysis, the inadequate resistance is reported; for design, the or area of steel is incremented.

9. Tension controlled strain condition

$\phi = 0.9$ For cast-in-place

$\varepsilon_{cu} = 0.003$

$\varepsilon_t = \varepsilon_{tl} = 0.005$ (for $f_y \leq 75.0$ ksi)

$\varepsilon_t = \varepsilon_{tl} = 0.005 + \frac{(f_y - 75.0)(0.003)}{25.0}$ (for $75.0 < f_y \leq 100.0$ ksi)

$d'' = d - \frac{h}{2}$

$c = \frac{\varepsilon_{cu}\, d}{\varepsilon_t + \varepsilon_{cu}}$

$a = \beta_1 c$

$C_c = 0.85 f'_c \beta_1 c b$

$T = A_{st} MIN(f_y, \varepsilon_t E_s)$

$P_{(9)} = \phi \{C_c - T\}$

$M_{(9)} = \phi \left\{ C_c \left(d - \frac{a}{2} - d'' \right) + T d'' \right\}$

10. Balanced condition

$\varepsilon_{cu} = 0.003$

$d'' = d - \frac{h}{2}$

$\varepsilon_t = \frac{f_y}{E_s}$

$c = \frac{\varepsilon_{cu}\, d}{\varepsilon_t + \varepsilon_{cu}}$

$a = \beta_1 c$

$C_c = 0.85 f'_c \beta_1 c b$

$T = A_{st} MIN(f_y, \varepsilon_t E_s)$

$\phi = 0.75$ (for cast-in-place)

$P_{(10)} = \phi \{C_c - T\}$

$M_{(10)} = \phi \left\{ C_c \left(d - \frac{a}{2} - d'' \right) + T d'' \right\}$

11. Interaction point when axial load = $0.8P_o$

$\phi = 0.75$

$$P_{(11)} = \phi \left\{0.8\left[0.85\, f'_c \left(A_g - A_{st}\right) + f_y\, A_{st}\right]\right\}$$

$M_{(11)} =$ The intersection of the horizontal line from $P_{(12)}$ with the line between points 10 and $\phi(0.8 \cdot P_o)$

12. P_o - Pure axial compressive strength, P_o (Flexural Strength = 0.0)

$$\phi = 0.75$$

$$P_{(12)} = P_{(11)}$$

$M_{(12)} = 0$ (eccentricity of compressive force is ignored)

The factored points (7) to (11) are then sorted by increasing axial value (P) and stored as points (13) to (17) shown in Figure 3.6.2-2. Then, point (18) is set equal to point (12).

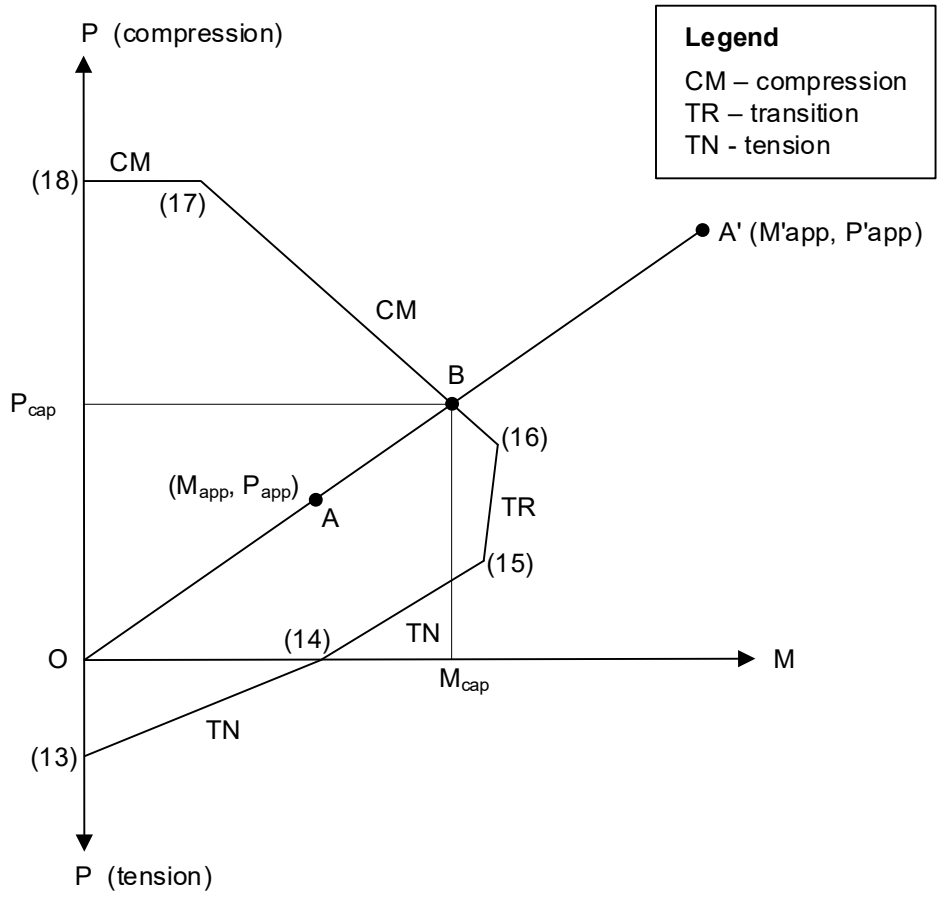


Figure 3.6.2-2 Factored Moment-Interaction Diagram

Where:

ϕ = Resistance factor

A_{st} is the area of the reinforcement

β_1= 0.85 for f'$_c$ <= 4 ksi

β_1= $0.85 - 0.05 * (f_c' - 4.0)$ for f'$_c$ > 4, but not less than 0.65 (A5.7.2.2)

d is the effective depth

h is the total structural depth

ε_{cu} is the crushing concrete strain (0.003)

ε_t is net tensile strain at nominal resistance

ε_{tl} is the tension controlled strain limit

ε_{cl} is compression-controlled strain limit

a is the depth rectangular stress distribution

b is the width of the section (1.0)

c is the distance from outer compressive fiber to neutral-axis

C_c is the concrete compressive force

T is the steel tensile force

For a given area of (fully developed) reinforcement, the Moment-Axial Interaction diagram is evaluated for the geometric and material properties of the section. Six points, (13) to (18), on the interaction diagram are computed explicitly as shown in Figures 3.6.2-1 and 3.6.2-2.

Figure 3.6.2-2 illustrates how the section capacity is determined. A line extending from the origin, point O, through point A (or A') intersects the factored interaction diagram at point B. The coordinates of point A define a case where the applied loading lies within the interaction space. Point A' represents a case when coordinates of the applied loading (M'$_{app}$ and P'$_{app}$) values lie outside the interaction space. In either case, the coordinates of point B define the axial and moment capacity for the given load case.

The applied loads from every strength limit state case are used to evaluate the capacity since the governing values cannot be determined by inspection. The case that yields the lowest performance ratio (capacity/demand) is considered to be the governing case.

3.6.2.2 Spacing Requirements (maximum and minimum)

The procedure used to check the spacing of reinforcement is identical to that used in the footing. Please refer to Section 3.5.2.6 for a description of the reinforcement spacing check.

3.6.2.3 Minimum Area

The procedure used to check the minimum area of reinforcement is identical to that used in the footing. Please refer to Section 3.5.2.7 for a description of the minimum area of reinforcement check.

3.6.2.4 Serviceability Allowable Stress

The procedure used to check allowable stress is identical to that used in the footing. Please refer to Section 3.5.2.8 for a description of the allowable stress check.

3.6.2.5 Shear

The program evaluates the shear capacity based on the properties of the concrete section. The procedure used is identical to that used in the footing. Please refer to Section 3.5.2.9 for a description of the shear capacity check.

3.6.3 Design of a Stem Section

The stem reinforcement design follows the footing algorithm. The program will compute the area of steel required for the applicable strength limit states. The area is determined by considering the combinations of applied factored moment (maximum and minimum) and axial load (maximum and minimum) for a given limit state. This is described in Section 3.6.2.1. The governing area of steel is the maximum area that was required based on all of the applicable load combinations.

The spacing for each bar size is evaluated for the governing area of steel. The bar spacing is reduced to the nearest user entered increment as described in Section 3.5.3.

For each bar size and spacing, the serviceability requirements are applied as described in Sections 3.6.2.2 through 3.6.2.4. They include minimum and maximum spacing requirements, minimum area of steel and allowable stress.

Furthermore, stem bars are considered to be hooked into the footing.

The development length of each bar is computed by the program. The development length is an indication of the bar length that is required to develop the tensile stress. It is computed based on the section properties at the base of the stem. Two development lengths are calculated for each bar size; one for hooked bars and one for straight bars. Bar sizes that have hooked bar development lengths greater than the footing thickness less the bottom cover are rejected. Typically, large bars cannot be developed in relatively thin footings. These bars are flagged in the output results table.

The program will try to determine a theoretical cutoff point for each bar as shown in Figure 3.6.3-1(a). The theoretical cutoff point is defined as that point where every other bar is no longer required in the section, i.e., for a given bar size, twice the rebar spacing at the theoretical cutoff location must satisfy the strength, serviceability, and shear requirements. Serviceability includes service-level crack control spacing checks and minimum and maximum bar spacing checks. The cutoff point must be greater than or equal to the straight bar development length of the given bar. In the figure, the rebar spacing at the base is 6 inches. Hence, the theoretical cutoff point is located where a 12 inch spacing is acceptable.

The actual (or physical) cutoff point for a bar is determined by adding the extension length of the bar to the theoretical cutoff point. The extension length for each bar is the larger of:

- effective depth of the section at the theoretical cutoff point; or,
- 15 bar diameters; or,
- 12 inches.

As Figure 3.6.3-1(a) shows, the physical cutoff points are not permitted within 2 ft. of the top of the stem. For each bar size, the program will identify those bar sizes that can be cutoff. In some cases (typically large bars), the allowable bar maximum spacing controls the spacing requirement at the base of the stem. Such bars cannot be cutoff.

The length of bars that are not cutoff will be the stem height (front face) less 3 inches. Figure 3.6.3-2 illustrates the stem height (front face) for Abutment Types I and II.

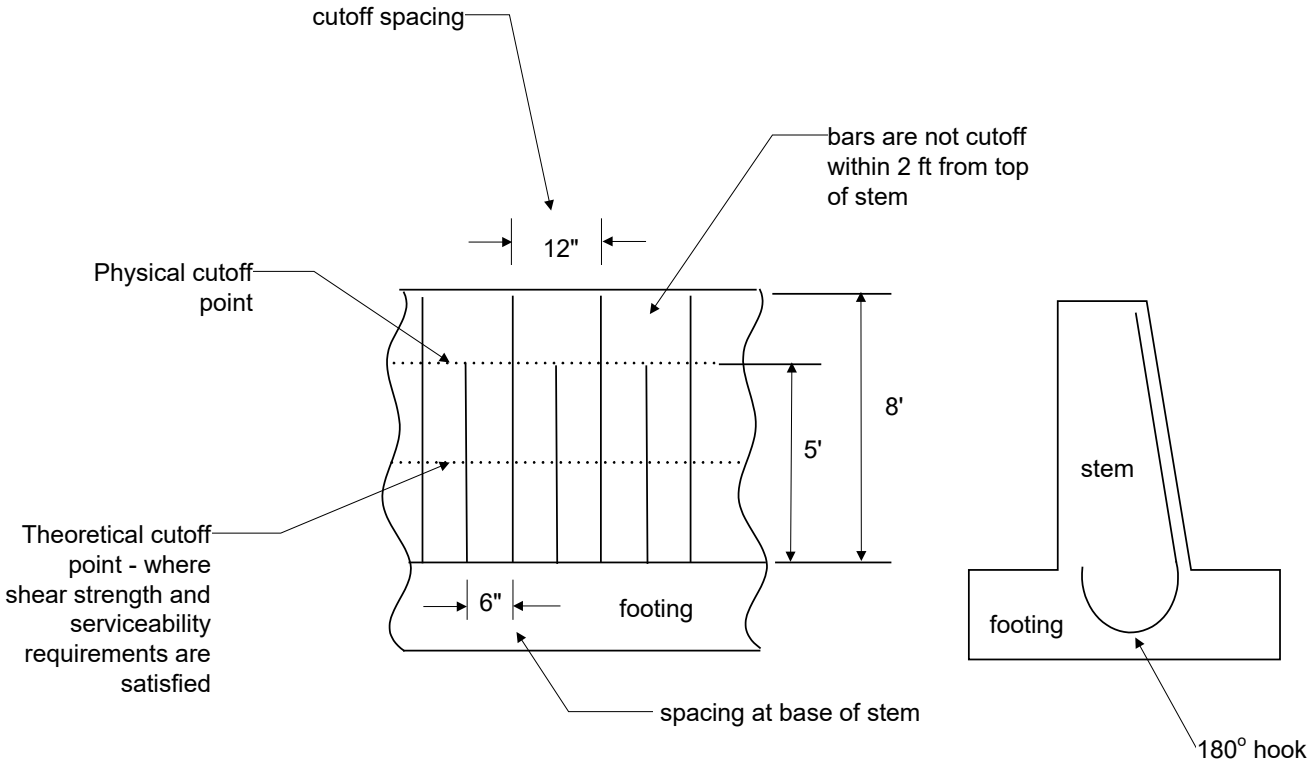
The program will also compute the lap length of each bar. The lap length is the bar overlap that is required to splice bars as shown in Figure 3.6.3-1(b). Typically, lapped bars can be found in very tall stems - where it is impractical to have bar lengths that extend from the footing to the top of the stem. This information is provided to be used at the discretion of the engineer.

The lap length is equal to the development length multiplied by the splice factor. The splice factor of 1.3 is based on a Class 'B' splice.

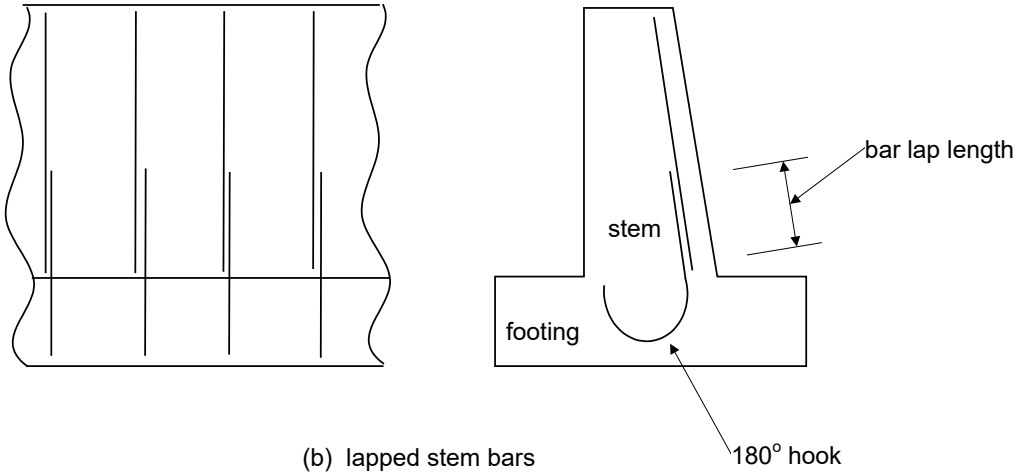
$$Lap = 1.3\, l_d$$

The development length calculations are described in Sections 3.5.2.3 and 3.5.2.4.

If the lap length for a given bar exceeds the height of the stem or the height of the backwall (if applicable), that bar will not be considered to be a valid solution.

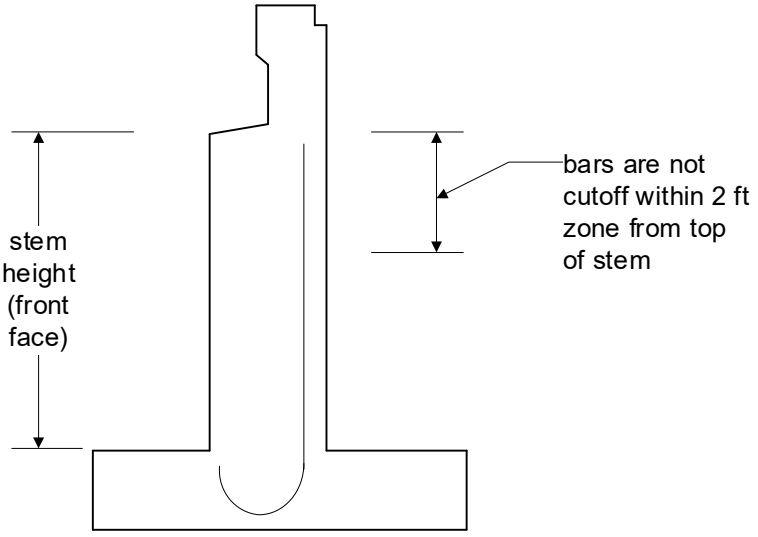


(a) theoretical and physical cutoff locations in the stem

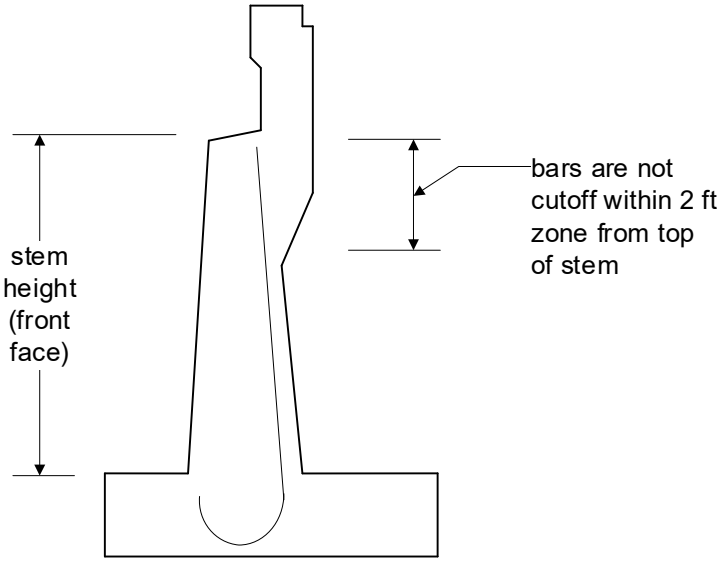


(b) lapped stem bars

Figure 3.6.3-1 Stem Design Considerations



(a) Abutment type I - zone where bars are not cutoff



(b) Abutment type II - zone where bars are not cutoff

Figure 3.6.3-2 Cutoff Considerations for Abutment Types I and II

3.6.3.1 Optimum Reinforcement Selection

The program provides two optimum bar sizes for the stem with each design run. The first optimum bar size is determined by calculating the weight of the reinforcement for the design width and then selecting the bar size that results in the least weight per design width. The second optimum bar size is similar to the first except the program considers if a bar can be cutoff and calculates the weight accordingly. In most design

cases the optimum bar for both will coincide but it is possible for the program to select two optimum bars. It is left to the user to decide which bar size to use depending on the applicability of cutoff stem bars in the final design.

3.6.4 Design of a Backwall Section

The backwall reinforcement design follows the stem algorithm. The program will compute the area of steel required for the applicable strength limit states. The area is determined by considering the combinations of applied factored moment (maximum and minimum) and axial load (maximum and minimum) for a given limit state. This is described in Section 3.6.2.1. The governing area of steel is the maximum area that was required based on all of the applicable load combinations.

The spacing for each bar size is evaluated for the governing area of steel. The program can then, through user input, either set the bar spacing to be a multiple of the optimum stem bar spacing or set the bar spacing independent of the optimum stem bar spacing. If the stem bars are cutoff and the user requests the backwall bars be aligned with the stem bars, then the backwall spacing is set to either 2x the stem bar spacing, or 4x the stem bar spacing (whichever is less than 18 inches and provides the least amount of reinforcement required). For cases when the program cannot find a valid design at the stem bar spacing with cutoffs, the program will reduce the backwall bar spacing to match the stem bar spacing without cutoffs and proceed through the design algorithm once more.

For each bar size and spacing, the serviceability requirements are applied as described in Sections 3.6.2.2 through 3.6.2.4. They include minimum and maximum spacing requirements, minimum area of steel and allowable stress. In addition, the program also calculates the splice length for each bar based on the development length described in Section 3.5.2.3.

If the $A_{sprov}/A_{sreqd} < 2$ – Class C splice

$$l_{spt} = 1.7 * l_d$$

If the $A_{sprov}/A_{sreqd} \geq 2$ – Class B splice

$$l_{spt} = 1.3 * l_d$$

The splice length is then compared to the available height in the backwall to develop the splice.

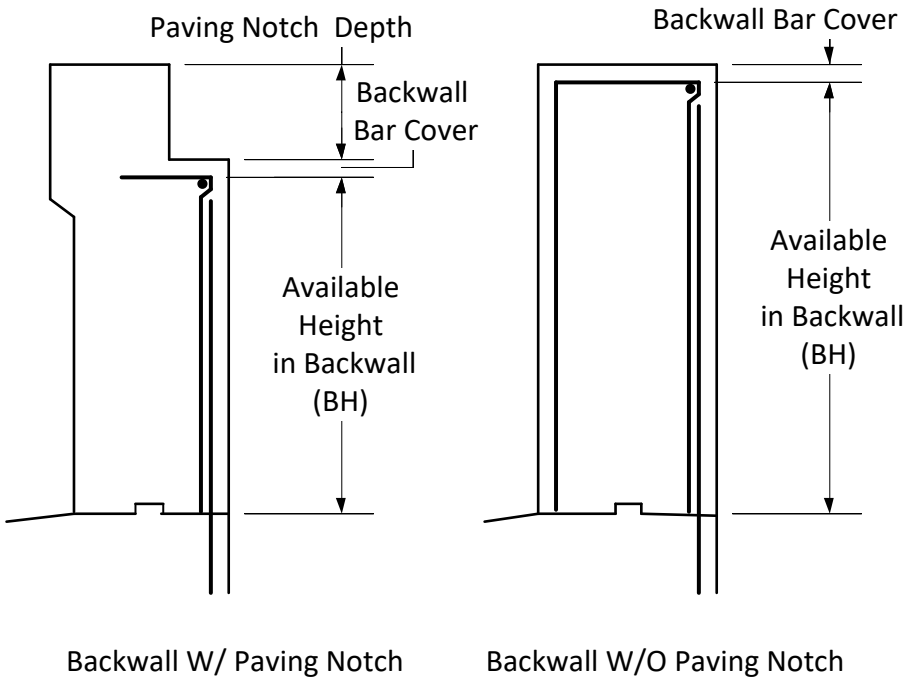


Figure 3.6.4-1 Backwall Height for Splice Check

If the splice length of a bar exceeds the backwall height, the program will solve for a new reduced bar spacing that may allow the splice to fit within the backwall height. The new splice length is set equal to the backwall height and a new area of steel (A_{sprov_new}) is solved for. The new area provided is used to determine the new bar spacing. A limit is placed on the ratio used to increase the area of steel to prevent the development length for the new spacing from being less than the 12 in minimum. Also, the area of steel in the A_{sprov_new} equation is limited to be no less than the area of steel required for strength.

$$S_{new}=\frac{A_{sbar}*12}{A_{sprov_new}}$$

$$A_{sprov_new} = MAX(A_{sprov_old}, A_{sreqd}) * Ratio$$

$$Ratio = MIN\left[\frac{l_{spt_old}}{BH}, \frac{l_{d_old}}{12}\right]$$

Where: s_{new} = Bar spacing needed so the splice will fit within the backwall (in)

A_{sprov_new} = Area of steel needed so splice will fit within the backwall (in^2)

A_{sreqd} = Area of steel required to satisfy backwall strength requirements (in^2)

A_{sprov_old} = Area of steel provided in backwall for specified bar size (in^2)

A_{sbar} = Area of the specified bar (in^2)

l_{spt_old} = Old splice length for the specified bar size (in)

l_{d_old} = Old development length for the specified bar size (in)

BH = Backwall height minus the backwall cover and minus the paving notch, if one is present. This is the largest available distance the splice can be and fit within the backwall (in)

Ratio = The ratio used to increase A_{sprov_old} so the splice will fit within the backwall

3.6.5 Gravity Wall Tension Check

Gravity walls are considered to be unreinforced structures. Consequently, the program checks for tension at the extreme fiber of the stem sections (in the back face or front face depending upon which face is in tension).

The stress in the stem wall is evaluated at each stem location. It is based on the gross cross section properties as shown in the equation below:

$$stress = \frac{-VLF}{A_{gross}} + \frac{M_{app}}{\frac{bh^2}{6}}$$

A positive value indicates that the stress is tensile. The allowable tension is set to 0.0.

3.7 DESIGN CONSIDERATIONS

The algorithm to select the optimal design solution varies for each type of footing (spread, pile, caisson, or pedestal). The following sections describe the unique features of the design algorithm and the choice of the optimal design solution for each footing type - spread in Section 3.7.1, pedestal in Section 3.7.2, and pile/caisson in Section 3.7.3.

3.7.1 Spread Footings

This section addresses the special considerations that are applied to spread footings. Design algorithm issues are addressed in Section 3.7.1.1. Design optimization issues are described in Section 3.7.1.2.

3.7.1.1 Design Algorithm

The algorithm follows the generic procedure of iterating through the footing geometry configurations that were described in Section 3.2.1. Footing Stability and Reinforcement design checks are applied for each footing configuration. Stability checks are described in Section 3.4.1. Reinforcement checks are identified in Section 3.5.2.

3.7.1.2 Evaluation of Optimal Design

The program will evaluate the cost of all successful configurations (all strength and serviceability checks were satisfied). The cost of the footing is a relative measure of optimal design. The cost function for spread footings may be based solely on the footing volume or on the cost required for the concrete footing and the cost of the excavation (if specified) and backfill. These procedures apply to footings founded on either soil or rock. The choice is specified in the SPR command (Section 5.11).

The volume option only considers the footing area per unit length, i.e. the volume is the footing thickness multiplied by the footing width multiplied by a unit length of the substructure. If two configurations have the same volume, the program will select the configuration with the **minimum** toe projection. **During the design, the program stores the design minimum footing volume. When footing width and thickness are incremented, the program ignores any footing size that exceeds the minimum volume.**

If the cost option is selected, the user must specify if the structure is situated in a cut or in a fill. In either case, the cost includes the cost of the volume of concrete required for the footing. The unit costs for concrete, excavation (if specified), and backfill must be entered by the user. The costs are based on a unit length of the substructure.

The cost of a structure (per unit length of the substructure) situated in a fill will be:

- the cost of the concrete footing (footing volume times concrete cost); plus,

- the cost of the backfill material (fill area times cost of backfill).

The cost of a structure (per unit length of the substructure) situated in a cut will be:

- the cost of the concrete footing (footing volume times concrete cost); plus,
- the cost of the excavation (cut area times cost of excavation); plus,
- the cost of the backfill material (fill area times cost of backfill).

Costs of excavation, backfill and concrete are specified in units of $\$/yd^3$ in the SPR command (Section 5.11).

A structure is considered to be situated in a cut if part of the original ground surface must be excavated (i.e. cut) in order to construct the structure.

If the user specifies that the structure is in a cut, the program will compute the cost for both the excavation and backfill. If the structure is situated in a fill, the program evaluates the cost of the backfill only. The program assumes a unit length of the substructure, hence the description is based on the cut area and the fill area.

Figure 3.7.1-1 shows the cross sectional area of the material that is cut. It is applicable for footings in either soil or rock. The area is bound: on the top by the original ground line ED; at the bottom by the elevation of the footing base, line FC, and on the sides by lines (EF and DC) that have a slope of 1 vertical unit per 1.5 horizontal units. Point F is located 1 ft to the left of the toe. Point C is located 1 ft to the right of the heel.

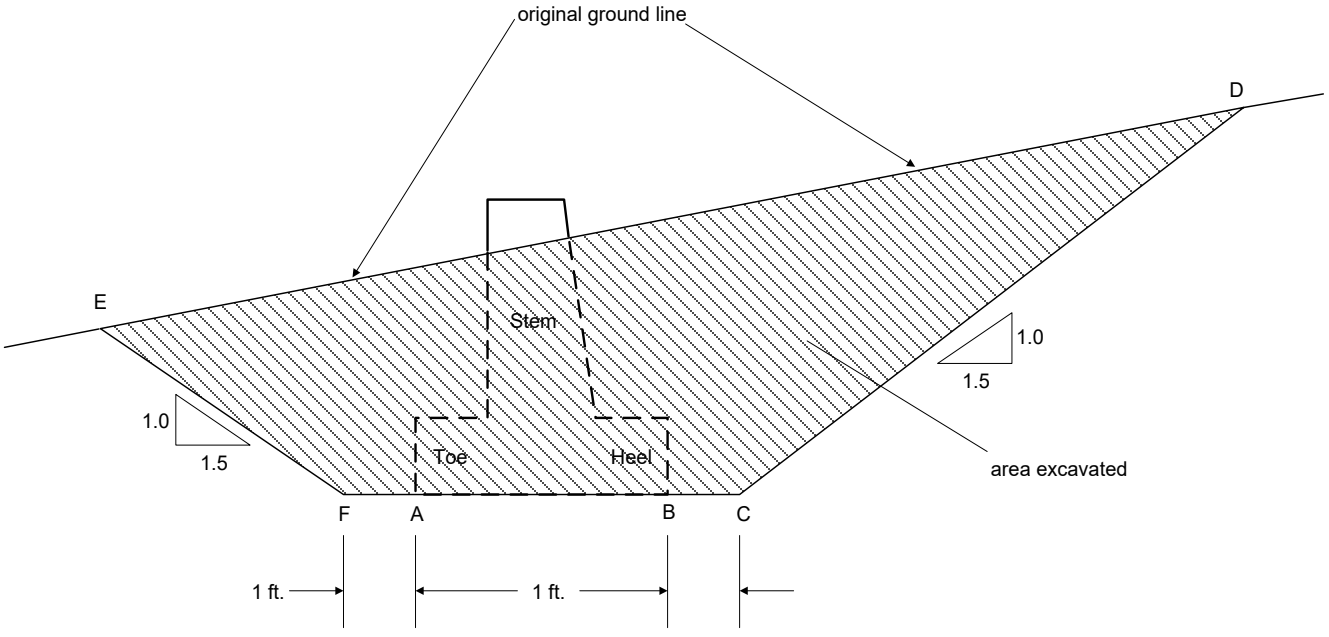


Figure 3.7.1-1 Cut Area For Structures Situated In a Cut

3.7.1.2.1 Backfill Area for Structures Situated In a Fill

Figure 3.7.1-2 illustrates the backfill areas for structures situated in a fill. Figure 3.7.1-2(a) shows the backfill area for a retaining wall with two backslope configurations. The backfill area is bound: at the top by the backfill surface; on the left side by the outline of the back face of the stem; on the bottom by the two line segments: line AB that is the top surface of heel projection; and, line BC that extends from the top corner of the heel at a slope of 1 (vertical) to 1.5 (horizontal) until it intersects the surface of the backfill. Hence, the backfill area for the straight backfill case is defined by the polygon ABCD, and the broken backfill case is defined by the polygon ABCED.

Figure 3.7.1-2(b) illustrates the backfill area of an Abutment Type II structure. Note that the backfill area extends into the paving notch area. The backfill area is defined by the striped area behind the backwall i.e. ABCD.

3.7.1.2.2 Backfill Area for Structures Situated In a Cut

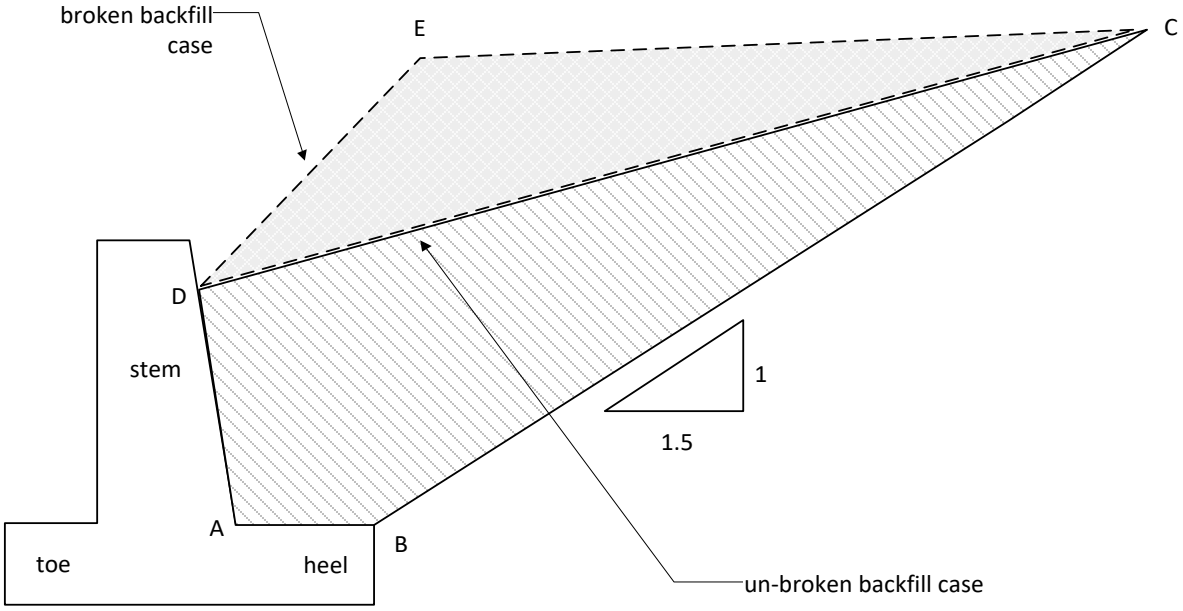
Figure 3.7.1-3 illustrates the backfill areas for structures situated in a cut. Two variations are shown in the figure: (a) when the original ground is sloping upwards towards the heel (slope type ‘H’ in the SPR command); and (b) when the original ground slope is sloping upwards towards the toe (slope type ‘T’ in the SPR command).

The backfill area is defined by the polygon ABCDE that is constrained: on the top by the surface of the backfill (line DE); on the left side by back face of the stem and heel projection; at the bottom by a 1 ft horizontal line (AB) extending from the base of the heel (point A); on the right side by two line segments; one a vertical segment BC that intersects the original ground line 1 ft to the right of the heel, and another segment that extends from the intersection point (c) at a slope of 1 (vertical) to 1.5 (horizontal) until it intersects the backfill at point D.

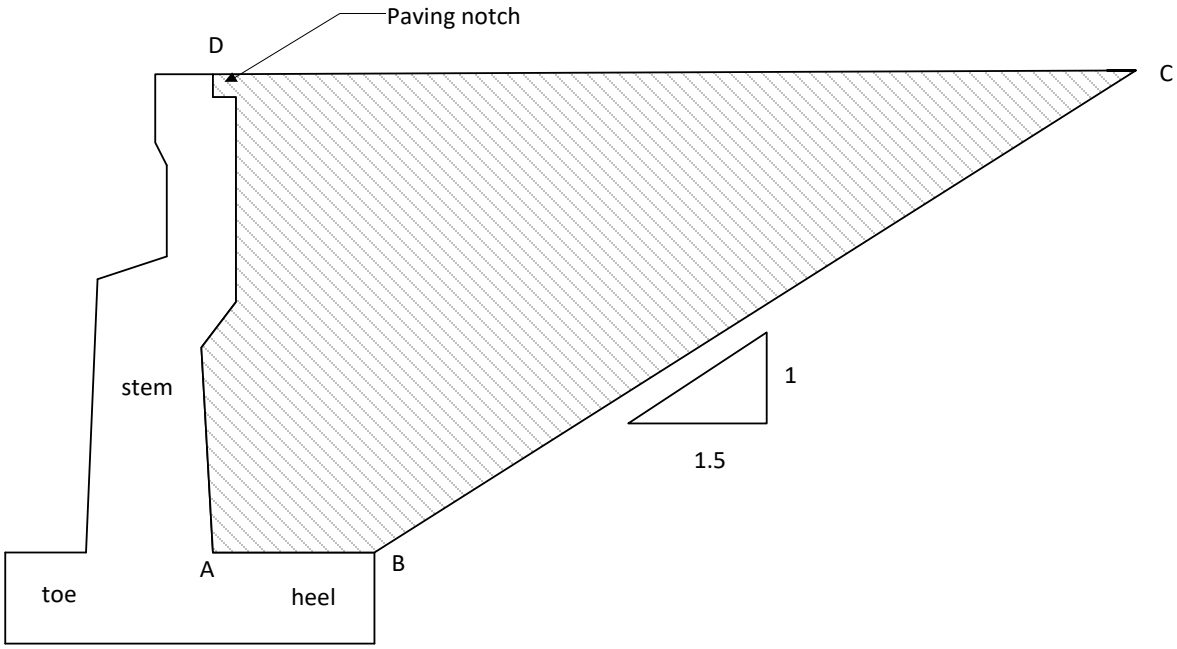
3.7.1.2.3 Special Cases of Backfill Areas for Structures Situated In a Cut

Figure 3.7.1-4(a) illustrates the case when the original ground is above the backfill elevation. The backfill area is bound: on the top by the backfill surface (line CD); on the left side by the back face of the stem and heel projection; on the bottom by a line (AB) extending 1 ft to the right from the base of the heel; on the right side by a vertical line (BC) situated 1 ft from the right of the heel that intersects the backfill.

Figure 3.7.1-4(b) illustrates the case when the original ground slope (type ‘H’) is steeper than 1 (vertical) to 1.5 (horizontal). This case is a variation of that shown in Figure 3.7.1-3(a). The difference is that the line segment CD has a steeper ground slope value instead of the 1 (vertical) to 1.5 (horizontal) slope.

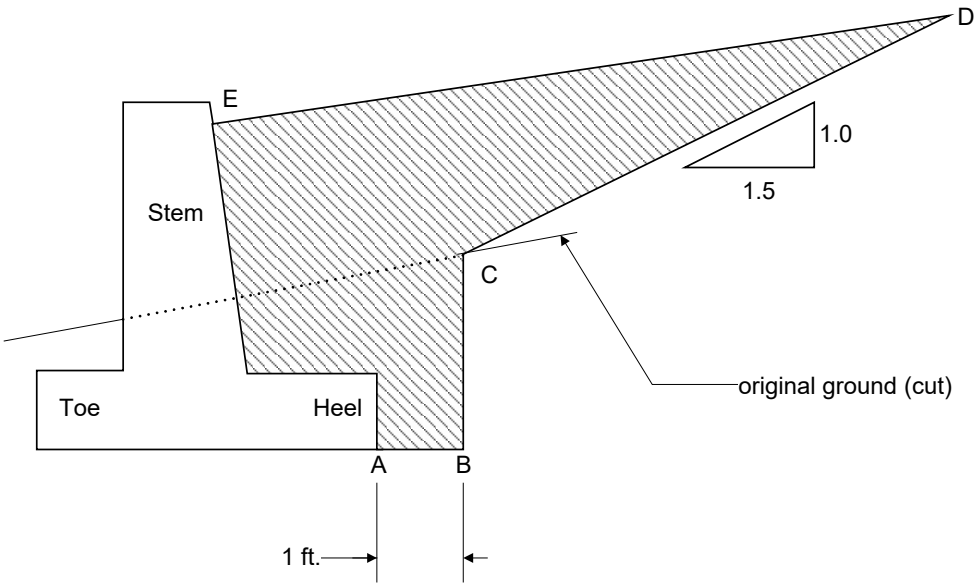


(a) Retaining wall showing broken and un-broken backfill cases

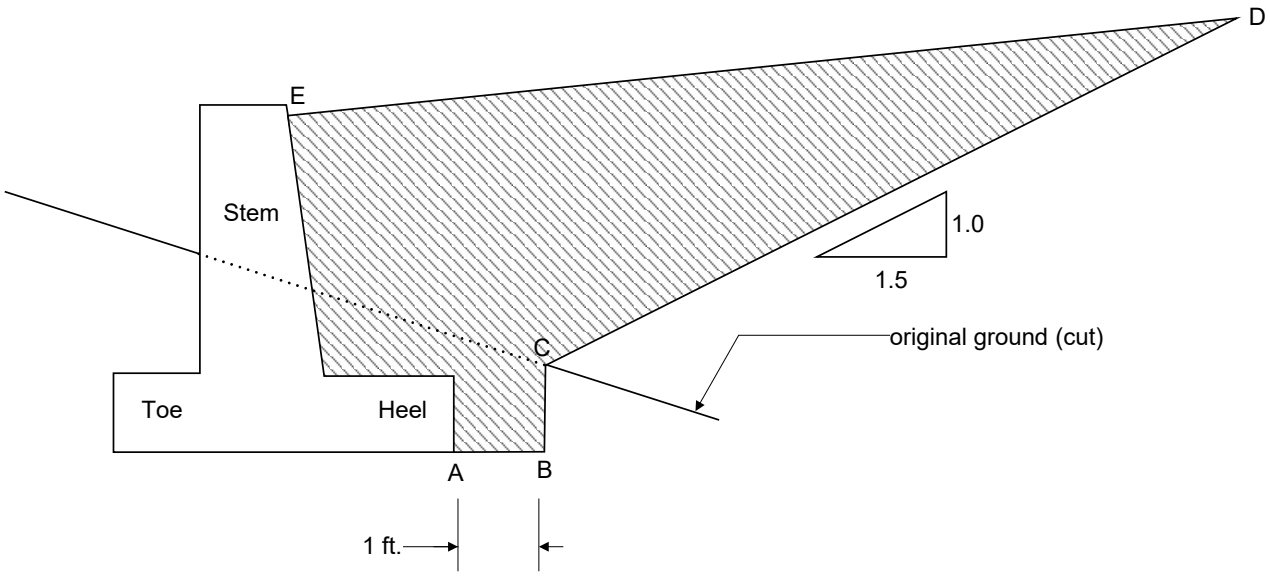


(b) Abutment Type II

Figure 3.7.1-2 Examples of Backfill Area for Structures Situated in a Fill

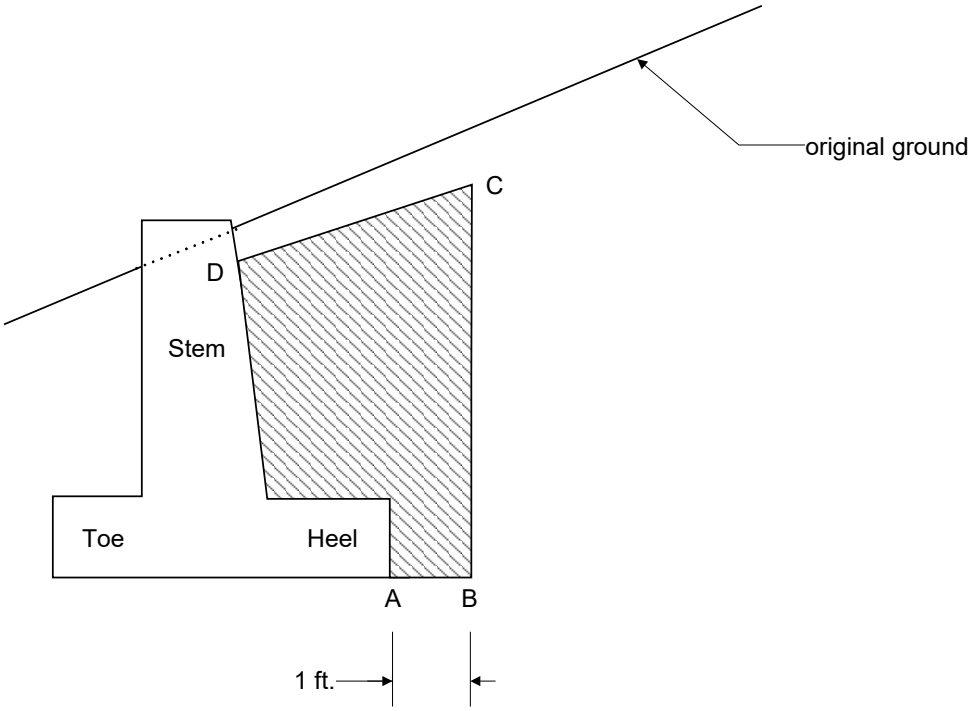


(a) Original ground with slope type 'H'

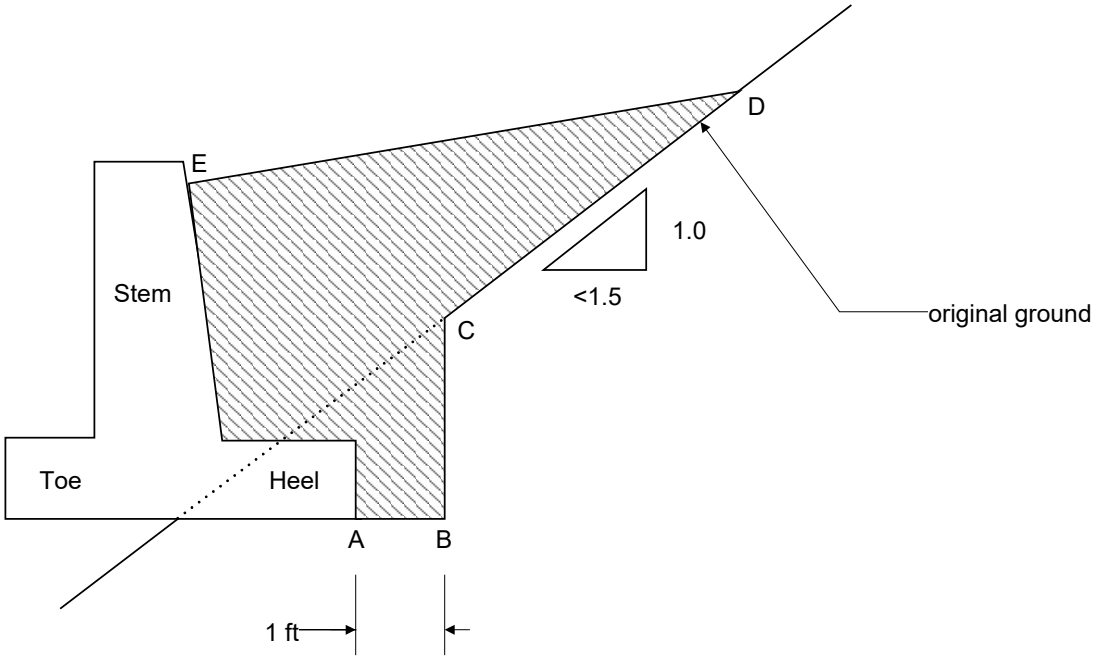


(b) Original ground with slope type 'T'

Figure 3.7.1-3 Examples of Backfill Areas for Structures Situated in a Cut



(a) Case when the original ground is above the backfill



(b) Case when the orignal ground has a slope steeper than 1.0 (vert) to 1.5 (horiz)

Figure 3.7.1-4 Special Cases of Backfill Areas for Structures Situated in a Cut

If two configurations have the same cost, the program will select the configuration with the least footing volume. If two configurations have the same cost and the same footing volume, the program will select the configuration with the maximum toe projection.

3.7.2 Pedestal Footings

The program is iterating through a range of footing configurations as described in Section 3.2.1. For each footing configuration (thickness, width, toe projection), the program will search for a pedestal configuration that satisfies the design specifications.

Section 3.7.2.1 describes the algorithm that is used to iterate through the range of user-specified pedestal configurations. The selection process for determining the optimal design from a set of successful geometrical configurations is described in Section 3.7.2.2.

3.7.2.1 Pedestal Design Algorithm

As the program iterates through the set of footing configurations, another set of iterations is performed for the pedestal geometry for each footing configuration. This section describes the pedestal design procedure. It refers to the step entitled “evaluate footing checks and perform pedestal design ...” at the top left hand side of Figure 3.2.1-2. The flowchart in Figure 3.7.2-1 is an overview the design procedure.

The pedestal design consists of three types of checks:

- Footing stability on the pedestal (Sections 3.4.2.1 through 3.4.2.1.3)
- Pedestal stability (Section 3.4.2.4) on the foundation
- Footing flexure (strength and serviceability) and shear (Section 3.5.1.3)

The results of these checks will determine how the pedestal geometry is adjusted. The variations in pedestal geometry are identified in Figure 3.7.2-2.

The set of pedestal configurations is defined by the user-specified maximum and minimum pedestal width, and the width incremental value which is a program parameter set to 3 inches. The user also specifies a range (minimum, maximum) of values for the pedestal thickness. The incremental value for the pedestal thickness is a program parameter set to 1 inch. Figure 3.7.2-2 is an overview of the salient features of the pedestal design.

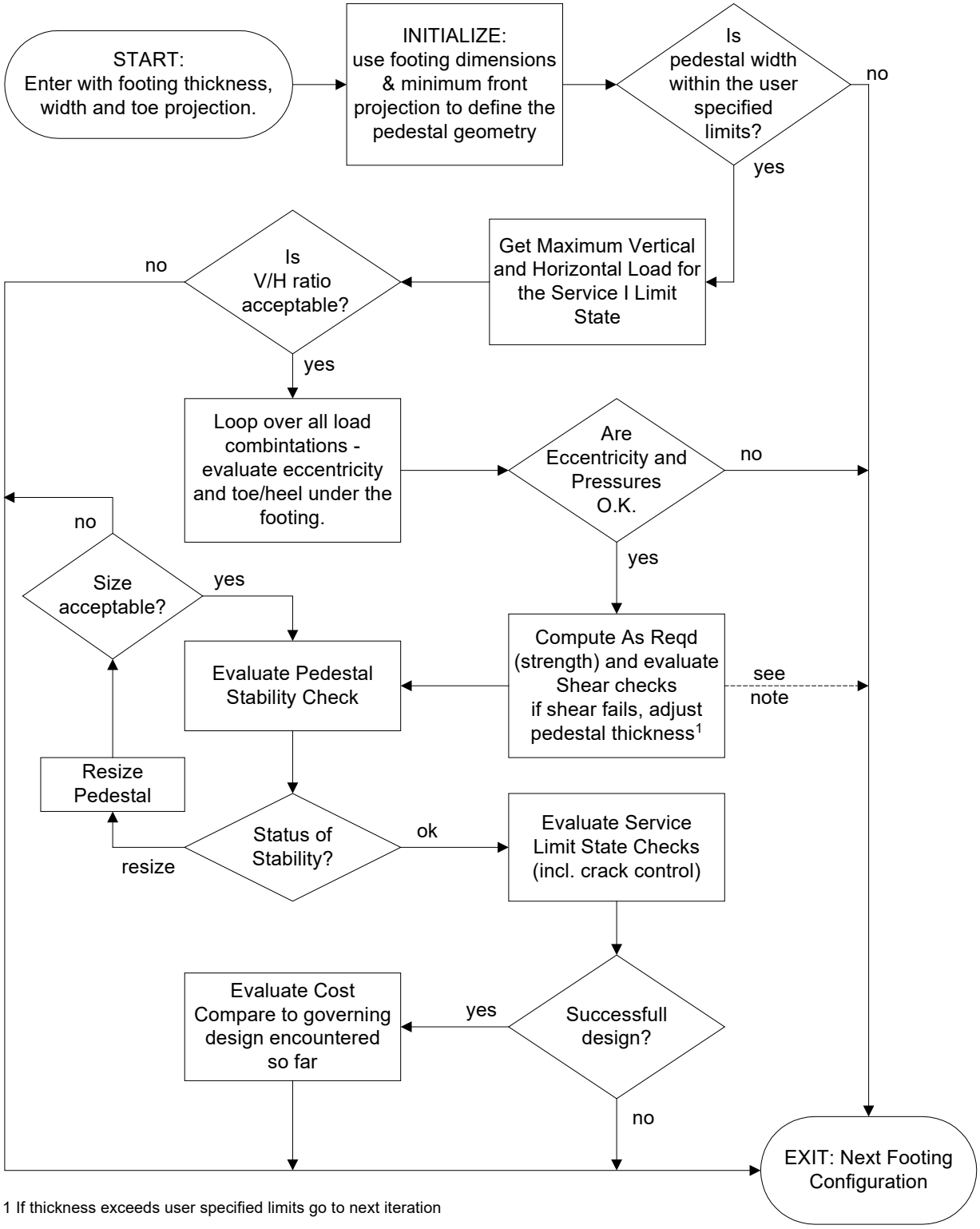
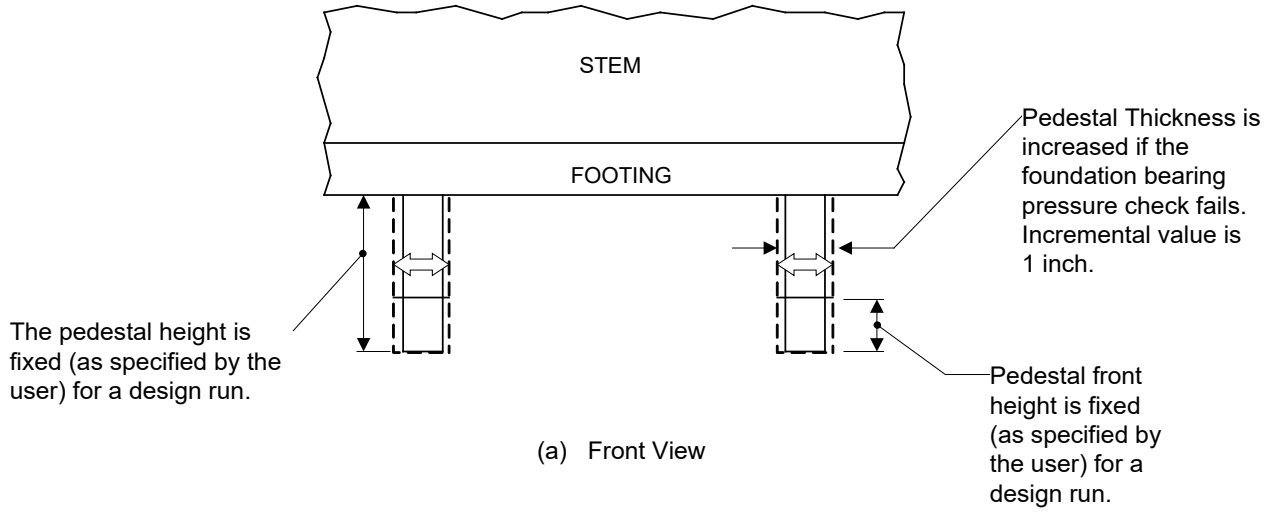


Figure 3.7.2-1 Outline of Pedestal Design Procedure



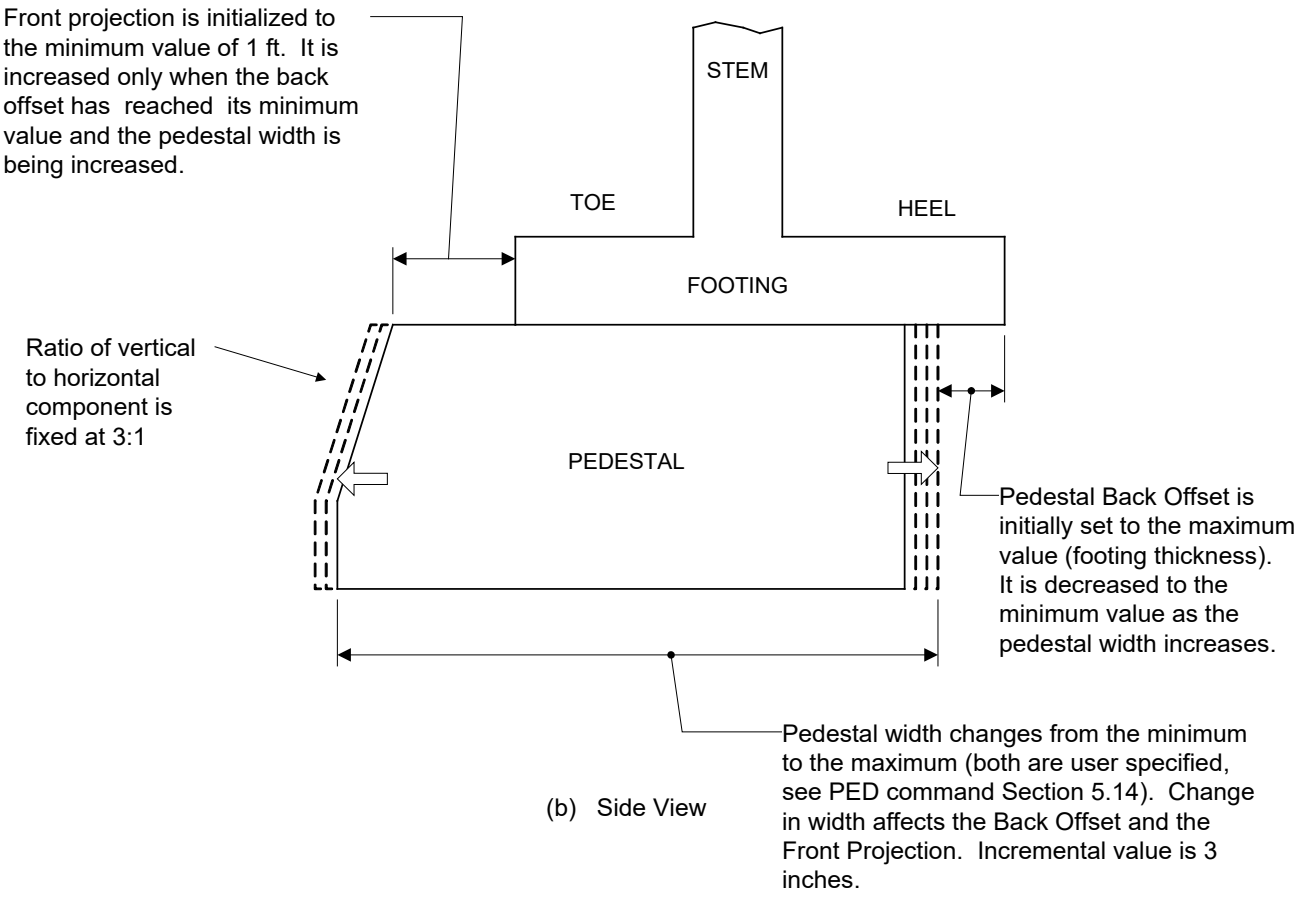


Figure 3.7.2-2 Pedestal Configurations for Design

The front projection as per DM-4 and the height of the pedestal as specified by the user are fixed for the design problem. In a design run, the user should not specify the pedestal back offset nor the front projection. The restrictions for input are described in the PED command (Section 5.14).

For a given footing configuration, the program will start with a pedestal configuration such that the front projection is set to 1 ft., and the back offset set to the value of footing thickness. Given the footing width, front projection, back offset and the horizontal projection of the pedestal front slope, the pedestal width can be computed. The width must be less than the maximum width and greater than the minimum width as specified by the user. If the maximum pedestal width is not specified, the default value is set to twice (program parameter) the footing width.

If the pedestal width falls outside the acceptable range, that configuration is ignored by the program. The program will skip to the next iteration in the footing iteration scheme (Section 3.2.1 through 3.4.2.3). As the footing dimensions (width and thickness) change, new pedestal dimensions will be computed.

When the program encounters a pedestal width that satisfies the geometrical requirements described above, the program will apply the stability (footing on pedestal) checks as described in Section 3.4.2. Sliding is checked by evaluating the ratio of vertical to horizontal loads. It is the first stability check to be evaluated as shown in Figure 3.7.2-1. If the bearing pressure check or the eccentricity check fails, the program will skip to the next iteration in the footing geometry.

If the footing is stable (see Section 3.4.2), the area of steel required (based on strength requirements) in the footing in the parallel direction is evaluated. The calculation of the applied moments (strength and service) is described in Section 3.5.1.3.1. The shear check, as described in Section 3.5.1.3.2, is also evaluated.

If the footing shear check fails, the program will skip to the next iteration in the footing geometry. Otherwise, the rebar spacing calculations are performed based on the area of steel required, as described in Section 3.5.2.

In the next step, the program evaluates the pedestal stability, i.e. pedestal on foundation as described in Section 3.4.2.4. There are three outcomes: bearing failure; eccentricity failure; or success.

If there is a bearing pressure failure, the program adjusts the pedestal thickness by an increment (by 1 inch), and the program re-evaluates the stability checks for the given width.

The pedestal thickness influences the parallel moment in the footing, because the clear spacing between pedestals, as described in Section 3.5.1.3, changes as the pedestal thickness changes. Hence, the reinforcement checks are affected by changes in the pedestal thickness. The program performs the footing

reinforcement (strength and serviceability) design only after the pedestal stability checks are satisfied. Changes in the thickness are only applied if the foundation bearing pressure check fails. That is, the pedestal thickness is incremented by 1 inch and the check is evaluated again if the new dimension is within the allowable limits specified by the user.

If an eccentricity failure occurs, the pedestal is resized. As the pedestal width is increased incrementally by 3 inches, the back offset is reduced by a corresponding decrement. When the back offset has reached the minimum allowable value of 1 ft., further increments in the pedestal width are matched by corresponding adjustments (increases) in the front projection.

After the pedestal width has been adjusted, the program will re-evaluate the pedestal stability. The program will ensure that the pedestal width falls within the acceptable limits. If the limits are exceeded, the program will skip to the next iteration of the footing geometry.

If the pedestal is stable (passes the eccentricity, bearing and settlement checks), the program will perform serviceability (the crack control) checks for the footing rebar as described in Section 3.5.2. To ensure that the variations in pedestal geometry have not altered the footing stability, the program will re-check the footing and pedestal stability.

If the program can find at least one bar that satisfies the serviceability requirements, the geometry is considered to be satisfactory and the pedestal economy (Section 3.7.2.2) is evaluated.

If the program cannot find a satisfactory solution given all of the variations in footing and pedestal geometry, a message is printed and the program terminates.

3.7.2.2 Evaluation of Pedestal Optimal Design

If all the checks (stability, strength and serviceability) are satisfied for a given footing/pedestal configuration, the cost of that configuration is evaluated. The cost function for pedestal footings may be based on pedestal density or on least footing volume. It is specified in the PED command (Section 5.14).

The pedestal density is defined as the pedestal volume divided by the pedestal center-to-center spacing (see Figure 5.14-1). The optimal design is the configuration with the least pedestal density. If two configurations have the same density, the least footing volume is used to select the optimal design. If the pedestal density and footing volumes are the same, the configuration with the **minimum** footing toe projection is selected.

The footing volume is defined as the thickness times the width times the length of **the footing**. **The footing length is entered as the third input value on the RCK command. Pedestals must be founded on rock.**

The optimal design is the configuration with the least footing volume. If two configurations have the same footing volume, the configuration with the least pedestal density is selected. If the footing volume and pedestal density are the same, the configuration with the **minimum** footing toe projection is selected.

3.7.3 Pile/Caisson Footings

The program iterates through a range of footing configurations as described in Section 3.2.1. For each footing configuration (thickness, width, toe projection), the program will search for an optimal pile placement geometry. Throughout this Section, the term ‘caisson’ can be used interchangeably with the term ‘pile’.

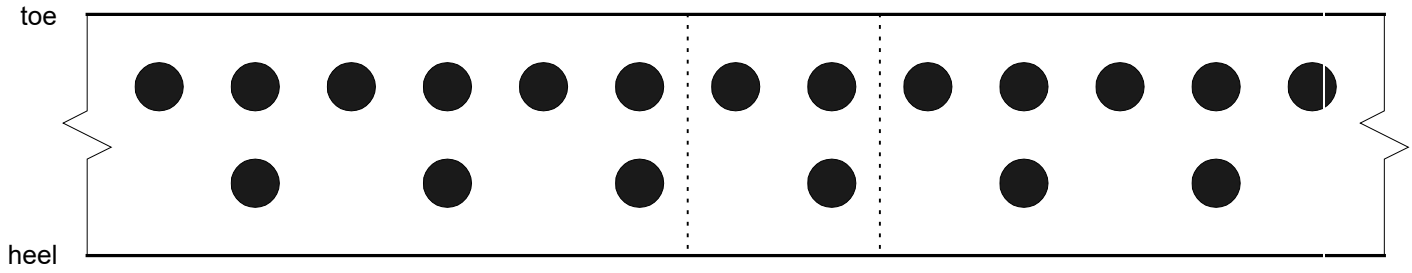
This section addresses the special considerations that are applied to pile footings. Design algorithm issues are addressed in Section 3.7.3.1. Design optimization issues are described in Section 3.7.3.2.

3.7.3.1 Design Algorithm for Pile Footings

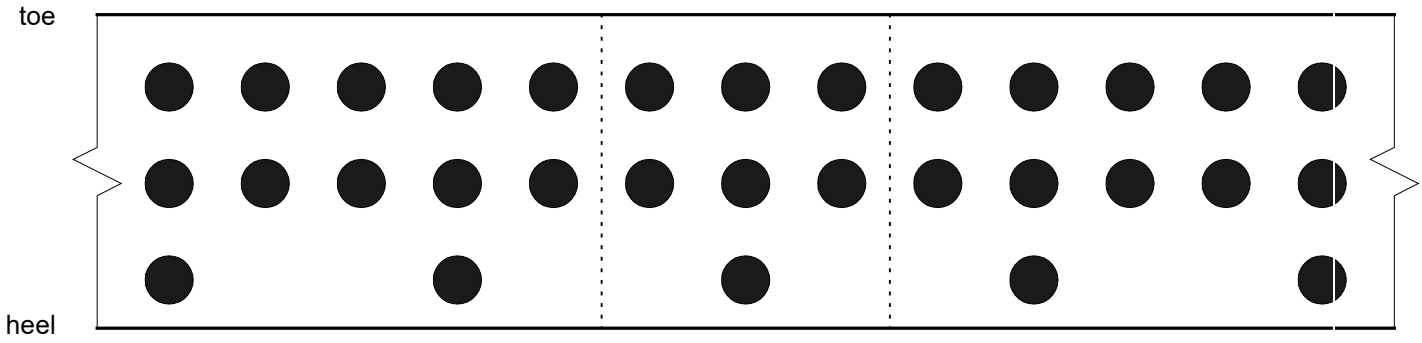
Inherent to the pile design algorithm is the use of patterns for placement of piles. This section therefore begins by describing pile patterns used in the program. Limits on spacing between piles are then outlined followed by a discussion of the design algorithm itself. The design algorithm is sufficiently complex as to warrant an example found at the end of this section. The example is referred to throughout the discussion of the design algorithm.

For each footing configuration (toe, heel, thickness and width), the program iterates through a set of pile patterns. A pile pattern is a numeric representation of the distribution of piles throughout the footing. It describes the number of pile rows and the number of piles in each row relative to the other rows. For example, the ‘4-4-2-1’ pattern indicates four rows of piles. For every 1 pile in the fourth row, there are 4 piles in the first row, 4 in the second and 2 in the third. Pile patterns are identified in Table 3.7.3-1.

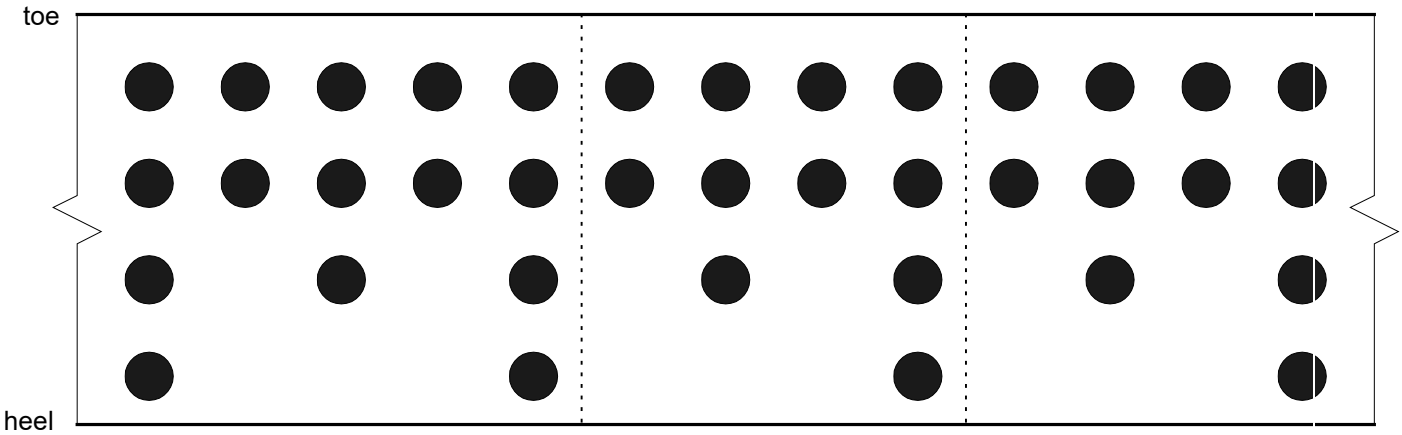
Piles and caissons may be arranged into a minimum of two rows, and a maximum of five rows. The first digit in the pattern definition represents the relative number of piles in the row closest to the toe. The remainder of the numbers correspond to piles in the rows that follow. Piles are positioned so that they are aligned with piles in other rows, thus allowing easy placement of reinforcement between piles. This is illustrated more clearly in Figures 3.7.3-1(a), (b) and (c) which show pile patterns ‘2-1’, ‘3-3-1’ and ‘4-4-2-1’ respectively. In this figure, the pile pattern is outlined by a dashed line. Note that the pattern is replicated along the length of the footing.



(a) 2-1 pattern for a two row configuration



(b) 3-3-1 pattern for a three row configuration



(c) 4-4-2-1 pattern for a four row configuration

Figure 3.7.3-1 Schematics of Sample Pile Patterns

Table 3.7.3-1 Pile Patterns used in the Program

Number of Rows	Pile Pattern Definition
2	1-1 2-1 3-1 4-1 5-1
3	1-1-1 2-1-1 2-2-1 3-1-1 4-1-1 3-3-1 4-2-1 5-1-1 4-4-1 5-5-1
4	1-1-1-1 2-1-1-1 2-2-1-1 3-1-1-1 2-2-2-1 4-1-1-1 3-3-1-1 4-2-1-1 5-1-1-1 4-2-2-1 3-3-3-1 4-4-1-1 4-4-2-1 5-5-1-1 4-4-4-1 5-5-5-1
5	1-1-1-1-1 2-1-1-1-1 2-2-1-1-1 3-1-1-1-1 2-2-2-1-1 4-1-1-1-1 2-2-2-2-1 3-3-1-1-1 4-2-1-1-1 5-1-1-1-1 4-2-2-1-1 3-3-3-1-1 4-2-2-2-1 4-4-1-1-1 4-4-2-1-1 3-3-3-3-1 4-4-2-2-1 5-5-1-1-1 4-4-4-1-1 4-4-4-2-1 4-4-4-4-1 5-5-5-1-1 5-5-5-5-1

It is important to note that the pile pattern is only a representation of the relative number of piles in each row and the pattern is expected to be repeated along the length of the physical abutment. The pattern is reflected in the pile spacings output by the program. For Design runs the program reports the pattern definition it uses in the Design algorithm, However it is the user's responsibility to apply the computed spacings to the physical footing.

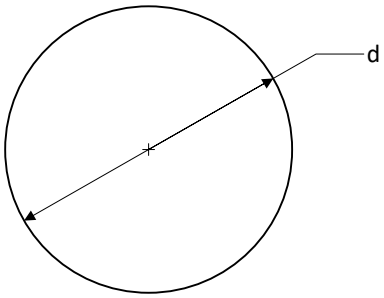
Spacings between pile rows and spacings within a pile row are limited by user input and the DM-4 Section 10.7.1.2. Spacing limits between piles are applicable in both the parallel and perpendicular directions (DM-4 Section 10.7.1.2):

- Maximum center to center spacing: 15 ft
- Minimum center to center spacing: 3 ft or
  - 2.5 times circular pile diameter
  - 2.0 times rectangular pile diagonal (the diagonal is equal to $\sqrt{d^2 + b^2}$)

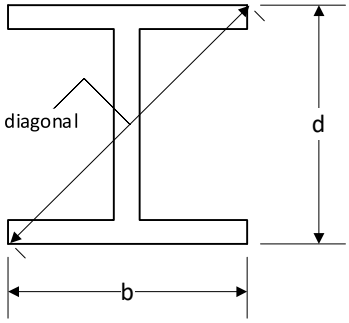
  } DM-4 Section 10.7.1.2
  - 4.0 times caisson diameter — LRFD Specifications Section 10.8.1.2

Figure 3.7.3-2 illustrates the minimum center to center spacing more clearly. Other limits include the following from DM-4 Section 10.7.1.2:

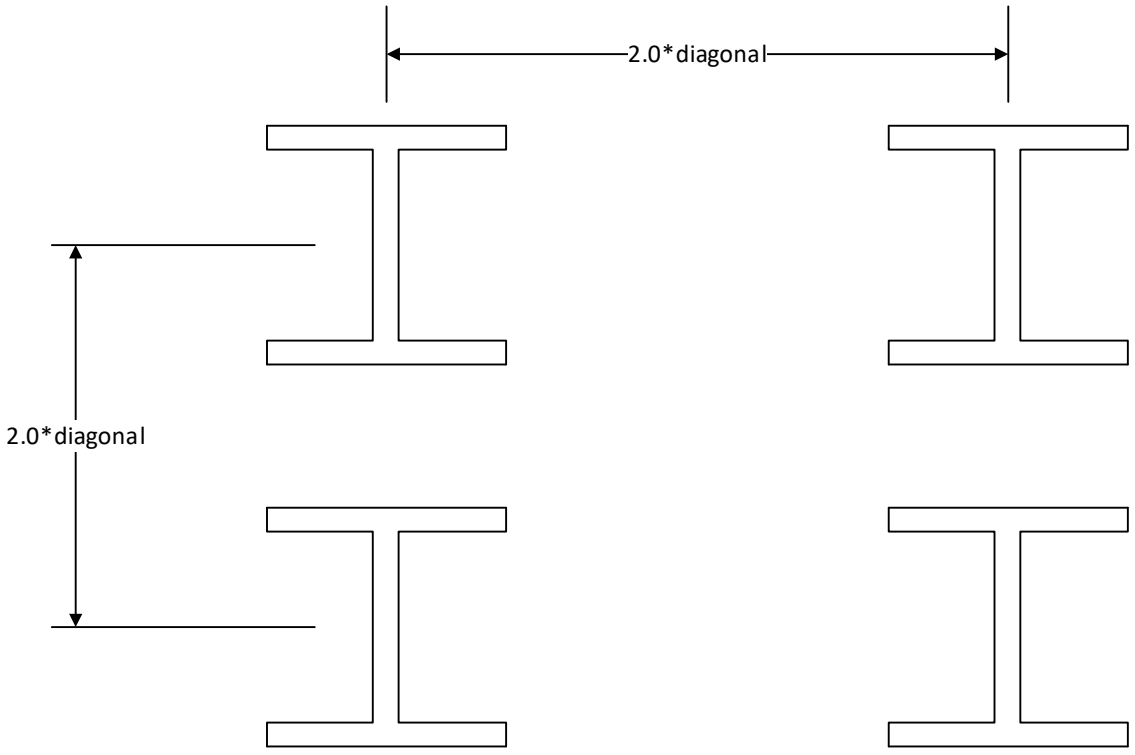
- Minimum footing edge to center of pile spacing: 18 in
- Minimum footing edge to edge of pile spacing: 9 in
- Minimum pile footing thickness: 2.5 ft
- Minimum pile embedment: 1 ft



Circular Piles - center to center
spacing is 2.5d
(4.0d for caissons)



typical rectangular (H) pile
dimenstions



Rectangular Piles - center to center spacing is 2.0 times the diagonal

Figure 3.7.3-2 Pile Spacings - Center to Center

Many of the limits described above can be checked before the actual design algorithm is executed and the program terminates if a limit is violated. Other limits are used within the design algorithm to assure complicity with the DM-4 specifications.

The design algorithm begins by placing rows of piles and then determining the spacing of piles within the rows. Example 1 at the end of this section represents the application of the design algorithm for a given footing configuration and pile pattern, and is useful as a reference for the following discussion. A convention has been adopted so that when a value is discussed, it can easily be found in the example problem. When (#N) is found in the text, the reader is directed to line N of the example problem to see the computed value.

For a given pattern, the program first determines whether the number of pile rows can fit within the footing width using the minimum spacing and edge distance limits. If the number of rows will fit, the first pile row is placed at the toe-to-first-row dimension and the last pile row is placed at the heel-to-last-row dimension. Interior pile rows are positioned evenly across the footing width or placed close to the toe depending on user input. Even placement results in interior pile rows placed at even intervals between the first and last row. If rounding is desired, the interior row positions relative to the first row are rounded to the nearest desired multiple, as input by the user. Rows placed close to the toe results in the interior rows positioned close to the toe, spaced at the minimum rounded up spacing entered by the user. The spacing between pile rows must conform to the minimum and maximum spacing criteria, or the pattern is rejected.

Once the pile rows have been positioned, the pile group centroid and moment of inertia are computed.

The pile group centroid is computed using this equation:

$$CG = \frac{\sum NP_i D_i}{\sum NP_i}$$

Where: *CG is the centroid of the pile group relative to the toe*
NP_i is the number of piles in the ith row from the pattern definition
D_i is the distance of the ith row from the toe of the footing

The moment of inertia used in the design algorithm is computed as if the entire pattern could fit within a unit length of abutment. This assumption is accounted for in the design algorithm equations that determine pile spacing within a row. Once the final layout of piles is determined, the moment of inertia is then modified to reflect a unit length of footing.

For the purposes of the design algorithm, the following equations are used:

$$I_g = \sum NP_i c_i^2 \text{ and } c_i = CG - D_i$$

Where: *I_g is the moment of inertia of the pile group*
c_i is the distance of the i^{th} row to the centroid of the pile group

The program then computes vertical pile loads and lateral loads for the pile group for each limit state load combination except for the Service limit state. Vertical pile loads are calculated using this equation:

$$V_i = \frac{V_{ftg}}{NP_{tot}} + \frac{V_{ftg}\, e\, c_i}{I_g}$$

Where: *V_i is the vertical load on a pile in the i^{th} row*

V_{ftg} is the vertical load (per unit length) acting at the footing bottom

NP_{tot} is the total number of piles from the pattern definition

e is the distance from the vertical load to the centroid of the pile group

The objective is now to determine the pile spacing within each row of piles. The program finds the greatest spacing allowed by the limits previously described so as to minimize the number of piles required to carry the load. The program batters piles if necessary to carry the load, starting with the row closest to the toe and moving toward the heel. If the user does not specify batter information in the input, the program will only consider an all vertical pile foundation and the references to battered piles that follow are not applicable.

The user enters two types of pile resistance which are used to determine pile spacings within a row. The user enters the lateral resistance of the pile assuming an all vertical pile foundation (#12). This resistance is generally obtained from an independent analysis using a program such as COM624 and is only applicable if all piles are vertical. The other resistance is the axial capacity of a pile (#11). For vertical piles, the axial capacity resists vertical loads but makes no contribution for lateral resistance. For battered piles, the axial capacity is resolved into a vertical and horizontal capacity (#16) using the batter slope and trigonometry. If the designed pile foundation has battered piles, the horizontal resistance is derived solely from the horizontal component of the axial capacity of piles that are battered.

The program computes pile spacings required to satisfy various conditions, such as vertical and lateral loads on vertical and battered piles. These spacings are collected for each row and a controlling spacing is determined. The equations consider each pile row separately, but produce a spacing for the row with the most piles in it (typically the first row). Therefore, as seen throughout the example problem, all computed spacings apply to the first row. After the design algorithm has found a satisfactory spacing for the first row, subsequent row spacings are simply a multiple of the first row spacing, depending on the number of piles for the row found in the pile pattern.

A corollary to the above assumption is that the maximum input pile spacing must be related to the row with the most piles. In other words, piles in the first row must be spaced such that piles in the last row will satisfy the maximum spacing criteria. This is accomplished with the following equation:

$$S_{max} = IN_{max}\left(\frac{NP_{min}}{NP_{max}}\right)$$

Where: S_{max} *is the maximum spacing of piles in the first row*

IN_{max} *is the maximum input spacing of piles*

NP_{min} *is the least piles in a row (last row)*

NP_{max} *is the most piles in a row (first row)*

The program begins by computing the pile spacing in each row required to carry the vertical load on the row. The spacing is computed first by assuming all piles in the row are vertical and then assuming all piles in the row are battered using the equations that follow:

$$S_{iVPVL} = \frac{CAP_A}{V_i\, NP_{max}}$$

$$S_{iBPVL} = \frac{CAP_V}{V_i\, NP_{max}}$$

Where: S_{iVPVL} *is the pile spacing in the* i^{th} *row (piles are vertical)*

S_{iBPVL} *is the pile spacing in the* i^{th} *row (piles are battered)*

CAP_A *is the axial capacity for a pile*

CAP_V *is the vertical component of axial capacity for a battered pile*

NP_{max} *is the most piles in a row (first row)*

The computed spacings are rounded down based on the input rounding values. If the vertical pile spacing for any row is less than the minimum spacing (#8), the pile group is unable to support the vertical load and a new pattern is tried.

Spacings required to resist vertical loads (computed above) are stored in a particular way that facilitates comparisons later on. For vertical piles, the stored spacing at a given row is the minimum of the computed spacing for the rows that follow. For battered piles on the other hand, the stored spacing at a given row is the minimum of the computed spacing for that row and any row towards the toe. This step is necessary when considering a partially battered pile footing, as explained below.

The algorithm only batters piles necessary to handle the lateral load, battering the first row and moving towards the heel. An intermediate row might be partially battered, while rows closer to the toe are assumed fully battered and rows closer to the heel are assumed fully vertical. Therefore, when comparing spacings for a given row, rows closer to the toe are controlled by battered pile spacings while rows closer to the heel are controlled by vertical pile spacings.

The program then computes the spacing required for an all vertical pile foundation to resist the lateral load on the foundation. This equation uses the COM624 capacity:

$$S_{VPHL} = \frac{NP_{tot} C_{624}}{NP_{\max} H_{ftg}}$$

Where: *S_{VPHL} is the pile spacing*
C_{624} is the lateral capacity of a pile in an all vertical pile foundation
H_{ftg} is the lateral load (per unit length) applied to the pile group
NP_{max} is the most piles in a row (first row)
NP_{tot} is the total number of piles from the pattern definition

The spacing required for battered piles to resist the lateral load is then computed. The equation is similar to the previous equation, but the capacities are cumulative because the first rows of piles may be battered while the last rows may be vertical:

$$S_{BPHL} = \frac{NP_{cum} CAP_H}{NP_{max} H_{ftg}}$$

Where: *$S_{BPHL}(I)$ is the pile spacing in the ith row (piles are battered)*
$NP_{cum}(I)$ is the cumulative number of battered piles for rows 1 to I
CAP_H is the axial pile capacity horizontal component for a battered pile
H_{ftg} is the lateral load (per unit length) applied to the pile group

For this step, the program batters all piles in a given row and later determines whether only a percentage of battered piles in the row will suffice. Implicit in this method is the assumption that for a partially battered pile row, the vertical load is resisted by fully battered piles in the row.

Now that the spacings for various configurations have been computed, the controlling spacing must be determined. For an all vertical pile foundation, the spacing is the minimum of $S_{VPVL}(I)$ and S_{VPHL}, as long as the minimum and maximum spacing limits are not violated. These spacings are shown in the example (#24, 25).

For a given row in a battered pile foundation, the spacing is the minimum of the stored values for $S_{VPVL}(I)$, $S_{BPVL}(I)$ and $S_{BPHL}(I)$ (#27, 29, 31, respectively). A valid spacing conforms to the input minimum and maximum spacing limits and is shown in the example (#32). The greatest valid spacing considering all rows is the control (#33). After the controlling spacing has been found, the program then determines how many piles to batter #36-39.

The above steps are performed for every applicable limit state load combination for a given pile pattern. Once the controlling spacing is found for the row with the most piles, the spacings of piles in all rows can be determined based on the pile pattern. A check is then made to determine if the footing and pile geometry is optimal (Section 3.7.3.2).

If a footing and pile configuration is determined to be optimal, design of the footing reinforcement is performed. The applied moments are obtained as described in Section 3.5.1.2. If the footing reinforcement design has a satisfactory solution, the footing and pile configuration is saved as an optimal design. Otherwise, the design is discarded. If a pattern is found to be unsatisfactory due to punching shear in the footing, the program will reanalyze the same pattern with a reduced pile spacing. This process is iterative and reduces the pile spacing until either a valid design is found, or the pile stability / spacing checks fail.

If the pile stability or spacing check fails at any time, a new pile pattern or footing configuration is tested. If a solution is not obtained, the program will issue a message and then terminate.

Example 1 Pile Design Algorithm

Input Data

			Assumptions		Line #
Footing width:		9.00	Rows are placed evenly		1
Toe to first row:		1.50	Spacings are not rounded		2
Heel to last row:		1.50			3
Number of rows:		3	Vertical batter:	3.00	4
			Horizontal batter	1.00	5
Pile	Row	Pile / Row			
Pattern	1	2	Last row % batter:	0.0%	6
Data	2	1			7
	3	1	Minimum spacing:	3.00	8
			Maximum spacing:	15.00	9
					10
Axial pile capacity:		25.00			11
Lateral pile capacity:		3.50	(COM624 - All piles are vertical)		12
Vertical load:		14.70	Toe to load:	3.67	13
Horizontal load:		3.90			14
(per unit length of footing)					

Computed Load and Pile Data

			Battered pile capacities		Line #
Total number piles:		4			15
			Vertical	Horizontal	
Max piles in a row:		2	23.72	7.91	16
Min piles in a row:		1			17
Max spacing (Row 1):		7.50			18
			Toe to CG Piles:	3.75	19
Load Eccentricity		0.08	Pile Group Inertia:	4.75	20

	1	**2**	**3**	Line #
Dist tow to row:	1.50	4.50	7.50	21
Dist CG piles to row:	2.25	-0.75	-3.75	22
Vertical load on pile:	3.78	3.64	3.50	23

(per unit length of footing)

Computed Spacings

Note: All spacings are computed from the row with the most piles (the first row)

All vertical pile foundation spacings

Spacing for vertical loads:	3.3052	OK	24
Spacing for lateral loads:	1.7949	NG	25

Battered pile foundation spacings

Legend: V = vertical, B = battered, L = lateral

Row:	1	2	3	
V loads, V piles	3.3052	3.4347	3.5747	26
Store (for B piles)	3.4347	3.5747	3.5747	27
	OK	OK	OK	
V loads, B piles	3.1356	3.2584	3.3912	28
Store (for B piles)	3.1356	3.1356	3.1356	29
	OK	OK	OK	
# of B piles (cumul.)	2	3	3	30
L loads, B piles	2.0271	3.0407	3.0407	31
	NG	OK	OK	
Valid spacing (min)	NG	3.0407	3.0407	32
Best valid spacing	3.0407			33

First Row Spacing Summary	All vertical piles:	1.79	NG	34
	Battered piles:	3.04	OK	35

Batter Summary			# piles to batter:	3	36
			Last battered row:	2	37
Actual spacing:	3.04	6.08	6.08		38
Percent batter:	100.0%	100.0%	Vert		39

3.7.3.2 Evaluation of Pile Optimal Design

The user has the following choices for the optimizing parameter: least pile density; minimum footing volume; and minimum foundation installation cost. The pile density is defined as the number of piles per unit length of abutment. The footing volume is defined as the footing width multiplied by the footing thickness per unit. The foundation installation cost. The footing and pile costs are specified in the LYD command (see Section 5.15).

If pile density is selected as the optimizing parameter and two configurations have the same density, the footing volume is used to determine the optimal design. If both configurations have the same footing volume, the configuration with the **minimum** toe projection will be selected as optimal.

If footing volume is selected as the optimizing parameter and two configurations have the same volume, the pile density is used to determine the optimal design. If both configurations have the same density, the configuration with the **minimum** toe projection will be selected as optimal. **During the design iterations, the program stores the design minimum footing volume. When footing width and thickness are incremented, the program ignores any footing size that exceeds the minimum volume.**

If the installation cost is selected as the optimizing parameter and two configurations have the same cost, the configuration with the least toe projection will be selected as optimal.

3.7.4 Shear Design

Shear design for footings follows the analysis procedure; refer to Section 3.5.2.9 for a description of the requirements. If the shear check is not satisfied in a design run, the footing configuration will be rejected. The program will skip to the next iteration of the footing geometry. The shear check is a function of the thickness of the footing.

Changes in the stem position (toe/heel projections) will alter the applied shear load. Changes in the footing thickness will affect the shear capacity of the footing sections.

The shear check as described in Section 3.5.2.9 is evaluated at the stem quarter points and backwall and seat level (if applicable). Stem and backwall sections are not modified by the program. Hence, the shear capacity cannot be increased. If there is a shear failure, the program will identify the point in the output.

If a solution cannot be found because there is a shear problem in the stem, the geometry (i.e. batter or stem thickness) may have to be revised. A larger section will provide a greater shear resistance.

Similarly, if there is a shear problem in the footing, the user can increase the upper limit of the footing thickness in the FTG command. By allowing the program to consider thicker footings, an acceptable solution may be found.

Alternatively, the user can change the strength of concrete. It is recommended that the user should check the magnitude of the applied loads, they may be unreasonably high.

3.8 TOLERANCES

The following sub-sections indicate where and how tolerances are applied. An example is provided for each case.

3.8.1 Spread Footing

A 1.5% tolerance is considered in the bearing resistance check. If the applied bearing pressure, either uniform for soil or maximum for rock, exceeds the bearing resistance, but the difference is less than 1.5% of the bearing resistance, the bearing check will be considered satisfactory.

Example:

- Applied pressure is 20.29 ksf.
- Bearing resistance is 20.00 ksf.
- Status: applied pressure is within acceptable tolerance of resistance.
- Explanation: (20.29 - 20.00) is less than 1.5% of 20.00.

3.8.2 Pile Footing

Tolerances are not applied to pile footing checks.

3.8.3 Pedestal Footing

A 1.5% tolerance is considered in the bearing resistance check at the front and back of the pedestal. If the percentage difference between the applied pressure and bearing resistance is less than 1.5%, the check is considered satisfactory.

Example:

- Factored rock bearing resistance is 30 ksf.
- Applied pressure at the front of the pedestal is 30.45 ksf.
- Status: the resistance is within an acceptable tolerance of applied pressure.
- Explanation: (30.45 - 30.00)/30.00 is less than or equal to 0.015.

3.8.4 Rebar Calculations

The following tolerances are applied to the rebar calculations in all applicable components of the structure i.e. stem, backwall, and footing.

Area of steel calculations: If the actual area of steel is within 1.5% of the required area of steel, the check will be considered satisfactory.

Example:

- Actual area of steel is 1.98 in^2.
- Required area of steel is 2.0 in^2.
- Status: actual area is within acceptable tolerance of required area.
- Explanation: 1.98 is greater than 2.0*(1-0.015).

Service stress tolerance: If the percentage difference between the actual stress and the allowable stress is less than or equal to 1.5%, the check will be considered satisfactory.

Example:

- Allowable stress is 36.00 ksi.
- Calculated stress is 36.54 ksi.
- Status: calculated stress is within an acceptable tolerance of allowable stress.
- Explanation: (36.54-36.00)/36.00 is less than or equal to 0.015.

Spacing for design: The tolerance is 1.5% of (0.5 inches). It is applied when the spacing is evaluated for each bar. The tolerance determines if a smaller spacing should be used, i.e. should the program round-down to a smaller value.

Example:

- Required spacing is 8.9925 inches
- Status: use a spacing of 9.0 inches instead of rounding down to 6.0 inches
- Explanation: (9.0 - 8.9925) is less than or equal to 1.5% of 0.5 inches

3.9 NO SOLUTION FOUND

During a design run, the program iterates through a range of footing configurations (see section 3.2.1). For any given footing configuration, if any design check fails, the program will skip to the next configuration. As the program is evaluating the design checks for each configuration, the configuration of the smallest footing width that was able to satisfy the most checks is saved.

If the program does not find a solution after evaluating all possible configurations, an informational message is displayed on the screen and printed in the output file. The message indicates the status of the run and the geometry of the footing configuration that satisfied the most design checks. The format of the message is identical for each footing type, however, the content differs. The following sub-sections explain how the No Solution Found message should be interpreted for each footing type.

3.9.1 Spread Footing

There are seven check points for the spread footing as illustrated in Figure 3.9.1-1. The list reflects the order in which the program evaluates the checks. An acceptable solution satisfies all of the checks. For the given example, bearing and sliding were not a problem. Since the program could not find a configuration that satisfied the settlement check, the strength and serviceability checks at the toe and heel locations were not evaluated.

```
For a footing width of   8.75 (toe proj:  5.00  / heel proj:  1.42 )
       * the BEARING       check PASSED
       * the SLIDING       check PASSED
       * the SETTLEMENT    check FAILED
       * the TOE STRENGTH  check was NOT EVALUATED
       * the HEEL STRENGTH check was NOT EVALUATED
       * the TOE SERVICE   check was NOT EVALUATED
       * the HEEL SERVICE  check was NOT EVALUATED
```

Figure 3.9.1-1 No-Solution-Found Message For Spread Footing

The bearing check includes considerations for the footing eccentricity (overall stability). The strength checkpoints refer to the shear and flexural strength checks in the toe and heel. The service checkpoints refer to the serviceability checks (allowable stress, spacing and development length) in the toe and heel locations.

If a solution is not found, the user should ensure that the loads and geometry have been correctly specified. The following suggestions address specific types of failures:

- Bearing: check the strength properties of the rock or soil.

- The eccentricity check will typically fail when geometry (maximum footing width) is too small.
- Sliding: check the strength reduction factor for sliding and the soil strength (SOI command Chapter 5).
- Settlement: examine the allowable settlement and soil / rock properties, e.g. modules of elasticity, depth of layers, and consolidation data for soils (CNS command Chapter 5).
- Shear Strength: a thicker footing may be required.
- Flexure: ensure that the bars can be developed.

The results shown in Figure 3.9.1-1 were generated by setting the allowable settlement to 0.01 inches.

The source of error can be corroborated by running the geometry of the footing configuration that satisfied the most design checks as an analysis problem using the footing geometry and a nominal area of steel. Performance ratios that are less than 1.0 indicate the checks that failed.

3.9.2 Pile Footing

There are eleven checkpoints for the pile footing as illustrated in Figure 3.9.2-1. The list reflects the order in which the program evaluates the checks. An acceptable solution satisfies all of the checks. For the example shown in Figure 3.9.2-1, the program could not get past the 'all loads' check. Consequently, the strength and service limit state checks were not evaluated for the footing (parallel and perpendicular directions).

```
For a footing width of   4.00 (toe proj:  0.60,   heel proj:  2.83)
       * the Pile/Caisson Pattern         check passed
       * the Pile/Caisson - Vertical Load check passed
       * the Pile/Caisson - All Loads     check failed
       * the Toe  Strength                check was not evaluated
       * the Toe  Service                 check was not evaluated
       * the Heel Strength                check was not evaluated
       * the Heel Service                 check was not evaluated
       * the Parallel Top    Strength     check was not evaluated
       * the Parallel Top    Service      check was not evaluated
       * the Parallel Bottom Strength     check was not evaluated
       * the Parallel Bottom Service      check was not evaluated
```

Figure 3.9.2-1 No-Solution-Found Message For Pile Footings

The pile footing will check the pattern data first. Next, the vertical loads are checked considering an all vertical-pile configuration. In the third step, the lateral and vertical loads are considered. When the pile considerations are satisfactory, the footing strength and serviceability (rebar) checks are evaluated in the perpendicular (toe/heel) and parallel (top/bottom) directions.

If the program does not pass the first check point (pattern check), the user should review the footing geometry - particularly the maximum width and pile spacing constraints.

If the configuration is failing at the second checkpoint (vertical load check), check the axial capacity of the piles.

If the configuration fails at the third checkpoint (as shown in Figure 3.9.2-1), there are several factors to consider. At this stage, the piles may be battered to accommodate the lateral load. However, if the piles are battered, the vertical load resistance of the pile group will be affected. Consequently, this check may fail because of the vertical and/or horizontal resistance of the pile group. Check the applied loads, axial capacity of the piles and the footing geometry.

The remaining checks concern the moment and shear capacity of the footing sections. A larger (deeper) footing may be required to satisfy the flexural and shear loads. For the flexural strength check, the rebar should have an adequate length to develop (applies to the perpendicular direction only).

The source of error can be corroborated by running the geometry of the footing configuration as that satisfied the most design checks an analysis problem using the footing geometry and a nominal area of steel. Performance ratios that are less than 1.0 indicate the checks that failed.

3.9.3 Pedestal Footing

There are six checkpoints for the pedestal footing as illustrated in Figure 3.9.3-1. The list reflects the order in which the program evaluates the checks (see Figure 3.7.2-1 Outline of pedestal design procedure). An acceptable solution satisfies all of the checks. For the example shown in Figure 3.9.3-1, the program was unable to find a solution because the footing could not be ‘adequately’ situated on the pedestal. Since the eccentricity check failed, the remainder of the checks were not evaluated.

```
For a footing width of  10.25 (toe proj:  1.00  / heel proj:  5.00 )
   * the SLIDING       check PASSED
   * the BEARING       check PASSED
   * the ECCENTRICITY  check FAILED
   * the FLEX & SHEAR  check was NOT EVALUATED
   * the STABILITY     check was NOT EVALUATED
   * the CRACK CONTROL check was NOT EVALUATED
```

Figure 3.9.3-1 No-Solution-Found Message For Pedestal Footings

The sliding check refers to the (V/H) ratio check (stability of the footing on the pedestal). The bearing check considers the bearing of the footing on the pedestal. The eccentricity check considers the stability of the footing on the pedestal. The ‘flex & shear’ check refers to the strength check (flexure and shear) of the footing in the parallel direction. The stability check concerns the stability of the pedestal on the rock foundation (i.e. bearing pressure, eccentricity and settlement). The crack control check refers to the

serviceability checks (e.g. allowable crack control spacing and bar spacing) of the footing in the parallel direction. If sliding is a problem, check the geometry and the applied loads. If bearing (footing on pedestal) is a problem, check the strength of the concrete, footing geometry and applied loads. If flexure and shear is a problem, a deeper footing section is required. Pedestal stability problems may be caused by weak rock properties or inadequate pedestal geometry.

The results shown in Figure 3.9.3-1 were caused by constraining the maximum width to 10.25 ft. A solution exists at a footing width of 10.75 ft. The solution is obtained by increasing the maximum footing width.

The source of error can be corroborated by running the geometry of the footing configuration that satisfied the most design checks as an analysis problem using the footing geometry and a nominal area of steel. Performance ratios that are less than 1.0 indicate the checks that failed.

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4 GETTING STARTED

4.1 INSTALLATION

This program is delivered via download from the Department's website. Once payment has been received by PennDOT you will receive a confirmation e-mail with instructions on how to download the software. The download file is a self-extracting installation file for the licensed PennDOT engineering software. The engineering program runs as a 32-bit application and is supported on Windows 10 and Windows 11 operating systems.

Your license number, license key and registered company name, found in the e-mail received from the Department, are required to be entered when installing the program and must be entered exactly as shown in the e-mail. The license number, license key and registered company name will also be needed when requesting future versions of the program (i.e., enhancements, modifications, or error corrections), and requesting program support. A backup copy of the program download and e-mail instructions should be made and used for future installations. You may want to print the software license agreement, record the license number, license key and registered company name and keep it in a safe place.

To install the program, follow the installation instructions provided with the original e-mail from the Department.

The following files will be installed in the program destination folder, which defaults to “C:\Program Files\PennDOT\ABLRFD v<version_number>\” or "C:\Program Files (x86)\PennDOT\ABLRFD v<version number>\" for 64-bit operating systems:

1. ABLRFD.exe, ABLRFD_DLL.dll - Executable program and Dynamic Link Library.
2. ABLRFD.pd - Parameter definition file.
3. ABLRFD Users Manual.pdf - Program User’s Manual (PDF Format).
4. ABLRFDRevReq.dotx - Revision Request form (MS Word template).
5. GettingStarted.pdf - A document describing installation and running of the program
6. LicenseAgreement.pdf - The program license agreement
7. MSVCR71.dll - Runtime Dynamic Link Library

The program example problem files (ex*.dat) will be installed in the program example folder, which defaults to “C:\PennDOT\ABLRFD v<version_number> Examples\”. Users must have write access in order to run the input files from this folder.

4.2 PREPARING INPUT

The program requires an ASCII input file. The input file consists of a series of command lines. Each command line defines a set of input parameters that are associated with that command. A description of the input commands can be found in Chapter 5 of the User's Manual. The input can be created using Engineering Assistant, described below, or any text editor.

4.3 ENGINEERING ASSISTANT

The Engineering Assistant (EngAsst) is a Windows application developed by the Pennsylvania Department of Transportation (PENNDOT) to provide a graphical user interface (GUI) for PENNDOT's engineering programs. The data for the input to the engineering program is presented in a user-friendly format, reflecting the implied structure of the data, showing each record type on a separate tab page in the display and showing each field on each record with a defining label.

With EngAsst the user can create a new input file, modify an existing input file, import input files, run the associated engineering program and view the output in a Windows environment. The help and documentation are provided, including text descriptions of each field, relevant images, and extended help text at both the record/tab level and the field level. Access to all parts of the Engineering Program User's Manual, where available, is also provided within EngAsst.

EngAsst is not included with this software. It requires a separate license that can be obtained through the Department's standard Engineering Software licensing procedures. Order forms can be obtained from program support website at http://penndot.engrprograms.com.

4.4 RUNNING THE PROGRAM WITHOUT ENGASST

The engineering programs are FORTRAN console application programs. They may be run from a command window, by double-clicking on the program icon from Windows Explorer, by selecting the shortcut from the Start menu under PennDOT ABLRFD vx.x.x.x subfolder, or by double-clicking the shortcut icon on the desktop. To run the program in a command window, the user must specify the directory in which the program has been installed or change to the directory.

The program will prompt for an input file name, and the user should then enter the appropriate input file name. The input file must be created before running the program. The program will then prompt for whether the output should be reviewed on the screen. The user should enter Y if the output is to be reviewed on the screen after execution or N if the output is not to be reviewed on the screen. The program will then prompt for the name of the output file in which the output is to be stored, and the user should then enter the desired output file name. If a file with the specified output file name already exists, the program will ask the user whether to overwrite the existing file. The user should enter Y if the existing file is to be overwritten or N if the existing file is not to be overwritten. If the user enters N to specify that the existing file is not to be overwritten, the program will prompt the user for another output file name. The program will then execute.

To cancel the program during execution, press <Ctrl C> or <Ctrl Break>, and then press <Enter>.

When the program completes execution, the user is prompted to “Press <ENTER> to exit program.” This allows the user to view the last messages written to the screen when the program was started by double-clicking on the program icon from Windows Explorer.

The user can view the *.OUT output file with a text editor and the *.PDF output file (for those programs that produce it) with Adobe Acrobat.

INPUT DESCRIPTION

5.1 INPUT DATA REQUIREMENTS

Before running the Abutment and Retaining Wall Analysis and Design program, the user must create an input file. The input file consists of a series of command lines. Each command line defines a set of input parameters that are associated with that command. The program interprets each command line and checks the input parameters to ensure that the input data is of the correct type and within the allowable ranges set by the program.

The syntax of a command line is given as:

KWD parm1, parm2, , , parm5, ,

Where, KWD is a 3 character keyword representing a command and,
parm1, parm2... are the parameter values associated with KWD.

If a command line begins with an exclamation point (!), then it is treated as a comment line that is not used by the program. Comment lines can be inserted by the user to provide descriptions and clarifications. The following are two examples of a comment line:

```
! THE FOLLOWING COMMMAND IS USED TO SPECIFY THE REINFORCEMENT IN THE FOOTING.
! NOTE THAT #6 BARS ARE ORIENTED IN THE PARALLEL DIRECTION.
```

To temporarily make a command line void, the user can use an exclamation point (!) to transform the command line into a comment line. For an input line to be treated as a comment line, the exclamation point must be put in column one of the input line. For example, in the following case, the program will use the input data on the second line, but will not use the input data on the first line:

```
! BAR      8, 8, 8, 8, 8
BAR        8, 8, 6, 8, 6
```

A command line must not exceed 256 characters in length. Command lines can be continued on any number of data lines in the input file by placing a hyphen (-) at the end of each data line to be continued, and by placing any remaining parameters on the following lines starting in column 4 of each continuation line. The limit of 256 characters includes all characters and parameters on all continuation lines of a given command line. Some commands are repeatable and some commands have parameters or groups of parameters that are repeatable. When parameters

are repeatable, the user must repeat the parameters within the command line. For example, the LYA command (Pile/Caisson Analysis Layout) first lists the total number of pile rows, followed by parameters that are repeatable for every row. The LYA command for 2 pile rows is input as follows:

```
LYA      2,        1.5,  3.0,  100.0,  3.0,  12.0,        3.0,  3.0,  50.0,  3.0,  12.0
```

Groups of repeatable parameters must stay together in a command line unless a continuation character (-) is used. When a continuation character is used, the repeatable data can be separated on two lines. The program reads all continuation lines as one command. For example,

Incorrect Input:

```
LYA  2,    1.5, 3.0, 100.0, 3.0, 12.0, 3.0
LYA  2,    3.0, 50.0, 3.0, 12.0
```

Correct Input:

```
LYA  2,    1.5, 3.0, 100.0, 3.0, 12.0, 3.0  -
           3.0, 50.0, 3.0, 12.0
```

The first three columns of each command line are reserved for keywords that define the command type. Columns 4 through 256 are to be used to input the parameters associated with a command. One or more spaces are recommended between the keyword and the input parameters to improve readability.

The parameters associated with each command must be entered in the order they appear in the command description tables. The user must place commas to separate the parameters on the command line. Blank spaces cannot be used to separate parameters. The parameter field width is not restricted; however, the total number of characters cannot exceed 256.

The default value for a parameter is assigned by the program by placing a comma without any value for the parameter. For example, in the command syntax example shown below, the default values will be assigned to parameters parm3 and parm4.

```
KWD parm1,   parm2,   ,   ,   parm5
```

If the user places a comma and there is no default value, the program will return an error status. If a comma is entered after the command keyword, the program will assign the default value to the first parameter. If the user does not enter all the parameters for a command, the program will assign default values for those parameters not entered. That is, the user is not required to place commas at the end of a command line. If the above example required seven parameters, parm6 and parm7 would also be assigned default values by the program.

The default values are stored in a parameter file, which can be changed by the Department's system manager. The parameter file stores the parameter description, type of data, units, upper limit, lower limit, error or warning status if the upper or lower limits are exceeded, and the default value for each parameter.

Any numerical value, within the upper and lower limits, can be entered for a parameter. The status codes, shown in parenthesis below the lower and upper limits, indicate the status if an input item exceeds the lower or upper limits. The status code, (E), indicates an error. The status code, (W), indicates a warning.

In the following sections, all available commands and associated parameters are described with two tables for each command. The first table contains the keyword for a particular command along with a description of the command. The second table gives all the parameters associated with the given command, parameter description, units, limits and default values.

The program will process all input and will check for errors and warnings. If the number of errors exceeds 25 during input processing, the program will terminate immediately. After all input is processed, the program checks if any errors were found. If an error was found, the program will terminate. If warnings are found, the program will continue to process. If the number of warnings exceeds 200 during input processing for a single run, the program will terminate immediately. The user should review all warnings in the output file to ensure that the input data is correct. Warnings are an indication that the input value has exceeded normally acceptable limits for that parameter.

5.2 ORDER OF COMMANDS

If the user wants to control the number of lines printed on a page or the number of lines to be left blank at the top of each page, the CFG (configure) command should be the first command. The CFG command is optional and the program will use default values if the CFG command is not entered. The first required command is the TTL (title) command, which is printed in the header at the top of each output page. A maximum of ten TTL commands are printed on the first page of the output. The second required command after the title commands is the CTL (control) command. The CTL command is used to specify the system of units, which is required for checking the range of the input data. The CTL command also includes other major control parameters.

The recommended order of commands is shown in Table 5.2-1. The commands are shown in alphabetical order in Table 2. The section headings in these tables refer to the section number of this chapter where these commands are described. Figure 5.2-1 shows the overall view of the typical input file with these commands.

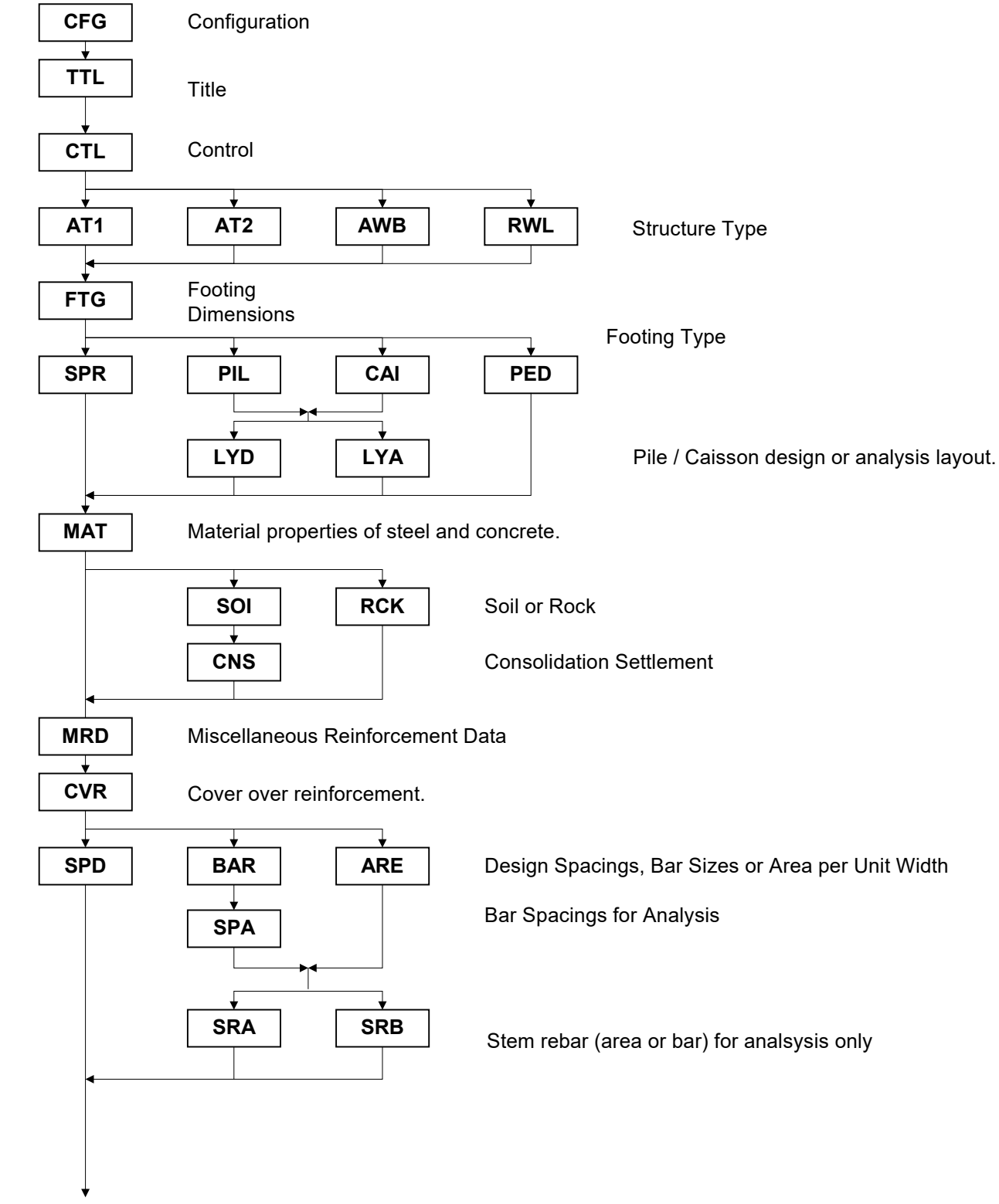


Figure 5.2-1 Overall View of the Input File

continued from bar spacing

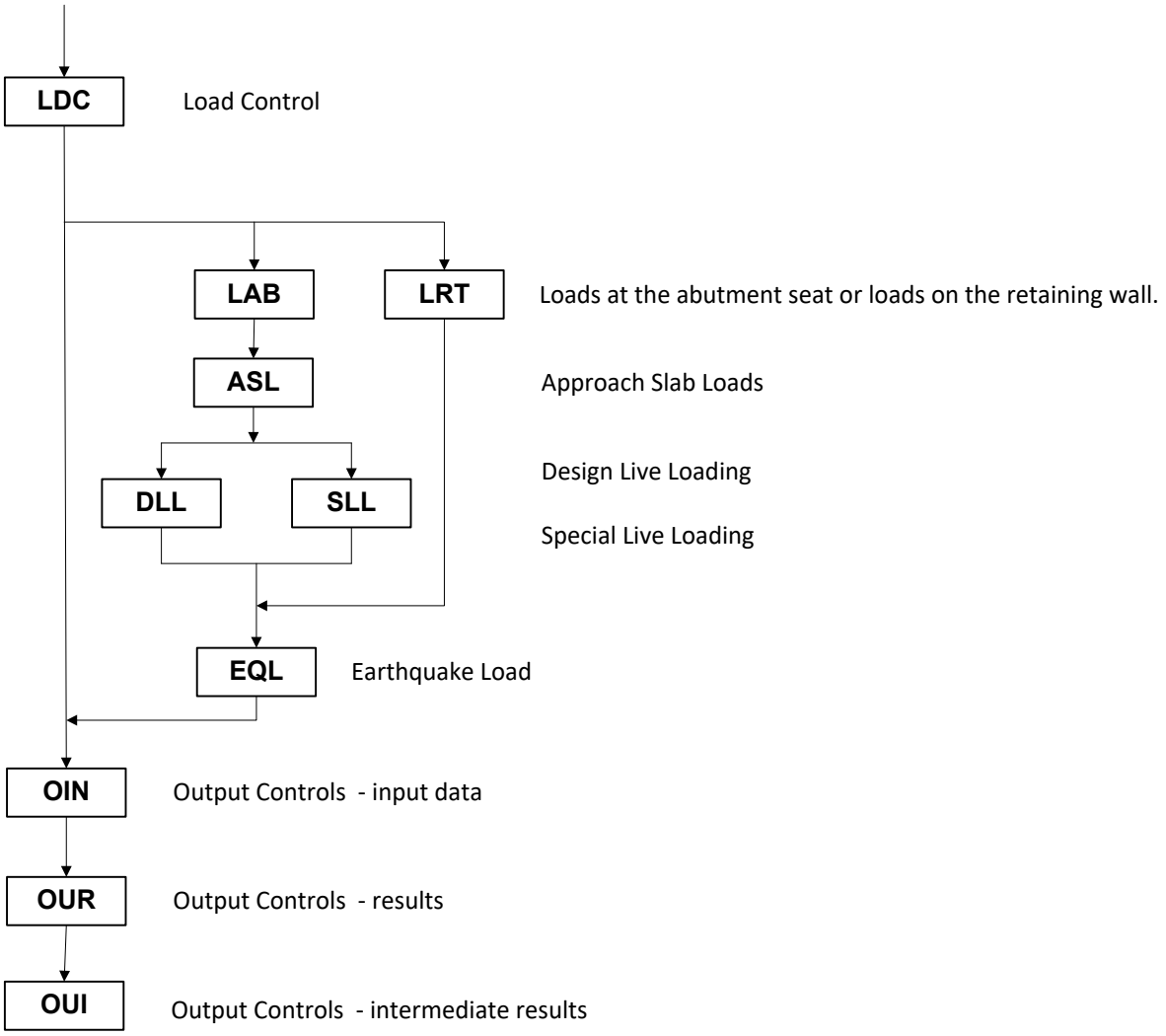


Figure 5.2-1 Overall View of the Input File (cont.)

Table 5.2-1 Recommended Order of Commands

Keyword	Command Description	Comments/Requirements	Section No.
CFG	Configuration	Optional for both Design and Analysis	5.3
TTL	Title	At least one TTL command required for both Design and Analysis	5.4
CTL	Control	Required before other Structure Commands for both Design and Analysis	5.5
AT1	Abutment Type I	Required only for Abutment Type I for both Design and Analysis	5.6
AT2	Abutment Type II	Required only for Abutment Type II for both Design and Analysis	5.7
AWB	Abutment Without Backwall	Required only for Abutment Without Backwall for both Design and Analysis	5.8
RWL	Retaining Wall	Required only for Retaining Wall for both Design and Analysis	5.9
FTG	Footing	Required for both Design and Analysis	5.10
SPR	Spread	Required only for Design of Spread Footing	5.11
PIL	Pile	Required only for Pile Footing for both Design and Analysis	5.12
CAI	Caisson	Required only for Caisson Footing for both Design and Analysis	5.13
PED	Pedestal	Required only for Pedestal Footing for both Design and Analysis	5.14
LYD	Pile/Caisson Layout Design	Required only for Design of Pile/Caisson Footing	5.15
LYA	Pile/Caisson Layout Analysis	Required only for Analysis of Pile/Caisson Footing	5.16
MAT	Materials	Required for both Design and Analysis	5.17
SOI	Soil Data	Required only for Spread Footing on Soil for both Design and Analysis	5.18
RCK	Rock Data	Required only for Spread/Pedestal Footing on Rock for both Design and Analysis	5.19
CNS	Consolidation Settlement	Required only for Spread Footing on Clay Soil and/or C-f soil for both Design and Analysis	5.20
MRD	Miscellaneous Reinforcement Data	Required only for Cantilever Structures for both Design and Analysis	5.21
CVR	Reinforcement Cover	Required only for Cantilever Structures for both Design and Analysis	5.22
SPD	Design Reinforcement	Required only for Design of Cantilever Structures	5.23

Table 5.2-1 Recommended Order of Commands (Cont.)

Keyword	Command Description	Comments/Requirements	Section No.
BAR	Bar Size	Required only for Analysis of Cantilever Structures - if ARE is not used	5.24
SPA	Bar Spacing for Analysis	Required only for Analysis of Cantilever Structures - if ARE is not used	5.25
ARE	Reinforcement Area	Required only for Analysis of Cantilever Structures - if BAR and SPA are not used	5.26
SRA	Stem Reinforcement Areas	Required only for Analysis of Cantilever Structures - if SRB is not used	5.27
SRB	Stem Reinforcement Bars	Required only for Analysis of Cantilever Structures - if SRA is not used	5.28
LDC	Load Control	Required for both Design and Analysis	5.29
LAB	Loads on Abutments	Required for Design and Analysis of Abutments	5.30
ASL	Approach Slab Loads	Optional for Design and Analysis of Abutments	5.31
LRT	Loads on Retaining Walls	Optional for Design and Analysis of Retaining Walls only	5.32
DLL	Design Live Loading	Required for Design and Analysis of Abutments	5.33
SLL	Special Live Loading	Optional for Design and Analysis of Abutments only	5.34
EQL	Earthquake Loads	Optional for both Design and Analysis	5.35
OIN	Output of Input	Optional for both Design and Analysis	5.36
OUR	Output of Results	Optional for both Design and Analysis	5.37
OUI	Output of Intermediate Data	Optional for both Design and Analysis	5.38

Table 5.2-2 Commands in Alphabetical Order

Keyword	Command Description	Comments/Requirements	Section No.
ARE	Reinforcement Area	Required only for Analysis of Cantilever Structures - if BAR and SPA are not used	5.26
ASL	Approach Slab Loads	Optional for Design and Analysis of Abutments	5.31
AT1	Abutment Type I	Required only for Abutment Type I for both Design and Analysis	5.6
AT2	Abutment Type II	Required only for Abutment Type II for both Design and Analysis	5.7
AWB	Abutment Without Backwall	Required only for Abutment Without Backwall for both Design and Analysis	5.8
BAR	Bar Size	Required only for Analysis of Cantilever Structures - if ARE is not used	5.24
CAI	Caisson	Required only for Caisson Footing for both Design and Analysis	5.13
CFG	Configuration	Optional for both Design and Analysis	5.3
CNS	Consolidation Settlement	Required only for Spread Footing on Clay Soil and/or C-ϕ soil for both Design and Analysis	5.20
CTL	Control	Required before other Structure Commands for both Design and Analysis	5.5
CVR	Reinforcement Cover	Required only for Cantilever Structures for both Design and Analysis	5.22
DLL	Design Live Loading	Required for Design and Analysis of Abutments	5.33
EQL	Earthquake Loads	Optional for both Design and Analysis	5.35
FTG	Footing	Required for both Design and Analysis	5.10
LAB	Loads on Abutments	Required for Design and Analysis of Abutments	5.30
LDC	Load Control	Required for both Design and Analysis	5.29
LRT	Loads on Retaining Walls	Optional for Design and Analysis of Retaining Walls only	5.32
LYA	Pile/Caisson Layout Analysis	Required only for Analysis of Pile/Caisson Footing	5.16
LYD	Pile/Caisson Layout Design	Required only for Design of Pile/Caisson Footing	5.15
MAT	Materials	Required for both Design and Analysis	5.17
MRD	Miscellaneous Reinforcement Data	Required only for Cantilever Structures for both Design and Analysis	5.21
OIN	Output of Input	Optional for both Design and Analysis	5.36
OUI	Output of Intermediate Data	Optional for both Design and Analysis	5.38
OUR	Output of Results	Optional for both Design and Analysis	5.37

Table 5.2-2 Commands in Alphabetical Order (Cont.)

Keyword	Command Description	Comments/Requirements	Section No.
PED	Pedestal	Required only for Pedestal Footing for both Design and Analysis	5.14
PIL	Pile	Required only for Pile Footing for both Design and Analysis	5.12
RCK	Rock Data	Required only for Spread/Pedestal Footing on Rock for both Design and Analysis	5.19
RWL	Retaining Wall	Required only for Retaining Wall for both Design and Analysis	5.9
SLL	Special Live Loading	Optional for Design and Analysis of Abutments only	5.34
SOI	Soil Data	Required only for Spread Footing on Soil for both Design and Analysis	5.18
SPA	Bar Spacing for Analysis	Required only for Analysis of Cantilever Structures - if ARE is not used	5.25
SPD	Design Reinforcement	Required only for Design of Cantilever Structures	5.23
SPR	Spread	Required only for Design of Spread Footing	5.11
SRA	Stem Reinforcement Areas	Required only for Analysis of Cantilever Structures - if SRB is not used	5.27
SRB	Stem Reinforcement Bars	Required only for Analysis of Cantilever Structures - if SRA is not used	5.28
TTL	Title	At least one TTL command required for both Design and Analysis	5.4

5.3 CFG - CONFIGURATION COMMAND

KEYWORD	COMMAND DESCRIPTION
CFG	CONFIGURATION - This command is used to set the control parameters for the characteristics of the printed output. An input file can have only one configuration command.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Lines per Page	Enter the maximum number of lines that will be allowed to be printed on each page of output.	--	50 (E)	83 (E)	83
2. Top Blank Lines per Page	Enter the number of blank lines that the program should leave at the top of each page of output to create a top margin.	--	0 (E)	5 (E)	0

5.4 TTL - TITLE COMMAND

KEYWORD	COMMAND DESCRIPTION
TTL	TITLE - As many as ten TTL commands may be entered by the user. The first TTL command is printed in the header at the top of each output page. A maximum of ten TTL commands are printed on the first page of the output. If more than ten TTL commands are entered, the program will not use the TTL commands following the first ten TTL commands and a warning will be printed. The input file must have at least one TTL command.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Title	Enter any descriptive information about the project or structure. Title information can be specified anywhere between column 4 and column 79.	--	--	--	--

5.5 CTL - CONTROL COMMAND

KEYWORD	COMMAND DESCRIPTION
CTL	CONTROL - This command is used to set up the control parameters for the input. This command is required input, and can only be entered once. Only the TTL and CFG commands can precede this command.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. System of Units	The system of units to be used in the input, computations and output reports: US - US Customary Units.	--	US (E)	--	US
2. Type of Run	Type of Run: D - Design the footing geometry and the reinforcing steel in both the footing and the stem. Note: Gravity walls and abutments cannot be designed. A - Analyze the structure using given dimensions and reinforcement.	--	D, A (E)	--	--
3. Footing Datum	For a design, indicate footing datum to be kept at a fixed elevation. Leave blank for Analysis. Refer to Figure 5.5-1. T - Keep the top of the footing at a fixed elevation. For a design, the footing thickness is increased by lowering the footing bottom while keeping the stem height constant. B - Keep the bottom of the footing at a fixed elevation. For a design, the footing thickness is increased by raising the footing top resulting in a decrease in the stem height.	--	T, B (E)	--	--

5.5 CTL - CONTROL COMMAND (Cont.)

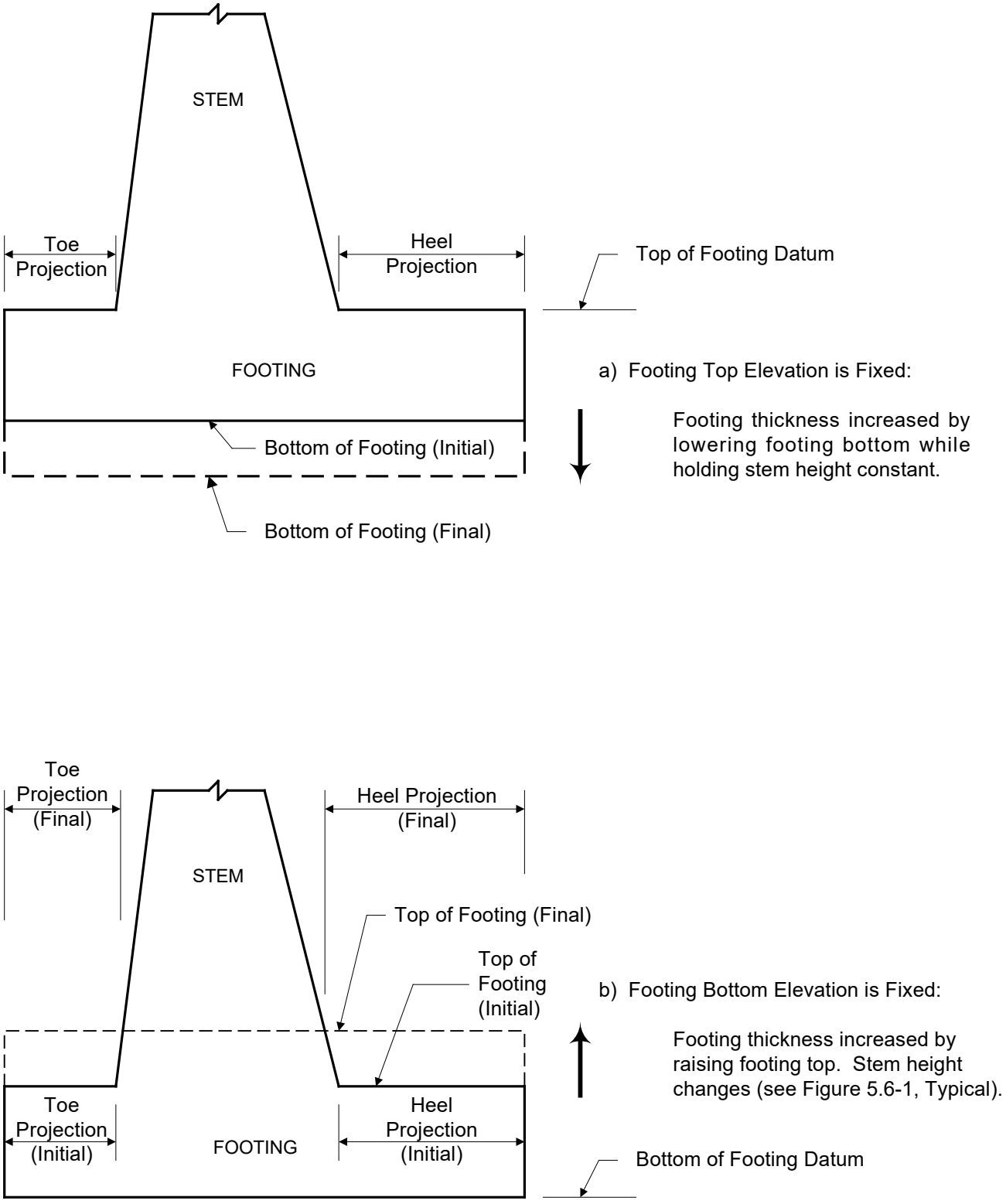


Figure 5.5-1 Footing Elevation Fixity

5.6 AT1 - ABUTMENT TYPE I COMMAND

KEYWORD	COMMAND DESCRIPTION
AT1	ABUTMENT TYPE I - This command describes the geometry of an abutment with a backwall and a straight stem. The dimensions are shown in Figure 5.6-1. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Height	The structure or stem & backwall height. For design, if the footing top elevation is fixed, the height of the stem and backwall is required. If the footing bottom elevation is fixed, the total height of the structure (stem, backwall and footing) is required. For analysis, enter the stem & backwall height.	ft	0.0 (E)	40.0 (W)	--
2. Top Width	The width of the backwall at the top of the structure.	in	15.0 (W)	60.0 (W)	15.0
3. Seat Width	The horizontal dimension of the abutment seat.	in	0.0 (E)	48.0 (W)	--
4. Seat Slope Height	If the abutment seat is sloped, the height of the slope is specified. A zero value indicates a level abutment seat.	in	0.0 (E)	6.0 (W)	--
5. Seat Face Height	The seat face height is measured from the back of the abutment seat to the bottom of the corbel. If a corbel does not exist, the seat face height is measured to the top of the structure.	in	0.0 (E)	96.0 (W)	--
6. Corbel Width	The corbel width is measured to the seat face of the abutment. A zero value indicates the absence of a corbel.	in	0.0 (E)	6.0 (W)	4.0
7. Corbel Height	The height of the corbel on the front face of the backwall is measured from the top of the backwall to the seat face.	in	0.0 (E)	48.0 (W)	24.0
8. Corbel Slope Height	The corbel slope height indicates whether the transition between the backwall and the corbel is sloped. A zero value indicates an abrupt change in backwall thickness.	in	0.0 (E)	6.0 (W)	4.0
9. Paving Notch Width	The width of the paving notch is measured from the back face of the backwall. A zero value indicates the absence of a paving notch.	in	0.0 (E)	24.0 (W)	9.0
10. Paving Notch Height	The height of the paving notch is measured from the top of the structure. A zero value indicates the absence of a paving notch.	in	0.0 (E)	36.0 (W)	16.0

5.6 AT1 - ABUTMENT TYPE I COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
11. Bearing Location X	Centerline of bearing measured from the front face of the stem.	in	0.0 (E)	36.0 (W)	--
12. Bearing Location Y	Location of horizontal bearing seat loads measured from the top of the backwall.	in	0.0 (E)	150.0 (W)	--[1]
13. Front (*) Water Level	The level of the water at the front of the structure measured from the top of the abutment. If a front water level does not exist, this parameter should be left blank. If left blank for a design, the program will calculate based on DM-4 Section 3.11.3 only if back water level is entered. For analysis, if the front water level is left blank, the program places the front water level at the bottom of the footing.	ft	0.0 (E)	300.0 (W)	--[2]
14. Back (*) Water Level	The level of the water at the back of the structure is measured from the top of the abutment. If a back water level does not exist, this parameter should be left blank. For spread footings on soil, this level should not be under the bottom of the lowest soil layer. The backwater level is used as the reference water level for bearing resistance and settlement calculations. For rock, the level should not be less than the bottom of the footing.	ft	0.0 (E)	300.0 (W)	--[2]
15. Architectural Treatment Thickness	The thickness of the architectural treatment measured from the front face of the stem. Leave blank if no architectural treatment is present.	in	0.0 (E)	6.0 (W)	0.0[3]
16. Backwall /Stem Bar Alignment	For design, indicate if the backwall bars should be aligned with the optimum stem bar. Leave blank for Analysis runs. Y - Backwall bar spacings will be aligned with the optimum stem bar spacing. N - Backwall bar spacings will not be aligned with the optimum stem bar spacing.		Y,N (E)		Y

[1] A blank indicates positioning loads on the bearing seat at the centerline of bearing.
[2] A blank indicates the absence of a water level.
[3] If no architectural treatment is present, this value can be left blank or set to zero.

* A minimum water differential of 3 ft. is required as specified in DM-4 Section 3.11.3. The minimum water differential must be applied even when the back water level is below the bottom of the footing.

5.6 AT1 - ABUTMENT TYPE I COMMAND (Cont.)

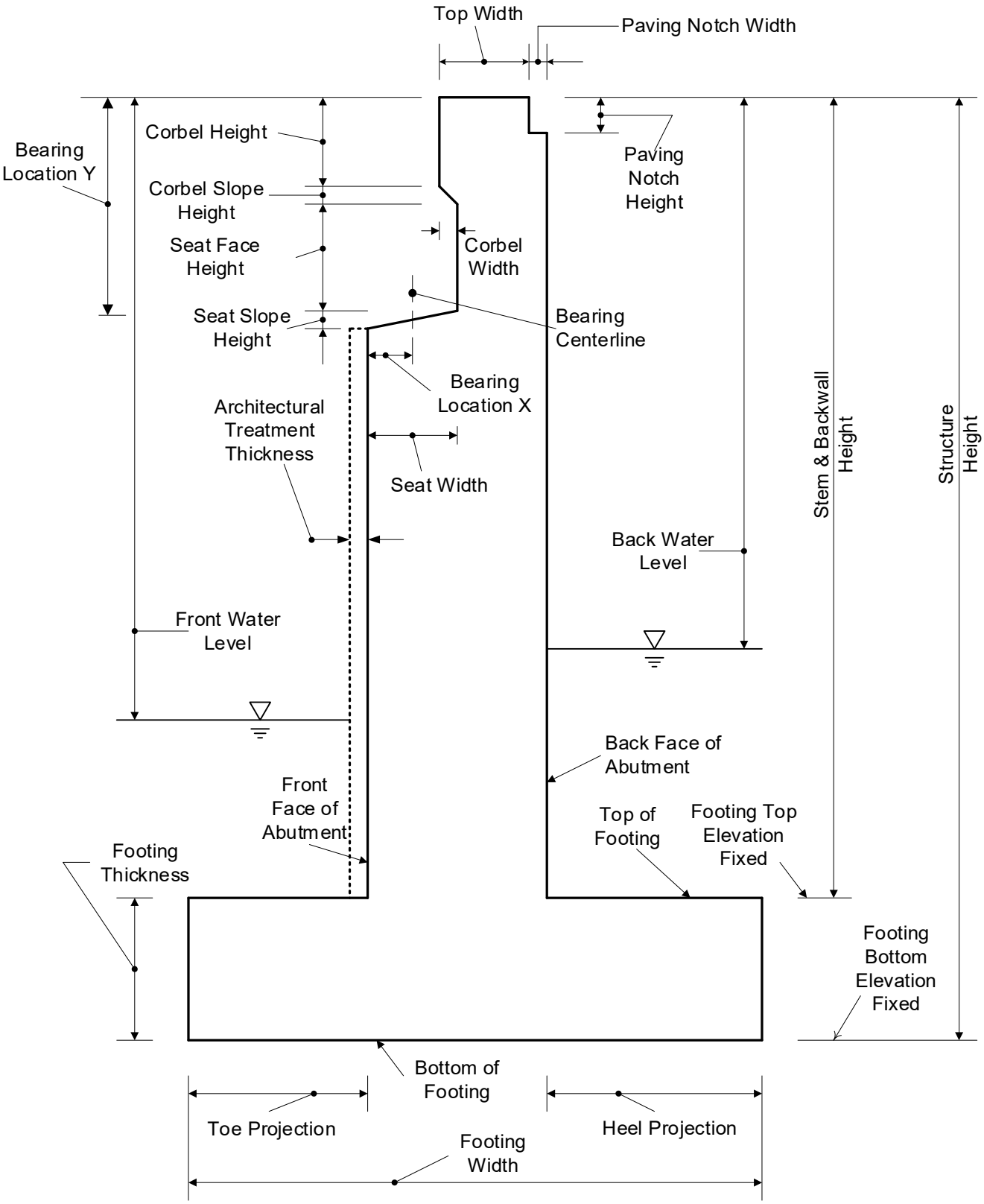


Figure 5.6-1 Abutment Type I

5.7 AT2 - ABUTMENT TYPE II COMMAND

KEYWORD	COMMAND DESCRIPTION
AT2	ABUTMENT TYPE II - This command describes the geometry of an abutment with a backwall and a notched stem. The dimensions are shown in Figure 5.7-1. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Height	The structure or stem & backwall height. For design, if the footing top elevation is fixed, the height of the stem and backwall is required. If the footing bottom elevation is fixed, the total height of the structure (stem, backwall and footing) is required. For analysis, enter the stem & backwall height.	ft	0.0 (E)	40.0 (W)	--
2. Top Width	The width of the backwall at the top of the structure.	in	15.0 (W)	60.0 (W)	15.0
3. Seat Width	The horizontal dimension of the abutment seat.	in	0.0 (E)	48.0 (W)	--
4. Seat Slope Height	If the abutment seat is sloped, the height of the slope is specified. A zero value indicates a level abutment seat.	in	0.0 (E)	6.0 (W)	--
5. Seat Face Height	The seat face height is measured from the back of the abutment seat to the bottom of the corbel. If a corbel does not exist, the seat face height is measured to the top of the structure.	in	0.0 (E)	96.0 (W)	--
6. Corbel Width	The corbel width is measured to the seat face of the abutment. A zero value indicates the absence of a corbel.	in	0.0 (E)	6.0 (W)	4.0
7. Corbel Height	The height of the corbel on the front face of the backwall is measured from the top of the backwall to the seat face.	in	0.0 (E)	48.0 (W)	24.0
8. Corbel Slope Height	The corbel slope height indicates whether the transition between the backwall and the corbel is sloped. A zero value indicates an abrupt change in backwall thickness.	in	0.0 (E)	6.0 (W)	4.0
9. Paving Notch Width	The width of the paving notch is measured from the back face of the backwall. A zero value indicates the absence of a paving notch.	in	0.0 (E)	24.0 (W)	9.0
10. Paving Notch Height	The height of the paving notch is measured from the top of the structure. A zero value indicates the absence of a paving notch.	in	0.0 (E)	36.0 (W)	16.0

5.7 AT2 - ABUTMENT TYPE II COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
11. Backwall Height	The height of the back face of the abutment backwall is measured from the bottom of the paving notch to the top of the stem notch.	in	0.0 (E)	160.0 (W)	--
12. Stem Notch Width	The width of the notch in the stem, below the backwall, is measured from the back face. A zero value indicates the absence of a stem notch.	in	0.0 (E)	60.0 (W)	20.0
13. Stem Notch Height	The stem notch height is measured from the bottom of the back face of the backwall to the notch point in the stem. If the stem notch width exists, but the stem notch height is a zero value, the stem notch overhang is level.	in	0.0 (E)	120.0 (W)	30.0
14. Front Face Horizontal Component	The horizontal component of the front face batter. Used in conjunction with the front face vertical component to describe a battered front face. If the front face is vertical, this parameter should be left blank.	--	0.0 (E)	100.0 (W)	--[1]
15. Front Face Vertical Component	The vertical component of the front face batter. Used in conjunction with the front face horizontal component to describe a battered front face. If the front face is vertical, this parameter should be left blank.	--	0.0 (E)	100.0 (W)	--[1]
16. Back Face Horizontal Component	The horizontal component of the back face batter. Used in conjunction with the back face vertical component to describe a battered back face. If the back face is vertical, this parameter should be left blank.	--	0.0 (E)	100.0 (W)	--[1]
17. Back Face Vertical Component	The vertical component of the back face batter. Used in conjunction with the back face horizontal component to describe a battered back face. If the back face is vertical, this parameter should be left blank.	--	0.0 (E)	100.0 (W)	--[1]
18. Bearing Location X	Centerline of bearing measured from the front face of the stem.	in	0.0 (E)	36.0 (W)	--
19. Bearing Location Y	Location of horizontal bearing seat loads measured from the top of the backwall.	in	0.0 (E)	150.0 (W)	--[2]
20. Front (*) Water Level	The level of the water at the front of the structure measured from the top of the abutment. If a front water level does not exist, this parameter should be left blank. If left blank for a design, the program will calculate based on DM-4 Section 3.11.3 only if back water level is entered. For analysis, if the front water level is left blank, the program places the front water level at the bottom of the footing.	ft	0.0 (E)	300.0 (W)	--[3]

5.7 AT2 - ABUTMENT TYPE II COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
21. Back Water Level (*)	The level of the water at the back of the structure measured from the top of the abutment. If a back water level does not exist, this parameter should be left blank. For spread footings on soil, this level should not be under the bottom of the lowest soil layer. The backwater level is used as the reference water level for bearing resistance and settlement calculations. For rock, the level should not be less than the bottom of the footing.	ft	0.0 (E)	300.0 (W)	--[3]
22. Architectural Treatment Thickness	The thickness of the architectural treatment measured from the front face of the stem. Leave blank if no architectural treatment is present.	in	0.0 (E)	6.0 (W)	0.0[4]
23. Backwall /Stem Bar Alignment	For design, indicate if the backwall bars should be aligned with the optimum stem bar. Leave blank for Analysis runs. Y - Backwall bar spacings will be aligned with the optimum stem bar spacing. N - Backwall bar spacings will not be aligned with the optimum stem bar spacing.		Y, N (E)		Y

[1] A blank for the horizontal and vertical batter indicate a vertical wall face.
[2] A blank indicates positioning loads on the bearing seat at the centerline of bearing.
[3] A blank indicates the absence of a water level.
[4] If no architectural treatment is present, this value can be left blank or set to zero.
* A minimum water differential of 3 ft. is required as specified in DM-4 Section 3.11.3. The minimum water differential must be applied even when the back water level is below the bottom of the footing.

5.7 AT2 - ABUTMENT TYPE II COMMAND (Cont.)

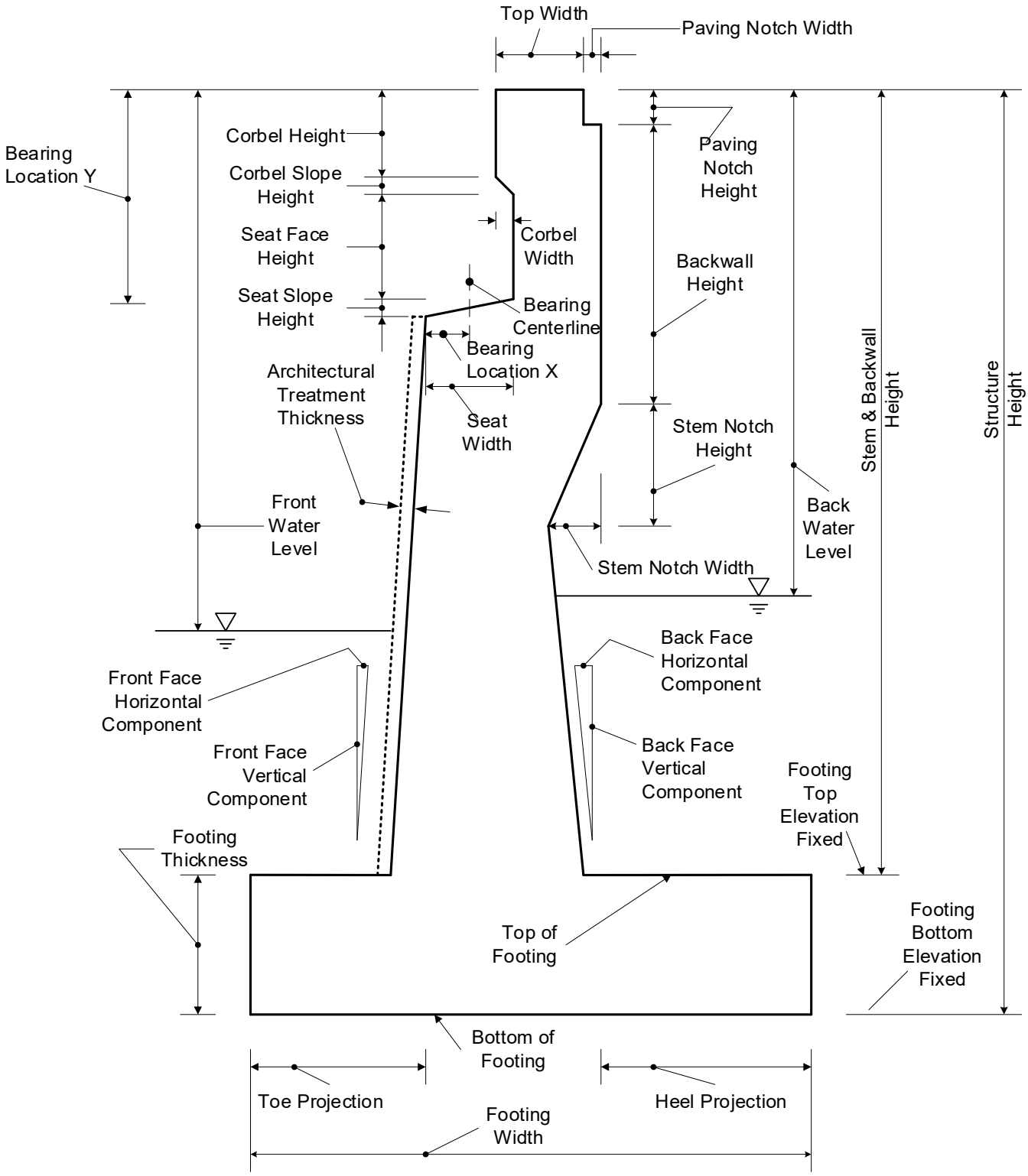


Figure 5.7-1 Abutment Type II

5.8 AWB - ABUTMENT WITHOUT BACKWALL COMMAND

KEYWORD	COMMAND DESCRIPTION
AWB	ABUTMENT WITHOUT BACKWALL - This command describes the geometry of an abutment without a backwall. The dimensions are shown in Figure 5.8-1. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Height	The structure or stem height. For design, if the footing top elevation is fixed, the height of the stem is required. If the footing bottom elevation is fixed, the total height of the structure (stem and footing) is required. For analysis, enter the stem height.	ft	0.0 (E)	40.0 (W)	--
2. Top Width	The width of the stem at the top of the structure.	in	18.0 (W)	60.0 (W)	18.0
3. Bearing Location	Centerline of bearing measured from the front face of the stem.	in	0.0 (E)	36.0 (W)	--
4. Front Face Horizontal Component	The horizontal component of the front face batter. Used in conjunction with the front face vertical component to describe a battered front face. If the front face is vertical, this parameter should be left blank.	--	0.0 (E)	100.0 (W)	--[1]
5. Front Face Vertical Component	The vertical component of the front face batter. Used in conjunction with the front face horizontal component to describe a battered front face. If the front face is vertical, this parameter should be left blank.	--	0.0 (E)	100.0 (W)	--[1]
6. Back Face Horizontal Component	The horizontal component of the back face batter. Used in conjunction with the back face vertical component to describe a battered back face. If the back face is vertical, this parameter should be left blank.	--	0.0 (E)	100.0 (W)	--[1]
7. Back Face Vertical Component	The vertical component of the back face batter. Used in conjunction with the back face horizontal component to describe a battered back face. If the back face is vertical, this parameter should be left blank.	--	0.0 (E)	100.0 (W)	--[1]
8. Additional Fill Height	The additional fill height is the distance from the top of the abutment to the finished grade of the backfill after the superstructure has been constructed.	ft	0.0 (E)	20.0 (W)	--

5.8 AWB - ABUTMENT WITHOUT BACKWALL COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
9. Front (*) Water Level	The level of the water at the front of the structure is measured from the top of the abutment. If a front water level does not exist, this parameter should be left blank. If left blank for a design, the program will calculate based on DM-4 Section 3.11.3 only if back water level is entered. For analysis, if the front water level is left blank, the program places the front water level at the bottom of the footing.	ft	0.0 (E)	300.0 (W)	--[2]
10. Back (*) Water Level	The level of the water at the back of the structure measured from the top of the abutment. If a back water level does not exist, this parameter should be left blank. For spread footings on soil, this level should not be under the bottom of the lowest soil layer. The backwater level is used as the reference water level for bearing resistance and settlement calculations. For rock, the level should not be less than the bottom of the footing.	ft	0.0 (E)	300.0 (W)	--[2]
11. Type of Abutment	Indicate the type of abutment: C - Cantilever abutment. G - Gravity abutment. Note: Gravity abutments cannot be designed.	--	C, G (E)	--	--
12. Architectural Treatment Thickness	The thickness of the architectural treatment measured from the front face of the stem. Leave blank if no architectural treatment is present.	in	0.0 (E)	6.0 (W)	0.0[3]

[1] A blank for the horizontal and vertical batter indicate a vertical wall face.
[2] A blank indicates the absence of a water level.
[3] If no architectural treatment is present, this value can be left blank or set to zero.
* A minimum water differential of 3 ft. is required as specified in DM-4 Section 3.11.3. The minimum water differential must be applied even when the back water level is below the bottom of the footing.

5.8 AWB - ABUTMENT WITHOUT BACKWALL COMMAND (Cont.)

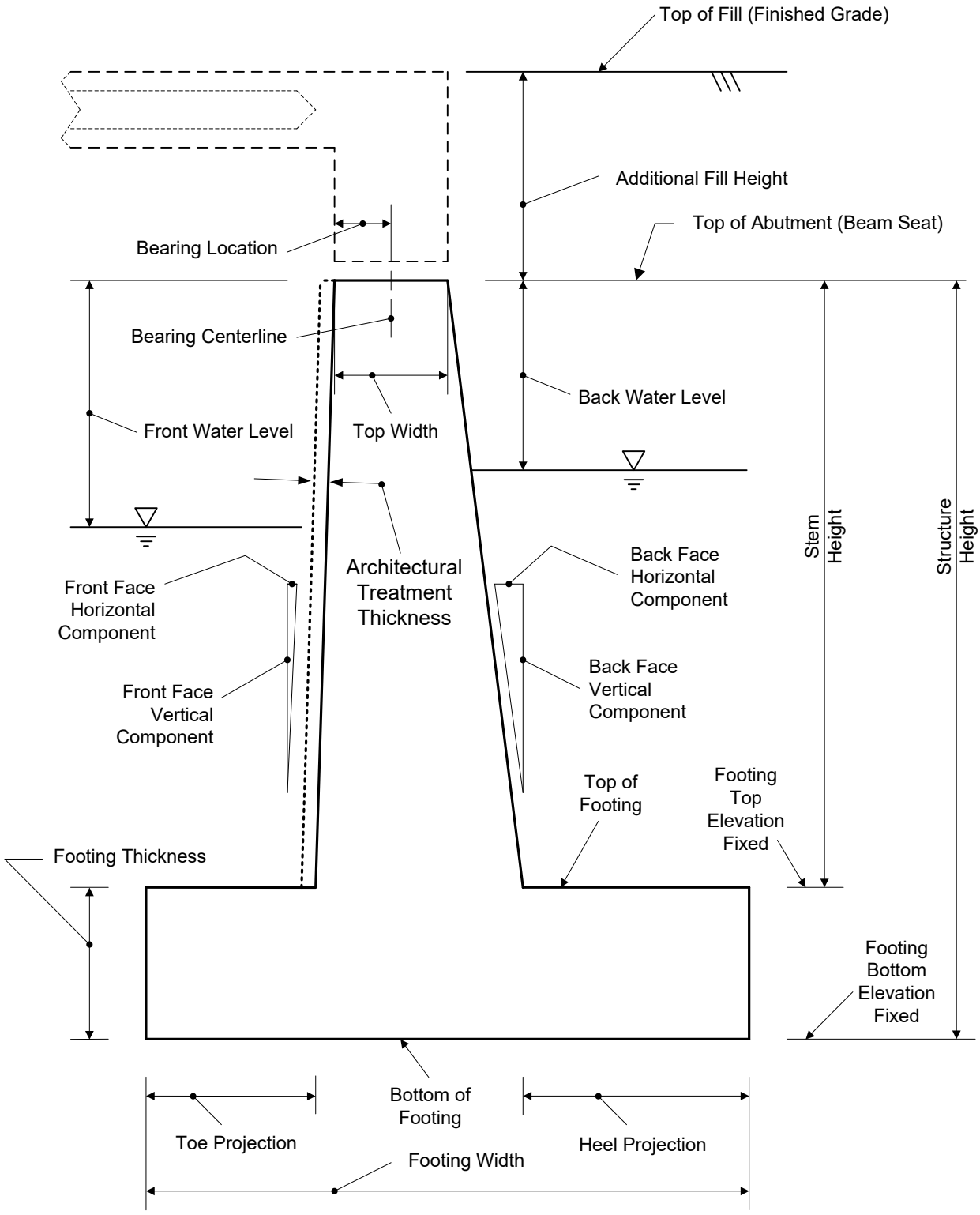


Figure 5.8-1 Abutment Without Backwall

5.9 RWL - RETAINING WALL COMMAND

KEYWORD	COMMAND DESCRIPTION
RWL	RETAINING WALL - This command describes the geometry of a retaining wall. The dimensions are shown in Figure 5.9-1. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Height	The structure or stem height. For design, if the footing top elevation is fixed, the height of the stem is required. If the footing bottom elevation is fixed, the total height of the structure (stem and footing) is required. For analysis, enter the stem height.	ft	0.0 (E)	40.0 (W)	--
2. Top Width	The width of the stem at the top of the structure.	in	0.0 (E)	60.0 (W)	18.0
3. Front Face Horizontal Component	The horizontal component of the front face batter. Used in conjunction with the front face vertical component to describe a battered front face. If the front face is vertical, this parameter should be left blank.	--	0.0 (E)	100.0 (W)	--[1]
4. Front Face Vertical Component	The vertical component of the front face batter. Used in conjunction with the front face horizontal component to describe a battered front face. If the front face is vertical, this parameter should be left blank.	--	0.0 (E)	100.0 (W)	--[1]
5. Back Face Horizontal Component	The horizontal component of the back face. Used in conjunction with the back face vertical component to describe a battered back face. If the back face is vertical, this parameter should be left blank.	--	0.0 (E)	100.0 (W)	--[1]
6. Back Face Vertical Component	The vertical component of the back face batter. Used in conjunction with the back face horizontal component to describe a battered back face. If the back face is vertical, this parameter should be left blank.	--	0.0 (E)	100.0 (W)	--[1]
7. Exposed Stem Height	For retaining walls with backfill less than the full height of the stem, the exposed stem height is measured vertically from the top of the stem to the start of the backfill.	in	0.0 (E)	120.0 (W)	--
8. Backfill (+) Horizontal Component	The horizontal component of the backfill. Used in conjunction with the backfill vertical component to describe a sloped backfill. If the backfill is flat, this parameter should be left blank.	--	0.0 (E)	100.0 (W)	--[2]

5.9 RWL - RETAINING WALL COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
9. Backfill (+) Vertical Component	The vertical component of the backfill. Used in conjunction with the backfill horizontal component to describe a sloped backfill. If the backfill is flat, this parameter should be left blank.	--	0.0 (E)	100.0 (W)	--[2,3]
10. Backfill Slope Height	The height of the sloped portion of a broken backfill. If the backfill is continuously sloping, or if the backfill is flat, this parameter should be left blank.	ft	0.0 (E)	50.0 (W)	--[4]
11. Front (*) Water Level	The level of the water at the front of the structure measured from the top of the structure. If a front water level does not exist, this parameter should be left blank. If left blank for a design, the program will calculate based on DM-4 Section 3.11.3 only if back water level is entered. For analysis, if the front water level is left blank, the program places the front water level at the bottom of the footing.	ft	0.0 (E)	300.0 (W)	--[5]
12. Back (*) Water Level	The level of the water at the back of the structure measured from the top of the structure. If a back water level does not exist, this parameter should be left blank. For spread footings on soil, this level should not be under the bottom of the lowest soil layer. The backwater level is used as the reference water level for bearing resistance and settlement calculations. For rock, the level should not be less than the bottom of the footing.	ft	0.0 (E)	300.0 (W)	--[5]
13. Type of Wall	Indicate the type of wall: C - Cantilever wall. G - Gravity wall. Note: Gravity walls cannot be designed.	--	C, G (E)	--	--
14. Architectural Treatment Thickness	The thickness of the architectural treatment measured from the front face of the stem. Leave blank if no architectural treatment is present.	in	0.0 (E)	6.0 (W)	0.0[6]

[1] A blank for the horizontal and vertical batter indicates a vertical wall face.
[2] A blank for the horizontal and vertical backfill slopes indicates a flat backfill.
[3] Maximum backfill slope is 1:1.5.
[4] A blank for the backfill slope height indicates a continuously sloping or flat backfill.
[5] A blank indicates the absence of a water level.
[6] If no architectural treatment is present, this value can be left blank or set to zero.
* A minimum water differential of 3 ft. is required as specified in DM-4 Section 3.11.3. The minimum water differential must be applied even when the back water level is below the bottom of the footing.
\+ The Backfill Slope Angle (arctangent (Backfill Vertical Component/ Backfill Horizontal Component)) must be less than the Backfill Internal Friction Angle entered on the MAT command (Parameter 8).

5.9 RWL - RETAINING WALL COMMAND (Cont.)

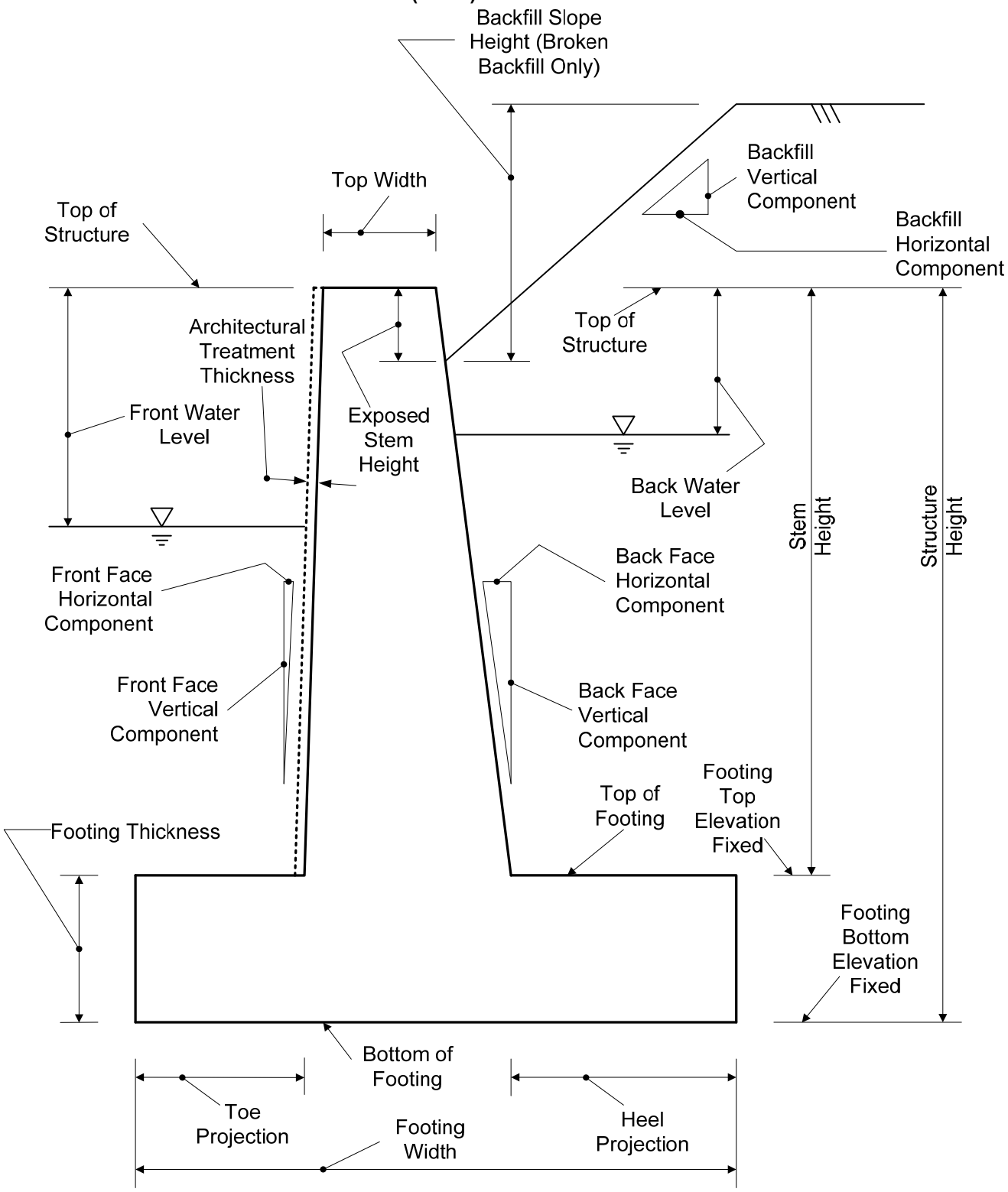


Figure 5.9-1 Retaining Wall

5.10 FTG - FOOTING COMMAND

KEYWORD	COMMAND DESCRIPTION
FTG	FOOTING - This command describes footing dimensions that apply to all structure and footing types. The footing dimensions are illustrated in Figures 5.6-1, 5.7-1, 5.8-1, or 5.9-1, depending on the structure type. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Minimum Footing Thickness	For design, this data item represents the minimum footing thickness permissible, which the program uses to begin the design process. For analysis, this parameter represents the footing thickness and must be entered by the user.	ft	*[5] (W)	5.0 (W)	*[4]
2. Minimum Toe Projection	For design, this data item represents the minimum toe projection permissible, which the program uses to begin the design process. For analysis, this parameter represents the toe projection and must be entered by the user.	ft	0.0 (E)	15.0 (W)	1.0
3. Minimum Heel Projection	For design, this data item represents the minimum heel projection permissible. For analysis, this parameter represents the heel projection and must be entered by the user.	ft	0.0 (E)	15.0 (W)	1.0
4. Minimum Footing Width	For design, this data item represents the minimum footing width permissible. If this parameter is left blank, there is no minimum footing width. Leave blank for analysis.	ft	0.0 (E)	50.0 (W)	--[3]
5. Maximum Footing Thickness	For design, the maximum footing thickness must be specified and must not be less than the minimum footing thickness. The maximum footing thickness may not extend below the bottom of the soil layer(s). Leave blank for analysis.	ft	0.0 (E)	10.0 (W)	--
6. Maximum Toe Projection	For design, the maximum toe projection must not be less than the minimum. If this parameter is left blank, there is no maximum toe projection. Leave blank for analysis.	ft	0.0 (E)	15.0 (W)	--[2]
7. Maximum Heel Projection	For design, the maximum heel projection must not be less than the minimum. If this parameter is left blank, there is no maximum heel projection. Leave blank for analysis.	ft	0.0 (E)	15.0 (W)	--[2]
8. Maximum Footing Width	For design, the maximum footing width must not be less than the minimum. If this parameter is left blank, there is no maximum footing width. Leave blank for analysis.	ft	0.0 (E)	50.0 (W)	--[2]
9. Footing Thickness Increment	The increment to add to the footing thickness to obtain the next footing size for a design run. This parameter can be used to speed up a design run (refer to Section 6.10.9 for details). Leave blank for Analysis runs.	in	1.0 (E)	12.0 (W)	2.0

5.10 FTG - FOOTING COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
10. Footing Width Increment	The increment to add to the footing width to obtain the next footing size for a design run. This parameter can be used to speed up a design run (refer to Section 6.10.10 for details). Leave blank for Analysis runs.	in	1.0 (E)	12.0 (W)	3.0
11. Footing Stem Increment	The increment used increase the toe projection during a design run. This parameter can be used to speed up a design run (refer to Section 6.10.11 for details). Leave blank for Analysis runs.	in	1.0 (E)	12.0 (W)	1.0

[1] A blank indicates no limit on the minimum dimension.
[2] A blank indicates no limit on the maximum dimension.
[3] For design only, the Minimum Footing Width of Pile/Caisson foundation is the larger of:
- Minimum Toe Projection + Stem Base Width + Minimum Heel Projection
- Toe to First Row + Minimum Row Spacing + Minimum Heel to Last Row

[4] For design only, spread footing = 2.0 ft; pile footing = 2.5 ft
[5] Spread footing 2.0 ft; Pile footing 2.5 ft

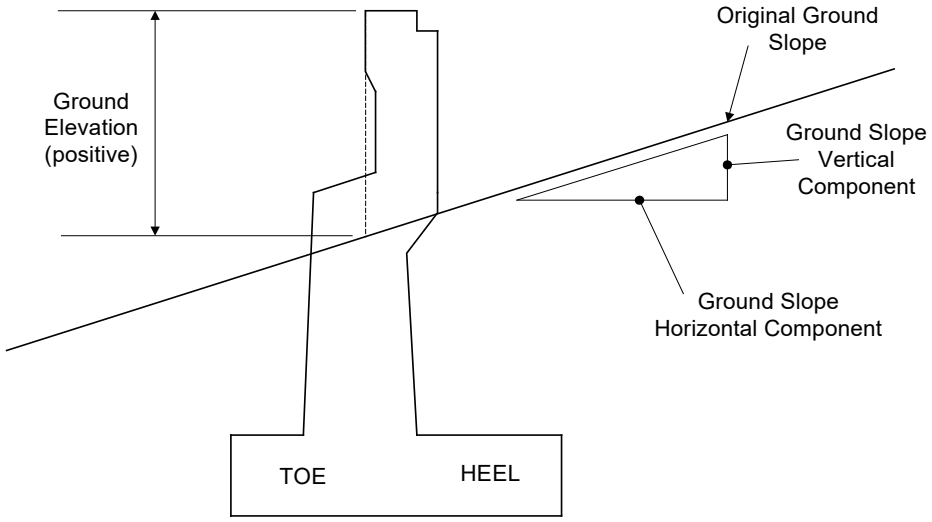
5.11 SPR - SPREAD COMMAND

KEYWORD	COMMAND DESCRIPTION
SPR	SPREAD - This command describes the parameters used to select and perform the spread footing design optimization. This command may only be specified once. The ground slope parameters are illustrated in Figure 5.11-1. Do not specify this command for an analysis run.

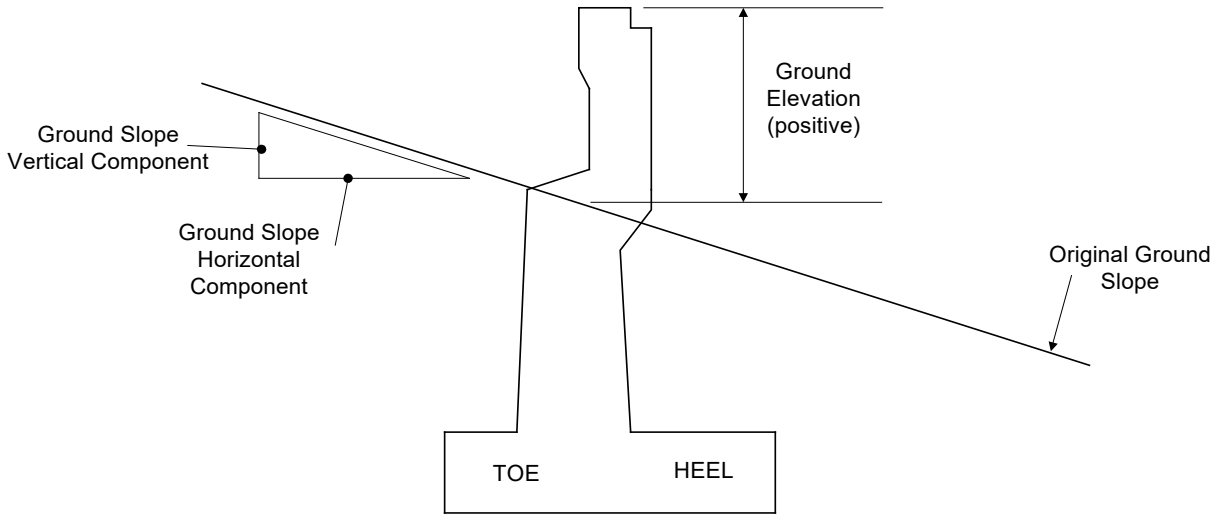
PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Design Optimizing	Optimize the design for: C - least footing cost V - least footing volume If V is selected by the user, all other parameters on this command should be left blank.	--	C, V (E)	--	--
2. Cost of Concrete	The cost of installed footing concrete.	$/yd^3	0.0 (E)	1000.0 (W)	--
3. Cut or Fill	Existing ground type: C - Structure is situated in a cut zone. F - Structure is situated in a fill zone. If F is selected by the user, parameters 5 through 9 should be left blank.	--	C, F (E)	--	--
4. Cost of Fill	Cost of installed structural backfill material. This parameter is applicable for structures in both a fill zone and a cut zone.	$/yd^3	0.0 (E)	1000.0 (W)	--
5. Cost of Cut	Cost to cut into existing soil for structure placement. This parameter is only applicable for structures in a cut zone. If the structure is in a fill zone, leave this parameter blank.	$/yd^3	0.0 (E)	1000.0 (W)	--
6. Ground Elevation	The elevation of the original ground relative to the final structure placement. The ground elevation is measured from the top of the structure. If the original ground is higher than the top of the structure, this dimension should be negative. This parameter is only applicable for structures in a cut zone.	ft	-100.0 (W)	100.0 (W)	--
7. Ground Slope Type	Indicate the direction of original ground slope. This parameter is only applicable for structures in a cut zone: T - Original ground slope increases toward the toe. H - Original ground slope increases toward the heel. F - Original ground slope is flat.	--	T, H, F (E)	--	--
8. Ground Slope Vert. Component	The vertical component of the original ground slope. This parameter is only applicable for structures in a cut zone where the ground is sloped. If the ground is flat, leave this parameter blank.	--	0.0 (E)	100.0 (W)	--

5.11 SPR - SPREAD COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
9. Ground Slope Horz. Component	The horizontal component of the original ground slope. This parameter is only applicable for structures in a cut zone where the ground is sloped. If the ground is flat, leave this parameter blank.	--	0.0 (E)	100.0 (W)	--



(a) Slope Type 'H', Positive Ground Elevation



(b) Slope Type 'T', Positive Ground Elevation

Figure 5.11-1 SPR Command Ground Slope Orientation

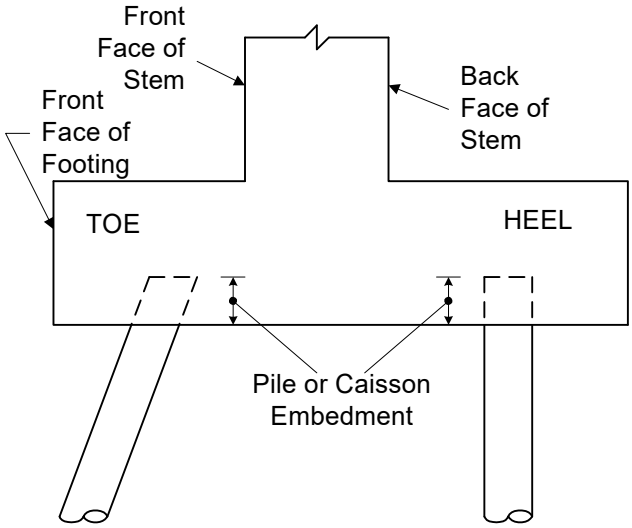
5.12 PIL - PILE COMMAND

KEYWORD	COMMAND DESCRIPTION
PIL	PILE - This command describes pile properties and individual pile dimensions. Individual pile dimensions are illustrated in Figure 5.12-1. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Pile Dimension A	Diameter of a circular pile or the flange width or web depth of an H pile, measured in the perpendicular direction of the footing. A pile footing may consist of only one type of pile (circular or H).	in	0.0 (E)	24.0 (W)	--
2. Pile Dimension B	Flange width or web depth of an H pile measured in the parallel direction of the footing. For a footing with circular piles, this dimension should be left blank.	in	0.0 (E)	24.0 (W)	--[1]
3. Pile Embedment	Vertical distance from the bottom of the footing to the top of the embedded piles within the footing.	in	12.0 (E)	24.0 (W)	--
4. Service Axial Capacity	NOTE: This parameter is no longer used and should be left blank.	--	--	--	--
5. Strength Axial Capacity	The factored compressive axial capacity of a single pile for strength conditions. This capacity will also be used when evaluating Extreme Event II. Refer to User's Manual Section 6.12.5 for Chief Bridge Engineer approval limitations.	kip	0.0 (E)	1000.0 (W)	--
6. Service Lateral Capacity	NOTE: This parameter is no longer used and should be left blank.	--	--	--	--
7. Strength Lateral Capacity	The factored lateral capacity of a single pile in an all vertical pile foundation for strength conditions. This capacity will also be used when evaluating Extreme Event II. This value should be left blank when battered piles are present. Refer to User's Manual Section 6.12.7 for Chief Bridge Engineer approval limitations.	kip	0.0 (E)	100.0 (W)	--
8. Pile Uplift Capacity	The uplift axial capacity of a single pile. Uplift is measured axially and allowed for all limit states except the service limit states.	kip	0.0 (E)	300.0 (W)	--

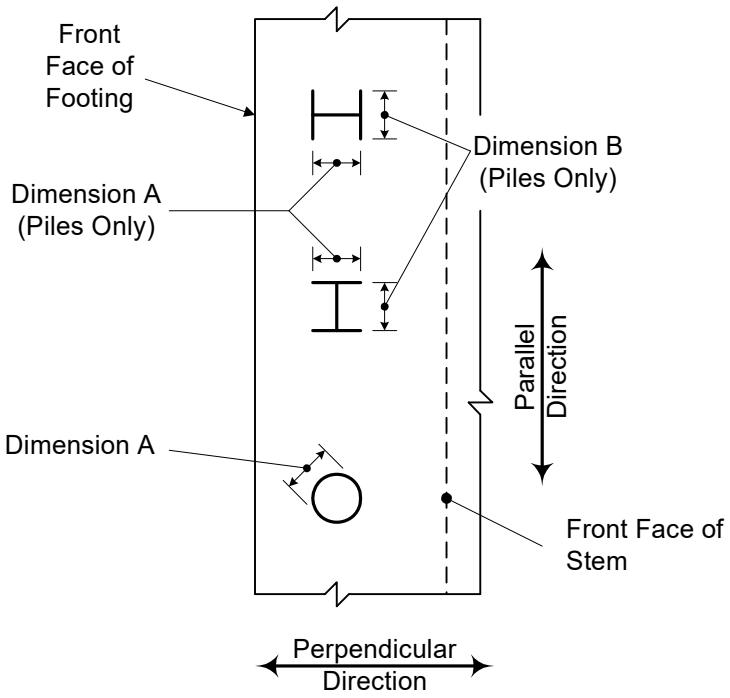
[1] A blank indicates circular piles.

5.12 PIL - PILE COMMAND (Cont.)



(a) Embedment

Note: A footing may only have one type and orientation of piles or caissons.



(b) Pile / Caisson Orientation

Figure 5.12-1 Pile / Caisson Dimensions

5.13 CAI - CAISSON COMMAND

KEYWORD	COMMAND DESCRIPTION
CAI	CAISSON - This command describes caisson properties and individual caisson dimensions. Individual caisson dimensions are illustrated in Figure 5.12-1. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Caisson Diameter	Diameter of a caisson.	in	0.0 (E)	60.0 (W)	--
2. Caisson Embedment	Vertical distance from the bottom of the footing to the top of the embedded caissons in the footing.	in	0.0 (E)	24.0 (W)	--
3. Service Axial Capacity	NOTE: This parameter is no longer used and should be left blank.	--	--	--	--
4. Strength Axial Capacity	The compressive axial capacity of a single caisson for strength conditions. This capacity will also be used when evaluating Extreme Event II.	kip	0.0 (E)	1600.0 (W)	--
5. Service Lateral Capacity	NOTE: This parameter is no longer used and should be left blank.	--	--	--	--
6. Strength Lateral Capacity	The lateral capacity of a single caisson in an all vertical caisson foundation for strength conditions. This capacity will also be used when evaluating Extreme Event II. This value should be left blank when battered piles are present.	kip	0.0 (E)	160.0 (W)	--
7. Caisson Uplift Capacity	The uplift axial capacity of a single caisson. Uplift is allowed for all limit states except the service limit states.	kip	0.0 (E)	300.0 (W)	--

5.14 PED - PEDESTAL COMMAND

KEYWORD	COMMAND DESCRIPTION
PED	PEDESTAL - This command describes pedestal properties and dimensions. Pedestal dimensions are illustrated in Figures 5.14-1 and 5.14-2. This command may be specified only once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Pedestal Spacing	Center to center spacing of pedestals in the parallel direction of the footing.	ft	0.0 (E)	30.0 (W)	--
2. Pedestal Height	The height of the pedestal measured from the bottom of the pedestal to the bottom of the footing.	ft	0.0 (E)	30.0 (W)	--
3. Pedestal Front Height	The height of the front part of the pedestal measured from the bottom of the pedestal to the beginning of the front slope. If the pedestal front has no slope, the total pedestal height should be used.	ft	* (E)	30.0 (W)	--
4. Minimum Pedestal Width	For design, this parameter represents the minimum pedestal width allowed, and the value, which the program uses to begin the design process. For analysis, this parameter is the pedestal width.	ft	0.0 (E)	30.0 (W)	--
5. Minimum Pedestal Thickness	For design, this parameter represents the minimum pedestal thickness allowed, and the value, which the program uses to begin the design process. For analysis, this parameter is the pedestal thickness.	in	* (E)	36.0 (W)	--
6. Pedestal Front Projection	For analysis only, this parameter is the pedestal front projection. Leave blank for design. This parameter is set by the program to 1 ft. as per DM-4 Section 10.6.5.2P for design.	ft	0.0 (E)	10.0 (W)	--
7. Pedestal Back Offset	For analysis only, specify the pedestal back offset. Leave blank for design. In design problems, the back offset is set by the program, with a maximum value equal to the footing thickness and a minimum value of 1 ft. as per DM-4 Section 10.6.5.2P.	ft	0.0 (E)	10.0 (W)	1.0
8. Maximum Pedestal Width	For design, this parameter represents the maximum pedestal width allowed. Leave blank for analysis.	ft	0.0 (E)	30.0 (W)	--
9. Maximum Pedestal Thickness	For design, this parameter represents the maximum pedestal thickness allowed. Leave blank for analysis.	in	24.0 (E)	36.0 (W)	--
10. Design Optimization	Optimize the design for: D - least pedestal density V - least footing volume Leave Blank for Analysis.	--	D, V (W)	--	--

* For analysis, the lower limit is equal to 0.0 and is processed as an error check. For design, the lower limit is equal to the value specified in DM-4 and is processed as an error check.

5.14 PED - PEDESTAL COMMAND (Cont.)

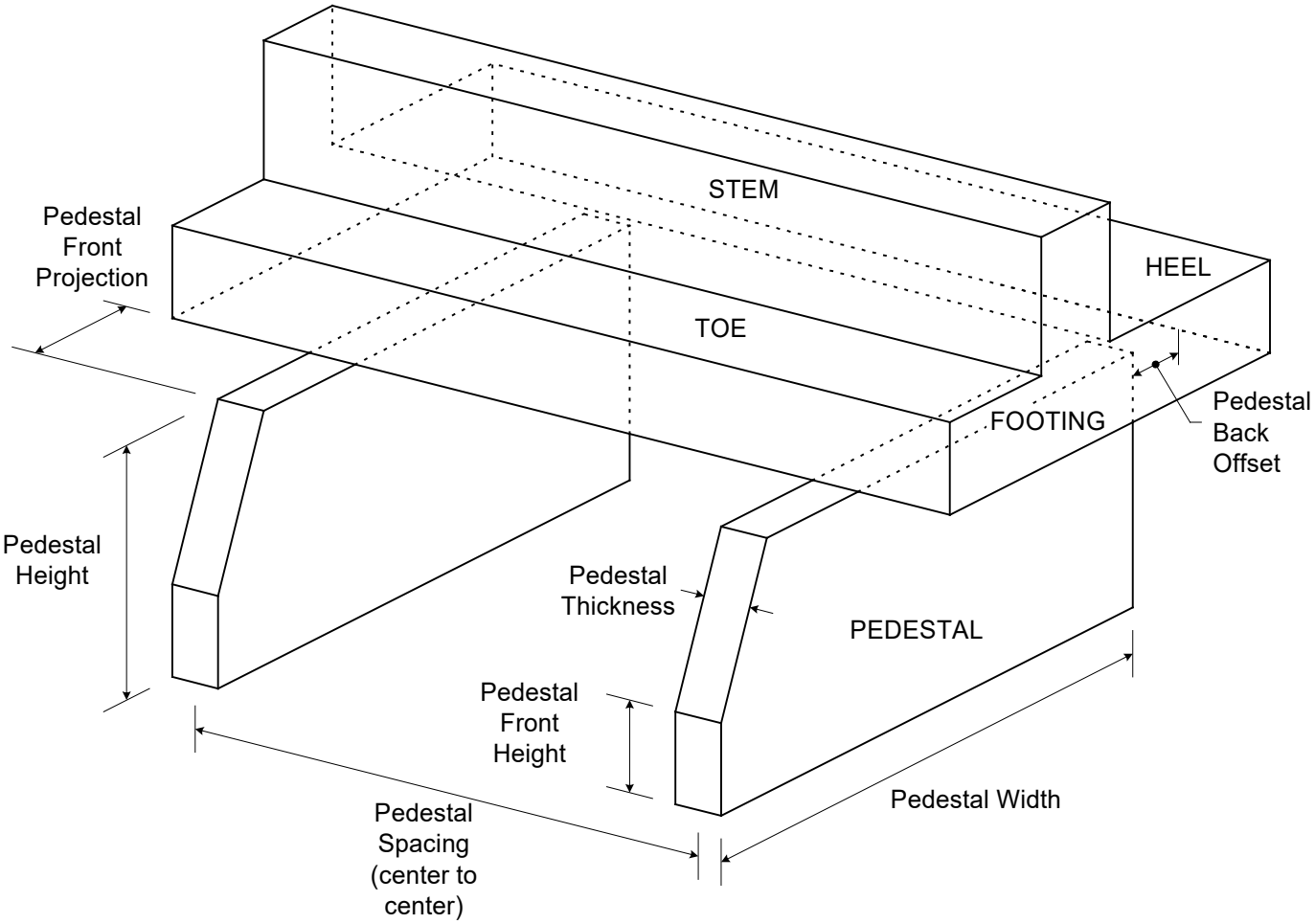
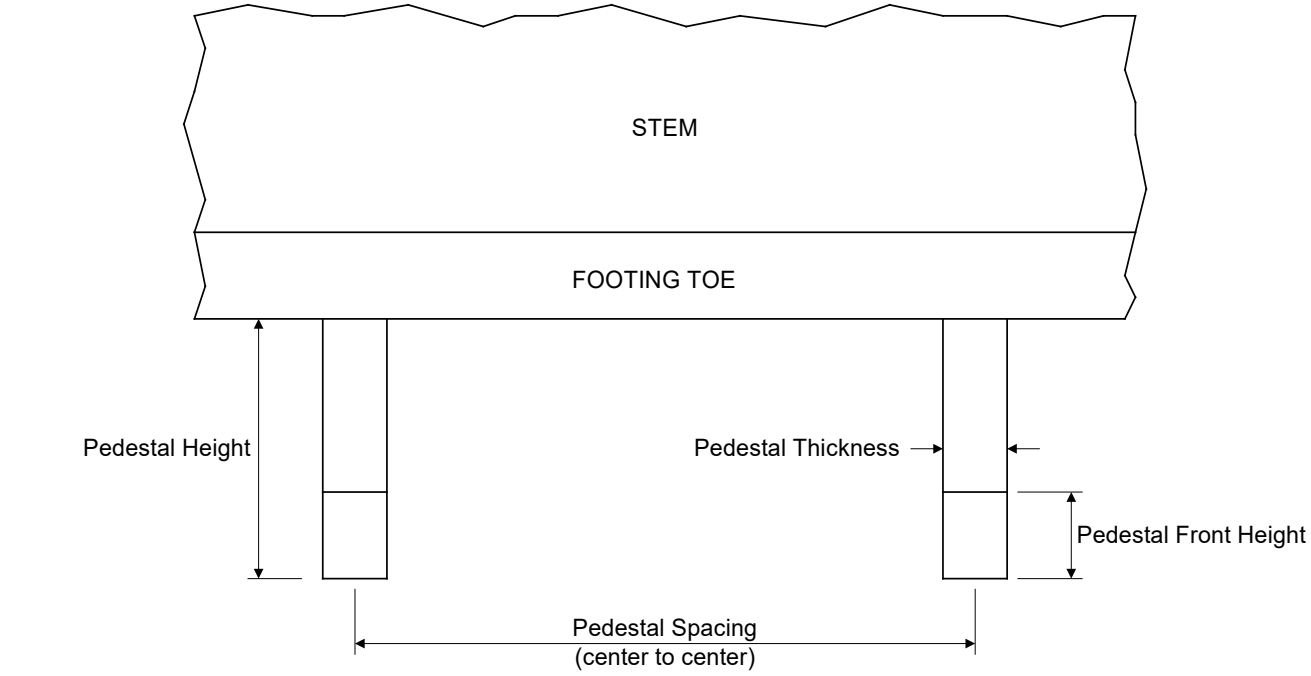
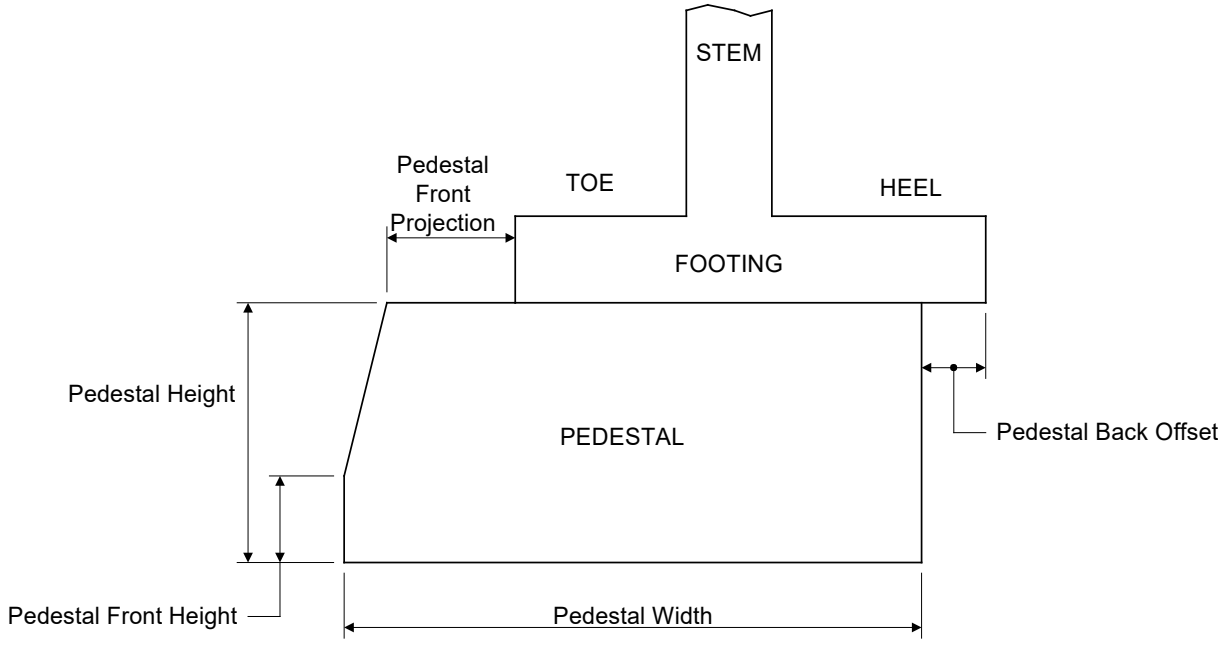


Figure 5.14-1 Pedestal Dimensions

5.14 PED - PEDESTAL COMMAND (Cont.)



(a) Front View



(b) Side View

Figure 5.14-2 Pedestal Dimensions

5.15 LYD - PILE/CAISSON LAYOUT DESIGN COMMAND

KEYWORD	COMMAND DESCRIPTION
LYD	PILE / CAISSON LAYOUT DESIGN - This command is used to describe dimensions and criteria necessary for the design of a pile or caisson footing. Dimensions are illustrated in Figure 5.15-1. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Toe to First Row	The distance from the toe edge of the footing to the centerline of the first pile or caisson row.	ft	1.5[2] (E)	6.0 (W)	-
2. Minimum Heel to Last Row	The minimum distance from the heel edge of the footing to the centerline of the last pile or caisson row. The last pile or caisson row may not be placed at this dimension, depending on the row placement and rounding.	ft	1.5[2] (E)	6.0 (W)	-
3. Minimum Spacing	The minimum spacing from centerline to centerline of piles or caissons for both piles in a row and distances between rows.	ft	3.0[2] (E)	10.0 (W)	-
4. Maximum Spacing	The maximum spacing from centerline to centerline of piles or caissons for both piles in a row and distances between rows.	ft	3.0[2] (E)	15.0 (E)	-
5. Row Placement	Indicate how the pile/caisson rows will be placed: T - Rows will be placed as close to the toe as allowed. E - Rows will be placed evenly throughout the footing.	--	T, E (E)	--	T
6. Pile Spacing Rounding	Pile or caisson spacings within a row will be rounded to the nearest multiple of this number. If rounding is not desired, use a zero value.	ft	0.0 (E)	1.0 (W)	0.25
7. Row Distances Rounding	Distance between pile or caisson rows will be rounded to the nearest multiple of this number while maintaining at least the minimum spacing. If rounding is not desired, use a zero value.	ft	0.0 (E)	1.0 (W)	0.25
8. Pile Batter Horizontal Component	The horizontal component of pile or caisson batter. Used in conjunction with the pile batter vertical component to describe the amount of batter that may be applied during a design. If battering is not allowed, leave this parameter blank. The ratio of the Horizontal Component to the Vertical Component is limited to 1:3 or 1/3.	--	1 (E)	12 (W)	--[1]
9. Pile Batter Vertical Component	The vertical component of pile or caisson batter. Used in conjunction with the pile batter horizontal component to describe the amount of batter that may be applied during a design. If battering is not allowed, leave this parameter blank. The ratio of the Horizontal Component to the Vertical Component is limited to 1:3 or 1/3.	--	1 (E)	12 (W)	--[1]

5.15 LYD - PILE/CAISSON LAYOUT DESIGN COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
10. Last Row % Batter	Maximum percentage of piles or caissons that are allowed to be battered on the last row for a design.	%	0.0 (E)	50.0 (E)	--
11. Optimize	Optimize the design according to: P - Least pile or caisson density. F - Least footing size (by volume). C - Least installed foundation (pile/caisson and footing) cost.	--	P, F, C (E)	--	--
12. Pile / Caisson Cost	The cost of a single installed pile or caisson. This parameter is only applicable when designing a footing according to cost.	$	0.00 (E)	1000.00 (W)	--
13. Footing Cost	The cost of an installed unit volume (cubic yard) of footing concrete. This parameter is only applicable when designing a footing according to cost.	$/yd^3	0.00 (E)	1000.00 (W)	--

[1] A blank for the horizontal and vertical batter indicates a vertical pile/caisson.

[2] The actual lower limit is a function of the pile diameter/dimensions. However, the minimum lower limit as per DM-4 Section 10.7.1.2 for driven piles are the values shown in this table. Other limits per DM-4 Section 10.7.1.2 and LRFD Specifications Section 10.8.1.2 are also checked for driven piles and caissons.

5.15 LYD - PILE/CAISSON LAYOUT DESIGN COMMAND (Cont.)

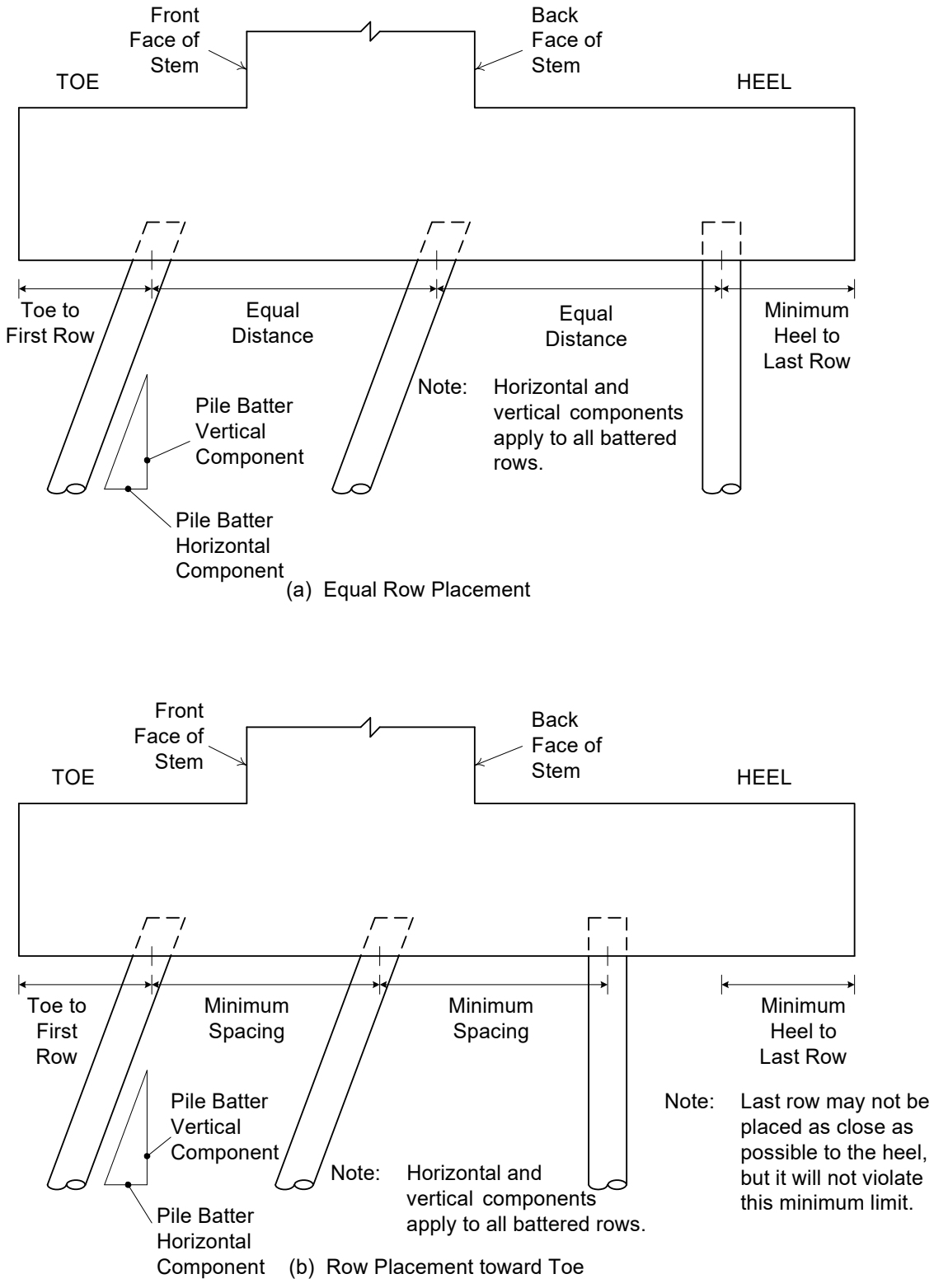


Figure 5.15-1 Pile / Caisson Design Layouts

5.16 LYA - PILE/CAISSON LAYOUT ANALYSIS COMMAND

KEYWORD	COMMAND DESCRIPTION
LYA	PILE / CAISSON LAYOUT ANALYSIS - This command is used to describe the pile or caisson layout of an existing footing. Parameters 2 through 6 may be repeated to enter up to 5 rows of piles or caissons. The dimensions are shown in Figure 5.16-1. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Number of Rows	The number of pile or caisson rows in the footing.	--	2 (E)	5 (E)	--
2. Row Distance	The distance between rows of piles or caissons measured from the centerline of the current row to the centerline of the previous row. In the case of the first row, the distance is measured to the toe edge of the footing.	ft	* (E)	15.0 (W)	--
3. Spacing Within a Row	The typical spacing between piles or caissons within a row measured from centerline to centerline of the piles or caissons.	ft	* (E)	15.0 (W)	--
4. Percent Battered	The number of battered piles or caissons within a row expressed as a percentage of the total piles or caissons in the row. If all piles or caissons in the row are completely vertical, enter a zero value. Note: Typically, the percentage of piles battered in the last row should not exceed 50%.	%	0.0 (E)	100.0 (E)	--
5. Horizontal Component	The horizontal component of the pile or caisson batter. Used in connection with the vertical component to fully describe the batter for a row of piles or caissons. Different rows may have different batters. This parameter should be left blank for an all vertical row. The ratio of the Horizontal Component to the Vertical Component is limited to 1:3 or 1/3.	--	1 (E)	12 (W)	--[1]
6. Vertical Component	The vertical component of the pile or caisson batter. Used in connection with the horizontal component to fully describe the batter for a row of piles or caissons. Different rows may have different batters. This parameter should be left blank for an all vertical row. The ratio of the Horizontal Component to the Vertical Component is limited to 1:3 or 1/3.	--	1 (E)	12 (W)	--[1]

* Lower limit values are computed as per DM-4 Section 10.7.1.2 for driven piles and LRFD Specifications Section 10.8.1.2 for caissons.

[1] A blank for the horizontal and vertical batter indicates a vertical pile/caisson.

5.16 LYA - PILE/CAISSON LAYOUT ANALYSIS COMMAND (Cont.)

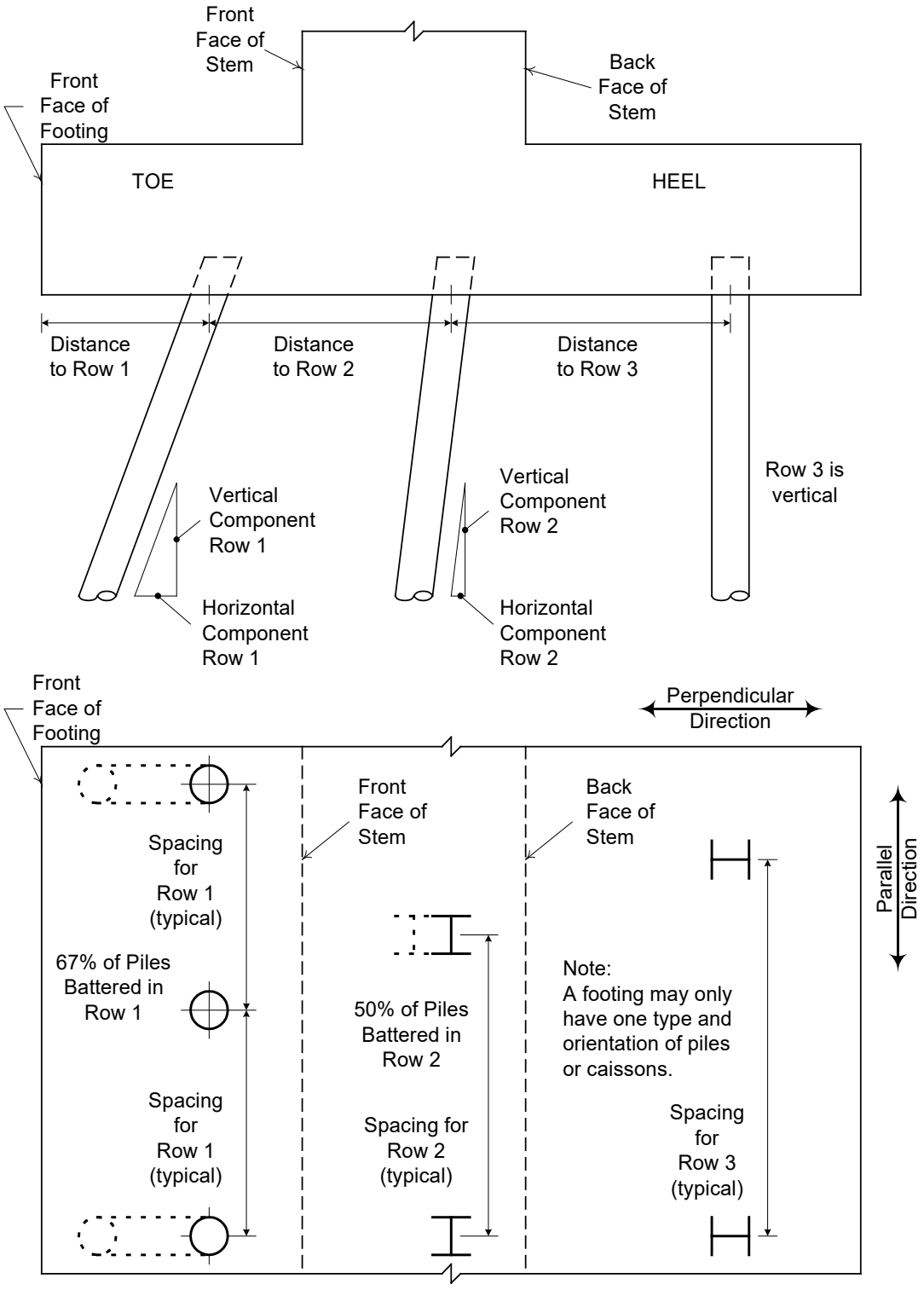


Figure 5.16-1 Pile / Caisson Analysis Layout

5.17 MAT - MATERIALS COMMAND

KEYWORD	COMMAND DESCRIPTION
MAT	MATERIALS - This command describes properties of materials used in the abutment or retaining wall. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Backwall f_c'	The 28-day compressive strength for concrete in the backwall. This parameter should be left blank for structures that do not have a backwall. If structure has a backwall, this value should be entered as 3.5 ksi, corresponding to Class AA concrete (BD-621M, Sheet 1).	ksi	2.4 (E)	--[1] (E)	--
2. Stem f_c'	The 28-day compressive strength for concrete in the stem. This value should be entered as 3.0 ksi, corresponding to Class A concrete (BD-621M, Sheet 1).	ksi	2.4 (E)	--[1] (E)	3.0
3. Footing f_c'	The 28-day compressive strength for concrete in the footing and pedestals. This value should be entered as 3.0 ksi, corresponding to Class A concrete (BD-621M, Sheet 1).	ksi	2.4 (E)	--[1] (E)	3.0
4. fy	The yield strength of reinforcing steel in the structure. For gravity structures, leave blank.	ksi	33.0 (W)	65.0 (W)	60.0
5. Backwall Reinf. Epoxy Coated	Enter: Y - Reinforcement used is epoxy coated. N - Reinforcement used is not epoxy coated. For gravity structures and structures without a backwall, leave blank.	--	Y, N (E)	--	--
6. Stem Reinf. Epoxy Coated	Enter: Y - Reinforcement used is epoxy coated. N - Reinforcement used is not epoxy coated. For gravity structures, leave blank.	--	Y, N (E)	--	--
7. Footing Reinf. Epoxy Coated	Enter: Y - Reinforcement used is epoxy coated. N - Reinforcement used is not epoxy coated. For gravity structures, leave blank.	--	Y, N (E)	--	--
8. Backfill Friction Angle	Enter the friction angle for the backfill material.	deg	30.00 (W)	36.00 (W)	33.25
9. Backfill Unit Weight - Dry	Enter the dry unit weight of the backfill material.	lb/ft^3	30.0 (W)	140.0 (W)	120.0 (W)

5.17 MAT - MATERIALS COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
10. Backfill Unit Weight - Saturated	Enter the saturated unit weight of the backfill material.	lb/ft^3	45.0 (W)	155.0 (W)	135.0 (W)
11. Minimum Equivalent Fluid Pressure - Backfill	Enter the minimum equivalent fluid pressure for the backfill.	lb/ft^3	30.0 (W)	45.0 (W)	35.0 (W)
12. Concrete Unit Weight for DL	Enter the concrete unit weight/density for computing the dead load of the abutment. This value should be entered as 150 lb/ft3 for normal weight concrete or as 115 lb/ft3 for lightweight concrete. This value must be greater than or equal to the "Concrete Unit Weight for E" (parameter 13)	lb/ft^3	95. (E)	160. (E)	150.
13. Concrete Unit Weight for E	Enter the beam concrete unit weight/density for computing the concrete modulus of elasticity. This value should be entered as 145 lb/ft3 for normal weight concrete or as 110 lb/ft3 for lightweight concrete. If the value entered is less than 135 lb/ft3, the concrete is considered to be lightweight.	lb/ft^3	90. (E)	155. (E)	145.
14. Unit Weight of Architectural Treatment	Enter the unit weight/density for the architectural treatment on the front face of stem.	lb/ft^3	100. (W)	180. (W)	150.
15. fu	The ultimate tensile strength of reinforcing steel in the structure. For gravity structures, leave blank.	ksi	50.0 (W)	100.0 (W)	--[2]

[1] Upper limit for f_c' is 15 ksi for normal weight concrete and 10 ksi for light weight concrete.
[2] Defaults to 90 ksi when fy is 60 ksi; otherwise no default value.

5.18 SOI - SOIL DATA COMMAND

KEYWORD	COMMAND DESCRIPTION
SOI	SOIL DATA - This command describes properties of soil below the footing. This command may not be used if the RCK command has been specified and is not applicable for pile, caisson, or pedestal footings. Figure 5.18-1 illustrates the dimensions described in this command. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default	Soil Type*
1. Stem Top to Soil Layer	This dimension is measured from the top of the structure to the top of the first soil layer.	ft	0.0 (E)	300.0 (W)	--	All
2. Footing Length (Parallel)	The length of the footing is measured in the parallel direction, see Figure 2.1-1.	ft	0.0 (E)	100.0 (W)	--	All
3. Footing Near Slope	Enter: Y - Footing is on or near a slope (see Figures 5.18-2 and 5.18-3) N - Footing is not on or near a slope.	--	Y, N (E)	--	--	All
4. Soil Level At Toe	Height of soil above the front face of the toe of the footing. For design, this value is used for all footing toe sizes. This parameter is used to calculate D_f when determining the bearing resistance. Note: For footings without a toe, the Soil Level shall be measured from the top of the footing.	ft	0.0 (E)	40.0 (W)	--	All
5. Allowable Settlement	Allowable total settlement of the structure.	in	0.0 (E)	1.0 (W)	1.0	All
6. Bearing Capacity Phi Factor	Strength reduction factor applied to bearing capacity.	--	0.35 (W)	0.75 (W)	--	c- φ Sand
7. Sliding Phi Factor	Strength reduction factor applied to sliding resistance.	--	0.80 (W)	1.0 (E)	--	c-φ Sand
8. Number of Soil Layers	The foundation may consist of one or two layers of soil.	--	1 (E)	2 (E)	--	All
9. Layer 1 Soil Layer Thickness	The thickness of the soil layer. The first soil layer must be sufficiently thick so that the footing does not punch through the layer i.e. the bottom elevation of the first soil layer must be situated below the bottom footing elevation.	ft	0.0 (E)	300.0 (W)	--	All
10. Layer 1 Undrained Shear Strength	Undrained shear strength (S_u) of the clay soil layer. Leave blank for sand or c-ϕ soils.	ksf	0.0 (E)	20.0 (W)	0.0	Clay

5.18 SOI - SOIL DATA COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default	Soil Type *
11. Layer 1 Mass Unit Weight/ Density	The mass (non-saturated) unit weight/ density (γ_m) of all soil layers.	lb/ft^3	65.0 (W)	150.0 (W)	120.0	All
12. Layer 1 Saturated Unit Weight/ Density	The saturated unit weight/density (γ_s) of the soil layer.	lb/ft^3	65.0 (W)	150.0 (W)	--	All
13. Layer 1 Elastic Modulus	The elastic modulus for the layer of soil used for determining settlement of a spread footing.	ksf	50.0 (W)	4000.0 (W)	--	All
14. Layer 1 Poisson's Ratio	Poisson's ratio for the layer of soil used for determining settlement of a spread footing. (Input temporarily not used in program. Leave blank. Program defaults to 0.5 for elastic settlement.)	--	0.1 (W)	0.5 (E)	--	All
15. Layer 1 Cohesion	The cohesion (c) of c-ϕ soil layer. Leave blank for sand and clay soils.	ksf	0.0 (E)	10.0 (W)	0.0	c-φ
16. Layer 1 Effective Friction Angle	The effective friction angle (ϕ'_f) of c-ϕ or sand soil layer. Leave blank for clay soils.	deg	0.0 (E)	45.0 (W)	--	c-φ Sand
17. Layer 1 N_{cq}	NOTE: This parameter is no longer used and should be left blank. Enter the reduction coefficient, RC_{BC}, instead.	--	--	--	--	--
18. Layer 1 $N_{\gamma q}$	NOTE: This parameter is no longer used and should be left blank. Enter the reduction coefficient, RC_{BC}, instead.	--	--	--	--	--
19. Layer 2 Soil Layer Thickness	The thickness of the soil layer	ft	0.0 (E)	300.0 (W)	--	All
20. Layer 2 Undrained Shear Strength	Undrained shear strength (S_u) of the clay soil layer. Leave blank for sand or c-ϕ soils.	ksf	0.0 (E)	20.0 (W)	0.0	Clay
21. Layer 2 Mass Unit Weight/ Density	The mass (non-saturated) unit weight/ density (γ_m) of all soil layers.	lb/ft^3	65.0 (W)	150.0 (W)	120.0	All
22. Layer 2 Saturated Unit Weight/ Density	The saturated unit weight/density (γ_s) of the soil layer.	lb/ft^3	65.0 (W)	150.0 (W)	--	All

5.18 SOI - SOIL DATA COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default	Soil Type*
23. Layer 2 Elastic Modulus	The elastic modulus for the layer of soil used for determining settlement of a spread footing.	ksf	50.0 (W)	4000.0 (W)	--	All
24. Layer 2 Poisson's Ratio	Poisson's ratio for the layer of soil used for determining settlement of a spread footing. (Input temporarily not used in program. Leave blank. Program defaults to 0.5 for elastic settlement.)	--	0.1 (W)	0.5 (E)	--	All
25. Layer 2 Cohesion	The cohesion (c) of c-ϕ soil layer. Leave blank for sand and clay soils.	ksf	0.0 (E)	10.0 (W)	0.0	c-φ
26. Layer 2 Effective Friction Angle	The effective friction angle (ϕ'_f) of c-ϕ or sand soil layer. Leave blank for clay soils.	deg	0.0 (E)	45.0 (W)	--	c-φ Sand
27. Layer 2 N_{cq}	NOTE: This parameter is no longer used and should be left blank. Enter the reduction coefficient, RC_{BC}, instead.	--	--	--	--	--
28. Layer 2 $N_{\gamma q}$	NOTE: This parameter is no longer used and should be left blank. Enter the reduction coefficient, RC_{BC}, instead.	--	--	--	--	--
29. Apply Inclination Factor	Enter whether the inclination factor should be applied when computing the bearing resistance: Y - Include inclination factors N - Do not include inclination factors.	--	Y, N (E)	--	Y	All
30. Precast or Cast-in-Place	Indicate if the structure is precast or cast-in-place: P - Precast Abutment, or Precast Retaining Wall C - Cast-in-Place Abutment/or Retaining Wall	--	P, C (E)	--	C	c-ϕ Sand
31. Layer 1 Reduction Coefficient, RC_{BC1}	Reduction coefficient, RC_{BC}, for the soil layer for footings placed near a slope. See LRFD Specifications Tables 10.6.3.1.2c-1 and 10.6.3.1.2c-2. If the footing is not on or near a slope (parameter 3 of this command), this parameter must be left blank.	--	0.0 (E)	1.0 (E)	**	All

5.18 SOI - SOIL DATA COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default	Soil Type *
32. Layer 2 Reduction Coefficient, RC_{BC2}	Reduction coefficient, RC_{BC}, for the soil layer for footings placed near a slope. See LRFD Specifications Table 10.6.3.1.2c-1 and 10.6.3.1.2c-2. If the footing is not on or near a slope (parameter 3 of this command), this parameter must be left blank.	--	0.0 (E)	1.0 (E)	**	All

* The Soil Type column indicates which parameters are required for the three possible soil types; Clay, c-φ, or Sand. A parameter should be left blank if the soil type does not appear in the column. Refer to Section 6.18 for more details.

** Leave blank if the soil is not on or near a slope. Refer to Parameter 3 of this command. If the soil is on or near a slope, this value must be entered.

5.18 SOI - SOIL DATA COMMAND (Cont.)

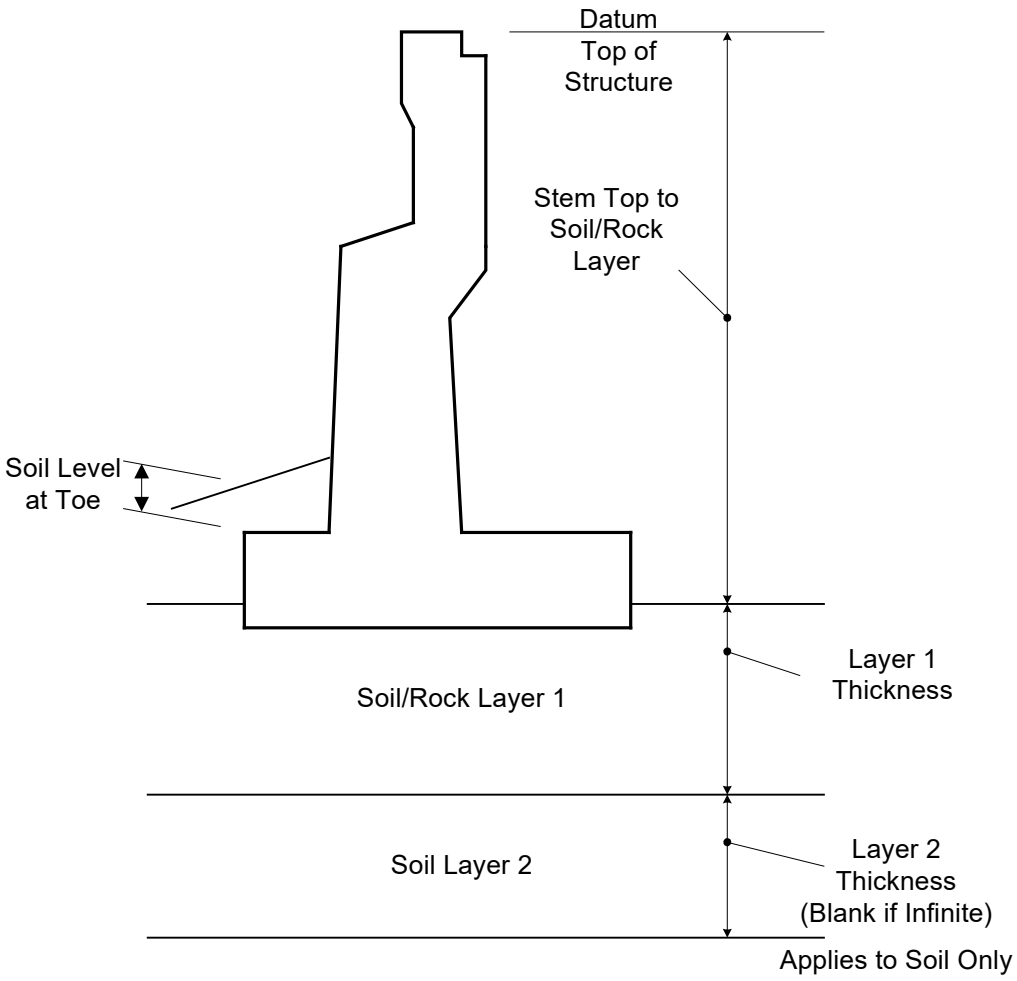


Figure 5.18-1 Soil / Rock Foundation Dimensions for Spread Footings

5.18 SOI - SOIL DATA COMMAND (Cont.)

Footing is considered to be on a slope if the front face of the toe of the footing is located within the limit of slope, as shown below, for all values of soil level at toe.

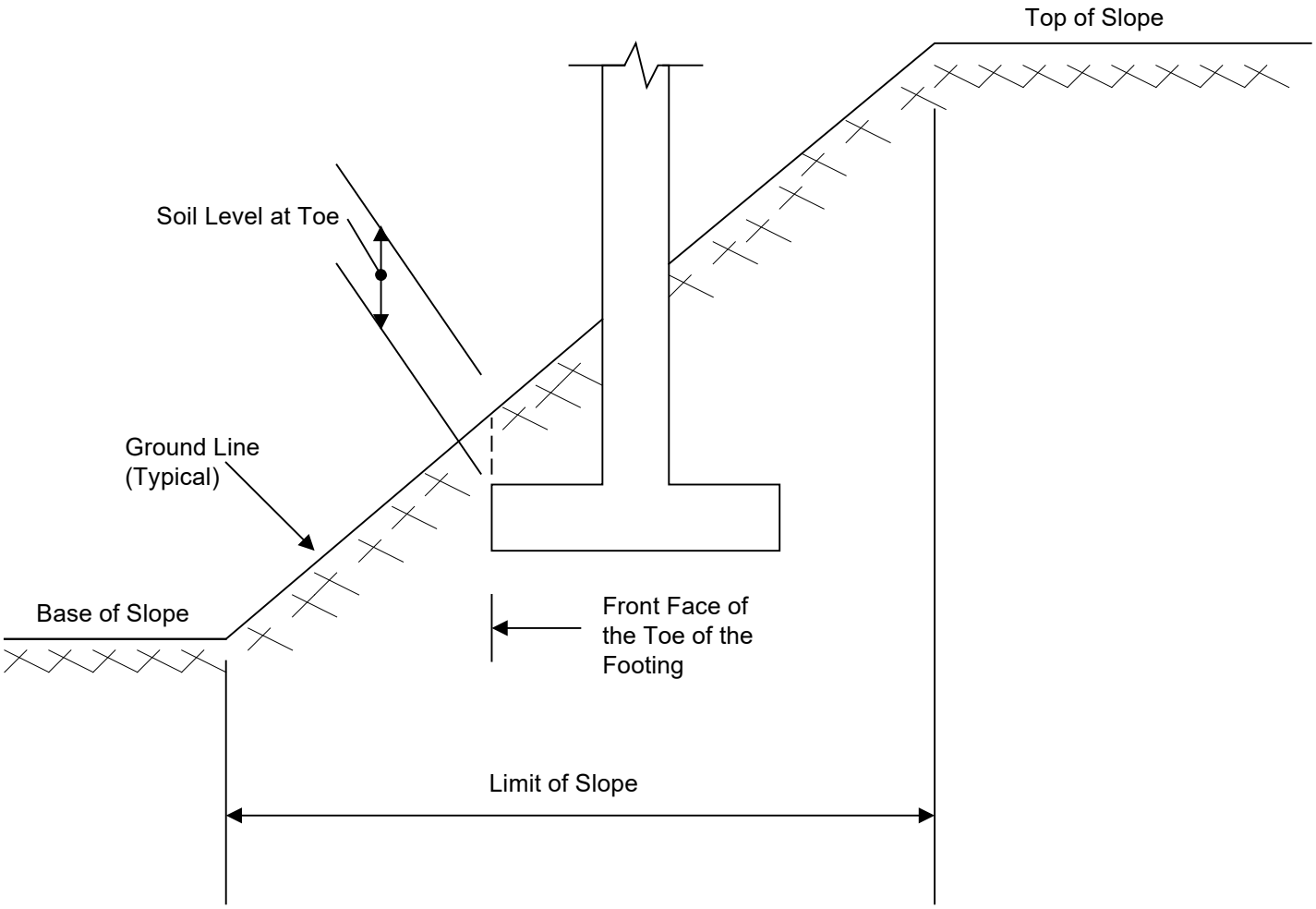


Figure 5.18-2 Footing on a Slope Criteria

5.18 SOI - SOIL DATA COMMAND (Cont.)

Footing is considered to be near slope if the front face of the toe of the footing is located within the distance of the limit of slope at the top of slope as shown below.

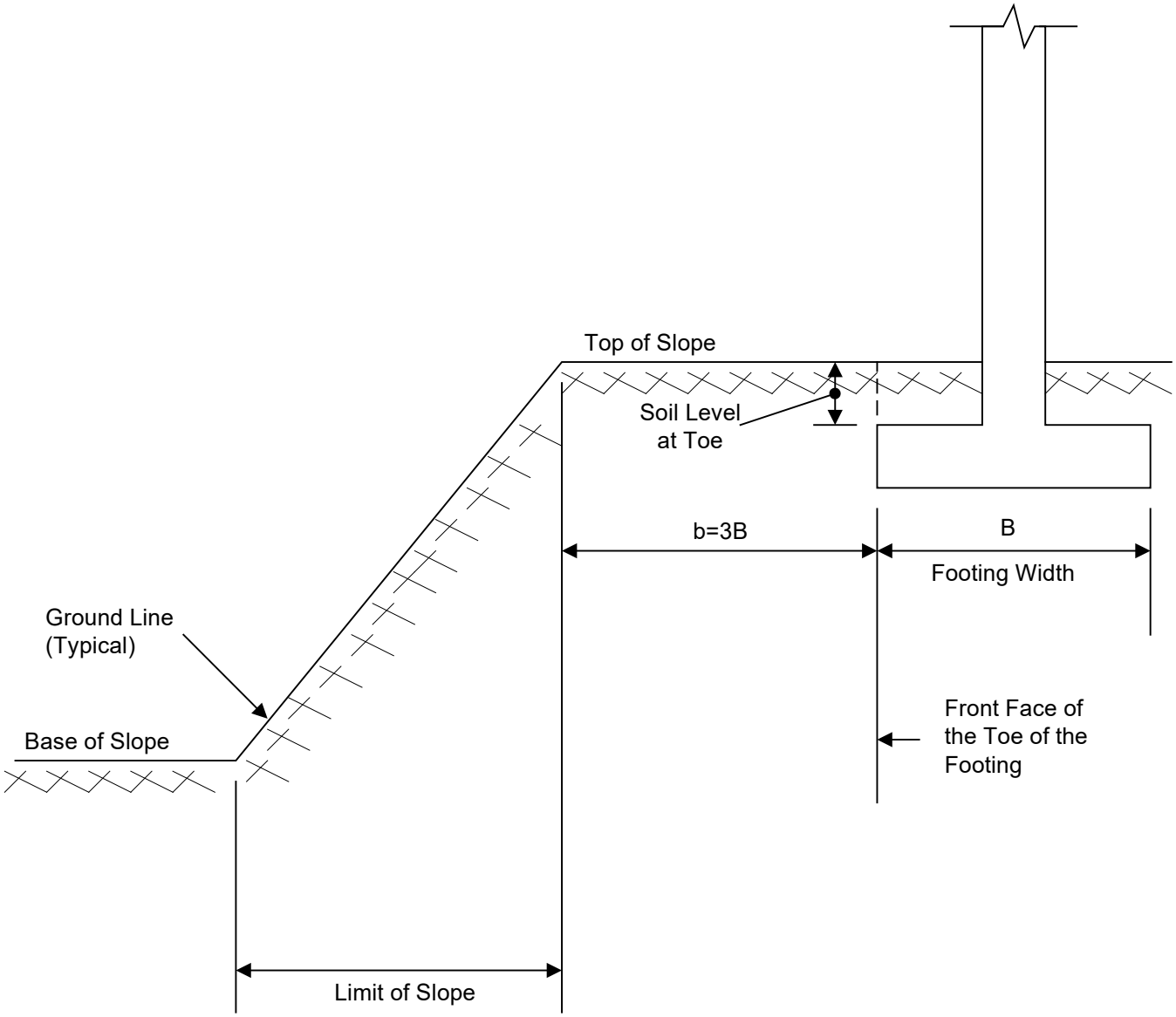


Figure 5.18-3 Footing Near a Slope

5.19 RCK - ROCK DATA COMMAND

KEYWORD	COMMAND DESCRIPTION
RCK	ROCK DATA - This command describes properties of rock below the footing. This command may not be used if the SOI command has been specified and is not applicable for pile or caisson footings. This command must be specified for pedestal footing problems. Only one rock layer can be described. Figures 5.18-1 and 2 illustrate the dimensions described in this command. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Empirical Bearing Capacity	The ultimate bearing capacity (q_{ult}) of the rock based on the empirical method as outlined in the DM-4.	ksf	0.0 (E)	200.0 (W)	--
2. Stem Top to Rock Layer	The elevation of the rock layer is specified as a distance from the top of the structure. For spread footings, the top of the rock layer must be situated within the elevation of the footing. If the footing is embedded in the rock layer, the EH load will be affected as described in Section 3.3.2.8. For pedestal footings, the top of the rock layer must be situated within the elevation of the pedestal (i.e. below the bottom of the footing and above the bottom of the pedestal).	ft	0.0 (E)	300.0 (W)	--
3. Footing Length (Parallel)	The length of the footing measured in the parallel direction, see Figure 2.1-1.	ft	0.0 (E)	100.0 (W)	--
4. Sliding Resistance	Sliding resistance on rock: Y - Perform check. N - Do not perform check.	--	Y, N (E)	--	--
5. Allowable Settlement	Allowable total settlement of the structure.	in	0.0 (E)	1.0 (W)	1.0
6. Bearing Capacity Phi Factor	Strength reduction factor ϕ applied to bearing capacity.	--	0.35 (W)	0.75 (W)	--
7. Sliding Phi Factor	Strength reduction factor ϕ applied to sliding resistance. Leave blank if sliding resistance is not to be checked.	--	0.80 (W)	1.0 (W)	--
8. RQD	NOTE: This parameter is no longer used and should be left blank.	--	--	--	--
9. Concrete / Rock Friction	The friction angle between the footing concrete and the layer of rock below it. This value is used when checking the sliding resistance of the foundation on rock.	deg	0.0 (E)	60.0 (W)	--
10. Intact Elastic Modulus	The intact elastic modulus for the layer of rock used for determining settlement of a spread footing.	ksi	0.1 (E)	16250.0 (W)	--

5.19 RCK - ROCK DATA COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
11. Poisson's Ratio	Poisson's ratio for the layer of rock used for determining settlement of a spread footing.	--	0.1 (W)	0.5 (E)	--
12. Rock Mass Rating	NOTE: This parameter is no longer used and should be left blank.	--	--	--	--
13. Elastic Modulus Reduction Factor	NOTE: This parameter is no longer used and should be left blank.	--	--	--	--
14. Rock Mass Modulus	The rock mass modulus as determined by LRFD Specifications and DM-4 Section 10.4.6.5 used for calculating settlement of a spread footing on rock.	ksi	0.1 (E)	16250.0 (W)	--

5.20 CNS - CONSOLIDATION SETTLEMENT COMMAND

KEYWORD	COMMAND DESCRIPTION
CNS	CONSOLIDATION SETTLEMENT - This command describes data used to calculate the consolidation and secondary settlement for spread footings on clay and/or c-ϕ soils. This command is not entered for soils composed only of sands. For clays or c-ϕ soils, this command must be entered. For two layer soils of which at least one layer is a clay or c-ϕ soil, each layer must be entered. Parameters 2 through 10 are repeated once for the description of a second layer of soil material. This command may only be used once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Number of Soil Layers	Enter number of soil layers	--	1 (E)	2 (E)	--
2. Void Ratio	Void ratio. Specify zero for sand soil layer.	--	0.1 (W)	3.0 (W)	--
3. Compression Index	Compression index, C_c (based on void ratio). Specify zero for sand soil layer.	--	0.001 (W)	1.0 (W)	--
4. Re-compression Index	Recompression index C_{cr} (based on void ratio). Specify zero for sand soil layer.	--	0.0 (E)	1.0 (W)	--
5. Secondary Compression Index	Compression index, C_α (based on strain), for change in height per log cycle of time. Specify zero for sand soil layer.	--	0.0 (E)	1.0 (W)	--
6. Initial Effective Stress	Effective stress at the top of the soil layer prior to construction. For layer 2 the effective stress at the top of the layer should normally be input as the effective stress at the top of layer 1 + the effective stress due to the thickness of soil in layer 1. Refer to section 6.20.6 for special cases.	ksi	0.0 (E)	50.0 (W)	--
7. Maximum Past Effective Stress - Top	Maximum past effective stress at the top of the soil layer. Specify zero for sand soil layer.	ksi	0.0 (E)	50.0 (W)	--
8. Primary Consolidation Time	The Time interval to the end of the primary consolidation (t1). This is used to compute the amount of secondary consolidation occurring after completion of the primary consolidation. Specify zero for a sand layer.	year	0.0 (E)	5.0 (W)	--
9. Service Life	End of time interval for secondary settlement to occur (t2). Specify zero for sand soil layer.	year	0.0 (E)	100.0 (W)	--
10. Maximum Past Effective Stress - Bottom	Maximum past effective stress at the bottom of the soil layer. Specify zero for a sand layer.	ksi	0.0 (E)	50.0 (W)	--

5.21 MRD - MISCELLANEOUS REINFORCEMENT DATA COMMAND

KEYWORD	COMMAND DESCRIPTION
MRD	MISCELLANEOUS REINFORCEMENT DATA - This command describes miscellaneous reinforcement related data for both design and analysis. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Aggregate Size	The size of aggregate used in the concrete mixture. This value is used for checking the minimum bar spacing requirements.	in	0.0 (E)	4.0 (W)	--
2. Development Correction	The correction factor applies to the development length computations. This factor should only be used to consider development length factors not currently used by the program.	--	0.0 (E)	2.0 (W)	1.0
3. Backwall Exposure	Exposure for allowable crack control spacing computation: 1 - Class 1 exposure condition. 2 - Class 2 exposure condition. Leave blank for structures without a backwall.	--	1, 2 (E)	--	--
4. Stem Exposure	Exposure for allowable crack control spacing computation: 1 - Class 1 exposure condition. 2 - Class 2 exposure condition.	--	1, 2 (E)	--	1
5. Footing Exposure	Exposure for allowable crack control spacing computation. 1 - Class 1 exposure condition. 2 - Class 2 exposure condition.	--	1, 2 (E)	--	1

5.22 CVR - REINFORCEMENT COVER COMMAND

KEYWORD	COMMAND DESCRIPTION
CVR	REINFORCEMENT COVER - This command describes the clear concrete cover for reinforcement at various locations in the backwall, stem, and footing. Cover is illustrated in Figure 5.22-1. Exposure conditions for the backwall, stem, and footing are also described on MRD. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Backwall Cover Back, Ver.	The cover measured from the back face of the backwall to the outside edge of the vertical reinforcement in the backwall. Leave blank for structures without a backwall.	in	2.0 (W)	6.0 (W)	--
2. Stem Cover Back, Ver.	The cover measured perpendicular from the back face of the stem to the outside edge of the vertical reinforcement in the stem.	in	2.0 (W)	6.0 (W)	3.0
3. Footing Cover Top, Perpend.	The cover measured from the top of the footing to the outside edge of the perpendicular reinforcement in the footing.	in	2.0 (W)	6.0 (W)	3.0
4. Footing Cover Top, Parallel	The cover measured from the top of the footing to the outside edge of the parallel reinforcement in the footing.	in	2.0 (W)	6.0 (W)	--[1]
5. Footing Cover Bot, Perpend.	The cover measured from the bottom of the footing to the outside edge of the perpendicular reinforcement in the footing.	in	3.0 (W)	6.0 (W)	4.0
6. Footing Cover Bot, Parallel	The cover measured from the bottom of the footing to the outside edge of the parallel reinforcement in the footing.	in	3.0 (W)	6.0 (W)	--[1]
7. Toe End Cover	The cover measured from the toe face of the footing to the end of the perpendicular reinforcement.	in	2.0 (W)	6.0 (W)	2.0
8. Heel End Cover	The cover measured from the heel face of the footing to the end of the perpendicular reinforcement.	in	2.0 (W)	6.0 (W)	2.0

[1] For Analysis runs of Pile/Caisson Foundations, the default cover is the perpendicular reinforcement cover + the perpendicular reinforcement bar diameter. The perpendicular reinforcement bar diameter is determined from either the bar size entered on the BAR command or the maximum bar diameter entered on the ARE command.

For Design runs of Pile/Caisson Foundations, the default cover is the perpendicular reinforcement cover + the perpendicular reinforcement maximum bar diameter. The perpendicular reinforcement maximum bar diameter is the “Footing Maximum Diameter” parameter from the SPD command.

5.22 CVR - REINFORCEMENT COVER COMMAND (Cont.)

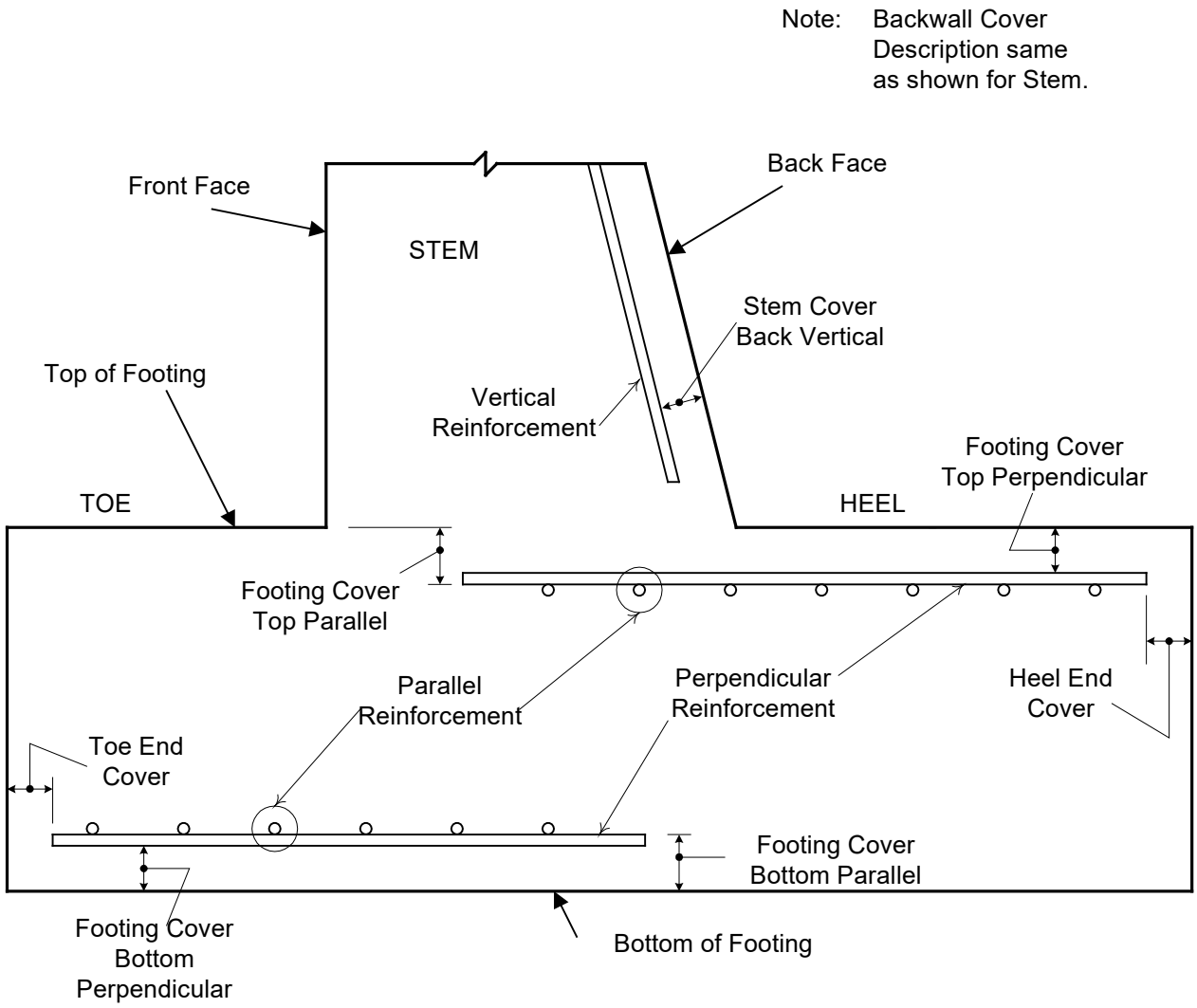


Figure 5.22-1 Concrete Cover

5.23 SPD - REINFORCEMENT DESIGN COMMAND

KEYWORD	COMMAND DESCRIPTION
SPD	DESIGN REINFORCEMENT - This command identifies the maximum bar diameter for the reinforcement in the backwall, stem and footing. These values are used for the purposes of computing the effective section depth. Footing reinforcement locations are illustrated in Figure 5.22-1. Backwall vertical reinforcement is situated like the stem back vertical reinforcement shown in Figure 5.22-1.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Backwall Maximum Diameter	The maximum diameter of the bar in the backwall used to compute the effective section depth. Leave blank if structure does not have a backwall.	in	0.0 (E)	1.41 (E)	-
2. Stem Maximum Diameter	The maximum diameter of the bar in the stem used to compute the effective section depth.	in	0.0 (E)	1.41 (E)	-
3. Footing Maximum Diameter	The maximum diameter of the bar in the footing used to compute the effective section depth.	in	0.0 (E)	1.41 (E)	-
4. Hooked Perpendicular Footing Bar	Consider hooked bars for perpendicular footing reinforcement development during design runs. (Only enter for Spread & Pile\Caisson footings) Y - Consider hooked bars N - Do not consider hooked bars.	--	Y,N (E)	--	N
5. User Requested Minimum Bar Spacing	The minimum center-to-center bar spacing the program will consider during a design run. This value should not be less than the largest of the following plus the bar diameter: 1.5 times the nominal diameter of the bars 1.5 times the maximum size of the coarse aggregate (MRD command) 2.5" as per LRFD Specifications and DM-4 Section 5.10.3.1.1	in	1.0 (E)	12.0 (W)	6.0
6. Bar Spacing Increment	The value of the increment that the program will round bar spacings to during design runs.	in	0.5 (E)	6.0 (W)	3.0

5.24 BAR - BAR SIZE COMMAND

KEYWORD	COMMAND DESCRIPTION
BAR	BAR SIZE - This command describes reinforcing bar sizes at various locations in the backwall and footing for an analysis problem. Reinforcement can be specified by using the BAR and SPA commands together, or by using the ARE command. This command may only be specified once. Footing reinforcement locations are illustrated in Figure 5.22-1. Backwall back face vertical reinforcement is situated similar to the stem back vertical reinforcement shown in Figure 5.22-1. Valid US bar sizes are 4, 5, 6, 7, 8, 9, 10, 11, 14 and 18.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Backwall Back Vertical	The size of a single vertical reinforcing bar in the back face at the backwall level. Leave blank for structures without a backwall.	US bar	4 (E)	18 (E)	--
2. Footing Top, Perpend.	The size of a single reinforcing bar in the top of the footing running in the perpendicular direction. Leave blank for pedestal footings.	US bar	4 (E)	18 (E)	--
3. Footing Top, Parallel	The size of a single reinforcing bar in the top of the footing running in the parallel direction. Leave blank for spread footings.	US bar	4 (E)	18 (E)	--
4. Footing Bottom, Perpend.	The size of a single reinforcing bar in the bottom of the footing running in the perpendicular direction. Leave blank for pedestal footings.	US bar	4 (E)	18 (E)	--
5. Footing Bottom, Parallel	The size of a single reinforcing bar in the bottom of the footing running in the parallel direction. Leave blank for spread footings.	US bar	4 (E)	18 (E)	--
6. Footing Top, Perpend. Bar Type	The bar type (Straight or Hooked) of the reinforcing bar in the top of the footing running in the perpendicular direction. Leave blank for pedestal footings.	--	H,S (E)	--	--*
7. Footing Bottom, Perpend. Bar Type	The bar type (Straight or Hooked) of the reinforcing bar in the bottom of the footing running in the perpendicular direction. Leave blank for pedestal footings.	--	H,S (E)	--	--*

* For non-pedestal footings, the program will default to Straight Bars if input value is left blank

5.25 SPA - BAR SPACING FOR ANALYSIS COMMAND

KEYWORD	COMMAND DESCRIPTION
SPA	BAR SPACING FOR ANALYSIS - This command describes the reinforcement bar spacings at various locations in the backwall and footing for an analysis problem. Reinforcement can be specified by using the SPA and BAR commands together, or by using the ARE command. This command may only be specified once. Figure 5.25-1 illustrates the spacing values to be specified.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Backwall Back Vertical	The spacing between vertical reinforcing bars in the back face of the backwall. Leave blank for structures without a backwall.	in	3.0 (W)	24.0 (W)	--
2. Footing Top, Perpend.	The spacing between reinforcing bars in the top of the footing that are running in the perpendicular direction. Leave blank for pedestal footings.	in	3.0 (W)	24.0 (W)	--
3. Footing Top, Parallel	The spacing between reinforcing bars in the top of the footing that are running in the parallel direction. Leave blank for spread footings.	in	3.0 (W)	24.0 (W)	--
4. Footing Bottom Perpend.	The spacing between reinforcing bars in the bottom of the footing that are running in the perpendicular direction. Leave blank for pedestal footings.	in	3.0 (W)	24.0 (W)	--
5. Footing Bottom, Parallel	The spacing between reinforcing bars in the bottom of the footing that are running in the parallel direction. Leave blank for spread footings.	in	3.0 (W)	24.0 (W)	--

5.25 SPA - BAR SPACING FOR ANALYSIS COMMAND (Cont.)

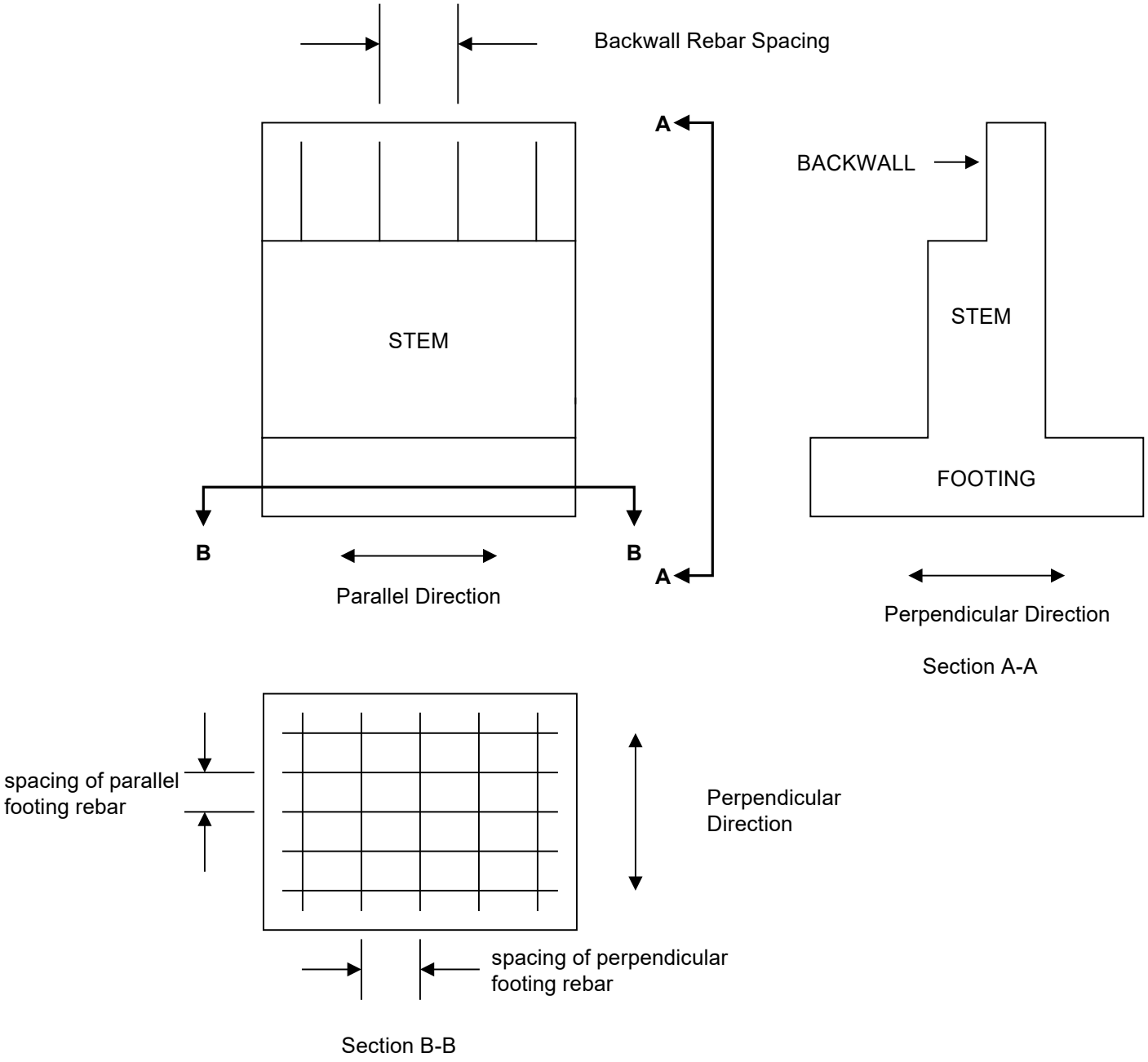


Figure 5.25-1 Rebar Spacing for SPA Command

5.26 ARE - REINFORCEMENT AREA COMMAND

KEYWORD	COMMAND DESCRIPTION
ARE	REINFORCEMENT AREA - This command describes reinforcement areas per unit width at various locations in the backwall and footing for an analysis problem. Reinforcement can be specified by using the ARE command or by using the BAR and SPA commands together. This command may only be specified once. Footing reinforcement locations are illustrated in Figure 5.22-1. Backwall vertical reinforcement is situated like the stem back vertical reinforcement shown in Figure 5.22-1.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Backwall Back Vertical	The area per width of vertical reinforcing bars in the back face of the backwall. Leave blank for structures without a backwall.	in^2/ft	0.01 (E)	4.0 (W)	--
2. Footing Top, Perpend.	The area per width of reinforcing bars in the top of the footing running in the perpendicular direction. Leave blank for pedestal footings.	in^2/ft	0.01 (E)	4.0 (W)	--
3. Footing Top, Parallel	The area per width of reinforcing bars in the top of the footing running in the parallel direction. Leave blank for spread footings.	in^2/ft	0.01 (E)	4.0 (W)	--
4. Footing Bottom, Perpend.	The area per width of reinforcing bars in the bottom of the footing running in the perpendicular direction. Leave blank for pedestal footings.	in^2/ft	0.01 (E)	4.0 (W)	--
5. Footing Bottom, Parallel	The area per width of reinforcing bars in the bottom of the footing running in the parallel direction. Leave blank for spread footings.	in^2/ft	0.01 (E)	4.0 (W)	--
6. Backwall Maximum Diameter	The maximum diameter in the backwall used to compute the effective section depth.	in	0.0 (E)	2.257 (E)	--
7. Footing Top Perpend. Maximum Diameter	The maximum diameter of the footing reinforcement -- top face / perpendicular direction -- used to compute the effective section depth and serviceability checks. Leave blank for pedestal footings.	in	0.0 (E)	2.257 (E)	--
8. Footing Top Parallel Maximum Diameter	The maximum diameter of the footing reinforcement -- top face / parallel direction -- used to compute the effective section depth and serviceability checks. Leave blank for spread footings.	in	0.0 (E)	2.257 (E)	--
9. Footing Bottom Perpend. Maximum Diameter	The maximum diameter of the footing reinforcement -- bottom face / perpendicular direction -- used to compute the effective section depth and serviceability checks. Leave blank for pedestal footings.	in	0.0 (E)	2.257 (E)	--

5.26 ARE - REINFORCEMENT AREA COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
10. Footing Bottom Parallel Maximum Diameter	The maximum diameter of the footing reinforcement -- bottom face / parallel direction -- that is used to compute the effective section depth and serviceability checks. Leave blank for spread footings.	in	0.0 (E)	2.257 (E)	--

5.27 SRA - STEM REINFORCEMENT AREAS COMMAND

KEYWORD	COMMAND DESCRIPTION
SRA	STEM REINFORCEMENT AREAS - This command is used to describe the back face vertical reinforcement in the stem for an analysis problem. The alternative is to use the SRB command. The reinforcement is described in segments as shown in Figure 5.27-1. The user is responsible for ensuring that the values of the parameters entered are representative of the effective area of the stem reinforcement as per the plan sheets. Parameters 1 through 3 may be repeated up to ten times. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Area per Unit Width	Area of fully developed reinforcement for the segment defined.	in^2	0.0 (E)	4.0 (W)	--
2. End Location	Distance from top of footing to where the reinforcement segment ends. Last segment entered should extend to the stem height.	ft	0.0 (E)	40.0 (W)	--
3. Maximum Bar Diameter	Bar diameter used for effective depth calculation and serviceability checks.	in	0.0 (E)	2.257 (W)	--

5.27 SRA - STEM REINFORCEMENT AREA COMMAND (Cont.)

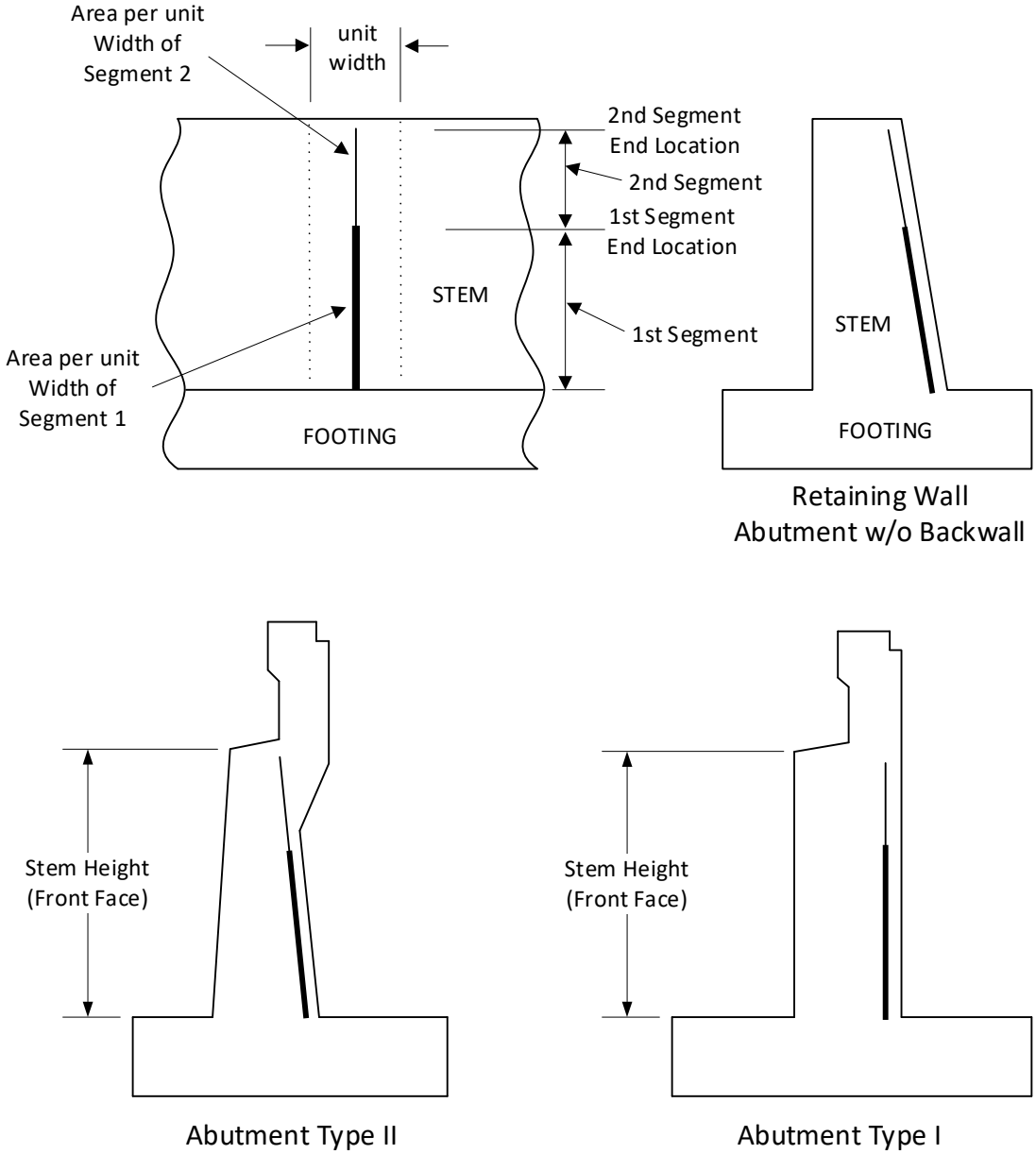


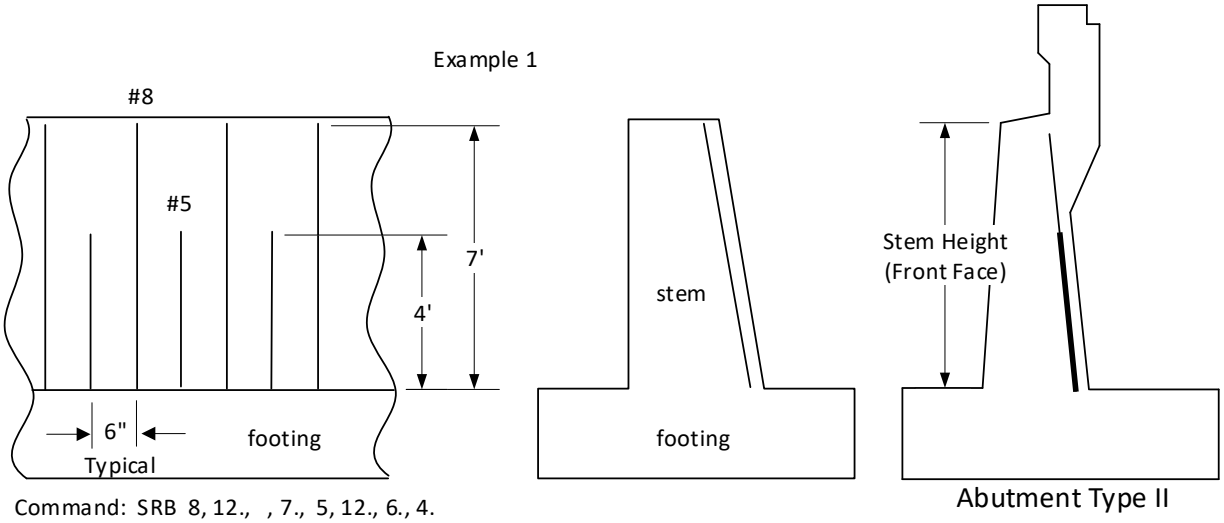
Figure 5.27-1 Stem Back face Reinforcement Areas Description

5.28 SRB - STEM REINFORCEMENT BARS COMMAND

KEYWORD	COMMAND DESCRIPTION
SRB	STEM REINFORCEMENT BARS - This command is used to describe the back face vertical reinforcement in terms of bar sizes and spacings in the stem for an analysis problem. Alternatively, the SRA command may be used. The effective reinforcement is identified by the bar size, spacing, and end location relative to the base of the stem, as shown in Figure 5.28-1. The program does not adjust the input data to account for the development length or extension length; thus, the end location of the bar entered is assumed to be the end location of the fully effective bar. Parameters 1 through 4 may be repeated up to ten times. This command may only be specified once.

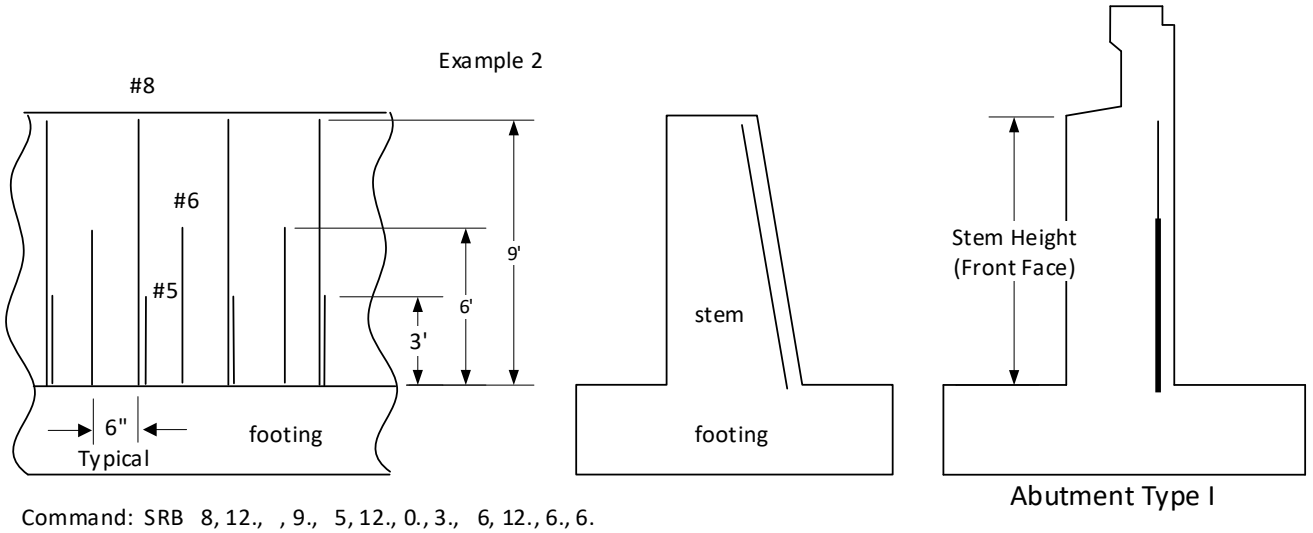
PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Bar Size	The Bar size designation.	US Bar	4 (E)	18 (W)	--
2. Bar Spacing	The spacing of the bar.	in	3. (E)	24. (W)	--
3. Group Offset	Offset (horizontal distance of the bar group) relative to the location of the first bar defined. Leave blank for the first occurrence of this parameter.	in	0. (E)	24. (W)	--
4. End Location	Location where the effective and fully developed rebar terminates relative to the base of the stem. Bars, which extend the stem height, should be entered with no reduction in length.	ft	0.0 (E)	40.0 (W)	--

5.28 SRB - STEM REINFORCEMENT BARS COMMAND (Cont.)



Command: SRB 8, 12., , 7., 5, 12., 6., 4.

Explanation: first bar defined is #8 @ 12" spacing & 0" offset (by definition) has 7' length
second bar defined is #5 @ 12" spacing at 6" offset (relative to the first bar) has 4' length



Command: SRB 8, 12., , 9., 5, 12., 0., 3., 6, 12., 6., 6.

Explanation: first bar defined is #8 @ 12" spacing & 0" offset (by definition), has 9' length
second bar defined is #5 @ 12" spacing & 0" offset (relative to the first bar), has 3' length
third bar defined is #6 @ 12" spacing & 6" offset (relative to the first bar), has 6' length

Figure 5.28-1 Stem Back face Reinforcement Bars Description

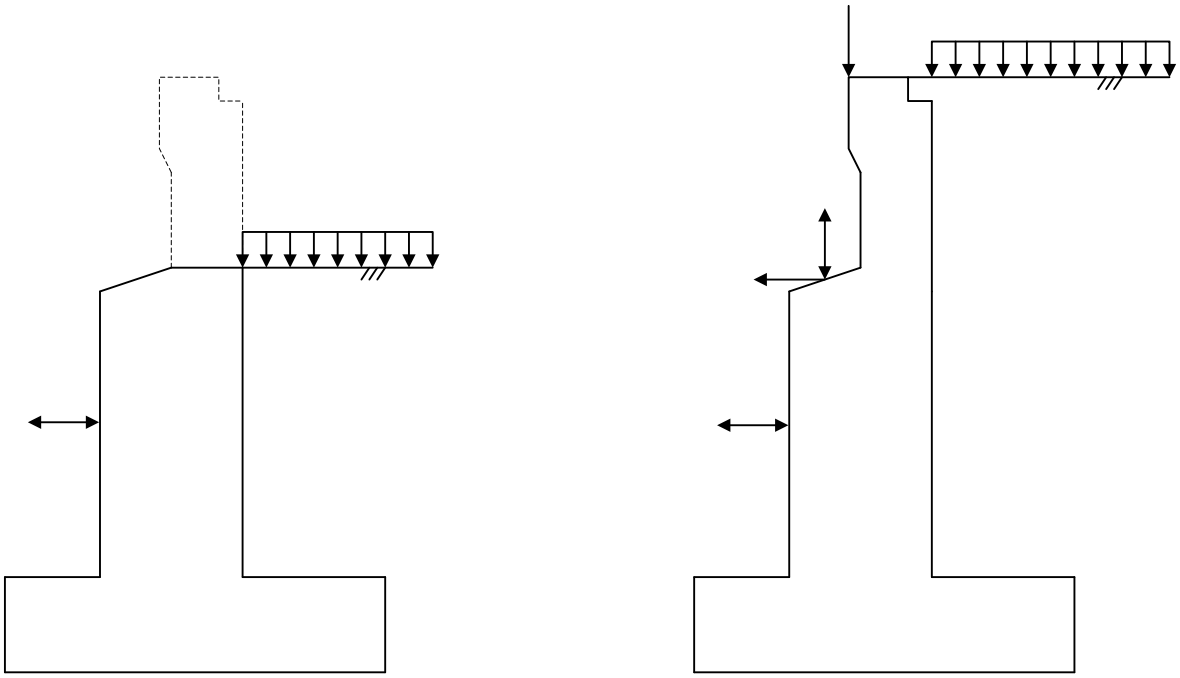
5.29 LDC - LOAD CONTROL COMMAND

KEYWORD	COMMAND DESCRIPTION
LDC	LOAD CONTROL - This command describes force effect factors and surcharges which are common to all structure types. Construction stages are illustrated in Figure 5.29-1. This command may only be specified once. In order to implement BD-628M, Sheet 2, Note 14 two separate runs of ABLRFD are usually required. One run with the ASL command entered and Final Stage Surcharge Loads entered as zero. And, the second run with no ASL command and the Final Stage Surcharge Loads entered. See Section 6.31 for a discussion on the required input for the two runs.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Ductility Factor	The factor relating to ductility (η_D).[1] As per DM-4 Section 1.3.3, a factor other than 1.0 is not permitted by PennDOT.	--	0.95 (E)	1.05 (E)	1.00
2. Redundancy Factor	The factor relating to redundancy (η_R).[1] As per DM-4 Section 1.3.4, a factor other than 1.0 is not permitted by PennDOT.	--	0.95 (E)	1.05 (E)	1.00
3. Importance Factor	The factor relating to operational importance (η_I).[1] As per DM-4 Section 1.3.5, a factor other than 1.0 is not permitted by PennDOT.	--	1.0 (E)	2.0 (E)	1.00
4. Temp. LS	The live load surcharge applied to the temporary construction stage expressed as height of fill. Refer to DM-4 Section 3.11.6.4 to determine the equivalent height of soil to be used to account for vehicular loading.	ft	0.0 (E)	5.5 (W)	--
5. Final LS	The live load surcharge applied to the final construction stage expressed as height of fill. Enter zero if approach slab loads are entered on the ASL command. Refer to DM-4 Section 3.11.6.4 to determine the equivalent height of soil to be used to account for vehicular loading.	ft	0.0 (E)	5.5 (W)	--
6. Temp. ES	The earth surcharge applied to the temporary construction stage expressed as height of fill.	ft	0.0 (E)	15.5 (W)	--
7. Final ES	The earth surcharge applied to the final construction stage expressed as height of fill. Enter zero if approach slab loads are entered on the ASL command.	ft	0.0 (E)	5.5 (W)	--

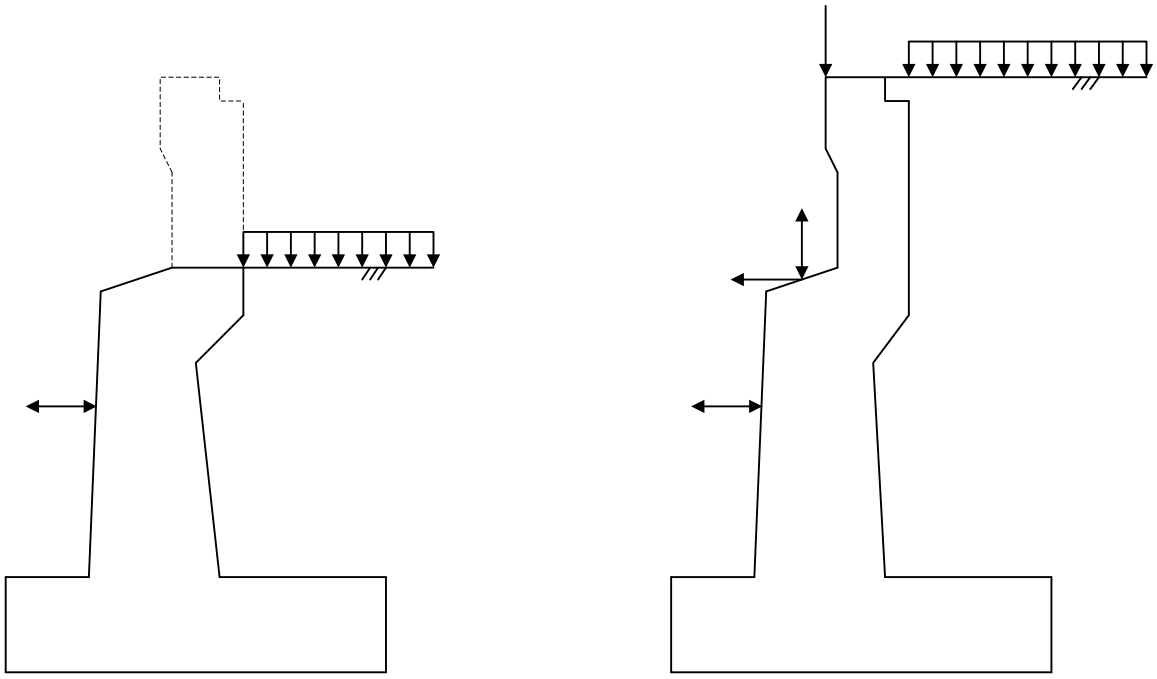
[1] As per DM-4 Section 1.3.2.1, the product of the Ductility, Redundancy, and Importance Factors must be 1.0.

5.29 LDC - LOAD CONTROL COMMAND (Cont.)



Temporary Final

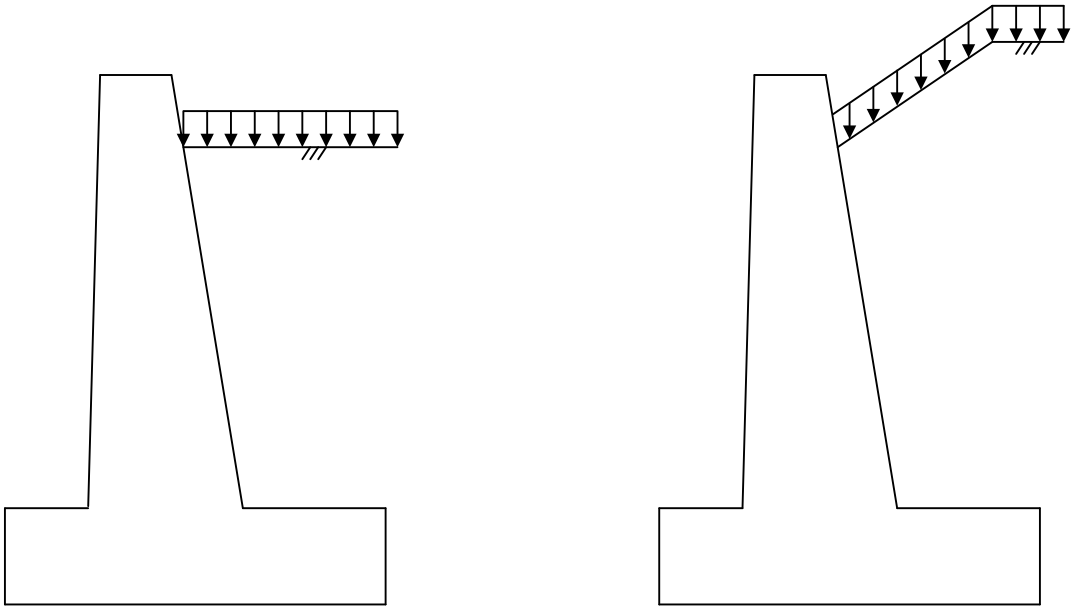
(a) Abutment Type I



Temporary Final

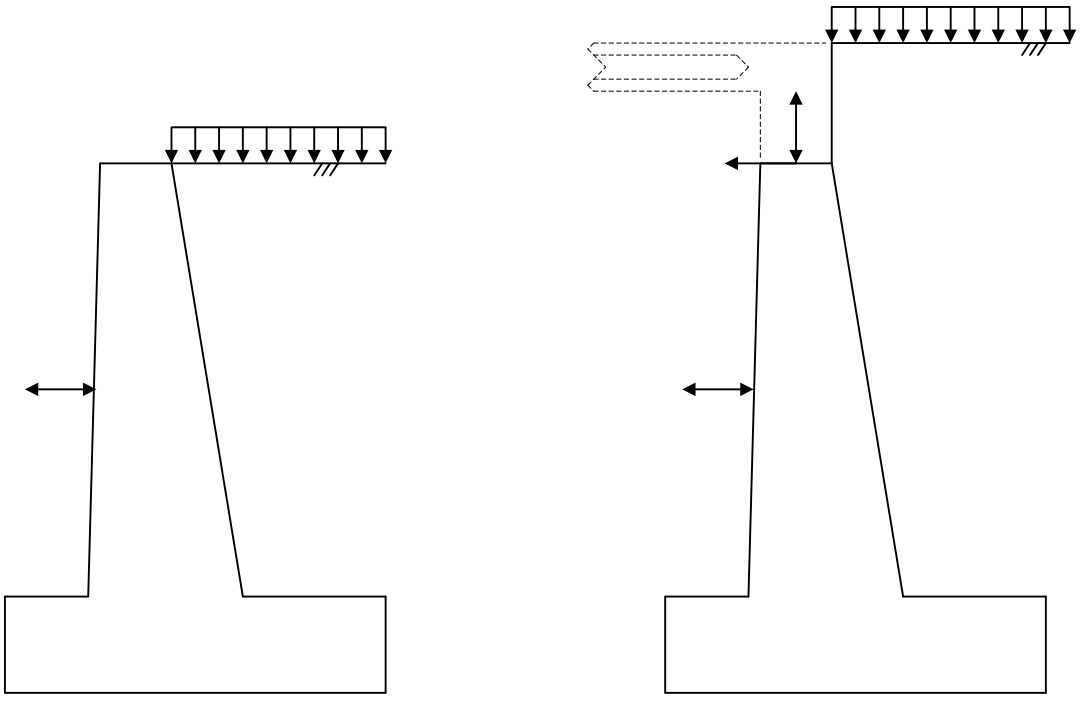
(b) Abutment Type II

Figure 5.29-1 Construction Stages



Temporary Final

(c) Retaining Wall



Temporary Final

(d) Abutment without Backwall

Figure 5.29-1 Construction Stages (cont.)

5.30 LAB - LOADS ON ABUTMENTS COMMAND

KEYWORD	COMMAND DESCRIPTION
LAB	LOADS ON ABUTMENTS - This command describes general loads per unit width applied at the bearing location of abutments. These loads are not applicable to retaining walls. External loads applied to abutments are depicted in Figure 5.30-1. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. DC	Dead load of the bridge superstructure and any attachments.	kip/ft	0.0 (W)	40.0 (W)	0.0
2. DW	Dead load of wearing surfaces and utilities on the superstructure.	kip/ft	0.0 (W)	5.0 (W)	0.0
3. PL	Pedestrian live load on the superstructure. If this parameter is left blank, the Strength IP limit state will not be evaluated.	kip/ft	0.0 (W)	1.0 (W)	--[1]
4. Vertical WS	Vertical wind load acting on the superstructure. As per LRFD Specifications Section 3.8.2, this load is only applied to the Strength-III load combination.	kip/ft	-1.0 (W)	0.0 (W)	0.0
5. Horizontal WS Superstructure	NOTE: This parameter is no longer used and should be left blank. The Horizontal WS Superstructure is now entered for each applicable limit state on parameters 12 through 14 of this command.				
6. WL	Horizontal wind load acting on the live load on the bridge superstructure. This load is applied in the direction that is perpendicular to the skew of the abutment. Hence, the magnitude of the load should be adjusted accordingly. The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts toward the superstructure.	kip/ft	0.0 (E)	1.0 (W)	0.0
7. TU	Horizontal load induced at the bearing location by thermal expansion and contraction in the superstructure. This load is applied in the direction that is perpendicular to the skew of the abutment. Hence, the magnitude of the load should be adjusted accordingly. The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts toward the superstructure. **Note that both TU and FR cannot be greater than zero.**	kip/ft	0.0 (E)	1.0 (W)	0.0
8. Vertical Backwall LL	The vertical live load on the backwall is applied along the front edge of the corbel. This vertical load includes any effects due to impact. This force is only considered in the backwall analysis and design.	kip/ft	0.0 (W)	5.0 (W)	--

5.30 LAB - LOADS ON ABUTMENTS COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
9. Horizontal Backwall LL	The horizontal live load applied to the top of the backwall. This horizontal load includes any effect due to impact. This force is only considered in the backwall analysis and design.	kip/ft	0.0 (W)	5.0 (W)	--
10. Horizontal WS Substructure	NOTE: This parameter is no longer used and should be left blank. The Horizontal WS Substructure is now entered for each applicable limit state on parameters 15 through 17 of this command.				
11. FR	Horizontal load induced at the bearing location by friction forces in sliding type expansion bearings. This load is applied in the direction that is perpendicular to the skew of the abutment. Hence, the magnitude of the load should be adjusted accordingly. The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts toward the superstructure. **Note that both FR and TU cannot be greater than zero.**	kip/ft	0.0 (E)	1.0 (W)	0.0
12. Horizontal WS Superstructure, Service-I	Horizontal wind load acting on the superstructure to be used with the Service-I limit state, calculated based on the Design 3-Second Gust Wind Speed from LRFD Specifications Table 3.8.1.1.2-1. This load is applied in the direction that is perpendicular to the skew of the abutment. Hence, the magnitude of the load should be adjusted accordingly. The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts toward the superstructure.	kip/ft	0.0 (E)	1.0 (W)	0.0
13. Horizontal WS Superstructure, Strength-III	Horizontal wind load acting on the superstructure to be used with the Strength-III limit state, calculated based on the Design 3-Second Gust Wind Speed from LRFD Specifications Table 3.8.1.1.2-1. This load is applied in the direction that is perpendicular to the skew of the abutment. Hence, the magnitude of the load should be adjusted accordingly. The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts toward the superstructure.	kip/ft	0.0 (E)	1.0 (W)	0.0

5.30 LAB - LOADS ON ABUTMENTS COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
14. Horizontal WS Superstructure, Strength-V	Horizontal wind load acting on the superstructure to be used with the Strength-V limit state, calculated based on the Design 3-Second Gust Wind Speed from LRFD Specifications Table 3.8.1.1.2-1. This load is applied in the direction that is perpendicular to the skew of the abutment. Hence, the magnitude of the load should be adjusted accordingly. The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts toward the superstructure.	kip/ft	0.0 (E)	1.0 (W)	0.0
15. Horizontal WS Substructure, Service-I	Horizontal wind load acting on the substructure to be used with the Service-I limit state. The following information applies to all Horizontal WS Substructure loads: Calculate the load based on the Design 3-Second Gust Wind Speed from LRFD Specifications Table 3.8.1.1.2-1. This force is applied at the midpoint of the exposed stem area in the direction that is perpendicular to the skew of the abutment (refer to User's Manual Figure 3.3.2.15-1). The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts toward the superstructure. If a water level is specified, the exposed stem area is located between the water line and the bearing seat. If no water is specified, then the exposed stem area is located between the top of the footing and the bearing seat. Note: ABLRFD factors the horizontal wind load on substructure so the calculated unfactored force must be entered.	kip/ft	-1.0[2] (W)	1.0 (W)	0.0
16. Horizontal WS Substructure, Strength-III	Horizontal wind load acting on the substructure to be used with the Strength-III limit state. See parameter 15 for additional details on how to calculate this load and how it is applied.	kip/ft	-1.0[2] (W)	1.0 (W)	0.0

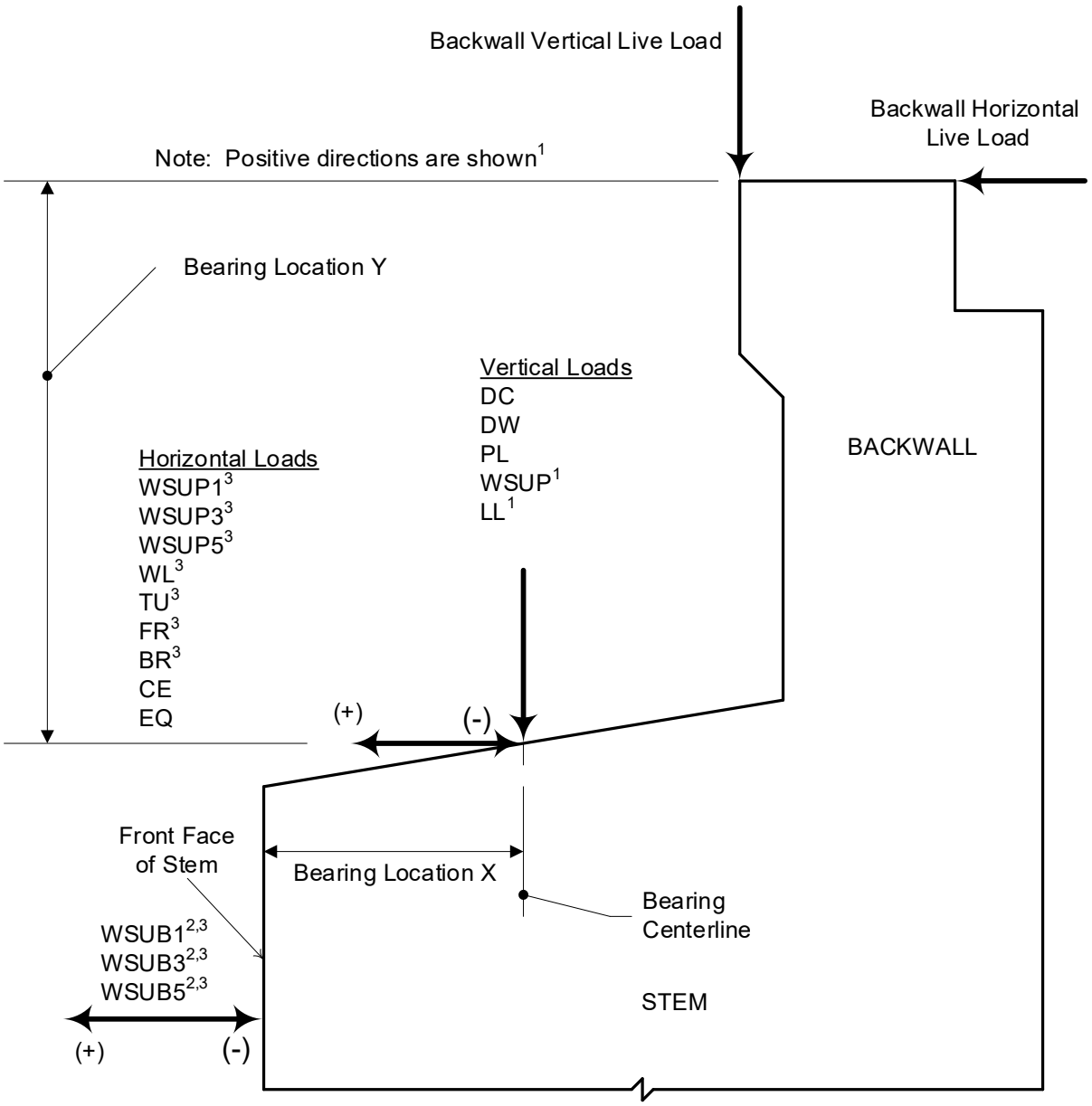
5.30 LAB - LOADS ON ABUTMENTS COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
17. Horizontal WS Substructure, Strength-V	Horizontal wind load acting on the substructure to be used with the Strength-V limit state. See parameter 15 for additional details on how to calculate this load and how it is applied.	kip/ft	-1.0[2] (W)	1.0 (W)	0.0

[1] A blank indicates the absence of the pedestrian live load.

[2] Even for negative values the load will be applied in both directions. The negative lower limit was kept to maintain compatibility with older input files.

5.30 LAB - LOADS ON ABUTMENTS COMMAND (Cont.)



[1]Exceptions for LL and WSUP loads

[2]WSUB# loads are applied at center of wind area on exposed stem

[3]Loads are applied both in positive direction and negative direction

Figure 5.30-1 Loads on Abutments

5.31 ASL – APPROACH SLAB LOAD COMMAND

KEYWORD	COMMAND DESCRIPTION
ASL	APPROACH SLAB LOAD - This command describes approach slab load magnitudes, locations, and application for approach slab Types 1, 2, 3, & 4 shown in Standard Drawings BD-628M. This command implements BD-628M, Sheet 2, Note 14 where the approach slab is modeled as a simple span beam between the abutment and the sleeper slab. In order to implement Note 14 two separate runs of ABLRFD are usually required. See Section 6.31 for a discussion on the required input for the two runs. The approach slab loads should be entered per unit width of the abutment. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Approach Slab DC	The dead load reaction due to the approach slab and barriers (if present) on an abutment. Refer to BD-628M, Sheet 2, Note 14. This applies to Type 1, 2, 3, or 4 Approach Slabs. Note: If the approach slab DC load is entered for this parameter then it should not be included in parameter 1 of the LAB command. Refer to Figures 5.31-1 to 5.31-5 for the location of the load. Leave this parameter blank if "Type 4 Flexible Pavement" is set to "Y".	kip/ft	0.0 (E)	5.0 (W)	--
2. Approach Slab LL	The live load reaction due to the approach slab on an abutment. Refer to BD-628M, Sheet 2, Note 14. This applies to Type 1, 2, 3 or 4 Approach Slabs. Note: If the approach slab LL load is entered for this parameter then it should not be included in parameter 1 of the DLL command. If "Type 4 Flexible Pavement" is set to "Y", enter the live load that is applied directly to the drain trough slab. Refer to Figures 5.31-1 to 5.31-6 for the location of the load.	kip/ft	0.0 (E)	1.0 (W)	--
3. X Distance to Approach Slab	The X distance to the approach slab DC, LL, and DW loads measured from the top front edge of the bearing seat on an abutment. **Refer to Figures 5.31-3 and 5.31-5.** Leave this parameter blank when Approach Slab on Beam Notch parameter is set to “Y”	in	0.0 (E)	132.0 (W)	--

5.31 ASL – APPROACH SLAB LOAD COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
4. Approach Slab on Beam Notch	Enter: Y – Approach slab load is applied through the beam notch as depicted in Figures 5.31-2 and 5.31-4. N – Approach slab load is not applied through the beam notch as depicted in Figures 5.31-1, 5.31-3, 5.31-5, and 5.31-6. If this parameter is answered 'Y' then the 'Vertical Backwall LL' parameter on the LAB command should be left blank. If a Type 4 Approach Slab is being defined, this value must be set to N.	--	Y,N (E)	--	--
5. Approach Slab DW	The DW load reaction due to the approach slab on an abutment. This applies to Type 1, 2, 3, or 4 Approach Slabs. Note: If the approach slab DW load is entered for this parameter then it should not be included in parameter 2 of the LAB command. Refer to Figures 5.31-1 to 5.31-5 for the location of the load. Leave this parameter blank if "Type 4 Flexible Pavement" is set to "Y".	kip/ft	0.0 (E)	5.0 (W)	--
Type 4 Approach Slab Input					
6. Type 4 Flexible Pavement	Enter: Y – Flexible Pavement is Adjacent to Tooth Dam N – Approach Slab is Adjacent to Tooth Dam Refer to Figures 5.31-5 and 5.31-6. Leave this parameter blank if abutment does not have a Type 4 Approach Slab.	--	Y/N (E)	--	--
7. Type 4 Drain Trough Width	The width of the drain trough from inside face to inside face, measured perpendicular to the abutment. Refer to Figures 5.31-5 and 5.31-6. Leave this parameter blank if abutment does not have a Type 4 Approach Slab.	in	25.0 (W)	46.0 (W)	--
8. Type 4 Average Drain Trough Height	The average distance between the bottom of the deck slab and the top of the drain trough bottom slab. Refer to Figures 5.31- and 5.31-6. Leave this parameter blank if abutment does not have a Type 4 Approach Slab.	in	24.0 (E)	48.0 (E)	--

5.31 ASL – APPROACH SLAB LOAD COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
9. Type 4 Drain Trough Wall Thickness	The distance between the end of the drain trough support pedestal and the drain trough inside face at approach slab side. Refer to Figures 5.31-5 and 5.31-6. Leave this parameter blank if abutment does not have a Type 4 Approach Slab.	in	18.0 (W)	27.0 (W)	--
10. Type 4 Drain Trough Bottom Slab Thickness	The drain trough bottom slab thickness. Refer to Figures 5.31-5 and 5.31-6. Leave this parameter blank if abutment does not have a Type 4 Approach Slab.	in	12.0 (E)	24.0 (W)	12.0
11. Type 4 Drain Trough Support Pedestal Width	The drain trough support pedestal width. Refer to Figures 5.31-7 and 5.31-8. Leave this parameter blank if abutment does not have a Type 4 Approach Slab.	in	12.0 (W)	24.0 (W)	18.0
12. Type 4 Drain Trough Support Pedestal Spacing	The distance between the centerlines of adjacent drain trough support pedestals. Refer to Figures 5.31-7 and 5.31-8. Leave this parameter blank if abutment does not have a Type 4 Approach Slab.	in	24.0 (E)	84.0 (W)	--
13. Type 4 Paving Notch Width	The width of the paving notch measured from the end of drain trough. Refer to Figure 5.31-5. Enter 0.0 if "Type 4 Flexible Pavement" is set to "Y". Leave this parameter blank if abutment does not have a Type 4 Approach Slab.	in	0.0 (E)	24.0 (W)	9.0
14. Type 4 Paving Notch Height	The height of the paving notch measured from the top of the structure. Refer to Figure 5.31-5. Enter 0.0 if "Type 4 Flexible Pavement" is set to "Y". Leave this parameter blank if abutment does not have a Type 4 Approach Slab.	in	0.0 (E)	36.0 (W)	16.0

5.31 ASL – APPROACH SLAB LOAD COMMAND (Cont.)

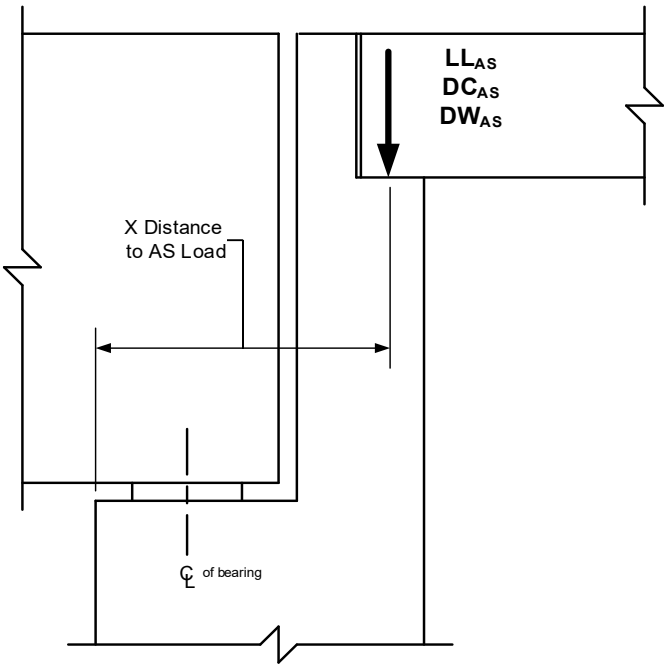


Figure 5.31-1 Type 1 or Type 2 Approach Slab – Abutment With Backwall

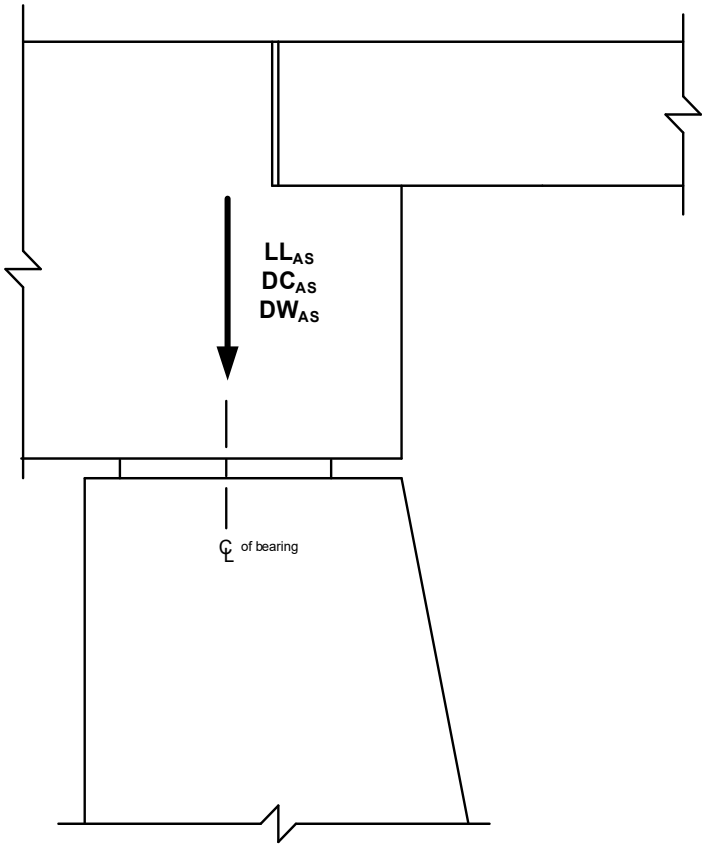


Figure 5.31-2 Type 1 or Type 2 Approach Slab – Abutment Without Backwall (Deep Beams)

5.31 ASL – APPROACH SLAB LOAD COMMAND (Cont.)

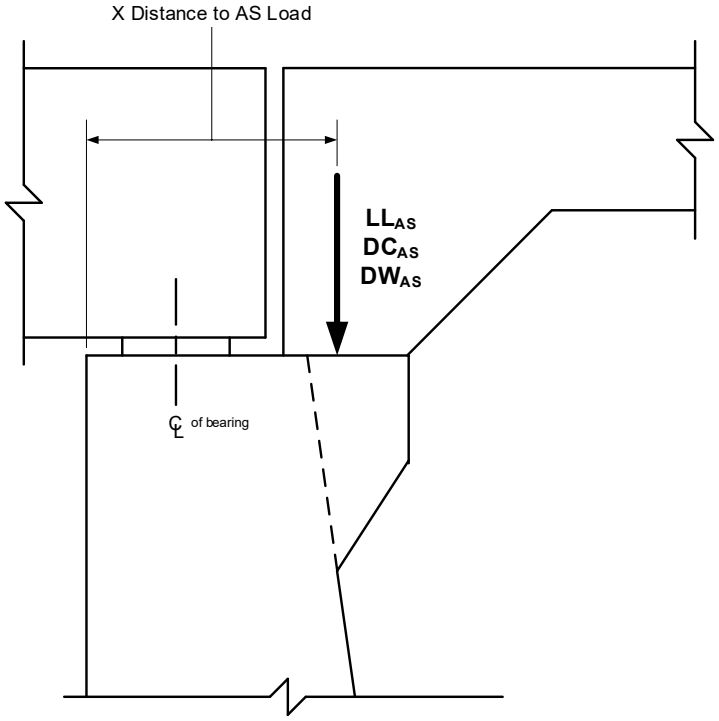


Figure 5.31-3 Type 1 or Type 2 Approach Slab – Abutment Without Backwall (Shallow Beams With Abutment Corbel)

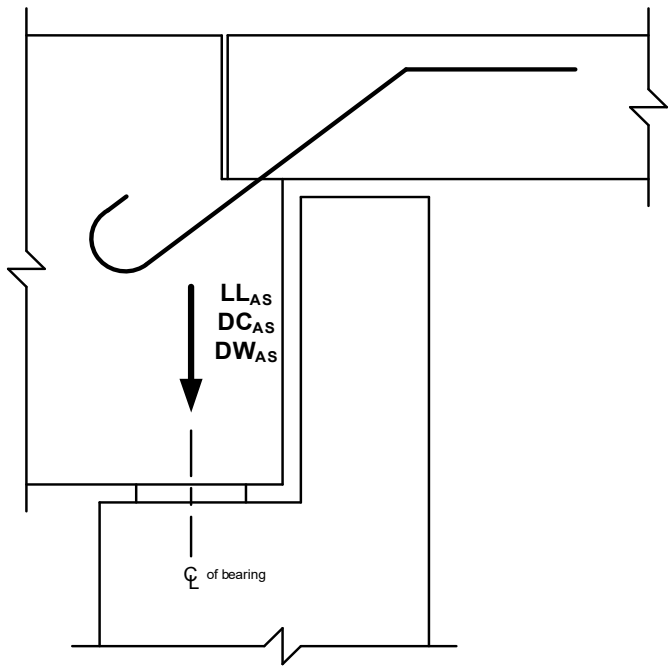


Figure 5.31-4 Type 3 Approach Slab – Abutment With Backwall (Approach Slab Connected to Superstructure)

5.31 ASL – APPROACH SLAB LOAD COMMAND (Cont.)

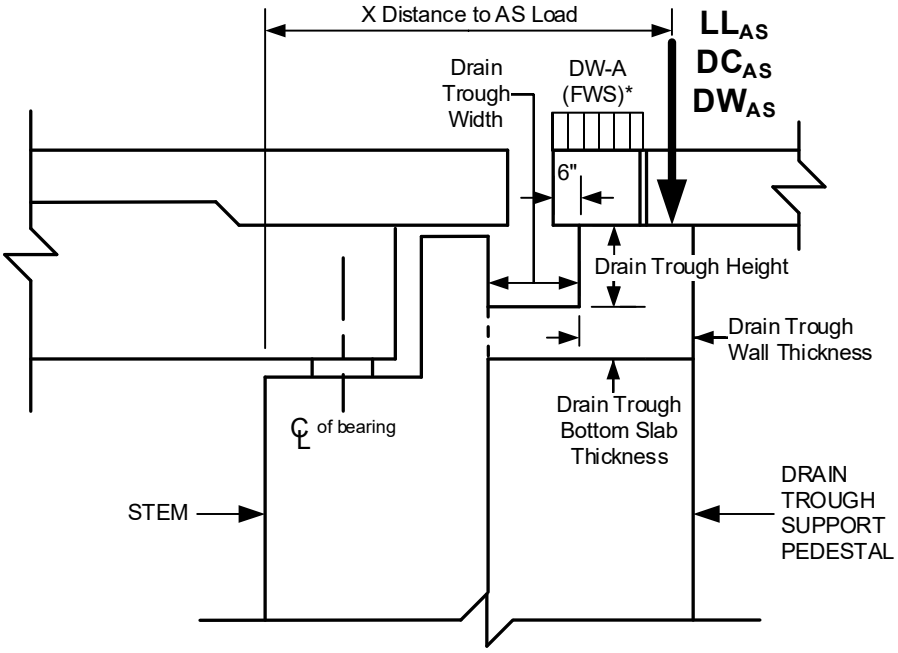


Figure 5.31-5 Type 4 Approach Slab – Abutment With Backwall (With Concrete Approach Slab)

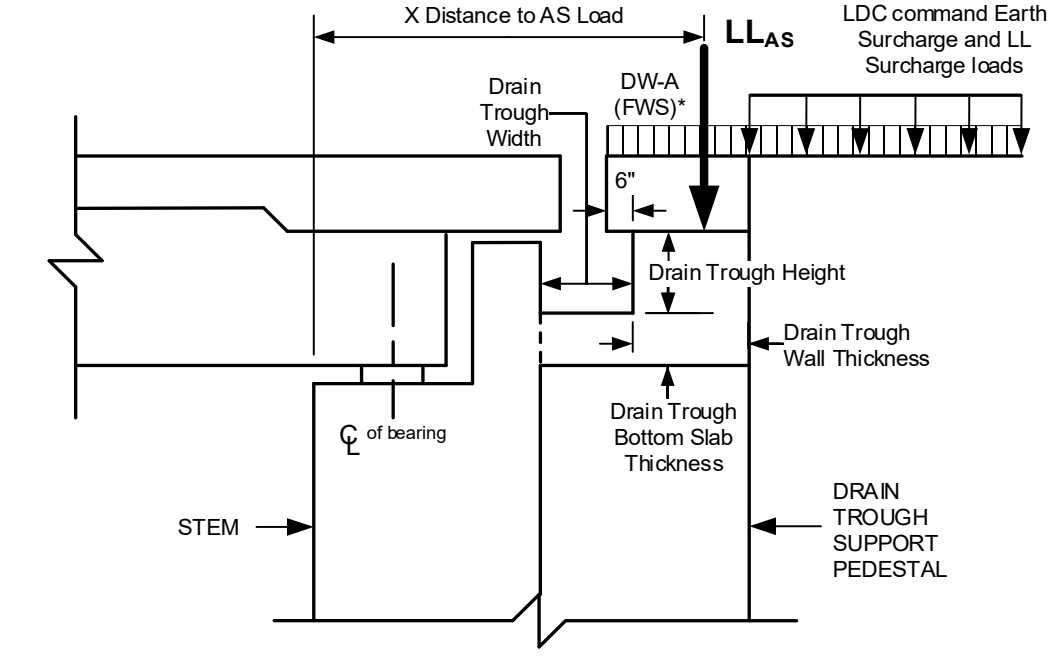


Figure 5.31-6 Type 4 Approach Slab – Abutment With Backwall (With Flexible Pavement)

5.31 ASL – APPROACH SLAB LOAD COMMAND (Cont.)

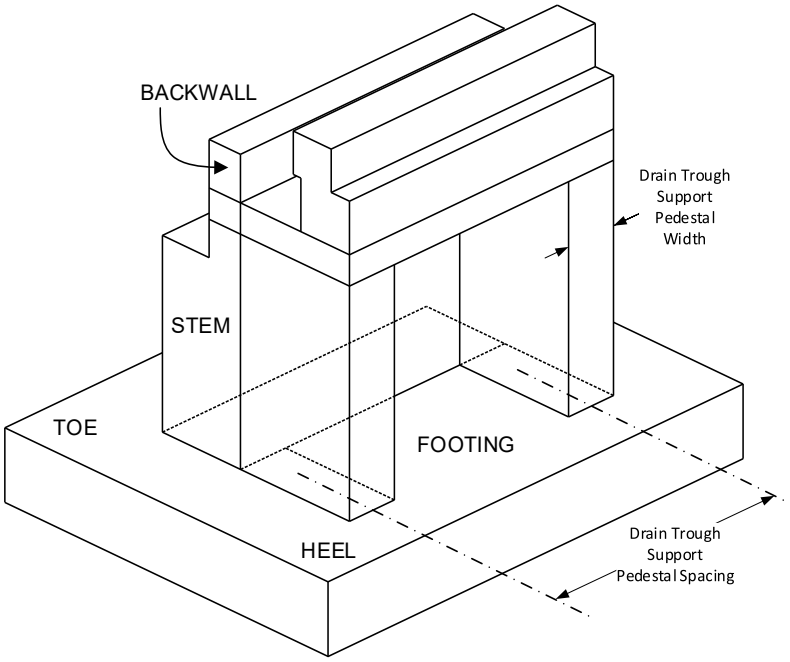


Figure 5.31-7 Abutment Type I with Type 4 Approach Slab

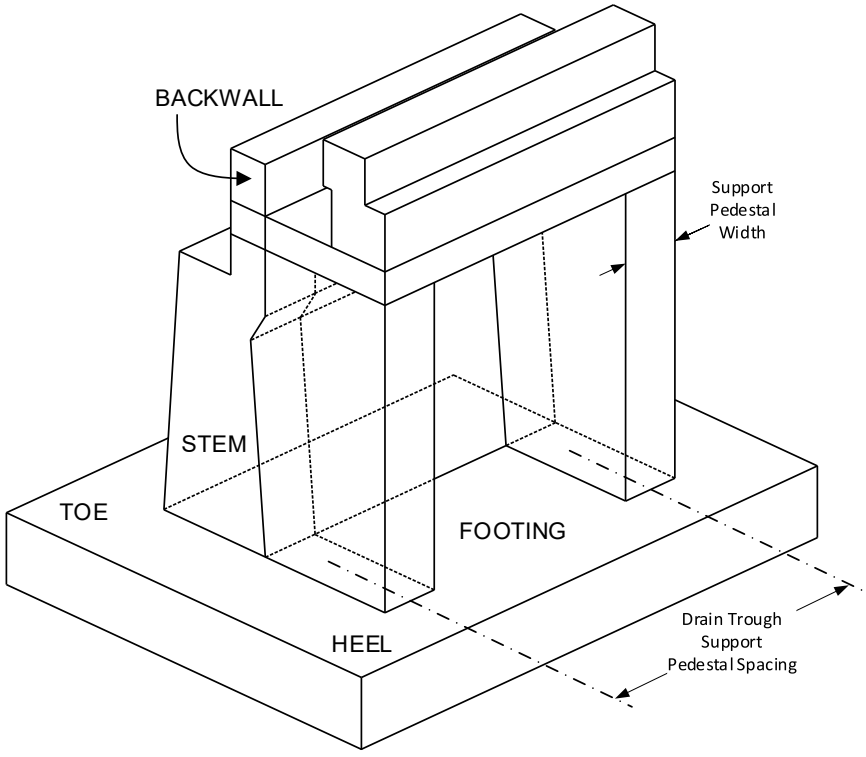


Figure 5.31-8 Abutment Type II with Type 4 Approach Slab

5.32 LRT - LOADS ON RETAINING WALLS COMMAND

KEYWORD	COMMAND DESCRIPTION
LRT	LOADS ON RETAINING WALLS - This command describes external loads per unit width applied to the top of retaining walls. These loads are not applicable to abutments. Loads applied to retaining walls are depicted in Figure 5.32-1. This command may only be specified once.

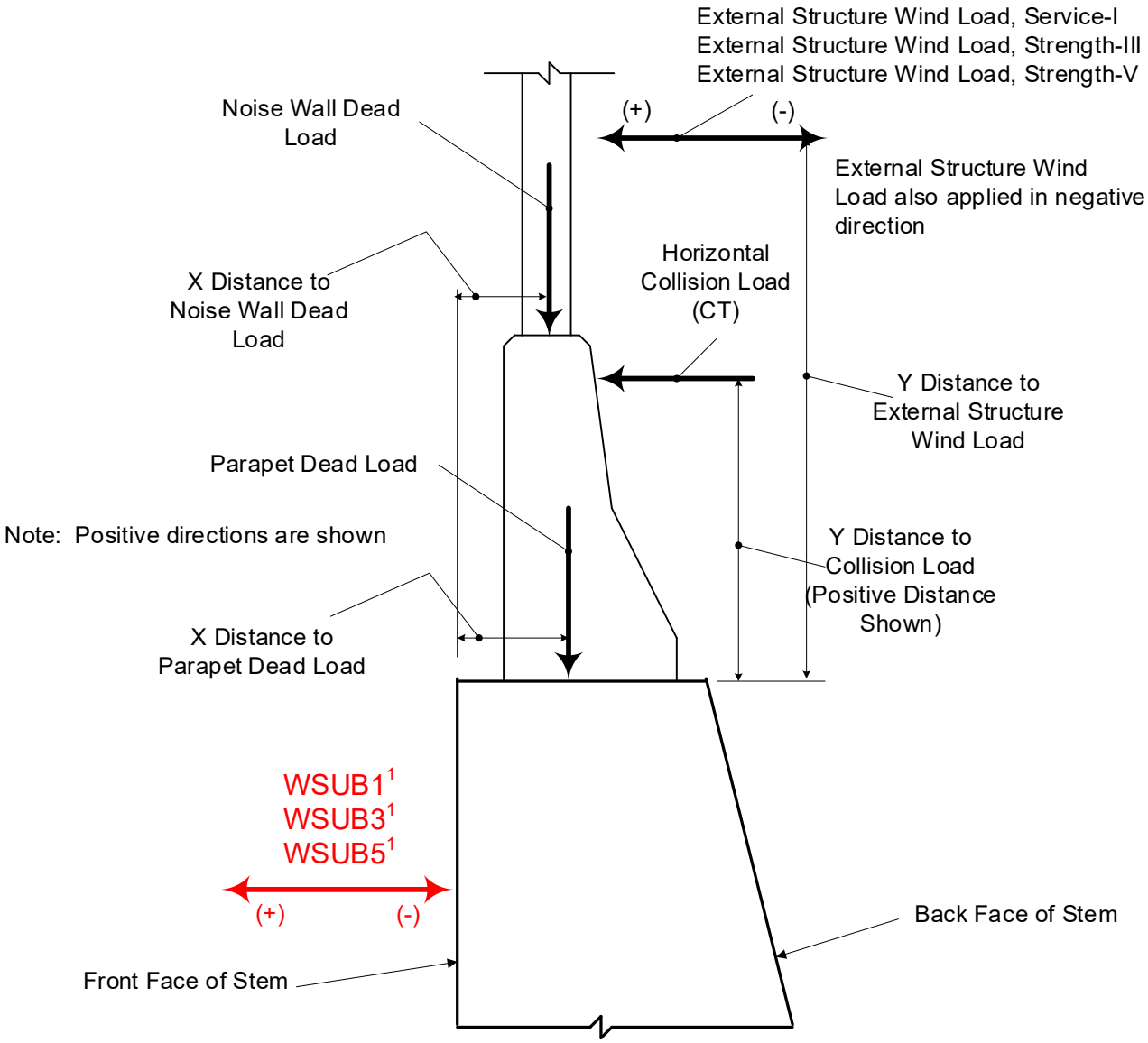
PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. CT	Horizontal vehicular collision load acting on a parapet or noise wall at the top of the retaining wall. If this parameter is left blank, the Extreme Event II limit state will not be evaluated.	kip/ft	0.0 (E)	2.0 (W)	--[1]
2. Y Distance to CT	The Y distance to the collision load measured from the top of the retaining wall. If a Y distance less than zero is entered, the absolute value of the Y distance cannot exceed the Exposed Stem Height value entered on the RWL command. Refer to Section 6.31 for more information.	in	-120.0 (E)	42.0 (W)	--[1]
3. Parapet Dead Load	The dead load due to the parapet on a retaining wall.	kip/ft	0.0 (E)	1.0 (W)	--[2]
4. X Distance to Parapet	The X distance to the parapet measured from the top front edge of the retaining wall.	in	0.0 (E)	60.0 (W)	--[2]
5. Noise Wall Dead Load	The dead load due to a noise wall located on a retaining wall.	kip/ft	0.0 (E)	1.0 (W)	--[3]
6. X Distance to Noise Wall	The X distance to the noise wall measured from the top front edge of the retaining wall.	in	0.0 (E)	60.0 (W)	--[3]
7. Wind Load on External Structure	NOTE: This parameter is no longer used and should be left blank. The Wind Load on External Structure is now entered for each applicable limit state on parameters 9 through 11 of this command.	kip/ft	0.0 (E)	1.0 (W)	--[4]
8. Y Distance to Wind Load on External Structure	The Y distance to the center of the wind load measured from the top of the retaining wall.	in	0.0 (E)	180.0 (W)	--[4]
9. Wind Load on External Structure, Service-I	The wind load due to the wind on an external structure, used with the Service-I limit state, calculated based on the Design 3-Second Gust Wind Speed from LRFD Specifications Table 3.8.1.1.2-1. The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts in the same direction as the collision load.	kip/ft	0.0 (E)	1.0 (W)	--[4]

5.32 LRT - LOADS ON RETAINING WALLS COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
10. Wind Load on External Structure, Strength-III	The wind load due to the wind on an external structure, used with the Strength-III limit state, calculated based on the Design 3-Second Gust Wind Speed from LRFD Specifications Table 3.8.1.1.2-1. The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts in the same direction as the collision load.	kip/ft	0.0 (E)	1.0 (W)	--[4]
11. Wind Load on External Structure, Strength-V	The wind load due to the wind on an external structure, used with the Strength-V limit state, calculated based on the Design 3-Second Gust Wind Speed from LRFD Specifications Table 3.8.1.1.2-1. The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts in the same direction as the collision load.	kip/ft	0.0 (E)	1.0 (W)	--[4]
12. Wind Load on Wall, Service-I	**The wind load due to the wind on the wall, used with the Service-I limit state, calculated based on the Design 3-Second Gust Wind Speed from LRFD Specifications Table 3.8.1.1.2-1. The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts in the same direction as the collision load.**	**kip/ft**	**0.0 (E)**	**1.0 (W)**	**--[5]**
13. Wind Load on Wall, Strength-III	**The wind load due to the wind on the wall, used with the Strength-III limit state, calculated based on the Design 3-Second Gust Wind Speed from LRFD Specifications Table 3.8.1.1.2-1. The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts in the same direction as the collision load.**	**kip/ft**	**0.0 (E)**	**1.0 (W)**	**--[5]**
14. Wind Load on Wall, Strength-V	**The wind load due to the wind on the wall, used with the Strength-V limit state, calculated based on the Design 3-Second Gust Wind Speed from LRFD Specifications Table 3.8.1.1.2-1. The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts in the same direction as the collision load.**	**kip/ft**	**0.0 (E)**	**1.0 (W)**	**--[5]**

[1] A blank indicates the absence of the collision load.
[2] A blank indicates the absence of a parapet dead load.
[3] A blank indicates the absence of a noise wall dead load.
[4] A blank indicates the absence of wind load on an external structure.
[5] **A blank indicates the absence of wind load on the wall.**

5.32 LRT - LOADS ON RETAINING WALLS COMMAND (Cont.)



[1]WSUB# loads are applied at center of wind area on exposed stem.
Loads are applied both in positive direction and negative direction.

Figure 5.32-1 Loads on Retaining Walls

5.33 DLL - DESIGN LIVE LOADING COMMAND

KEYWORD	COMMAND DESCRIPTION
DLL	DESIGN LIVE LOADING - This command describes design **and permit design** live loadings per unit width from the bridge superstructure applied to abutments due to the design loading. These loads are not applicable to retaining walls. Live loads from the bridge superstructure applied to abutments are depicted in Figure 5.30-1. This command may only be specified once. If DLL is specified SLL should not be used**.** The **permit design loadings are used to evaluate the** Strength II limit state.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. **Design** Downward LL	Design live loading reaction applied in a downward direction and does not include effects due to impact.	kip/ft	0.0 (E)	10.0 (W)	0.0
2. **Design** Upward LL	Design live loading reaction applied in an upward direction and does not include effects due to impact.	kip/ft	-2.0 (W)	0.0 (E)	0.0
3. **Design** BR	Design horizontal live loading braking force. This load is applied in the direction that is perpendicular to the skew of the abutment. Hence, the magnitude of the load should be adjusted accordingly. The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts toward the superstructure.	kip/ft	0.0 (E)	1.0 (W)	0.0
4. **Design** CE	Design horizontal live loading centrifugal force. This load is applied in the direction that is perpendicular to the skew of the abutment. Hence, the magnitude of the load should be adjusted accordingly.	kip/ft	0.0 (E)	1.0 (W)	0.0
5. Permit Downward LL	**Permit live loading reaction applied in a downward direction and does not include effects due to impact.**	**kip/ft**	**0.0 (E)**	**10.0 (W)**	**0.0**
6. Permit Upward LL	**Permit live loading reaction applied in an upward direction and does not include effects due to impact.**	**kip/ft**	**-2.0 (W)**	**0.0 (E)**	**0.0**
7. Permit BR	**Permit horizontal live loading braking force. This load is applied in the direction that is perpendicular to the skew of the abutment. Hence, the magnitude of the load should be adjusted accordingly. The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts toward the superstructure.**	**kip/ft**	**0.0 (E)**	**1.0 (W)**	**0.0**
8. Permit CE	**Permit horizontal live loading centrifugal force. This load is applied in the direction that is perpendicular to the skew of the abutment. Hence, the magnitude of the load should be adjusted accordingly.**	**kip/ft**	**0.0 (E)**	**1.0 (W)**	**0.0**

5.34 SLL - SPECIAL LIVE LOADING COMMAND

KEYWORD	COMMAND DESCRIPTION
SLL	SPECIAL LIVE LOADING - This command describes a special (or permit P-82) live loading per unit width from the bridge superstructure applied to abutments. The Strength II limit state is only evaluated if the SLL command is specified. These loads are not applicable to retaining walls. Live loads from the bridge superstructure applied to abutments are depicted in Figure 5.30-1. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Downward LL	Special live loading reaction applied in a downward direction and does not include effects due to impact.	kip/ft	0.0 (E)	5.0 (W)	0.0
2. Upward LL	Special live loading reaction applied in an upward direction and does not include effects due to impact.	kip/ft	-2.0 (W)	0.0 (E)	0.0
3. BR	Special horizontal live loading braking force. This load is applied in the direction that is perpendicular to the skew of the abutment. Hence, the magnitude of the load should be adjusted accordingly. The force is applied as both a positive force and as a negative force to maximize the force effects on the foundation. A positive force acts toward the superstructure.	kip/ft	0.0 (E)	1.0 (W)	0.0
4. CE	Special horizontal live loading centrifugal force. This load is applied in the direction that is perpendicular to the skew of the abutment. Hence, the magnitude of the load should be adjusted accordingly.	kip/ft	0.0 (E)	1.0 (W)	0.0
5. Strength I Factor	The Strength I limit state load factor applied to the special live loads described above.	--	0.0 (E)	2.0 (E)	--
6. Strength IP Factor	The Strength IP limit state load factor applied to the special live loads described above.	--	0.0 (E)	2.0 (E)	--
7. Strength II Factor	The Strength II limit state load factor applied to the special live loads described above.	--	0.0 (E)	2.0 (E)	--
8. Strength III Factor	The Strength III limit state load factor applied to the special live loads described above.	--	0.0 (E)	2.0 (E)	--
9. Strength V Factor	The Strength V limit state load factor applied to the special live loads described above.	--	0.0 (E)	2.0 (E)	--
10. Extreme I Factor	The Extreme I limit state load factor applied to the special live loads described above.	--	0.0 (E)	2.0 (E)	--
11. Service I Factor	The Service I limit state load factor applied to the special live loads described above.	--	0.0 (E)	2.0 (E)	--

5.35 EQL - EARTHQUAKE LOADS COMMAND

KEYWORD	COMMAND DESCRIPTION
EQL	EARTHQUAKE LOADS - This command describes earthquake criterion for all structures and loads per unit width applicable to abutments. The Extreme Event I limit state is only evaluated if the EQL command is specified. External earthquake loads are depicted in Figure 5.30-1. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Response Modification	The response modification factor applied to the earthquake design loads.	--	0.0 (E)	5.0 (W)	1.0
2. Soil Pressure Factor	The factor by which the soil pressure load, EH, is to be multiplied to obtain earthquake effects.	--	1.0 (E)	2.5 (W)	1.0
3. Phi Factor Foundation	For spread footings and pedestal footings, strength reduction factor applied to the bearing capacity for the Extreme Event I limit state. For piles and caissons, factor applied to the strength axial capacity and strength lateral capacity entered on the PIL and CAI commands to determine the axial capacity and lateral capacity for the Extreme Event I limit state.	--	*	**	--
4. Vertical EQ Soil	NOTE: This parameter is no longer used and should be left blank.	--	--	--	--
5. Horizontal Superstructure Force	The horizontal force at the abutment bearing location due to earthquake effect on the superstructure. Leave blank for retaining walls. This load is applied in the direction that is perpendicular to the skew of the abutment. Hence, the magnitude of the load should be adjusted accordingly.	kip/ft	0.0 (E)	4.0 (W)	0.0
6. Horizontal External Structure Force	The horizontal force at the top of the retaining wall due to earthquake effect on an external structure. Leave blank for abutments. This load is applied in the direction that is perpendicular to the retaining wall.	kip/ft	0.0 (E)	4.0 (W)	0.0

* For spread and pedestal footings, must be greater than 0.0 (E).
For piles and caissons, 1.0(E).

** For spread and pedestal footings, 1.0(W).
For piles and caissons, 2.0(W).

5.36 OIN - OUTPUT OF INPUT COMMAND

KEYWORD	COMMAND DESCRIPTION
OIN	OUTPUT OF INPUT - This command is used to control the type of input data reports which can be requested by the user. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Input File Echo	An input file echo may be generated in the output. 0 - Do not print input file echo. 1 - Print input file echo.	--	0 (E)	1 (E)	0
2. Input Commands	The input data may be organized according to the command, with a short description for each data item. 0 - Do not print input commands. 1 - Print input commands.	--	0 (E)	1 (E)	0
3. Input Summary	A summary of the input data may be printed. 0 - Do not print input summary. 1 - Print input summary.	--	0 (E)	1 (E)	1

5.37 OUR - OUTPUT OF RESULTS COMMAND

KEYWORD	COMMAND DESCRIPTION
OUR	OUTPUT OF RESULTS - This command is used to control the type of result reports, which can be requested by the user. Each report is applicable for both design and analysis. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Footing Geometry	The geometry of the footing may be printed. 0 - Do not print footing geometry. 1 - Print footing geometry.	--	0 (E)	1 (E)	*
2. Output Legend	The output legend lists abbreviations found throughout the reports. 0 - Do not print output legend. 1 - Print output legend.	--	0 (E)	1 (E)	*
3. Factored Forces	Factored forces for the backwall, stem and footing may be printed. 0 - Do not print factored forces. 1 - Print factored forces.	--	0 (E)	1 (E)	*
4. Footing Stability	Footing stability reports depend on the footing type. For spread footings, bearing capacity, sliding and settlement are reported. For pile or caisson footings, the pile pattern, axial loads and lateral loads are reported. 0 - Do not print footing stability. 1 - Print footing stability.	--	0 (E)	1 (E)	*
5. Footing Controlling Forces	Controlling forces used to analyze or design reinforcement in the footing may be printed. 0 - Do not print controlling forces. 1 - Print controlling forces.	--	0 (E)	1 (E)	*
6. Footing Flexure	The flexural capacity of the footing may be printed. 0 - Do not print footing flexure. 1 - Print footing flexure.	--	0 (E)	1 (E)	*
7. Reinforce-ment Summary	For a design run, two types of data are reported. The first type identifies the bar spacing (for all bar sizes) required for strength and serviceability requirements at all stem, footing and backwall (if applicable) locations. The second type of information is reported in a separate table; the optimal bar in each component (stem - location d, footing, backwall) is identified. The format follows the design details report - see parameter 10. A summary of status checks is reported for the backwall, stem and footing. 0 - Do not print reinforcement summary. 1 - Print reinforcement summary.	--	0 (E)	1 (E)	*

5.37 OUR - OUTPUT OF RESULTS COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
8. Crack Control	Crack control results for the backwall, stem and footing may be printed. 0 - Do not print crack control. 1 - Print crack control.	--	0 (E)	1 (E)	*
9. Shear Results	Shear results for the backwall, stem and footing may be printed. 0 - Do not print shear results. 1 - Print shear results.	--	0 (E)	1 (E)	*
10. Development Length	For a design run, the information reported depends on the location. For the footing locations, the bar size and corresponding spacing is reported. At toe and heel locations (perpendicular locations), the development length is also shown. For the backwall location (seat level), for each bar size, the corresponding spacing and development length is reported. For the stem location (base location D), the bar size, spacing, development length (straight and hooked), lap length, cutoff location and shear at the cutoff (if applicable) is reported. In an analysis run, the development length related information is reported in the footing flexure report only for the perpendicular direction (toe and heel locations). If the bars are not fully developed, a note will indicate the area of partially developed steel. Bars in the parallel direction of a footing, stem bars, and backwall bars are not checked for development. 0 - Do not print development length. 1 - Print development length.	--	0 (E)	1 (E)	*

* The default values for every parameter on this command are determined based on the type of run (analysis or design). The defaults for all output commands are detailed in Chapter 6.

5.38 OUI - OUTPUT OF INTERMEDIATE DATA COMMAND

KEYWORD	COMMAND DESCRIPTION
OUI	OUTPUT OF INTERMEDIATE DATA - This command is used to control the type of intermediate data reports, which can be requested by the user. These reports are applicable for both design and analysis. This command may only be specified once.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Unfactored Forces	Unfactored forces for the backwall, stem and footing may be printed. 0 - Do not print unfactored loads. 1 - Print unfactored loads.	--	0 (E)	1 (E)	*
2. Load Factors	Load factors for the backwall, stem and footing may be printed. 0 - Do not print load factors. 1 - Print load factors.	--	0 (E)	1 (E)	*
3. Moment / Axial Interaction	Moment / Axial interaction results may be printed for the stem and backwall. 0 - Do not print moment / axial interaction. 1 - Print moment / axial interaction.	--	0 (E)	1 (E)	*
4. Internal Footing Forces	Internal forces in the footing for each limit state, stage and load case may be printed. Vertical pile loads are also included for pile footings. 0 - Do not print internal footing forces. 1 - Print internal footing forces.	--	0 (E)	1 (E)	*
5. Intermediate Bearing Resistance Values	Intermediate bearing resistance values for each state, stage and load case may be printed, 0 - Do not print inter. bearing resist. values. 1 - Print inter. bearing resist. values.	--	0 (E)	1 (E)	*
6. Detailed Stem Cutoff Load Values	Detailed cutoff location load values at the cutoff location for each bar for each state, stage and load case may be printed on the “Factored Force Table” and the “Moment/Axial Interaction Table” 0 - Do not print detailed cutoff location load values 1 - Print detailed cutoff location load values	--	0 (E)	1 (E)	*
7. Minimum Reinforcement Check	For an analysis run, detailed minimum reinforcement calculation values for the backwall, stem and footing are reported. 0 - Do not print minimum reinforcement check values 1 - Print minimum reinforcement check values	--	0 (E)	1 (E)	*
8. Intermediate Settlement Data	**Intermediate settlement data may be printed for spread and pedestal footing types. 0 - Do not print intermediate settlement data 1 - Print intermediate settlement data**	**--**	**0 (E)**	**1 (E)**	*

* The default values for every parameter on this command are determined based on the type of run (analysis or design). The defaults for all output commands are detailed in Chapter 6.

DETAILED INPUT DESCRIPTION

This chapter provides a detailed description of some of the input parameters, which were described in Chapter 5, but may need further explanation or commentary. The numbering scheme used in this chapter is as follows. The section number for a command corresponds to the same section number in Chapter 5. The parameter being described is preceded by a section number, whose last extension number refers to the parameter number in the corresponding command in Chapter 5. For example, 6.5.3 Footing Datum corresponds to Section 5.5 CTL - Control Command, Parameter 3.

Only the commands and parameters for which detailed description is given are included here. For parameters, which are not presented in this chapter, sufficient description and explanation is provided in Chapter 5.

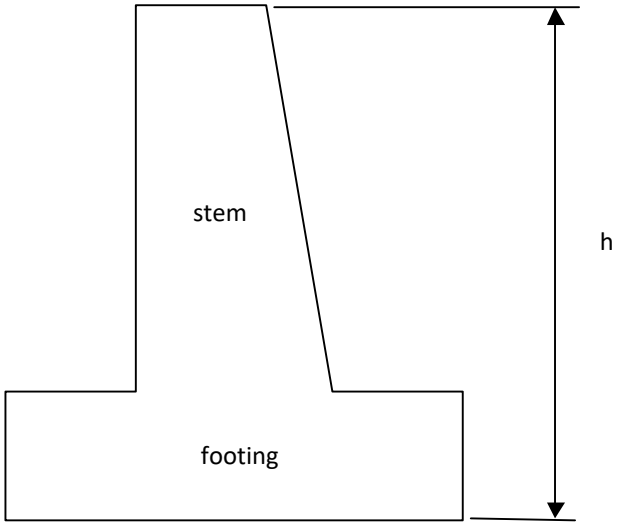
6.5 CTL - CONTROL COMMAND

6.5.3 Footing Datum

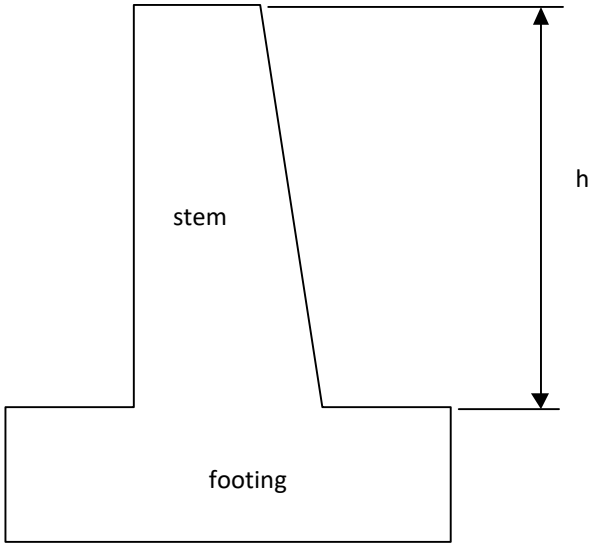
The footing datum can only be set for a design run. The footing datum determines how the footing thickness will be changed. This is explained in Figure 5.5-1.

For an analysis run, the datum is set to the top of the footing, and should be left blank.

The footing datum defines how the height parameter that is specified in commands AT1, AT2, AWB, and RWL is interpreted by the program. If the footing datum is set to the top of the footing, the height is interpreted as the stem height. If the footing datum is set to the bottom of the footing, the height is interpreted as the structure height. Refer to Figure 6.5.3-1.



(a) height definition when footing datum = 'B'



(b) height definition when footing datum = 'T'

Figure 6.5.3-1 Height and Footing Datum

6.6 AT1 - ABUTMENT TYPE 1 COMMAND

6.6.13 Front Water Level

The depth is specified from the top of the structure. Leave this parameter blank if the front water is not present. A value of 0 implies that the front water level is at the top of the structure. The back water level must be entered if a front water level is entered. If the front water level is left blank and a back water level is entered for a design run, the program will calculate the front water level based on DM-4 Section 3.11.3. For analysis, if the front water level is left blank, the program places the front water level at the bottom of the footing.

The weight of the water above the toe is considered in the calculation for the WA load. WA also includes the uplift pressure due to buoyancy as shown in Figure 6.6.14-1.

6.6.14 Back Water Level

The depth is specified from the top of the structure. Leave this parameter blank if the back water is not present. A value of 0 implies that the back water level is at the top of the structure.

The backfill soil below the back water level is considered to be saturated. The soil above the back water level is considered to be dry (or moist).

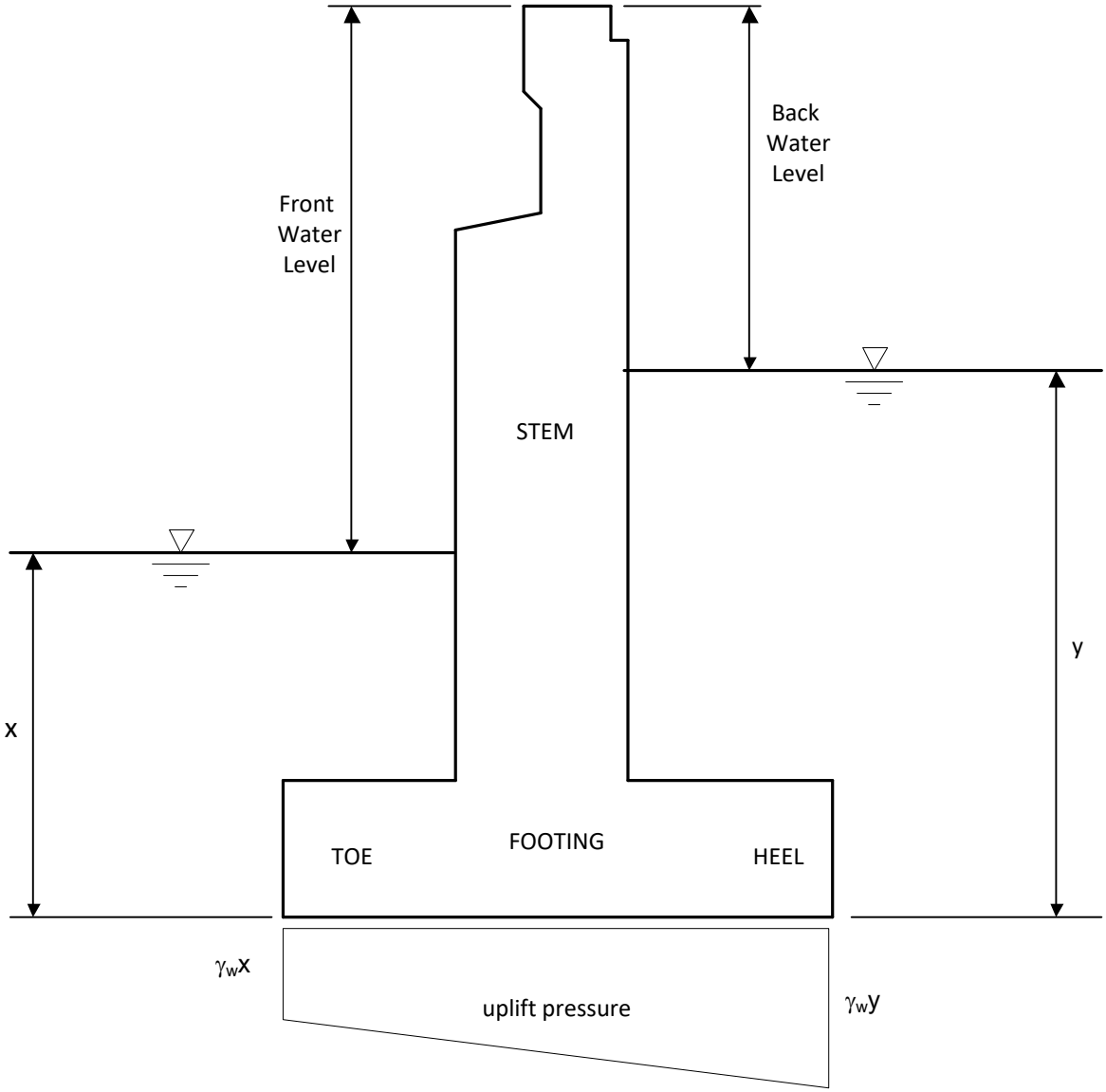


Figure 6.6.14-1 Water Level and Uplift Pressure **– Abutment Type 1**

6.7 AT2 - ABUTMENT TYPE 2 COMMAND

6.7.20 Front Water Level

The depth is specified from the top of the structure. Leave this parameter blank if the front water is not present. A value of 0 implies that the front water level is at the top of the structure. The back water level must be entered if a front water level is entered. If the front water level is left blank and a back water level is entered for a design run, the program will calculate the front water level based on DM-4 Section 3.11.3. For analysis, if the front water level is left blank, the program places the front water level at the bottom of the footing.

The weight of the water above the toe is considered in the calculation for the WA load. WA also includes the uplift pressure due to buoyancy as shown in Figure 6.7.21-1.

6.7.21 Back Water Level

The depth is specified from the top of the structure. Leave this parameter blank if the back water is not present. A value of 0 implies that the back water level is at the top of the structure.

The backfill soil below the back water level is considered to be saturated. The soil above the back water level is considered to be dry (or moist).

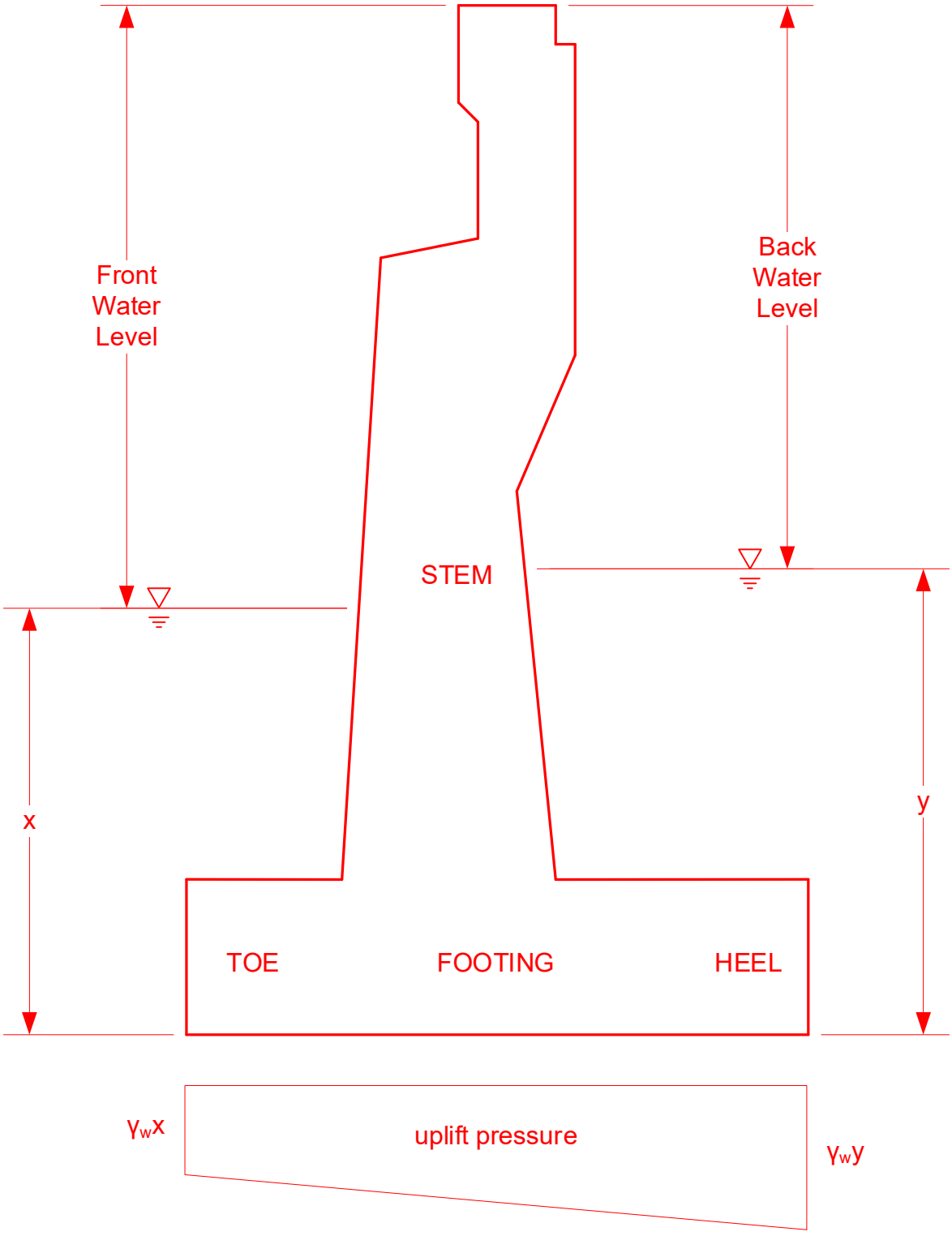


Figure 6.7.21-1 Water Level and Uplift Pressure – Abutment Type 2

6.8 AWB - ABUTMENT WITHOUT BACKWALL COMMAND

6.8.9 Front Water Level

The depth is specified from the top of the structure. Leave this parameter blank if the front water is not present. A value of 0 implies that the front water level is at the top of the structure. The back water level must be entered if a front water level is entered. If the front water level is left blank and a back water level is entered for a design run, the program will calculate the front water level based on DM-4 Section 3.11.3. For analysis, if the front water level is left blank, the program places the front water level at the bottom of the footing.

The weight of the water above the toe is considered in the calculation for the WA load. WA also includes the uplift pressure due to buoyancy as shown in Figure 6.8.10-1.

6.8.10 Back Water Level

The depth is specified from the top of the structure. Leave this parameter blank if the back water is not present. A value of 0 implies that the back water level is at the top of the structure.

The backfill soil below the back water level is considered to be saturated. The soil above the back water level is considered to be dry (or moist).

6.8.11 Type of Abutment

Gravity type abutments or retaining walls should be described without any reinforcement; i.e. the use of SRA, SRB, SPA, BAR, ARE command will result in an error. Do not use these commands. The program will check the stem wall quarter points for tensile stresses. Flexure and Shear Checks are not performed in the footing. The user can distinguish between gravity and cantilever structures. There is a variation in the calculation of k_a, the effective depth and soil pressure. See Chapter 3 for further details.

A gravity wall depends on its self-weight for stability. Usually it does not have a significant toe or heel. It is usually unreinforced. A cantilever wall has a distinct footing heel and stem. It depends on the soil over the toe and footing for stability and it is reinforced.

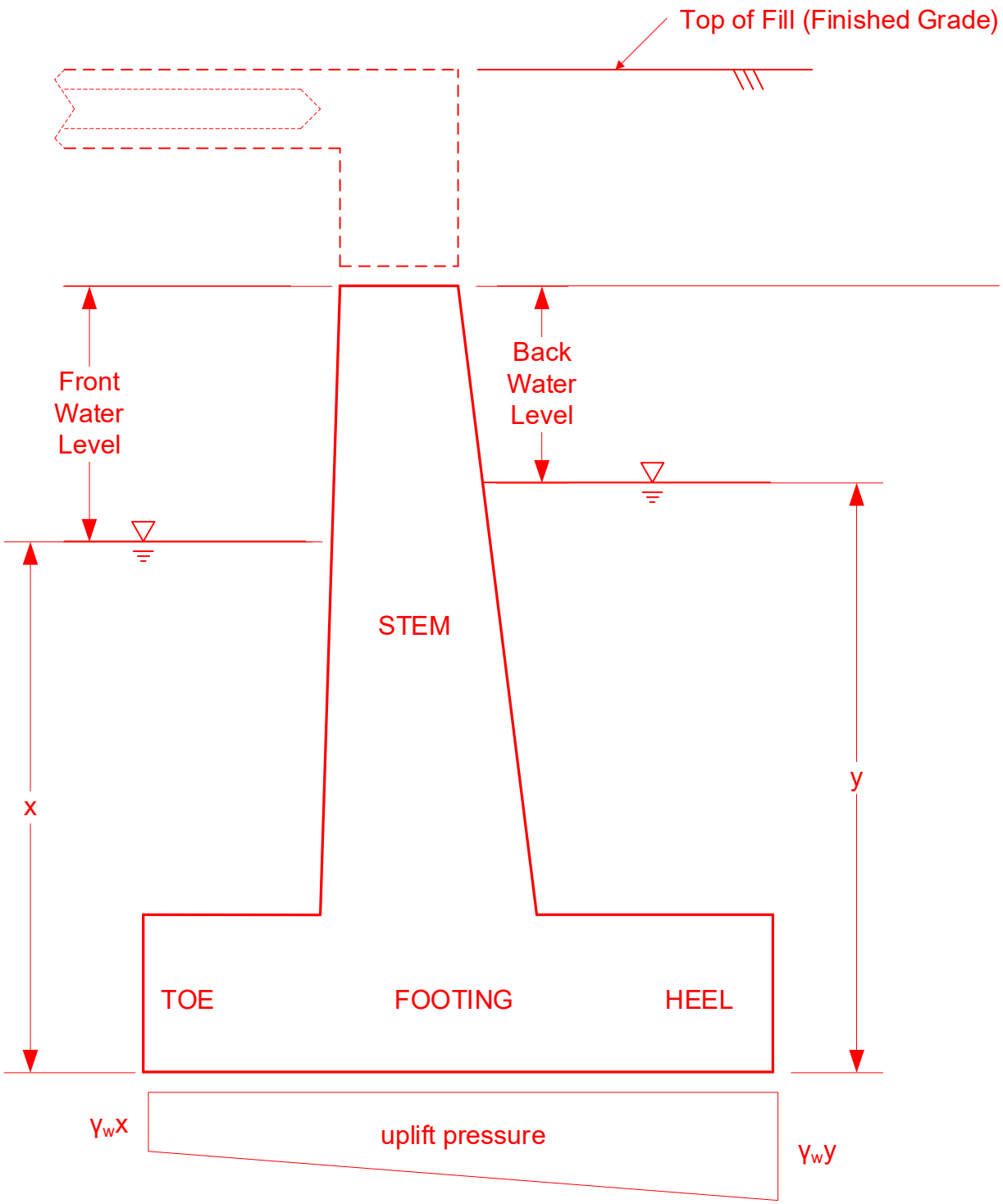


Figure 6.8.10-1 Water Level and Uplift Pressure – Abutment without Backwall

6.9 RWL - RETAINING WALL COMMAND

6.9.11 Front Water Level

The depth is specified from the top of the structure. Leave this parameter blank if the front water is not present. A value of 0 implies that the front water level is at the top of the structure. The back water level must be entered if a front water level is entered. If the front water level is left blank and a back water level is entered for a design run, the program will calculate the front water level based on DM-4 Section 3.11.3. For analysis, if the front water level is left blank, the program places the front water level at the bottom of the footing.

The weight of the water above the toe is considered in the calculation for the WA load. WA also includes the uplift pressure due to buoyancy as shown in Figure 6.9.12-1.

6.9.12 Back Water Level

The depth is specified from the top of the structure. Leave this parameter blank if the back water is not present. A value of 0 implies that the back water level is at the top of the structure.

The backfill soil below the back water level is considered to be saturated. The soil above the back water level is considered to be dry (or moist).

6.9.13 Type of Wall

Gravity type abutments or retaining walls should be described without any reinforcement; i.e. the use of SRA, SRB, SPA, BAR, ARE command will result in an error. Do not use these commands. The program will check the stem wall quarter points for tensile stresses. Flexure and Shear Checks are not performed in the footing. The user can distinguish between gravity and cantilever structures. There is a variation in the calculation of k_a, the effective depth and soil pressure. See Chapter 3 for further details.

A gravity wall depends on its self-weight for stability. Usually it does not have a significant toe or heel. It is usually unreinforced. A cantilever wall has a distinct footing heel and stem. It depends on the soil over the toe and footing for stability and it is reinforced.

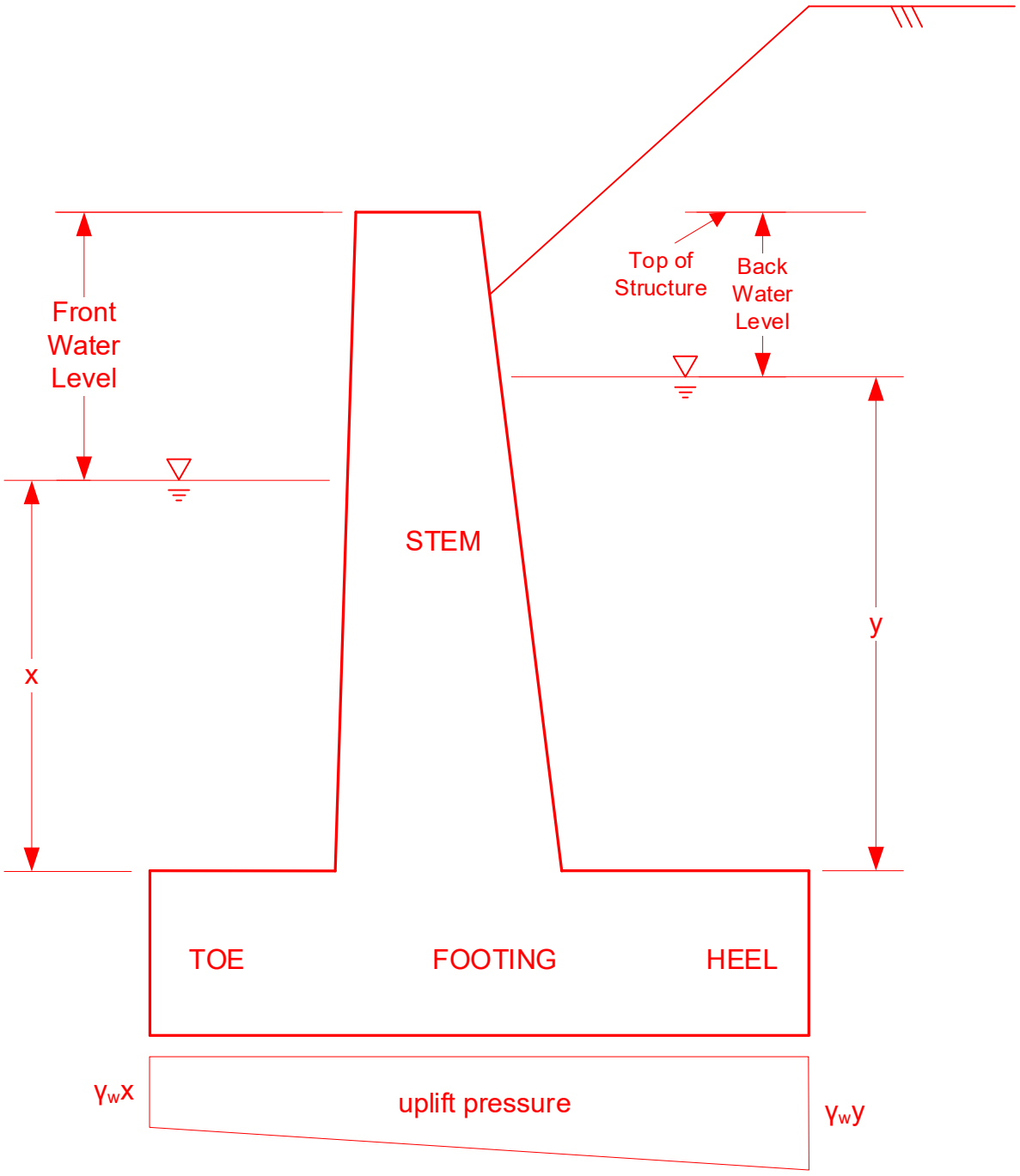


Figure 6.9.12-1 Water Level and Uplift Pressure - Retaining Wall

6.10 FTG - FOOTING COMMAND

For a design run, the footing command controls the search for the solution. Hence, the choice and values selected for the parameters play a critical role in determining the length of the run and the optimal solution. The special notes for this command (applicable for a design run only) are organized into five sections as follows:

- An overview of the issues concerning conflicting input data.
- Description of specific rules and guidelines, this includes samples of common error messages and how to resolve them.
- Recommended choices for input data.
- Considerations for efficiency.
- Suggested strategies for running a design problem.

Conflicting Input Data

The footing command has been developed to provide the user with a variety of ways in which to describe the range of abutment configuration that should be considered for design. The drawback to providing this flexibility is the potential conflicts that may arise from the choice and values specified for the input parameters.

The user has the option of constraining the thickness, width, toe projection and heel projection by specifying maximum and minimum values for each variable type. Errors typically occur when the user has inadvertently “over-constrained” the scope of configurations, i.e., there is an inconsistency in the input data.

The program will stop when a footing dimension limit that is specified by the user cannot be evaluated because of constraints imposed by other limiting values. For example, if the user specifies a value of 1 for the minimum width, minimum toe projection and minimum heel projection, the program will stop because a width of 1 cannot possibly exist when the toe and heel projections of 1 are also required.

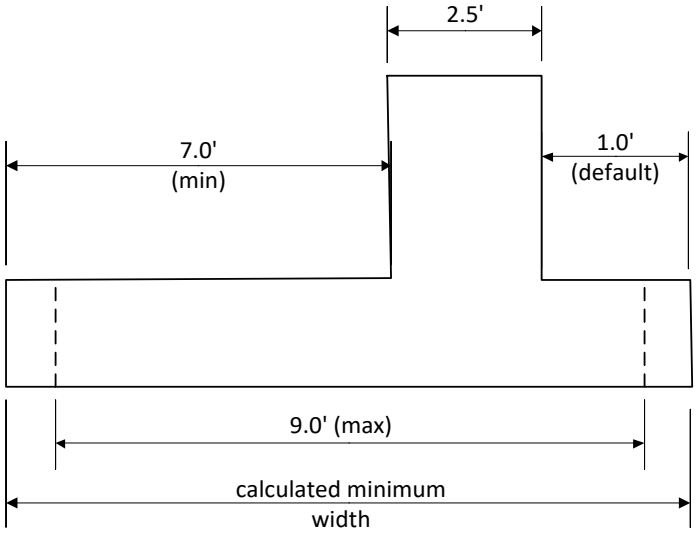
Typically, most conflicts occur between the projections and width. Since the footing thickness is not “coupled” to the width and projections, it is not discussed in much detail in the examples that follow.

Rules and Guidelines

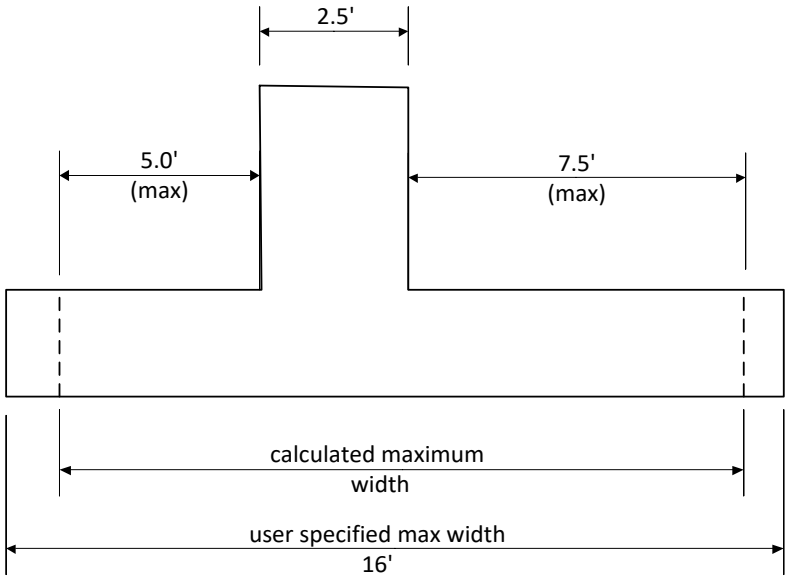
Each rule has an example that illustrates how the rule was violated. An explanation and some guidelines are also provided.

In the first four examples, the stem thickness is assumed to be 2.5 ft. In the last example, the stem thickness is 1.5 ft.

Rule 1:	A ‘minimum’ parameter cannot exceed ‘maximum’ parameter
Input example:	FTG 2, , , 12, 2, , , 10
Error message:	“ftg - min > max”
Explanation:	Program encountered minimum width (12) that is greater than maximum width (10)
Solution:	Switch the values.
Guideline:	Review the input for typographic errors, or data in the incorrect field.
Rule 2:	Maximum specified width cannot be less than the sum of the toe projection, heel projection and stem width.
Input example:	FTG 2, 7, , , 2, , , 9.
Error message:	“width greater than max”
Explanation:	The calculated width exceeds the maximum user-defined width as illustrated in Figure 6.10-1(a), where 7' + 2.5' + 1' > 9'.
Solution:	Do not specify minimum toe projection or maximum width.
Guidelines:	If toe and/or heel projections are specified, ensure that there is no conflict with the maximum width. The program assumes a default value of 1 ft for the toe and heel projections.
Rule 3:	Maximum specified width cannot be greater than the sum of the toe projection, heel projection and stem width.
Input example:	FTG 2, , , , 2, 5, 7.5, 16
Error message:	“maximum width is too big”
Explanation:	The maximum user-specified width is greater than calculated-width as illustrated in Figure 6.10-1(b) where 16'> 5' + 2.5' + 7.5'
Solution:	Do not specify one of the following: maximum toe, heel or width
Guidelines:	See guidelines for rule 2.
Rule 4:	Minimum width (if specified) cannot be less than the sum of the minimum toe projection, minimum heel projection and stem width.
Input example:	FTG 2, 3, 4, 8, 2, , ,
Error message:	“minimum width too small”
Explanation:	Minimum width is less than calculated minimum as illustrated in Figure 6.10-1(c) where 8' < 3' + 2.5' + 4.0'
Solution:	Do not specify minimum width, or revise the projections accordingly
Guidelines:	See guidelines for rule 2.

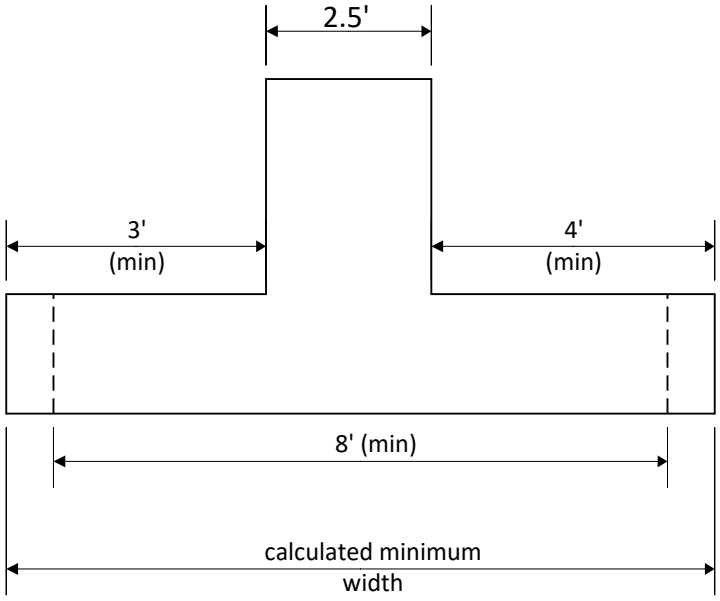


(a) FTG error type: width greater than max

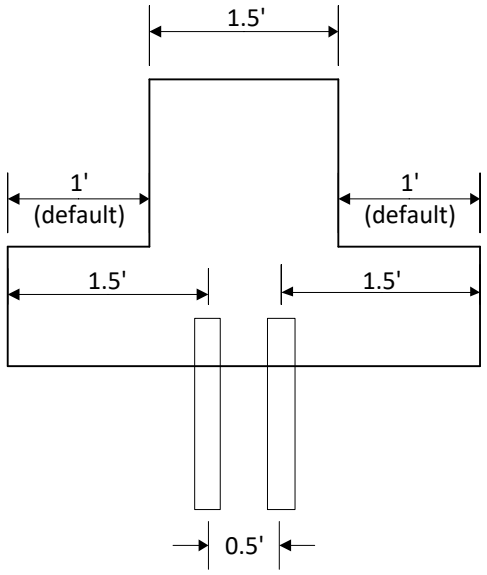


(b) FTG error type: maximum footing width is too big

Figure 6.10-1 Conflicting Input



(c) FTG error type: minimum width is too small



not enough room for 3' spacing

(d) footing width too small to accomodate pile layout

Figure 6.10-1 Conflicting Input (cont.)

Rule 5:	For pile footings, the width should be sufficiently wide to accommodate the pile layout (minimum).
Input example:	FTG 2, , , , 2.5, , LYD 1.5, 1.5, 3, ...
Error message:	first footing width too small for 2 pile rows
Explanation:	The minimum width and projections were not specified; hence, the default projections were used. Consequently, the first footing size was 3.5'. According to the LYD command, the distance from: the toe to first row is 1.5 ft; and, heel to last row is 1.5 ft. There is no room for a minimum spacing of 3 ft. as shown in Figure 6.10-1(d).
Solution:	Specify a minimum footing width of at least 6 ft.
Guidelines:	Check the LYD command, particularly the distance to first and last pile rows from the edge of the footing. Also, check the minimum footing width.

Rule 6:	The heel projection of the footing is controlled either by the maximum heel projection or maximum footing width cannot be less than the stem notch width minus the back batter.
Input example:	FTG 750, , , , ,250 AT2 4000, , , , , , , , ,400,1250,300,1000, ,2,10 ....
Error message:	Backwall completely overhangs heel
Explanation:	The calculated overhang extends beyond the limit of the heel.
Solution:	Increase maximum heel
Guidelines:	Check to ensure maximum heel width is not too small

Recommended Choices for Input Data

The table below provides suggestions on combinations of input data. Since the thickness is independent of the horizontal geometry, it has been omitted.

Case	minimum			maximum		
	toe	heel	width	toe proj	heel	width
1	o	-	x	x	-	x
1a	-	-	x	o	-	x
2	-	o	x	-	-	x
2a	-	-	x	-	o	x
3	x	x	-	-	-	o
4	-	-	o	x	x	-
5	x	x	-	x	x	-

Legend: 'x'=value specified; '-' value not specified; 'o' - optional, check for conflict

Notes:

Case 1 and 1a, avoid conflict for footing widths if the toe projections are specified.

Case 2 and 2a, avoid conflict for footing widths if the heel projections are specified.

Case 3, ensure that the maximum width is large enough.

Case 4, ensure that the minimum width is small enough.

Case 5, ensure that minimum parameters are less than maximum parameters.

Efficiency Considerations

If the maximum width is not specified, the program will use a value of three times the structure height, which is the height from the top of abutment including backwall or retaining wall to the bottom of the footing. This structure height is based on the initial footing thickness established during the programs first trial run. During the run, if a solution is found, the upper limit of the width will be revised to the lesser of the original computed maximum width; or, the width for the first valued design plus 3.5 ft. It would be more efficient to select a reasonable footing width based on engineering judgment.

- Footing thickness should be considered for shear. Shear is usually not a problem for spread and pedestal footings - use 2 ft for both minimum and maximum. For pile footings, ensure that there is enough depth for pile embedment. Use that value for both minimum and maximum (see note that follows).

- The design algorithm uses a triple nested loop with built-in optimization. The program starts with the maximum footing thickness and determines a valid design width. The thickness is then reduced to the minimum and the footing width is reduced by 1/2 the maximum footing thickness. However, if the water table is close enough to the footing bottom to affect bearing capacity, then the thickness is reduced to the minimum footing thickness input and the footing width is reduced to the point at which the water table will not be considered minus 1/2 the maximum footing thickness. By reducing the footing width beyond where the water table is not considered in the footing design (DM-4 Equation 10.6.3.1.2gP-2), the program will try

additional footing design widths, where water does not need to be considered. The thickness is then incremented up to the lesser of the maximum footing thickness of the last designed footing thickness. For each thickness and width combination, all possible stem positions are checked.

Consequently:

- As the width increases, so does the number of stem positions. Expect the width to change slowly as the program approaches the maximum width.

Strategies and Other Considerations

Based on the user's level of confidence concerning a solution, pick a tolerance value to define the maximum and minimum footing widths. Use smaller tolerances with higher confidence limits. For example, if the user is confident that a solution should exist for a 12 ft width, constrain the problem to check a range of 11.5 ft to 12.5 ft. Otherwise, try something from 10 ft. to 14 ft.

If a solution is not found, the program will indicate where the problem might exist (See Section 3.9). To corroborate this, run an analysis problem. Performance factors that are less than 1.0 will identify the sources of error.

6.10.9 Footing Thickness Increment

The footing thickness increment, the footing width increment and the stem increment values can be used to speed up a design run by using the following process.

- Make the first design run with no limits on the footing size, and with a footing thickness increment and width increment set to 12".
- Review the output file to determine the footing size and change the input file to set the min/max footing thickness to the thickness from the first run.
- Set the min/max footing width within a 1 or 2 foot range of the footing size from the first run.
- Set the thickness and width increments to 2" and make a second run.
- Set the stem increment to 1" and make a second run.

6.10.10 Footing Width Increment

See Section 6.10.9

6.10.11 Footing Stem Increment

See Section 6.10.9

6.12 PIL - PILE COMMAND

6.12.3 Pile Embedment

Pile embedment is used when evaluating the punching shear requirements. The program compares the pile embedment to the minimum acceptable value as per DM-4 Section 10.7.1.2. The user may describe footing rebar over the piles or alongside the piles (see CVR command).

6.12.5 Strength Axial Capacity

The Strength Axial Capacity is equal to the smaller of (a) factored geotechnical capacity or (b) the factored strength axial structural capacity as indicated below.

For steel piles driven to bedrock, the factored strength axial capacity should be in accordance with DM-4 Section 6.15.2.

For concrete filled steel pipe piles, determine the factored strength axial structural capacity in accordance with DM-4 Section 5.12.9.6.1P. The resistance factor, ϕ, to use for concrete piles is given in DM-4 Section 5.5.4.2.

The strength axial capacity for friction piles is equal to the factored geotechnical resistance at Strength Limit State, and is to be computed in accordance with DM-4 Section 10.7.3.8.

The program operates in accordance with the DM-4 Section 6.15.1 general pile design procedure. However, of the five conditions that require approval of the Chief Bridge Engineer only the last condition, "Vertical load to horizontal load ratio less than 2.4 at the service limit state" is checked by the program. The user should determine if any of the first four conditions exist and obtain Chief Bridge Engineer approval if any of those conditions apply.

6.12.7 Strength Lateral Capacity

The Strength Lateral Capacity is a factored capacity and depends on the type of pile group.

For a pile group with all vertical piles, the Strength Lateral Capacity is to be determined using either the COM624P or LPILE Program. Strength Lateral Capacity is based on a lateral deflection of 1.0 inch, at a strength limit state as discussed in DM-4 Section 10.7.2.2. The procedure that must be followed is iterative and is described in DM-4 Section 10.7.3.12.2P.

For a pile group with battered and vertical piles, the lateral capacity is equal to the horizontal component of strength axial capacity of the battered piles. Lateral capacities are assigned to battered piles only.

The program operates in accordance with the DM-4 Section 6.15.1 general pile design procedure. However, of the five conditions that require approval of the Chief Bridge Engineer only the last condition, "Vertical load to horizontal load ratio less than 2.4 at the service limit state" is checked by the program. The user

should determine if any of the first four conditions exist and obtain Chief Bridge Engineer approval if any of those conditions apply.

6.12.8 Pile Uplift Capacity

The uplift capacity must be based on geotechnical analysis with or without pullout testing, refer to DM-4 Section 10.7.1.6.3. Alternately, in the absence of analysis or testing, the uplift capacity may be taken as 10% of the axial structural capacity for steel piles, $0.1\ f_y\ A_s$.

No uplift is permitted under a service limit state.

6.13 CAI - CAISSON COMMAND

6.13.2 Caisson Embedment

Please refer to Section 6.12.3.

6.13.4 Strength Axial Capacity

Refer to DM-4 Section 10.8.3.5 for factored geotechnical capacity and DM-4 Section 5 for factored structural capacity.

6.13.6 Strength Lateral Capacity

For designs in which all the caissons are vertical (which is almost always the case in Pennsylvania), the Strength Lateral Capacity is to be determined using either the COM624P or LPILE Program. Strength Lateral Capacity is based on limiting the lateral deflection to 1.0 inch at the strength limit state in accordance with, LRFD Specifications Section 10.8.3.8, DM-4 Sections 10.7.2.2 and 10.8.3.8. The procedure that must be followed is iterative and is described in DM-4 Section 10.7.3.12.2P.

6.13.7 Caisson Uplift Capacity

The uplift capacity must be based on geotechnical analysis with or without pullout testing, refer to DM-4 Section 10.8.3.7.

No uplift is permitted under a service limit state.

6.14 PED - PEDESTAL COMMAND

6.14.4 Minimum Pedestal Width

The minimum pedestal width is used as the pedestal width for an analysis run. For a design run, the program will test all pedestal variations using a width that varies incrementally from minimum to the maximum value specified by the user.

The pedestal must be sufficiently wide enough to support the footing and have acceptable front, back and sloped projections as shown in Figure 5.14-2.

6.14.5 Minimum Pedestal Thickness

The minimum pedestal thickness is used as the pedestal thickness for an analysis run. For a design run, the program will test all pedestal variations using a thickness that varies incrementally from minimum to the maximum value specified by the user.

The pedestal thickness will determine the clear spacing between pedestals. The clear spacing is used to compute the moments in the footing (parallel direction).

6.14.8 Maximum Pedestal Width

The maximum pedestal width should be left blank for an analysis run. For a design run, the program will test all pedestal variations using a width that varies incrementally from minimum to the maximum value specified by the user.

The pedestal must be sufficiently wide enough to support the footing and have acceptable front, back and sloped projections as shown in Figure 5.14-2. If the maximum pedestal width is not specified for a design run, the program will use a value equal to two times the current footing width under consideration for design (see Section 5.10). Hence, the maximum footing width will vary during the design run.

6.14.9 Maximum Pedestal Thickness

The maximum pedestal thickness should be left blank for an analysis run. For a design run, the program will test all pedestal variations using a thickness that varies incrementally from minimum to the maximum value specified by the user.

The pedestal thickness will determine the clear spacing between pedestals. The clear spacing is used to compute the moments in the footing (parallel direction).

6.15 LYD - PILE/CAISSON LAYOUT DESIGN COMMAND

6.15.6 Pile Spacing Rounding

The program will ensure that the pile spacing within a row is rounded to the lowest multiple of this parameter as follows. For example, if this parameter is set to 0.25 ft, a required pile spacing of 3.9 ft will be rounded to a design value of 3.75 ft, and a required pile spacing of 3.55 ft will be rounded to 3.5 ft.

6.15.7 Row Distances Rounding

The program will ensure that the pile spacing between rows is rounded to the lowest multiple of this parameter. For example, if this parameter is set to 0.5 ft, a required row spacing of 3.9 ft will be rounded to a design value of 4.0 ft, and a required pile spacing of 3.55 ft will be rounded to 4.0 ft.

6.15.10 Last Row % Batter

This parameter is used to limit the number of piles in the last row that can be battered. For example, a value of 25 indicates that 25% of the piles in that row are battered.

6.16 LYA - PILE/CAISSON LAYOUT ANALYSIS COMMAND

6.16.4 Percent Battered

This parameter is used to specify the percentage of battered pile found within a row of piles. Typically, for the last row of piles this value should not be greater than 50 percent. If more than 50% of the last row is specified as battered, the program will issue a warning message in the output and continue the analysis.

6.17 MAT - MATERIALS COMMAND

6.17.8 Backfill Friction Angle

If river gravel is used for backfill, a friction angle close to 30 degrees is appropriate.

6.17.11 Minimum Equivalent Fluid Pressure

DM-4 Section 3.11.5.5 indicates a design earth pressure of 35 lb/ft^3 for yielding walls. Based upon the user input value for the backfill angle of friction, and the earth pressure theory used, the calculated design earth pressure may result in a value less than the 35 lb/ft^3. The input for minimum earth pressure has been made available to ensure that the design earth pressure is not less than a specified value. Therefore, a value of 35 lb/ft^3 should be input unless a lesser value is required due to use of lightweight fill, or for other atypical conditions, and has been approved by the Chief Bridge Engineer.

6.18 SOI - SOIL DATA COMMAND

This command can only be used for spread footings on soil.

Do not use this command for spread footings on rock, and for footings on piles, pedestals or caissons.

Soil Layers:

The program can handle one or two layers of soil. If multiple layers are present, they must be modeled as one or two layers.

(a) Single Soil Layer: In this case, the soil parameters for the single soil layer are input under "SOI" command. The program assumes that a very stiff layer exists under this one layer of soil. The soil layer thickness is input to indicate where the soil layer ends and the stiff layer begins.

(b) Two Soil Layers: When there are two soil layers, properties and thicknesses for each layer must be input under the "SOI" command. The program assumes a very stiff layer under the two soil layers.

Normal input values for soils are as follows:

Clay Soils: Input "S_u" (3.1 notations) value only. Leave c (3.1 notations) and Phi values blank.

Typical values for S_u are 2.1 to 12.5 ksf for supporting footings (also refer to BC-795M).

C-Phi Soils: Input both c-value and Phi value. Leave S_u - value blank.

Typical c values are 1.0 to 2.1 ksf and typical Phi values from 25 to 40 degrees

Sand Soils: Input Phi-value only. Leave S_u and C-values blank.

Soft Soil: When there is a "soft layer" of soil below the footing, the program terminates due to the soft layer. In practice, we do not construct bridge substructures on very soft soils; instead, pile, pedestal or caisson foundations are used. Therefore, limiting values of soil parameters are used to define what a "soft soil" is and the spread footing design is terminated when these low values of soil parameters are present. These limiting soil values are:

Clay Soils (S_u only)	$S_u \leq 0.626$ ksf
C-Phi Soils (Mixed)	$c \leq 0.626$ ksf AND Phi $\leq 20°$
Sand Soils	Phi $\leq 20°$

6.18.3 Footing Near Slope

A footing is considered to be near a slope when any portion of the footing is located within a distance of three times the footing width of the crest of slope. A sloping ground surface in front of a footing will reduce the bearing resistance. Please refer to LRFD Specifications Section 10.6.3.1.2c.

If the footing is near the slope or on a slope the value of RC_{BC} for each layer (parameters 31 and 32 of the SOI command) must be specified by the user. Otherwise, leave RC_{BC} blank for each layer.

6.18.5 Allowable Settlement

The computed settlement is compared to the value of this parameter. For clay and c-phi soil, the computed settlement is the sum of the elastic, consolidation and secondary settlement. For a sand foundation, only the elastic settlement is considered. The temporary stage settlement is reported but is not deducted from the total settlement. The allowable settlement should be selected using engineering judgment either to include the temporary stage settlement or not to include it.

6.18.6 Bearing Capacity Phi Factor

The value of this parameter is applied to the unfactored bearing resistance of the soil foundation to evaluate the factored bearing resistance. The factored bearing resistance is compared to the applied factored loads.

Values for the bearing capacity resistance factors at the strength limit state range from 0.35 to 0.55 depending on the foundation analytical method, soil type and test method. See DM-4 Table 10.5.5.2.2-1.

6.18.7 Sliding Phi Factor

The value of this parameter is applied to the unfactored sliding resistance of the soil foundation to evaluate the factored sliding resistance. The factored sliding resistance is compared to the applied factored horizontal loads.

Typical values for the sliding resistance factor range from 0.80 to 1.0. See DM-4 Table 10.5.5.2.2-1

6.18.10 Layer 1 Undrained Shear Strength

This value is only applicable to clay foundations. The bearing capacity of clay foundations is similar to that of c-phi soils. The S_u value is substituted for all values of the cohesive strength (c) in the equations of Chapter 3 with the friction angle inputted as 0.

Typical values of S_u are in the range of 0.5 to 3.0 ksf.

6.18.12 Layer 1 Saturated Unit Weight / Density

Enter the saturated unit weight / density of the soil layer. This value must be greater than the mass (non-saturated) unit weight /density of the soil.

$$\gamma_{sat} = \gamma_{dry} + \left[\frac{e}{1+e}\right]\gamma_{wat}$$

Where: γ_{dry} = mass (non-saturated) unit weight/density of soil

γ_{wat} = density of water, 62.5 lbs/ft^3

γ_{sat} = saturated unit weight/density of soil

e = void ratio

The saturated unit weight / density can be calculated using the following equation if the void ratio is known.

6.18.14 Layer 1 Poisson's Ratio

This input item is temporarily not used. The program computes elastic settlement using the elastic effects of a Poisson's ratio of 0.5.

6.18.15 Layer 1 Cohesion

The cohesion value (c) of the soil must be specified for c-phi soils. Leave this parameter blank for clays and sands. The cohesion value of the soil is used in the bearing capacity computations. See Chapter 3 for further details.

Typical values of c are in the range of 1.0 to 3.0 ksf.

6.18.16 Layer 1 Effective Friction Angle

This value must be specified for c-phi soils and sands.

Typical values of soil friction angles are in the range of 20 to 40 degrees.

6.18.20 Layer 2 Undrained Shear Strength

See Section 6.18.10.

6.18.22 Layer 2 Saturated Unit Weight / Density

See Section 6.18.12.

6.18.24 Layer 2 Poisson's Ratio

See Section 6.18.14.

6.18.25 Layer 2 Cohesion

See Section 6.18.15.

6.18.26 Layer 2 Effective Friction Angle

See Section 6.18.16.

6.18.29 Apply Inclination Factors

The inclination factors are used when computing the bearing resistance to account for a resultant force formed by shear and axial load components from a wall or column applied to a footing. LRFD Specifications Section C10.6.3.1.2a states that using inclination factors in conjunction with shape factors can result in overly-conservative bearing capacities. The inclination factors were originally developed without consideration of footing embedment. When footings with an embedment of $D_f/B = 1$ or greater, the effects of inclination on bearing resistance is relatively small. As such, this input allows the user to determine whether to apply inclination factors.

The program defaults to Y for inclusion of the inclination factors.

6.18.30 Precast or Cast-in-Place

This value is used to specify whether the footing is precast (with a smooth base) or concrete cast against soil (with a rough footing base). This parameter is applicable only for structures with spread footings on Sand or Clayey-Sandy “C-Phi” soils. If precast is selected then a 0.8 factor is applied when computing the nominal resistance for sliding between the soil and the foundation.

The program defaults to C for cast-in-place spread footings.

6.19 RCK - ROCK DATA COMMAND

Rock foundations must be specified for pedestal footings and may be described for spread footings. Rock foundations may not be specified for pile footings.

Only one rock layer may be specified. The material below the rock layer is assumed to be very stiff. RCK and SOI commands are mutually exclusive.

6.19.1 Empirical Bearing Capacity

The program does not calculate the capacity of rock foundations; this value must be specified. Refer to DM-4 Section 10.6.3.2 for a detailed description of evaluating the rock bearing capacity.

Typical values of allowable bearing capacity of rock are in the range to 4 to 40 ksf.

6.19.4 Sliding Resistance

The user has the option of checking the sliding between the spread footing and rock foundation. If the value of this parameter is N, the sliding phi factor (parameter 7) should be left blank. Per LRFD Specifications Section 10.6.3.4, failure by sliding shall be investigated for footings that support inclined loads and/or are found on slopes.

Please note that this does not apply to the sliding check of footings on pedestals. Footings on pedestals have special considerations as described in Chapter 3.

6.19.5 Allowable Settlement

The computed settlement is compared to the value of this parameter. For a rock foundation, only the elastic settlement is considered. The temporary stage settlement is reported but not deducted from the total settlement. The allowable settlement should be selected using engineering judgment. The total allowable settlement may or may not include the temporary stage settlement. The maximum allowable settlement is 1.0 inch. Typically, settlement in rock is between 0 and 0.5 inch.

Temporary Stage Settlement:

This refers to the settlement which occurs during the substructure construction. The user may want to know the temporary stage settlement to decide whether to include this in the amount of tolerable settlement for the structure.

The program calculates temporary stage settlement using the “Consolidation, Secondary Settlement” Load Combination without any superstructure loads or live loads.

6.19.6 Bearing Capacity Phi Factor

The value of this parameter is applied to the unfactored bearing resistance of the rock foundation to evaluate the factored bearing resistance. The factored bearing resistance is compared to the applied factored loads.

Typical values are 0.35 to 0.55.

6.19.7 Sliding Phi Factor

The value of this parameter is applied to the unfactored sliding resistance of the rock foundation to evaluate the factored sliding resistance. The factored sliding resistance is compared to the applied factored horizontal loads.

Typical values are 0.8 to 0.85.

6.19.9 Concrete / Rock Friction

This value is used to evaluate the sliding capacity of the footing as described in Section 3.4.1.2.1.

This value represents the friction angle between the base of the concrete footing and the underlying rock foundation material. For mass concrete cast directly on various materials, LRFD Specifications Table C3.11.5.3-1 is often used. This table provides an angle of friction for concrete on clean sound rock of 35 degrees. The values to be used should be provided as part of the geotechnical recommendations for design of the foundation.

Typical values are in the range of 30 deg to 45 deg.

6.19.10 Intact Rock Modulus

This value is used to calculate the rock modulus used in the elastic settlement of rock equations as described in User Manual Section 3.4.1.3.1. The intact modulus of rock is determined though unilateral compression testing of rock material.

6.20 CNS - CONSOLIDATION SETTLEMENT COMMAND

This command should only be specified for clay and c-phi soils (see SOI command 5.18). It is used to describe the data that will evaluate the consolidation and secondary settlement.

Consolidation Settlement is calculated for clay soils when water is present in the soil layer(s). This settlement is a result of the excess water being forced out of the layer, allowing the soil to increase in density. The program, however, always assumes the soil layer(s) are saturated and will consider the entire layer for consolidation regardless of water presence.

Program Limitation

As currently configured, the program only computes settlement from the loads imposed by the spread footing. It is possible to manipulate the inputs for each layer to get the program to compute settlement due to the weight of fill placed beneath the footing. However, the program does not account for settlement produced by the weight of fill placed behind the footing to the top of the wall. In many cases, settlement induced by the wall backfill or weight of the bridge approach embankment (See Figure 6.20-1) contributes significantly to the settlement of the wall or abutment (and of course to settlement of the embankment itself). If consideration of the effects of adjacent fills is important, the settlement must be computed by hand.

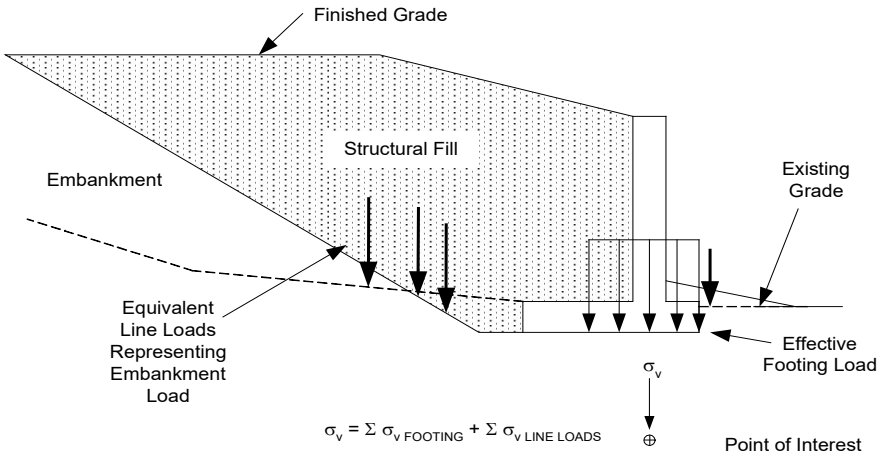


Figure 6.20 -1 Embankment Effects on Settlement

6.20.1 Number of soil layers

The number of soil layers must match the number of soil layers specified in the SOI command. A maximum of 2 layers is allowed.

6.20.2 Void Ratio

The void ratio is the ratio of the volume of voids to the volume of solids. Void ratios are based on test data.

Typical values are in the range of 0.4 to 1.5.

6.20.3 Compression Index

Input should be based on test data and based on the void ratio definition.

Typical values of compression index are 0.1 to 0.4. If the compression index and re-compression index are set to 0.0, consolidation settlement will not be computed for this layer.

6.20.4 Re-compression Index

Input should be based on test data and based on the void ratio definition.

Typical values of Re-compression index are 0.01 to 0.04. If the compression index and re-compression index are set to 0.0, consolidation settlement will not be computed for this layer.

6.20.5 Secondary Compression Index

Input should be based on test data and be based on the strain definition.

Typical values of secondary compression index are in the range of 0.001 to 0.002

6.20.6 Initial Effective Stress

Typical values are in the range of 0.07 ksi to 0.28 ksi.

If the value of this parameter is greater than the maximum past effective stress, the soil is considered under consolidated. The program will not compute settlement for this condition. Hand calculations must be performed and then approved by the Chief Bridge Engineer. See Section 3.4.1.3.2.

In most cases, the initial effective stress at the top of layer 1 will be zero and the initial effective stress at the top of layer 2 is the effective stress at the bottom of layer 1. This can be calculated as:

$\sigma'_{01} = 0$

$\sigma'_{02} = \sigma'_{01} + H_1\gamma 1 - H_{w1}\,\gamma_w$

Where H_{w1} is the height of water above the bottom of layer 1 and cannot exceed the height of layer 1. If the water level is below the bottom of layer 1, then $H_{w1} = 0$.

Refer to the figures below for definition of the remaining variables

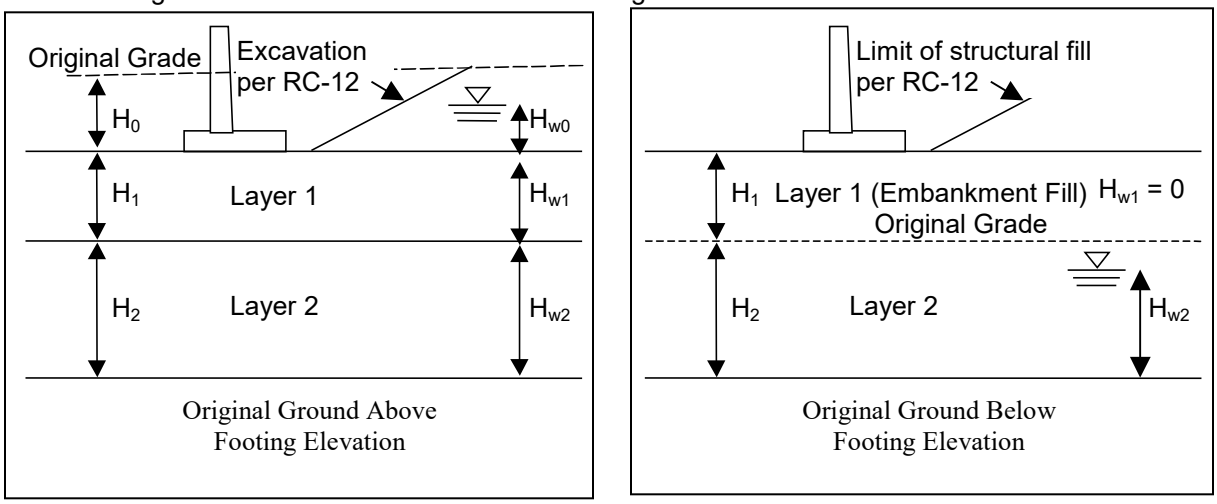


Figure 6.20.6 -1 Initial Effective Stress

There are two special cases in which the above does not apply. These are discussed in more detail below:

Special Case 1: Footing Excavated below grade, short construction period

This case occurs when excavation is performed below original grade to reach footing elevation and the time between excavation and establishment of final footing load is short enough so that equalization of pore pressure due to loss of overburden stress does not occur. This would be the case if the clay layer has very low permeability or if construction is very rapid. Equalization of pore pressure under rebound conditions is usually fairly rapid. Evaluation of void ratio vs. time relationships during the rebound portion of a consolidation test can help determine if this will be the case. For this case, the initial effective stress would be that which existed prior to excavation or:

$\sigma'_{01} = H_0 \gamma_0 - H_{wo} \gamma_w$

$\sigma'_{02} = \sigma'_{01} + H_1 \gamma_1 - H_{w1} \gamma_w$

Refer to the left half of the figures above for explanation of the variables.

Note that there are some instances when σ'_{02} cannot be calculated as indicated above. Such a case might include the case of a deep shored excavation where the first layer might have reached equilibrium due to the stress relief of the excavation but deeper layers either have not equalized or do not see the full effect of removing a small block of overburden material near the surface.

Special Case 2: Embankment fill placed to raise grade to footing elevation, excess pore pressure in original ground not allowed to dissipate prior to construction of footing.

In this case the computed primary settlement would include the settlement induced in the original soil by the weight of the embankment fill placed above it plus the settlement due to the weight of the structure. Note that if the embankment is not saturated, it will not undergo primary consolidation and C_{cr} , C_c for layer 1 should be set to zero to reflect this. In this case, the initial effective stress at the top of the first and the second layer is set to zero.

$\sigma'_{01} = 0$

$\sigma'_{02} = 0$

6.20.7 Maximum Past Effective Stress

Typical values are in the range of 0.28 ksi to 0.7 ksi.

Case 1 Normally consolidated soil

By definition, a normally consolidated soil is one where the initial effective stress is equal to the maximum past effective stress. Thus, to specify a pure normally consolidated case, preconsolidation pressure is set equal to the initial pressure at the top and bottom of the layer. This would mean:

$\sigma'_{p1\ TOP} = \sigma'_{01}$

$\sigma'_{p1\ BOTTOM} = \sigma'_{p2\ TOP} = \sigma'_{02}$

$\sigma'_{p2\ BOTTOM} = \sigma'_{02} + H_2\ \sigma_2 - H_{w2}\ \gamma_w$

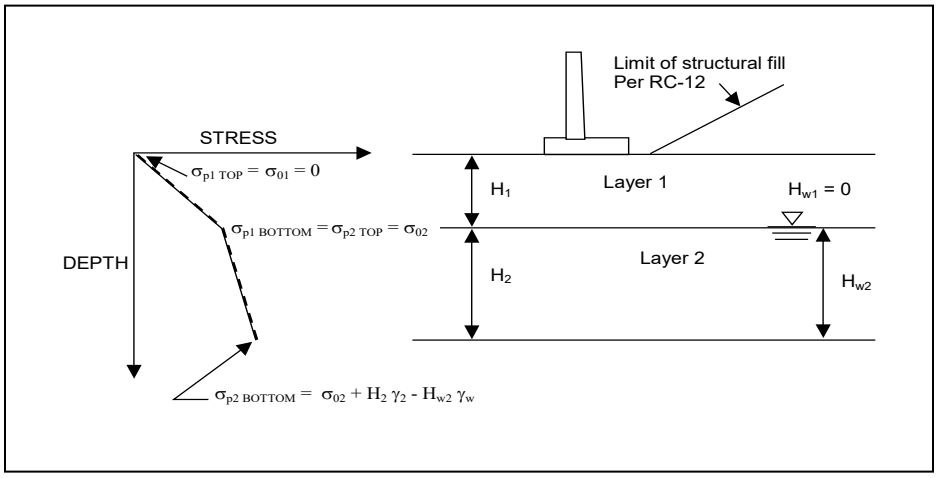


Figure 6.20.7-1 Case 1 - Normal Consolidation

Note that if the water table occurs in the middle of a layer, an under consolidated condition will be detected and the program print a warning message (see figure below). To resolve this, the individual layer thickness

should be selected such that the water elevation is coincident with one of the layer boundaries as shown above.

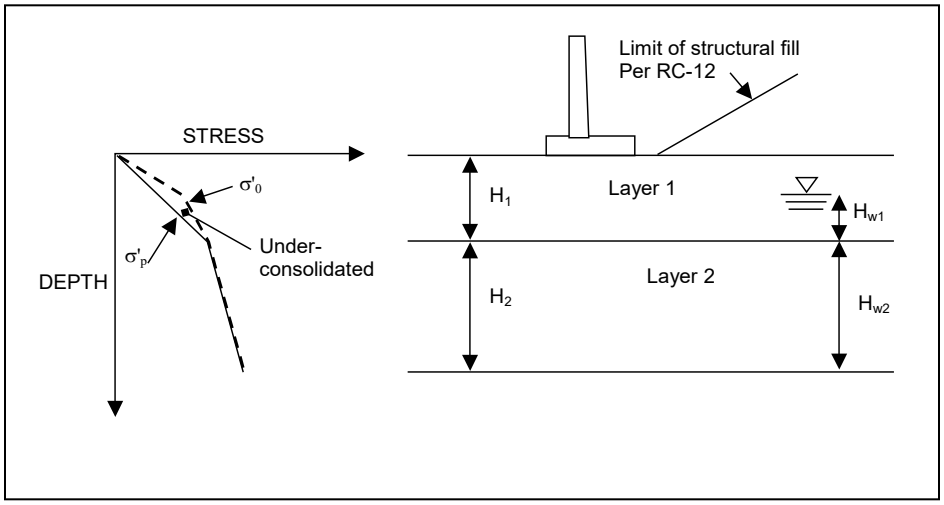


Figure 6.20.7-2 Case 1 - Underconsolidation

Case 2 Soil Overconsolidated due to Past Regional Stress

This could be due to regional glaciation, erosion of overlying soil and rock layers (the case for most residual soils), regional ground water fluctuations, excavation of a large area to reach proposed grade, or other reasons. This type of overconsolidation tends to produce a preconsolidation pressure that is higher than the existing stress by a constant value with respect to depth. To specify this condition, the user would first compute the initial effective stress at the top of each layer and at the bottom of the second layer. The constant value of stress that represents the regional stress that has been since removed would then be added to each of the initial effective stress values and specified as $\sigma_{p1\ TOP}$, $\sigma_{p1\ BOTTOM}$, $\sigma_{p2\ TOP}$, $\sigma_{p2\ BOTTOM}$ in the program. This would be calculated as:

$\sigma'_{p1\ TOP} = \sigma'_{01} + \sigma_R$

$\sigma'_{p1\ BOTTOM} = \sigma'_{p2\ TOP} = \sigma'_{02} + \sigma_R$

$\sigma'_{p2\ BOTTOM} = \sigma'_{02} + H_2\ \sigma_2 - H_{w2}\ \gamma_w + \sigma_R$

Where σ_R = the past regional stress

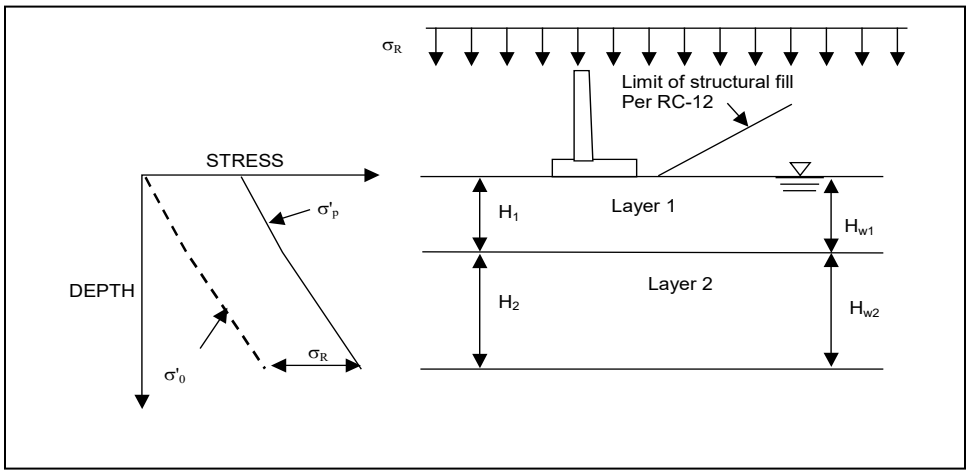


Figure 6.20.7-3 Case 2 - Overconsolidation due to Past Regional Stress

Case 3 Overconsolidation due to Discrete Surface Loads

This would be the case where soils are highly overconsolidated near the surface due to discrete static surface loads that have been removed (building loads, excavation to reach footing level, etc.) or due to mechanical compaction from traffic or other discrete sources at the surface of the soil. This condition also commonly results from desiccation (repeated wetting and drying) of near surface soils. The preconsolidation pressure profile for such a case consists of a high initial value that decreases with depth to a point and then starts increasing with depth as it approaches the initial stress. This means that near surface soils are treated as highly overconsolidated and soils at depth are essentially normally consolidated. There are two ways to define such a profile.

A) If enough consolidation test information is available to define a complete preconsolidation pressure profile with respect to depth, the layer thickness and preconsolidation pressure can be set to approximate the profile with three points as shown in the figure below.

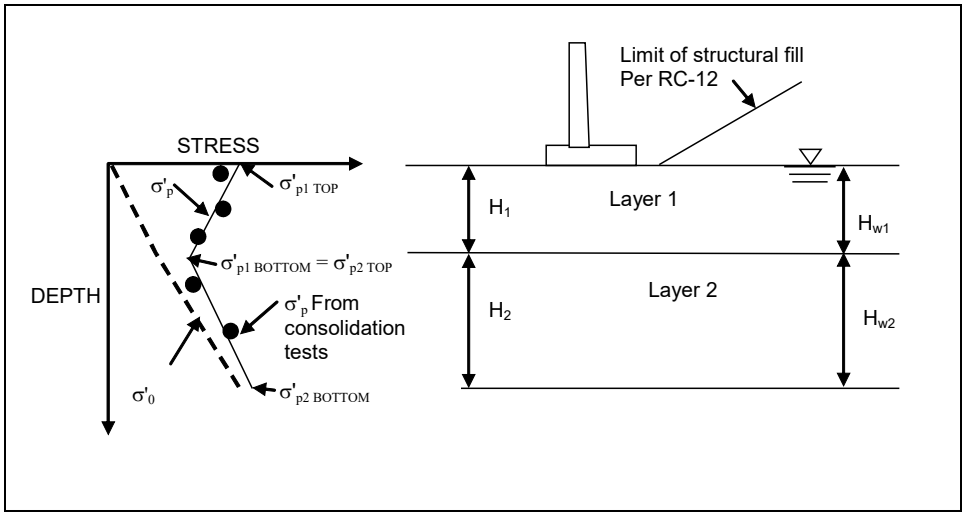


Figure 6.20.7-4 Case 3 - Overconsolidation due to Discrete Surface Loads-A

B) If the magnitude, location and extent of the discrete load that caused the overconsolidation is known (such as in the case of a soil surcharge placed to preconsolidate the foundation soils or the case of excavation of a discrete block of soil to reach foundation elevation), the stress increase with respect to depth due to that load can be computed by various forms of the Bousinesq equation and added to the initial stress. This presumes that the soil was fully consolidated under the applied load. The resulting preconsolidation stress profile can then be approximated by three points as described above. An example of this is provided below.

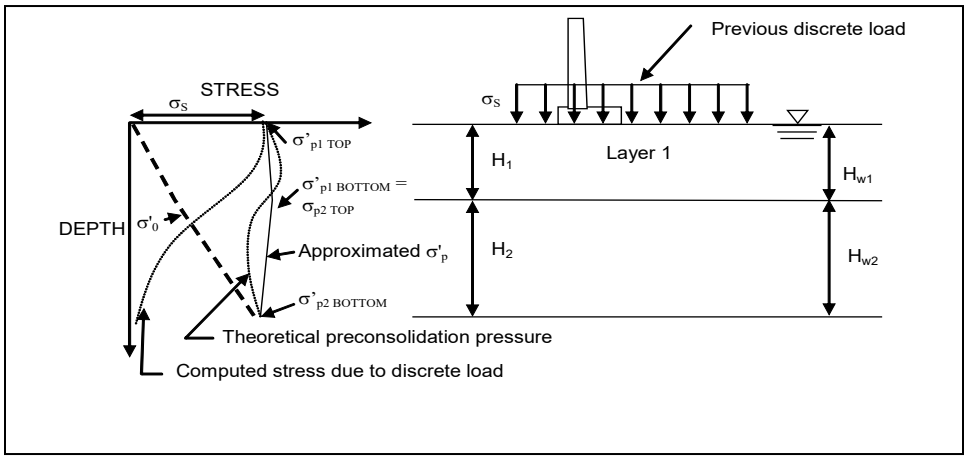


Figure 6.20.7-5 Case 3 - Overconsolidation due to Discrete Surface Loads-B

Case 4 Soil overconsolidated due to mechanical compaction of the soil

This would be the rare case in which the soil has been mechanically densified by some means. Such a case would be a compacted embankment that has since become saturated or a soil that has been subject to in-situ densification techniques. For these soils, the preconsolidation pressure is relatively constant with depth and is a function of the amount of energy that was used to densify the soil. This would be specified by setting

$\sigma'_{p1\ TOP}$, $\sigma'_{p1\ BOTTOM}$, $\sigma'_{p2\ TOP}$, and $\sigma'_{p2\ BOTTOM}$ to a constant value.

$\sigma'_{p1\ TOP} = \sigma_M$

$\sigma'_{p1\ BOTTOM} = \sigma_M$

$\sigma'_{p2\ TOP} = \sigma_M$

$\sigma'_{p2\ BOTTOM} = \sigma_M$

Where σ_M = the amount of preconsolidation achieved by mechanical means.

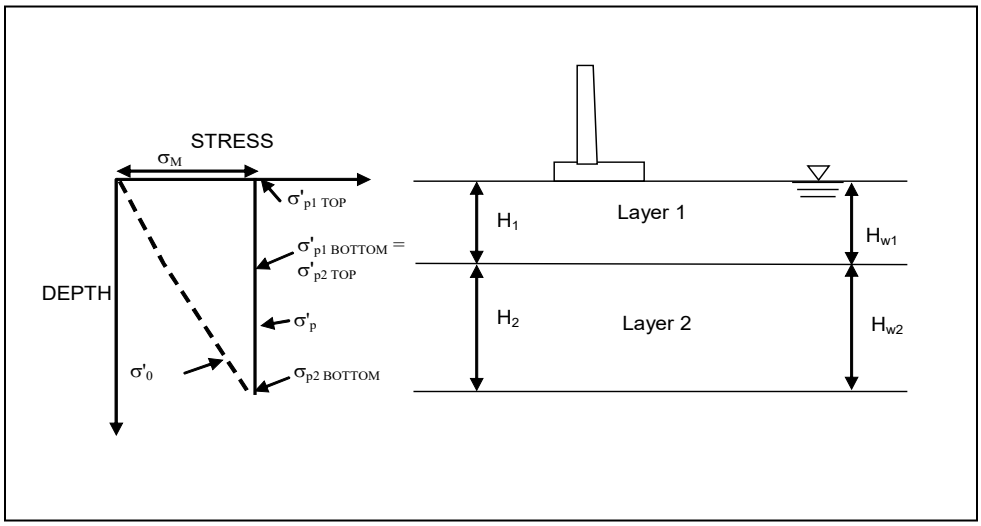


Figure 6.20.7-6 Case 4 - Overconsolidated due to Mechanical Compaction of the soil

Note: At some depth the existing stress will exceed the constant value of prestress and the soil will consolidate under its own weight to a normally consolidated state. The program will detect this as an underconsolidated condition and print a warning message.

Case 5 Underconsolidated soil $\left(\sigma'_p < \sigma'_o\right)$

The ABLRFD program does not consider settlement for Under-Consolidated soil. If Under-consolidation is encountered, the input file should be checked for errors. Hand calculations are required along with approval from the Chief Bridge Engineer. If Under-Consolidation is detected during a design run, a warning will be issued and primary consolidation settlement will be calculated assuming a normal consolidation condition.

6.20.8 Primary Consolidation Time

This value is based on consolation test data.

Typical values are 0.5 to 3.0 years.

6.20.9 Service Life

Depends on the type of structure. Usually 5 to 10 years is used for the computation of secondary compression, although theoretically it goes forever.

6.21 MRD - MISCELLANEOUS REINFORCEMENT DATA COMMAND

6.21.1 Aggregate Size

The aggregate size is used to check the minimum acceptable spacing between bars that are used for flexural reinforcement.

6.21.2 Development Correction Factor

The development correction factor input parameter is used to account for development length correction factors that are not currently considered by the program. Development length correction factors that are considered by the program are described in Section 3.5.2.3. This factor is applied to all reinforcement in all components. As such, multiple runs may be required to accurately apply a factor to the correct component.

The factor is applied in the calculations for the development length as described in Section 3.5.2.3.

6.21.3 Backwall Exposure

The exposure is used in the serviceability check. The allowable spacing for the crack control check depends on the exposure. The allowable spacing under Class 1 is greater than the allowable spacing under Class 2. Please refer to Section 3.5.2.8 for further details.

6.21.4 Stem Exposure

See 6.21.3

6.21.5 Footing Exposure

See 6.21.3

6.23 SPD - REINFORCEMENT DESIGN COMMAND

6.23.5 User Requested Minimum Bar Spacing & 6.23.6 Bar Spacing Increment

The User Requested Minimum Bar Spacing and the Bar Spacing Increment are used to control what bar spacings are allowable during a design run. The following table shows how different combinations of these two parameters will affect bar spacing during design runs.

User Requested Minimum Bar Spacing (in.)	Bar Spacing Increment (in.)	Resulting Bar Spacings (in.)
6.0	3.0	6, 9, 12, 15, 18
6.0	2.0	6, 8, 10, 12, 14, 16, 18
2.5	3.0	2.5, 5.5, 8.5, 11.5, 14.5, 17.5
4.0	5.0	4, 9, 14

Because the maximum allowable spacing permitted by DM-4 is 18 in, the spacings computed by the program are limited to 18 in or less.

6.27 SRA - STEM REINFORCEMENT AREAS COMMAND

Figure 6.27-1 is an illustrated example of how the stem rebar layout is described in terms of the SRA command syntax.

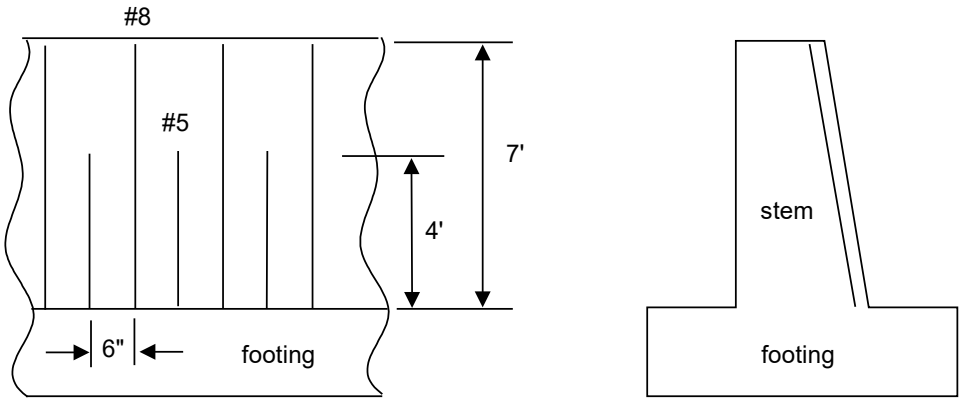


Figure 6.27-1 SRA Example

Description:

* #8 @ 12" spacing at 0" offset (by definition) has 7' length
* #5 @ 12" spacing at 6" offset (relative to #8) has 4' length

SRA Input:

#8 -- Area of bar = 0.79 in^2; Diameter of bar = 1.0 in.

#5 -- Area of bar = 0.31 in^2; Diameter of bar = 0.625 in.

From footing top to 4' - Total area per unit width is 1.10 in^2 (#8 + #5)

From 4' to 7' - Total area per unit width is 0.79 in^2 (#8)

Consequently: SRA 1.10, 4, 1.0, 0.79, 7, 1.0

(Equivalent SRB Command syntax: SRB 8, 12., ,7., 5, 12., 6., 4.)

6.31 ASL – APPROACH SLAB LOAD COMMAND

In order to satisfy the requirements of BD-628M, Sheet 2, Note 14, abutments with approach slabs usually require two runs of the program, with different program input based on the approach slab type. The first run assumes that a rigid approach slab is present, while the second run assumes a future condition where the rigid approach slab is not present. For Type 4 Approach Slabs with Flexible Pavement Adjacent to Tooth Dam, a rigid approach slab is never present, so only one run is necessary.

Run #1 - Rigid approach slab present:

Type 1, 2, or 3 Approach Slab:

Enter "Final LS" and "Final ES" on the LDC command as 0.0.

On the ASL command, enter "Approach Slab DL", "Approach Slab LL", and "Approach Slab DW" considering one half of the load applied to the approach slab (see Section 6.31.1, 6.31.2, and 6.31.5).

Type 4 Approach Slab with Approach Slab Adjacent to Tooth Dam:

Enter "Final LS" and "Final ES" on the LDC command as 0.0.

On the ASL command, enter "Approach Slab DL", "Approach Slab LL", and "Approach Slab DW" considering one half of the load applied to the approach slab (see Section 6.31.1, 6.31.2, and 6.31.5).

Enter "Type 4 Flexible Pavement" as "N". Enter all Type 4 dimensions (parameters 7 - 14).

Type 4 Approach Slab Type 4 with Flexible Pavement Adjacent to Tooth Dam:

There is no rigid approach slab for this condition. Therefore, Run #1 is not needed.

Run #2 - Rigid approach slab is NOT present:

Type 1, 2, or 3 Approach Slab:

Enter "Final LS" and "Final ES" on the LDC command. These loads will be applied over the entire abutment heel.

The ASL command should be omitted entirely.

Type 4 Approach Slab with Approach Slab Adjacent to Tooth Dam:

Enter "Final LS" and "Final ES" on the LDC command. These loads will be applied over the abutment heel beyond the drain trough.

On the ASL command, enter "Approach Slab DL" and "Approach Slab DW" as zero. Enter "Approach Slab LL" as nonzero, but only consider lane live load over the drain trough wall (see Section 6.31.2).

Enter "Type 4 Flexible Pavement" as "N". Enter all Type 4 dimensions (parameters 7 - 14).

Type 4 Approach Slab with Flexible Pavement Adjacent to Tooth Dam:

Enter "Final LS" and "Final ES" on the LDC command. These loads will be applied over the abutment heel beyond the drain trough.

On the ASL command, enter "Approach Slab DL" and "Approach Slab DW" as zero. Enter "Approach Slab LL" as nonzero, but only consider lane live load over the drain trough wall (see Section 6.31.2).

Enter "Type 4 Flexible Pavement" as "Y". Enter all Type 4 dimensions (parameters 7 - 14).

6.31.1 Approach Slab DC

As shown below, the approach slab is considered to be simply supported by the sleeper slab on the highway side and by the end of the beam, backwall or corbel on the bridge side. As per BD-628M Sheet 2, Note 14, one-half of the Approach Slab Dead Load shall be applied to the abutment. This applies to Type 1, 2, or 3 Approach Slabs or Type 4 Approach Slab with Approach Slab Adjacent to Tooth Dam. Live Load Surcharge and Earth Surcharge are ignored for the Final stage when Approach Slab loads are entered.

For Type 4 Approach Slabs with Flexible Pavement Adjacent to Tooth Dam, enter Approach Slab DC as 0.0.

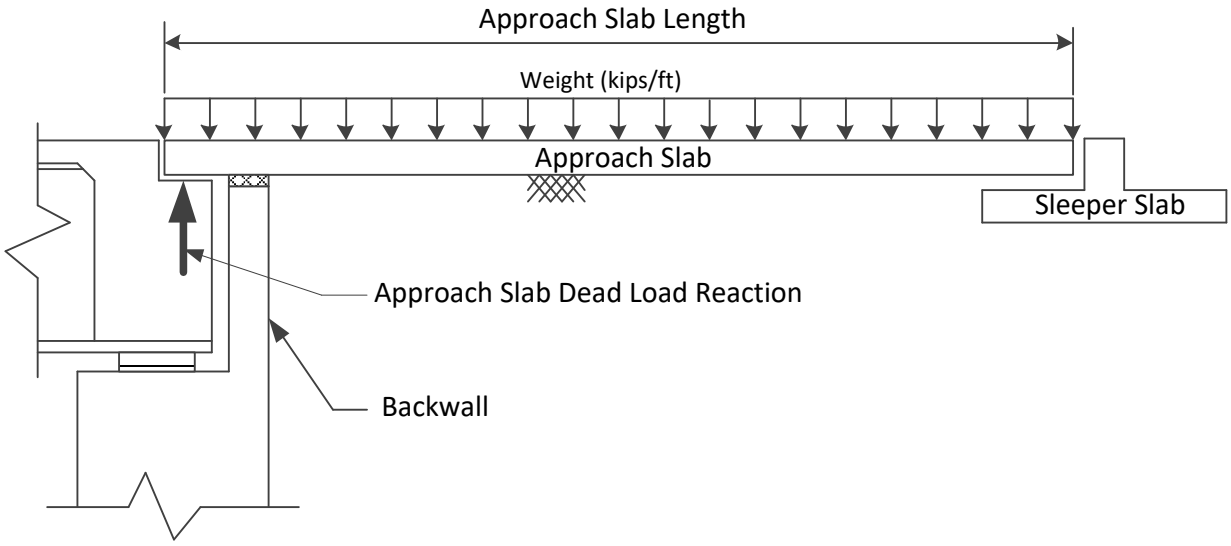


Figure 6.31.1-1 - Approach Slab Dead Load (Types 1, 2, & 3 Approach Slabs and Type 4 Approach Slab with Approach Slab Adjacent to Tooth Dam)

6.31.2 Approach Slab LL

Since the maximum live load beam reaction from live load acting on the superstructure is based on the PHL-93 loading (vehicle plus lane load) being positioned near the abutment support, the live load acting on the approach slab shall consist of the lane load only (0.64 kips/ft). As shown below, the approach slab is considered to be simply supported by the sleeper slab on the highway side and by the end of the beam, backwall or corbel on the bridge side. As per BD-628M Sheet 2, Note 14, one-half of the Approach Slab Live Load shall be applied to the abutment. This applies to Type 1, 2, & 3 Approach Slabs and Type 4 Approach Slab with Approach Slab Adjacent to Tooth Dam. Live Load Surcharge and Earth Surcharge cannot be entered for the Final stage when Approach Slab loads are entered.

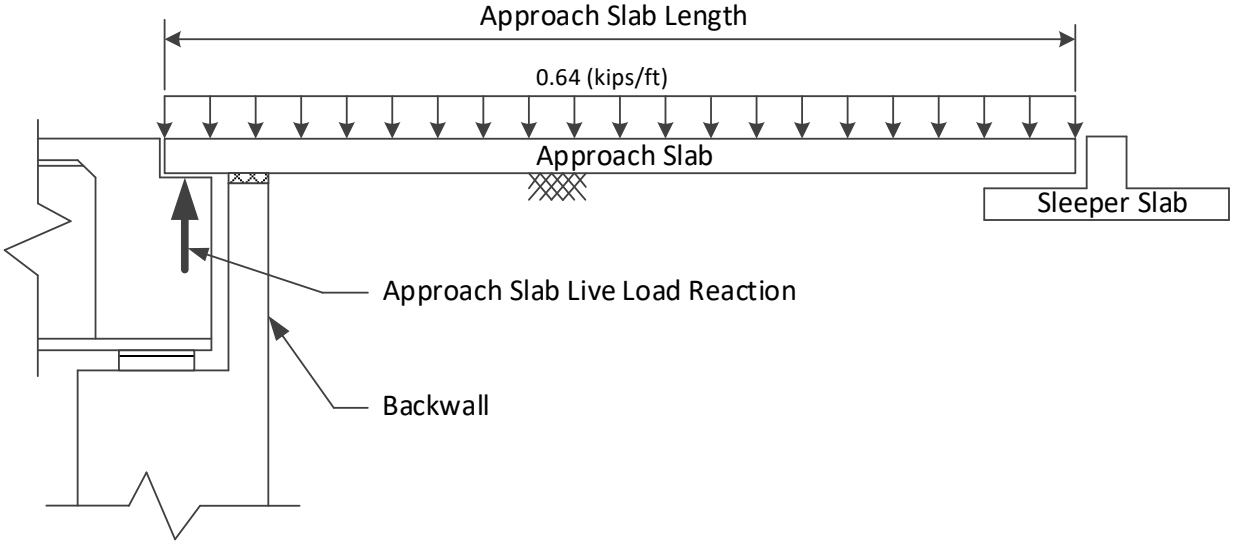


Figure 6.31.2-1 Approach Slab Live Load (Types 1, 2, & 3 Approach Slabs and Type 4 Approach Slab with Approach Slab Adjacent to Tooth Dam)

For an abutment with Type 4 Approach Slab with Flexible Pavement Adjacent to Tooth Dam (refer to Figure 6.31.2-2), an approach slab does not exist and therefore the live load is transmitted as two loads to the abutment as shown below. Since the maximum live load beam reaction acting on the superstructure is based on the PHL-93 loading (vehicle plus lane load) being positioned near the abutment support, the live load acting on the drain trough wall shall consist of the lane load only (0.64 kips/ft). Simultaneously, the live load from the flexible pavement shall be entered as a LL Surcharge on the LDC Command.

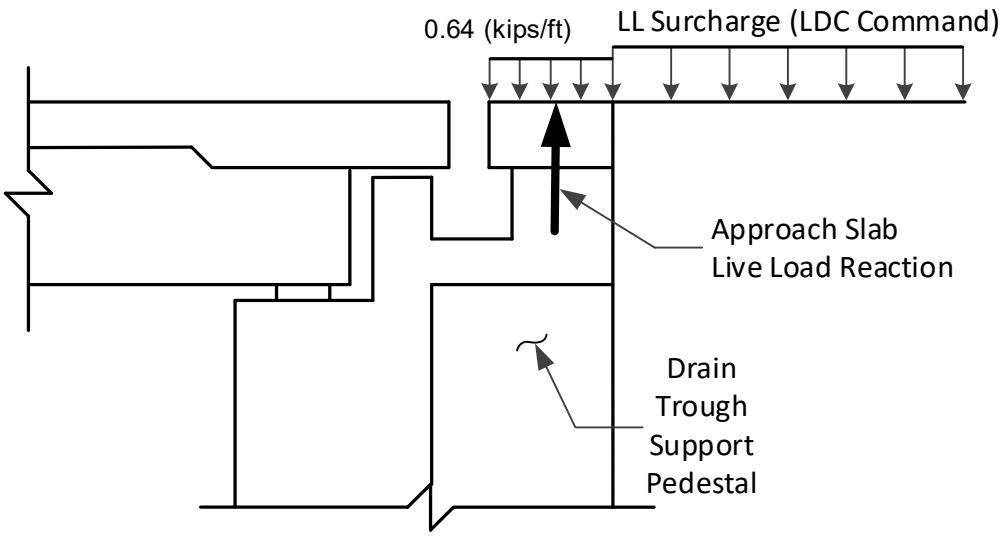


Figure 6.31.2-2 Approach Slab Live Load (Type 4 Approach Slab with Flexible Pavement Adjacent to Tooth Dam)

6.31.5 Approach Slab DW

Similar to the DC load shown in Figure 6.31.1-1, this value should be determined as one half of the DW load applied to the approach slab (calculated by applying a FWS load of 30 psf over the length of the approach slab).

For a Type 4 Approach Slab with Approach Slab Adjacent to Tooth Dam, the program will calculate an additional DW load equivalent to the FWS applied over the drain trough wall thickness, as shown in Figure 6.31.3-1:

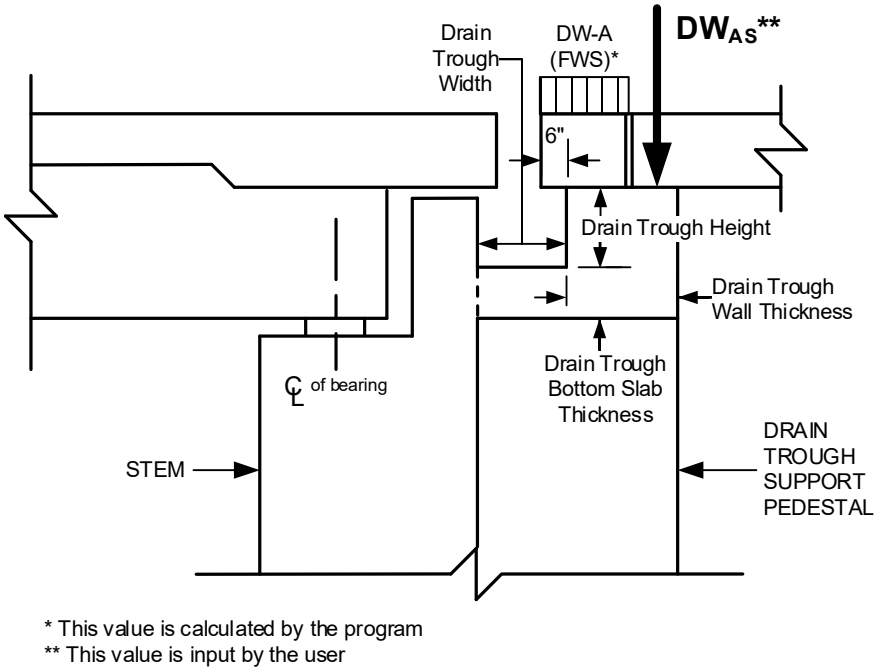


Figure 6.31.3-1 Additional DW Load for Type 4 Approach Slab with Rigid Pavement

For a Type 4 Approach Slab with Flexible Pavement Adjacent to Tooth Dam, the program will calculate a DW load equivalent to the FWS applied over the drain trough wall thickness and the footing heel, as shown in Figure 6.31.3-2. For this case, the Approach Slab DW should be entered as 0.0.

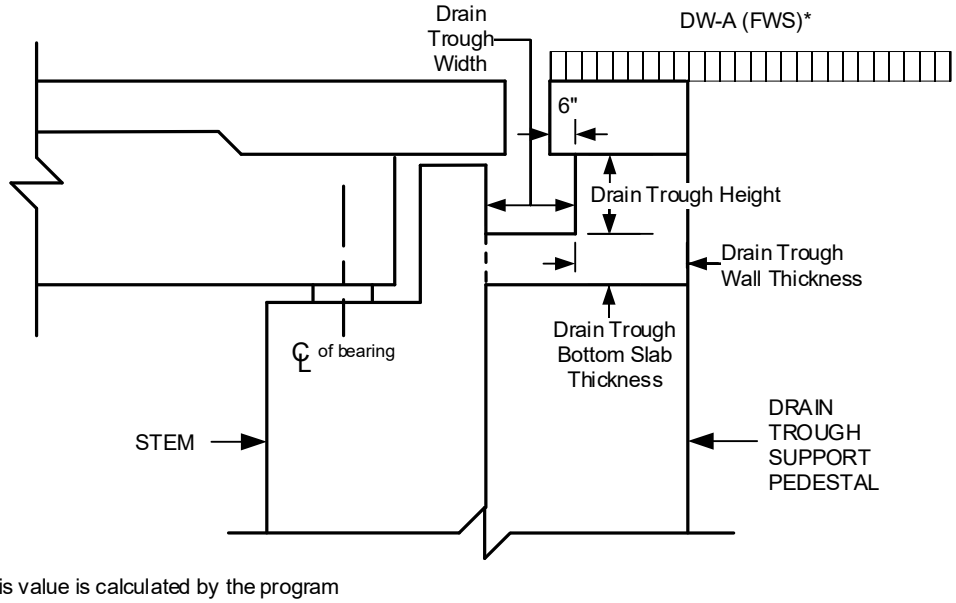


Figure 6.31.3-2 Additional DW Load for Type 4 Approach Slab with Flexible Pavement Adjacent to Tooth Dam

For Type 1, 2, or 3 Approach Slabs, the program will not calculate any additional DW load other than the Approach Slab DW load entered on this command.

6.32 LRT – LOADS ON RETAINING WALL COMMAND

6.32.2 Y Distance to CT

The Y distance to the collision force is applicable to locations above and below the top of the stem. When the Y distance is negative in relation to the top of the stem, the program will ensure that the entered value does not extend below the Exposed stem Height behind the stem as defined on the RWL command. Figure 6.32-1 depicts a retaining wall scenario where the collision force would be applied to the stem and is based on Standard Drawing BD-679.

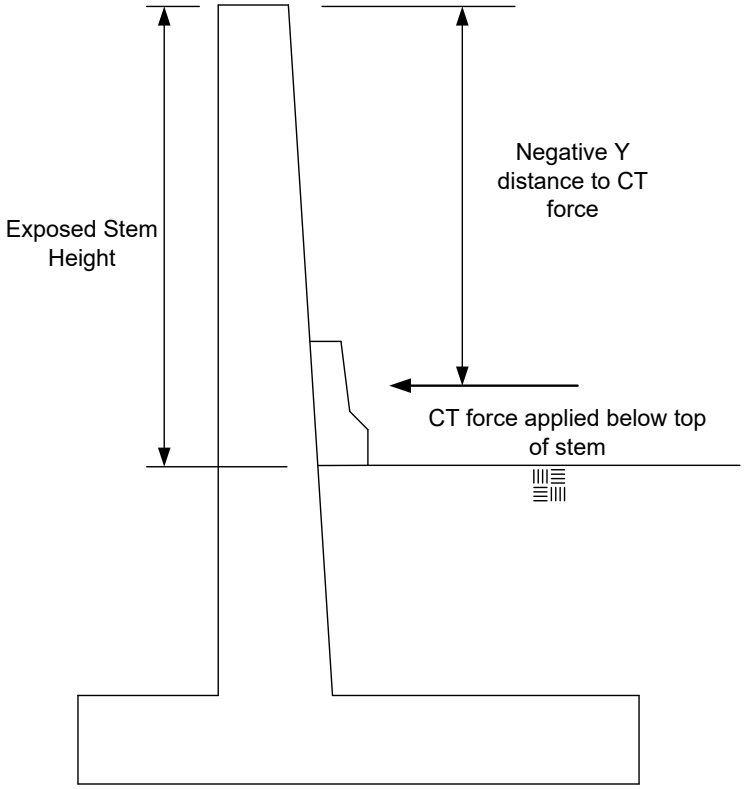


Figure 6.32-1 Y Distance to CT

6.35 EQL - EARTHQUAKE LOADS COMMAND

The earthquake loads applied to the abutment emanate from three sources: the abutment mass-inertia effect; the inertia effect of the soil; and, the forces transmitted from the superstructure.

It is typically acceptable to ignore the mass-inertia effect of the abutment (assuming that it is not important). This effect is ignored in ABLRFD.

6.35.1 Response Modification

Please refer to LRFD Specifications Section 3.10.7 for information concerning the value of the response modification factor.

The modification factor will be applied to the soil (horizontal and vertical) pressure and superstructure force (see Section 6.34.5), i.e., the earthquake loads are divided by the response modification factor.

6.35.2 Soil Pressure Factor

The inertia effect of the soil is also assumed to be unimportant in most cases. If considered, it is common to include this effect as an increased horizontal static pressure from the soil. If it is determined that this effect needs to be included, its magnitude should be determined by a geotechnical engineer.

The soil pressure factor is applied to the horizontal and vertical components of the soil pressure loads. The user has the option of including or neglecting the vertical component (see 6.34.4).

6.35.3 Phi Factor Foundation

This parameter is interpreted as follows:

For Spread and Pedestal Footing Problems: It is the bearing resistance reduction factor for the EXTREME-I limit state only. The acceptable range of values is from 0. to 1.0.

For Pile and Caisson Footing Problems: This factor is applied to the strength (axial and lateral) of the pile/caisson. The axial and lateral capacity of the pile/caisson is specified in the PIL/CAI command. Typical values range from 1.0 to 2.0.

6.35.5 Horizontal Superstructure Force

The superstructure effects should be determined from a seismic analysis of the bridge. Such an analysis is independent of ABLRFD. The superstructure force in the longitudinal direction of the bridge is specified

here. ABLRFD will apply this force as a static horizontal force in the direction “away from the embankment”, at the superstructure elevation location. This value cannot be specified for retaining walls.

6.35.6 Horizontal External Structure Force

The external structure effects should be determined from a seismic analysis of the structure atop the retaining wall. Such an analysis is independent of ABLRFD. The external structure force in the perpendicular direction of the retaining wall is specified here. ABLRFD will apply this force as a static horizontal force in the direction “away from the embankment”, at the top of the stem. This value cannot be specified for abutments.

6.36 OIN - OUTPUT OF INPUT COMMAND

This command is used to specify reports that are variations of the input data. The table below identifies the output tables that are associated with each parameter. The defaults for the type of run (analysis and design) are also shown; 0 indicates that the table is not reported.

Table 6.36-1 Summary of Defaults for OIN Command

PARAMETER	OUTPUT TABLES INCLUDED	DEFAULTS	
		ANALYSIS RUN	DESIGN RUN
Input File Echo	Input File Echo - Applicable to all footing and structure types	0	0
Input Commands	Input Data for each command - Applicable to all footing and structure types	0	0
Input Summary	Input Data Summary- Applicable to all footing and structure types	1	1

6.37 OUR - OUTPUT OF RESULTS COMMAND

This command is used to specify reports of the results. The table below identifies the output tables that are associated with each parameter. The defaults for the type of run (analysis and design) are also shown; 0 indicates that the table is not reported.

Table 6.37-1 Summary of Defaults for OUR Command

PARAMETER	OUTPUT TABLES INCLUDED	DEFAULTS	
		ANALYSIS RUN	DESIGN RUN
Footing Geometry	Pedestal / Pile or Caisson/ Spread: Footing Thickness, Width, Projections Pedestal: Pedestal Thickness, Width, Offsets, Projections	1	1
Output Legend	Abbreviation used in output - Applicable to all footing and structure types	1	1
Factored Forces	Pedestal / Pile or Caisson/ Spread: Backwall forces (if applicable) - axial and moment Stem Forces at Critical Points - axial and moment Footing - shear and moment (internal toe & heel locations) Foundation - vertical and horizontal components of forces and moments (taken about toe). Pedestal Forces - shear and moment (unique to Pedestal Ftg)	1	1
Footing Stability	Pedestal: Bearing; Sliding; Settlement; and, Overturning. Pile or Caisson: Pile Pattern Data; Axial Forces; and, Lateral Forces Spread: Bearing; Sliding; Settlement; and, Overturning.	1	1
Footing Controlling Forces	Pedestal: Parallel (top/bot) Shear and Moments Pile or Caisson: Toe/Heel and Parallel (top/bot) Shear and Moments Spread: Toe/ Heel Shear and Moments	1	1
Footing Flexure	Controlling Load Combination, Applied Moment, Moment Resistance, and Performance Ratio reported at the following footing locations: Pedestal: Parallel (top and bot) Pile or Caisson: Parallel (top / bottom) and Perpendicular (toe / heel) Spread: Perpendicular (toe / heel)	1	1
Reinforcement Summary	Strength (Flexural), Service (Crack Control) and Shear Status reported for the following locations: Backwall - backwall and seat; Stem - quarter points Footing - parallel direction (top and bot) [Pedestal, Piles] - perpendicular direction (toe / heel) [Spread, Piles] Tension check reported for gravity walls	1 1	1 (NA)

Table 6.37-1 Summary of Defaults for OUR command (Cont.)

PARAMETER	OUTPUT TABLES INCLUDED	DEFAULTS	
		ANALYSIS RUN	DESIGN RUN
Crack Control	Area/width, Allowable Stress, Actual Stress, Controlling Loads, and Status codes reported at the following locations: Backwall - backwall and seat; Stem - quarter points Footing - parallel direction (top and bot) [Pedestal, Piles] - perpendicular direction (toe / heel) [Spread, Piles]	ANALYSIS RUN	DESIGN RUN
Shear Results	Controlling Load Combination, Applied Moment, Moment Resistance, and Performance Ratio reported at the following footing locations: Pedestal: Parallel (distance 'd' from pedestal) Pile or Caisson: Parallel (top / bottom) and Perpendicular (toe / heel) Spread: Perpendicular (toe / heel)	1	1
Development Length	Applicable for a Design Run Only. Stem location (for each bar size): Development length Bar cap length Theoretical cutoff location Physical cutoff location Hooked bar development length for footing Bar spacing Extension length Backwall locations (for each bar size) Development length and bar spacing Footing perpendicular direction (for each bar size): Development length and bar spacing	NA	1

6.38 OUI - OUTPUT OF INTERMEDIATE DATA COMMAND

This command is used to specify reports of data that were used to generate the final results (data listed in the tables that were identified in Section 6.36). The table below identifies the output tables that are associated with each parameter. The defaults for the type of run (analysis and design) are also shown; 0 indicates that the table is not reported.

Table 6.38-1 Summary of Defaults for OUI Command

PARAMETER	OUTPUT TABLES INCLUDED	DEFAULTS	
		ANALYSIS RUN	DESIGN RUN
Unfactored Forces	Forces and Moments for each load case (vertical and horizontal components // temporary and final construction stages) evaluated at the: foundation, backwall (if applicable) and stem locations. Pile or Caisson Footings: Vertical and Lateral Pile forces.	0	0
Load Factors	Load Factor and Eta factor reported for each limit state combination for each load case (vertical and horizontal component) applicable.	0	0
Moment / Axial Interaction	Applied Moment and Axial loads, Moment and Axial Resistance and the corresponding performance ratio is reported for each load combination.	1	1
Internal Footing Forces	Internal shear and moment for each load case (temporary and final construction stage) evaluated at the toe and heel locations of the Pile and Spread footings only.	0	0
Intermediate Bearing Resistance Values	Intermediate bearing resistance values for each load case (temporary and final construction stage) for Soil foundation runs only.	0	0
Detailed Stem Cutoff Values	Loads at the cutoff location for each bar for each load case on the Factored Forces Table and the Moment Axial Interaction Table. The cutoff loads will only be displayed if the associated table is select for display in the output	0	0
Minimum Reinforcement Check Values	Minimum reinforcement calculation values for back wall, stem and footing locations.	1	N/A
Intermediate Settlement Data	**Intermediate settlement data for spread and pedestal footing types.**	**0**	**0**

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OUTPUT DESCRIPTION

This chapter describes the reports that are generated by the program. Section 7.1 addresses the general information about the output. The cover page is described in section 7.2. Sections 7.3, 7.4 and 7.5 describe the reports associated with the OIN (Section 5.36), OUR (Section 5.37), and OUI (Section 5.38) commands respectively. Section 7.5.7 contains the formats for all of the tables used by the program. The chapter concludes with some remarks about the error reporting in Sections 7.6.24 and 7.8.

The reports are output in the following order (section identified in parenthesis): Input Summary (7.3); Footing Additional Information (7.4.1); Pile Pattern (7.4.2); Output Legend (7.4.3); Unfactored Loads (7.5.1); Load Factors (7.5.2); Factored Forces (7.4.4); Footing Stability (7.4.5); Internal Footing Forces (7.5.5); Controlling Footing Forces (7.4.6); Moment/Axial Interaction (7.5.4); Footing Flexure (7.4.7); Crack Control (7.4.8); Reinforcement Summary (7.4.9); Shear Results (7.4.10); Reinforcement Design Details (7.4.11); and, Optimum Design Details (7.4.12).

7.1 GENERAL OUTPUT INFORMATION

Information is provided for describing output table controls, page format, page numbering, and page header. In general, the page format is built into the program and cannot be changed by the user for either the .OUT output file or the .PDF output file. The one exception is that the user can specify the number of blank lines to be printed at the top of each page before the page header is printed. This formatting change will be reflected in both the .OUT and .PDF output files accordingly.

7.1.1 Output Table Controls

The output table controls are specified using a number of input commands and parameters to control the output reports to be printed. The commands and their defaults are discussed in Section 6.36 through 6.38.

7.1.2 Page Format

There is a maximum of 102 columns in the output file. Columns 1, 2, 3, and 4 have been left blank to provide a margin on the left side of the page. This has been done to make the output file less dependent on the output device capabilities. The output is therefore limited to 98 characters; column 5 through 102 inclusive. The user can specify the number of lines to be left blank at the top of the page with the CFG command.

7.1.3 Page Numbering

The program assigns page numbers and determines when a new page should begin.

7.1.4 Page Header

The header information is printed for all pages except for the cover page. The header is shown in Figure 7.1.4-1.

The following items are identified in the header:

1. Program Name, Version Number - located at the top left hand corner of the header;
2. Page Number - located on the top right hand corner of the header;
3. Input file - the name and path of the directory of the data file used to create this output is shown on the left side of the second line;
4. Date and Time - the date and time when the program was executed is displayed on the right side of the second line.
5. A separator line is printed between program specific header information and the user specified header information.
6. The next header line contains the first title line input by the user via the TTL command. The title should be a general descriptive line used to describe the problem to be run.
7. The next header line identifies the type of output that is being displayed; and,
8. The final header line is a separator line.

```
*************************************************************************
LRFD Abutment and Retaining Wall, Version x.xx.x.x                PAGE   2
Input File:  EX11.IN                                 mm/dd/yyyy  hh:mm:ss
-------------------------------------------------------------------------
     Example Problem 11 - Analysis of Abutment Type I on Pile Footing
                            ECHO OF INPUT FILE
```

Figure 7.1.4-1 Page Header

7.1.5 Units

For each value presented in the output, the corresponding units are identified. The units are displayed in the column headings directly below the column description. Table 7.1-1 identifies the typical set of units corresponding to the given variable type.

Table 7.1-1 Typical Units

Variable	**US (US Customary)**
AGGREGATE SIZE	in
AREA (REINFORCEMENT**)**	in^2
BAR: DIAMETER, SPACING, GROUP, COVER	in
BEARING CAPACITY	ksf
COMPRESSIVE STRENGTH OF CONCRETE	ksi
CONSOLIDATION STRESSES (INITIAL, PAST EFFECTIVE)	ksi
COSTS (CONCRETE, CUT, FILL, FTG) FOR DESIGN	$\$/yd^3$
ECCENTRICITY (LOAD RESULTANT)	ft
FOOTING DIMENSIONS (TOE/HEEL PROJ, WIDTH)	ft
FORCES (AXIAL, SHEAR, PILE AXIAL, PILE LATERAL)	kip
FRICTION ANGLE	degrees
LOCATION (STEM, BACKWALL, TOE/HEEL)	ft
MODULUS OF ELASTICITY (CONCRETE, ROCK)	ksi
MODULUS OF ELASTICITY (SOIL)	ksf
MOMENTS (INTERNAL, OVERTURNING)	kip-ft
PEDESTAL DIMENSIONS (OTHER THAN THICKNESS)	in
PEDESTAL THICKNESS	ft
PILE CAPACITY (AXIAL, LATERAL)	kip
PILE DIMENSIONS AND EMBEDMENT	in
PILE SPACING (BETWEEN AND WITHIN ROWS)	ft
SETTLEMENT	in
SURCHARGED DEPTH AND SOIL DEPTH OVER TOE	ft
SOIL STRENGTH (COHESIVE, UNDRAINED)	ksf
SOIL UNIT “WEIGHT” (MASS, SATURATED)	pcf
TIME (FOR CONSOLIDATION - SERVICE LIFE)	years
UNIFORM DISTRIBUTED LOAD	k/f

Note: Pile related data applies to Caissons too

7.1.6 Sign Conventions

Table 7.1-2 identifies the sign convention that is used by the program. Notes are also used to identify the sign convention for some reports (see for example Figure 7.9-1; Internal footing forces at the toe).

Table 7.1-2 Sign Conventions

Variable	Sign Convention
MOMENT	Footing Internal: Causes tension on bottom face of footing Overturning: Clockwise (toe on right and heel on the left of stem)
REACTION	Upward reaction is positive
LOAD	Downward, Left (toe on the right and heel on the left of stem)
SHEAR	In the Unfactored Loads Report (see Section 7.5.1), the sign convention for shear is consistent with the sign convention for moment. In Specification Checks (see Section 7.4) the absolute value of shear is used.
DEFLECTION	A downward deflection is positive
FORCE	A force causing tension is positive
STRESS	Compressive

7.2 COVER PAGE

The first page of the output is the cover page. The cover page has three distinct regions. The following information is identified at the top region of the cover page.

1. Program Title - LRFD Abutment and Retaining Wall.
2. Program Name – ABLRFD.
3. Version ii.nn - where ii represents the numeric designation for major revisions and enhancements to the program and nn represents the numeric designation for minor revisions.
5. Date of Last Update - this is the date of the program was last revised.
6. Date of Corresponding Documentation - this is the date the User's Manual was last revised.
7. License Number - this is a unique number assigned to all licensees per the License Agreement.

The second region is reserved for the first four lines of the TTL command specified by the user. This information should be used to describe the bridge, location, stationing, span length and any other relevant information.

The copyright notice and disclaimer are displayed in the third region. This is the standard copyright notice and warranty disclaimer that is printed by all PennDOT programs. Per the license agreement, any duplications, alterations, or unauthorized use of these materials is strictly prohibited.

7.3 INPUT DATA

The input data may be reported in three formats identified as: an echo of the input file; input commands; and, input summary tables. Each variation may be turned off -- please refer to the OIN command described in Section 5.36, and the summary of output tables given in Section 6.36.

7.3.1 Echo of Input Data

The echo of the input file is a listing of the input commands and comments that were specified by the user. The user can refer to this section to trace input errors and warnings by comparing the input data to the appropriate command syntax described in chapter 5.

```
*************************************************************************
*                                                                       *
*  Program Title         LRFD Abutment and Retaining Wall               *
*  Program Name          ABLRFD                                         *
*  Version               x.xx.x.x                                       *
*  Last Updated          mm/dd/yyyy                                     *
*  Documentation         mm/yyyy                                        *
*  License No.           111111                                         *
*                                                                       *
*************************************************************************
*                                                                       *
*  EXAMPLE PROBLEM x - ANALYSIS OF ABUTMENT WITHOUT BACKWALL ON PEDESTALS *
*                                                                       *
*  THIS EXAMPLE CORRESPONDS TO EXAMPLE PROBLEM x IN THE LFD PROGRAM MANUAL*
*                                                                       *
*************************************************************************
*                                                                       *
*                          COPYRIGHT © 1997-20xx                        *
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*                       DEPARTMENT OF TRANSPORTATION                    *
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*                                                                       *
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*     SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES ARISING OUT         *
*     OF ANY DEFECT IN THE SOFTWARE OR ANY ACCOMPANYING DOCUMENTATION.  *
*                                                                       *
*************************************************************************
```

Figure 7.3.1-1 Cover Page

The input file may contain up to 256 characters in a single line. However, the output is limited to 102 characters per line. If the input consists of more than 102 characters, the characters will be wrapped to the next row.

7.3.2 Input Commands

The input commands report includes a detailed description of each input parameter for each command that was specified by the user. The report is formatted as a two column table. The left column of the table identifies the input parameter for the command, and the right column identifies the value of the parameter. A sample of this report is shown in Figure 7.3.3-1.

The following information is identified in the input command report:

1. Command Keyword.
2. Input Parameter description.
3. Value of the input parameter as entered or the default value. The value displayed has the same number of significant digits as specified by the user or as stored in the input parameter file. Default items are identified by the (default) symbol on the right side of the number. An asterisk (*) implies that the input value is optional and that it was not entered.
4. Applicable units.
5. Any warnings or errors encountered with respect to the input data.

Input values may be optional or required. Required input may be specified by the user or defaulted to the value recommended by the program. Default values are identified by the term (default) on the right side of the value. If the user does not specify a required input item and the default value does not exist, an error will occur and the program will identify the fault.

Optional input data does not have to be specified by the user. An asterisk (*) is printed beside the command parameter of such items. Further details are described in chapter five.

Warning and error messages concerning input data will be displayed in the output file even when the parameters in the OIN command are not selected.

7.3.3 Input Summary Tables

The input summary tables identify all of the input parameters in a horizontal tabular format. This report also includes all processed input. Processed input is defined as input data that is computed by the program based on user specified input data. Chapters five and six provide a detailed explanation of the input data. Please refer to them for further information about the input data

```
COMMAND:  MRD
  AGGREGATE SIZE                              1.0 in
  DEVELOPMENT CORRECTION                      1.0            (default)
  BACKWALL EXPOSURE                             2
  STEM     EXPOSURE                             2
  FOOTING  EXPOSURE                             1

COMMAND:  DLL
  DESIGN LL - LIVE LOAD - DOWNWARD            3.5 kip/ft
  DESIGN LL - LIVE LOAD -   UPWARD            0.0 kip/ft
  DESIGN BR - BRAKING FORCE                  0.16 kip/ft
  DESIGN CE - CENTRIFUGAL FORCE               0.0 kip/ft
  PERMIT LL - LIVE LOAD - DOWNWARD            0.0 kip/ft     (default)
  PERMIT LL - LIVE LOAD -   UPWARD            0.0 kip/ft     (default)
  PERMIT BR - BRAKING FORCE                   0.0 kip/ft     (default)
  PERMIT CE - CENTRIFUGAL FORCE               0.0 kip/ft     (default)

COMMAND:  EQL
  RESPONSE MODIFICATION                       2.0
  SOIL PRESSURE FACTOR                        1.0
  PHI FACTOR FOUNDATION                       0.7
  VERTICAL EQ SOIL                              *            (computed, if necessary)
  HORIZ SUPER FORCE                             * kip/ft     (computed, if necessary)
  HORIZ EXTERN STRUCT FORCE                     * kip/ft     (computed, if necessary)
```

Figure 7.3.3-1 Sample Input Command Report - illustrating the MRD, DLL and EQL commands

A portion of the input summary table is shown in Figure 7.3.3-1. The figure illustrates the following points:

1. A description/name of the data item.
2. Input parameter header containing an abbreviated parameter description and corresponding set of units.
3. Input parameter value. The input values are shown to a fixed number of decimal places because of the tabular format. The actual value may be rounded to fit the output format description. Please refer to the input command report (Section 7.3.2) to see the actual value that was input by the user.

7.4 RESULTS

This section describes the reports associated with parameters from the OUR command (see Section 5.37).

7.4.1 Additional Information

The additional information report identifies the dimensions of the footing and the effective depth at the toe and heel locations. Also if the front water elevation is computed, it is displayed in this section. For a pedestal footing, the geometry of the pedestal follows the footing table as shown in Figure 7.4.1-1.

ABUTMENT TYPE I

Height (ft)	Top Width (in)	Seat Width (in)	Seat Slope Height (in)	Seat Face Height (in)	Corbel Width (in)	Corbel Height (in)	Corbel Slope Height (in)
39.33	36.0	37.5	4.5	54.0	4.0	24.0	4.0

Paving Notch Width (in)	Paving Notch Height (in)	Bearing X Locn (in)	Bearing Y Locn (in)	Front Water Level (ft)	Back Water Level (ft)	Architectural Treatment Thickness (in)	Backwall/ Stem Bar Alignment
10.0	16.0	19.5	82.5	none	17.75	0.0	Y

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
4.25	6.50	11.50	none	none	none	none	none

Figure 7.4.1-1 Sample Summary Input Command Description of the AT1 and FTG command

FOOTING GEOMETRY

Footing Thick (ft)	Footing Width (ft)	Projection Toe (ft)	Projection Heel (ft)	Effective Depth Toe (ft)	Effective Depth Heel (ft)	Stem Width Footing Top (ft)
1.50	10.00	1.00	4.62	1.04	1.21	4.38

Moments are assumed to cause tension on the bottom face of the footing at the toe and on the top face of the footing at the heel. Effective depths are based on this assumption.

Note: The acceptable range of toe projections for the given FOOTING GEOMETRY is: 1.00 ft to 3.75 ft.

Note: The acceptable range of toe projections for the given FOOTING GEOMETRY and PEDESTAL GEOMETRY is: 1.00 ft to 1.08 ft.

PEDESTAL GEOMETRY

Back Offset (ft)	Width (ft)	Height (ft)	Front Height (ft)	Front Proj (ft)	Clear Spacing (ft)	Thick (ft)	Slope Horiz Proj (ft)	Density (ft^3/ft)
1.00	13.25	10.00	2.00	1.50	7.50	2.50	2.75	30.38

COMPUTED VALUES

Front Water Level (ft)(1)	Concrete Density Factor (2)	Modulus of Rupture (3) Backwall (ksi)	Modulus of Rupture (3) Stem (ksi)	Modulus of Rupture (3) Footing (ksi)	Modulus of Elasticity Backwall (ksi)	Modulus of Elasticity Stem (ksi)	Modulus of Elasticity Footing (ksi)	Modular Ratio Bckw	Modular Ratio Stem	Modular Ratio Foot
13.95	1.000	0.449	0.416	0.416	3400.	3100.	3100.	8.	9.	9.

Notes: (1) The computed value complies with DM-4 Section 3.11.3.
(2) The concrete density modification factor is defined according to AASHTO LRFD Specifications Section 5.4.2.8.
(3) Modulus of Rupture defined according to AASHTO LRFD Specifications Section 5.4.2.6.

Figure 7.4.1-2 Footing and Pedestal Geometry

The following information is reported for all footing types:

1. Footing Thick - footing thickness; final design value (design run) or user input (analysis run).
2. Footing Width - width of footing; final design value (design run) or user input (analysis run).
3. Projection - toe and heel projections based on given footing width.
4. Effective Depth - effective depths at toe and heel locations based on given footing thickness and note in Figure 7.4.1-1.

The following information is reported for a design:

1. The acceptable range of toe projections for which a design will work for the **given footing geometry**.

The following additional information is reported for a non-spread footing design optimized for volume:

1. **The acceptable range of toe projections for which a design will work for the given footing geometry and either pile pattern, caisson pattern, or pedestal geometry.**

The following information is reported for a design with no front water level entered:

1. Calculated Front Water Level - distance from top of stem to front water elevation computed based on the back water elevation and the minimum allowable water differential as stated in DM-4 Section 3.11.3.

The following information is only reported for pedestal footings (see Figure 5.14-2):

1. Back offset - offset from back of the footing to the heel of the footing.
2. Width - base width of the pedestal.
3. Height - height of pedestal.
4. Front Height - pedestal front height.
5. Front Proj - front projection of pedestal.
6. Clear Spacing - clear spacing between pedestals in the perpendicular direction.
7. Thick - thickness of the pedestal.
8. Slope Horiz Proj - horizontal projection of the front slope of pedestal.
9. Density - pedestal density i.e. volume of pedestal / pedestal spacing.

7.4.2 Pile Pattern

A sample of the pattern data is shown in Figure 7.4.2-1. The pile pattern data identifies: the distance to the c.g. of the pile pattern relative to the toe, the moment of inertia of the pile group, the pile density, and the pile pattern (for design runs only). This is followed by a description of the piles in each row. The information consists of: the distance from the toe to the given row; the pile spacing within the row; the horizontal and

vertical batter; and the percentage of piles that are battered. Vertical piles do not have a horizontal or vertical batter component.

The ADDITIONAL INFORMATION report for a pile footing (pile pattern table, Figure 7.4.2-1) contains the following data:

PILE PATTERN

1. Toe to CG of Piles - distance from the toe to the center of gravity of the pile group.
2. Pile Group Inertia - moment of inertia of the pile group per unit width of structure about center of gravity of the pile group.
3. Pile Density - density of the pile group (number of piles per unit width of structure).
4. Pile Pattern - pile pattern definition used (design runs only)
5. Row - row number (numbering starts at toe side).
6. Distance Toe to Row - distance from the toe to the given row of piles.
7. Pile Spacing within row - distance between piles for the given row.
8. Batter Component Horiz - horizontal component of battered piles in the given row.
9. Batter Component Vert - vertical component of battered piles in the given row.
10. Percent Battered - percentage of piles that were battered in the given row.

PILE PATTERN

Toe to CG of Piles (ft)	Pile Group Inertia (ft^4)	Pile Density (pile/ft)	Pile Pattern
2.52	0.834	0.267	3-1

Row	Distance Toe to Row (ft)	Pile Spacing within Row (ft)	Batter Component Horiz	Batter Component Vert	Percent Battered (%)
1	1.50	5.00	3.00	12.00	100.0
2	5.58	15.00	Vertical Piles		

Figure 7.4.2-1 Pile Pattern Component of the Stability Report

7.4.3 Output Legend

This report identifies the description of each abbreviation and status code that is used in the remainder of the output. A sample is shown in Figure 7.4.4-1

7.4.4 Factored Forces

This report identifies the loads that were generated for each load combination. A load combination consists of three parts, namely: the limit state, the load case (maximum, minimum, max Vert Min Horz, or Min Vert

Min Horz) and the stage (temporary or final). The abbreviations for each part can be found in the Legend (see Figure 7.4.4-1).

The loads are reported for the following components (where applicable): foundation, pedestal, backwall, stem, and footing. There are variations in the tabular format for each component.

The foundations report identifies the distance from the toe to the resultant of the loads. The definition of the resultant was presented in Section 3.4. The force and moment values are reported in terms of the vertical and horizontal directions. The moment is defined about the toe at the bottom of the footing. For pile and caisson footings, the Service Limit State V/H Ratio check is added to this table. Figure 7.4.4-1 illustrates part of this report.

```
Abbrev    Load Case       Description
Max       Maximum       - Maximum downward vertical force, maximum moment, maximum
                          shear, reversible horizontal loads towards superstructure
Min       Minimum       - Minimum downward vertical force, maximum moment, maximum
                          shear, reversible horizontal loads towards superstructure
MxVMnH    MxVMnH        - Maximum downward vertical force, reversible horizontal
                          loads toward abutment
MnVMnH    MnVMnH        - Minimum downward vertical force, reversible horizontal
                          loads toward abutment

Abbrev    Stage           Description
Tmp       Temporary     - Temporary Construction Condition
Fin       Final         - Final Construction Condition

Abbrev    Loads           Description
DC-A      DC            - Dead Load of Concrete, Parapet
DC-S      DC            - Dead Load of Superstructure
DW-A      DW            - FWS on Abutment
DW-S      DW            - Wearing Surface / Utilities
EV        EV            - Dead Load of Earth
...
          Status Code     Description
          OK            - Check was satisfied
          NG            - Check failed
          NC            - Not checked
          NA            - Not applicable
```

Figure 7.4.4-1 Output Legend

The following information is reported for the foundation in the FACTORED FORCES report (for all footing types):

FOUNDATION FORCES AT FOOTING TOE (Spread and Pedestal Foundation Types)

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Toe to Result - distance from the toe to the resultant of the applied force (see Figure 3.4.1.2.3-1).
3. Vertical Force - resultant of all forces applied in the vertical direction.
4. Vertical Moment - resultant of all moments produced by vertical forces about the toe of the footing.
5. Horizontal Force - resultant of all forces applied in the horizontal direction.
6. Horizontal Moment - resultant of all moments produced by horizontal forces about the toe of the footing.

FOUNDATION FORCES AT FOOTING TOE (Pile and Caisson Foundation Types)

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Toe to Result - distance from the toe to the resultant of the applied force (see Figure 3.4.1.2.3-1).
3. Vertical Force - resultant of all forces applied in the vertical direction.
4. Vertical Moment - resultant of all moments produced by vertical forces about the toe of the footing.
5. Horizontal Force - resultant of all forces applied in the horizontal direction.
6. Horizontal Moment - resultant of all moments produced by horizontal forces about the toe of the footing.
7. V/H Ratio – Ratio of Vertical to Horizontal Factored forces for the Service limit states.

The factored forces for the pedestal are shown in Figure 7.4.4-3. The format is comparable to the foundation report. A note at the end of the table defines the orientation of a positive moment. The distance to the resultant is defined from the front of the pedestal base.

FOUNDATION FORCES AT FOOTING TOE - VERTICAL

Limit State	Load Case	Stage	Toe to Result (ft)	Force (kip)	Moment (kip-ft)	V/H Ratio
STR-I	Max	Tmp	4.44	24.61	-153.35	
STR-I	Min	Tmp	4.06	18.69	-119.88	
STR-I	Max	Fin	4.09	26.60	-170.12	
STR-I	Min	Fin	3.57	20.33	-134.00	
STR-I	MxVMnH	Fin	4.09	26.60	-170.12	
STR-I	MnVMnH	Fin	3.57	20.33	-134.00	
STR-III	Max	Tmp	4.78	22.12	-135.84	
STR-III	Min	Tmp	4.45	16.20	-102.37	
STR-III	Max	Fin	4.52	24.11	-152.61	
STR-III	Min	Fin	4.08	17.85	-116.49	
STR-III	MxVMnH	Fin	4.52	24.11	-152.61	
STR-III	MnVMnH	Fin	4.08	17.85	-116.49	
...						
SER-I	Max	Tmp	4.52	17.78	-108.75	3.27
SER-I	Min	Tmp	4.52	17.78	-108.75	3.27
SER-I	Max	Fin	4.22	19.21	-120.69	2.87
SER-I	Min	Fin	4.22	19.21	-120.69	2.87
SER-I	MxVMnH	Fin	4.22	19.21	-120.69	2.87
SER-I	MnVMnH	Fin	4.22	19.21	-120.69	2.87

Note: Moments are taken about the bottom of the footing at the toe.
Positive moment clockwise; negative moment counterclockwise;
toe on right; heel on left.

Figure 7.4.4-2 Factored Forces at the Foundation.

FOUNDATION FORCES AT BOTTOM OF PEDESTAL

Limit State	Load Case	Stage	Front to Result (ft)	Vertical Force (kip)	Vertical Moment (kip-ft)	Horizontal Force (kip)	Horizontal Moment (kip-ft)
STR-I	Max	Tmp	4.65	149.53	-1117.92	34.58	422.30
STR-I	Min	Tmp	3.94	115.32	-877.18	34.58	422.30
STR-I	Max	Fin	4.81	296.80	-2075.65	48.30	646.73
STR-I	Min	Fin	3.60	173.17	-1269.30	48.30	646.73
STR-I	MxVMnH	Fin	5.42	296.80	-2075.65	38.29	465.88
STR-I	MnVMnH	Fin	4.64	173.17	-1269.30	38.29	465.88
...							
SER-I	Max	Tmp	4.99	112.52	-829.16	21.98	267.19
SER-I	Min	Tmp	4.99	112.52	-829.16	21.98	267.19
SER-I	Max	Fin	4.56	216.78	-1512.96	37.42	525.51
SER-I	Min	Fin	4.22	179.84	-1285.07	37.42	525.51
SER-I	MxVMnH	Fin	5.98	216.78	-1512.96	20.31	216.23
SER-I	MnVMnH	Fin	5.94	179.84	-1285.07	20.31	216.23

Notes:

Vertical Force and Moment values include the factored pedestal self weight.

All forces and moments include the footing forces and moments (see Foundation Forces at Footing Toe) multiplied by the pedestal center-to-center spacing.

Figure 7.4.4-3 Factored Forces at the Pedestal Base

The following information is reported for the pedestal in the FACTORED FORCES report:

FOUNDATION FORCES AT BOTTOM OF PEDESTAL

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Front to Result - distance from the front of the pedestal to the resultant of the applied loads (see x_{resp} Figure 3.4.2.1-1).
3. Vertical Force - resultant of all forces applied in the vertical direction.
4. Vertical Moment - resultant of all moments about the front of the pedestal, produced by vertical forces.
5. Horizontal Force - resultant of all forces applied in the horizontal direction.
6. Horizontal Moment - resultant of all moments about the front of the pedestal, produced by horizontal forces.
7. Notes concerning forces and moments.

The factored forces in the stem are reported at the quarter-point locations. The axial force, moment and shear force is reported for all applicable load combinations. A sample of this report is shown in Figure 7.4.4-4.

For a design run in which bars can be cutoff, the factored forces are reported at the theoretical cutoff location of the largest bar that can be cutoff. These results are provided so that the user can corroborate the moment

axial load check (see Section 7.5.3) at the cutoff location. The moment axial load check provides the engineer with information about the margin of safety (i.e. performance factor) for the strength limit states at the cutoff location.

STEM LOCATION A 3.25 (ft) FROM TOP OF STRUCTURE

Limit State	Load Case	Stage	Axial (kip)	Moment (kip-ft)	Shear (kip)
STR-I	Max	Tmp	1.26	0.38	0.41
STR-I	Min	Tmp	0.93	0.37	0.41
STR-I	Max	Fin	1.33	0.45	0.46
STR-I	Min	Fin	0.98	0.43	0.46
STR-III	Max	Tmp	1.18	0.14	0.13
STR-III	Min	Tmp	0.85	0.13	0.13
STR-III	Max	Fin	1.25	0.18	0.15
STR-III	Min	Fin	0.90	0.16	0.15

Figure 7.4.4-4 Factored Loads in the Stem

The following information is reported for backwall and stem locations in the FACTORED FORCES report:

ABUTMENT BACKWALL (if applicable) xxx.xx ( ) FROM TOP OF STRUCTURE
ABUTMENT BACKWALL SEAT LEVEL (if applicable) xxx.xx ( ) FROM TOP OF STRUCTURE
STEM LOCATION a xxx.xx ( ) FROM TOP OF STRUCTURE
(Shown for all bar cutoff locations when selected on the OUI command)

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Axial - axial load applied to the section at the given stem location.
3. Moment - applied moment acting on the section at the given stem location.
4. Shear - shear forces applied to the section at the given stem location.

The factored forces in the footing are reported at the toe and heel critical locations. The critical location for flexure is at the face (front and back) of the wall. The shear force critical location is situated at a distance “d” from the face of the stem wall for the toe section, and at the face of the stem wall for the heel section.

Further details about the footing critical location can be found in Section 2.9.1. A sample of the footing factored forces report is shown in Figure 7.4.4-5.

FOOTING – W/O FOUNDATION PRESSURE

Limit State	Load Case	Stage	Toe Shear Eff D (kip)	Toe Shear at Face (kip)	Toe Moment (kip-ft)	Heel Shear Eff D (kip)	Heel Shear at Face (kip)	Heel Moment (kip-ft)
STR-I	Max	Tmp	0.00	0.97	1.11	7.12	14.52	38.43
STR-I	Min	Tmp	0.00	0.62	0.71	5.64	11.22	30.31
STR-I	Max	Fin	0.00	0.97	1.11	8.04	15.95	42.98
STR-I	Min	Fin	0.00	0.62	0.71	6.37	12.33	33.95
STR-III	Max	Tmp	0.00	0.97	1.11	6.19	12.45	33.35
STR-III	Min	Tmp	0.00	0.62	0.71	4.71	9.15	25.23
STR-III	Max	Fin	0.00	0.97	1.11	7.11	13.89	37.90
STR-III	Min	Fin	0.00	0.62	0.71	5.44	10.27	28.86

Figure 7.4.4-5 Factored Forces in the Footing

The following information is reported for all footing types in the FACTORED FORCES report:

FOOTING – W/O FOUNDATION PRESSURE

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Toe Shear Eff D - shear in the footing at a distance “d” (effective depth) from the stem towards the toe.
3. Toe Shear at Face - shear in the footing at the face of the stem (toe side).
4. Toe Moment - applied moment at the toe section (at face of stem).
5. Heel Shear Eff D - shear in the footing at a distance “d” (effective depth) from the stem towards the heel.
6. Heel Shear at Face - shear in the footing at the face of the stem (heel side).
7. Heel Moment - applied moment at the heel section (at face of stem).

7.4.5 Footing Stability

The stability reports are unique to each type of footing. The pile, spread and pedestal footing variations are described in sub-sections 1, 2 and 3 respectively.

7.4.5.1 Pile Footing

This pile footing report is composed of two parts, namely: pile axial loads, and pile lateral loads.

The first part of the pile stability report is shown in Figure 7.4.5-1. It describes how the factored axial loads are distributed to each row of piles. The program can accommodate up to five rows of piles. The axial load is identified for every applicable load combination (limit state / load type / stage). The axial resistance and the performance ratio are also shown. Each row of piles is identified as being battered or vertical (see previous component).

Typically, the compressive strength of a pile is reported. If a pile is in tension, and it was the governing case, the tensile capacity will be reported. Note: The EXTREME-I limit state (earthquake load) may have a non-zero tensile resistance. Tensile values are reported as negative numbers.

PILE FACTORED AXIAL LOADS / PILE FACTORED AXIAL RESISTANCE

Limit State	Load Case	Stage	Factored Axial Loads Row 1 Batter (kip)	Row 2 Vert (kip)	Factored Axial Resist (kip)	Perform Ratio
STR-I	Max	Tmp	88.16	103.51	280.80	2.713
STR-I	Min	Tmp	73.30	68.37	280.80	3.831
STR-I	Max	Fin	103.65	98.37	280.80	2.709
STR-I	Min	Fin	88.51	60.20	280.80	3.172
STR-I	MxVMnH	Fin	103.65	98.37	280.80	2.709
STR-I	MnVMnH	Fin	88.51	60.20	280.80	3.172
STR-III	Max	Tmp	72.79	103.50	280.80	2.713
STR-III	Min	Tmp	57.92	68.37	280.80	4.107

Performance Ratio = Pile Factored Axial Resistance / Maximum Factored Pile Axial Load

Figure 7.4.5-1 Pile Axial Loads and Resistance in Footing Stability Report

The FOOTING STABILITY report for a pile footing (pile axial loads / resistance, Figure 7.4.5-2) contains the following data:

PILE FACTORED AXIAL LOADS / PILE FACTORED AXIAL RESISTANCE

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Factored Axial force data, where each column (representing a pile row) in the table identifies:
   - Pile row number.
   - Orientation of piles: battered or vert (vertical).
   - Factored Axial force in each pile of the given pile row for the given load combination.
3. Factored Axial Resist – factored axial resistance of each pile.
4. Perform Ratio - ratio of axial resistance to largest pile force for the given load combination.

The second part of the pile stability report is shown in Figure 7.4.5-2. It consists of a comparison between the applied factored lateral loads and the lateral resistance of the pile group. The lateral loads are reported for every applicable load combination (limit state / load type / stage). The performance ratio of the lateral capacity is also displayed.

FACTORED LATERAL LOADS / PILE GROUP FACTORED LATERAL RESISTANCE

Resistance based on battered piles only

Limit State	Load Case	Stage	Factored Lateral Load (kips/ft)	Factored Lateral Resist (kips/ft)	Performance Ratio
STR-I	Max	Tmp	8.12	11.35	1.398
STR-I	Min	Tmp	8.12	11.35	1.398
STR-I	Max	Fin	10.04	11.35	1.130
STR-I	Min	Fin	10.04	11.35	1.130
STR-I	MxVMnH	Fin	10.04	11.35	1.130
STR-I	MnVMnH	Fin	10.04	11.35	1.130
		...			
SER-I	Max	Tmp	5.44	N/A	N/A
SER-I	Min	Tmp	5.44	N/A	N/A
SER-I	Max	Fin	6.70	N/A	N/A
SER-I	Min	Fin	6.70	N/A	N/A
SER-I	MxVMnH	Fin	6.70	N/A	N/A
SER-I	MnVMnH	Fin	6.70	N/A	N/A

Performance Ratio = Pile Group Factored Lateral Resistance / Factored Lateral Load

Warning: A performance ratio less than 1 was found

Figure 7.4.5-2 Pile Lateral Resistance in Footing Stability Report

The FOOTING STABILITY report for a pile footing (lateral loads / resistance) contains the following data:

FACTORED LATERAL LOADS / PILE GROUP FACTORED LATERAL RESISTANCE

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Factored Lateral Load - total applied factored lateral load per unit length of structure.
3. Factored Lateral Resist – factored lateral resistance of pile group per unit length of structure.
4. Performance Ratio - ratio of lateral resistance to applied lateral load.

Unit Length is defined in Figure 7.4.5-3:

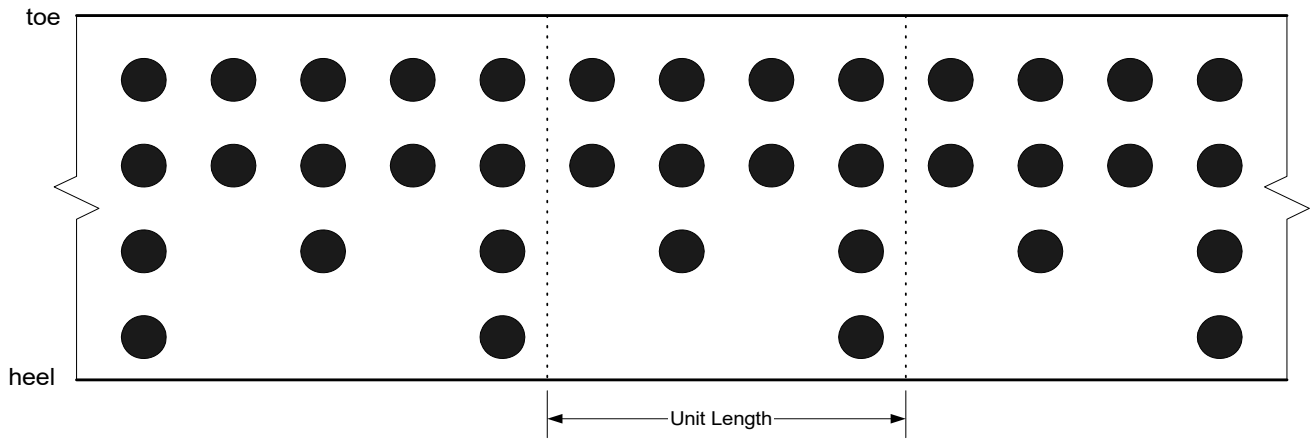

Diagram showing Unit Length

Figure 7.4.5-3 Unit Length Diagram

7.4.5.2 Spread Footing

The footing stability report for the spread footing consists of the overturning and bearing, the sliding, and the settlement checks.

The overturning and bearing check are reported in one table, as shown in Figure 7.4.5-4. If the location of the load resultant lies outside the kern, the eccentricity value is flagged with an asterisk (*) and the eccentricity performance ratio will be less than 1.0. A footnote will be printed explaining that the eccentricity check has failed (i.e., the resultant is outside the kern).

The bearing pressure at the toe and the heel are identified. The applied pressure depends on the characteristics of the foundation (soil, hard rock). For soil foundations, the Uniform Bearing pressure is reported as the actual bearing pressure. Otherwise, the maximum bearing pressure is reported as the actual bearing pressure.

The FOOTING STABILITY report for a spread footing (bearing, Figure 7.4.5-4) contains the following data:

SPREAD FOOTING - BEARING RESISTANCE

Limit State	Load Case	Stage	Ecc (ft)	Allow Ecc (ft)	Ecc Perform Ratio	Factored Footing Pressure Toe (ksf)	Factored Footing Pressure Heel (ksf)	Uniform Factored Bearing Pressure (ksf)	Factored Bearing Resist (ksf)	Perform Ratio
STR-I	Max	Tmp	0.68	2.67	3.94	1.73	0.57	1.38	16.35	11.816
STR-I	Min	Tmp	1.50	2.67	1.78	1.77	0.00	1.33	12.91	9.724
STR-I	Max	Fin	0.19	2.67	14.14	3.31	2.49	3.05	17.11	5.616
STR-I	Min	Fin	1.54	2.67	1.73	3.33	0.00	2.50	12.09	4.836
STR-I	MxVMnH	Fin	-0.45	2.67	5.87	1.91	3.89	3.28	18.80	5.739
STR-I	MnVMnH	Fin	0.32	2.67	8.22	1.91	1.16	1.67	18.50	11.052
STR-III	Max	Tmp	-0.01	2.67	284.60	1.04	1.05	1.05	19.19	18.320
STR-III	Min	Tmp	0.63	2.67	4.25	1.07	0.38	0.86	17.80	20.662
...										
SER-I	Max	Fin		NA*		2.91	1.10		NA*	
SER-I	Min	Fin		NA*		2.88	0.26		NA*	
SER-I	MxVMnH	Fin		NA*		0.53	3.47		NA*	
SER-I	MnVMnH	Fin		NA*		0.51	2.64		NA*	

Performance Ratio = Factored Bearing Resistance / Maximum Factored Bearing Pressure
Eccentricity Performance Ratio = Allowable Eccentricity / Eccentricity

The eccentricity is the distance from the center of the footing to
the load resultant. Positive towards toe; negative towards heel.
The allowable eccentricity is the distance from the center of the
Footing to the edge of the kern.

NA* Indicates Eccentricity and Bearing Resistance checks Not Applicable for Service I

Figure 7.4.5-4 Bearing Capacity Report for Footing Stability

SPREAD FOOTING - BEARING RESISTANCE

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Ecc - eccentricity of resultant of the applied loads measured from the center of the footing, positive toward toe, negative toward heel (See Figure 3.4.1-1).
3. Allow Ecc – allowable eccentricity measured from the center of the footing to the edge of the kern (See Figure 3.4.1-1).
4. Ecc Perform Ratio - performance ratio for the given load combination defined as allowable eccentricity over actual eccentricity.
5. Factored Footing Pressure Toe - pressure underneath the footing under the toe (see Figure 3.4.1-2).
6. Factored Footing Pressure Heel - pressure underneath the footing under the heel (see Figure 3.4.1-2).
7. Uniform Factored Bearing Pressure - applies to soil foundations as the actual factored bearing pressure for the given load combination.
8. Factored Bearing Resistance – factored bearing resistance of soil or rock for the given load combination.
9. Perform Ratio - performance ratio for the given load combination defined as bearing resistance over actual bearing pressure.

The sliding check for the spread footing stability report shows the comparison of the horizontal force to the sliding resistance for each applicable load combination as shown in Figure 7.4.5-5. The sliding resistance includes the strength reduction factor specified by the user (as the note indicates). The performance ratio is computed for each case. If the performance ratio is less than 1, a warning message will be issued.

The FOOTING STABILITY report for a spread footing (sliding, Figure 7.4.5-5) contains the following data:

SPREAD FOOTING – SLIDING

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Factored Horizontal Force - applied factored horizontal force per unit width of structure.
3. Factored Sliding Resistance – factored lateral load resistance per unit width of structure.
4. Perform Ratio - performance ratio for the given load combination (defined by note).

SPREAD FOOTING - SLIDING

Limit State	Load Case	Stage	Factored Horizontal Force (kip)	Factored Sliding Resistance (kip)	Performance Ratio
STR-I	Min	Tmp	3.27	9.65	2.951
STR-I	Min	Fin	8.21	15.65	1.905
STR-III	Min	Tmp	2.22	8.93	4.029
STR-III	Min	Fin	6.68	15.53	2.326
STR-V	Min	Tmp	3.12	9.55	3.062
STR-V	Min	Fin	8.10	15.51	1.913
EXT-I	Min	Fin	5.61	15.61	2.785

Note: Only the Min Load Cases are checked for sliding.
Sliding resistance is based on a phi factor of 0.85

Performance Ratio = Factored Sliding Resistance / Factored Horizontal Force

Figure 7.4.5-5 Sliding Resistance

The settlement table of the spread footing stability report is shown in Figure 7.4.5-6. There are several variations of this table. If the foundation is a rock, the consolidation and secondary settlements are not applicable (see the pedestal settlement 7.4.5.3). If the consolidation and secondary settlement values are negative, a second line is displayed. The new line replaces the negative components of settlement with a zero. The table shows the governing load combination, i.e., the case that generated the largest total settlement.

The notes include references to the effective width of footing so that the uniform bearing pressures can be determined. The bearing pressure is computed by dividing the vertical force by the effective width.

SETTLEMENT

Primary and Secondary Consolidation Values

Layer No. 1

Sub Layer Depth (ft)	Z (ft)	Sigma O (psf)	Sigma P (psf)	Sigma F (psf)	Settlement Consol (in)	Settlement Second (in)	Condition
4.59	2.297	967.	1608.	1863.	1.23	0.77	OC f>p
4.59	6.890	1232.	1482.	1747.	0.84	0.77	OC f>p
4.59	11.483	1496.	1357.	1830.	1.05	0.77	UC
4.59	16.076	1761.	1232.	2002.	1.71	0.77	UC
4.59	20.669	**2025**	**1107**	**2212**	**2.44**	**0.77**	**UC**

Legend : Condition Codes
OC f>p : Over-Consolidation - Sigma F > than Sigma P
OC f<=p : Over-Consolidation - Sigma P >= Sigma F
NC : Normal-Consolidation
UC : Under-Consolidation

Note: Primary Consolidation Reduction Factor is not included in the Consolidation values shown above.

SETTLEMENT SUMMARY

Elastic (in)	Layer 1 Height (ft)	Layer 2 Height (ft)	Settlement Consol (in)	Settlement Second (in)	Settlement Total (in)	Allow (in)	Perform Ratio	Temp Stage Settlement (in)
0.25	22.97	NA	--	3.85	--	50.00	--	0.25

Notes:

Elastic settlement is based on:
effective width of 6.44 (ft) from SER-I Max Fin

Consolidation and Secondary settlement are based on:
effective width of 6.44 (ft) from CSS Max Fin

Temporary Stage settlement is based on:
effective width of 6.55 (ft) from SER-I Max Tmp

Uniform pressures (Vertical Force/Effective Width)
are used for settlement calculations.

Performance Ratio = Allowable Settlement / Total Settlement

Figure 7.4.5-6 Settlement - Spread Footing Stability Report

The FOOTING STABILITY report for a spread footing (settlement, Figure 7.4.5-6) contains the following data:

SETTLEMENT

1. Sub-layer Depth - depth of sub-layer.
2. Z - depth to sub-layer from top of soil layer.
3. Sigma O - Initial Effective Stress at the center of the sub-layer.
4. Sigma P - Maximum Past Effective Stress at the center of the sub-layer.
5. Sigma F - Final Effective Stress at the center of the sub-layer.
6. Settlement Consol - consolidation settlement for sub-layer.
7. Settlement Second - secondary settlement for sub-layer.
8. Condition - Indicates which consolidation condition is present in the sub-layer.

SETTLEMENT SUMMARY

1. Elastic - elastic settlement.
2. Settlement Consol - consolidation settlement (applies to soil foundations only).
3. Settlement Second - secondary consolidation settlement (applies to soil foundations only).
4. Settlement Total - sum of elastic, consolidation and secondary settlement.
5. Settlement Allow - allowable settlement.
6. Perform Ratio - settlement performance ratio (allowable/total).
7. Temp Stage Settlement - settlement due to temporary (construction) stage loads.
8. Width and load combination used to compute elastic, consolidation and secondary settlement.

7.4.5.3 Pedestal Footing

This report is a variation of the report that is used for the spread footing.

There are two overturning and bearing tables. The first overturning and bearing table is based on the footing bearing on the pedestal. The pedestal concrete is considered as a hard rock, hence the maximum uniform pressure is used in the computation of the performance ratio as shown in Figure 7.4.5-7.

```
                                FOOTING BEARING RESULTS

    Maximum Factored Actual Pressure    :    6.16    (ksf)   from:  STR-I   Max     Fin
    Pedestal Factored Bearing Resistance:  257.04    (ksf)
    Performance Ratio                   :   41.74

                                                                          Maximum
                                              Ecc        Factored        Factored  Factored
  Limit   Load                      Allow    Perform  Footing Pressure    Bearing   Bearing  Perform
  State   Case    Stage    Ecc      Ecc      Ratio      Toe      Heel      Pressure    Resist   Ratio
                         (ft)      (ft)               (ksf)    (ksf)       (ksf)     (ksf)
  STR-I   Max     Tmp    -0.33     2.00     6.13      1.34     2.64        2.64     257.04   97.471
  STR-I   Min     Tmp    -0.14     2.00    14.68      1.35     1.78        1.78     257.04  144.677
  STR-I   Max     Fin     0.36     2.70     7.49      6.16     2.89        6.16     257.04   41.738
  STR-I   Min     Fin     0.60     2.70     4.50      4.10     1.02        4.10     257.04   62.727
  STR-I   MxVMnH  Fin    -0.00     2.70   666.04      4.51     4.54        4.54     257.04   56.558
  STR-I   MnVMnH  Fin    -0.04     2.70    61.08      2.45     2.67        2.67     257.04   96.134
...
  SER-I   Max     Tmp              NA*               0.87     2.07                  NA*
  SER-I   Min     Tmp              NA*               0.87     2.07                  NA*
  SER-I   Max     Fin              NA*               5.06     1.47                  NA*
  SER-I   Min     Fin              NA*               4.09     1.15                  NA*

    Performance Ratio =  Factored Bearing Resistance / Maximum Factored Bearing
                         Pressure
    Eccentricity Performance Ratio = Allowable Eccentricity / Eccentricity

    The eccentricity is the distance from the center of the pedestal at
    The base to the load resultant.  Positive towards front; negative
    towards back. The allowable eccentricity is the distance from the
    center of the footing to the edge of the kern.

    NA*  Indicates Eccentricity and Bearing Resistance checks Not Applicable for Service I
```

Figure 7.4.5-7 Overturning and Bearing - Pedestal on Foundation

The FOOTING STABILITY report for a pedestal footing (footing on pedestal - bearing, Figure 7.4.5-7) contains the following data:

FOOTING BEARING RESULTS

1. Governing Load Combination:
   - Maximum Factored Actual Pressure - maximum factored applied pressure from all load combinations followed by the abbreviated description of the limit state, load case and stage.
   - Pedestal Factored Bearing Resistance – factored resisting pressure of the pedestal, based on concrete strength of the pedestal concrete.
   - Performance Ratio - Resistance/Actual Pressure.

FOOTING BEARING RESISTANCE

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Ecc - eccentricity of resultant of the applied loads measured from the center of the portion of the footing over the pedestal; positive toward toe negative toward heel (See Figure 3.4.2-1).
3. Allow Ecc - allowable eccentricity measured from the center of the portion of the footing over the pedestal to the edge of the kern (See Figure 3.4.2-1).
4. Ecc Perform Ratio - performance ratio for the given load combination, defined as allowable eccentricity over actual eccentricity.
5. Factored Footing Pressure Toe - pressure underneath the footing under the toe (see Figure 3.4.2-1).

6. Factored Footing Pressure Heel - pressure underneath the footing under the heel (see Figure 3.4.2-1).
7. Maximum Factored Bearing Pressure - larger of toe or heel pressure.
8. Factored Bearing Resistance – factored bearing resistance of pedestal, based on concrete strength of pedestal.
9. Perform Ratio - performance ratio for the given load combination (defined by note).

The second overturning and bearing report is based on the pedestal bearing on the rock, as shown in Figure 7.4.5-8. The governing bearing case is reported separately from the table that identifies the eccentricity and bearing values for each load case. The bearing capacity of rock foundations is specified by the user. Hence, the same value is used for all load combinations. The bearing resistance is not considered for the temporary stage, hence “NA” is reported. The note at the end of the table defines the orientation of the eccentricity. For both reports, if the location of the load resultant lies outside the kern, the eccentricity value is flagged with an asterisk (*) and the eccentricity performance ratio will be less than 1.0. A footnote will be printed explaining that the eccentricity check has failed (i.e., the resultant is outside the kern).

The FOOTING STABILITY report for a pedestal footing (bearing, Figure 7.4.5-8) contains the following data:

PEDESTAL BEARING RESISTANCE

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Ecc - eccentricity of resultant of the applied loads measured from the center of the pedestal at the base; positive toward front, negative toward back (see Figure 3.4.2-1).
3. Allow Ecc – allowable eccentricity measured from the center of the pedestal at the base to the edge of the kern (see Figure 3.4.2-1).
4. Ecc Perform Ratio - performance ratio for the given load combination defined as allowable eccentricity over actual eccentricity.
5. Factored Footing Pressure Front - pressure underneath the pedestal at the front corner (see Figure 3.4.2-1).
6. Factored Footing Pressure Back - pressure underneath the pedestal under the back corner (see Figure 3.4.2-1) .
7. Factored Uniform Bearing Pressure - applies to final stage only.
8. Factored Bearing Resistance - bearing resistance of soil or rock for the given load combination as input by the user.
9. Perform Ratio - performance ratio for the given load combination (defined by note).

The sliding of the footing on the pedestal is checked by comparing the ratio of the vertical (V) and horizontal (H) components of the overturning forces. If the V/H ratio is less than the minimum allowable value, sliding is a problem. Figure 7.4.5-9 shows the sliding results in the table named “Footing Stability on Pedestal”.

PEDESTAL BEARING RESISTANCE

Limit State	Load Case	Stage	Ecc (ft)	Allow Ecc (ft)	Ecc Perform Ratio	Factored Pedestal Pressure Front (ksf)	Factored Pedestal Pressure Back (ksf)	Maximum Factored Bearing Pressure (ksf)	Factored Bearing Resist (ksf)	Perform Ratio
STR-I	Max	Tmp	0.18	3.22	9.88	6.89	5.48	NA	NA	NA
STR-I	Min	Tmp	0.89	3.22	23.66	7.41	2.13	NA	NA	NA
STR-I	Max	Fin	0.02	4.35	12.07	12.43	12.12	12.43	110.00	8.846
STR-I	Min	Fin	1.24	4.35	7.25	12.67	1.65	12.67	110.00	8.679
STR-I	MxVMnH	Fin	-0.59	4.35	1073.28	7.79	16.76	16.76	110.00	6.562
STR-I	MnVMnH	Fin	0.20	4.35	98.43	8.03	6.29	8.03	110.00	13.694
STR-III	Max	Tmp	-0.47	3.22	5.42	3.94	7.17	NA	NA	NA
STR-III	Min	Tmp	0.12	3.22	7.11	4.46	3.82	NA	NA	NA
STR-III	Max	Fin	0.41	4.35	13.47	12.05	7.15	12.05	110.00	9.127
STR-III	Min	Fin	1.29	4.35	7.10	12.74	1.42	12.74	110.00	8.635
STR-III	MxVMnH	Fin	-0.39	4.35	24.59	7.25	11.95	11.95	110.00	9.203
STR-III	MnVMnH	Fin	0.20	4.35	69.29	7.94	6.22	7.94	110.00	13.854
STR-V	Max	Tmp	0.10	3.22	8.95	6.47	5.72	NA	NA	NA
STR-V	Min	Tmp	0.79	3.22	18.43	6.99	2.38	NA	NA	NA
STR-V	Max	Fin	0.15	4.35	11.21	12.76	10.57	12.76	110.00	8.621
STR-V	Min	Fin	1.34	4.35	6.59	13.11	1.22	13.11	110.00	8.394
STR-V	MxVMnH	Fin	-0.61	4.35	62.19	7.26	16.08	16.08	110.00	6.843
STR-V	MnVMnH	Fin	0.10	4.35	41.84	7.60	6.72	7.60	110.00	14.469
SER-I	Max	Tmp		NA*		4.19	5.12		NA*	
SER-I	Min	Tmp		NA*		4.19	5.12		NA*	
SER-I	Max	Fin		NA*		10.52	7.41		NA*	
SER-I	Min	Fin		NA*		10.26	4.62		NA*	
SER-I	MxVMnH	Fin		NA*		2.59	15.35		NA*	
SER-I	MnVMnH	Fin		NA*		2.32	12.55		NA*	

Performance Ratio = Factored Bearing Resistance / Maximum Factored Bearing Pressure
Eccentricity Performance Ratio = Allowable Eccentricity / Eccentricity

The eccentricity is the distance from the center of the pedestal at the base to the load resultant. Positive towards front; negative towards back. The allowable eccentricity is the distance from the center of the footing to the edge of the kern.

NA* Indicates Eccentricity and Bearing Resistance checks Not Applicable for Service I

Figure 7.4.5-8 Overturning and Bearing - Pedestal on Footing

FOOTING SLIDING STABILITY ON PEDESTAL

Limit State	Load Case	Stage	Vertical Force (kip)	Horiz Force (kip)	V/H Ratio	Min Allow Ratio	Perform Ratio
SER-I	Min	Tmp	8.81	2.27	3.88	2.00	1.94
SER-I	Min	Fin	15.77	3.87	4.08	2.00	2.04

Notes:

Forces are based on a unit width thickness of the footing.

Performance Ratio = (V/H Ratio) / (Min Allow Ratio)

Figure 7.4.5-9 Pedestal Sliding (Footing Stability)

The FOOTING STABILITY report for a pedestal footing (footing on pedestal - v/h ratio, Figure 7.4.5-9) contains the following data:

FOOTING SLIDING STABILITY ON PEDESTAL

1. Load combination description - abbreviated description of the limit state, load case and stage that produces the smallest performance ratio.
2. Vertical Force - applied vertical force on the pedestal tap of the pedestal from the given load combination.
3. Horizontal Force - total applied horizontal force about the top of the pedestal from the given load combination.
4. Min Allow Ratio - minimum allowable v/h ratio program defined.
5. Perform Ratio - performance ratio for the given load combination (defined by note).

The settlement of the pedestal on the foundation is shown in Figure 7.4.5-10. It resembles the settlement report for spread footings. Consolidation and secondary settlement are not applicable for rock foundations.

SETTLEMENT

Settlement					Perform	Temp Stage
Elastic (in)	Consol (in)	Second (in)	Total (in)	Allow (in)	Ratio	Settlement (in)
0.**99**	NA	NA	0.**99**	1.00	**1.007**	0.**49**

Notes:

Elastic settlement is based on:
effective width of **9.11** (ft) from SER-I Max Fin

Temporary Stage settlement is based on:
effective width of 9.3**5** (ft) from SER-I Max Tmp

Maximum pressures (Vertical Force/Effective Width)
are used for settlement calculations.

Performance Ratio = Allowable Settlement / Total Settlement

Figure 7.4.5-10 Pedestal Settlement

The FOOTING STABILITY report for a pedestal footing (settlement, Figure 7.4.5-10) contains the following data:

SETTLEMENT

1. Elastic - elastic settlement.
2. Settlement Consol - consolidation settlement (not applicable).
3. Settlement Second - secondary consolidation settlement (not applicable).
4. Settlement Total - elastic settlement only.

5. Settlement Allow - allowable settlement.
6. Perform Ratio - settlement performance ratio (allowable/total).
7. Temp Stage Settlement - settlement for temporary construction stage.
8. Width and load combination used to compute elastic, consolidation and secondary settlement.

7.4.6 Controlling Footing Forces

This report is only available for the pile foundations and spread footings. For pedestal foundations, the controlling shear and moment values are referenced by special notes in the crack control, shear and flexural strength tables.

This report identifies the forces and moments that were used for the flexural and shear calculations. The maximum moment is used for the strength check. The service moment is used for the crack control check and the shear force is used for the shear check. For each value, the load combination (limit state / load type / stage) that generated the value is reported along with a flag indicating the origin of the controlling moment in the footing. The critical shear location (at the face or effective depth or at the X distance for heel only) in the footing is also identified. Figure 7.4.6-1 shows the results from a pile footing analysis. Pile footings are distinguished from the spread footing by the summary forces in the parallel direction. Note that shear is not checked in the parallel direction hence only the moments are reported.

The CONTROLLING FOOTING FORCES report contains the following data:

TOE – WITH FOUNDATION PRESSURE (bottom perpendicular) for spread and pile footings
HEEL – WITH FOUNDATION PRESSURE (top perpendicular) for spread and pile footing

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Moment - largest strength and service limit state moments followed by a “T” or “H” which indicates which side of the footing the moment originates.
3. Shear - largest shear force and location (stem face or distance ‘d’ from face) at toe and heel, or X distance from back face) at toe and heel of the stem at the heel.

PARALLEL MOMENT for pedestal and pile footings

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Moment - largest strength and service limit state moments.

```
                                TOE - WITH FOUNDATION PRESSURE
Limit   Load                                          Limit   Load
State   Case   Stage   Moment                         State   Case   Stage    Shear
    (Controlling)     (kip-ft)                            (Controlling)       (kip)
STR-I   Max     Fin     11.46T  (Strength)            Sec. beyond ftg.         0.00
SER-I   Max     Fin      7.98T  (Crack Control)

Note: A "T" following the moment value indicates that the controlling
      moment for the bottom perpendicular reinforcement was found in the
      Toe. An "H" indicates the controlling moment was found in the Heel.

Note: Sec. beyond ftg. indicates that the controlling limit state is not
      applicable because the section is beyond the footing dimensions.

                               HEEL - WITH FOUNDATION PRESSURE
Limit   Load                                          Limit   Load
State   Case   Stage   Moment                         State   Case   Stage    Shear
    (Controlling)     (kip-ft)                            (Controlling)       (kip)
STR-I   Min     Fin     13.38H  (Strength)            STR-I   Min     Fin      6.31
SER-I   Max     Fin      4.52H  (Crack Control)                  (Face)

Note: An "H" following the moment value indicates that the controlling
      moment for the top perpendicular reinforcement was found in the
      Heel. A "T" indicates the controlling moment was found in the Toe.

Note: A moment direction of "2" in the heel has been detected. The
      critical shear location of limit states that caused the moment
      direction to be "2" in the heel are set to the Eff D location as
      documented in the User's Manual Section 3.5.1.    Limit   Case   Stage
      Max moment in direction "2":   -2.02 (kip-ft)     STR-III Max     Tmp

                                       PARALLEL MOMENT

                 Limit   Load           Parallel
                 State   Case   Stage    Moment
                    (Controlling)       (kip-ft)
Strength:        STR-I   Max     Fin      13.29
Crack Control:   SER-I   Max     Fin       9.60
```

Figure 7.4.6-1 Controlling Forces

7.4.7 Footing Flexure

The footing flexural strength report identifies the maximum applied moment from the analysis and the corresponding load combination (limit state / load case / stage) along with a flag indicating origin of the moment value. The moment resistance is shown in the adjacent column. It includes a strength reduction factor. The values reported are based on a unit width of structure.

The procedure that evaluates the nominal resistance (see Section 3.5.2) in the perpendicular direction is also used for the parallel direction. Pile footings have flexural reinforcement in both directions, as shown in Figure 7.4.7-1. Spread footings are analyzed in the perpendicular direction only. Hence, the report for a spread footing will only show the results at the toe and heel locations. Pedestal footings are analyzed in the parallel direction only because the footing and pedestal are assumed to be made integral using transverse shear keys and dowels as per DM-4 Section 10.6.5.2P. Hence, the report for a pedestal footing will only show the results for the parallel direction.

If the bars at the toe and heel locations do not have a sufficient development length, they are not considered in the strength calculations. Hence, the Performance Ratio may be zero even though the user has described some reinforcement at those locations.

The procedure for evaluating parallel moments for pile footing is described in Section 3.5.1.2. The equation that evaluates the parallel moment and its corresponding variable values is shown after the table of results.

Development length is checked only when the reinforcement is specified in terms of bar and spacing. If the reinforcement is specified in terms of area, the program does not check for development length; it is assumed that the area specified is fully developed. The format shown in Figure 7.4.7-1 also applies to this case. The program classifies the moment in the footing that causes tensile stresses at the bottom face of the toe and at the top face of the heel as Condition “1”. When the moment is negative, this is Condition “2”. See Section 3.5.1 for more information on the Moment Direction Condition.

7.4.7.1 Footing Flexure – Analysis

FLEXURAL STRENGTH

Location	Limit State (Controlling)	Load Case	Stage	Applied Moment (kip-ft)	Moment Resist (kip-ft)	Phi Factor	Perform Ratio	Area Prov (in^2)
Toe	STR-I	Max	Fin	11.46T	59.70	0.900	5.210	0.413
Heel	STR-I	Min	Fin	13.38H	59.70	0.900	4.463	0.413
Top Parallel	STR-I	Max	Fin	13.29	61.39	0.900	4.618	0.440
Bot Parallel	STR-I	Max	Fin	13.29	61.39	0.900	4.618	0.440

NOTE: A "T" following the applied moment indicates that the controlling
moment is found in the Toe for the current location.
An "H" following the applied moment indicates that the controlling
moment is found in the Heel for the current location

Notes:

Applied moments are based on:
vertical force = 26.60 (kip)
footing width = 10.00 (ft)
uniform distrib load (udl) = 2.66 (klf)
maximum pile spacing (s) = 10.00 (ft)

Parallel moment = 0.5*udl*s*s/10
Performance Ratio = Moment Resistance / Applied Moment

Phi Factor Epsilon (cl) = 0.00200
Phi Factor Epsilon (tl) = 0.00500

Figure 7.4.7-1 Flexural Strength Report for a Pile Footing Analysis

The FOOTING FLEXURAL - ANALYSIS report contains the following data:

FLEXURAL STRENGTH (spread footing)

1. Location - toe (bottom perpendicular) and heel (top perpendicular).
2. Load combination description - abbreviated description of the limit state, load case and stage.

3. Applied Moment - maximum applied moment at the given location and load combination followed by a "T" or "H" which indicates which side of the footing the controlling moment originates.
4. Moment Resist - resisting moment at the given location based on developed area of steel.
5. Phi Factor – the flexural resistance factor
6. Perform Ratio - performance ratio for the given load combination (defined by note).
7. Area Prov - area of steel provided at the given location.

FLEXURAL STRENGTH (pedestal footing)

1. Location - top and bottom parallel.
2. Load combination description - abbreviated description of the limit state, load case and stage.
3. Applied Moment - maximum applied moment at the given location and load combination.
4. Moment Resist - resisting moment at the given location.
5. Phi Factor – the flexural resistance factor
6. Perform Ratio - performance ratio for the given load combination (defined by note).
7. Area Prov - area of steel provided at the given location.
8. Notes that indicate how the parallel moment (if applicable) was evaluated - it consists of:
    - vertical force - largest applied vertical force
    - footing width
    - uniform distrib load (udl) - uniform dead load (force/width)
    - pedestal spacing
    - equation to compute the moment
    - Note explaining why pedestal footings do not design the footing reinforcement in the perpendicular direction (toe and heel locations).

FLEXURAL STRENGTH (pile footing)

1. Location - toe (bottom perpendicular), heel (top perpendicular), top and bottom parallel.
2. Load combination description - abbreviated description of the limit state, load case and stage.
3. Applied Moment - maximum applied moment at the given location and load combination followed by a "T" or "H" which indicates which side of the footing the controlling moment originates.
4. Moment Resist - resisting moment at the given location; perpendicular direction is based on developed area of steel, parallel direction is based on total area.
5. Phi Factor – the flexural resistance factor
6. Perform Ratio - performance ratio for the given load combination (defined by note).
7. Area Prov - area of steel provided at the given location.
8. Notes that indicate how the parallel moment (if applicable) was evaluated - it consists of:
    - vertical force - largest applied vertical force
    - footing width
    - uniform distrib load (udl) - uniform dead load (force/width)
    - maximum pile spacing

- equation to compute the moment

7.4.7.2 Footing Flexure – Design

```
                                  FLEXURAL STRENGTH

              Limit   Load          Applied   Moment    Phi    Perform   1.33 Mu   Area  Status
 Location     State   Case   Stage  Moment    Resist   Factor   Ratio              Reqd   Codes
                  (Controlling)    (kip-ft)  (kip-ft)                   (kip-ft)  (in^2)
     Toe      No control found        0.00T     0.14    0.900  999.999     0.00    0.001    A
    Heel      STR-I   Max     Fin     4.00H     5.32    0.900    1.330     5.32    0.054    A
Top Parallel  STR-I   Max     Fin    58.80     76.74    0.900    1.305    78.21    0.839     B
Bot Parallel  STR-I   Max     Fin    58.80     76.74    0.900    1.305    78.21    0.876     B

NOTE: A "T" following the applied moment indicates that the controlling
      moment is found in the Toe for the current location.
      An "H" following the applied moment indicates that the controlling
      moment is found in the Heel for the current location.

Cracking Moment M(cr):    76.74 (kip-ft)

Status Code Descriptions
   A -  1.33*Mu Minimum Criteria Controlled Moment Resistance
   B -  Mcr Minimum Criteria Controlled Moment Resistance


Notes:

Applied moments are based on:
     vertical force             =    37.02 (kip)
     footing width              =     7.08 (ft)
     uniform distrib load (udl) =     5.23 (klf)
     maximum pile spacing   (s) =    15.00 (ft)

Parallel moment = 0.5*udl*s*s/10

Performance Ratio = Moment Resistance / Applied Moment

Phi Factor Epsilon (cl) =  0.00172
Phi Factor Epsilon (tl) =  0.00500
```

Figure 7.4.7-2 Flexural Strength Report for a Pile Footing Design

The FOOTING FLEXURAL - DESIGN report contains the following data:

FLEXURAL STRENGTH (spread footing)

1. Location - toe (bottom perpendicular) and heel (top perpendicular).
2. Load combination description - abbreviated description of the limit state, load case and stage.
3. Applied Moment - maximum applied moment at the given location and load combination followed by a “T” or “H” which indicates which side of the footing the controlling moment originates.
4. Moment Resist - resisting moment at the given location based on developed area of steel.
5. Phi Factor – the flexural resistance factor
6. Perform Ratio - performance ratio for the given load combination (defined by note).
7. 1.33 Mu – 1.33 * Applied Moment.
8. Area Reqd - area of steel required at the given location.
9. Status Codes – indicates which minimum criteria controls the design if applicable.

FLEXURAL STRENGTH (pedestal footing)

1. Location - top and bottom parallel.
2. Load combination description - abbreviated description of the limit state, load case and stage.
3. Applied Moment - maximum applied moment at the given location and load combination.
4. Moment Resist - resisting moment at the given location.
5. Phi Factor – the flexural resistance factor
6. Perform Ratio - performance ratio for the given load combination (defined by note).
7. Area Reqd - area of steel required at the given location.
8. Status Codes – indicates which minimum criteria controls the design if applicable.
9. Notes that indicate how the parallel moment (if applicable) was evaluated - it consists of:
    - vertical force - largest applied vertical force
    - footing width
    - uniform distrib load (udl) - uniform dead load (force/width)
    - pedestal spacing
    - equation to compute the moment
    - Note explaining why pedestal footings do not design the footing reinforcement in the perpendicular direction (toe and heel locations).

FLEXURAL STRENGTH (pile footing)

1. Location - toe (bottom perpendicular), heel (top perpendicular), top and bottom parallel.
2. Load combination description - abbreviated description of the limit state, load case and stage.
3. Applied Moment - maximum applied moment at the given location and load combination followed by a “T” or “H” which indicates which side of the footing the controlling moment originates.
4. Moment Resist - resisting moment at the given location; perpendicular direction is based on developed area of steel, parallel direction is based on total area.
5. Phi Factor – the flexural resistance factor
6. Perform Ratio - performance ratio for the given load combination (defined by note).
7. Area Reqd - area of steel required at the given location.
8. Status Codes – indicates which minimum criteria controls the design if applicable.
9. Notes that indicate how the parallel moment (if applicable) was evaluated - it consists of:
    - vertical force - largest applied vertical force
    - footing width
    - uniform distrib load (udl) - uniform dead load (force/width)
    - maximum pile spacing
    - equation to compute the moment

Cracking Moment – moment used in determining the minimum area of steel needed to prevent concrete cracking in the footing section.

7.4.8 Crack Control

The type of crack control check that is evaluated depends on the component. A special case applies to gravity wall stem locations.

7.4.8.1 Crack Control in Footings and Cantilever Stems

The crack control analysis report identifies the allowable tensile reinforcement spacing, and, the computed serviceability stress in the tensile reinforcement. For stem and backwall locations, the controlling moment and axial load is printed as shown in Figure 7.4.8-1. For the footing locations, only the governing moment value is displayed (the axial load is zero), as shown in Figure 7.4.8-2. The status codes indicate which crack control checks failed. The codes are identified at the bottom of the Figure 7.4.8-2. Both reports have the same set of codes. If the applied loads do not crack the section, the stress is 0 and status code E is flagged. If a negative moment is detected, the program will issue a warning which requires further user attention. The location of the negative moment will be indicated in the table with an asterisk following the location.

BACKWALL AND STEM

Location	Dist from Struc Top (ft)	Area/ Width (in^2)	Actual Stress (ksi)	Allow Spacing (in)	Controlling Moment (kip-ft)	Controlling Axial (kip)	Status Codes
Backwall	3.05	0.79	0.00	999.99	0.64	0.89	E
Seat	6.10	0.79	0.00	999.99	3.01	1.65	E
Stem A	7.75	0.79	0.00	999.99	21.46	18.56	E
Stem B	9.40	0.79	0.00	999.99	26.42	19.57	E
Stem C	11.05	0.79	0.00	999.99	32.60	20.58	E
Stem D	12.70	0.79	0.00	999.99	39.52	21.59	E

Figure 7.4.8-1 Crack Control in Backwall and Stem (Analysis Run)

The CRACK CONTROL - ANALYSIS (backwall and stem / analysis run, Figure 7.4.8-1) report contains the following data:

BACKWALL AND STEM
STEM (no backwall)

1. Location - list of locations in backwall (if applicable) and stem locations (A-D).
2. Distance from Struc Top - distance from the top of the structure to given location.
3. Area / Width - area per unit width of structure.
4. Actual Stress - stress due to applied loads.
5. Allow Spacing - allowable spacing determined according to Section 3.5.2.8.
6. Controlling Moment - moment from combination that generates the largest stress.
7. Controlling Axial - axial load from combination that generates the largest stress.
8. Status Codes - status codes that apply.

```
                                FOOTING

                Area/    Actual      Allow     Control     Status
  Location      Width    Stress     Spacing     Moment      Codes
                (in^2)     (ksi)      (in)    (kip-ft)
     Toe         0.79      0.00     999.99      15.10T       E
    Heel         0.79      0.00     999.99       2.53H       E

NOTE: A "T" following the moment indicates that the controlling
      moment is found in the Toe for the current location.
      An "H" following the moment indicates that the controlling
      moment is found in the Heel for the current location

Status Code Descriptions                    (Blank indicates an OK status)
  A - area smaller than that required for shrinkage/temperature
      control or rho min
  B - actual spacing is greater than maximum allowed
  C - actual stress calculation did not converge
  D - actual spacing is greater than allowable crack control spacing
  E - applied loads did not crack the cross section.  Rebar tensile
      stress is set to zero.
  F - spacing is less than the minimum allowed
  G - Actual stress limited to 0.6*fy in allowable spacing calculation
```

Figure 7.4.8-2 Footing Crack Control Report (Analysis Run)

The CRACK CONTROL ANALYSIS (footing / analysis run, Figure 7.4.8-2) report contains the following data:

FOOTING (spread)

1. Location - toe (bottom perpendicular) and heel (top perpendicular).
2. Area / Width - area per unit width of structure.
3. Actual Stress - stress due to applied loads.
4. Allow Spacing - allowable spacing determined according to Section 3.5.2.8.
5. Controlling Moment - moment from combination that generates the largest stress followed by a “T” or “H” which indicates which side of the footing the controlling moment originates.
6. Status Codes - status codes that apply.
7. Status Codes Descriptions for codes A-G (see Figure 7.4.8-2).

FOOTING (pedestal)

1. Location - top and bottom parallel.
2. Area / Width - area per unit width of structure.
3. Actual Stress - stress due to applied loads.
4. Allow Spacing - allowable spacing determined according to Section 3.5.2.8.
5. Controlling Moment - moment from combination that generates the largest stress.
6. Status Codes - status codes that apply.
7. Notes that indicate what the stresses (parallel direction) are based on - it consists of:

- vertical force - largest applied vertical force
- footing width
- uniform distrib load (udl) - uniform dead load (force/width)
- pedestal spacing
- equation to compute the parallel moment

8. Status Codes Descriptions for codes A-G (see Figure 7.4.8-2).

FOOTING (pile)

1. Location - toe (bottom perpendicular), heel (top perpendicular), top and bottom parallel.
2. Area / Width - area per unit width of structure.
3. Actual Stress - stress due to applied loads.
4. Allow Spacing - allowable spacing determined according to Section 3.5.2.8.
5. Controlling Moment - moment from combination that generates the largest stress followed by a “T” or “H” which indicates which side of the footing the controlling moment originates.
6. Status Codes - status codes that apply.
7. Notes that indicate what the stresses (parallel direction) are based on - it consists of:
   - vertical force - largest applied vertical force
   - footing width
   - uniform distrib load (udl) - uniform dead load (force/width)
   - maximum pile spacing
   - equation to compute the parallel moment
8. Status Codes Descriptions for codes A-G (see Figure 7.4.8-2).

In a design run, at each location, the results are reported for each bar size, as shown in Figure 7.4.8-3. The status code differ between an analysis and design run. Hence, code F is flagged if the section was uncracked in a design run. If a negative moment is detected, the program will issue a warning footnote which requires further user attention immediately following the table for the location. The results for a footing are shown in Figure 7.4.8-4.

The CRACK CONTROL DESIGN (backwall and stem - design run, Figure 7.4.8-3) report contains the following data for each applicable location:

ABUTMENT BACKWALL (if applicable)
ABUTMENT BACKWALL AT SEAT LEVEL (if applicable)
STEM LOCATION A-D
STEM CUTOFF LOCATION - SHOWN FOR EACH BAR CUTOFF (if applicable)

1. Bar Size - list of applicable bar sizes.
2. Bar Spacing - spacing for a given bar size.
3. Area / Width - area per unit width of structure.
4. Actual Stress - stress due to applied loads.

5. Allow Spacing - allowable spacing determined according to Section 3.5.2.8.
6. Controlling Moment - moment from combination that generates the largest stress.
7. Controlling Axial - axial force from combination that generates the largest stress.
8. Status Codes - status codes that apply.

STEM LOCATION D 10.00 (ft) FROM TOP OF STRUCTURE
Back Face Vertical Reinforcement

Bar Size	Bar Spacing (in)	Area/ Width (in^2)	Actual Stress (ksi)	Allow Spacing (in)	Controlling Moment (kip-ft)	Controlling Axial (kip)	Status Codes
4	3.50	0.69	0.00	999.99	33.56	12.62	E
5	5.50	0.68	0.00	999.99	33.56	12.62	E
6	8.00	0.66	0.00	999.99	33.56	12.62	E
7	11.00	0.65	0.00	999.99	33.56	12.62	E
8	13.50	0.70	0.00	999.99	33.56	12.62	DE
9	15.00	0.80	0.00	999.99	33.56	12.62	DE
10	24.00	0.63	0.00	999.99	33.56	12.62	E
11	24.00	0.78	0.00	999.99	33.56	12.62	E

Warning: An applied moment was negative (See Moment Axial Interaction Table) and may have cracked the section in the front face. User should determine if the front face has cracked. If so compute an allowable crack control spacing and compare it to the temp/shrinkage reinforcement spacing.

Figure 7.4.8-3 Crack Control in Backwall and Stem (Design Run)

FOOTING PARALLEL BOTTOM REINFORCEMENT

Bar Size	Bar Spacing (in)	Area/ Width (in^2)	Actual Stress (ksi)	Allow Spacing (in)	Control Moment (kip-ft)	Status Codes
4	1.00	0.96	0.00	999.99	41.04	B E
5	2.00	0.93	0.00	999.99	41.04	B E
...	...	...	....	...	...	
11	10.00	1.87	0.00	999.99	41.04	E

Status Code Descriptions (Blank indicates an OK status)
A - min area & max spacing governed by shrinkage/temp requirements
B - spacing is less than minimum allowed, actual stress not computed
C - actual stress calculation did not converge
D - spacing modified by development length ratio reduction
E - applied loads did not crack the cross section. Rebar tensile stress is set to 0.
F - Actual stress limited to 0.6*fy in allowable spacing calculation
++ - Design spacing is less than minimum spacing. Bar size is not applicable

Figure 7.4.8-4 Footing Crack Control Report (Design Run)

The CRACK CONTROL DESIGN (footing - parallel direction / design run, Figure 7.4.8-4) report contains the following data for each applicable location in the footing:

FOOTING PARALLEL BOTTOM REINFORCEMENT (pile and pedestal)

FOOTING PARALLEL TOP REINFORCEMENT (pile and pedestal)
FOOTING TOE (pile and spread)
FOOTING HEEL (pile and spread)

1. Bar Size - list of applicable bar sizes.
2. Bar Spacing - spacing for a given bar size.
3. Area / Width - area per unit width of structure.
4. Actual Stress - stress due to applied loads.
5. Allow Spacing - allowable spacing determined according to Section 3.5.2.8.
6. Controlling Moment - moment from combination that generates the largest stress followed by a “T” or “H” which indicates which side of the footing the controlling moment originates (For perpendicular reinforcement in Pile and Spread Footings Only).
7. Status Codes - status codes that apply.

7.4.8.2 Crack Control Check for Gravity Walls

Gravity wall structures (see AWB or RWL command) are only checked for tension in the stem wall. Tensile stresses are reported as negative values. No reinforcement can be specified for such problems. A sample of the results is shown in Figure 7.4.8-5. The results are reported for the stem quarter points. Cases that fail are flagged with an asterisk (*).

The GRAVITY WALL STRESS CHECK (stem) report contains the following data at a given stem location:

STEM LOCATION (A-D) FROM TOP OF STRUCTURE

1. Load combination description - abbreviated description of the limit state, load case and stage .
2. Applied Moment - applied moment at the given location and load combination.
3. Applied Axial - applied axial force the given location and load combination.
4. Actual Stress - stress caused by applied loads for the given load combination.
5. Status - status code for the given load combination.
6. Note about calculating the tensile stress and the applied moment.

```
                        STEM LOCATION D    7.75 (ft)  FROM TOP OF STRUCTURE

               Stress is based on a stem thickness of    4.73 (ft)

    Limit   Load              Applied    Applied      Actual
    State   Case   Stage      Moment      Axial       Stress    Status
                              (kip-ft)    (kip)        (ksf)
    STR-I   Max     Tmp          8.36      9.55         0.22      NG
    STR-I   Min     Tmp          8.48      7.86         0.61      NG
    STR-I   Max     Fin         32.80     21.97         4.15      NG
    STR-I   Min     Fin         23.96     12.89         3.70      NG
...
    SER-I   Min     Fin         20.51     12.19         2.92      NG

    Warning: A negative applied moment was encountered.

    Note:  Positive applied axial loads produce compressive stress.

    Actual stress is evaluated on the face where moment produces tensile
    stress.  A positive applied moment generates a flexural tensile stress
    on backface of stem.  A negative applied moment generates a flexural
    tensile stress on frontface of stem.  Positive actual stress indicates
    that the combined stresses (axial and flexure) produced a tensile stress
    at the extreme fiber of the section.
```

Figure 7.4.8-5 Gravity Wall - Tension Check

7.4.9 Reinforcement Summary

This report shows the flexural reinforcement at each location that was checked in the structure. Backwall and stem sections are identified by the distance from the top of structure to the location being considered. Toe and heel locations are examined in pile and spread footings. In pedestal and pile footings, the top and bottom locations are checked in the parallel direction.

In an analysis run, for each location that is examined in the backwall (if applicable) and stem, the status of the flexural strength check, the serviceability (crack-control) check and the shear check is reported as shown in Figure 7.4.9-1. In a design run, the program will report the bar spacing required for strength and serviceability conditions, as shown in Figure 7.4.9-2.

The REINFORCEMENT SUMMARY - ANALYSIS (backwall and stem / analysis run, Figure 7.4.9-1) report contains the following data:

ABUTMENT BACKWALL AT SEAT LEVEL (bar size and spacing only)

1. Bar Size - Bar size at the given location.
2. Bar Spacing - Bar spacing at given location.
3. Development Length - Development length of bar at location.
4. Area of Steel Required - Area of steel required for capacity.
5. Area of Steel Provided - Area of steel provided by bar size and spacing.

6. Splice Length – Length of splice required by the bar size and spacing.
7. Status Codes – Status codes that apply

STEM LOCATION D xx.xx (ft) FROM TOP OF STRUCTURE (bar size nd spacing only)

1. Bar Size - Bar size at the given location.
2. Bar Spacing - Bar spacing at given location.
3. Development Length Hooked - Development length of hooked bar at location.
4. Development Length Straight - Development length of straight bar at location.
5. Area Required - Area of steel required for capacity.
6. Area Provided - Area of steel provided by bar size and spacing.
7. Splice Length – Length of splice required by the bar size and spacing.
8. Status Codes – Status codes that apply

FOOTING REINFORCEMENT DETAILS (spread - bar size and spacing only)

1. Bar Size - Bar size at the given location.
2. Bar Spacing - Bar spacing at given location.
3. Development Length - Development length of bar at location.
4. Actual Length - Available Length to develop the bar within the geometry of the component.
5. Bar Type - Straight or Hooked bar.
6. Area of Steel Required - Area of steel required for capacity.
7. Area of Steel Provided - Area of steel provided by bar size and spacing.

```
                        ABUTMENT BACKWALL AT SEAT LEVEL

Bar      Bar     Develop  Area   Area   Splice  Status
Size   Spacing   Length   Reqd   Prov   Length  Codes
         (in)      (in)   (in^2) (in^2)   (in)
  5      18.0      12.4   0.204  0.207    21.0

  Available Height in Backwall =   26.2 (in)

Status Code Descriptions
  A - Splice length exceeds backwall height

                      STEM LOCATION D   27.14 (ft) FROM TOP OF STRUCTURE

Bar      Bar      Develop Length   Area   Area   Splice  Status
Size   Spacing   Hooked  Straight  Reqd   Prov   Length  Codes
         (in)      (in)     (in)   (in^2) (in^2)   (in)
  8       9.0      20.9    39.7    1.047  1.053    51.6     B

  Available Length in Footing =   30.0 (in)

Status Code Descriptions
  A - Hooked development length exceeds available length
  B - Straight development length exceeds available length

                         FOOTING REINFORCEMENT DETAILS

                   FOOTING TOE (BOTTOM)

Bar      Bar     Develop  Actual  Bar    Area     Area
Size   Spacing   Length   Length  Type   Reqd     Prov
         (in)      (in)     (in)         (in^2)   (in^2)
  5       9.0      14.4     18.4   S      0.16     0.41

                   FOOTING HEEL (TOP)

Bar      Bar     Develop  Actual  Bar    Area     Area
Size   Spacing   Length   Length  Type   Reqd     Prov
         (in)      (in)     (in)         (in^2)   (in^2)
  5       9.0      14.4 +   13.0   S      0.27     0.41

+ Indicates bar cannot be developed.

Bar Type Description
   S - Straight Bar
   H - Hooked Bar
```

Figure 7.4.9-1 Summary of Reinforcement Perpendicular Footing Bar Development (Analysis Run)

The REINFORCEMENT SUMMARY - ANALYSIS (backwall and stem / analysis run, Figure 7.4.9-2) report contains the following data:

BACKWALL AND STEM
STEM (if no backwall)

1. Location - list of locations in backwall (backwall and seat, if applicable) and stem (a-d).
2. Dist from Struc Top - distance from the top of the structure to given location.

3. Bar @ Spacing - Bar size and spacing If an area is entered for reinforcement, the program will display the calculated spacing using the maximum bar diameter for crack control checks.
4. Total Area / Design Width - area per unit width of structure.
5. Strength Status - status of strength check.
6. Service Status - status of serviceability (crack control) checks.
7. Shear Status - status of shear check.

BACKWALL AND STEM

Location	Dist from Struc Top (ft)	Bar @ Spacing (in)	Total Area/ Design Width (in^2)	Strength Status	Service Status	Shear Status
Backwall	3.05	8 @ 12.00	0.79	OK	OK	OK
Seat	6.10	8 @ 12.00	0.79	OK	OK	OK
Stem A	7.75	8 @ 12.00	0.79	OK	OK	OK
Stem B	9.40	8 @ 12.00	0.79	OK	OK	OK
Stem C	11.05	8 @ 12.00	0.79	OK	OK	OK
Stem D	12.70	8 @ 12.00	0.79	OK	OK	OK

Figure 7.4.9-2 Summary of Reinforcement in the Stem & Backwall (Analysis Run)

BACKWALL

Bar Size	Backwall 3.05 (ft) from top of structure Strength (in)	Crack Control (in)	Seat 6.10 (ft) from top of structure Strength (in)	Crack Control (in)
4	109.50	12.00	23.00	12.00
5	170.00	18.00	35.50	18.00
	...	...	...	...
11	857.50	24.00	180.00	24.00

STEM

Bar Size	Location A 7.75 (ft) Streng (in)	Crack Control (in)	Location B 9.40 (ft) Streng (in)	Crack Control (in)	Location C 11.05 (ft) Streng (in)	Crack Control (in)	Location D 12.70 (ft) Streng (in)	Crack Control (in)
4	10.00	10.00	8.50	8.50	6.50	6.50	5.50	5.50
5	15.50	15.50	13.00	13.00	10.50	10.50	8.50	8.50
6	22.50	19.50	18.50	16.00	15.00	13.00	12.00	10.50
	...		...		...		...	
11	80.00	24.00	66.00	24.00	53.50	24.00	43.00	24.00

Figure 7.4.9-3 Summary of Reinforcement in the Stem and Backwall (Design Run)

The REINFORCEMENT SUMMARY - DESIGN (backwall and stem / design run, Figure 7.4.9-3) report contains the following data:

BACKWALL (if applicable)

STEM

1. Location - list of locations in backwall (backwall and seat, if applicable) and stem (a-d).
2. Distance from top of structure - distance from the top of the structure to given location.
3. Bar Size - list of applicable bar sizes.
4. Strength - Spacing to the nearest user entered increment for given bar size based on strength checks.
5. Crack Control - Spacing to the nearest user entered increment for given bar size based on service checks.

If the reported spacing is less than the User Requested Minimum spacing or the LRFD specified minimum spacing the program will show the unrounded spacing for information purposes.

The locations checked in a footing depend on the type of footing. In pile footings, the parallel reinforcement at the top and bottom faces of the footing are reported, see Figure 7.4.9-3. The punching shear results are reported too. Shear is not checked in the parallel direction in the pile footing - hence the “NA”. In a design run, the program will report the bar spacing required for strength and serviceability conditions, as shown in Figure 7.4.9-4. For spread footings, only the toe and heel locations are checked. In pedestal footings, only the parallel direction is checked. The results of an analysis run are shown in Figure 7.4.9-5, it has a slight variation from the pile and spread results. The strength and service results for flexure are output for the two (top and bottom) locations. Only one shear check applies. It is reported on a separate line.

FOOTING

Location	Bar @ Spacing (in)	Total Area/ Design Width (in^2)	Strength Status	Service Status	Shear Status
Toe	5 @ 9.00	0.41	OK	OK	OK
Heel	5 @ 9.00	0.41	OK	OK	OK
Top Parallel	6 @ 12.00	0.44	OK	OK	NA
Bot Parallel	6 @ 12.00	0.44	OK	OK	NA

Punching shear status is OK

Figure 7.4.9-4 Summary of Reinforcement in the Pile Footing (Analysis Run)

The REINFORCEMENT SUMMARY - ANALYSIS (footing / analysis run, Figure 7.4.9-4) report contains the following data:

FOOTING (spread)

1. Location - toe (bottom perpendicular) and heel (top perpendicular).
2. Bar @ Spacing - Bar size and spacing at the given . If area is entered for reinforcement, program will display the calculated spacing using the maximum bar diameter used for crack control checks.
3. Total Area / Design Width - area per unit width of structure.
4. Strength Status - status of strength check.

5. Service Status - status of serviceability (crack control) checks.
6. Shear Status - status of shear check.

FOOTING

Bar Size	Footing Toe Strength (in)	Footing Toe Crack Control (in)	Footing Heel Strength (in)	Footing Heel Crack Control (in)
4	12.50	12.00	30.50	12.00
5	19.50	18.00	47.50	18.00
	...	...	...	...
11	100.00	24.00	240.50	24.00

Bar Size	Parallel Top Strength (in)	Parallel Top Crack Control (in)	Parallel Bottom Strength (in)	Parallel Bottom Crack Control (in)
4	3.00	3.00	1.00	1.00
5	4.50	4.50	2.00	2.00
	...	...	...	...
11	23.00	23.00	10.00	10.00

Figure 7.4.9-5 Summary of Reinforcement in the Pile Footing (Design Run)

FOOTING (pedestal)

1. Location - top and bottom parallel.
2. Bar @ Spacing - Bar size and spacing at the given location (not applicable if area has been entered for analysis).
3. Area / Width - area per unit width of structure.
4. Strength Status - status of strength check.
5. Service Status - status of serviceability (crack control) checks.
6. Shear Status - status of shear check.

FOOTING (pile)

1. Location - toe (bottom perpendicular), heel (top perpendicular) , top and bottom parallel.
2. Bar @ Spacing - Bar size and spacing at the given location.
3. Area / Width - area per unit width of structure.
4. Strength Status - status of strength check.
5. Service Status - status of serviceability (crack control) checks.
6. Shear Status - status of shear check.
7. Punching Shear status.

The REINFORCEMENT SUMMARY - DESIGN (footing / design run, Figure 7.4.9-5) report contains the following data for each applicable location in the footing:

FOOTING TOE (pile and spread)
FOOTING HEEL (pile and spread)
PARALLEL TOP (pile)

PARALLEL BOTTOM (pile)
FOOTING PARALLEL TOP (pedestal)
FOOTING PARALLEL BOTTOM (Pedestal)

1. Bar Size - list of applicable bar sizes.
2. Strength - Spacing to the nearest user entered increment for given bar size based on strength checks.
3. Crack Control - Spacing to the nearest user entered increment for given bar size based on service checks.

If the reported spacing is less than the User Requested Minimum spacing or the LRFD specified minimum spacing the program will show the unrounded spacing for information purposes.

The shear capacity is evaluated based on the properties of the concrete section only. Hence, there is no shear reinforcement reported. A detailed shear report is also generated, it is described in Section 7.4.10.

7.4.10 Shear Results

Backwall and stem are grouped together in one table. Footing results are displayed in a separate table with a similar format. Refer to Figures 7.4.10-1 and 7.4.10-2 for the explanation that follows.

BACKWALL AND STEM

Location	Dist from Struc Top (ft)	Limit State (Controlling)	Load Case (Controlling)	Stage (Controlling)	Applied Shear (kip)	Shear Resist (kip)	Perform Ratio
Backwall	3.05	STR-I	Max	Fin	0.62	20.36	32.960
Seat	6.10	STR-I	Max	Fin	1.72	20.36	11.812
Stem A	7.75	STR-V	Max	Fin	3.08	53.03	17.239
Stem B	9.40	STR-V	Max	Fin	3.97	53.03	13.341
Stem C	11.05	STR-I	Max	Fin	5.02	53.03	10.555
Stem D	12.70	STR-I	Max	Fin	6.32	53.03	8.393

Note: Shear resistance is based on a phi factor of 0.90

Figure 7.4.10-1 Shear Results in the Backwall and Stem

Backwall and stem positions are identified by their location from the top of the structure. At each location, the maximum shear force that is reported is preceded by the governing load combination. The combination is a function of the limit state / load case / stage which is identified in an abbreviated format. The resistance of the section, which is based on the concrete section properties only, is shown in the column adjacent to the applied shear. In the rightmost column, the performance ratio is identified.

STEM CUTOFF LOCATIONS

Bar Size	Dist from Struc Top (ft)	Limit State (Controlling)	Load Case (Controlling)	Stage (Controlling)	Applied Shear (kip)	Shear Resist (kip)	Perform Ratio
4	5.55	STR-I	Max	Fin	3.00	23.73	7.909
5	6.00	STR-I	Max	Fin	3.27	24.15	7.385
6	5.68	STR-I	Max	Fin	3.08	23.72	7.704

Note: Shear resistance is based on a phi factor of 0.90

Figure 7.4.10-2 Shear Results at cutoff locations

The cutoff locations for each bar are identified by their location from the top of the structure. At each location, the maximum shear force that is reported is preceded by the governing load combination. The combination is a function of the limit state / load case / stage which is identified in an abbreviated format. The resistance of the section, which is based on the concrete section properties only, is shown in the column adjacent to the applied shear. In the rightmost column, the performance ratio is identified.

FOOTING

Location	Limit State (Controlling)	Load Case (Controlling)	Stage (Controlling)	Applied Shear (kip)	Shear Resist (kip)	Perform Ratio
Toe	STR-I	Max	Tmp	0.89	29.02	32.619
Heel	STR-I	Max	Fin	14.29	30.21	2.114
Pile Punching	STR-V	MxVMnH	Fin	253.42	196.90	0.777
Drain Trough Support Punching	STR-I	Max	Fin	70.24	964.95	13.738

Note: Shear resistance is based on a phi factor of 0.90
Note: Punching shear resistance is based on a phi factor of 0.90

Warning: A performance ratio less than 1 was found

Performance Ratio = Shear Resistance / Applied Shear

Figure 7.4.10-3 Shear Results in the Footing (Pile Footing Variation)

The applied shear is a factored force. The shear resistance value shown includes the strength reduction (φ) factor. The strength reduction factor is reported for both the stem and footing reports.

The definition of the performance ratio (resistance/applied shear) is displayed at the bottom of this report, as shown in Figure 7.4.10-2. A value greater than one implies that the check is satisfactory.

The footing portion of the shear report shows the results obtained from the toe and heel critical sections.

Further details concerning the calculation of the shear capacity are described in Section 3.5.2.9. Punching Shear for piles is described in Section 3.5.2.10.

The SHEAR RESULTS (backwall and stem, Figure 7.4.10-1) report contains the following data:

BACKWALL AND STEM

STEM (no backwall case)

1. Location - list of locations in backwall (if applicable) and stem (a-d).
2. Distance from Struc Top - distance from the top of the structure to given location.
3. Load combination description - abbreviated description of the limit state, load case and stage.
4. Applied Shear - shear from the controlling load combination at the given location.
5. Shear Resist - shear resistance at the given location.
6. Perform Ratio - performance ratio.
7. Note about the phi factor for shear.

The SHEAR RESULTS (footing, Figure 7.4.10-2) report contains the following data:

FOOTING (spread)

1. Location - toe (bottom perpendicular), heel (top perpendicular), and drain trough support punching (Type 4 Approach Slab only).
2. Load combination description - abbreviated description of the limit state, load case and stage.
3. Applied Shear - shear from the controlling load combination at the given location.
4. Shear Resist - shear resistance at the given location.
5. Perform Ratio - performance ratio.
6. Note about the phi factor for shear.

FOOTING - parallel direction (pedestal)

1. Location - parallel direction.
2. Load combination description - abbreviated description of the limit state, load case and stage.
3. Applied Shear - shear from the controlling load combination at the given location.
4. Shear Resist - shear resistance at the given location.
5. Perform Ratio - performance ratio.
6. Note about the phi factor for shear.
7. Description of governing applied shear force:
    - vertical force - largest applied vertical force
    - footing width
    - uniform distrib load (udl) - uniform dead load (force/width)
    - pedestal clear spacing
    - effective depth near pedestal
    - equation to compute the applied shear force in the parallel direction

FOOTING (pile)

1. Location - toe (bottom perpendicular), heel (top perpendicular), pile punching, and drain trough support punching (Type 4 Approach slab only) case.
2. Load combination description - abbreviated description of the limit state, load case and stage.
3. Applied Shear - shear from the controlling load combination at the given location.
4. Shear Resist - shear resistance at the given location.
5. Perform Ratio - performance ratio.
6. Notes about the phi factor for shear (toe and heel) and punching case.

7.4.11 Reinforcement Design Details

This reinforcement design details has a unique format for each component. For the backwall component, the program will report the bar spacing and development length for each bar at the seat level, as shown in Figure 7.4.11-1. The optimal solution (least area per unit width of structure) is identified by an asterisk (*) on the right of optimal bar size. Status codes are used to indicate if the development length of the bar exceeds the backwall or stem heights.

```
ABUTMENT BACKWALL AT SEAT LEVEL
(with optimum stem bar alignment option)

Bar      Bar     Develop  Area   Splice  Status   Reqd Bar Spacing
Size   Spacing   Length   Prov   Length  Codes       for Splice
         (in)      (in)   (in^2)   (in)                 (in)
  4       6.1   ++ N/A     N/A     N/A
  5       6.9   ++ N/A     N/A     N/A
  6 *     9.0      12.0   0.587    20.4
  7      12.0      13.0   0.600    22.2
  8      15.0      16.3   0.632    27.7     C            14.2
  9      18.0      19.6   0.667    33.3     C            14.2
 10      18.0      19.6   0.847    33.3     C            14.2
 11      18.0      19.6   1.040    33.3     C            16.7

  Area Reqd     =  0.125 (in^2) **

  Available Height in Backwall =   26.2 (in)

** Indicates area required was governed by the minimum temperature
   and shrinkage reinforcement criteria.

* Indicates bar size and spacing with the least area of steel per unit
  width of the structure in the backwall.

Status Code Descriptions
  A - Development length exceeds stem height
  B - Development length exceeds backwall height
  C - Splice length exceeds backwall height
  D - Area provided is less than area required
```

Figure 7.4.11-1 Design Details for Abutment Backwall

The REINFORCEMENT DESIGN DETAILS report (backwall tables, Figure 7.4.11-1) contains the following data:

ABUTMENT BACKWALL AT SEAT LEVEL

1. Location - backwall results are reported at the seat level.
2. Bar Size - list of bar sizes that were considered.
3. Indicator - an asterisk “*” is used to flag the bar/spacing with the least area.
4. Bar Spacing - spacing to the nearest user entered increment for the given bar size.
5. Develop Length - length required to develop the given bar (straight) at the given location.
6. Area Provided - area of steel provided based on bar size and spacing for design width.
7. Splice Length - length required to develop the splice given bar (straight) at the given location.
8. Status Codes - applicable status codes applicable for the given bar.
9. Required Bar Spacing for Splice – provides the calculated bar spacing that may work when the splice length for the bar size and spacing do not. (Only appears in output if applicable)
10. Area Required - area of steel required.
11. Backwall Height – available height in the backwall to accommodate the splice.
12. Note defining "**", area of steel required by temperature and shrinkage minimum.
13. Note defining “*”, optimal bar.
14. Description of Status codes (see Figure 7.4.11-1).

Figure 7.4.11-2 identifies the bar spacing and development length for each bar at all applicable footing locations, The optimal solution (least area per unit width of structure) is identified by an asterisk (‘*’) on the right of optimal bar size. Bars that cannot be developed in the footing are identified by the ‘+’ symbol next to the development length. The development length check only applies to rebar in the perpendicular direction.

```
          FOOTING TOE (BOTTOM)                    FOOTING HEEL (TOP)

   Bar    Bar    Develop Bar   Area        Bar    Bar    Develop Bar   Area
   Size Spacing  Length  Type  Prov        Size Spacing  Length  Type  Prov
          (in)    (in)        (in^2)              (in)    (in)        (in^2)
    4      7.5    13.6    S    0.320        4      2.0    18.4    S    1.200
    5 *   12.0    17.6    S    0.310        5      3.0    22.3    S    1.240
    6     17.0    22.3    S    0.311        6 *    4.5    29.9    S    1.173
...
   10     18.0    23.6    S    0.847       10     11.0    79.8    S    1.385
   11     17.5    28.7    S    1.070       11     13.0   113.0 +  S    1.440

     Area Reqd     =  0.303 (in^2)           Area Reqd     =  1.084 (in^2)
     Actual Length =   29.0 (in)             Actual Length =   83.0 (in)

   ++ - Design Spacing is less than the minimum spacing. Bar size is not
        applicable.

   + Indicates bar cannot be developed.

   ** Indicates area required was governed by the minimum temperature
      and shrinkage reinforcement criteria.

   * Indicates bar size and spacing with the least area of steel per unit
     width of the structure in the footing.

   Bar Type Description
      S - Straight Bar
      H - Hooked Bar
```

Figure 7.4.11-2 Design Details for a Footing (Perpendicular Direction)

The REINFORCEMENT DESIGN DETAILS report (footing tables, Figure 7.4.11-2) contains the following data:

FOOTING TOE (BOTTOM) - pile and spread footings
FOOTING HEEL (TOP) - pile and spread footings

1. Location - toe (bottom perpendicular) and heel (top perpendicular).
2. Bar Size - list of bar sizes that were considered.
3. Indicator - an asterisk “*” is used to flag the bar spacing with the least area.
4. Bar Spacing - spacing to the nearest user entered increment for the given bar size.
5. Develop Length - length required to develop the given bar at the given location.
6. Indication if the given bar cannot be developed - a “+” sign is used.
7. Bar Type - indicates whether a straight or hooked bar development length is used.
8. Area Provided - area of steel provided based on bar size and spacing for design width.
9. Area Required - area of steel required.
10. Actual Length - Available geometric length available in component to develop the bar.
11. Note defining "**", area of steel required by temperature and shrinkage minimum.
12. Notes for definition of “+” (bar cannot be developed) and “*” (optimal bar).

FOOTING PARALLEL TOP - pile and pedestal footings
FOOTING PARALLEL BOTTOM - pile and pedestal footings

1. Location - top and bottom parallel locations.
2. Bar Size - list of bar sizes that were considered.
3. Indicator - an asterisk “*” is used to flag the bar spacing with the least area .
4. Bar Spacing - spacing to the nearest user entered increment for the given bar size.
5. Develop Length - length required to develop the given bar at the given location; bars in the parallel direction are not checked for development - this is provided as detailing information only.
6. Area Provided - area of steel provided based on bar size and spacing for design width.
7. Area Required - area of steel required.
8. Note defining "**", area of steel required by temperature and shrinkage minimum.
9. Notes for definition of “+” (bar cannot be developed) and “*” (optimal bar).
10. Note explaining why pedestal footings do not design the footing reinforcement in the perpendicular direction (toe and heel locations).

In the stem component, the rebar details are reported for location D (base of stem), as shown in Figure 7.4.11-3.

If the reported spacing is less than the User Requested Minimum spacing or the LRFD specified minimum spacing the program will not report any development length information and will show the unrounded spacing for information purposes.

```
                                STEM Location D

                             Hooked   Straight
                              Bar      Bar              Weight    Weight
    Bar    Bar      Bar Lap  Develop  Develop  Area     with     without   Status
    Size  Space     Length   Length   Length   Prov    Cutoffs   Cutoffs   Codes
           (in)      (in)     (in)     (in)   (in^2)    (lbs)     (lbs)
     4      4.0     20.4     12.2     12.0     0.600    16.16     20.42
     5 *+   6.5     24.9     16.0     14.6     0.572    15.65     19.47
...
    10     18.0     77.0     22.0     45.3     0.847    28.81     28.81      F
    11     18.0     77.0     19.9     45.3     1.040    35.39     35.39

      Area Reqd                =  0.422 (in^2)
      Actual Length in Footing =   26.2 (in)

    Bar    Bar   Theoret    Extension    Physical   Status
    Size  Space  Cutoff   Length  Code   Cutoff     Codes
           (in)    (in)     (in)          (in)
     4      4.0    49.7     20.4   A      70.0
     5 *+   6.5    52.8     20.1   A      72.9
...
    11     18.0    N/A      N/A    A      N/A         C

    NOTE: Optimum stem bars cannot be cutoff for this design.

    Status Code Descriptions
      A - Cutoff location controlled by strength check at cutoff
      B - Cutoff location controlled by service load check at cutoff
      C - Bars could not be cut off because the resulting bar spacing would
          be greater than the maximum allowable bar spacing.
      D - Physical cutoff is at the top of wall/stem because the calculated
          value is within 2 feet of the top of wall/stem
      E - Physical cutoff is at top of wall/stem because the calculated value
          is above the actual top of wall/stem.
      F - Could not develop the bar into the footing due to insufficient
          footing thickness
      G - Development length exceeds stem height
      * - Indicates bar size and spacing with the least weight of steel per
          unit width of the structure at the base of stem when bars are
          NOT cutoff
      + - Indicates bar size and spacing with the least weight per
          unit width of the structure for the whole height of the stem
          when bars are both cutoff and full height
      **- Indicates area required was governed by the minimum temperature
          and shrinkage reinforcement criteria
      ++ - Design Spacing is less than the minimum spacing. Bar size is not
           applicable.

    Extension Length Code
      A - Effective Depth Controlled
      B - Fifteen Bar Diameters Controlled
      C - 12 inch Minimum Controlled

      Note:  The theoretical cutoff point is where every other
             bar is no longer required in the stem.

      Note:  Stem Bars at Location D are always epoxy coated as per
             DM-4 Section 5.4.3.6P
```

Figure 7.4.11-3 Design Details for Stem Location

For sake of brevity, Figure 7.4.11-3 only shows the results for the first (#4) and last bar (#11). The REINFORCEMENT DESIGN DETAILS report (stem tables, Figure 7.4.11-3) contains the following data:

STEM Location D

1. Bar Size - bar sizes considered at the given location.
2. Optimum Full Height Bar Size - an asterisk "*" is used to flag the bar/spacing with the least weight when considering full height stem bars.
3. Optimum Bar Size – a plus sign "+" is used to flag the bar/spacing with the least weight when considering full height stem bars and cutoff stem bars.
4. Spacing - spacing to the nearest user entered increment for the given bar size at the given location.
5. Bar Lap Length - lap length for the given bar size; provided as detailing information only.
6. Hooked Bar Development Length - length required to develop hooked bar in footing.
7. Develop Length - length required to develop the given bar (straight) in the stem; provided as detailing information only.
8. Area Provided - area of steel provided based on bar size and spacing for design width.
9. Weight with Cutoffs – weight of reinforcement considering cutoff stem bars for the design section of the structure.
10. Weight without Cutoffs – weight of reinforcement considering only full height stem bars for the design section of the structure.
11. Status Codes - various informational and failure codes regarding development length.
12. Area Required - area of steel required.
13. Actual Length in Footing - Available geometric length available in footing to develop the stem bar.
14. Theoret Cutoff - location where the given bar can be cutoff; based on area of required steel at that location.
15. Extension Length - extension length beyond theoretical cutoff for the given bar size.
16. Extension Code – indicates which criteria controlled the extension length.
17. Physical Cutoff - calculated location where the given bar can be cutoff; based on extension length and theoretical cutoff location.
18. Status Codes - various informational and failure codes regarding development length and cutoff locations.
19. Status Code Descriptions - definitions associated with status code A-G (see Figure 7.4.11-3).

If the reported spacing is less than the User Requested Minimum spacing or the LRFD specified minimum spacing the program will not report any development length information and will show the unrounded spacing for information purposes.

7.4.12 Optimal Design Details

The tables shown in Figure 7.4.12-1 identify the optimal rebar solution for each applicable location. The optimal solution (least area per unit width of structure) is identified by an asterisk (*) on the right of optimal

bar size in the design details report (Section 7.4.11). This format is identical to the design details format. An explanation of the format can be found in Section 7.4.11.

The OPTIMUM DESIGN DETAILS report (footing and backwall tables, Figure 7.4.12-1) contains the following data:

ABUTMENT BACKWALL AT SEAT LEVEL

1. Bar Size - optimal bar size for design at the given location.
2. Spacing - optimal bar spacing for the optimum bar size.
3. Develop Length - length required to develop the optimal bar (straight) at the given location.
4. Area Provided - area of steel provided based on bar size and spacing for design width.
5. Splice Length - length required to develop the splice of a given bar (straight).

```
ABUTMENT BACKWALL AT SEAT LEVEL

Bar      Bar     Develop  Area   Splice
Size   Spacing   Length   Prov   Length
         (in)      (in)   (in^2)   (in)
  6       9.0      12.0   0.587    20.4
```

Figure 7.4.12-1 Optimal Design Results (Backwall)

```
          FOOTING TOE (BOTTOM)                FOOTING HEEL (TOP)
Bar      Bar      Develop  Bar       Bar      Bar      Develop  Bar
Size   Spacing   Length   Type      Size   Spacing   Length   Type
         (in)      (in)                       (in)      (in)
  5       6.5      12.2    S          4      12.0      12.0    S

 Bar Type Description
    S - Straight Bar
    H - Hooked Bar

                              STEM Location D

                          Hooked   Straight
                           Bar      Bar       Weight    Weight
Bar    Bar      Bar Lap  Develop  Develop     with     without   Status
Size  Space     Length   Length   Length     Cutoffs   Cutoffs   Codes
       (in)      (in)     (in)     (in)       (lbs)     (lbs)
 6 *     9.5     32.4     19.7     19.1       18.91     18.91
 5  +    6.5     24.9     16.0     14.6       15.65     19.47

Bar   Bar   Theoret Extension Physical   Status
Size Space  Cutoff   Length   Cutoff     Codes
      (in)    (in)     (in)     (in)
 6 *    9.5    N/A      N/A      N/A         C
 5  +   6.5    52.8     20.1     72.9

NOTE: Stem bars cannot be cutoff for this design.

An architectural treatment was considered in the design of this substructure by
applying an additional dead load to the front face of the stem/wall.  However,
it is important to note all dimensions in the output are referenced to the front
face of the stem/wall that would exist when no architectural treatment is present.

Status Code Descriptions
  A - Cutoff location controlled by strength check at cutoff
  B - Cutoff location controlled by service load check at cutoff
  C - Bars could not be cut off because the resulting bar spacing would
      be greater than the maximum allowable bar spacing.
  D - Physical cutoff is at the top of wall/stem because the calculated
      value is within 2 feet of the top of wall/stem
  E - Physical cutoff is at top of wall/stem because the calculated value
      is above the actual top of wall/stem.
  F - Could not develop the bar into the footing due to insufficient
      footing thickness
  G - Development length exceeds stem height
  * - Indicates bar size and spacing with the least weight of steel per
      unit width of the structure at the base of stem when bars are
      NOT cutoff
  + - Indicates bar size and spacing with the least weight per
      unit width of the structure for the whole height of the stem
      when bars are both cutoff and full height

  Note: The theoretical cutoff point is where every other
        bar is no longer required in the stem.

  Note:  Stem Bars at Location D are always epoxy coated as per
         DM-4 Section 5.4.3.6P
```

Figure 7.4.12-2 Optimal Design Results (Footing and Stem)

The OPTIMUM DESIGN DETAILS report (footing, Figure 7.4.12-2) contains the following data:

FOOTING TOE (BOTTOM) - reported for pile and spread footings
FOOTING HEEL (TOP) - reported for pile and spread footings

1. Bar Size - optimal bar size for design at the given location.
2. Spacing - optimum bar spacing for the optimal bar size.
3. Develop Length - length required to develop the optimal bar as a straight bar.
4. Bar Type - indicates whether a straight or hooked bar development length is used.

FOOTING PARALLEL TOP - reported for pile and pedestal footings
FOOTING PARALLEL BOTTOM - reported for pile and pedestal footings

1. Bar Size - optimal bar size for design at the given location.
2. Spacing - optimal bar spacing for the optimal bar size.
3. Develop Length - length required to develop the bar as a straight bar (provided for information only to assist the engineer in detailing the reinforcement).

The OPTIMUM DESIGN DETAILS report (stem tables, Figure 7.4.12-2) contains the following data:

STEM Location D

1. Bar Size - optimal bar size for design.
2. Optimum Full Height Bar Size - an asterisk "*" is used to flag the bar/spacing with the least weight when considering full height stem bars.
3. Optimum Bar Size – a plus sign "+" is used to flag the bar/spacing with the least weight when considering full height stem bars and cutoff stem bars.
4. Spacing - optimal spacing for the optimal bar size.
5. Bar Lap Length - lap length for the optimal bar size; provided for information only to assist the engineer in detailing the reinforcement.
6. Hooked Bar Development Length - length required to develop optimal bar as a hooked bar in footing.
7. Develop Length - length required to develop the optimal bar as a straight bar in the stem; provided for information only to assist the engineer in detailing the reinforcement .
8. Weight with Cutoffs – weight of reinforcement considering cutoff stem bars for the design section of the structure.
9. Weight without Cutoffs – weight of reinforcement considering only full height stem bars for the design section of the structure.
10. Status Codes - various informational and failure codes regarding development length.
11. Theoret Cutoff - calculated location where given optimal bar size can be cutoff based on the design area of steel required at that location.
12. Extension Length - extension length required beyond the theoretical cutoff location for the optimal bar size.

13. Physical Cutoff - calculated location where the given optimal bar can be cutoff (terminated) based on the combination of the cutoff and extension length.
14. Status Codes - various informational and failure codes regarding development length and cutoff locations.
15. Status Code Descriptions - definitions associated with status code A-G (see Figure 7.4.12-2) .

7.5 INTERMEDIATE RESULTS

7.5.1 Unfactored Loads

The first section of this report provides intermediate information about the equivalent fluid pressure (Ka) used in the lateral earth pressure loads. The table provides the failure method type and all relevant values used in calculation of the Ka. A sample report is shown in Figure 7.5.1-1

LATERAL EARTH PRESSURE (EH) INTERMEDIATE VALUES

Temporary Stage

Locn	Failure Method	Ka	Kah	Kav	Soil Height (ft)	Height Ratio	Alpha (deg)	Theta (deg)	Phi-Prime (deg)	Beta (deg)
Found	Brok	--	0.32	0.06	10.57	0.50	--	--	37.00	23.59
Stem	Brok	--	0.32	0.06	8.57	0.50	--	--	37.00	23.59

Final Stage

Locn	Failure Method	Ka	Kah	Kav	Soil Height (ft)	Height Ratio	Alpha (deg)	Theta (deg)	Phi-Prime (deg)	Beta (deg)
Found	Brok	--	0.32	0.06	13.70	0.50	--	--	37.00	23.59
Stem	Brok	--	0.32	0.06	8.57	0.50	--	--	37.00	23.59

Legend
- Alpha - Angle of soil wedge measured from the vertical
- Theta - Stem back face batter angle
- Phi-Prime - Backfill internal friction angle
- Beta - Backfill slope measured from the horizontal

Figure 7.5.1-1 Sample Unfactored Loads Report for Stem Location A

The next section of the report identifies the unfactored loads that are applied to the foundation, backwall (if applicable), stem, footing and pedestal. The foundation report identifies the force and moment from the horizontal and vertical load components. A similar format is used for the backwall and stem components. However, when the vertical bearing loads are present, the stem report will show two sets of vertical moments. The 2 inch positive eccentricity (towards the toe) moment is used for the maximum load case, while a 2 inch negative eccentricity (towards the heel) moment is used for the minimum load case. If there are no vertical bearing loads present, the program will output a single moment. The footing report identifies the shear (at the face and at the effective depth) and the moment at the toe and heel locations.

The loads are reported for each applicable load type. Both vertical and horizontal load values are identified where applicable.

The unfactored loads are divided into those loads applied during the temporary construction stage and the final construction stage. A sample report of the backwall unfactored loads is shown in Figure 7.5.1-2. A sample report of the stem with vertical bearing loads is shown in Figure 7.5.1-3.

BACKWALL

Final Stage 3.05 (ft) from top of structure

Applied Load	Vertical Force (kip)	Vertical Moment (kip-ft)	Applied Load	Horizontal Force (kip)	Horizontal Moment (kip-ft)
DC-A	0.71	0.16	EH	0.16	0.20
DW-A	0.06	0.01	ES	0.00	0.00
EV	0.12	-0.06	LS	0.21	0.33
LLBW	0.00	0.00	LLBH	0.00	0.00

BACKWALL (cont.)

Final Stage 6.10 (ft) from top of structure

Applied Load	Vertical Force (kip)	Vertical Moment (kip-ft)	Applied Load	Horizontal Force (kip)	Horizontal Moment (kip-ft)
DC-A	1.47	0.16	EH	0.65	1.59
DW-A	0.06	0.01	ES	0.00	0.00
EV	0.12	-0.06	LS	0.43	1.30
LLBW	0.00	0.00	LLBH	0.00	0.00

Figure 7.5.1-2 Sample Unfactored Loads Report for the Backwall

The UNFACTORED LOADS report (backwall tables, Figure 7.5.1-2) contains the following data:

BACKWALL

1. Stage - construction stage for which loads are reported; Temporary or Final.
2. Location - backwall or stem location distance from top of structure.
3. Applied Load - abbreviated description of the load case.
4. Vertical Force - applied force due to loads applied vertically.
5. Vertical Moment - applied moment due to loads applied vertically.
6. Horizontal Force - applied force due to loads applied horizontal.
7. Horizontal Moment - applied moment due to loads applied horizontally.

STEM

Temporary Stage Location A 1.94 (ft) from top of structure

Applied Load	Vertical Force (kip)	Vertical Moment (kip-ft)	Applied Load	Horizontal Force (kip)	Horizontal Moment (kip-ft)
DC-A	0.55	0.06	EH	0.08	0.05
EV	0.08	-0.07	ES	0.00	0.00
EH-V	0.05	-0.05	LS	0.31	0.30
ES	0.00	0.00	WA	0.00	0.00
LS	0.30	-0.25	WA-E	0.00	0.00
DCAT	0.00	0.00	WSUB1+	0.00	0.00
			WSUB3+	0.00	0.00
			WSUB5+	0.00	0.00

STEM (cont.)

Final Stage Location A 1.94 (ft) from top of structure

	Vertical				Horizontal		
Applied Load	Force (kip)	2" +ecc Moment (kip-ft)	2" -ecc Moment (kip-ft)	Applied Load	Force (kip)	Moment (kip-ft)
DC-A*	0.55	0.06		EH	0.32	0.42
DC-S	3.75	1.53	0.28	ES	0.00	0.00
DW-A*	0.02	-0.02		LS	0.63	1.24
DW-S	0.35	0.14	0.03	WA	0.00	0.00
EV*	0.23	-0.20		WL+	0.10	0.19
EH-V*	0.23	-0.16		TU+	0.70	1.36
ES*	0.00	0.00		BR+D	0.12	0.23
LS*	0.30	-0.25		CE-D	0.00	0.00
WSUP	-0.22	-0.09	-0.02	BR+P	0.00	0.00
PL	0.00	0.00	0.00	CE-P	0.00	0.00
LLDD	3.14	1.28	0.24	FR+	0.00	0.00
LLDU	0.00	0.00	0.00	WA-E	0.00	0.00
LLPD	0.00	0.00	0.00	WSUP1+	0.04	0.07
LLPU	0.00	0.00	0.00	WSUP3+	0.17	0.33
DCAT*	0.00	0.00		WSUP5+	0.05	0.09
				WSUB1+	0.00	0.00
				WSUB3+	0.00	0.00
				WSUB5+	0.00	0.00

Note: An asterisk (*) indicates that the vertical load does not act through the bearings.

Figure 7.5.1-3 Sample Unfactored Loads Report for Stem Location A

The UNFACTORED LOADS report (backwall and stem tables, Figure 7.5.1-3) contains the following data:

BACKWALL

STEM

1. Stage - construction stage for which loads are reported; Temporary or Final.

2. Location - backwall or stem location distance from top of structure.
3. Applied Load - abbreviated description of the load case.
4. Vertical Force - applied force due to loads applied vertically.
5. Vertical 2”+ecc Moment - applied moment due to loads applied vertically. This column contains the single moment for non-bearing loads and the maximum load case moment with a 2 inch offset towards the toe for bearing loads.
6. Vertical 2”-ecc Moment - applied moment due to loads applied vertically . The minimum load case moment with a 2 inch offset towards the heel for bearing loads only.
7. Horizontal Force - applied force due to loads applied horizontal.
8. Horizontal Moment - applied moment due to loads applied horizontally.

Some loads applied in the final stage may not appear in the temporary stage. Furthermore, some loads only have one direction of application, either vertical or horizontal.

The pedestal unfactored load is reported as part of the footing report as shown in Figure 7.5.1-4. The pedestal self-weight values are appended to the final stage of the unfactored footing forces table. The following note defines the orientation of the moment: Foundation moments are taken about the bottom of the footing at the toe. Stem and Backwall moments are taken about the centerline of the section at the location analyzed. Positive moment clockwise; negative moment counterclockwise; toe on right; heel on left. Footing moments are the moments at the section of the toe or heel due only to those loads applied directly to the toe or heel.

FOOTING
Final Stage

Applied Load	Toe Shear Eff D (kip)	Toe Shear at Face (kip)	Toe Moment (kip-ft)	Applied Load	Heel Shear Eff D (kip)	Heel Shear at Face (kip)	Heel Moment (kip-ft)
DC-A	0.03	0.52	0.46	DC-A	0.42	0.94	1.46
WA	0.00	0.00	0.00	DW-A	0.04	0.09	0.15
				EV	1.84	4.14	6.46
				EH-V	1.16	1.16	3.63
				ES	0.00	0.00	0.00
				LS	0.33	0.75	1.17
				WA	0.00	0.00	0.00

Pedestal Self Weight : 27.32 (kip)
Pedestal Self Weight Moment : 145.91 (kip-ft)

Note: Pedestal self weight moment is taken about the front bottom corner of the pedestal acting in a counter clockwise direction, with the front face on the left side and the back face on the right side.

Figure 7.5.1-4 Sample Showing Unfactored Loads for Pedestal

The UNFACTORED LOADS report (footing tables, Figure 7.5.1-4) contains the following data:

FOOTING (pile, spread and pedestal)

1. Stage - construction stage for which loads are reported; Temporary or Final.
2. Applied Load - abbreviated description of the load case.
3. Toe Shear Eff D - shear in the toe at a distance “d” (effective depth) from face of the stem.
4. Toe Shear at Face - shear in the toe at the face of the stem.
5. Toe Moment - moment in the toe at the face of the stem.
6. Heel Shear Eff D - shear in the heel at a distance “d” (effective depth) from face of the stem.
7. Heel Shear at Face - shear in the heel at the face of the stem.
8. Heel Moment - moment in the heel at the face of the stem.

Foundation moments are taken about the bottom of the footing at the toe. Stem and Backwall moments are taken about the centerline of the section at the location analyzed. Positive moment clockwise; negative moment counterclockwise; toe on right; heel on left. Footing moments are the moments at the section of the toe or heel due only to those loads applied directly to the toe or heel.

The following information is appended for pedestal footings only:

1. Pedestal Self Weight - the self weight of the pedestal.
2. Pedestal Self Weight Moment - the moment (about the front bottom corner of the pedestal) generated by the self weight of the pedestal.
3. Note defining the pedestal self weight moment.

7.5.2 Load Factors

This report identifies the load factors that are applied for each load combination. A load combination is defined by three parts, namely: the limit state, the load case (maximum, minimum, max Vert min Horz, or min Vert min Horz) and the construction stage (temporary or final). Refer to the legend for the abbreviations.

The report is grouped by the applicable components, which are the foundation, the backwall (if applicable), the stem, the footing, and the pedestal (if applicable). The factors are applied to the unfactored loads that were described in the previous section.

For each load combination entry, a load factor is reported for each applicable load type in the vertical and/or horizontal direction. In addition, the value of the Eta factor is reported with the appropriate application symbol: “*” or “/”. The asterisk symbol indicates that the load factor is multiplied by the Eta factor. The slash symbol indicates that the load factor is divided by the Eta factor. Refer to Section 3.3.5 for further details concerning the application of the Eta factor.

Sample reports are shown in Figure 7.5.2-1 (backwall) and Figure 7.5.2-2 (footing).

BACKWALL

			Vertical						Horizontal					
Limit State	Load Case	Stage	Applied Load		Load Factor		Eta Factor		Applied Load		Load Factor		Eta Factor	
STR-I	Min	Fin	DC-A	*	0.90	/	1.01		EH	*	1.50	*	1.01	
			DW-A	*	0.65	/	1.01		ES	*	1.50	*	1.01	
			EV	*	1.00	/	1.01		LS	*	1.75	*	1.01	
			LLBW	*	0.00	/	1.01							
STR-IP	Max	Fin	DC-A	*	1.25	*	1.01		EH	*	1.50	*	1.01	
			DW-A	*	1.50	*	1.01		ES	*	1.50	*	1.01	
			EV	*	1.35	*	1.01		LS	*	1.35	*	1.01	
			LLBW	*	1.35	*	1.01							

Figure 7.5.2-1 Load Factors Applied to the Backwall Loads

FOOTING

			Toe						Heel					
Limit State	Load Case	Stage	Applied Load		Load Factor		Eta Factor		Applied Load		Load Factor		Eta Factor	
STR-I	Max	Tmp	DC-A	*	1.25	*	1.01		DC-A	*	1.25	*	1.01	
			WA	*	1.00	/	1.01		EV	*	1.35	*	1.01	
									EH-V	*	1.50	*	1.01	
									ES	*	1.50	*	1.01	
									LS	*	1.75	*	1.01	
									WA	*	1.00	/	1.01	
STR-I	Min	Tmp	DC-A	*	0.90	/	1.01		DC-A	*	0.90	/	1.01	
			WA	*	1.00	*	1.01		EV	*	1.00	/	1.01	
									EH-V	*	1.50	*	1.01	
									ES	*	1.50	*	1.01	
									LS	*	1.75	*	1.01	
									WA	*	1.00	*	1.01	

Figure 7.5.2-2 Load Factors in the Footing

Some loads applied in the final stage may not be applied in the temporary stage. Furthermore, some loads only have one orientation of application, vertical or horizontal. Hence, the only the applicable load factors are reported.

The LOAD FACTORS report (foundation, backwall and stem tables, Figure 7.5.2-1) contains the following data:

BACKWALL
STEM
FOUNDATION

1. Location - abutment component (stem, footing or backwall).
2. Load combination description - abbreviated description of the limit state, load case and stage.
3. Vertical Applied Load - abbreviated description of the load case for vertical loads.
4. Vertical Load Factor - load factor value applied to the vertical load case for the given load combination. It is preceded by the arithmetic operator ("*" multiplication or "/" division).
5. Vertical Eta Factor - eta factor value applied to the vertical load case for the given load combination. It is preceded by the applicable arithmetic operator ("*" multiplication or "/" division).
6. Horizontal Applied Load - abbreviated description of the horizontal load case for Horizontal loads.
7. Horizontal Load Factor - load factor value applied to the horizontal load case for the given load combination. It is preceded by the arithmetic operator ("*" multiplication or "/" division).
8. Horizontal Eta Factor - eta factor value applied to the horizontal load case for the given load combination. It is preceded by the applicable arithmetic operator ("*" multiplication or "/" division).

The LOAD FACTORS report (footing tables, Figure 7.5.2-2) contains the following data:

FOOTING

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Toe Applied Load - abbreviated description of the load case applied to the toe.
3. Toe Load Factor - load factor value applied to the load case for the given load combination. It is preceded by the arithmetic operator ("*" multiplication or "/" division).
4. Toe Eta Factor - eta factor value applied to the load case for the given load combination. It is preceded by the applicable arithmetic operator ("*" multiplication or "/" division).
5. Heel Applied Load - abbreviated description of the load case applied to the heel.
6. Heel Load Factor - load factor value applied to the load case for the given load combination. It is preceded by the arithmetic operator ("*" multiplication or "/" division).
7. Heel Eta Factor - eta factor value applied to the load case for the given load combination. It is preceded by the applicable arithmetic operator ("*" multiplication or "/" division).

7.5.3 Intermediate Bearing Resistance Values

This report provides intermediate values used in the calculation of the bearing resistance of soil foundations. Intermediate values are shown for each load combination (limit state / load case / stage). The list of data is for all possible values that can be shown in this report. The reports will be shown based on the soil condition and will only show values that are pertinent for that soil condition.

```
                INTERMEDIATE BEARING RESISTANCE VALUES (cont.)

                                        Number
   Limit                    Soil  Soil     of
   State   Case   Stage     Cat   Cond   Layers       Description
                             4     7      2          Loose over Dense Sand - H1<2*B'

   STR-I   Max      Tmp
                                    Gamma    Gamma
      Layer   qult     c    phi     Mass      Sat     Gamma   Sub   N       s       i     RC(BC)
              (ksf)  (ksf) (deg)    (pcf)     (pcf)   (pcf)
        1     5.52    0.0  25.0     100.0     105.0   100.00   c  46.124   1.271   0.728    n/a
                                                               g  10.887   0.682   0.526
                                                               q  10.666   1.383   0.676

                                    Gamma    Gamma
      Layer  *qult     c    phi     Mass      Sat     Gamma   Sub   N       s       i     RC(BC)
              (ksf)  (ksf) (deg)    (pcf)     (pcf)   (pcf)
        2    14.19    0.0  32.0     110.0     120.0   110.00   c  35.494   1.003   0.003   n/a
                                                               g  30.219   0.683   0.522
                                                               q  23.186   1.514   0.671

    Bearing  Final
    Resist   qult     H1     Df     Df1     B'     L'      Zw      Hu          Vu
     (ksf)   (ksf)   (ft)   (ft)   (ft)    (ft)   (ft)    (ft)  (kips/ft)   (kips/ft)
      5.53   12.2    1.90   4.00   4.00    8.11   10.0   -----     2.84       12.68

* Layer 2 qult calculation uses Gamma for Layer 1 and Gamma for Layer 2.  Refer to User
  Manual Chapter 3 / Bearing Capacity Check / Category 4: Soil Condition  7 for details.
```

Figure 7.5.3-1 Intermediate Bearing Resistance

The INTERMEDIATE BEARING RESISTANCE VALUES report contains the following data:

1. Soil Category - displays the category of the soil.
2. Soil Condition - displays the condition of the soil.
3. Description - provides a brief description of the soil condition.
4. Load combination description - abbreviated description of the limit state, load case and stage.
5. Layer – the current soil layer the values are associated with.
6. qult – the bearing resistance of the soil layer.
7. c – the cohesion value of the soil layer.
8. phi – the computed internal angle of friction (ϕ_f)for the soil layer.
9. Gamma Mass -- unit weight of moist soil.
10. Gamma Sat -- unit weight of saturated soil.
11. Gamma – the computed unit weight of soil (γ) for the soil layer.
12. Nc,Ng,Nq – bearing capacity factors (N_c,N_γ,N_q) used to calculate qult for a soil layer.
13. Sc,Sg,Sq – the footing shape factors (s_c,s_γ,s_q) used to calculate qult for a soil layer.
14. ic,ig,iq – the inclination factors (i_c,i_γ,i_q) used to calculate qult for a soil layer.
15. RC(BC) – the reduction coefficient for bearing resistance due to slope effects for a soil layer
16. Bearing Resistance – the final factored bearing resistance value for the foundation.
17. Final qult – the final bearing resistance value before factoring.
18. Df – the foundation embedment depth (D_f) taken from the ground surface to the bottom of the footing.
19. Df2 - the foundation embedment depth (D_{f2}) taken from the ground surface to the bottom of the first layer.

20. B' – the effective width of the foundation.
21. L' – the effective length of the foundation.
22. Nm – a bearing capacity factor (N_m).
23. phi f – the final average phi value (ϕ_f) of soil friction for two layers, computed for Conditions 2,3, and 9.
24. Kappa – the ratio of the cohesion values for two soil layers (κ).
25. Bm – the punching index (β_m).
26. H1 – the distance between the bottom of the footing and bottom of the first layer (H_1).
27. Delta H – the difference (Δh) between the maximum effective bearing depth (D) and the depth of the first layer (H_1).
28. H crit – The critical height of soil (H_{crit}) where a two layer soil system may be considered a single layer system.
29. qult2 – the bearing resistance value (q_{ult2})for the second layer for soil condition 6.
30. Ks – the punching shear coefficient (K_s).
31. qult,eq4 – bearing resistance value ($q_{ult,eq4}$) calculated for soil condition 8.
32. Zw -- depth of water table relative to base of footing.
33. Hu -- unfactored horizontal force on footing.
34. Vu -- unfactored vertical force on footing.

7.5.4 Moment/Axial Interaction

The moment axial report is generated for sections in the backwall and stem. At each section, the applied moment and axial force from each load combination (limit state / load case / stage) are compared to the resistance values of the section that is being checked based on either the area of steel provided (analysis run or area of steel required (design run). This table is not applicable for gravity wall structures.

The reinforcement in the section can be determined by examining the summary reinforcement report. The capacity of the section is determined from the interaction diagram based on the section properties and reinforcement. Further details about the section capacity are described in Section 3.6.2.

In a design run, the area required for each load combination is reported. The area required to satisfy rho-min considerations is reported at the end of the table, as shown in Figure 7.5.4-1. In an analysis run, the area provided (specified by the user) is reported.

For a design run in which bars can be cutoff, the results of the moment-axial interaction check are reported at the theoretical cutoff location of the largest bar that can be cutoff. These results provide the engineer with information about the margin of safety (i.e. performance factor) for strength limit states at the cutoff location. The user can corroborate the applied loads by referring to the factored forces report (see Section 7.4.4).

STEM LOCATION D 12.70 (ft) FROM TOP OF STRUCTURE

Limit State	Load Case	Stage	Applied Moment (kip-ft)	Moment Resist (kip-ft)	Applied Axial (kip)	Axial Resist (kip)	Zone	Perform Ratio	Area Reqd (in^2)	Phi Factor
STR-I	Max	Tmp	5.89	574.03	5.36	522.61	TR	97.456	0.00	0.787
STR-I	Min	Tmp	5.70	6.83	3.86	4.62	TN	1.198	0.00	0.900
STR-I	Max	Fin	51.97	52.01	29.33	29.35	TN	1.001	0.06	0.900
STR-I	Min	Fin	37.42	37.47	16.25	16.28	TN	1.001	0.08	0.900
STR-III	Max	Tmp	3.22	425.73	5.36	708.54	CM	132.128	0.00	0.750
STR-III	Min	Tmp	3.03	499.89	3.86	636.06	CM	164.741	0.00	0.750
STR-III	Max	Fin	37.47	37.48	23.20	23.21	TN	1.000	0.02	0.900
STR-III	Min	Fin	29.29	29.31	16.25	16.26	TN	1.001	0.04	0.900
STR-V	Max	Tmp	5.51	574.00	5.36	558.74	TR	104.194	0.00	0.754
STR-V	Min	Tmp	5.32	574.11	3.86	416.56	TR	107.889	0.00	0.884
STR-V	Max	Fin	50.25	50.31	27.93	27.96	TN	1.001	0.06	0.900
STR-V	Min	Fin	37.15	37.19	16.25	16.27	TN	1.001	0.08	0.900
SER-I	Max	Tmp	3.78	532.48	4.29	604.22	CM	140.844	0.00	0.750
SER-I	Min	Tmp	3.78	532.48	4.29	604.22	CM	140.844	0.00	0.750
SER-I	Max	Fin	38.51	38.51	21.84	21.84	TN	1.000	0.04	0.900
SER-I	Min	Fin	30.73	30.97	18.34	18.48	TN	1.008	0.03	0.900

Section Thickness = 49.00 (in)
Effective Depth = 45.50 (in)

Area required based on rho-min: 0.41 (in^2) **
Cracking Moment M(cr): 204.73 (kip-ft)
1.33 Mu: 69.12 (kip-ft)

** Indicates governing area of steel for the stem location

Performance Ratio = Axial Resistance / Applied Axial Force

Zone Code Descriptions
TN - Tension controlled section
TR - Transition section
CM - Compression controlled section

Phi Factor Epsilon (cl) = 0.00172
Phi Factor Epsilon (tl) = 0.00500

Notes:

A positive applied moment produces tensile stress on the backface reinforcement. A positive applied axial force produces a compressive stress on the entire cross section. Applied loads are assumed to be positive. The resistance is based on backface reinforcement only.

Figure 7.5.4-1 Moment Axial Interaction

The MOMENT AXIAL INTERACTION report contains the following data:

ABUTMENT BACKWALL
STEM LOCATION
(Shown for all bar cutoff locations when selected on the OUI command)

1. Location - backwall (backwall, seat) and stem locations (A-D) followed by distance from top of structure.
2. Load combination description - abbreviated description of the limit state, load case and stage. The results at cutoff location, if applicable, are reported at the theoretical cutoff location for the largest bar that can be cutoff.
3. Applied Moment - factored moment acting on the section for the given load combination.
4. Moment Resist - resisting moment of the section.
5. Applied Axial - factored axial load acting on the section for the given load combination.
6. Axial Resist - axial load resistance of the section.

7. Zone – indicates which strain region the phi factor is based on (see Section 3.5.2.5)
8. Perform Ratio - performance ratio (is the same for moment and axial values).
9. Area Prov - for an analysis run the provided area of steel is reported or; Area Reqd - for a design run the required area of steel is reported.
10. Section Thickness – the thickness of the section at the current location is reported.
11. Effective Depth – the effective depth of the section at the current location is reported.
12. For a design run, the following are also reported:
    - area required to satisfy rho-min
    - the cracking moment of concrete at the given location, M(cr)
    - 1.33 * M(u) – 1.33 times the controlling moment at the given location, Mu
13. Phi Factor – indicates the resistance phi factor (see Section 3.5.2.5)
14. Note defining the performance ratio.

7.5.5 Internal Footing Forces

Internal footing forces are only reported for pile and spread footings.

The internal moment reports identify the net moment that is applied at the face of the stem wall for the toe and heel sections. The net moment is the difference between the footing moment and the moment generated by the soil pressure. The moment direction condition is provided to indicate where the moment in the footing creates tension in the perpendicular reinforcement. The heel internal moments are shown in Figure 7.5.5-1.

The internal shear report identifies the net shear in the footing at the critical section location. Typically, it is a distance “d” from the face of the stem in the toe and at the face of the stem for the heel. The format of this table resembles the internal moment report. Figure 7.5.5-2 for a sample report at the heel shear location.

The vertical pile loads table identifies the vertical load on a given pile within each row (maximum of five rows). The pile load is determined for every applicable load case. A sample is shown in Figure 7.5.5-3.

The INTERNAL FOOTING FORCES - (spread footing tables, Figures 7.5.5-1, 7.5.5-2) report contains the following data:

HEEL MOMENT (spread footing)
TOE MOMENT (spread footing)

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Moment due to Soil Pressure - factored moment for the given load combination due to uniform soil pressure.
3. Moment due to Footing - factored moment from loads above footing for the given load combination.

4. Total Moment (or Total Shear) - net resultant of the applied moments or shears.
5. Moment Direction(or Shear Location) - provides the direction of moment to indicate whether the top or bottom face of the footing is in tension.
6. Definitions of total moment.

HEEL MOMENT
Critical section at stem back face

Limit State	Load Case	Stage	Moment due to Soil Pressure (kip-ft)	Moment due to Footing (kip-ft)	Total Moment (kip-ft)	Moment Direction
STR-I	Max	Tmp	3.92	5.19	1.26	1
STR-I	Min	Tmp	2.61	4.12	1.51	1
STR-I	Max	Fin	6.28	8.59	2.31	1
STR-I	Min	Fin	2.15	6.76	4.61	1
...						
SER-I	Max	Tmp	2.90	3.51	0.61	1
SER-I	Min	Tmp	2.90	3.51	0.61	1
SER-I	Max	Fin	4.33	5.98	1.65	1
SER-I	Min	Fin	3.71	5.98	2.27	1
CSS	Max	Fin	5.72	5.33	-0.39	2
CSS	Min	Fin	5.72	5.33	-0.39	2

Note: Moment direction "1" indicates that tension occurs in the top perpendicular reinforcement. Moment direction "2" indicates that tension occurs in the bottom perpendicular reinforcement.

Total Heel Moment = Moment due to Footing - Moment due to Soil Pressure

Figure 7.5.5-1 Heel Internal Moment

HEEL SHEAR (spread footing)
TOE SHEAR (spread footing)

1. Load combination description - abbreviated description of the limit state, load case and stage
2. Shear due to Soil Pressure - factored shear for the given load combination due to uniform soil pressure
3. Shear due to Footing - factored shear from loads above footing for the given load combination
4. Total Shear - net resultant of the applied shears
5. Shear Location - this indicates if the shear applies to the section at the face of the stem, at a distance “d” from the stem, or at an X distance from the back face of the stem
6. Definitions of total shear
7. The effective depth, “d”, for the cross section is reported

HEEL SHEAR

Limit State	Load Case	Stage	Shear due to Soil Pressure (kip)	Shear due to Footing (kip)	Total Shear (kip)	Shear Location
STR-I	Max	Tmp	3.32	4.20	0.88	Face
STR-I	Min	Tmp	2.23	3.29	1.06	Face
STR-I	Max	Fin	3.55	4.70	1.15	0.79 ft
STR-I	Min	Fin	2.29	5.30	3.01	Face
...						
CSS	Max	Fin	0.09	0.43	0.33	2.28 ft
CSS	Min	Fin	0.09	0.43	0.33	2.28 ft

Effective Depth 1.71 (ft)

Shear Location as distance is measured from back face of stem

Total Heel Shear = ABS(Shear due to Footing - Shear due to Soil Pressure)

Figure 7.5.5-2 Heel Shear from Internal Force Report

VERTICAL PILE LOADS

Limit State	Load Case	Stage	Eccent (ft)	Load on Single Pile within Row: Row 1 (kip)	Row 2 (kip)
STR-I	Max	Tmp	-0.18	48.25	58.71
STR-I	Min	Tmp	0.14	39.38	33.53
STR-I	Max	Fin	0.69	232.33	90.71
STR-I	Min	Fin	1.31	164.28	3.96
STR-I	MxVMnH	Fin	0.47	216.79	121.80
STR-I	MnVMnH	Fin	0.93	148.74	35.05
...					
SER-I	MnVMnH	Fin	0.16	125.35	104.53

The eccentricity is the distance from the center of gravity of the piles to the load resultant. Positive towards toe; negative towards heel.

Figure 7.5.5-3 Pile Loads from Internal Force Report

The INTERNAL FOOTING FORCES - (pile footing tables, Figure 7.5.5-3) report contains the following data:

VERTICAL PILE LOADS

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Eccent - eccentricity of the pile group measured from the center of gravity of the pile group; positive towards toe, negative towards heel.
3. Loads on Single Pile within Row - each pile row has a separate column. The vertical pile forces for a pile in a given row for the given load combination is reported.
4. Note defining the eccentricity.

The toe and heel reports for a pile footing are similar to those of a spread footing (as illustrated in Figures 7.5.5-1 and 7.5.5-2). Instead of reporting the shear and moment due to soil pressure, the shear and moment due to piles is reported.

HEEL MOMENT (pile footing)
TOE MOMENT (pile footing)

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Moment due to Piles - factored moment for the given load combination due to piles.
3. Moment due to Footing - factored moment from loads above footing for the given load combination.
4. Total Moment - net resultant of the applied moments.
5. Moment Direction - provides the direction of moment to indicate whether the top or bottom face of the footing is in tension.
6. Definitions of total moment.

HEEL SHEAR (pile footing)
TOE SHEAR (pile footing)

1. Load combination description - abbreviated description of the limit state, load case and stage.
2. Shear due to Piles - factored shear for the given load combination due to piles.
3. Shear due to Footing - factored shear from loads above footing for the given load combination.
4. Total Shear - net resultant of the applied moments or shears.
5. Shear Location - this indicates if the shear applies to the section at the face of the stem, at a distance “d” from the stem, or at an X distance from the back face of the stem.
6. Definitions of total shear.
7. The effective depth for the cross section is reported.

7.5.6 Minimum Reinforcement Check

The Minimum Reinforcement Check table is only reported for analysis runs.

The Minimum Reinforcement Check table reports relevant intermediate values used in determining the minimum reinforcement area of steel for each design location.

BACKWALL AND STEM

Location	Dist from Struc Top (ft)	Cracking Moment M(cr) (kip-ft)	1.33*M(u) (kip-ft)	Rho Min Area (in^2)	Temp Shrink Area (in^2)	Area Prov/ Width (in^2)	Status Code
Backwall	2.50	42.34	-2.64+	0.03	0.20*	0.20	
Seat	5.00	42.34	-1.36+	0.02	0.20*	0.20	
Stem A	7.38	80.04	11.41+	0.10	0.27*	1.20	
Stem B	9.58	120.98	30.62+	0.21	0.27*	1.20	
Stem C	11.79	170.35	54.19+	0.31*	0.27	1.20	
Stem D	14.00	228.15	81.70+	0.40*	0.27	1.20	

FOOTING

Location	Cracking Moment M(cr) (kip-ft)	1.33*M(u) (kip-ft)	Rho Min Area (in^2)	Temp Shrink Area (in^2)	Area Prov/ Width (in^2)	Status Code
Toe	74.82	34.68+	0.31*	0.27	0.59	
Heel	74.82	14.43+	0.12	0.27*	0.59	
Top Parallel	74.82	56.04+	0.50*	0.27	0.59	
Bot Parallel	74.82	56.04+	0.52*	0.27	0.59	

Status Code Descriptions
+ - Controlling moment for Rho Min Area calculation
* - Controlling minimum area of steel
A - Area provided smaller than required minimum area of steel

Figure 7.5.6-1 Minimum Reinforcement Check Report

BACKWALL AND STEM

1. Location - backwall (backwall, seat) and stem locations (A-D).
2. Distance from Struc Top - distance from the top of the structure to given location.
3. Cracking Moment M(cr) – cracking moment of concrete at the given location.
4. 1.33*M(u) – 1.33 times the controlling moment at the given location.
5. Rho Min Area – controlling minimum area of steel based on M(cr) and 1.33*M(u).
6. Temp Shrink Area – minimum area of steel based on temperature and shrinkage requirements.
7. Area Prov/ Width –the provided area of steel per design width is reported.
8. Status Code – indicates in the area provided is less than the minimum area required.

FOOTING

1. Location - backwall (backwall, seat) and stem locations (A-D) followed by distance from top of structure.
2. Cracking Moment M(cr) – cracking moment of concrete at the given location.
3. 1.33*M(u) – 1.33 times the controlling moment at the given location.
4. Rho Min Area – controlling minimum area of steel based on M(cr) and 1.33*M(u).
5. Temp Shrink Area – minimum area of steel based on temperature and shrinkage requirements.
6. Area Prov/ Width –the provided area of steel per location is reported.
7. Status Code – indicates in the area provided is less than the minimum area required.

7.5.7 Intermediate Settlement Data

The Intermediate Settlement Data table reports relevant intermediate values used in determining the elastic settlement for the temporary and final stages. The values reported depend on the type of footing and the type of soil or rock. The following report applies to pedestal footings on rock and rectangular footings on rock.

INTERMEDIATE SETTLEMENT DATA
(Pedestal footing on Rock)
(Rectangular footing on Rock)

Stage	Intact Elastic Modulus (ksi)	Rock Mass Modulus (ksi)	Rock Modulus (ksi)	Effective Footing Length (ft)	Effective Footing Width (ft)
Final	3.48	3.35	3.35	9.11	2.50
Temp	3.48	3.35	3.35	9.35	2.50

Stage	Ratio Length Width	Betaz Factor	Rock Factor Ip	Christian Carrier Factor (ft)	Poisson Ratio	Bearing Pressure (ksf)	Elastic Settlement (in)
Final	3.64	1.18	1.62	3.79	0.25	10.52	0.99
Temp	3.74	1.18	1.63	3.83	0.25	5.12	0.49

Figure 7.5.7-1 Intermediate Settlement Data Report for Footing on Rock

INTERMEDIATE SETTLEMENT DATA (Pedestal/Rectangular footing on Rock)

1. Stage – construction stage for which the values are reported; Temporary or Final
2. Intact Elastic Modulus – value entered on the RCK command
3. Rock Mass Modulus – value entered on the RCK command
4. Rock Modulus – the minimum of the Intact Elastic Modulus or the Rock Mass Modulus
5. Effective Footing Length – footing dimension reduced for eccentric loads
6. Effective Footing Width – footing dimension reduced for eccentric loads
7. Ratio Length Width – ratio of effective footing length to effective footing width
8. Betaz Factor – factor to account for footing shape and rigidity from AASHTO Table 10.6.2.4.2-1
9. Rock Factor Ip – influence coefficient to account for rigidity and dimensions of footing
10. Christian Carrier Factor – settlement influence factor from DM-4 Figure 10.6.2.4.2-2
11. Poisson Ratio – value entered on the RCK command
12. Bearing Pressure – maximum bearing pressure pedestal/footing
13. Elastic Settlement – computed elastic settlement

The following report applies to footings on a single soil layer, footings on two soil layers where the lower layer is much stiffer than the top layer, and footing on two soil layers where the settlement is summed for each layer.

INTERMEDIATE SETTLEMENT DATA
(Rectangular footing on single soil layer)
(Two Soil Layers - Scenario 1: lower layer much stiffer than top layer)

Stage	Soil Elastic Modulus (ksf)	Depth Factor	Effective Footing Length (ft)	Effective Footing Width (ft)	Layer Thickness Coefficient	Christian Carrier Factor (ft)	Bearing Pressure (ksf)	Elastic Settlement (in)
Final	1148.00	1.00	50.00	6.63	0.998	6.62	1.58	0.11
Temp	1148.00	1.00	50.00	6.66	0.996	6.63	1.50	0.10

Figure 7.5.7-2 Intermediate Settlement Data Report for Single Soil Layer or stiffer lower layer

INTERMEDIATE SETTLEMENT DATA (single soil or stiffer lower layer)

1. **Stage – construction stage for which the values are reported; Temporary or Final**
2. **Soil Elastic Modulus – value entered on SOI command of first/single soil layer**
3. **Depth Factor – taken as 1.0 per DM-4 10.6.2.4.2**
4. **Effective Footing Length – footing dimension reduced for eccentric loads**
5. **Effective Footing Width – footing dimension reduced for eccentric loads**
6. **Layer Thickness Coefficient – taken from DM-4 Figure 10.6.2.4.2-2**
7. **Christian Carrier Factor – elastic settlement factor used in Christian and Carrier method**
8. **Bearing Pressure – uniform bearing pressure for controlling load case**
9. **Elastic Settlement – computed elastic settlement**

The following report applies to footings on two soil layers where the lower layer is softer than the upper layer.

INTERMEDIATE SETTLEMENT DATA
(Two Soil Layers - Scenario 2: lower layer softer than upper layer)

Stage	Soil 1 Elastic Modulus (ksf)	Soil 2 Elastic Modulus (ksf)	Total Soil Depth (ft)	Elastic Distortion Factor	Shape Rigidity Factor	Depth Factor
Final	400.00	320.00	28.60	0.901	1.672	1.00
Temp	400.00	320.00	28.60	0.901	1.672	1.00

Stage	Effective Footing Length (ft)	Effective Footing Width (ft)	Layer Thickness Coefficient	Christian Carrier Factor (ft)	Bearing Pressure (ksf)	Elastic Settlement (in)
Final	51.93	20.09	0.465	14.06	4.19	2.21
Temp	51.93	20.09	0.506	13.78	2.20	1.14

Figure 7.5.7-3 Intermediate Settlement Data Report for Two Layers with lower layer softer

INTERMEDIATE SETTLEMENT DATA (lower layer softer)

1. **Stage – construction stage for which the values are reported; Temporary or Final**
2. **Soil 1 Elastic Modulus – value entered on SOI command for soil layer 1**
3. **Soil 2 Elastic Modulus – value entered on SOI command for soil layer 2**
4. **Total Soil Depth – depth of soil from bottom of footing to bottom of second soil layer**
5. **Elastic Distortion Factor – taken from User Manual Table 3.4.1-2**

6. Shape Rigidity Factor – taken from User Manual Table 3.4.1-3
7. Depth Factor – taken as 1.0 per DM-4 10.6.2.4.2
8. Effective Footing Length – footing dimension reduced for eccentric loads
9. Effective Footing Width – footing dimension reduced for eccentric loads
10. Layer Thickness Coefficient – taken from DM-4 Figure 10.6.2.4.2-2
11. Christian Carrier Factor – elastic settlement factor used in Christian and Carrier method
12. Bearing Pressure – uniform bearing pressure for controlling load case
13. Elastic Settlement – computed elastic settlement

7.6 FORMATTED OUTPUT TABLES

The following pages contain the format (i.e. the title, output parameters, units, field width and decimal locations and legends) for each output table described in this chapter in the order listed in this chapter. On each table, the character "a" represents a character value for that column and the number of "a" characters shows the number of characters possible there. The character "i" represents an integer value for that column and the character "x" represents a real value for that column with the decimal location indicated. The output available for every run of the program may not include all of the output tables shown. Depending on such items as the live loadings, type of run, specifications checked, and output commands and parameters chosen, the program will print different combinations of these output reports.

7.6.1 INPUT ECHO Report Format - Using Spread Footing Input

```
                                    EX14.DAT
                                    --------
TTL Example Problem 14 - Analysis of Abutment Type I on spread footing
TTL
TTL
TTL This problem is based on Example 1
!
CFG 83,0
!
! Control Data
!
CTL  US, A,
!
!
! Abutment Type 1
!
AT1  12.7, 15.0, 29.0, 0.0, 48.2, 4.0, 21.0, 4.0, 9.0, 16.0, 14.0, , ,-
    10.95
!
!
! Footing
!
FTG  2.0, 2.58, 2.33, , , , ,
!
!
! Spread Footing - analysis case: don't specify anything
!
!
! Materials
!
MAT  3.5, 3.0, 3.0, 50.0, N, N, N
!
!
! Soil Layer
!
SOI  14.7, 50.2, N, 2.0, 1.0, 0.5, 0.85, 1, 10., ,  120., 135., 500., 0.3,-
    1.0, 30., ,
```

7.6.2 INPUT COMMANDS Report Format - Using Spread Footing Input

```
COMMAND:  CFG
  MAXIMUM   LINES PER PAGE            83
  TOP BLANK LINES PER PAGE             0

COMMAND:  CTL
  SYSTEM OF UNITS                     US
  TYPE OF RUN                          A
  FOOTING DATUM                        *        (computed, if necessary)

COMMAND:  AT1
  HEIGHT                           12.7 ft
  TOP WIDTH                        15.0 in
  SEAT WIDTH                       29.0 in
  SEAT SLOPE HEIGHT                 0.0 in
  SEAT FACE HEIGHT                 48.2 in
  CORBEL WIDTH                      4.0 in
  CORBEL HEIGHT                    21.0 in
  CORBEL SLOPE HEIGHT               4.0 in
  PAVING NOTCH WIDTH                9.0 in
  PAVING NOTCH HEIGHT              16.0 in
  BEARING LOCATION - X DIR         14.0 in
  BEARING LOCATION - Y DIR            * in     (computed, if necessary)
  FRONT WATER LEVEL                   * ft     (computed, if necessary)
  BACK  WATER LEVEL               10.95 ft
  ARCHT TREAT THICKNESS             0.0 in         (default)
  BACKWALL STEM  BAR ALIGN            *        (computed, if necessary)

COMMAND:  FTG
  MINIMUM FOOTING THICKNESS         2.0 ft
  MINIMUM TOE  PROJECTION          2.58 ft
  MINIMUM HEEL PROJECTION          2.33 ft
  MINIMUM FOOTING WIDTH               * ft     (computed, if necessary)
  MAXIMUM FOOTING THICKNESS           * ft     (computed, if necessary)
  MAXIMUM TOE  PROJECTION             * ft     (computed, if necessary)
  MAXIMUM HEEL PROJECTION             * ft     (computed, if necessary)
  MAXIMUM FOOTING WIDTH               * ft     (computed, if necessary)
  FOOTING THICK INCREMENT           2.0 in         (default)
  FOOTING WIDTH INCREMENT           3.0 in         (default)
  FOOTING STEM INCREMENT            1.0 in         (default)

COMMAND:  MAT
  BACKWALL CONC. STRENGTH           3.5 ksi
  STEM     CONC. STRENGTH           3.0 ksi
  FOOTING  CONC. STRENGTH           3.0 ksi
  REINF.   YIELD STRENGTH          50.0 ksi
  EPOXY COAT BARS - BACK              N
  EPOXY COAT BARS - STEM              N
  EPOXY COAT BARS - FOOT              N
  BACKFILL FRICTION ANGLE         33.25 deg        (default)
  BACKFILL UNIT WEIGHT DRY        120.0 lb/ft^3    (default)
  BACKFILL UNIT WEIGHT SAT        135.0 lb/ft^3    (default)
  MIN EQUIV EARTH PRESSURE         35.0 lb/ft^3    (default)
  DENSITY OF CONC. FOR DL         150.0 lb/ft^3    (default)
  DENSITY OF CONC. FOR E          145.0 lb/ft^3    (default)
  DENSITY OF CONC. FOR AT         150.0 lb/ft^3    (default)
  REINF ULT TENS STRENGTH            75 ksi
```

```
COMMAND:  SOI
 STEM TOP TO SOIL LAYER          14.7 ft
 FOOTING LENGTH (PARALLEL)       50.2 ft
 FOOTING NEAR SLOPE?                N
 SOIL LEVEL OVER TOE              2.0 ft
 ALLOWABLE SETTLEMENT             1.0 in
 BEARING CAPACITY PHI             0.5
 SLIDING PHI FACTOR              0.85
 NUMBER OF SOIL LAYERS              1
 L1 SOIL LAYER THICKNESS          10. ft
 L1 UNDRAINED SHEAR STR             * ksf    (computed, if necessary)
 L1 MASS UNIT WEIGHT             120. lb/ft^3
 L1 SAT UNIT WEIGHT              135. lb/ft^3
 L1 ELASTIC MODULUS              500. ksf
 L1 POISSONS RATIO                0.3
 L1 COHESION                      1.0 ksf
 L1 FRIC ANGLE(EFFECT)            30. deg
 L1 NCQ (NEAR SLOPE)                *        (computed, if necessary)
 L1 N_GAMMA_Q(NEAR SLOPE)           *        (computed, if necessary)
 L2 SOIL LAYER THICKNESS            * ft     (computed, if necessary)
 L2 UNDRAINED SHEAR STR             * ksf    (computed, if necessary)
 L2 MASS UNIT WEIGHT                * lb/ft^3 (computed, if necessary
 L2 SAT UNIT WEIGHT                 * lb/ft^3 (computed, if necessary
 L2 ELASTIC MODULUS                 * ksf    (computed, if necessary)
 L2 POISSONS RATIO                  *        (computed, if necessary)
 L2 COHESION                        * ksf    (computed, if necessary)
 L2 FRIC ANGLE (EFFECT)             * deg    (computed, if necessary)
 L2 NCQ     (NEAR SLOPE)            *        (computed, if necessary)
 L2 N_GAMMA_Q(NEAR SLOPE)           *        (computed, if necessary)
 APPLY INCLINATION FACTORS          Y            (default)
 PRECAST OR CAST-IN-PLACE           C            (default)
 L1 REDUC COEFF RCBC                *        (computed, if necessary)
 L2 REDUC COEFF RCBC                *        (computed, if necessary)

COMMAND:  CNS
 NUMBER OF LAYERS                   1
 VOID RATIO                       0.8
 COMPRESSION INDEX                0.1
 RECOMPRESSION INDEX             0.02
 SECONDARY COMP. INDEX          0.002
 EFF. STRESS (INITIAL)        0.01041 ksi
 EFF. STRESS (MAX PAST-T)     0.01388 ksi
 PRIMARY CONSOLID. (T1)           0.1 year
 SERVICE LIFE      (T2)            5. year
 EFF. STRESS (MAX PAST-B)     0.01388 ksi

COMMAND:  MRD
  AGGREGATE SIZE                  1.0 in
  DEVELOPMENT CORRECTION          1.0            (default)
  BACKWALL EXPOSURE                 S
  STEM     EXPOSURE                 S
  FOOTING  EXPOSURE                 S

COMMAND:  CVR
  BACKWALL BACK  - VERT.          3.0 in
  STEM BACK  - VERTICAL           3.0 in
  FOOTING TOP    PERPEND.         3.0 in
  FOOTING TOP    PARALLEL         4.0 in
  FOOTING BOTTOM PERPEND.         4.0 in
```

```
  FOOTING BOTTOM PARALLEL          5.0 in
  TOE  END COVER                   4.0 in         (default)
  HEEL END COVER                   4.0 in         (default)

COMMAND:  SPA
  BACKWALL BACK  - VERT.          12.0 in
  FOOTING TOP    PERPEND.         12.0 in
  FOOTING TOP    PARALLEL            * in     (computed, if necessary)
  FOOTING BOTTOM PERPEND.         12.0 in
  FOOTING BOTTOM PARALLEL            * in     (computed, if necessary)

COMMAND:  BAR
  BACKWALL BACK  - VERT.             8 US bar
  FOOTING TOP    PERPEND.            8 US bar
  FOOTING TOP    PARALLEL            * US bar (computed, if necessary)
  FOOTING BOTTOM PERPEND.            8 US bar
  FOOTING BOTTOM PARALLEL            * US bar (computed, if necessary)

COMMAND:  SRB
  BAR SIZE                           8 US bar
  BAR SPACING                     12.0 in
  GROUP OFFSET                       * in     (computed, if necessary)
  END   LOCATION                  12.7 ft

COMMAND:  LDC
  DUCTILITY  FACTOR (ETA)          1.0
  REDUNDANCY FACTOR (ETA)          1.0
  IMPORTANCE FACTOR (ETA)          1.0
  LS  (TEMP  STAGE)                2.0 ft
  LS  (FINAL STAGE)                2.0 ft
  ES  (TEMP  STAGE)                0.0 ft
  ES  (FINAL STAGE)                0.0 ft

COMMAND:  LAB
 DC - SUPERSTRUCTURE              11.4 kip/ft
 DW - SUPERSTRUCTURE               1.0 kip/ft
 PL - PEDESTRIAN                     * kip/ft (computed, if necessary)
 WS - WIND VERT ON SUP             0.0 kip/ft
 WS - WIND HORZ ON SUP               * kip/ft (computed, if necessary)
 WL - WIND ON LIVE LOAD           0.21 kip/ft
 TU - THERMAL FORCE               0.37 kip/ft
 BACKWALL VERTICAL LL              0.0 kip/ft
 BACKWALL HORIZONTAL LL              * kip/ft (computed, if necessary)
 WS - WIND HORZ ON SUB             0.0 kip/ft     (default)
 FR - FRICTION FORCE               0.0 kip/ft     (default)
 WS1 - WIN HORZ SUP SRV 1        0.117 kip/ft
 WS3 - WIN HORZ SUP STR 3        0.546 kip/ft
 WS5 - WIN HORZ SUP STR 5        0.156 kip/ft
 WS1 - WIN HORZ SUB SRV 1          0.0 kip/ft     (default)
 WS3 - WIN HORZ SUB STR 3          0.0 kip/ft     (default)
 WS5 - WIN HORZ SUB STR 5          0.0 kip/ft     (default)

COMMAND:  ASL
  APPROACH SLAB DEAD LOAD            4 kip/ft
  APPROACH SLAB LIVE LOAD            1 kip/ft
  X DISTANCE TO AS LOAD             24 in
  APPR SLAB ON BEAM NOTCH            N
  APPROACH SLAB DW LOAD            0.0 kip/ft
  TYPE 4 FLEXIBLE PAVEMENT?          N
```

```
    TYPE 4 DRAIN WIDTH                46.0 in
    TYPE 4 AVG DRAIN HEIGHT           24.0 in
    TYPE 4 DRAIN WALL THK             27.0 in
    TYPE 4 DRAIN BOT SLAB THK         12.0 in
    TYPE 4 DRAIN SUP PED WID          18.0 in
    TYPE 4 DRAIN SUP PED SPC          84.0 in
    TYPE 4 PAVING NOTCH WIDTH          9.0 in
    TYPE 4 PAVING NOTCH HT            16.0 in

  COMMAND:  DLL
    LL - LIVE LOAD - DOWNWARD          3.5 kip/ft
    LL - LIVE LOAD -   UPWARD          0.0 kip/ft
    BR - BRAKING FORCE                0.16 kip/ft
    CE - CENTRIFUGAL FORCE             0.0 kip/ft

  COMMAND:  EQL
   RESPONSE MODIFICATION              1.0
   SOIL PRESSURE FACTOR               1.0            (default)
   PHI FACTOR FOUNDATION              0.7
   VERTICAL EQ SOIL                     Y
   HORIZ SUPER FORCE                  1.5 kip/ft
   HORIZ EXTERN STRUCT FORCE            * kip/ft (computed, if necessary)

   COMMAND:  OIN
    INPUT FILE ECHO                     1
    INPUT COMMANDS                      1
    INPUT SUMMARY                       1

  COMMAND:  OUR
    FOOTING GEOMETRY                    1
    OUTPUT LEGEND                       1
    FACTORED FORCES                     1
    FOOTING STABILITY                   1
    CONTROL FOOTING FORCES              1
    FOOTING FLEXURE                     1
    REINFORCEMENT SUMMARY               1
    CRACK CONTROL                       1
    SHEAR RESULTS                       1
    DEVELOPMENT LENGTH                  1

  COMMAND:  OUI
    UNFACTORED LOADS                    1
    LOAD FACTORS                        1
    MOMENT AXIAL INTERACTION            1
    INTERNAL FOOTING FORCES             1
    DETAILED CUTOFF VALUES              1
    MIN REINFORCEMENT CHECK             1
```

7.6.3 INPUT SUMMARY Report Format

```
                                CONFIGURATION
 Lines      Blank
  per       Lines
  Page     on Top
   ii         ii
```

CONTROL

Sys of Units	Type of Run	Footing Datum
aa	a	a

ABUTMENT TYPE I

Height (ft)	Top Width (in)	Seat Width (in)	Seat Slope Height (in)	Seat Face Height (in)	Corbel Width (in)	Corbel Height (in)	Corbel Slope Height (in)
xxx.xx	xxx.x	xxx.x	xx.x	xxx.x	xx.x	xxx.x	xx.x

Paving Notch Width (in)	Paving Notch Height (in)	Bearing X Locn (in)	Bearing Y Locn (in)	Front Water Level (ft)	Back Water Level (ft)	Architectural Treatment Thickness (in)	Backwall/ Stem Bar Alignment
xx.x	xx.x	xx.x	xxx.x	xxx.xx	xxx.xx	xx.x	aaa

NOTE: An architectural treatment has been specified. All structure dimensions shown do not account for the architectural treatment. For drafting purposes the architectural treatment thickness is used to dimension the architectural treatment along the front face of the stem.

ABUTMENT TYPE II

Height (ft)	Top Width (in)	Seat Width (in)	Seat Slope Height (in)	Seat Face Height (in)	Corbel Width (in)	Corbel Height (in)	Corbel Slope Height (in)	Paving Notch Width (in)	Paving Notch Height (in)
xxx.xx	xxx.x	xxx.x	xx.x	xxx.x	xx.x	xxx.x	xx.x	xx.x	xx.x

Backwall Height (in)	Stem Notch Width (in)	Stem Notch Height (in)	Front Face Horizontal Component	Front Face Vertical Component	Back Face Horizontal Component	Back Face Vertical Component
xxx.x	xxx.x	xxx.x	xxx.xx	xxx.xx	xxx.xx	xxx.xx

Bearing X Locn (in)	Bearing Y Locn (in)	Front Water Level (ft)	Back Water Level (ft)	Architectural Treatment Thickness (in)	Backwall/ Stem Bar Alignment
xx.x	xxx.x	xxx.xx	xxx.xx	xx.x	aaa

ABUTMENT WITHOUT BACKWALL

Height (ft)	Top Width (in)	Bearing Location (in)	Front Face Horizontal Component	Front Face Vertical Component	Back Face Horizontal Component	Back Face Vertical Component
xxx.xx	xxx.x	xx.x	xxx.xx	xxx.xx	xxx.xx	xxx.xx

Additional Fill Height (ft)	Front Water Level (ft)	Back Water Level (ft)	Type of Wall	Architectural Treatment Thickness (in)
xx.xx	xxx.xx	xxx.xx	a	xx.x

RETAINING WALL

Height (ft)	Top Width (in)	Front Face Horizontal Component	Front Face Vertical Component	Back Face Horizontal Component	Back Face Vertical Component
xxx.xx	xxx.x	xxx.xx	xxx.xx	xxx.xx	xxx.xx

Exposed Stem Height (in)	Backfill Horizontal Component	Backfill Vertical Component	Backfill Slope Height (ft)	Front Water Level (ft)	Back Water Level (ft)	Type of Wall	Architectural Treatment Thickness (in)
xxx.x	xxx.xx	xxx.xx	xxx.xx	xxx.xx	xxx.xx	a	xx.x

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
xx.xx	xx.xx	xx.xx	xxx.xx	xxx.xx	xxx.xx	xxx.xx	xxx.xx

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
xx.xx	xx.xx	xx.xx

SPREAD

Design Optim	Cost of Concrete ($/yd^3)	Cut or Fill	Cost of Fill ($/yd^3)	Cost of Cut ($/yd^3)	Ground Elev (ft)	Ground Slope Type	Ground Slope Vert	Ground Slope Horiz
a	xxxx.xx	a	xxxx.xx	xxxx.xx	xxxx.xx	a	xxx.x	xxx.x

PILE

Pile Dim A (in)	Pile Dim B (in)	Pile Embedment (in)	Service Axial Capacity (kip)	Strength Axial Capacity (kip)	Service Lateral Capacity (kip)	Strength Lateral Capacity (kip)	Allowed Uplift (kip)
xx.x	xx.x	xx.x	xxxx.xx	xxxx.xx	xxx.xx	xxx.xx	xxx.xx

CAISSON

Caisson Diameter (in)	Caisson Embedment (in)	Service Axial Capacity (kip)	Strength Axial Capacity (kip)	Service Lateral Capacity (kip)	Strength Lateral Capacity (kip)	Allowed Uplift (kip)
xxx.x	xxx.x	xxxx.xx	xxxx.xx	xxx.xx	xxx.xx	xx.x

PEDESTAL FOOTING

Pedestal Spacing (ft)	Overall Height (ft)	Front Height (ft)	Min Width (ft)	Min Thick (in)	Front Proj (ft)	Back Offset (ft)	Max Width (ft)	Max Thick (in)	**Design Optimization**
xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	**aaaa**

PILE/CAISSON LAYOUT DESIGN

Toe to First Row (ft)	Minimum Heel to Last Row (ft)	Minimum Spacing (ft)	Maximum Spacing (ft)	Row Placement	Pile Spacing Rounding (ft)	Row Distances Rounding (ft)
xx.xx	xx.xx	xx.xx	xx.xx	a	xx.xx	xx.xx

Design Batt Horizontal Component	Design Batt Vertical Component	Last Row % Batter (%)	Optimize	Pile/ Caisson Cost ($/pile)	Footing Cost ($/yd^3)
xxx.xx	xxx.xx	xx.x	a	xxxxx.xx	xxxx.xx

PILE/CAISSON LAYOUT ANALYSIS

Row Number	Row Distance (ft)	Spacing within a Row (ft)	Percent Battered (%)	Horizontal Component	Vertical Component
ii	xx.xx	xx.xx	xxx.x	xxx.xx	xxx.xx
ii	xx.xx	xx.xx	xxx.x	xxx.xx	xxx.xx

MATERIALS

Backwall f'c (ksi)	Stem f'c (ksi)	Footing f'c (ksi)	fy (ksi)	Reinforcement Backwall	Epoxy Coated Stem	Epoxy Coated Footing
x.xxx	x.xxx	x.xxx	xx.xxx	aa	aa	aa

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	Concrete Density For Ec (lb/ft^3)
xx.xx	xxxx.x	xxxx.x	xxxx.x	xxx.x	xxx.x

Architectural Treatment Density (lb/ft^3)	fu (ksi)
xxx.x	xxx.xx

SOIL

Stem Top to Soil Layer (ft)	Footing Length (Parallel) (ft)	Footing Near Slope	Soil Level At Toe (ft)	Allow Settle (in)	Bearing Cap Resistance Factor	Sliding Resist Factor	No.Soil Layers
xxx.xx	xxx.xx	a	xxx.xx	xx.xx	x.xx	x.xx	i

Soil Layer Number	Soil Layer Thick (ft)	Undrained Shear Strength (ksf)	Mass Unit Weight/ Density (lb/ft^3)	Saturated Unit Weight/ Density (lb/ft^3)	Elastic Modulus (ksf)	Poissons Ratio
i	xxx.xx	xxxx.xx	xxx.xx	xxxx.xx	xxxx.xx	x.xx

Soil Layer Number	Cohesion (ksf)	Effective Fraction Angle (deg)	Ncq	N Gamma q
i	xsx.xx	xxx.xx	n/a	n/a
i	xsx.xx	xxx.xx	n/a	n/a

Apply Inclination Factors a	Precast or Cast-in-Place a	Reduction Coefficients RC(BC) Layer 1	Layer 2
		x.xx	x.xx

ROCK

Empirical Bearing Capacity (ksf)	Stem Top to Rock Layer (ft)	Footing Length Parallel (ft)	Sliding Resistance	Allow Settle (in)	Bear Cap Resist Factor	Sliding Resist Factor
xxxxx.xx	xxx.xx	xxx.xx	a	xx.xx	x.xx	x.xx

RQD (%)	Concrete /Rock Friction (deg)	Intact Elastic Modulus (ksi)	Poissons Ratio	Rock Mass Rating	Elastic Modulus Reduction	Rock Mass Modulus (ksi)
aaaaa	xx.xx	xxxxx.xx	x.xx	aaaaa	aaaaa	xxxxx.xx

CONSOLIDATION SETTLEMENT

Layer Number	Void Ratio	Compr Index	Recompr Index	Second Compr Index	Init Effect Stress (ksi)	Max Past Effect Stress Top (ksi)	Prim Consol (year)	Serv Life (year)	Max Past Effect Stress Bottom (ksi)
i	x.xx	x.xx	x.xx	x.xxx	xxx.xx	xxx.xx	xxx.x	xxx.x	xxx.xx
i	x.xx	x.xx	x.xx	x.xxx	xxx.xx	xxx.xx	xxx.x	xxx.x	xxx.xx

MISCELLANEOUS REINFORCEMENT DATA

Aggregate Size (in)	Development Correction	Backwall Exposure Class	Stem Exposure Class	Footing Exposure Class
x.xx	x.xx	a	a	a

REINFORCEMENT COVER

Backwall Back Vertical (in)	Stem Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)	Toe End (in)	Heel End (in)
xx.x	xx.x	xx.x	xx.xa	xx.x	xx.xa	xx.x	xx.x

* - Calculated minimum parallel cover controlled for design

BAR SPACING FOR DESIGN

Backwall Maximum Bar Diam (in)	Stem Maximum Bar Diam (in)	Footing Maximum Bar Diam (in)	Hooked Footing Bars	User Requested Minimum Bar Spacing (in)	Bar Spacing Increment (in)
x.xx	x.xx	x.xx	aaa	xx.xx	xx.xx

BAR SIZE

Backwall Back Vertical (US bar)	Footing Perpend Top (US bar)	Footing Parallel Top (US bar)	Footing Perpend Bottom (US bar)	Footing Parallel Bottom (US bar)	Footing Perp Top Bar Type	Footing Perp Bot Bar Type
ii	ii	ii	ii	ii	aaaaaaaa	aaaaaaaa

BAR SPACING FOR ANALYSIS

Backwall Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)
xx.x	xx.x	xx.x	xx.x	xx.x

REINFORCEMENT AREA

Backwall Back Vertical (in^2)	Footing Top Perpend (in^2)	Footing Top Parallel (in^2)	Footing Bottom Perpend (in^2)	Footing Bottom Parallel (in^2)
xx.xx	xx.xx	xx.xx	xx.xx	xx.xx

Effective Diam in Backwall (in)	Eff Diam Ftg Top Perpend (in)	Eff Diam Ftg Top Parallel (in)	Eff Diam Ftg Bot Perpend (in)	Eff Diam Ftg Bot Parallel (in)
x.xx	x.xx	x.xx	x.xx	x.xx

STEM REINFORCING AREA

Range Number	Area/ Width (in^2)	End Location (ft)	Max Bar Diameter (in)
ii	xx.xx	xxx.xx	x.xxx
ii	xx.xx	xxx.xx	x.xxx

STEM REINFORCING BARS

Range Number	Bar Size (US bar)	Bar Spacing (in)	Group Offset (in)	End Location (ft)
ii	ii	xx.xx	xx.xx	xxx.xx
ii	ii	xx.xx	xx.xx	xxx.xx

LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
x.xx	x.xx	x.xx	xx.xx	xx.xx	xx.xx	xx.xx

LOADS ON ABUTMENTS

							Backwall	
			Vertical	Horizontal			Vertical	Horizontal
DC (kip/ft)	DW (kip/ft)	PL (kip/ft)	WSUP (kip/ft)	WSUP (kip/ft)	WL (kip/ft)	TU (kip/ft)	LL (kip/ft)	LL (kip/ft)
xxx.xx	xxx.xx	xxx.xx	xxx.xx	n/a	xxx.xx	xxx.xx	xxx.xx	aaaaaa

Horizontal		Horizontal WSUP			Horizontal WSUB		
WSUB (kip/ft)	FR (kip/ft)	SER-I (kip/ft)	STR-III (kip/ft)	STR-V (kip/ft)	SER-I (kip/ft)	STR-III (kip/ft)	STR-V (kip/ft)
n/a	xxx.xx	xxx.xx	xxx.xx	xxx.xx	xxx.xx	xxx.xx	xxx.xx

APPROACH SLAB LOADS

Approach Slab DC (kip/ft)	Approach Slab LL (kip/ft)	X distance to Approach Slab Load (in)	Approach Slab on Beam Notch	Approach Slab DW (kip/ft)
xxx.xx	xxx.xx	xxx.xx	a	xxx.xx

Approach Slab Type 4 Properties

Flexible Pavement?	Drain Width (in)	Average Drain Height (in)	Drain Wall Thickness (in)	Bottom Slab Thickness (in)	Drain Pedestal Width (in)	Drain Pedestal Spacing (in)	Paving Notch Width (in)	Paving Notch Height (in)
a	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx

LOADS ON RETAINING WALLS

CT (kip/ft)	Y Distance to CT (in)	Parapet Dead Load (kip/ft)	X Distance to Parapet (in)	Noise Wall Dead Load (kip/ft)	X Distance to Noise Wall (in)
aaaaaa	aaaaaa	xxx.xx	xxx.x	xxx.xx	xxx.x

Wind on External Structure (kip/ft)	Y Distance to Wind on External Structure (in)	Wind on External Structure SER-I (kip/ft)	STR-III (kip/ft)	STR-V (kip/ft)
n/a	xxx.x	aaaaaa	aaaaaa	aaaaaa

Wind on Substructure (Wall)

SER-I (kip/ft)	**STR-III (kip/ft)**	**STR-V (kip/ft)**
aaaaaa	**aaaaaa**	**aaaaaa**

DESIGN LIVE LOAD

Downward LL (kip/ft)	Upward LL (kip/ft)	BR (kip/ft)	CE (kip/ft)
xxx.xx	xxx.xx	xxx.xx	xxx.xx

SPECIAL LIVE LOAD

Downward LL (kip/ft)	Upward LL (kip/ft)	BR (kip/ft)	CE (kip/ft)	STR 1 Factor	STR 1P Factor	STR 2 Factor	STR 3 Factor	STR 5 Factor	EXT 1 Factor	SER 1 Factor
xxx.xx	xxx.xx	xxx.xx	xxx.xx	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx

EARTHQUAKE LOADS

Response Modification	Soil Pressure Factor	Phi Factor Foundation	Vertical EQ Soil	Horizontal Superstructure Force (kip/ft)	Horizontal External Structure Force (kip/ft)
x.xx	x.xx	x.xx	N/A	aaaaaa	aaaaaa

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
I	I	I

OUTPUT OF RESULTS

Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Footing Flexure	Reinf Summary
I	I	I	I	I	I	I

Crack Control	Shear Results	Development Length
I	I	I

OUTPUT OF INTERMEDIATE DATA

Unfactored **Forces**	Load Factors	Moment/Axial Interaction	Internal Footing Forces	Intermediate Bearing Resist**ance** Values	Detailed Stem Cutoff Load Values
I	I	I	I	I	I

Minimum Reinf**orcement** Check	**Intermediate Settlement Data**
I	**I**

7.6.4 ADDITIONAL INFORMATION Report Summary

FOOTING GEOMETRY

Footing Thick (ft)	Footing Width (ft)	Projection Toe (ft)	Projection Heel (ft)	Effective Depth Toe (ft)	Effective Depth Heel (ft)	Stem Width Footing Top (ft)
xxx.xx	xxx.xx	xxx.xx	xxx.xx	xxx.xx	xxx.xx	xxx.xx

NOTE: An architectural treatment has been specified. The toe projection is referenced from the front face of the stem and does not include the thickness of the architectural treatment.

Moments are assumed to cause tension on the bottom face of the footing at the toe and on the top face of the footing at the heel. Effective depths are based on this assumption.

Note: The acceptable range of toe projections for **the given FOOTING GEOMETRY is**: xx.xx ft to xx.xx ft.

Note: The acceptable range of toe projections for the given FOOTING GEOMETRY and PEDESTAL GEOMETRY is: xx.xx ft to xx.xx ft.

Note: The acceptable range of toe projections for the given FOOTING GEOMETRY and PILE PATTERN is: xx.xx ft to xx.xx ft.

Note: The acceptable range of toe projections for the given FOOTING GEOMETRY and CAISSON PATTERN is: xx.xx ft to xx.xx ft.

COMPUTED VALUES

Front Water Level (ft)(1)	Concrete Density Factor (2)	Modulus of Rupture (3) Backwall (ksi)	Modulus of Rupture (3) Stem (ksi)	Modulus of Rupture (3) Footing (ksi)	Modulus of Elasticity Backwall (ksi)	Modulus of Elasticity Stem (ksi)	Modulus of Elasticity Footing (ksi)	Modular Ratio Bckw	Modular Ratio Stem	Modular Ratio Foot
xx.xx	X.XXX	X.XXX	X.XXX	X.XXX	XXXX.	XXXX.	XXXX.	XX.	XX.	XX

Notes: (1) The computed value complies with DM-4 Section 3.11.3.
(2) The concrete density modification factor is defined according to AASHTO LRFD Specifications Section 5.4.2.8.
(3) Modulus of Rupture defined according to AASHTO LRFD Specifications Section 5.4.2.6.

PEDESTAL GEOMETRY

Back Offset (ft)	Width (ft)	Height (ft)	Front Height (ft)	Front Proj (ft)	Clear Spacing (ft)	Thick (ft)	Slope Horiz Proj (ft)	Density (ft^3/ft)
xx.xxx	xx.xxx	xx.xxx	xx.xxx	xx.xxx	xx.xxx	xx.xxx	xx.xxx	xxx.xxx

PILE PATTERN
CAISSON PATTERN

Toe to CG of Piles / Toe to CG of Caissons (ft)	Pile Group Inertia / Caisson Group Inertia (ft^4)	Pile Density / Caisson Density (pile/ft)	(design runs only) Pile Pattern
xxxx.xx	xxxxx.xxx	xxxxx.xxx	aaaaaaaaa

```
  Toe to CG of Piles     Pile Group Inertia       Footing Size
Toe to CG of Caissons   Caisson Group Inertia     Footing Size
      (ft)                    (ft^4)                (ft^3)
      xxxx.xx               xxxxx.xxx            xxxxx.xxx             aaaaaaaaa
  Toe to CG of Piles     Pile Group Inertia       Footing Cost
Toe to CG of Caissons   Caisson Group Inertia     Footing Cost
      (ft)                    (ft^4)                ($/ft)
      xxxx.xx               xxxxx.xxx            xxxxx.xxx             aaaaaaaaa


            Distance    Pile Spacing    Batter Component     Percent
     Row   Toe to Row    within Row     Horiz       Vert    Battered
              (ft)          (ft)                              (%)
      xx     xxx.xx        xxx.xx       xxx.xx    xxx.xx      xxx.x
      xx     xxx.xx        xxx.xx        Vertical Piles
      xx     xxx.xx        xxx.xx       Vertical Caisson
```

7.6.5 OUTPUT LEGEND Report Summary

```
    Abbrev    Limit State    Description
    aaaaaaa   aaaaaaaaaaaa - aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa

    Abbrev    Load Case      Description
    aaaaaa    aaaaaaa      - aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa

    Abbrev    Stage          Description
    aaa       aaaaaaaaa    - aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa

    Abbrev    Loads          Description
    aaaaaaaa  aa           - aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa

              Symbol         Explanation
              a            - aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa

              Status Code    Description
              aa           - aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
```

7.6.6 FACTORED FORCES Report Format

```
                ABUTMENT BACKWALL  xxx.xx (ft) FROM TOP OF STRUCTURE
 ABUTMENT BACKWALL AT SEAT LEVEL  xxx.xx (ft) FROM TOP OF STRUCTURE

    Limit   Load
    State   Case   Stage      Axial     Moment      Shear
                              (kip)    (kip-ft)     (kip)
    aaaaaaaaaaaaaaaaaaa   xxxxx.xx   xxxxx.xx   xxxxx.xx


             STEM LOCATION a  xx.xxx (ft)  FROM TOP OF STRUCTURE
      STEM CUTOFF LOCATION - #II @ xxx.xx (ft)  FROM TOP OF STRUCTURE

    Limit   Load
    State   Case   Stage      Axial     Moment      Shear
                              (kip)    (kip-ft)     (kip)
    aaaaaaaaaaaaaaaaaaa   xxxxx.xx   xxxxx.xx   xxxxx.xx
```

FOOTING – W/O FOUNDATION PRESSURE

Limit State	Load Case	Stage	Toe Eff D (kip)	Shear at Face (kip)	Toe Moment (kip-ft)	Heel Eff D (kip)	Shear at Face (kip)	Heel Moment (kip-ft)
aaaaaaaaaaaaaaaaaaa			xxxxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xx

FOUNDATION FORCES AT FOOTING TOE - VERTICAL
FOUNDATION FORCES AT FOOTING TOE - HORIZONTAL

(Spread and Pedestal foundations)

Limit State	Load Case	Stage	Toe to Result (ft)	Force (kip)	Moment (kip-ft)
aaaaaaaaaaaaaaaaaaaa			xx.xxx	xxxx.xxa	xxxx.xx

(Pile and Caisson foundations)

Limit State	Load Case	Stage	Toe to Result (ft)	Force (kip)	Moment (kip-ft)	V/H Ratio
aaaaaaaaaaaaaaaaaaaa			xx.xxx	xxxx.xxa	xxxx.xx	xx.xxxa

FOUNDATION FORCES AT BOTTOM OF PEDESTAL

Limit State	Load Case	Stage	Front to Result (ft)	Vertical Force (kip)	Vertical Moment (kip-ft)	Horizontal Force (kip)	Horizontal Moment (kip-ft)
aaaaaaaaaaaaaaaaaaaa			xxxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xx

* Warning: The ratio of the SERVICE-I limit state unfactored vertical load to horizontal load is less than 2.4 and does not meet the requirements of DM-4 Section 6.15.1P for pile foundations.

Note: Moments are taken about the bottom of the footing at the toe. Positive moment clockwise; negative moment counterclockwise; toe on right; heel on left.

Note: Moment critical sections in the footing are at the front and back face of the stem. Shear critical sections in the footing are located at the effective depth distance away from the front face of the stem for the toe and at the back face of the stem for the heel.

Notes:

Vertical Force and Moment values include the factored pedestal self weight.

All forces and moments include the footing forces and moments (see Foundation Forces at Footing Toe) multiplied by the pedestal center-to-center spacing.

7.6.7 FOOTING STABILITY Report Format

SPREAD FOOTING - BEARING RESISTANCE

Ecc	Factored	Uniform Factored	Factored

Limit State	Load Case	Stage	Ecc (ft)	Allow Ecc (ft)	Perform Ratio	Footing Pressure Toe (ksf)	Footing Pressure Heel (ksf)	Bearing Pressure (ksf)	Bearing Resist (ksf)	Perform Ratio
aaaaaaaaaaaaaaaaaaa			xxx.xxx	*xxx.xxx	xxx.xxx	xxxx.xx	xxxx.xx	xxxx.xx	xxxx.xx	xxx.xxx

Performance Ratio = Factored Bearing Resistance / aaaaaaa Factored Bearing Pressure
Eccentricity Performance Ratio = Allowable Eccentricity / Eccentricity

The eccentricity is the distance from the center of the footing to the load resultant. Positive towards toe; negative towards heel. The allowable eccentricity is the distance from the center of the footing to the edge of the kern.

SPREAD FOOTING - SLIDING

Limit State	Load Case	Stage	Factored Horizontal Force (kip)	Factored Sliding Resistance (kip)	Performance Ratio
aaaaaaaaaaaaaaaaaaa			xxxxx.xx	xxxxx.xx	xxx.xxx

Note: Only the Min Load Cases are checked for sliding.
Sliding resistance is based on a phi factor of x.xx.
A 0.8 precast sliding reduction factor has been applied for COHESIONLESS soil as per LRFD Specifications Section 10.6.3.4.
A 0.8 precast sliding reduction factor has been applied for C-PHI soil as per DM-4 Section 10.6.3.4.

Performance Ratio = Factored Sliding Resistance / Factored Horizontal

SETTLEMENT

Primary and Secondary Consolidation Values

Layer No. x

Sub Layer Depth (ft)	Z (ft)	Sigma O (psf)	Sigma P (psf)	Sigma F (psf)	Settlement Consol (in)	Settlement Second (in)	Conditon
xx.xxx	x.xxx	xxxxxxx.	xxxxxxx.	xxxxxxxx.	xxx.xx	xxx.xx	aaaaaaaa

Legend: Condition Codes
OC f>p : Over-Consolidation - Sigma F > than Sigma P
OC f<=p : Over-Consolidation - Sigma P >= Sigma F
NC : Normal-Consolidation
UC : Under-Consolidation

Note: Primary Consolidation Reduction Factor is not included in the Consolidation values shown above.

SETTLEMENT SUMMARY

Settlement Elastic (in)	Settlement Consol (in)	Settlement Second (in)	Settlement Total (in)	Allow (in)	Perform Ratio	Temp Stage Settlement (in)
xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xxx.xxx	xx.xx

Notes:

```
  Elastic settlement is based on:
     effective width of  xx.xx (ft) from aaaaaaaaaaaaaaaaaaa

  Consolidation and Secondary settlement are based on:
     effective width of xx.xxx (aa) from aaaaaaaaaaaaaaaaaaa

  Temporary Stage settlement is based on:
     effective width of  xx.xx (ft) from aaaaaaaaaaaaaaaaaaa

  Uniform pressures (Vertical Force/Effective Width)
  are used for settlement calculations.

  Maximum pressures from Bearing Resistance Report
  are used for settlement calculations.

  Performance Ratio = Allowable Settlement / Total Settlement

  Error:  A performance ratio less than 1 was found

  Warning: total settlement exceeds xx aaaa
```

CAISSON FACTORED AXIAL LOADS / CAISSON FACTORED AXIAL RESISTANCE
PILE FACTORED AXIAL LOADS / PILE FACTORED AXIAL RESISTANCE

Limit State	Load Case	Stage	Factored Axial Loads Row 1 Batter (kip)	Row 2 Batter (kip)	Row 3 Batter (kip)	Row 4 Vert (kip)	Row 5 Vert (kip)	Factored Axial Resist (kip)	Perform Ratio
aaaaaaaaaaaaaaaaaaa			xxxx.xx	xxxx.xx	xxxx.xx	xxxx.xx	xxxx.xx	xxxx.xxTxxx.xxx	
aaaaaaaaaaaaaaaaaaa			xxxx.xx	xxxx.xx	xxxx.xx	xxxx.xx	xxxx.xx	xxxx.xx	xxx.xxx

Performance Ratio = Factored Pile Axial Resistance / Maximum Factored Pile Axial Load
Performance Ratio = Factored Caisson Axial Resistance / Max Factored Caisson Axial Load

T indicates tensile resistance controlled and is reported

FACTORED LATERAL LOADS / PILE GROUP FACTORED LATERAL RESISTANCE
FACTORED LATERAL LOADS / CAISSON GROUP FACTORED LATERAL RESISTANCE

Resistance based on battered piles only
Resistance based on battered caissons only
Resistance based on vertical piles only
Resistance based on vertical caissons only

Limit State	Load Case	Stage	Factored Lateral Load (kips/ft)	Factored Lateral Resist (kips/ft)	Performance Ratio
aaaaaaaaaaaaaaaaaaa			xxxxx.xx	xxxxx.xx	xxx.xxx

Performance Ratio = Pile Group Factored Lateral Resistance / Factored Lateral Load
Performance Ratio = Caisson Group Factored Lateral Resistance / Factored Lateral Load

PEDESTAL BEARING RESISTANCE

Limit State	Load Case	Stage	Ecc (ft)	Allow Ecc (ft)	Ecc Perform Ratio	Factored Pedestal Pressure Front (ksf)	Factored Pedestal Pressure Back (ksf)	Uniform Factored Bearing Pressure (ksf)	Factored Bearing Resist (ksf)	Perform Ratio
aaaaaaaaaaaaaaaaaaa			xxx.xx *	xxx.xx	xxx.xxx	xxxx.xx	xxxx.xx	xxxx.xx	xxxx.xx	xxx.xxx
aaaaaaaaaaaaaaaaaaa			xxx.xx *	xxx.xx	xxx.xxx	xxxx.xx	xxxx.xx	xxxx.xx	xxxx.xx	xxx.xxx

FOOTING BEARING RESULTS

```
 Maximum Factored Actual Pressure     :  xxx.xx    (ksf)   from:  aaaaaaaaaaaaaaaaaaa
 Pedestal Factored Bearing Resistance :  xxx.xx    (ksf)
 Performance Ratio                    :  xxx.xx
```

Limit State	Load Case	Stage	Ecc (ft)	Allow Ecc (ft)	Ecc Perform Ratio	Factored Footing Pressure Toe (ksf)	Factored Footing Pressure Heel (ksf)	Maximum Factored Bearing Pressure (ksf)	Factored Bearing Resist (ksf)	Perform Ratio
aaaaaaaaaaaaaaaaaaa			xxx.xx	* xxx.xxx	xxx.xx	xxxx.xx	xxxx.xx	xxxx.xx	xxxx.xx	xxx.xxx

Performance Ratio = Factored Bearing Resistance / Maximum Factored Bearing Pressure
Eccentricity Performance Ratio = Allowable Eccentricity / Eccentricity

The eccentricity is the distance from the center of the pedestal at the base to the load resultant. Positive towards front; negative towards back. The allowable eccentricity is the distance from the center of the footing to the edge of the kern.

The eccentricity is the distance from the center of the footing contact length with the pedestal to the load resultant. Positive towards toe negative towards heel.

Modulus of elasticity of rock is less than modulus of elasticity of footing concrete, thus rock is treated as soil.

FOOTING SLIDING STABILITY ON PEDESTAL

Limit State	Load Case	Stage	Vertical Force (kip)	Horiz Force (kip)	V/H Ratio	Min Allow Ratio	Perform Ratio
aaaaaaaaaaaaaaaaaaa			xxxx.xx	xxxx.xx	xxx.xx	xxx.xx	xxx.xx

Notes:

Forces are based on a unit width thickness of the footing.

Performance Ratio = (V/H Ratio) / (Min Allow Ratio)

Notes:

Elastic settlement is based on:
effective width of xx.xxx (aa) from aaaaaaaaaaaaaaaaaaa

Consolidation and Secondary settlement are based on:
effective width of xx.xxx (aa) from aaaaaaaaaaaaaaaaaaa

Temporary Stage settlement is based on:
effective width of xx.xxx (aa) from aaaaaaaaaaaaaaaaaaa

Uniform pressures (Vertical Force/Effective Width)
are used for settlement calculations.

Maximum pressures from Bearing Resistance Report
are used for settlement calculations.

Warning: A performance ratio less than 1 was found

* Indicates an eccentricity outside the kern.

T indicates tensile resistance controlled and is reported

```
Warning:  Tension in piles is unacceptable
```

7.6.8 CONTROLLING FOOTING FORCES Report Format

```
                        TOE – WITH FOUNDATION PRESSURE
                        HEEL – WITH FOUNDATION PRESSURE
Limit   Load                                      Limit   Load
State   Case   Stage   Moment                     State   Case   Stage    Shear
    (Controlling)     (kip-ft)                        (Controlling)       (kip)
aaaaaaaaaaaaaaaaaaa xxxxx.xxa (Strength)       aaaaaaaaaaaaaaaaaaa xxxxx.xx
aaaaaaaaaaaaaaaaaaa xxxxx.xxa (Crack Control)            (aaaaa)
```

Note: A "T" following the moment value indicates that the controlling moment for the bottom perpendicular reinforcement was found in the Toe. An "H" indicates the controlling moment was found in the Heel.

Note: An "H" following the moment value indicates that the controlling moment for the top perpendicular reinforcement was found in the Heel. A "T" indicates the controlling moment was found in the Toe.

The Maximum shear in Heel is located at Xdist from the back face of stem, where Xdist is (xxx.xx)ft

Note: A moment direction of "x" in the aaaa has been detected. The critical shear location of limit states that caused the moment direction to be "x" in the aaaa are set to the aaaaa location as documented in the User's Manual Section 3.5.1. Limit Case Stage
Max moment in direction "x": xxx.xx (kp-ft) aaaaaaaaaaaaaaaaaaa

PARALLEL MOMENT

```
                Limit  Load         Parallel
                State  Case Stage    Moment
                  (Controlling)     (kip-ft)
 Strength:      aaaaaaaaaaaaaaaa    xxxxx.xx
 Crack Control: aaaaaaaaaaaaaaaa    xxxxx.xx
```

Note: Sec. beyond ftg. indicates that the controlling limit state is not applicable because the section is beyond the footing dimensions.

7.6.9 FOOTING FLEXURE – ANALYSIS Report Format

FLEXURAL STRENGTH

```
             Limit   Load           Applied    Moment    Phi    Perform    Area
 Location    State   Case   Stage   Moment     Resist   Factor  Ratio     Prov
                 (Controlling)     (kip-ft)   (kip-ft)                   (in^2)
    Toe      aaaaaaaaaaaaaaaaaaa  xxxxx.xxa  xxxxx.xx   x.xxx  xxx.xxx a  xx.xxx a
   Heel      aaaaaaaaaaaaaaaaaaa  xxxxx.xxa  xxxxx.xx   x.xxx  xxx.xxx a  xx.xxx a
Top Parallel aaaaaaaaaaaaaaaaaaa  xxxxx.xx   xxxxx.xx   x.xxx  xxx.xxx a  xx.xxx a
Bot Parallel aaaaaaaaaaaaaaaaaaa  xxxxx.xx   xxxxx.xx   x.xxx  xxx.xxx a  xx.xxx a
```

NOTE: A "T" following the applied moment indicates that the controlling moment is found in the Toe for the current location.
An "H" following the applied moment indicates that the controlling moment is found in the Heel for the current location.

+ Reinforcement could not develop in the aaaa.

```
 + Reinforcement could not develop in the aaaa. A bar spacing
   of xxx.xx in. or less is required to develop the bar.

  Performance Ratio =  Moment Resistance / Applied Moment

  Notes:

  Applied moments are based on:
       vertical force               =  xxx.xxx (kip)
       footing width                =  xxx.xxx (ft)
       uniform distrib load   (udl) =  xxx.xxx (klf)
       pedestal clear spacing   (s) =  xxx.xxx (ft)

  Bottom moment (between pedestals) = 3*udl*s*s/40
  Top moment (over pedestals)       = udl*s*s/10

  Phi Factor Epsilon (cl) =  x.xxxxx
  Phi Factor Epsilon (tl) =  x.xxxxx

  Performance Ratio =  Moment Resistance / Applied Moment

   Note: Pedestal footing reinforcement is not analyzed in the perpendicular direction
         (toe and heel locations) because the footing and pedestal are assumed to be made
         integral using transverse shear keys and dowels as per DM-4 Section 10.6.5.2P.

  Notes:

  Applied moments are based on:
       vertical force            =  xxxx.xx (kip)
       footing width             =  xxx.xxx (ft)
       uniform distrib load (udl) =  xxxx.xx (klf)
       maximum pile spacing   (s) =  xxx.xxx (ft)

  Parallel moment = 0.5*udl*s*s/10

  Performance Ratio =  Moment Resistance / Applied Moment

  Phi Factor Epsilon (cl) =  x.xxxxx
  Phi Factor Epsilon (tl) =  x.xxxxx

  Warning:  A performance ratio less than 1 was found
```

7.6.10 FOOTING FLEXURE - DESIGN Report Format

FLEXURAL STRENGTH

Location	Limit State (Controlling)	Load Case	Stage	Applied Moment (kip-ft)	Moment Resist (kip-ft)	Phi Factor	Perform Ratio	1.33 Mu (kip-ft)	Area Reqd (in^2)	Status Codes
Toe	aaaaaaaaaaaaaaaaaaaaxxxxx.xxa			xxxxx.xx		x.xxx	xxx.xxxa	xxxx.xx	xx.xxxa	aa
Heel	aaaaaaaaaaaaaaaaaaaaxxxxx.xxa			xxxxx.xx		x.xxx	xxx.xxxa	xxxx.xx	xx.xxxa	aa
Top Parallel	aaaaaaaaaaaaaaaaaaaaxxxxx.xx			xxxxx.xx		x.xxx	xxx.xxxa	xxxx.xx	xx.xxxa	aa
Bot Parallel	aaaaaaaaaaaaaaaaaaaaxxxxx.xx			xxxxx.xx		x.xxx	xxx.xxxa	xxxx.xx	xx.xxxa	aa

```
NOTE: A "T" following the applied moment indicates that the controlling
      moment is found in the Toe for the current location.
      An "H" following the applied moment indicates that the controlling
      moment is found in the Heel for the current location.

 + Reinforcement could not develop in the aaaa.
```

```
+ Reinforcement could not develop in the aaaa. A bar spacing
  of xxx.xx in. or less is required to develop the bar.

 Performance Ratio =  Moment Resistance / Applied Moment

 Cracking Moment M(cr):  xxxxx.xx (kip-ft)

 Note: Pedestal footing reinforcement is not analyzed in the perpendicular direction
       (toe and heel locations) because the footing and pedestal are assumed to be made
       integral using transverse shear keys and dowels as per DM-4 Section 10.6.5.2P.

 Notes:

 Applied moments are based on:
      vertical force               =  xxx.xxx (kip)
      footing width                =  xxx.xxx (ft)
      uniform distrib load   (udl) =  xxx.xxx (klf)
      pedestal clear spacing   (s) =  xxx.xxx (ft)

 Bottom moment (between pedestals) = 3*udl*s*s/40
 Top moment (over pedestals)       = udl*s*s/10

 Performance Ratio =  Moment Resistance / Applied Moment

 Status Code Descriptions
    A -  1.33*Mu Minimum Criteria Controlled Resisting Moment
    B -  Mcr Minimum Criteria Controlled Resisting Moment

  Notes:

  Applied moments are based on:
       vertical force             =  xxxx.xx (kip)
       footing width              =  xxx.xxx (ft)
       uniform distrib load (udl) =  xxxx.xx (klf)
       maximum pile spacing   (s) =  xxx.xxx (ft)

  Parallel moment = 0.5*udl*s*s/10

  Performance Ratio =  Moment Resistance / Applied Moment

   Phi Factor Epsilon (cl) =  x.xxxxx
   Phi Factor Epsilon (tl) =  x.xxxxx

  Warning:  A performance ratio less than 1 was found
```

7.6.11 CRACK CONTROL - ANALYSIS Report Format

BACKWALL AND STEM
STEM (if no backwall)

Location		Dist from Struc Top (ft)	Area/ Width (in^2)	Actual Stress (ksi)	Allow Spacing (in)	Controlling Moment (kip-ft)	Controlling Axial (kip)	Status Codes
Backwall	a	xxx.xx	xxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xx	xxxx.xx	aaaaaa
Backwall	a	xxx.xx	xxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xx	xxxx.xx	aaaaaa
Seat	a	xxx.xx	xxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xx	xxxx.xx	aaaaaa
Stem A	a	xxx.xx	xxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xx	xxxx.xx	aaaaaa
Stem B	a	xxx.xx	xxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xx	xxxx.xx	aaaaaa
Stem C	a	xxx.xx	xxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xx	xxxx.xx	aaaaaa
Stem D	a	xxx.xx	xxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xx	xxxx.xx	aaaaaa

* Warning: An applied moment was negative (See Moment Axial Interaction Table) and may have cracked the section in the front face. User should determine if the front face has cracked. If so compute an allowable crack control spacing and compare it to the temp/shrinkage reinforcement spacing.

FOOTING

Location	Area/ Width (in^2)	Actual Stress (ksi)	Allow Spacing (in)	Control Moment (kip-ft)	Status Codes
Toe	xxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xxa	aaaaaaa
Toe	xxxxx.	xxxxx.xx	xxxxx.xx	xxxxx.xxa	aaaaaaa
Heel	xxxxx.	xxxxx.xx	xxxxx.xx	xxxxx.xxa	aaaaaaa
Bot Parallel	xxxxx.	xxxxx.xx	xxxxx.xx	xxxxx.xx	aaaaaaa
Top Parallel	xxxxx.	xxxxx.xx	xxxxx.xx	xxxxx.xx	aaaaaaa

NOTE: A "T" following the moment indicates that the controlling Moment is found in the Toe for the current location.
An "H" following the moment indicates that the controlling moment is found in the Heel for the current location.

Status Code Descriptions (Blank indicates an OK status)

- A - area smaller than that required for shrinkage/temperature control or rho min
- B - actual spacing is greater than maximum allowed
- C - actual stress calculation did not converge
- D - actual spacing is greater than allowable crack control spacing
- E - applied loads did not crack the cross section. Rebar tensile stress is set to zero.
- F - spacing is less than the minimum allowed
- G - Actual stress limited to 0.6*fy in allowable spacing calculation

Stresses in footing are based on:

vertical force	=	xxx.xxx (kip)
footing width	=	xxx.xxx (ft)
uniform distrib load (udl)	=	xxx.xxx (klf)
pedestal clear spacing (s)	=	xxx.xxx (ft)

Bottom moment (between pedestals) = 3*udl*s*s/40
Top moment (over pedestals) = udl*s*s/10

Stresses in footing are based on:

```
      vertical force             =  xxxx.xx (kip)
      footing width              =  xxx.xxx (ft)
      uniform distrib load (udl) =  xxxx.xx (klf)
      maximum pile spacing   (s) =  xxx.xxx (ft)

 Parallel moment = 0.5*udl*s*s/10
 Warning: Applied moment was negative; section cracked in front face.  Actual
 Stress set to 0, crack control check was not evaluated.
```

7.6.12 CRACK CONTROL - DESIGN Report Format

```
                ABUTMENT BACKWALL  xxx.xx (ft) FROM TOP OF STRUCTURE
 ABUTMENT BACKWALL AT SEAT LEVEL  xxx.xx (ft) FROM TOP OF STRUCTURE
                STEM LOCATION a  xxx.xx (ft) FROM TOP OF STRUCTURE
                STEM CUTOFF LOCATION - SHOWN FOR EACH BAR CUTOFF
                         Back Face Vertical Reinforcement

  Bar      Bar    Area/    Actual     Allow      Controlling       Status
 Size  Spacing    Width    Stress    Spacing   Moment     Axial     Codes
          (in)   (in^2)     (ksi)      (in)   (kip-ft)     (kip)
   ii   xxx.xx aaxxx.xx  xxxxx.xx  xxxxx.xx  xxxxx.xx  xxxxx.xx    aaaaaaa
   ii   xxx.xx aaxxx.xx  xxxxx.xx  xxxxx.xx  xxxxx.xx  xxxxx.xx    aaaaaaa

Warning:  An applied moment was negative (See Moment Axial Interaction
          Table) and may have cracked the section in the front face.
          User should determine if the front face has cracked. If so
          compute an allowable crack control spacing and compare it to
          the temp/shrinkage reinforcement spacing.


                                FOOTING TOE
                                FOOTING HEEL
                        FOOTING PARALLEL TOP REINFORCEMENT
                      FOOTING PARALLEL BOTTOM REINFORCEMENT

  Bar      Bar    Area/    Actual     Allow   Control     Status
 Size  Spacing    Width    Stress    Spacing   Moment      Codes
          (in)   (in^2)     (ksi)      (in)   (kip-ft)
   ii   xxx.xx aaxxx.xx  xxxxx.xx  xxxxx.xx  xxxxx.xxa    aaaaaaa
   ii   xxx.xx aaxxx.xx  xxxxx.xx  xxxxx.xx  xxxxx.xxa    aaaaaaa

 Note: Controlling moment was found in the toe
 Note: Controlling moment was found in the heel

 Status Code Descriptions                    (Blank indicates an OK status)
   A - min area & max spacing governed by shrinkage/temp requirements
   B - spacing is less than minimum allowed, actual stress not computed
   C - actual stress calculation did not converge
   D - spacing modified by development length ratio reduction
   E - applied loads did not crack the cross section.  Rebar tensile
       stress is set to 0.
   F - Actual stress limited to 0.6*fy in allowable spacing calculation
   ++ - Design spacing is less than minimum spacing. Bar size is not
        applicable
```

7.6.13 GRAVITY WALL STRESS CHECK Report Format

The status codes reported for each load combination (shown below as "aa") may be "ok" or "NG".

```
               STEM LOCATION a  xxx.xx (ft) FROM TOP OF STRUCTURE

               Stress is based on a stem thickness of xxx.xx (ft)

    Limit   Load              Applied    Applied      Actual
    State   Case   Stage      Moment      Axial       Stress    Status
                              (kip-ft)    (kip)        (ksf)
    aaaaaaaaaaaaaaaaaaa     xxxxx.xx  xxxxx.xx     xxxxx.xx      aa

    Note:  Positive axial loads produce compressive stress.

    Actual stress is evaluated on the face where moment produces tensile
    stress.  A positive applied moment generates a flexural tensile stress
    on backface of stem.  A negative applied moment generates a flexural
    tensile stress on frontface of stem.  Positive actual stress indicates
    that the combined stresses (axial and flexure) produced a tensile stress
    at the extreme fiber of the section.

    Warning: A negative applied load was encountered.
```

7.6.14 REINFORCEMENT SUMMARY - ANALYSIS Report Format

```
                        ABUTMENT BACKWALL AT SEAT LEVEL

    Bar      Bar     Develop  Area   Area   Splice  Status
    Size   Spacing   Length   Reqd   Prov   Length  Codes
           (in)      (in)   (in^2) (in^2)   (in)
     ii     xxx.x     xxx.x   xx.xx  xx.xx   xx.xx   aa

      Available Height in Backwall =   xx.xx (in)

    Status Code Descriptions
      A - Splice length exceeds backwall height

                       STEM LOCATION D   xx.xx (ft) FROM TOP OF STRUCTURE

    Bar      Bar      Develop Length   Area   Area   Splice  Status
    Size   Spacing   Hooked  Straight  Reqd   Prov   Length  Codes
           (in)      (in)     (in)   (in^2) (in^2)   (in)
     ii      xx.x      xx.x    xx.x   xx.xxx xx.xxx    xx.x    aa

      Available Length in Footing =   xx.x (in)

    Status Code Descriptions
      A - Hooked development length exceeds available length
      B - Straight development length exceeds available length
```

FOOTING REINFORCEMENT DETAILS

FOOTING TOE (BOTTOM)

Bar Size	Bar Spacing (in)	Develop Length (in)	Acutal Length (in)	Bar Type	Area Reqd (in^2)	Area Prov (in^2)
ii	xxx.x	xxx.x a	xxx.x	a	xx.xx a	xx.xx

FOOTING HEEL (TOP)

Bar Size	Bar Spacing (in)	Develop Length (in)	Acutal Length (in)	Bar Type	Area Reqd (in^2)	Area Prov (in^2)
ii	xxx.x	xxx.x a	xxx.x	a	xx.xx a	xx.xx

Development Length information is not available when area per width is specified for footing reinforcement during an analysis run.

* Indicates area required was governed by the minimum temperature and shrinkage reinforcement criteria.

+ Indicates bar cannot be developed.

Bar Type Description
S - Straight Bar
H - Hooked Bar

BACKWALL AND STEM
STEM

Location	Dist from Struc Top (ft)	Bar @ Spacing (in)	Total Area/ Design Width (in^2)	Strength Status	Service Status	Shear Status
Backwall	xxx.xx	ii @ xx.xx	xxx.xx	aa	aa	aa
Backwall	xx.xxx	ii @ xx.xx	xxx.xx	aa	aa	aa
Seat	xx.xxx	ii @ xx.xx	xxx.xx	aa	aa	aa
Stem A	xx.xxx	ii @ xx.xx	xxx.xx	aa	aa	aa
Stem B	xx.xxx	ii @ xx.xx	xxx.xx	aa	aa	aa
Stem C	xx.xxx	ii @ xx.xx	xxx.xx	aa	aa	aa
(alternative when bar/space not provided):						
Stem D	xxx.xx	N/A @ xx.xx	xxx.xx	aa	aa	aa

FOOTING

Location	Bar @ Spacing (in)	Total Area/ Design Width (in^2)	Strength Status	Service Status	Shear Status
Toe	ii @ xx.xx	xxx.xx	aa	aa	aa
Toe	ii @ xx.xx	xxx.xx	aa	aa	aa
Heel	ii @ xx.xx	xxx.xx	aa	aa	aa
Top Parallel	ii @ xx.xx	xxx.xx	aa	aa	aa
Bot Parallel	ii @ xx.xx	xxx.xx	aa	aa	aa
(alternative when bar/space not provided):					
Heel	N/A @ xx.xx	xxx.xx	aa	aa	aa

Punching shear status is OK

FOOTING
Parallel Direction

Location	Bar @ Spacing (in)	Total Area/ Design Width (in^2)	Strength Status	Service Status
Bottom	ii @ xx.xx	xxx.xx	aa	aa
Toe	ii @ xx.xx	xxx.xx	aa	aa
(alternative when bar/space not provided):				
Toe	N/A @ xx.xx	xxx.xx	aa	aa

SHEAR STATUS : OK

NOTE: No bar size is available because reinforcement was entered with the ARE and or SRA commands. Spacings are calculated based on the maximum bar diameters.

7.6.15 REINFORCEMENT SUMMARY - DESIGN Report

BACKWALL

Bar Size	Backwall xxx.xx (ft) from top of structure Strength (in)	Backwall xxx.xx (ft) from top of structure Crack Control (in)	Seat xxx.xx (ft) from top of structure Strength (in)	Seat xxx.xx (ft) from top of structure Crack Control (in)
ii	xxx.xx	aaxxx.xx	xxx.xx	aaxxx.xx
ii	xxx.xx	aaxxx.xx	xxx.xx	aaxxx.xx

STEM

Bar Size	Location A xxx.xx (ft) Streng (in)	Location A xxx.xx (ft) Crack Control (in)	Location B xxx.xx (ft) Streng (in)	Location B xxx.xx (ft) Crack Control (in)	Location C xxx.xx (ft) Streng (in)	Location C xxx.xx (ft) Crack Control (in)	Location D xxx.xx (ft) Streng (in)	Location D xxx.xx (ft) Crack Control (in)
ii	xx.xx	aaxx.xx	aaxx.xx	aaxx.xx	aaxx.xx	aaxx.xx	aaxx.xx	aaxx.xx
ii	xx.xx	aaxx.xx	aaxx.xx	aaxx.xx	aaxx.xx	aaxx.xx	aaxx.xx	aaxx.xx

++ - Design Spacing is less than the minimum spacing. Bar size is not applicable.

FOOTING

Bar Size	Footing Toe Strength (in)	Footing Toe Crack Control (in)	Footing Heel Strength (in)	Footing Heel Crack Control (in)
ii	xx.xx	aaxx.xx	xx.xx	aaxx.xx
ii	xx.xx	aaxx.xx	xx.xx	aaxx.xx

Bar Size	Parallel Top Strength (in)	Parallel Top Crack Control (in)	Parallel Bottom Strength (in)	Parallel Bottom Crack Control (in)
ii	xx.xx	aaxx.xx	xx.xx	aaxx.xx
ii	xx.xx	aaxx.xx	xx.xx	aaxx.xx

++ - Design Spacing is less than the minimum spacing. Bar size is not applicable.

7.6.16 SHEAR RESULTS Report Format

BACKWALL AND STEM
STEM

Location	Dist from Struc Top (ft)	Limit State (Controlling)	Load Case Stage (Controlling)	Applied Shear (kip)	Shear Resist (kip)	Perform Ratio
Backwall	xx.xx	aaaaaaaaaaaaaaaaaaa		xxxx.xx	xxxx.xx	xxx.xxx
Seat	xx.xx	aaaaaaaaaaaaaaaaaaa		xxxx.xx	xxxx.xx	xxx.xxx
Stem A	xx.xx	aaaaaaaaaaaaaaaaaaa		xxxx.xx	xxxx.xx	xxx.xxx
Stem B	xx.xx	aaaaaaaaaaaaaaaaaaa		xxxx.xx	xxxx.xx	xxx.xxx
Stem C	xx.xx	aaaaaaaaaaaaaaaaaaa		xxxx.xx	xxxx.xx	xxx.xxx
Stem D	xx.xx	aaaaaaaaaaaaaaaaaaa		xxxx.xx	xxxx.xx	xxx.xxx

Note: Shear resistance is based on a phi factor of x.xx

STEM CUTOFF LOCATIONS

Bar Size	Dist from Struc Top (ft)	Limit State (Controlling)	Load Case Stage (Controlling)	Applied Shear (kip)	Shear Resist (kip)	Perform Ratio
xx	xx.xx	aaaaaaaaaaaaaaaaaaa		xxxx.xx	xxxx.xx	xxx.xxx

FOOTING

Location	Limit State (Controlling)	Load Case Stage (Controlling)	Applied Shear (kip)	Shear Resist (kip)	Perform Ratio
Toe	aaaaaaaaaaaaaaaa		xxxx.xx	xxxx.xx	xxx.xxx
Heel	aaaaaaaaaaaaaaaa		xxxx.xx	xxxx.xx	xxx.xxx
Caisson Punching	aaaaaaaaaaaaaaaa		xxxx.xx	xxxx.xx	xxx.xxx
Pile Punching	aaaaaaaaaaaaaaaa		xxxx.xx	xxxx.xx	xxx.xxx
Drain Trough					
Suppport Punching	aaaaaaaaaaaaaaaa		xxxx.xx	xxxx.xx	xxx.xxx

Performance Ratio = Shear Resistance / Applied Shear

FOOTING
Parallel Direction

Limit State (Controlling)	Load Case Stage (Controlling)	Applied Shear (kip)	Shear Resist (kip)	Perform Ratio
aaaaaaaaaaaaaaaaaaa		xxxx.xx	xxxx.xx	xxx.xxx

Note: Shear resistance is based on a phi factor of 0.90

```
Applied Footing Shear is based on:
     vertical force               =  xxx.xxx (kip)
     footing width                =  xxx.xxx (ft)
     uniform distrib load   (udl) =  xxx.xxx (kip/ft)
     pedestal clear spacing   (s) =  xxx.xxx (ft)
     eff depth near pedestal  (d) =   xx.xxx (ft)

Shear = udl*(s/2 - d)

Performance Ratio =  Shear Resistance / Applied Shear

Note: Sec. beyond ftg. indicates that the controlling limit state is not
      applicable because the section is beyond the footing dimensions.

Warning:  A performance ratio less than 1 was found
```

7.6.17 REINFORCEMENT AND OPTIMUM DESIGN DETAILS Report Formats

The optimum report only shows the optimal solution (that satisfies all of the checks) at each applicable location and component. The reinforcement design report shows the spacing for all bar sizes and identifies the optimal bar. Furthermore, the reinforcement design report will identify bars that cannot be developed.

7.6.17.1 Reinforcement Design Details

```
 ABUTMENT BACKWALL AT SEAT LEVEL
(with optimum stem bar alignment option)

 Bar      Bar     Develop  Area   Splice  Status   Reqd Bar Spacing
 Size   Spacing   Length   Prov   Length  Codes       for Splice
          (in)      (in)   (in^2)   (in)                 (in)
  ii a   xxx.x   aaxxx.x  x.xxx   xxx.xx  aaa          xxxx.x

  Area Reqd     =  x.xxx (in^2) aa

  Available Height in Backwall =  xxx.xx (in)

** Indicates area required was governed by the minimum temperature
   and shrinkage reinforcement criteria.

 * Indicates bar size and spacing with the least area of steel per unit
   width of the structure in the backwall.

 Status Code Descriptions
   A - Development length exceeds stem height
   B - Development length exceeds backwall height
   C - Splice length exceeds backwall height
   D - Area provided is less than area required
```

```
      FOOTING PARALLEL BOTTOM            FOOTING PARALLEL TOP

Bar    Bar    Develop   Area        Bar    Bar    Develop   Area
Size Spacing  Length    Prov        Size Spacing  Length    Prov
       (in)    (in)    (in^2)              (in)    (in)    (in^2)
ii a  xxx.x aa xxx.x    x.xxx       ii a  xxx.x aa xxx.x    x.xxx

  Area Reqd     =  x.xxx (in^2)       Area Reqd     =  x.xxx (in^2)

        FOOTING TOE (BOTTOM)               FOOTING HEEL (TOP)

Bar    Bar    Develop Bar   Area        Bar    Bar    Develop Bar   Area
Size Spacing  Length  Type  Prov        Size Spacing  Length  Type  Prov
       (in)    (in)        (in^2)              (in)    (in)        (in^2)
ii a  xxx.x    xxx.x   a   x.xxx       ii a  xxx.x    xxx.x   a    x.xxx

  Area Reqd     =  x.xxx (in^2)         Area Reqd     =  x.xxx (in^2)
  Actual Length =  xxx.x (in)           Actual Length =  xxx.x (in)

++ - Design Spacing is less than the minimum spacing. Bar size is not
      applicable.

** Indicates area required was governed by the minimum temperature
   and shrinkage reinforcement criteria.

 + Indicates bar cannot be developed.

 * Indicates bar size and spacing with the least area of steel per unit
   width of the structure in the footing.

 Note: Pedestal footing reinforcement is not analyzed in the perpendicular direction
       (toe and heel locations) because the footing and pedestal are assumed to be made
       integral using transverse shear keys and dowels as per DM-4 Section 10.6.5.2P.

Bar Type Description
   S - Straight Bar
   H - Hooked Bar

                              STEM Location D

                         Hooked   Straight
                          Bar      Bar                Weight    Weight
Bar    Bar     Bar Lap  Develop  Develop  Area       with     without   Status
Size  Space     Length  Length   Length   Prov      Cutoffs   Cutoffs   Codes
       (in)      (in)    (in)     (in)   (in^2)     (lbs)     (lbs)
 ii aa xxx.x  aa xxx.x   xxx.x    xxx.x    x.xxx    xxx.xx    xxx.xx   aa

  Area Reqd               =  x.xxx (in^2) aa

  Actual Length in Footing =  xxx.x (in)

Bar    Bar    Theoret    Extension     Physical   Status
Size  Space   Cutoff   Length  Code    Cutoff     Codes
       (in)    (in)     (in)            (in)
 ii aaxxx.x aa xxx.x    xxx.x    a      xxx.x     aaaaa

NOTE: Optimum stem bars cannot be cutoff for this design.

 Status Code Descriptions
   A - Cutoff location controlled by strength check at cutoff
```

```
   B - Cutoff location controlled by service load check at cutoff
   C - Bars could not be cut off because the resulting bar spacing would
       be greater than the maximum allowable bar spacing.
   D - Physical cutoff is at the top of wall/stem because the calculated
       value is within aaaaaaa of the top of wall/stem
   E - Physical cutoff is at top of wall/stem because the calculated value
       is above the actual top of wall/stem.
   F - Could not develop the bar into the footing due to insufficient
       footing thickness
   G - Development length exceeds stem height
   * - Indicates bar size and spacing with the least weight of steel per
       unit width of the structure at the base of stem when bars are
       NOT cutoff
   + - Indicates bar size and spacing with the least weight per
       unit width of the structure for the whole height of the stem
       when bars are both cutoff and full height.
  ** - Indicates area required was governed by the minimum temperature
       and shrinkage reinforcement criteria
  ++ - Design Spacing is less than the minimum spacing. Bar size is not
       applicable.

 Extension Length Code
   A - Effective Depth Controlled
   B - Fifteen Bar Diameters Controlled
   C - 12 inch Minimum Controlled

  Note:  The theoretical cutoff point is where every other
         bar is no longer required in the stem.

  Note: Stem Bars at Location D are always epoxy coated as per
        DM-4 Section 5.4.3.6P
```

7.6.17.2 Optimum Design Details

```
ABUTMENT BACKWALL AT SEAT LEVEL

Bar      Bar     Develop  Area  Splice
Size   Spacing   Length   Prov  Length
         (in)      (in)   (in^2)  (in)
  ii    xxx.x    xxxx.x  x.xxx  xxx.x
 No bar design found for the backwall. Refer to the
 REINFORCEMENT DESIGN DETAILS output for further information.

       FOOTING TOE (BOTTOM)                    FOOTING HEEL (TOP)

Bar      Bar     Develop  Bar      Bar      Bar     Develop  Bar
Size   Spacing   Length   Type     Size   Spacing   Length   Type
         (in)      (in)                     (in)      (in)
ii a    xxx.x    xxx.x     a       ii      xxx.x     xxx.x    a

   FOOTING PARALLEL BOTTOM          FOOTING PARALLEL TOP

Bar      Bar     Develop           Bar      Bar     Develop
Size   Spacing   Length            Size   Spacing   Length
         (in)      (in)                     (in)      (in)
ii      xxx.x    xxx.x              ii      xxx.x     xxx.x

Bar Type Description
```

```
   S - Straight Bar
   H - Hooked Bar
                              STEM Location D

                         Hooked   Straight
                          Bar      Bar       Weight    Weight
Bar    Bar     Bar Lap  Develop  Develop     with     without   Status
Size  Space     Length  Length   Length     Cutoffs   Cutoffs   Codes
       (in)      (in)    (in)     (in)       (lbs)     (lbs)
 ii aa xxx.x    xxx.x   xxx.x    xxx.x       xxx.xx    xxx.xx     aa

Bar     Bar   Theoret Extension Physical   Status
Size   Space  Cutoff   Length   Cutoff     Codes
        (in)    (in)     (in)     (in)
 ii aa xxx.x   xxx.x    xxx.x    xxx.x     aaaaa

NOTE: Stem bars cannot be cutoff for this design.

 Status Code Descriptions
   A - Cutoff location controlled by strength check at cutoff
   B - Cutoff location controlled by service load check at cutoff
   C - Bars could not be cut off because the resulting bar spacing would
       be greater than the maximum allowable bar spacing.
   D - Physical cutoff is at the top of wall/stem because the calculated
       value is within aaaaaaa of the top of wall/stem
   E - Physical cutoff is at top of wall/stem because the calculated value
       is above the actual top of wall/stem.
   F - Could not develop the bar into the footing due to insufficient
       footing thickness
   G - Development length exceeds stem height
   * - Indicates bar size and spacing with the least weight of steel per
       unit width of the structure at the base of stem when bars are
       NOT cutoff
   + - Indicates bar size and spacing with the least weight per
       unit width of the structure for the whole height of the stem
       when bars are both cutoff and full height

   Note:  The theoretical cutoff point is where every other
          bar is no longer required in the stem.

   Note:  Stem Bars at Location D are always epoxy coated as per
          DM-4 Section 5.4.3.6P
```

7.6.18 UNFACTORED LOADS Report Summary

```
              LATERAL EARTH PRESSURE (EH) INTERMEDIATE VALUES

                              Temporary Stage

       Failure                    Soil  Height                Phi-
Locn   Method   Ka    Kah    Kav  Height Ratio  Alpha  Theta  Prime  Beta
                                   (ft)         (deg)  (deg)  (deg)  (deg)
aaaaa  aaaa   x.xxx x.xxx x.xxx  xx.xx   xxxx  xx.xx  xx.xx  xx.xx  xx.xx
aaaaa  aaaa   x.xxx*x.xxx*x.xxx* xx.xx   xxxx  xx.xx  xx.xx  xx.xx  xx.xx
```

Final Stage

Locn	Failure Method	Ka	Kah	Kav	Soil Height (ft)	Height Ratio	Alpha (deg)	Theta (deg)	Phi-Prime (deg)	Beta (deg)
aaaaa	aaaa	x.xxx	x.xxx	x.xxx	xx.xx	xxxx	xx.xx	xx.xx	xx.xx	xx.xx
aaaaa	aaaa	x.xxx*	x.xxx*	x.xxx*	xx.xx	xxxx	xx.xx	xx.xx	xx.xx	xx.xx

Legend
- Alpha - Angle of soil wedge measured from the vertical
- Theta - Stem back face batter angle
- Phi-Prime - Backfill internal friction angle
- Beta - Backfill slope measured from the horizontal

* Note: The Minimum Equivalent Fluid Pressure (MEFP) controlled the Kah calculation. Ka, Kah and Kav are based on the Minimum Equivalent Fluid Pressure.

FOUNDATION

Temporary Stage (footing bottom at toe)
Final Stage (Footing bottom at toe)

Applied Load	Vertical Force (kip)	Vertical Moment (kip-ft)	Applied Load	Horizontal Force (kip)	Horizontal Moment (kip-ft)
aaaaaaaa	xxxxx.xx	xxxxxx.xx	aaaaaaaa	xxxxx.xx	xxxxxx.xx

BACKWALL

Final Stage xxx.xx (ft) from top of structure

Applied Load	Vertical Force (kip)	Vertical Moment (kip-ft)	Applied Load	Horizontal Force (kip)	Horizontal Moment (kip-ft)
aaaaaaaa	xxxxx.xx	xxxxxx.xx	aaaaaaaa	xxxxx.xx	xxxxxx.xx

STEM

Temporary Stage Location a xxx.xx (ft) from top of structure
Final Stage Location a xxx.xx (ft) from top of structure

Applied Load	Vertical Force (kip)	Vertical Moment (kip-ft)	Applied Load	Horizontal Force (kip)	Horizontal Moment (kip-ft)
aaaaaaaa	xxxxx.xx	xxxxxx.xx	aaaaaaaa	xxxxx.xx	xxxxxx.xx

STEM (cont.)

Final Stage Location a xxx.xx (ft) from top of structure

Vertical Applied Load	Force (kip)	2" +ecc Moment (kip-ft)	2" -ecc Moment (kip-ft)	Horizontal Applied Load	Force (kip)	Moment (kip-ft)
aaaaaaaaa	xxxxx.xx	xxxxx.xx	xxxxx.xx	aaaaaaaa	xxxxx.xx	xxxxx.xx

Note: An asterisk (*) indicates that the vertical load does not act through the bearings.

FOOTING

```
                                Temporary Stage
                                Final Stage

Applied          Toe Shear       Toe          Applied         Heel Shear       Heel
  Load        Eff D   at Face   Moment           Load        Eff D   at Face   Moment
              (kip)    (kip)   (kip-ft)                     (kip)    (kip)   (kip-ft)
  aaaaaaaa xxxxx.xx xxxxx.xx  xxxxx.xx          aaaaaaaa xxxxx.xx xxxxx.xx  xxxxx.xx
                                                 aaaaaaaa xxxxx.xx xxxxx.xx  xxxxx.xx

  Pedestal Self Weight        : xxxxxx.xx (kip)
  Pedestal Self Weight Moment : xxxxxx.xx (kip-ft)

  Note:  Pedestal self weight moment is taken about the front bottom
         corner of the pedestal acting in a counter clockwise direction,
         with the front face on the left side and the back face on the
         right side.

  Foundation moments are taken about the bottom of the footing at the
  toe.  Stem and Backwall moments are taken about the centerline of the
  section at the location analyzed.  Positive moment clockwise; negative
  moment counterclockwise; toe on right; heel on left.  Footing moments
  are the moments at the section of the toe or heel due only to those
  loads applied directly to the toe or heel.
```

7.6.19 LOAD FACTORS Report Summary

```
                                      FOUNDATION

                                   Vertical                      Horizontal

Limit   Load           Applied       Load      Eta      Applied       Load      Eta
State   Case   Stage     Load       Factor   Factor      Load       Factor   Factor
aaaaaaaaaaaaaaaaaaaa    aaaaaaaa  a xx.xx  a xx.xx      aaaaaaaa  a xx.xx  a xx.xx

                                         STEM

                                   Vertical                      Horizontal

Limit   Load           Applied       Load      Eta      Applied       Load      Eta
State   Case   Stage     Load       Factor   Factor      Load       Factor   Factor
aaaaaaaaaaaaaaaaaaaa    aaaaaaaa  a xx.xx  a xx.xx      aaaaaaaa  a xx.xx  a xx.xx

                                       BACKWALL

                                   Vertical                      Horizontal

Limit   Load           Applied       Load      Eta      Applied       Load      Eta
State   Case   Stage     Load       Factor   Factor      Load       Factor   Factor
aaaaaaaaaaaaaaaaaaaa    aaaaaaaa  a xx.xx  a xx.xx      aaaaaaaa  a xx.xx  a xx.xx

                                       FOOTING

                                    Toe                          Heel

Limit   Load           Applied       Load      Eta      Applied       Load      Eta
State   Case   Stage     Load       Factor   Factor      Load       Factor   Factor
aaaaaaaaaaaaaaaaaaaa    aaaaaaaa  a xx.xx  a xx.xx      aaaaaaaa  a xx.xx  a xx.xx
```

7.6.20 INTERMEDIATE BEARING RESISTANCE VALUES Report Format

```
                                          Number
    Limit                  Soil  Soil      of
    State   Case   Stage   Cat   Cond    Layers       Description
                            i      i       i          aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
    aaaaaaaaaaaaaaaaaaaa
```

(Soil Cond 1)

```
                                 Gamma    Gamma
Layer  qult    c    phi          Mass      Sat     Gamma   Sub   N     s     i     RC(BC)
       (ksf) (ksf) (deg)         (pcf)    (pcf)    (pcf)
  i   xxx.xx xxx.x xx.x        xxx.xx   xxx.xx   xxx.xx    a xxx.xxx x.xxx x.xxx   x.xx

Bearing    Final
Resist     qult      Df       B'      L'       Zw        Hu          Vu
(ksf)      (ksf)    (ft)     (ft)    (ft)     (ft)    (kips/ft)   (kips/ft)
xxx.xx     xxx.xx   xxx.xx   xx.xx   xx.xx    xx.xx     xxx.xx      xxx.xx
```

(Soil Cond 2)

```
Layer  qult    c    phi     Gamma m Gamma sat  Gamma     Nm      Nc      Nq    RC(BC)
       (ksf) (ksf) (deg)      (pcf)    (pcf)    (pcf)
  i   xxx.xx xxx.x  xx.x     xxx.xx   xxx.xx   xxx.xx   xx.xxx  xx.xxx  xx.xxx  x.xx

Bearing  Final
Resist   qult   phi f   Kappa   Bm     H1     Df    B'    L'     Zw      Hu        Vu
 (ksf)   (ksf)  (deg)                (ft)    (ft)  (ft)  (ft)   (ft)  (kips/ft) (kips/ft)
xxx.xx   xxx.xx  xx.x   xx.xx  xx.xx  xx.xx xx.xx  xx.xx xx.xx  xx.xx   xxx.xx    xxx.xx
```

(Soil Cond 3)

```
Layer  qult    c    phi     Gamma m Gamma sat  Gamma     Nc      Nq      Sc    RC(BC)
       (ksf) (ksf) (deg)      (pcf)    (pcf)    (pcf)
  i   xxx.xx xxx.x  xx.x     xxx.xx   xxx.xx   xxx.xx   xx.xxx  xx.xxx  xx.xxx  x.xx

Bearing  Final
Resist   qult   phi f   Nm  Kappa  Bm    H1    Df    B'    L'    Zw      Hu        Vu
 (ksf)   (ksf)  (deg)                   (ft)  (ft)  (ft)  (ft)  (ft)  (kips/ft) (kips/ft)
xxx.xx  xxx.xx   xx.x xx.xx xx.xx xx.xx xx.xx xx.xx xx.xx xx.xx xx.xx   xxx.xx    xxx.xx
```

(Soil Cond 4)

```
                                 Gamma    Gamma
Layer  qult    c    phi          Mass      Sat     Gamma   Sub   N      s       i     RC(BC)
       (ksf) (ksf) (deg)         (pcf)    (pcf)    (pcf)
  i   xxx.xx xxx.x xx.x        xxx.xx   xxx.xx   xxx.xx    a  xx.xxx  x.xxx  x.xxx   x.xx

Bearing  Final
Resist   qult    H1    Delta H    Df      B'     L'      Zw       Hu         Vu
 (ksf)   (ksf)  (ft)    (ft)     (ft)   (ft)   (ft)     (ft)  (kips/ft)  (kips/ft)
xxx.xx  xxx.xx  xx.xx   xx.xx    xx.xx  xx.xx  xx.xx    xx.xx    xxx.xx     xxx.xx
```

(Soil Cond 5)

```
                                Gamma    Gamma
Layer  qult    c    phi         Mass      Sat     Gamma   Sub   N     s     i     RC(BC)
       (ksf) (ksf) (deg)        (pcf)    (pcf)    (pcf)
  i   xxx.xx xxx.x xx.x       xxx.xx   xxx.xx   xxx.xx    a   x.xxx x.xxx x.xxx   x.xx

Bearing  Final
Resist   qult    H1    H crit     Df      B'     L'      Zw       Hu         Vu
 (ksf)   (ksf)  (ft)    (ft)     (ft)   (ft)   (ft)     (ft)  (kips/ft)  (kips/ft)
xxx.xx  xxx.xx  xx.xx   xx.xx    xx.xx  xx.xx  xx.xx    xx.xx    xxx.xx     xxx.xx
```

(Soil Cond 6)

Layer	qult (ksf)	c (ksf)	phi (deg)	Gamma Mass (pcf)	Gamma Sat (pcf)	Gamma (pcf)	Sub	N	s	i	RC(BC)
i	xxx.xx	xxx.x	xx.x	xxx.xx	xxx.xx	xxx.xx	a	x.xxx	x.xxx	x.xxx	x.xx

Bearing Resist (ksf)	Final qult (ksf)	H1 (ft)	Ks	Df (ft)	Df2 (ft)	B' (ft)	L' (ft)	Zw (ft)	Hu (kips/ft)	Vu (kips/ft)
xxx.xx	xxx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xxx.xx	xxx.xx

(Soil Cond 7)

Layer	qult (ksf)	c (ksf)	phi (deg)	Gamma Mass (pcf)	Gamma Sat (pcf)	Gamma (pcf)	Sub	N	s	i	RC(BC)
i	xxx.xx	xxx.x	xx.x	xxx.xx	xxx.xx	xxx.xx	a	x.xxx	x.xxx	x.xxx	x.xx

Bearing Resist (ksf)	Final qult (ksf)	H1 (ft)	Df (ft)	Df1 (ft)	B' (ft)	L' (ft)	Zw (ft)	Hu (kips/ft)	Vu (kips/ft)
xxx.xx	xxx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xxx.xx	xxx.xx

(Soil Cond 8)

Layer	qult (ksf)	c (ksf)	phi (deg)	Gamma Mass (pcf)	Gamma Sat (pcf)	Gamma (pcf)	Sub	N	s	i	RC(BC)
i	xxx.xx	xxx.x	xx.x	xxx.xx	xxx.xx	xxx.xx	a	x.xxx	x.xxx	x.xxx	x.xx

Bearing Resist (ksf)	Final qult (ksf)	qult,eq4 (ksf)	H crit (ft)	H1 (ft)	Df (ft)	B' (ft)	L' (ft)	Zw (ft)	Hu (kips/ft)	Vu (kips/ft)
xxx.xx	xxx.xx	xxx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xxx.xx	xxx.xx

(Soil Cond 9)

Layer	qult (ksf)	c (ksf)	phi (deg)	Gamma m Gamma (pcf)	Gamma sat (pcf)	Gamma (pcf)	Nm	Nc	Nq	Sc	RC(BC)
i	xxx.xx	xxx.x	xx.x	xxx.xx	xxx.xx	xxx.xx	xx.xx	xx.xx	xx.xx	xx.xx	x.xx

Bearing Resist (ksf)	Final qult (ksf)	phi f (deg)	Kappa (ft)	Bm (ft)	H1 (ft)	Df (ft)	B' (ft)	L' (ft)	Zw (ft)	Hu (kips/ft)	Vu (kips/ft)
xxx.xx	xxx.xx	xx.x	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xxx.xx	xxx.xx

(Soil Cond 10)

Layer	qult (ksf)	c (ksf)	phi (deg)	Gamma Mass (pcf)	Gamma Sat (pcf)	Gamma (pcf)	Sub	N	s	i	RC(BC)
i	xxx.xx	xxx.x	xx.x	xxx.xx	xxx.xx	xxx.xx	a	xxx.xxx	x.xxx	x.xxx	x.xx

Bearing Resist (ksf)	Final qult (ksf)	H1 (ft)	Df (ft)	B' (ft)	L' (ft)	Zw (ft)	Hu (kips/ft)	Vu (kips/ft)
xxx.xx	xxx.xx	xxx.xx	xxx.xx	xx.xx	xx.xx	xx.xx	xxx.xx	xxx.xx

NOTE: The Bearing Resistance values are based on a Bearing Capacity Resistance Factor (Phi) of x.xx times the Final qult value for all limit states except the Service limit state. The Service limit state uses a Phi of 1.0 times the Final qult value.

7.6.21 MOMENT AXIAL INTERACTION Report Format

```
                ABUTMENT BACKWALL  xxx.xx (ft) FROM TOP OF STRUCTURE
 ABUTMENT BACKWALL AT SEAT LEVEL  xxx.xx (ft) FROM TOP OF STRUCTURE

Limit   Load          Applied    Moment  Applied    Axial          Perform    Area    Phi
State   Case   Stage   Moment    Resist   Axial    Resist   Zone    Ratio     Reqd   Factor
                     (kip-ft)  (kip-ft)   (kip)     (kip)                   (in^2)
aaaaaaaaaaaaaaaaaaaa xxxxx.xxa xxxxx.xx xxxxx.xx  xxxxx.xx    aa    xxx.xxx   xx.xx   xx.xxx

                       STEM LOCATION A  xxx.xx (ft) FROM TOP OF STRUCTURE

Limit   Load          Applied    Moment  Applied    Axial          Perform    Area    Phi
State   Case   Stage   Moment    Resist   Axial    Resist   Zone    Ratio     Reqd   Factor
                     (kip-ft)  (kip-ft)   (kip)     (kip)                   (in^2)
aaaaaaaaaaaaaaaaaaaa xxxxx.xxa xxxxx.xx xxxxx.xx axxxxx.xx    aa    xxx.xxx   xx.xx   xx.xx

      STEM CUTOFF LOCATION - #ii @ xx.xxx (ft)  FROM TOP OF STRUCTURE

Limit   Load          Applied    Moment  Applied    Axial          Perform    Area    Phi
State   Case   Stage   Moment    Resist   Axial    Resist   Zone    Ratio     Reqd   Factor
                     (kip-ft)  (kip-ft)   (kip)     (kip)                   (in^2)
aaaaaaaaaaaaaaaaaaaa xxxxx.xxa xxxxx.xx xxxxx.xx axxxxx.xx    aa    xxx.xxx   xx.xx   xx.xx

 Performance Ratio =  Axial Resistance / Applied Axial Force

 Section Thickness =xxx.xx (in)
 Effective Depth =xxx.xx (in)

 Area required based on rho-min: xxx.xx (in^2) a
 Cracking Moment M(cr):        xxxxx.xx (kip-ft)
 1.33 Mu:                      xxxxx.xx (kip-ft)

  ** Indicates governing area of steel for the stem location

 Zone Code Descriptions
        TN - Tension controlled section
        TR - Transition section
        CM - Compression controlled section

 Phi Factor Epsilon (cl) =  x.xxxxx
 Phi Factor Epsilon (tl) =  x.xxxxx

  Warning:  A performance ratio less than 1 was found

  + Warning:  Negative applied load encountered in the stem, Temp/Shrink
              steel in front face of stem does not meet capacity requirements.
              This message will result in a specification check warning.

  + Note: Negative applied load encountered in the backwall. Temp/Shrink
          steel in front face of backwall provides adequate capacity.
          This message will result in a specification check warning.

  + Warning:  Negative applied load encountered in the backwall, Temp/Shrink
              steel in front face of backwall does not meet capacity requirements.

  + Note: Negative applied load encountered in the stem. Temp/Shrink
          steel in front face of stem provides adequate capacity.
          This message will result in a specification check warning.

  + Warning: Negative applied load encountered in the stem. Temp/Shrink
             steel in front face of stem does not meet capacity requirements.

 A positive applied moment produces tensile stress on the backface
 reinforcement.  A positive applied axial force produces a compressive
 stress on the entire cross section.  Applied loads are assumed to be
 positive.  The resistance is based on backface reinforcement only.
```

A positive applied moment produces tensile stress on the backface reinforcement. A positive applied axial force produces a compressive stress on the entire cross section. Applied loads are assumed to be positive. The resistance is based on backface reinforcement for positive loads. When negative applied loads are detected the capacity is checked using the standard temperature and shrinkage steel(#4 @ 12in) found in the front face of the stem.

Warning: negative applied load encountered in backwall, assumptions for moment axial load interaction are violated.

Warning: negative applied load encountered in stem, assumptions for moment axial load interaction are violated.

7.6.22 INTERNAL FOOTING FORCES Report Format

TOE SHEAR
HEEL SHEAR

Limit State	Load Case	Stage	Shear due to Soil Pressure (kip)	Shear due to Footing (kip)	Total Shear (kip)	Shear Location
aaaaaaaaaaaaaaaaaaa			xxxxxx.xx	xxxxxx.xx	xxxxxx.xx	aaaaaaaa

Effective Depth xxx.xx (ft)

Shear Location as distance is measured from back face of stem

Total Toe Moment = Moment due to Piles - Moment due to Footing
Total Heel Moment = Moment due to Footing - Moment due to Piles
Total Toe Moment = Moment due to Caissons - Moment due to Footing
Total Heel Moment = Moment due to Footing - Moment due to Caissons

Total Toe Moment = Moment due to Soil Pressure - Moment due to Footing
Total Heel Moment = Moment due to Footing - Moment due to Soil Pressure

Total Toe Moment = Moment due to Rock Pressure - Moment due to Footing
Total Heel Moment = Moment due to Footing - Moment due to Rock Pressure

Total Toe Shear = ABS(Shear due to Piles - Shear due to Footing)
Total Heel Shear = ABS(Shear due to Footing - Shear due to Piles)

Total Toe Shear = ABS(Shear due to Caissons - Shear due to Footing)
Total Heel Shear = ABS(Shear due to Footing - Shear due to Caissons)

Total Toe Shear = ABS(Shear due to Soil Pressure - Shear due to Footing)
Total Heel Shear = ABS(Shear due to Footing - Shear due to Soil Pressure)

Total Toe Shear = ABS(Shear due to Rock Pressure - Shear due to Footing)
Total Heel Shear = ABS(Shear due to Footing - Shear due to Rock Pressure)

TOE MOMENT
HEEL MOMENT
Critical section at stem back face

Limit State	Load Case	Stage	Moment due to Soil Pressure (kip-ft)	Moment due to Footing (kip-ft)	Total Moment (kip-ft)	Moment Direction
aaaaaaaaaaaaaaaaaaa			xxxxxx.xx	xxxxxx.xx	xxxxxx.xx	a

Note: Moment direction "1" indicates that tension occurs in the bottom perpendicular reinforcement. Moment direction "2" indicates that tension occurs in the top perpendicular reinforcement.

Note: Moment direction "1" indicates that tension occurs in the top perpendicular reinforcement. Moment direction "2" indicates that tension occurs in the bottom perpendicular reinforcement.

Total Toe Moment = Moment due to Piles - Moment due to Footing

VERTICAL CAISSON LOADS
VERTICAL PILE LOADS

Limit State	Load Case	Stage	Eccent (ft)	Load on Single Caisson within Row / Load on Single Pile within Row: Row 1 (kip)	Row 2 (kip)	Row 3 (kip)	Row 4 (kip)	Row 5 (kip)
aaaaaaaaaaaaaaaaaaa			xxxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xx	xxxxx.xx

The eccentricity is the distance from the center of gravity of the piles to the load resultant. Positive towards toe; negative towards heel.

Moments are assumed to cause tension on the bottom face of the footing at the toe and on the top face of the footing at the heel.

7.6.23 MINIMUM REINFORCEMENT CHECK Report Format

BACKWALL AND STEM

Location	Dist from Struc Top (ft)	Cracking Moment M(cr) (kip-ft)	1.33*M(u) (kip-ft)	Rho Min Area (in^2)	Temp Shrink Area (in^2)	Area Prov/ Width (in^2)	Status Code
aaaaaa	xx.xx	xxx.xxa	xxx.xxa	xx.xxa	xx.xxa	xx.xx	a

FOOTING

Location	Cracking Moment M(cr) (kip-ft)	1.33*M(u) (kip-ft)	Rho Min Area (in^2)	Temp Shrink Area (in^2)	Area Prov/ Width (in^2)	Status Code
aaaaaaaaaaaa	xxx.xxa	xxx.xxa	xx.xxa	xx.xxa	xx.xx	a

Status Code Descriptions
+ - Controlling moment for Rho Min Area calculation
* - Controlling minimum area of steel
A - Area provided smaller than required minimum area of steel

7.6.24 INTERMEDIATE SETTLEMENT DATA Report Format

```
                                  INTERMEDIATE SETTLEMENT DATA
                                  (Pedestal footing on Rock)
                                  (Rectangular footing on Rock)

          Intact      Rock                    Effective    Effective
 Stage    Elastic     Mass         Rock       Footing      Footing
          Modulus     Modulus      Modulus    Length       Width
          (ksi)       (ksi)        (ksi)      (ft)         (ft)
 aaaaa    xxxx.xx     xxxx.xx      xxxx.xx    xxx.xx       xxx.xx

          Ratio                Rock      Christian
 Stage    Length     Betaz     Factor    Carrier      Poisson    Bearing     Elastic
          Width      Factor     Ip       Factor       Ratio      Pressure    Settlement
                                          (ft)                    (ksf)       (in)
 aaaaa    xxx.xx     xx.xx     xx.xx     xx.xx        xx.xx      xxx.xx      xxx.xx


                          INTERMEDIATE SETTLEMENT DATA
                  (Rectangular footing on single soil layer)
        (Two Soil Layers - Scenario 1: lower layer much stiffer than top layer)

         Soil                Effective   Effective   Layer         Christian
 Stage   Elastic    Depth    Footing     Footing     Thickness     Carrier     Bearing    Elastic
         Modulus    Factor   Length      Width       Coefficient   Factor      Pressure   Settlement
         (ksf)               (ft)        (ft)                      (ft)        (ksf)      (in)
 aaaaa   xxxx.xx    xx.xx    xxx.xx      xxx.xx      xx.xxx        xx.xx       xxx.xx     xxx.xx


                          INTERMEDIATE SETTLEMENT DATA
            (Two Soil Layers - Scenario 2: lower layer softer than upper layer)

          Soil 1      Soil 2      Total     Elastic        Shape
 Stage    Elastic     Elastic     Soil      Distortion     Rigidity     Depth
          Modulus     Modulus     Depth     Factor         Factor       Factor
          (ksf)       (ksf)       (ft)
 aaaaa    xxxx.xx     xxxx.xx     xxx.xx    xx.xxx         xx.xxx       xx.xx

          Effective     Effective     Layer          Christian
 Stage    Footing       Footing       Thickness      Carrier       Bearing     Elastic
          Length        Width         Coefficient    Factor        Pressure    Settlement
          (ft)          (ft)                         (ft)          (ksf)       (in)
 aaaaa    xxx.xx        xxx.xx        xx.xxx         xxx.xx        xxx.xx      xxx.xx


                          INTERMEDIATE SETTLEMENT DATA
                (Two Soil Layers - Scenario 3: sum settlement for each layer)

Layer i
------
         Soil                Effective   Effective   Layer         Christian
 Stage   Elastic    Depth    Footing     Footing     Thickness     Carrier     Bearing    Elastic
         Modulus    Factor   Length      Width       Coefficient   Factor      Pressure   Settlement
         (ksf)               (ft)        (ft)                      (ft)        (ksf)      (in)
 aaaaa   xxxx.xx    xx.xx    xxx.xx      xxx.xx      xx.xxx        xxx.xx      xxx.xx     xxx.xx
```

7.7 SPECIFICATION CHECK WARNINGS

This output table gives a summary of the titles of all of the output tables, which contain a specification check warning. Even if a specification checking output table and/or an analysis point is not printed the specification check is done. If a warning occurs, the output table title will appear on this report with a page number if the table is printed or an asterisk if the table is not printed. This table prints for both design and analysis runs, and will still print, even if all other output is turned off.

A sample specification check warning table is shown in Figure 7.7-1.

```
LRFD Abutment and Retaining Wall, Version x.x.x.x                 PAGE  47
Input File: tnab1B.dat                                 xx/xx/xxxx  xx:xx:xx
-------------------------------------------------------------------------------
       S.R. 0219 - C10 S102 ALT. 1  NEAR ABUTMENT DESIGN W/HP 14X117
                     SUMMARY - SPECIFICATION CHECKS
-------------------------------------------------------------------------------

                       SPECIFICATION CHECK WARNINGS

For the live loadings input by the user, the program did not
encounter any specification check warnings for any of the
applicable limit states.  It should be noted that the program
does not perform the specification checking corresponding to
commands that have not been input by the user.


THE FOLLOWING TABLES HAVE SPEC CHECK WARNINGS                  PAGE NO.
-------------------------------------------                    --------
MOMENT AXIAL INTERACTION
     STEM LOCATION D   36.00 (ft) FROM TOP OF STRUCTURE.......... 42
     STEM CUTOFF LOCATION - SHOWN FOR LARGEST BAR CUTOFF......... 42
CRACK CONTROL - ANALYSIS*
     FOOTING*

 * - An asterisk indicates the table was not printed
```

Figure 7.7-1 Specification Check Warnings Page

7.8 SPECIFICATION CHECK FAILURES

This output table gives a summary of the titles of all of the output tables, which contain a specification check failure. Even if a specification checking output table and/or an analysis point is not printed the specification check is done. If a warning occurs, the output table title will appear on this report with a page number if the table is printed or an asterisk if the table is not printed. This table prints for both design and analysis runs, and will still print, even if all other output is turned off.

A sample specification check failure table is shown in Figure 7.8-1.

```
LRFD Abutment and Retaining Wall, Version x.x.x.x                  PAGE  48
Input File: tnab1B.dat                                 xx/xx/xxxx  xx:xx:xx
-------------------------------------------------------------------------
       S.R. 0219 - C10 S102 ALT. 1  NEAR ABUTMENT DESIGN W/HP 14X117
                  SUMMARY - SPECIFICATION CHECKS (cont.)
-------------------------------------------------------------------------

                        SPECIFICATION CHECK ERRORS

For the live loadings input by the user, the program encountered
one or more specification check failures. The following is a
list of output table headings for which failures have occurred.
It should be noted that the program does not perform
specification checking corresponding to commands that have
not been input by the user.


THE FOLLOWING TABLES HAVE SPEC CHECK ERRORS                    PAGE NO.
-------------------------------------------                    --------
FOOTING FLEXURE*
     FLEXURAL STRENGTH*
CRACK CONTROL - ANALYSIS
     FOOTING..................................................... 44
REINFORCEMENT SUMMARY - ANALYSIS
     FOOTING..................................................... 45
SHEAR RESULTS
     FOOTING..................................................... 46

 * - An asterisk indicates the table was not printed
```

Figure 7.8-1 Specification Check Failures Page

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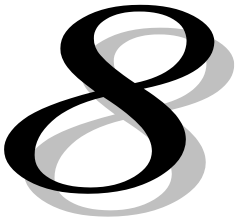

EXAMPLE PROBLEMS

8.1 EXAMPLE PROBLEMS

This chapter contains the example problems used to test and verify this program. Table 1 shows the example problem matrix, which lists each example problem and the key input items used to differentiate the problems. For each example problem, the following information is given: a brief narrative description of the problem; the input items from the example problem matrix; additional assumptions and input items required to create the input data file; and a sketch which shows the abutment geometry. The actual input data file for each example problem is not listed in this manual, but is included electronically. along with the executable program.

Table 8.1-1 Example Problem Matrix

	Example Problem						
Input Item	**1***	**2***	**3***	**4***	**5**	**6**	**7**
Solution Type	DSGN	DSGN	ANAL	ANAL	ANAL	DSGN	ANAL
Structure Type (1)	AT1	AWB	RWL	AWB	AT2	AT2	RWL-g
Footing Type (2)	PIL	SPR	PIL	PED	PIL	SPR	SPR
Units	US	US	US	US	US	US	US
Footing Elv. Fixity	TOP	TOP	def	def	def	BOT	def
Footing Near Slope?	N.A.	YES	N.A.	N.A.	N.A.	N.A.	NO
Input Height	12.7 ft	10.0 ft	13.0 ft	7.57 ft	14.0 ft	34.5 ft	8.67 ft
Stem Batter (3)	N.A.	BACK	BACK	BACK	BOTH	BOTH	BOTH
Front Water Level	NONE	NONE	14.25 ft	NONE	10.0 ft	13.0 ft	6.5 ft
Back Water Level	10.95 ft	4.85 ft	11.25 ft	NONE	7.0 ft	10.0 ft	3.5 ft
Backfill Slope y:x	N.A.	N.A.	1:2	N.A.	N.A.	N.A.	3:12
Min. Footing Thickness	2.5 ft	2.0 ft	3.0 ft	2.0 ft	2.5 ft	2.25 ft	1.33 ft
Minimum Toe Projection	1.0 ft	1.0 ft	2.25 ft	1.75 ft	2.75 ft	1.5 ft	0.83 ft
Minimum Heel Projection	1.0 ft	1.0 ft	4.92 ft	3.12 ft	7.97 ft	1.5 ft	1.33 ft
Max. Footing Thickness	5.0 ft	2.5 ft	N.A.	N.A.	N.A.	3.0 ft	N.A.
Maximum Toe Projection	1.75 ft	def	N.A.	N.A.	N.A.	def	N.A.
Maximum Heel Projection	def	def	N.A.	N.A.	N.A.	def	N.A.
Pile/Cai Batter x:y	3:12	N.A.	varies	N.A.	varies	N.A.	N.A.
Batter Piles per Row	0%	N.A.	varies	N.A.	varies	N.A.	N.A.
Pile/Cai Optimization	DENS	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
# of Pile/Cai Rows	N.A.	N.A.	2	N.A.	4	N.A.	N.A.
Epoxy Coated Rebar	N	N	N	N	N	Y	N.A.
Rock or Soil-# Layers	N.A.	Soil-1	N.A.	Rock-1	N.A.	Rock-1	Soil-1
Live Load Surcharge	Y	Y	Y	Y-Temp	Y-Temp	N	N
Earth Surcharge	N	N	N	N	Y-Temp	Y	N

(1) AT1 = Abutment Type I, AT2 = Abutment Type II, RWL = Retaining Wall, AWB = Abutment w/o backwall, "-g" = Gravity Wall

(2) SPR = Spread Footing, PIL = Pile Footing, CAI = Caisson Footing, PED = Pedestal Footing

(3) Back = Stem has back batter, Front = Stem has front batter, Both = Stem has front and back batter

* Example problem taken from existing Abutment and Retaining Wall manual

Table 8.1-1 Example Problem Matrix (cont.)

	Example Problem						
Input Item	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Solution Type	ANAL	DSGN	ANAL	ANAL	DSGN	DSGN	ANAL
Structure Type (1)	AT2	RWL	AWB-g	AT1	AT2	RWL	AT1
Footing Type (2)	PIL	PED	SPR	PIL	CAI	SPR	SPR
Units	US	US	US	US	US	US	US
Footing Elv. Fixity	def	BOT	def	def	BOT	TOP	def
Footing Near Slope?	N.A.	N.A.	N.A.	N.A.	N.A.	NO	NO
Input Height	14.0 ft	12.0 ft	7.75 ft	39.5 ft	14.75 ft	25.0 ft	12.7 ft
Stem Batter (3)	BOTH	BACK	BOTH	N.A.	BOTH	BACK	N.A.
Front Water Level	10.0 ft	7.2 ft	11.0 ft	21.0 ft	9.0 ft	21.0 ft	13.95 ft
Back Water Level	7.0 ft	4.2 ft	8.0 ft	17.0 ft	6.0 ft	18.0 ft	10.95 ft
Backfill Slope y:x	N.A.	2:12	N.A.	N.A.	N.A.	Def	N.A.
Min. Footing Thickness	2.5 ft	1.5 ft	1.25 ft	4.25 ft	2.5 ft	def	2.0 ft
Minimum Toe Projection	2.75 ft	def	0.4 ft	6.5 ft	10.0 ft	def	2.58 ft
Minimum Heel Projection	5.19 ft	def	2.12 ft	11.5 ft	def	def	2.33 ft
Max. Footing Thickness	N.A.	2.5 ft	N.A.	N.A.	6.0 ft	4.0 ft	N.A.
Maximum Toe Projection	N.A.	def	N.A.	N.A.	def	6.0 ft	N.A.
Maximum Heel Projection	N.A.	def	N.A.	N.A.	def	4.0 ft	N.A.
Pile/Cai Batter x:y	varies	N.A.	N.A.	varies	3:12	N.A.	N.A.
Batter Piles per Row	varies	N.A.	N.A.	varies	0%	N.A.	N.A.
Pile/Cai Optimization	N.A.	N.A.	N.A.	N.A.	COST	N.A.	N.A.
# of Pile/Cai Rows	4	N.A.	N.A.	5	N.A.	N.A.	N.A.
Epoxy Coated Rebar	N	Y	N.A.	Y	Y	Y	N
Rock or Soil-# Layers	N.A.	Rock-1	Rock-1	N.A.	N.A.	Soil-2	Soil-1
Live Load Surcharge	Y-Temp	Y	Y	N	Y	Y	Y
Earth Surcharge	Y-Temp	Y	N	Y	Y	Y	N

(1) AT1 = Abutment Type I, AT2 = Abutment Type II, RWL = Retaining Wall, AWB = Abutment w/o backwall, "-g" = Gravity Wall

(2) SPR = Spread Footing, PIL = Pile Footing, CAI = Caisson Footing, PED = Pedestal Footing

(3) Back = Stem has back batter, Front = Stem has front batter, Both = Stem has front and back batter

* Example problem taken from existing Abutment and Retaining Wall manual

8.2 EXAMPLE 1 (DESIGN)

Example 1 is a type I abutment on a pile footing. The structure geometry is shown in the following figure. Earthquake loads are not considered in this problem.

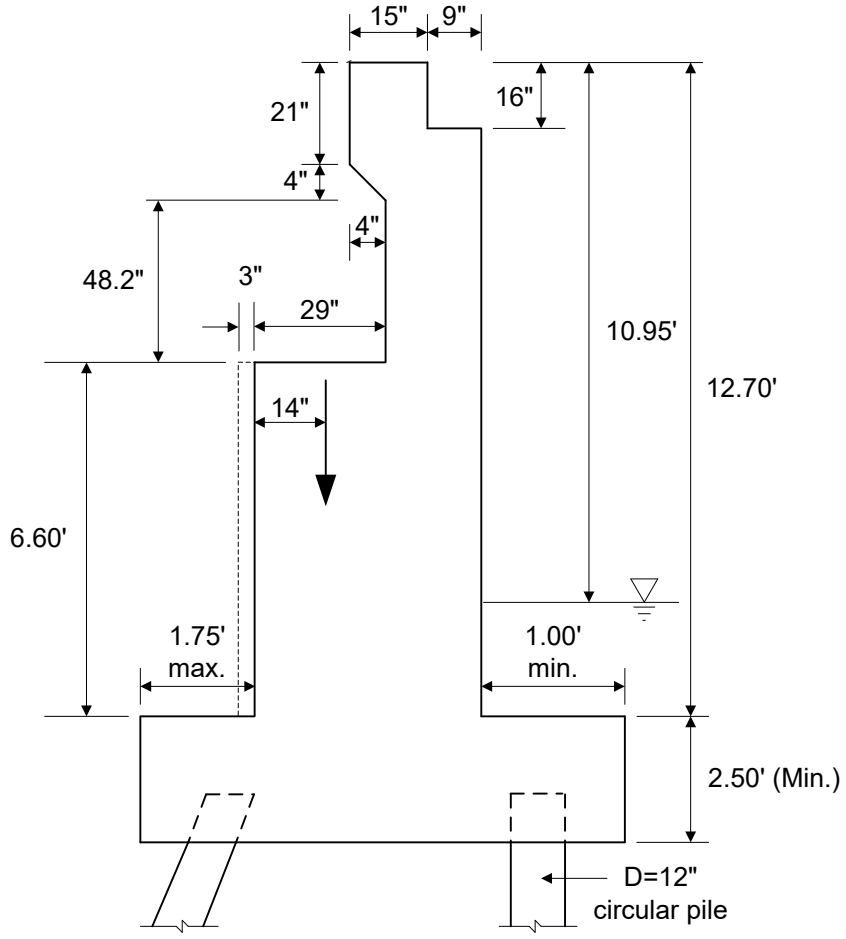

Figure 8.2-1 Example 1 Abutment Geometry

CONFIGURATION

Lines per Page	Blank Lines on Top
83	0

CONTROL

Sys of Units	Type of Run	Footing Datum
US	D	T

ABUTMENT TYPE I

Height (ft)	Top Width (in)	Seat Width (in)	Seat Slope Height (in)	Seat Face Height (in)	Corbel Width (in)	Corbel Height (in)	Corbel Slope Height (in)
12.70	15.0	29.0	0.0	48.2	4.0	21.0	4.0

Paving Notch Width (in)	Paving Notch Height (in)	Bearing X Locn (in)	Bearing Y Locn (in)	Front Water Level (ft)	Back Water Level (ft)	Architectural Treatment Thickness (in)	Backwall/ Stem Bar Alignment
9.0	16.0	14.0	none	none	10.95	3.0	Y

NOTE: An architectural treatment has been specified. All structure dimensions shown do not account for the architectural treatment. For drafting purposes the architectural treatment thickness is used to dimension the architectural treatment along the front face of the stem.

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
2.50	1.00	1.00	6.08	5.00	1.75	none	none

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
2.00	3.00	1.00

PILE

Pile Dim A (in)	Pile Dim B (in)	Pile Embedment (in)	Service Axial Capacity (kip)	Strength Axial Capacity (kip)	Service Lateral Capacity (kip)	Strength Lateral Capacity (kip)	Allowed Uplift (kip)
12.0	0.0	12.0	N/A	280.00	N/A	0.00	0.00

PILE/CAISSON LAYOUT DESIGN

Toe to First Row (ft)	Minimum Heel to Last Row (ft)	Minimum Spacing (ft)	Maximum Spacing (ft)	Row Placement	Pile Spacing Rounding (ft)	Row Distances Rounding (ft)
1.50	1.50	3.00	15.00	E	0.25	0.25

Design Batt Horizontal Component	Design Batt Vertical Component	Last Row % Batter (%)	Optimize	Pile/ Caisson Cost ($/pile)	Footing Cost ($/yd^3)
3.00	12.00	0.0	P	none	none

MATERIALS

Backwall f'c (ksi)	Stem f'c (ksi)	Footing f'c (ksi)	fy (ksi)	Reinforcement Epoxy Coated Backwall	Stem	Footing
3.500	3.000	3.000	50.000	N	N	N

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	Concrete Density For Ec (lb/ft^3)
33.25	120.0	135.0	35.0	150.0	145.0

Architectural Treatment Density (lb/ft^3)	fu (ksi)
150.0	65.000

MISCELLANEOUS REINFORCEMENT DATA

Aggregate Size (in)	Development Correction	Backwall Exposure Class	Stem Exposure Class	Footing Exposure Class
1.00	1.00	2	2	1

REINFORCEMENT COVER

Backwall Back Vertical (in)	Stem Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)	Toe End (in)	Heel End (in)
3.0	3.0	2.8	4.2	3.8	5.2	2.0	2.0

BAR SPACING FOR DESIGN

Backwall Maximum Bar Diam (in)	Stem Maximum Bar Diam (in)	Footing Maximum Bar Diam (in)	Hooked Footing Bars	User Requested Minimum Bar Spacing (in)	Bar Spacing Increment (in)
1.00	1.00	1.41	N	6.00	3.00

LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
1.00	1.00	1.00	2.00	2.00	0.00	0.00

LOADS ON ABUTMENTS

DC (kip/ft)	DW (kip/ft)	PL (kip/ft)	Vertical WSUP (kip/ft)	Horizontal WSUP (kip/ft)	WL (kip/ft)	TU (kip/ft)	Backwall Vertical LL (kip/ft)	Backwall Horizontal LL (kip/ft)
11.40	1.00	none	0.00	n/a	0.21	0.37	0.00	none

Horizontal WSUB (kip/ft)	FR (kip/ft)	Horizontal WSUP SER-I (kip/ft)	Horizontal WSUP STR-III (kip/ft)	Horizontal WSUP STR-V (kip/ft)	Horizontal WSUB SER-I (kip/ft)	Horizontal WSUB STR-III (kip/ft)	Horizontal WSUB STR-V (kip/ft)
n/a	0.00	0.12	0.55	0.16	0.00	0.00	0.00

DESIGN LIVE LOAD

Downward LL (kip/ft)	Upward LL (kip/ft)	BR (kip/ft)	CE (kip/ft)
3.50	0.00	0.16	0.00

PERMIT LIVE LOAD

Downward LL (kip/ft)	Upward LL (kip/ft)	BR (kip/ft)	CE (kip/ft)
0.00	0.00	0.00	0.00

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
1	0	1

OUTPUT OF RESULTS

Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Footing Flexure	Reinf Summary
1	1	1	1	1	1	1

Crack Control	Shear Results	Development Length
1	1	1

OUTPUT OF INTERMEDIATE DATA

Unfactored Forces	Load Factors	Moment/Axial Interaction	Internal Footing Forces	Intermediate Bearing Resistance Values	Detailed Stem Cutoff Load Values
1	1	1	1	0	1

Minimum Reinforcement Check	Intermediate Settlement Data
0	0

8.3 EXAMPLE 2 (DESIGN)

Example 2 is an abutment without backwall on a spread footing. The structure geometry is shown in the following figure. Earthquake loads are not considered in this problem.

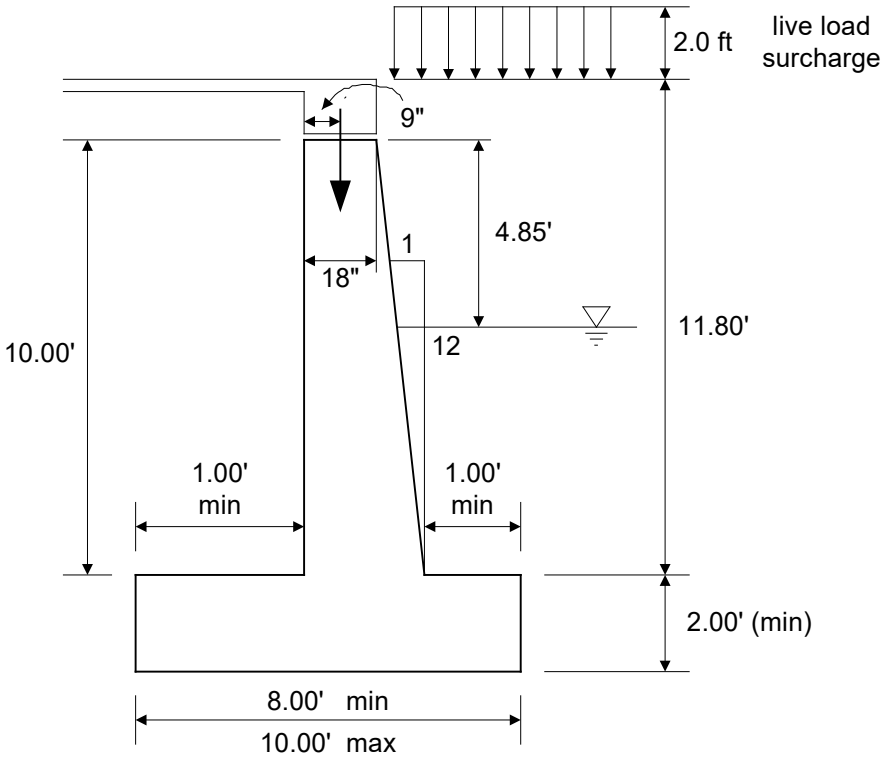

Figure 8.3-1 Example 2 Abutment Geometry

CONFIGURATION

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CONTROL

Sys of Units	Type of Run	Footing Datum
US	D	T

ABUTMENT WITHOUT BACKWALL

Height (ft)	Top Width (in)	Bearing Location (in)	Front Face Horizontal Component	Front Face Vertical Component	Back Face Horizontal Component	Back Face Vertical Component
10.00	18.0	9.0	none	none	1.00	12.00

Additional Fill Height (ft)	Front Water Level (ft)	Back Water Level (ft)	Type of Wall	Architectural Treatment Thickness (in)
1.80	none	4.85	C	0.0

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
2.00	1.00	1.00	8.00	2.50	none	none	10.00

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
2.00	3.00	1.00

SPREAD

Design Optim	Cost of Concrete ($/yd^3)	Cut or Fill	Cost of Fill ($/yd^3)	Cost of Cut ($/yd^3)	Ground Ground Elev (ft)	Ground Slope Type	Ground Slope Vert	Slope Horiz
C	400.00	F	150.00	none	none	none	none	none

MATERIALS

Backwall f'c (ksi)	Stem f'c (ksi)	Footing f'c (ksi)	fy (ksi)	Reinforcement Backwall	Epoxy Coated Stem	Epoxy Coated Footing
NA	3.000	3.000	50.000	NA	N	N

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	Concrete Density For Ec (lb/ft^3)
33.25	120.0	135.0	35.0	150.0	145.0

Architectural Treatment Density (lb/ft^3)	fu (ksi)
150.0	65.000

SOIL

Stem Top to Soil Layer (ft)	Footing Length (Parallel) (ft)	Footing Near Slope	Soil Level At Toe (ft)	Allow Settle (in)	Bearing Cap Resistance Factor	Sliding Resist Factor	No. Soil Layers
12.00	30.00	Y	0.00	1.00	0.50	1.00	1

Soil Layer Number	Soil Layer Thick (ft)	Undrained Shear Strength (ksf)	Mass Unit Weight/ Density (lb/ft^3)	Saturated Unit Weight/ Density (lb/ft^3)	Elastic Modulus (ksf)	Poissons Ratio
1	7.50	none	120.00	135.00	500.00	0.25

Soil Layer Number	Cohesion (ksf)	Effective Friction Angle (deg)	Ncq	N Gamma q
1	1.50	30.00	n/a	n/a

Apply Inclination Factors	Precast or Cast-in-Place	Reduction Coefficients RC(BC) Layer 1	Layer 2
Y	C	0.85	none

CONSOLIDATION SETTLEMENT

Layer Number	Void Ratio	Compr Index	Recomp Index	Second Comp Index	Init Effect Stress (ksi)	Max Past Effect Stress Top (ksi)	Prim Consol (year)	Serv Life (year)	Max Past Effect Stress Bottom (ksi)
1	0.80	0.10	0.02	0.002	0.01	0.02	1.0	10.0	0.01

MISCELLANEOUS REINFORCEMENT DATA

Aggregate Size (in)	Development Correction	Backwall Exposure Class	Stem Exposure Class	Footing Exposure Class
1.00	1.00	none	2	1

REINFORCEMENT COVER

Backwall Back Vertical (in)	Stem Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)	Toe End (in)	Heel End (in)
none	3.0	2.8	3.8	3.8	4.8	2.0	2.0

BAR SPACING FOR DESIGN

Backwall Maximum Bar Diam (in)	Stem Maximum Bar Diam (in)	Footing Maximum Bar Diam (in)	Hooked Footing Bars	User Requested Minimum Bar Spacing (in)	Bar Spacing Increment (in)
none	1.00	1.41	N	6.00	3.00

LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
1.00	1.00	1.00	2.00	2.00	0.00	0.00

LOADS ON ABUTMENTS

DC (kip/ft)	DW (kip/ft)	PL (kip/ft)	Vertical WSUP (kip/ft)	Horizontal WSUP (kip/ft)	WL (kip/ft)	TU (kip/ft)	Backwall Vertical LL (kip/ft)	Backwall Horizontal LL (kip/ft)
4.84	0.54	none	-0.24	n/a	0.10	0.79	none	none

Horizontal WSUB (kip/ft)	FR (kip/ft)	Horizontal WSUP SER-I (kip/ft)	Horizontal WSUP STR-III (kip/ft)	Horizontal WSUP STR-V (kip/ft)	Horizontal WSUB SER-I (kip/ft)	Horizontal WSUB STR-III (kip/ft)	Horizontal WSUB STR-V (kip/ft)
n/a	0.00	0.04	0.17	0.05	0.00	0.00	0.00

DESIGN LIVE LOAD

Downward LL (kip/ft)	Upward LL (kip/ft)	BR (kip/ft)	CE (kip/ft)
3.44	0.00	0.13	0.00

PERMIT LIVE LOAD

Downward LL (kip/ft)	**Upward LL (kip/ft)**	**BR (kip/ft)**	**CE (kip/ft)**
0.00	**0.00**	**0.00**	**0.00**

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
1	0	1

OUTPUT OF RESULTS

Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Footing Flexure	Reinf Summary
1	1	1	1	1	1	1

Crack Control	Shear Results	Development Length
1	1	1

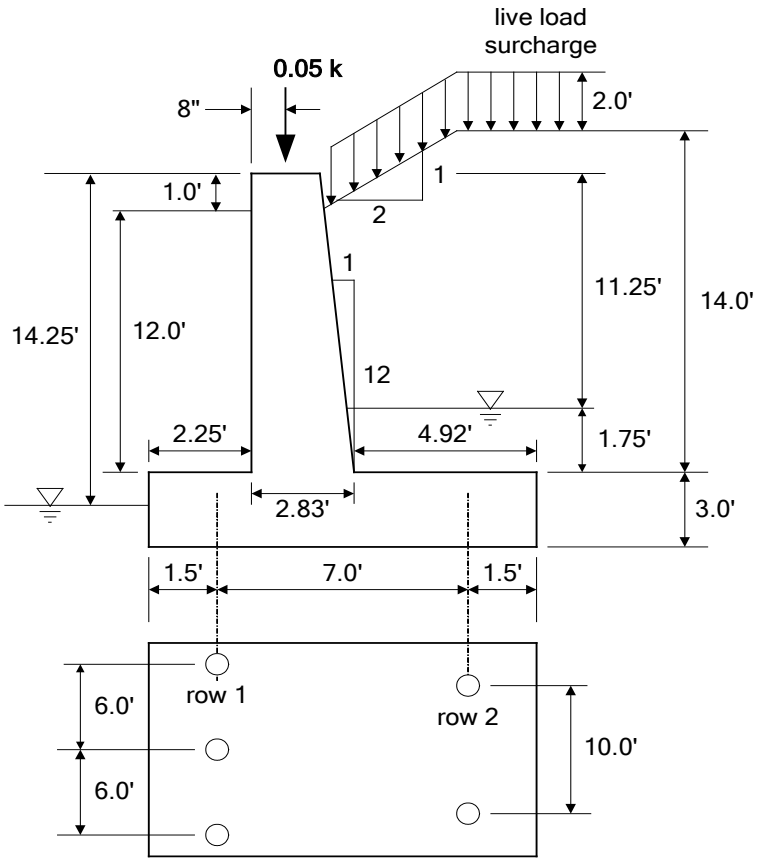
OUTPUT OF INTERMEDIATE DATA

Unfactored **Forces**	Load Factors	Moment/Axial Interaction	Internal Footing Forces	Intermediate Bearing Resist**ance** Values	Detailed Stem Cutoff Load Values
1	1	1	1	1	1

Minimum Reinf**orcement** Check	**Intermediate Settlement Data**
0	**1**

8.4 EXAMPLE 3

Example 3 is a cantilever retaining wall on pile footing. The structure geometry is shown in the following figure. This is an analysis problem for a retaining wall. Earthquake is not considered for this problem.



Rebar Layout:

Stem: #6 @ 9" for entire height
Footing Parallel Direction: top and bottom: #6 @ 12"
Footing Perpendicular Direction: top and bottom: #5 @ 9"

Figure 8.4-1 Example 3 Wall Geometry

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                    CONFIGURATION

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CONTROL

Sys of Units	Type of Run	Footing Datum
US	A	T

RETAINING WALL

Height (ft)	Top Width (in)	Front Face Horizontal Component	Front Face Vertical Component	Back Face Horizontal Component	Back Face Vertical Component
13.00	21.0	none	none	1.00	12.00

Exposed Stem Height (in)	Backfill Horizontal Component	Backfill Vertical Component	Backfill Slope Height (ft)	Front Water Level (ft)	Back Water Level (ft)	Type of Wall	Architectural Treatment Thickness (in)
12.0	2.00	1.00	2.00	14.25	11.25	C	0.0

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
3.00	2.25	4.92	none	none	none	none	none

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
2.00	3.00	1.00

PILE

Pile Dim A (in)	Pile Dim B (in)	Pile Embedment (in)	Service Axial Capacity (kip)	Strength Axial Capacity (kip)	Service Lateral Capacity (kip)	Strength Lateral Capacity (kip)	Allowed Uplift (kip)
12.0	0.0	12.0	N/A	280.80	N/A	0.00	0.00

PILE/CAISSON LAYOUT ANALYSIS

Row Number	Row Distance (ft)	Spacing within a Row (ft)	Percent Battered (%)	Horizontal Component	Vertical Component
1	1.50	6.00	100.0	3.00	12.00
2	7.00	10.00	0.0	none	none

MATERIALS

Backwall f'c (ksi)	Stem f'c (ksi)	Footing f'c (ksi)	fy (ksi)	Reinforcement Epoxy Coated Backwall	Stem	Footing
NA	3.000	3.000	60.000	NA	N	N

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	For Ec (lb/ft^3)
33.25	120.0	135.0	35.0	150.0	145.0

Architectural Treatment Density (lb/ft^3)	fu (ksi)
150.0	90.000

MISCELLANEOUS REINFORCEMENT DATA

Aggregate Size (in)	Development Correction	Backwall Exposure Class	Stem Exposure Class	Footing Exposure Class
1.00	1.00	none	2	1

REINFORCEMENT COVER

Backwall Back Vertical (in)	Stem Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)	Toe End (in)	Heel End (in)
none	3.2	3.2	4.2	3.2	4.2	2.0	2.0

BAR SIZE

Backwall Back Vertical (US bar)	Footing Perpend Top (US bar)	Footing Parallel Top (US bar)	Footing Perpend Bottom (US bar)	Footing Parallel Bottom (US bar)	Footing Perp Top Bar Type	Footing Perp Bot Bar Type
none	5	6	5	6	Straight	Straight

BAR SPACING FOR ANALYSIS

Backwall Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)
none	9.0	12.0	9.0	12.0

STEM REINFORCING BARS

Range Number	Bar Size (US bar)	Bar Spacing (in)	Group Offset (in)	End Location (ft)
1	6	9.00	0.00	13.00

LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
1.00	1.00	1.00	2.00	2.00	0.00	0.00

LOADS ON RETAINING WALLS

CT (kip/ft)	Y Distance to CT (in)	Parapet Dead Load (kip/ft)	X Distance to Parapet (in)	Noise Wall Dead Load (kip/ft)	X Distance to Noise Wall (in)
none	none	0.05	8.0	0.00	0.0

Wind on External Structure (kip/ft)	Y Distance to Wind on External Structure (in)	Wind on External Structure SER-I (kip/ft)	STR-III (kip/ft)	STR-V (kip/ft)
n/a	0.0	none	none	none

Wind on Substructure (Wall) SER-I (kip/ft)	STR-III (kip/ft)	STR-V (kip/ft)
none	none	none

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
1	0	1

OUTPUT OF RESULTS

Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Footing Flexure	Reinf Summary
1	1	1	1	1	1	1

Crack Control	Shear Results	Development Length
1	1	1

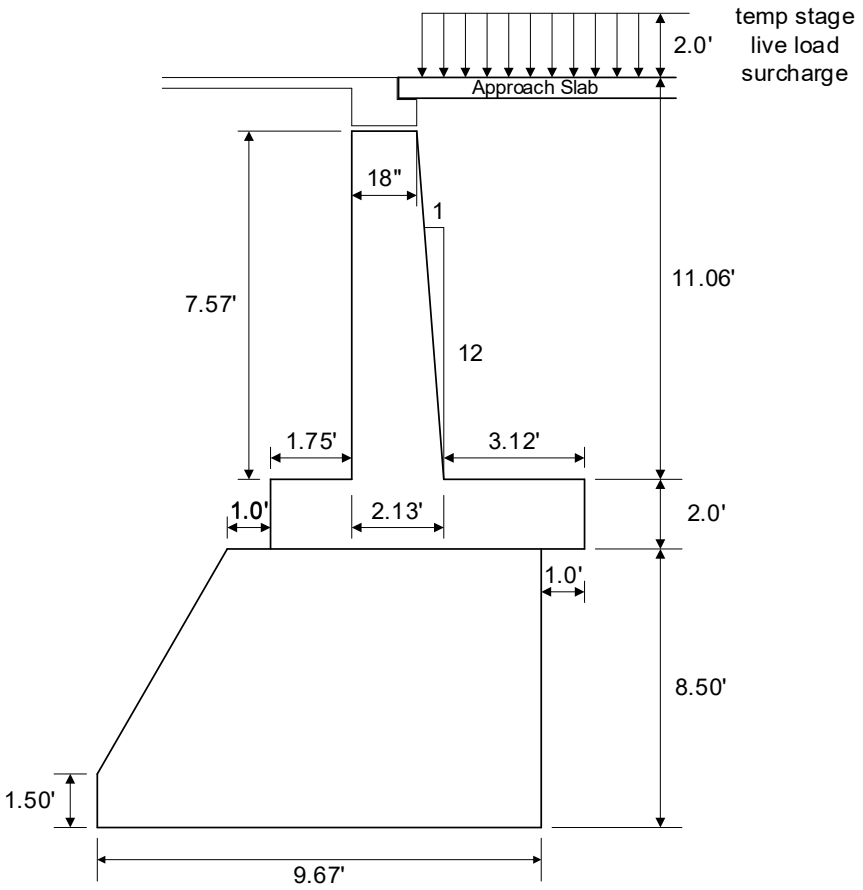
OUTPUT OF INTERMEDIATE DATA

Unfactored Forces	Load Factors	Moment/Axial Interaction	Internal Footing Forces	Intermediate Bearing Resistance Values	Detailed Stem Cutoff Load Values
1	1	1	1	0	1

Minimum Reinforcement Check	Intermediate Settlement Data
1	0

8.5 EXAMPLE 4

Example 4 is an analysis problem for an abutment w/o backwall on pedestal footing. The structure geometry is shown in the following figure. The abutment is to be analyzed. Earthquake was not considered for this problem. There is an assumed 30’ approach slab resting on a beam notch. This Analysis run will consider the approach slab to act as a simple span per standard drawing BD-628M, Sheet 2, Note 14. A second run of the program applying the Final Stage Surcharge Loads is needed to satisfy Note 14.



Rebar Layout:

Stem: #6 @ 12" for entire height
Footing Parallel Direction: top and bottom: **#5 @ 9"**

Figure 8.5-1 Example 4 Abutment and Pedestal Geometry

CONFIGURATION

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CONTROL

Sys of Units	Type of Run	Footing Datum
US	A	T

ABUTMENT WITHOUT BACKWALL

Height (ft)	Top Width (in)	Bearing Location (in)	Front Face Horizontal Component	Front Face Vertical Component	Back Face Horizontal Component	Back Face Vertical Component
7.57	18.0	9.0	none	none	1.00	12.00

Additional Fill Height (ft)	Front Water Level (ft)	Back Water Level (ft)	Type of Wall	Architectural Treatment Thickness (in)
3.49	none	none	C	0.0

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
2.00	1.75	3.12	none	none	none	none	none

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
2.00	3.00	1.00

PEDESTAL FOOTING

Pedestal Spacing (ft)	Overall Height (ft)	Front Height (ft)	Min Width (ft)	Min Thick (in)	Front Proj (ft)	Back Offset (ft)	Max Width (ft)	Max Thick (in)	**Design Optimization**
9.67	8.50	1.50	9.67	30.00	1.00	1.00	none	none	**none**

MATERIALS

Backwall f'c (ksi)	Stem f'c (ksi)	Footing f'c (ksi)	Footing fy (ksi)	Reinforcement Backwall	Epoxy Coated Stem	Epoxy Coated Footing
NA	3.000	3.000	50.000	NA	N	N

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	Concrete Density For Ec (lb/ft^3)
33.25	120.0	135.0	35.0	150.0	145.0

Architectural Treatment Density (lb/ft^3)	fu (ksi)
150.0	65.000

ROCK

Empirical Bearing Capacity (ksf)	Stem Top to Rock Layer (ft)	Footing Length Parallel (ft)	Sliding Resistance	Allow Settle (in)	Bear Cap Resist Factor	Sliding Resist Factor
200.00	9.57	100.00	N	1.00	0.55	0.00

RQD (%)	Concrete /Rock Friction (deg)	Intact Elastic Modulus (ksi)	Poissons Ratio	Rock Mass Rating	Elastic Modulus Reduction	Rock Mass Modulus (ksi)
N/A	30.00	3.48	0.25	N/A	N/A	3.35

MISCELLANEOUS REINFORCEMENT DATA

Aggregate Size (in)	Development Correction	Backwall Exposure Class	Stem Exposure Class	Footing Exposure Class
1.00	1.00	none	1	1

REINFORCEMENT COVER

Backwall Back Vertical (in)	Stem Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)	Toe End (in)	Heel End (in)
none	3.1	3.2	4.2	4.2	5.2	2.0	2.0

BAR SIZE

Backwall Back Vertical (US bar)	Footing Perpend Top (US bar)	Footing Parallel Top (US bar)	Footing Perpend Bottom (US bar)	Footing Parallel Bottom (US bar)	Footing Perp Top Bar Type	Footing Perp Bot Bar Type
none	none	5	none	5	none	none

BAR SPACING FOR ANALYSIS

Backwall Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)
none	0.0	9.0	0.0	9.0

STEM REINFORCING BARS

Range Number	Bar Size (US bar)	Bar Spacing (in)	Group Offset (in)	End Location (ft)
1	6	12.00	0.00	7.50

LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
1.00	1.00	1.00	2.00	0.00	0.00	0.00

LOADS ON ABUTMENTS

DC (kip/ft)	DW (kip/ft)	PL (kip/ft)	Vertical WSUP (kip/ft)	Horizontal WSUP (kip/ft)	WL (kip/ft)	TU (kip/ft)	Backwall Vertical LL (kip/ft)	Backwall Horizontal LL (kip/ft)
2.75	0.00	none	-0.21	n/a	0.08	0.65	none	none

Horizontal WSUB (kip/ft)	FR (kip/ft)	Horizontal WSUP SER-I (kip/ft)	Horizontal WSUP STR-III (kip/ft)	Horizontal WSUP STR-V (kip/ft)	Horizontal WSUB SER-I (kip/ft)	Horizontal WSUB STR-III (kip/ft)	Horizontal WSUB STR-V (kip/ft)
n/a	0.00	0.04	0.21	0.06	0.00	0.00	0.00

APPROACH SLAB LOADS

Approach Slab DC (kip/ft)	Approach Slab LL (kip/ft)	X distance to Approach Slab Load (in)	Approach Slab on Beam Notch	Approach Slab DW (kip/ft)
3.00	0.96	N/A	Y	0.00

Approach Slab Type 4 Properties

Flexible Pavement?	Drain Width (in)	Average Drain Height (in)	Drain Wall Thickness (in)	Bottom Slab Thickness (in)	Drain Pedestal Width (in)	Drain Pedestal Spacing (in)	Paving Notch Width (in)	Paving Notch Height (in)
none	none	none	none	none	none	none	none	none

DESIGN LIVE LOAD

Downward LL (kip/ft)	Upward LL (kip/ft)	BR (kip/ft)	CE (kip/ft)
2.86	0.00	0.11	0.00

PERMIT LIVE LOAD

Downward LL (kip/ft)	**Upward LL (kip/ft)**	**BR (kip/ft)**	**CE (kip/ft)**
0.00	**0.00**	**0.00**	**0.00**

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
1	0	1

OUTPUT OF RESULTS

Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Footing Flexure	Reinf Summary
1	1	1	1	1	1	1

Crack Control	Shear Results	Development Length
1	1	1

```
                                OUTPUT OF INTERMEDIATE DATA
                                                 Internal      Intermediate       Detailed
Unfactored     Load      Moment/Axial    Footing     Bearing Resistance    Stem Cutoff
  Forces      Factors     Interaction    Forces           Values          Load Values
     1           1            1             1               0                1
 Minimum Reinforcement     Intermediate
         Check             Settlement Data
           1                       1
```

8.6 EXAMPLE 5

Example 5 is the same as Example 8, with a Type 4 Approach Slab added, and the footing heel extended beyond the drain trough support pedestal.

The example is a type II abutment on pile footing. The structure geometry is shown in the following figure. The abutment is to be analyzed. The earthquake consideration was neglected for this example. There is an assumed 25' approach slab resting in the paving notch of the Type 4 drain trough. This Analysis run will consider the approach slab to act as a simple span per standard drawing BD-628M, Sheet 2, Note 14. A second run of the program applying the Final Stage Surcharge Loads is needed to satisfy Note 14.

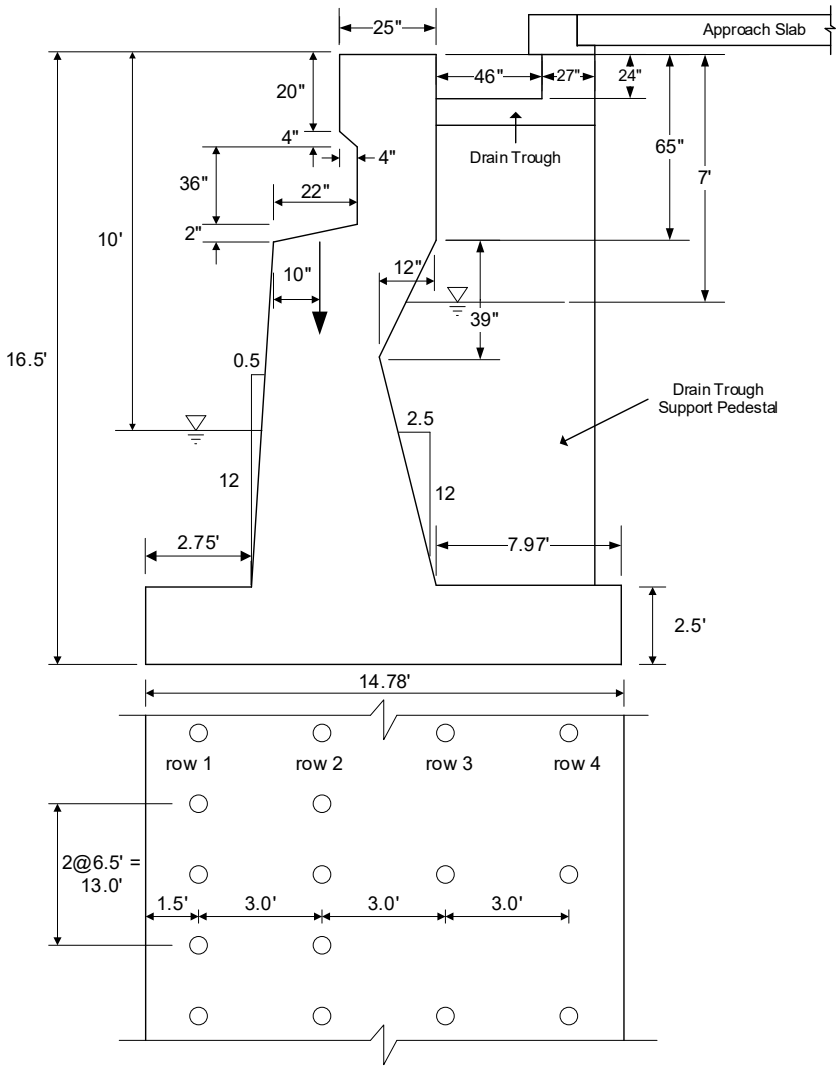

Figure 8.6-1 Example 5 Abutment Geometry

CONFIGURATION

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CONTROL

Sys of Units	Type of Run	Footing Datum
US	A	T

ABUTMENT TYPE II

Height (ft)	Top Width (in)	Seat Width (in)	Seat Slope Height (in)	Seat Face Height (in)	Corbel Width (in)	Corbel Height (in)	Corbel Slope Height (in)	Paving Notch Width (in)	Paving Notch Height (in)
14.00	25.0	22.0	2.0	36.0	4.0	20.0	4.0	0.0	0.0

Backwall Height (in)	Stem Notch Width (in)	Stem Notch Height (in)	Front Face Horizontal Component	Front Face Vertical Component	Back Face Horizontal Component	Back Face Vertical Component
65.0	12.0	39.0	0.50	12.00	2.50	12.00

Bearing X Locn (in)	Bearing Y Locn (in)	Front Water Level (ft)	Back Water Level (ft)	Architectural Treatment Thickness (in)	Backwall/ Stem Bar Alignment
10.0	none	10.00	7.00	0.0	N/A

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
2.50	2.75	7.97	none	none	none	none	none

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
2.00	3.00	1.00

PILE

Pile Dim A (in)	Pile Dim B (in)	Pile Embedment (in)	Service Axial Capacity (kip)	Strength Axial Capacity (kip)	Service Lateral Capacity (kip)	Strength Lateral Capacity (kip)	Allowed Uplift (kip)
10.0	0.0	12.0	N/A	180.00	N/A	0.00	0.00

PILE/CAISSON LAYOUT ANALYSIS

Row Number	Row Distance (ft)	Spacing within a Row (ft)	Percent Battered (%)	Horizontal Component	Vertical Component
1	1.50	6.50	100.0	3.00	10.00
2	3.00	6.50	100.0	3.00	10.00
3	3.00	13.00	0.0	none	none
4	3.00	13.00	0.0	none	none

MATERIALS

Backwall f'c (ksi)	Stem f'c (ksi)	Footing f'c (ksi)	fy (ksi)	Reinforcement Epoxy Coated Backwall	Stem	Footing
4.000	4.000	3.000	60.000	N	N	N

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	For Ec (lb/ft^3)
33.25	120.0	135.0	35.0	150.0	145.0

Architectural Treatment Density (lb/ft^3)	fu (ksi)
150.0	90.000

MISCELLANEOUS REINFORCEMENT DATA

Aggregate Size (in)	Development Correction	Backwall Exposure Class	Stem Exposure Class	Footing Exposure Class
1.50	1.00	2	2	1

REINFORCEMENT COVER

Backwall Back Vertical (in)	Stem Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)	Toe End (in)	Heel End (in)
3.0	3.0	3.5	4.2	4.5	5.2	2.0	2.0

BAR SIZE

Backwall Back Vertical (US bar)	Footing Perpend Top (US bar)	Footing Parallel Top (US bar)	Footing Perpend Bottom (US bar)	Footing Parallel Bottom (US bar)	Footing Perp Top Bar Type	Footing Perp Bot Bar Type
6	6	6	6	6	Straight	Straight

BAR SPACING FOR ANALYSIS

Backwall Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)
9.0	9.0	9.0	9.0	9.0

STEM REINFORCING BARS

Range Number	Bar Size (US bar)	Bar Spacing (in)	Group Offset (in)	End Location (ft)
1	9	10.00	0.00	8.00

LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
1.00	1.00	1.00	2.00	0.00	2.00	0.00

LOADS ON ABUTMENTS

DC (kip/ft)	DW (kip/ft)	PL (kip/ft)	Vertical WSUP (kip/ft)	Horizontal WSUP (kip/ft)	WL (kip/ft)	TU (kip/ft)	Backwall Vertical LL (kip/ft)	Backwall Horizontal LL (kip/ft)
17.13	1.37	0.69	0.00	n/a	0.34	0.69	0.00	none

Horizontal WSUB (kip/ft)	FR (kip/ft)	Horizontal WSUP SER-I (kip/ft)	Horizontal WSUP STR-III (kip/ft)	Horizontal WSUP STR-V (kip/ft)	Horizontal WSUB SER-I (kip/ft)	Horizontal WSUB STR-III (kip/ft)	Horizontal WSUB STR-V (kip/ft)
n/a	0.00	0.25	1.15	0.33	0.00	0.00	0.00

APPROACH SLAB LOADS

Approach Slab DC (kip/ft)	Approach Slab LL (kip/ft)	X distance to Approach Slab Load (in)	Approach Slab on Beam Notch	Approach Slab DW (kip/ft)
2.50	0.80	111.50	N	0.00

Approach Slab Type 4 Properties

Flexible Pavement?	Drain Width (in)	Average Drain Height (in)	Drain Wall Thickness (in)	Bottom Slab Thickness (in)	Drain Pedestal Width (in)	Drain Pedestal Spacing (in)	Paving Notch Width (in)	Paving Notch Height (in)
N	46.00	24.00	27.00	12.00	18.00	84.00	9.00	16.00

DESIGN LIVE LOAD

Downward LL (kip/ft)	Upward LL (kip/ft)	BR (kip/ft)	CE (kip/ft)
4.80	0.00	0.34	0.00

PERMIT LIVE LOAD

Downward LL (kip/ft)	**Upward LL (kip/ft)**	**BR (kip/ft)**	**CE (kip/ft)**
0.00	**0.00**	**0.00**	**0.00**

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
1	0	1

OUTPUT OF RESULTS

Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Footing Flexure	Reinf Summary
1	1	1	1	1	1	1

Crack Control	Shear Results	Development Length
1	1	1

```
                                OUTPUT OF INTERMEDIATE DATA
                                                 Internal      Intermediate       Detailed
Unfactored     Load      Moment/Axial            Footing     Bearing Resistance   Stem Cutoff
  Forces      Factors     Interaction             Forces           Values         Load Values
     1           1            1                    1               0                1
 Minimum Reinforcement     Intermediate
         Check             Settlement Data
           1                       0
```

8.7 EXAMPLE 6 (DESIGN)

Example 6 is a type II abutment on a spread footing. The structure geometry is shown in the following figure. Earthquake loads are considered in this problem.

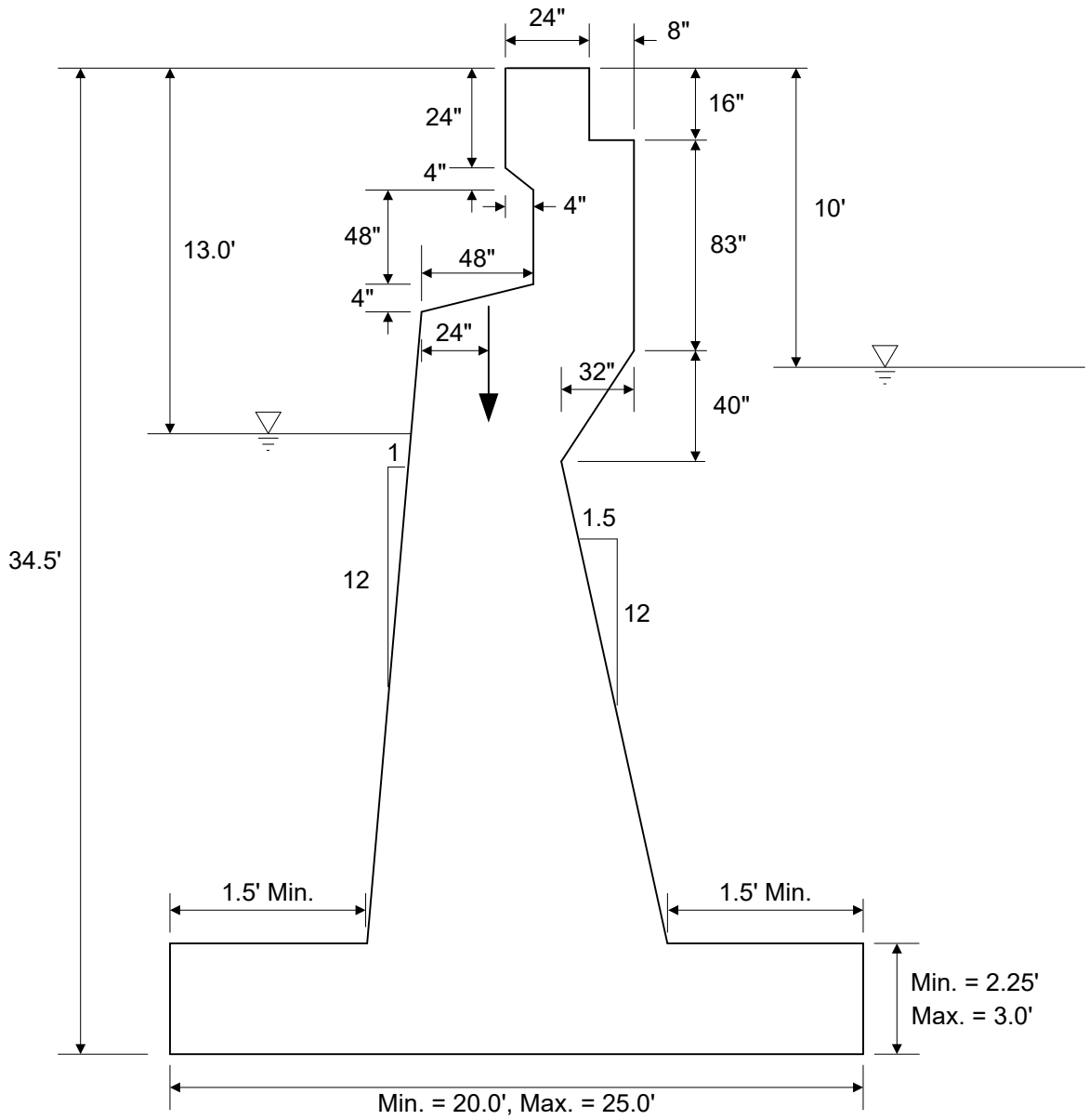

Figure 8.7-1 Example 6 Abutment Geometry

CONFIGURATION

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83	0

CONTROL

Sys of Units	Type of Run	Footing Datum
US	D	B

ABUTMENT TYPE II

Height (ft)	Top Width (in)	Seat Width (in)	Seat Slope Height (in)	Seat Face Height (in)	Corbel Width (in)	Corbel Height (in)	Corbel Slope Height (in)	Paving Notch Width (in)	Paving Notch Height (in)
34.50	24.0	48.0	4.0	48.0	4.0	24.0	4.0	8.0	16.0

Backwall Height (in)	Stem Notch Width (in)	Stem Notch Height (in)	Front Face Horizontal Component	Front Face Vertical Component	Back Face Horizontal Component	Back Face Vertical Component
83.0	32.0	40.0	1.00	12.00	1.50	12.00

Bearing X Locn (in)	Bearing Y Locn (in)	Front Water Level (ft)	Back Water Level (ft)	Architectural Treatment Thickness (in)	Backwall/ Stem Bar Alignment
24.0	none	13.00	10.00	0.0	Y

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
2.25	1.50	1.50	20.00	3.00	none	none	25.00

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
2.00	3.00	1.00

SPREAD

Design Optim	Cost of Concrete ($/yd^3)	Cut or Fill	Cost of Fill ($/yd^3)	Cost of Cut ($/yd^3)	Ground Elev (ft)	Ground Slope Type	Ground Slope Vert	Ground Slope Horiz
C	18.73	C	8.56	1.02	8.25	H	2.0	12.0

MATERIALS

Backwall f'c (ksi)	Stem f'c (ksi)	Footing f'c (ksi)	fy (ksi)	Reinforcement Epoxy Coated Backwall	Stem	Footing
4.000	4.000	3.500	50.000	Y	Y	Y

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	Concrete Density For Ec (lb/ft^3)
33.25	120.0	135.0	35.0	150.0	145.0

Architectural Treatment Density (lb/ft^3)	fu (ksi)
150.0	65.000

ROCK

Empirical Bearing Capacity (ksf)	Stem Top to Rock Layer (ft)	Footing Length Parallel (ft)	Sliding Resistance	Allow Settle (in)	Bear Cap Resist Factor	Sliding Resist Factor
20.88	34.25	82.00	Y	1.00	0.55	0.90

RQD (%)	Concrete /Rock Friction (deg)	Intact Elastic Modulus (ksi)	Poissons Ratio	Rock Mass Rating	Elastic Modulus Reduction	Rock Mass Modulus (ksi)
N/A	30.00	2900.00	0.25	N/A	N/A	2000.00

MISCELLANEOUS REINFORCEMENT DATA

Aggregate Size (in)	Development Correction	Backwall Exposure Class	Stem Exposure Class	Footing Exposure Class
1.00	1.00	2	2	1

REINFORCEMENT COVER

Backwall Back Vertical (in)	Stem Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)	Toe End (in)	Heel End (in)
3.0	3.0	3.0	none	4.0	none	2.0	2.0

BAR SPACING FOR DESIGN

Backwall Maximum Bar Diam (in)	Stem Maximum Bar Diam (in)	Footing Maximum Bar Diam (in)	Hooked Footing Bars	User Requested Minimum Bar Spacing (in)	Bar Spacing Increment (in)
1.41	1.41	1.41	N	6.00	3.00

LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
1.00	1.00	1.00	0.00	0.00	1.65	0.00

LOADS ON ABUTMENTS

DC (kip/ft)	DW (kip/ft)	PL (kip/ft)	Vertical WSUP (kip/ft)	Horizontal WSUP (kip/ft)	WL (kip/ft)	TU (kip/ft)	Backwall Vertical LL (kip/ft)	Backwall Horizontal LL (kip/ft)
0.85	0.40	0.02	-0.07	n/a	0.01	0.03	0.23	none

Horizontal WSUB (kip/ft)	FR (kip/ft)	Horizontal WSUP SER-I (kip/ft)	Horizontal WSUP STR-III (kip/ft)	Horizontal WSUP STR-V (kip/ft)	Horizontal WSUB SER-I (kip/ft)	Horizontal WSUB STR-III (kip/ft)	Horizontal WSUB STR-V (kip/ft)
n/a	0.00	0.01	0.04	0.01	0.00	0.00	0.00

SPECIAL LIVE LOAD

Downward LL (kip/ft)	Upward LL (kip/ft)	BR (kip/ft)	CE (kip/ft)	STR 1 Factor	STR 1P Factor	STR 2 Factor	STR 3 Factor	STR 5 Factor	EXT 1 Factor	SER 1 Factor
0.31	-0.17	0.08	0.09	1.75	1.35	1.35	0.00	1.35	0.50	1.00

EARTHQUAKE LOADS

Response Modification	Soil Pressure Factor	Phi Factor Foundation	Vertical EQ Soil	Horizontal Superstructure Force (kip/ft)	Horizontal External Structure Force (kip/ft)
2.30	1.00	0.70	N/A	1.82	none

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
1	0	1

OUTPUT OF RESULTS

Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Footing Flexure	Reinf Summary
1	1	1	1	1	1	1

Crack Control	Shear Results	Development Length
1	1	1

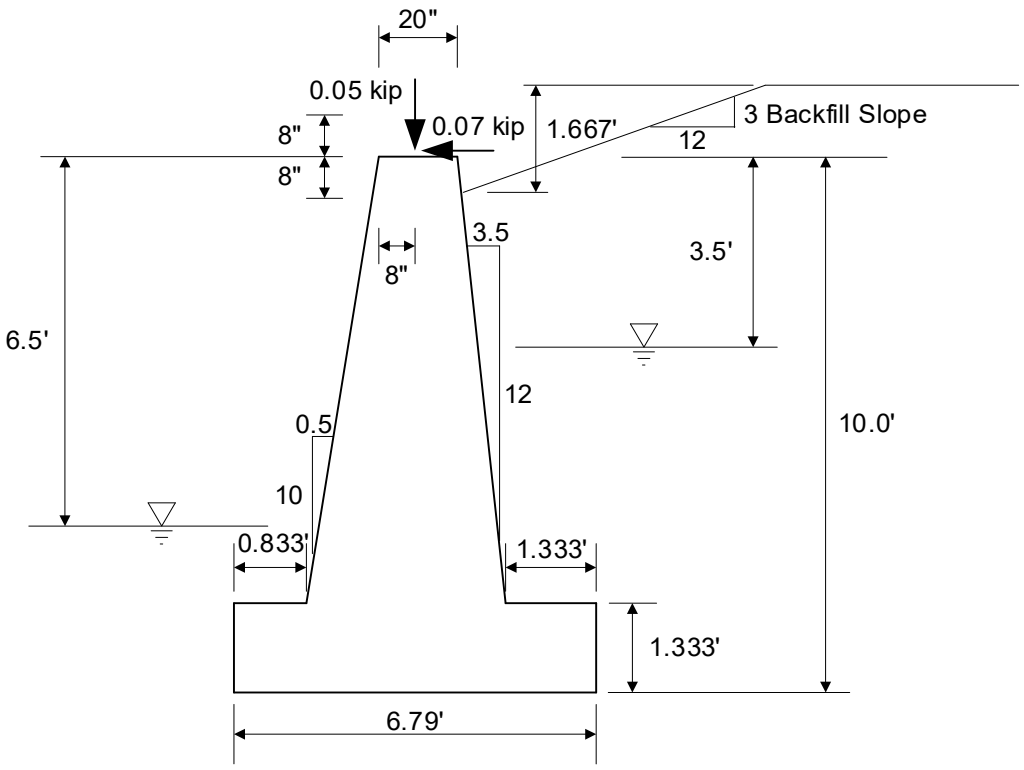
OUTPUT OF INTERMEDIATE DATA

Unfactored **Forces**	Load Factors	Moment/Axial Interaction	Internal Footing Forces	Intermediate Bearing Resist**ance** Values	Detailed Stem Cutoff Load Values
1	1	1	1	0	1

Minimum Reinf**orcement** Check	**Intermediate Settlement Data**
0	**1**

8.8 EXAMPLE 7

Example 7 is an analysis problem for a gravity retaining wall on spread footing. The structure geometry is shown in the following figure. The retaining wall is to be analyzed. Earthquake was not considered for this problem.



Rebar Layout:

not specified for gravity retaining wall

Figure 8.8-1 Example 7 Gravity Wall Geometry

```
                                CONFIGURATION

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 per       Lines
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                                  CONTROL

Sys of      Type      Footing
 Units     of Run      Datum
  US         A           T
```

RETAINING WALL

Height (ft)	Top Width (in)	Front Face Horizontal Component	Front Face Vertical Component	Back Face Horizontal Component	Back Face Vertical Component
8.67	20.0	0.50	10.00	3.50	12.00

Exposed Stem Height (in)	Backfill Horizontal Component	Backfill Vertical Component	Backfill Slope Height (ft)	Front Water Level (ft)	Back Water Level (ft)	Type of Wall	Architectural Treatment Thickness (in)
8.0	12.00	3.00	1.67	6.50	3.50	G	0.0

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
1.33	0.83	1.33	none	none	none	none	none

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
2.00	3.00	1.00

MATERIALS

Backwall f'c (ksi)	Stem f'c (ksi)	Footing f'c (ksi)	Footing fy (ksi)	Reinforcement Epoxy Coated Backwall	Stem	Footing
NA	4.000	3.000	60.000	NA	NA	NA

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	For Ec (lb/ft^3)
33.25	120.0	135.0	35.0	150.0	145.0

Architectural Treatment Density (lb/ft^3)	fu (ksi)
150.0	90.000

SOIL

Stem Top to Soil Layer (ft)	Footing Length (Parallel) (ft)	Footing Near Slope	Soil Level At Toe (ft)	Allow Settle (in)	Bearing Cap Resistance Factor	Sliding Resist Factor	No. Soil Layers
10.00	65.50	N	1.00	1.00	0.50	1.00	1

Soil Layer Number	Soil Layer Thick (ft)	Undrained Shear Strength (ksf)	Mass Unit Weight/ Density (lb/ft^3)	Saturated Unit Weight/ Density (lb/ft^3)	Elastic Modulus (ksf)	Poissons Ratio
1	40.00	none	120.00	150.00	315.00	0.50

Soil Layer Number	Cohesion (ksf)	Effective Friction Angle (deg)	Ncq	N Gamma q
1	1.00	30.00	n/a	n/a

Apply Inclination Factors	Precast or Cast-in-Place	Reduction Coefficients RC(BC) Layer 1	Layer 2
Y	C	none	none

CONSOLIDATION SETTLEMENT

Layer Number	Void Ratio	Compr Index	Recomp Index	Second Comp Index	Init Effect Stress (ksi)	Max Past Effect Stress Top (ksi)	Prim Consol (year)	Serv Life (year)	Max Past Effect Stress Bottom (ksi)
1	0.50	0.25	0.06	0.002	0.01	0.01	1.0	5.0	0.01

LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
1.00	1.00	1.00	0.00	0.00	0.00	0.00

LOADS ON RETAINING WALLS

CT (kip/ft)	Y Distance to CT (in)	Parapet Dead Load (kip/ft)	X Distance to Parapet (in)	Noise Wall Dead Load (kip/ft)	X Distance to Noise Wall (in)
0.07	8.0	0.05	8.0	0.00	0.0

Wind on External Structure (kip/ft)	Y Distance to Wind on External Structure (in)	Wind on External Structure SER-I (kip/ft)	STR-III (kip/ft)	STR-V (kip/ft)
n/a	0.0	none	none	none

Wind on Substructure (Wall) SER-I (kip/ft)	**STR-III (kip/ft)**	**STR-V (kip/ft)**
none	**none**	**none**

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
1	0	1

OUTPUT OF RESULTS

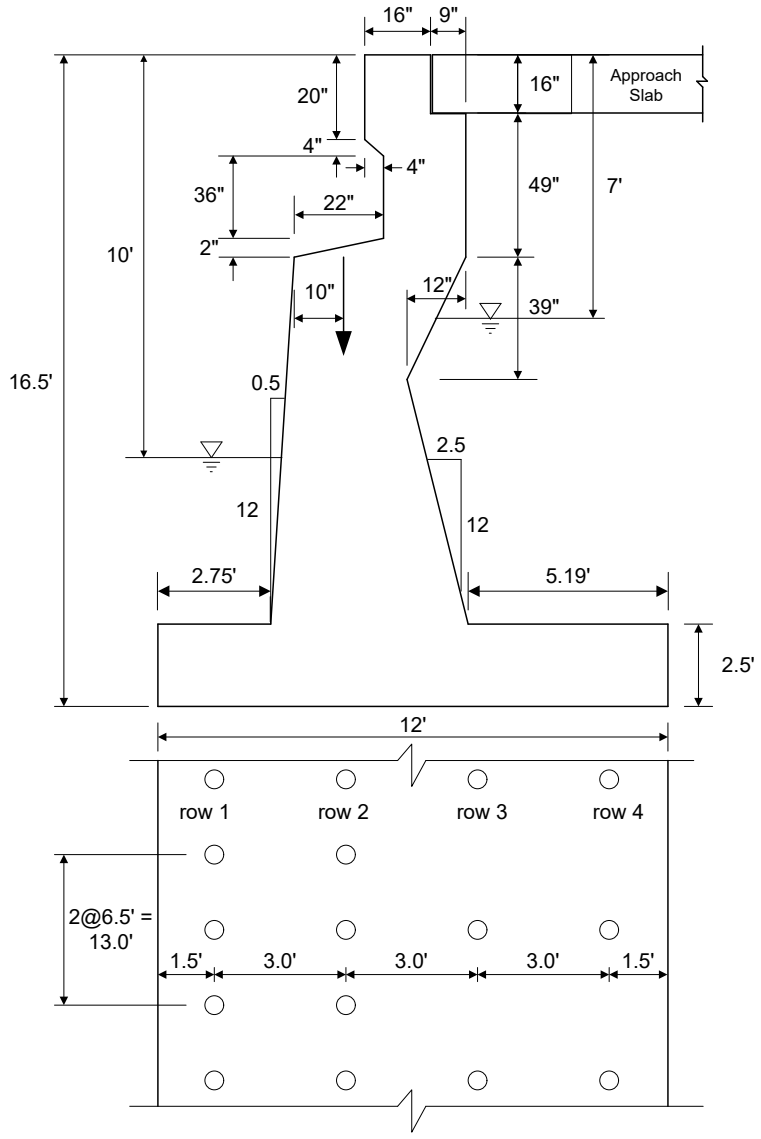
Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Footing Flexure	Reinf Summary
1	1	1	1	1	1	1

Crack Control	Shear Results	Development Length
1	1	1

```
                                OUTPUT OF INTERMEDIATE DATA
                                                 Internal      Intermediate       Detailed
Unfactored     Load      Moment/Axial    Footing     Bearing Resistance    Stem Cutoff
  Forces      Factors     Interaction    Forces           Values          Load Values
     1           1            1             1               1                1
 Minimum Reinforcement     Intermediate
         Check             Settlement Data
           1                       1
```

8.9 EXAMPLE 8

Example 8 is a type II abutment on pile footing. The structure geometry is shown in the following figure. The abutment is to be analyzed. The earthquake consideration was neglected for this example. There is an assumed 25’ approach slab resting in the paving notch of the backwall. This Analysis run will consider the approach slab to act as a simple span per standard drawing BD-628M, Sheet 2, Note 14. A second run of the program applying the Final Stage Surcharge Loads is needed to satisfy Note 14.



Rebar Layout:

Stem: **#9** @ 9" for entire height
Footing Parallel Direction: top and bottom: **#6** @ 9"
Footing Perpendicular Direction: top and bottom: **#6** @ 9"

Figure 8.9-1 Example 8 Abutment and Footing Geometry

CONFIGURATION

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CONTROL

Sys of Units	Type of Run	Footing Datum
US	A	T

ABUTMENT TYPE II

Height (ft)	Top Width (in)	Seat Width (in)	Seat Slope Height (in)	Seat Face Height (in)	Corbel Width (in)	Corbel Height (in)	Corbel Slope Height (in)	Paving Notch Width (in)	Paving Notch Height (in)
14.00	16.0	22.0	2.0	36.0	4.0	20.0	4.0	9.0	16.0

Backwall Height (in)	Stem Notch Width (in)	Stem Notch Height (in)	Front Face Horizontal Component	Front Face Vertical Component	Back Face Horizontal Component	Back Face Vertical Component
49.0	12.0	39.0	0.50	12.00	2.50	12.00

Bearing X Locn (in)	Bearing Y Locn (in)	Front Water Level (ft)	Back Water Level (ft)	Architectural Treatment Thickness (in)	Backwall/ Stem Bar Alignment
10.0	none	10.00	7.00	0.0	N/A

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
2.50	2.75	5.19	none	none	none	none	none

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
2.00	3.00	1.00

PILE

Pile Dim A (in)	Pile Dim B (in)	Pile Embedment (in)	Service Axial Capacity (kip)	Strength Axial Capacity (kip)	Service Lateral Capacity (kip)	Strength Lateral Capacity (kip)	Allowed Uplift (kip)
10.0	0.0	12.0	N/A	180.00	N/A	0.00	0.00

PILE/CAISSON LAYOUT ANALYSIS

Row Number	Row Distance (ft)	Spacing within a Row (ft)	Percent Battered (%)	Horizontal Component	Vertical Component
1	1.50	6.50	100.0	3.00	10.00
2	3.00	6.50	100.0	3.00	10.00
3	3.00	13.00	0.0	none	none
4	3.00	13.00	0.0	none	none

MATERIALS

Backwall f'c (ksi)	Stem f'c (ksi)	Footing f'c (ksi)	fy (ksi)	Reinforcement Backwall	Epoxy Coated Stem	Epoxy Coated Footing
4.000	4.000	3.000	60.000	N	N	N

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	Concrete Density For Ec (lb/ft^3)
33.25	120.0	135.0	35.0	150.0	145.0

Architectural Treatment Density (lb/ft^3)	fu (ksi)
150.0	90.000

MISCELLANEOUS REINFORCEMENT DATA

Aggregate Size (in)	Development Correction	Backwall Exposure Class	Stem Exposure Class	Footing Exposure Class
1.50	1.00	2	2	1

REINFORCEMENT COVER

Backwall Back Vertical (in)	Stem Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)	Toe End (in)	Heel End (in)
3.0	3.0	3.5	4.2	4.5	5.2	2.0	2.0

BAR SIZE

Backwall Back Vertical (US bar)	Footing Perpend Top (US bar)	Footing Parallel Top (US bar)	Footing Perpend Bottom (US bar)	Footing Parallel Bottom (US bar)	Footing Perp Top Bar Type	Footing Perp Bot Bar Type
6	6	6	6	6	Straight	Straight

BAR SPACING FOR ANALYSIS

Backwall Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)
9.0	9.0	9.0	9.0	9.0

STEM REINFORCING BARS

Range Number	Bar Size (US bar)	Bar Spacing (in)	Group Offset (in)	End Location (ft)
1	9	10.00	0.00	8.00

LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
1.00	1.00	1.00	2.00	0.00	2.00	0.00

LOADS ON ABUTMENTS

DC (kip/ft)	DW (kip/ft)	PL (kip/ft)	Vertical WSUP (kip/ft)	Horizontal WSUP (kip/ft)	WL (kip/ft)	TU (kip/ft)	Backwall Vertical LL (kip/ft)	Backwall Horizontal LL (kip/ft)
17.13	1.37	0.69	0.00	n/a	0.34	0.69	0.00	none

Horizontal WSUB (kip/ft)	FR (kip/ft)	Horizontal WSUP SER-I (kip/ft)	Horizontal WSUP STR-III (kip/ft)	Horizontal WSUP STR-V (kip/ft)	Horizontal WSUB SER-I (kip/ft)	Horizontal WSUB STR-III (kip/ft)	Horizontal WSUB STR-V (kip/ft)
n/a	0.00	0.25	1.15	0.33	0.00	0.00	0.00

APPROACH SLAB LOADS

Approach Slab DC (kip/ft)	Approach Slab LL (kip/ft)	X distance to Approach Slab Load (in)	Approach Slab on Beam Notch	Approach Slab DW (kip/ft)
2.50	0.80	38.50	N	0.00

Approach Slab Type 4 Properties

Flexible Pavement?	Drain Width (in)	Average Drain Height (in)	Drain Wall Thickness (in)	Bottom Slab Thickness (in)	Drain Pedestal Width (in)	Drain Pedestal Spacing (in)	Paving Notch Width (in)	Paving Notch Height (in)
none	none	none	none	none	none	none	none	none

DESIGN LIVE LOAD

Downward LL (kip/ft)	Upward LL (kip/ft)	BR (kip/ft)	CE (kip/ft)
4.80	0.00	0.34	0.00

PERMIT LIVE LOAD

Downward LL (kip/ft)	**Upward LL (kip/ft)**	**BR (kip/ft)**	**CE (kip/ft)**
0.00	**0.00**	**0.00**	**0.00**

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
1	0	1

OUTPUT OF RESULTS

Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Footing Flexure	Reinf Summary
1	1	1	1	1	1	1

Crack Control	Shear Results	Development Length
1	1	1

```
                                OUTPUT OF INTERMEDIATE DATA
                                                 Internal      Intermediate       Detailed
Unfactored     Load      Moment/Axial            Footing     Bearing Resistance   Stem Cutoff
  Forces      Factors     Interaction             Forces           Values         Load Values
     1           1            1                    1               0                1
 Minimum Reinforcement     Intermediate
         Check             Settlement Data
           1                       0
```

8.10 EXAMPLE 9 (DESIGN)

Example 9 is a retaining wall on pedestal footing. The structure geometry is shown in the following figure. Earthquake loads are not considered for this problem.

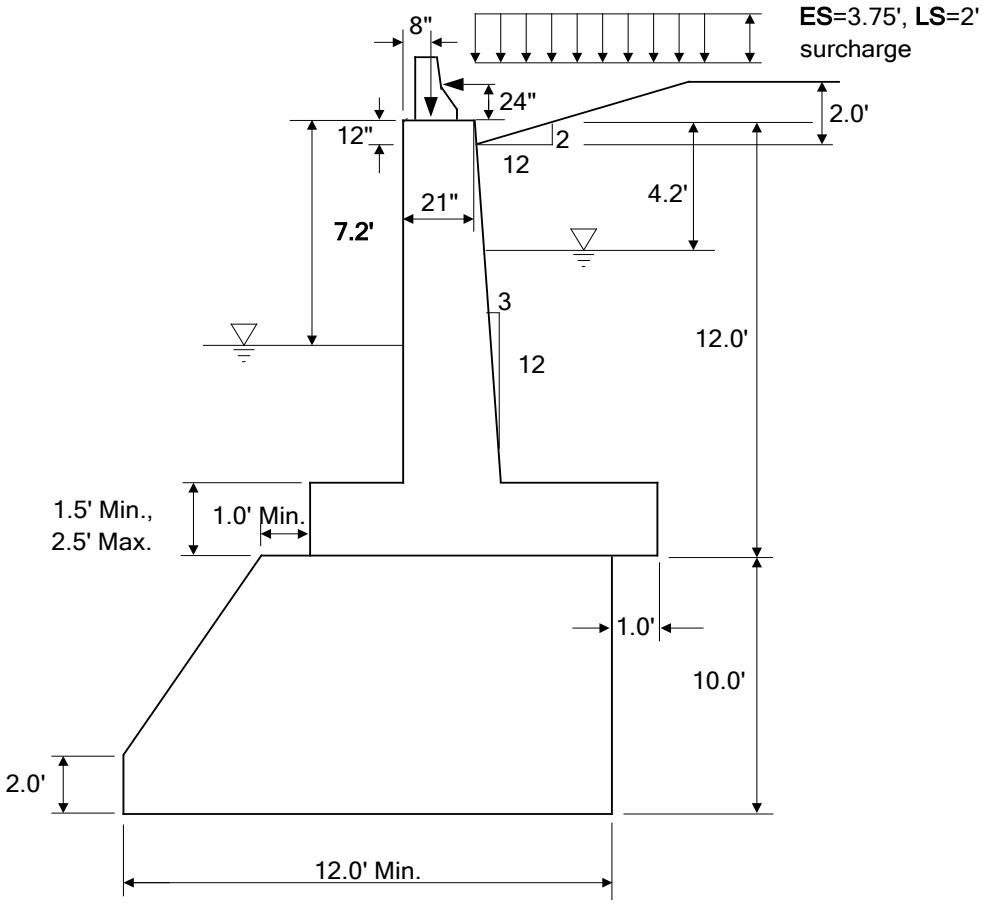

Figure 8.10-1 Example 9 Retaining Wall and Pedestal Geometry

CONFIGURATION

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83	0

CONTROL

Sys of Units	Type of Run	Footing Datum
US	D	B

RETAINING WALL

Height (ft)	Top Width (in)	Front Face Horizontal Component	Front Face Vertical Component	Back Face Horizontal Component	Back Face Vertical Component
12.00	21.0	none	none	3.00	12.00

Exposed Stem Height (in)	Backfill Horizontal Component	Backfill Vertical Component	Backfill Slope Height (ft)	Front Water Level (ft)	Back Water Level (ft)	Type of Wall	Architectural Treatment Thickness (in)
12.0	12.00	2.00	2.00	7.20	4.20	C	0.0

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
1.50	0.00	0.00	10.00	2.50	none	none	11.00

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
2.00	3.00	1.00

PEDESTAL FOOTING

Pedestal Spacing (ft)	Overall Height (ft)	Front Height (ft)	Min Width (ft)	Min Thick (in)	Front Proj (ft)	Back Offset (ft)	Max Width (ft)	Max Thick (in)	**Design Optimization**
10.00	10.00	2.00	12.00	30.00	1.00	1.00	none	none	**D**

MATERIALS

Backwall f'c (ksi)	Stem f'c (ksi)	Footing f'c (ksi)	Footing fy (ksi)	Reinforcement Epoxy Coated Backwall	Stem	Footing
NA	3.000	3.000	60.000	NA	Y	Y

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	Concrete Density For Ec (lb/ft^3)
33.25	120.0	135.0	35.0	150.0	145.0

Architectural Treatment Density (lb/ft^3)	fu (ksi)
150.0	90.000

ROCK

Empirical Bearing Capacity (ksf)	Stem Top to Rock Layer (ft)	Footing Length Parallel (ft)	Sliding Resistance	Allow Settle (in)	Bear Cap Resist Factor	Sliding Resist Factor
30.00	12.00	75.00	Y	1.00	0.55	0.90

RQD (%)	Concrete /Rock Friction (deg)	Intact Elastic Modulus (ksi)	Poissons Ratio	Rock Mass Rating	Elastic Modulus Reduction	Rock Mass Modulus (ksi)
N/A	30.00	1400.00	0.25	N/A	N/A	1200.00

MISCELLANEOUS REINFORCEMENT DATA

Aggregate Size (in)	Development Correction	Backwall Exposure Class	Stem Exposure Class	Footing Exposure Class
0.75	0.95	none	2	1

REINFORCEMENT COVER

Backwall Back Vertical (in)	Stem Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)	Toe End (in)	Heel End (in)
none	3.0	2.8	3.8	4.8	5.8	2.0	2.0

BAR SPACING FOR DESIGN

Backwall Maximum Bar Diam (in)	Stem Maximum Bar Diam (in)	Footing Maximum Bar Diam (in)	Hooked Footing Bars	User Requested Minimum Bar Spacing (in)	Bar Spacing Increment (in)
none	1.41	1.41	N/A	6.00	3.00

LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
1.00	1.00	1.00	2.00	2.00	3.75	3.75

LOADS ON RETAINING WALLS

CT (kip/ft)	Y Distance to CT (in)	Parapet Dead Load (kip/ft)	X Distance to Parapet (in)	Noise Wall Dead Load (kip/ft)	X Distance to Noise Wall (in)
2.00	24.0	0.05	8.0	0.00	0.0

Wind on External Structure (kip/ft)	Y Distance to Wind on External Structure (in)	Wind on External Structure SER-I (kip/ft)	STR-III (kip/ft)	STR-V (kip/ft)
n/a	0.0	none	none	none

Wind on Substructure (Wall) SER-I (kip/ft)	STR-III (kip/ft)	STR-V (kip/ft)
none	none	none

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
1	0	1

OUTPUT OF RESULTS

Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Footing Flexure	Reinf Summary
1	1	1	1	1	1	1

```
  Crack       Shear     Development
 Control     Results       Length
    1           1            1

                                OUTPUT OF INTERMEDIATE DATA
                                      Internal      Intermediate       Detailed
Unfactored     Load     Moment/Axial  Footing    Bearing Resistance   Stem Cutoff
  Forces      Factors    Interaction   Forces          Values         Load Values
    1           1           1           1              0               1
 Minimum Reinforcement     Intermediate
         Check             Settlement Data
           0                       1
```

8.11 EXAMPLE 10

Example 10 is an abutment w/o backwall (gravity type) on spread footing. The structure geometry is shown in the following figure. The abutment is to be analyzed. The earthquake was not considered for this problem.

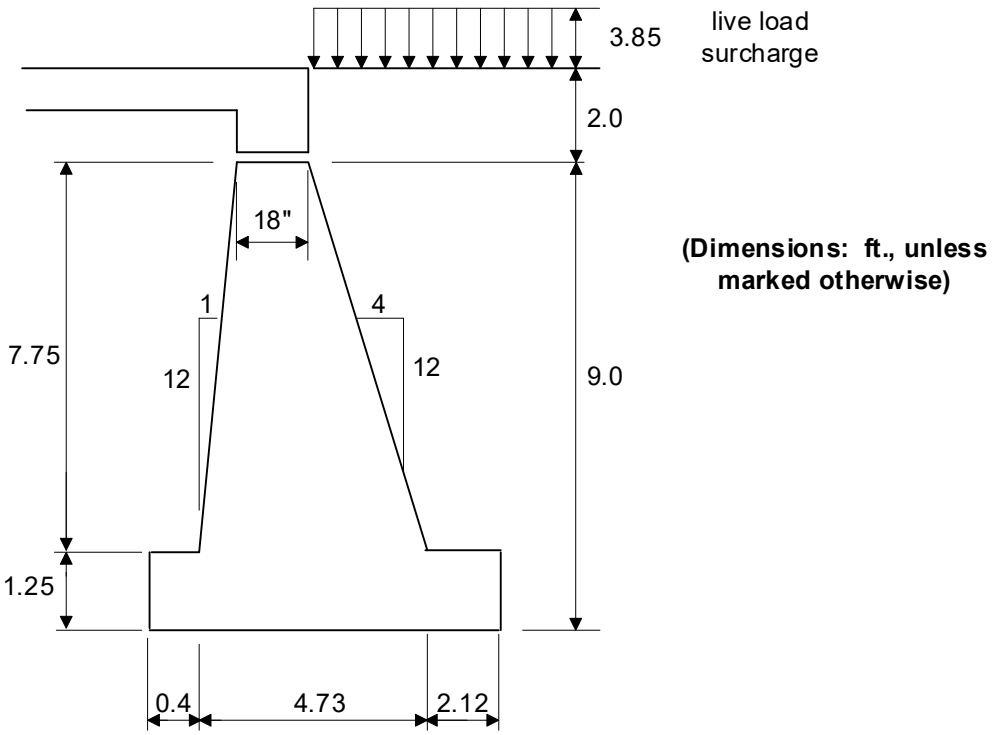

Figure 8.11-1 Example 10 Gravity Wall Geometry

```
                                CONFIGURATION

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                                  CONTROL

Sys of      Type      Footing
 Units     of Run      Datum
  US         A           T
```

ABUTMENT WITHOUT BACKWALL

Height (ft)	Top Width (in)	Bearing Location (in)	Front Face Horizontal Component	Front Face Vertical Component	Back Face Horizontal Component	Back Face Vertical Component
7.75	18.0	9.0	1.00	12.00	4.00	12.00

Additional Fill Height (ft)	Front Water Level (ft)	Back Water Level (ft)	Type of Wall	Architectural Treatment Thickness (in)
2.00	11.00	8.00	G	0.0

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
1.25	0.40	2.12	none	none	none	none	none

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
2.00	3.00	1.00

MATERIALS

Backwall f'c (ksi)	Stem f'c (ksi)	Footing f'c (ksi)	Footing fy (ksi)	Reinforcement Epoxy Coated Backwall	Stem	Footing
NA	3.000	3.000	50.000	NA	NA	NA

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	Concrete Density For Ec (lb/ft^3)
33.25	120.0	135.0	35.0	150.0	145.0

Architectural Treatment Density (lb/ft^3)	fu (ksi)
150.0	90.000

ROCK

Empirical Bearing Capacity (ksf)	Stem Top to Rock Layer (ft)	Footing Length Parallel (ft)	Sliding Resistance	Allow Settle (in)	Bear Cap Resist Factor	Sliding Resist Factor
26.30	9.00	42.00	Y	1.00	0.55	1.00

RQD (%)	Concrete /Rock Friction (deg)	Intact Elastic Modulus (ksi)	Poissons Ratio	Rock Mass Rating	Elastic Modulus Reduction	Rock Mass Modulus (ksi)
N/A	35.00	1420.00	0.10	N/A	N/A	1350.00

LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
1.00	1.00	1.00	3.85	3.85	0.00	0.00

LOADS ON ABUTMENTS

DC (kip/ft)	DW (kip/ft)	PL (kip/ft)	Vertical WSUP (kip/ft)	Horizontal WSUP (kip/ft)	WL (kip/ft)	TU (kip/ft)	Backwall Vertical LL (kip/ft)	Backwall Horizontal LL (kip/ft)
3.75	0.35	0.00	-0.22	n/a	0.10	0.70	none	none

Horizontal WSUB (kip/ft)	FR (kip/ft)	Horizontal WSUP SER-I (kip/ft)	Horizontal WSUP STR-III (kip/ft)	Horizontal WSUP STR-V (kip/ft)	Horizontal WSUB SER-I (kip/ft)	Horizontal WSUB STR-III (kip/ft)	Horizontal WSUB STR-V (kip/ft)
n/a	0.00	0.04	0.17	0.05	0.00	0.00	0.00

DESIGN LIVE LOAD

Downward LL (kip/ft)	Upward LL (kip/ft)	BR (kip/ft)	CE (kip/ft)
3.14	0.00	0.12	0.00

PERMIT LIVE LOAD

Downward LL (kip/ft)	**Upward LL (kip/ft)**	**BR (kip/ft)**	**CE (kip/ft)**
0.00	**0.00**	**0.00**	**0.00**

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
1	0	1

OUTPUT OF RESULTS

Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Footing Flexure	Reinf Summary
1	1	1	1	1	1	1

Crack Control	Shear Results	Development Length
1	1	1

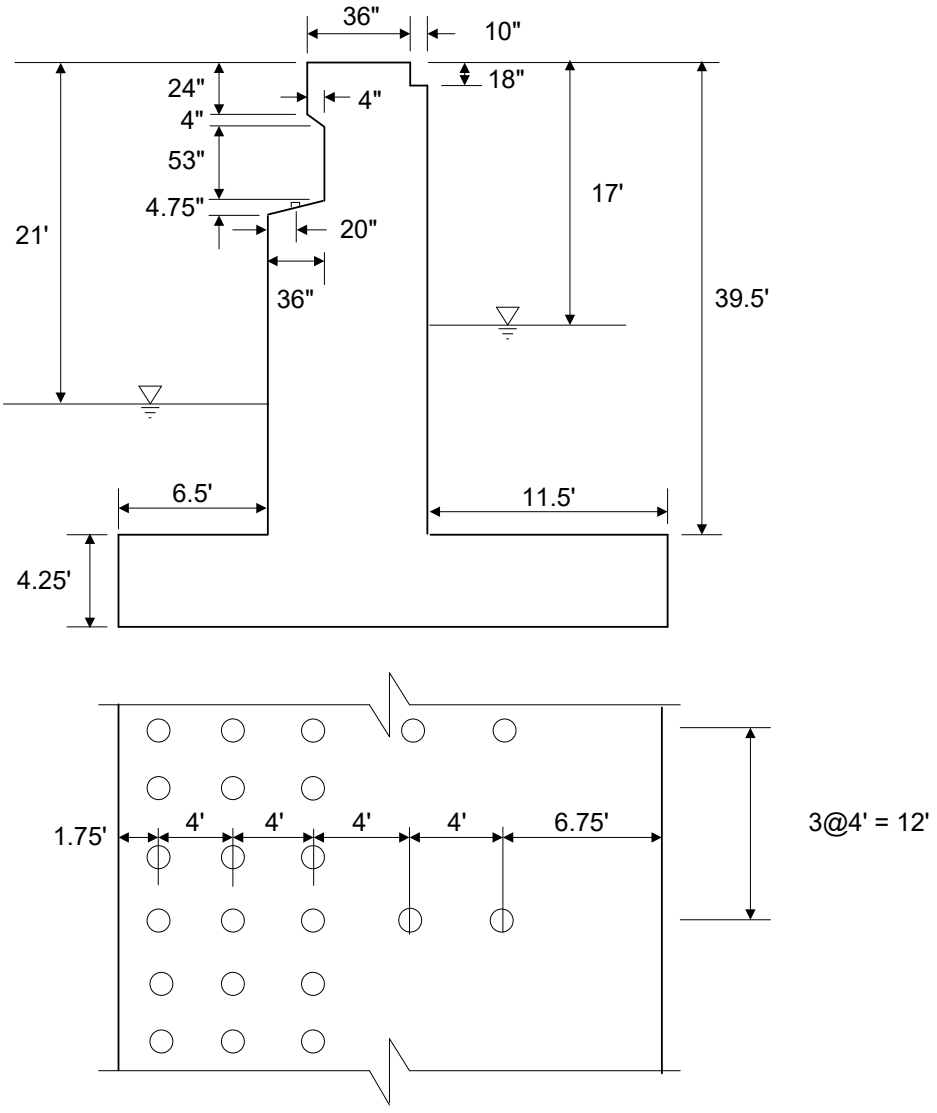
OUTPUT OF INTERMEDIATE DATA

Unfactored **Forces**	Load Factors	Moment/Axial Interaction	Internal Footing Forces	Intermediate Bearing Resist**ance** Values	Detailed Stem Cutoff Load Values
1	1	1	1	0	1

Minimum Reinf**orcement** Check	**Intermediate Settlement Data**
1	**1**

8.12 EXAMPLE 11

Example 11 is an analysis problem for a type I abutment on a pile footing. The structure geometry is shown in the following figure. The abutment and the pile footing is to be analyzed. The earthquake consideration was performed.



Rebar Layout:

Stem: **#11** @ 6" for entire height
Footing Parallel Direction: top and bottom: **#9** @ 12"
Footing Perpendicular Direction: top **#11** @ 6" bottom: #9 @ 6"

Figure 8.12-1 Example 11 Abutment Geometry

CONFIGURATION

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CONTROL

Sys of Units	Type of Run	Footing Datum
US	A	T

ABUTMENT TYPE I

Height (ft)	Top Width (in)	Seat Width (in)	Seat Slope Height (in)	Seat Face Height (in)	Corbel Width (in)	Corbel Height (in)	Corbel Slope Height (in)
39.50	36.0	36.0	4.8	53.0	4.0	24.0	4.0

Paving Notch Width (in)	Paving Notch Height (in)	Bearing X Locn (in)	Bearing Y Locn (in)	Front Water Level (ft)	Back Water Level (ft)	Architectural Treatment Thickness (in)	Backwall/ Stem Bar Alignment
10.0	18.0	20.0	82.5	21.00	18.00	0.0	N/A

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
4.25	6.50	11.50	none	none	none	none	none

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
2.00	3.00	1.00

PILE

Pile Dim A (in)	Pile Dim B (in)	Pile Embedment (in)	Service Axial Capacity (kip)	Strength Axial Capacity (kip)	Service Lateral Capacity (kip)	Strength Lateral Capacity (kip)	Allowed Uplift (kip)
10.0	10.0	12.0	N/A	270.00	N/A	0.00	0.00

PILE/CAISSON LAYOUT ANALYSIS

Row Number	Row Distance (ft)	Spacing within a Row (ft)	Percent Battered (%)	Horizontal Component	Vertical Component
1	1.75	4.00	100.0	4.00	10.00
2	4.00	4.00	100.0	3.00	10.00
3	4.00	4.00	100.0	3.00	10.00
4	4.00	12.00	0.0	none	none
5	4.00	12.00	0.0	none	none

MATERIALS

Backwall f'c (ksi)	Stem f'c (ksi)	Footing f'c (ksi)	fy (ksi)	Reinforcement Epoxy Coated Backwall	Stem	Footing
4.000	4.000	3.000	60.000	Y	Y	Y

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	For Ec (lb/ft^3)
33.25	120.0	135.0	35.0	150.0	145.0

Architectural Treatment Density (lb/ft^3)	fu (ksi)
150.0	90.000

MISCELLANEOUS REINFORCEMENT DATA

Aggregate Size (in)	Development Correction	Backwall Exposure Class	Stem Exposure Class	Footing Exposure Class
1.00	1.00	1	1	1

REINFORCEMENT COVER

Backwall Back Vertical (in)	Stem Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)	Toe End (in)	Heel End (in)
3.0	3.0	2.5	3.9	3.2	4.5	2.0	2.0

BAR SIZE

Backwall Back Vertical (US bar)	Footing Perpend Top (US bar)	Footing Parallel Top (US bar)	Footing Perpend Bottom (US bar)	Footing Parallel Bottom (US bar)	Footing Perp Top Bar Type	Footing Perp Bot Bar Type
8	11	6	9	9	Straight	Straight

BAR SPACING FOR ANALYSIS

Backwall Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)
12.0	6.0	12.0	6.0	12.0

STEM REINFORCING BARS

Range Number	Bar Size (US bar)	Bar Spacing (in)	Group Offset (in)	End Location (ft)
1	11	6.00	0.00	39.50

LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
1.00	1.00	1.00	0.00	0.00	3.00	3.00

LOADS ON ABUTMENTS

DC (kip/ft)	DW (kip/ft)	PL (kip/ft)	Vertical WSUP (kip/ft)	Horizontal WSUP (kip/ft)	WL (kip/ft)	TU (kip/ft)	Backwall Vertical LL (kip/ft)	Backwall Horizontal LL (kip/ft)
13.70	2.06	0.21	0.00	n/a	0.21	0.34	0.14	none

Horizontal WSUB (kip/ft)	FR (kip/ft)	Horizontal WSUP SER-I (kip/ft)	Horizontal WSUP STR-III (kip/ft)	Horizontal WSUP STR-V (kip/ft)	Horizontal WSUB SER-I (kip/ft)	Horizontal WSUB STR-III (kip/ft)	Horizontal WSUB STR-V (kip/ft)
n/a	0.00	0.12	0.57	0.16	0.00	0.00	0.00

DESIGN LIVE LOAD

Downward LL (kip/ft)	Upward LL (kip/ft)	BR (kip/ft)	CE (kip/ft)
3.43	0.00	0.21	0.10

PERMIT LIVE LOAD

Downward LL (kip/ft)	**Upward LL (kip/ft)**	**BR (kip/ft)**	**CE (kip/ft)**
0.00	**0.00**	**0.00**	**0.00**

EARTHQUAKE LOADS

Response Modification	Soil Pressure Factor	Phi Factor Foundation	Vertical EQ Soil	Horizontal Superstructure Force (kip/ft)	Horizontal External Structure Force (kip/ft)
1.00	1.00	1.00	N/A	3.43	none

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
1	0	1

OUTPUT OF RESULTS

Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Footing Flexure	Reinf Summary
1	1	1	1	1	1	1

Crack Control	Shear Results	Development Length
1	1	1

OUTPUT OF INTERMEDIATE DATA

Unfactored **Forces**	Load Factors	Moment/Axial Interaction	Internal Footing Forces	Intermediate Bearing Resist**ance** Values	Detailed Stem Cutoff Load Values
1	1	1	1	0	1

Minimum Reinf**orcement** Check	**Intermediate Settlement Data**
1	**0**

8.13 EXAMPLE 12 (DESIGN)

Example 12 is a type II abutment on a caisson footing. The structure geometry is shown in the following figure. Earthquake loads were not considered in this problem.

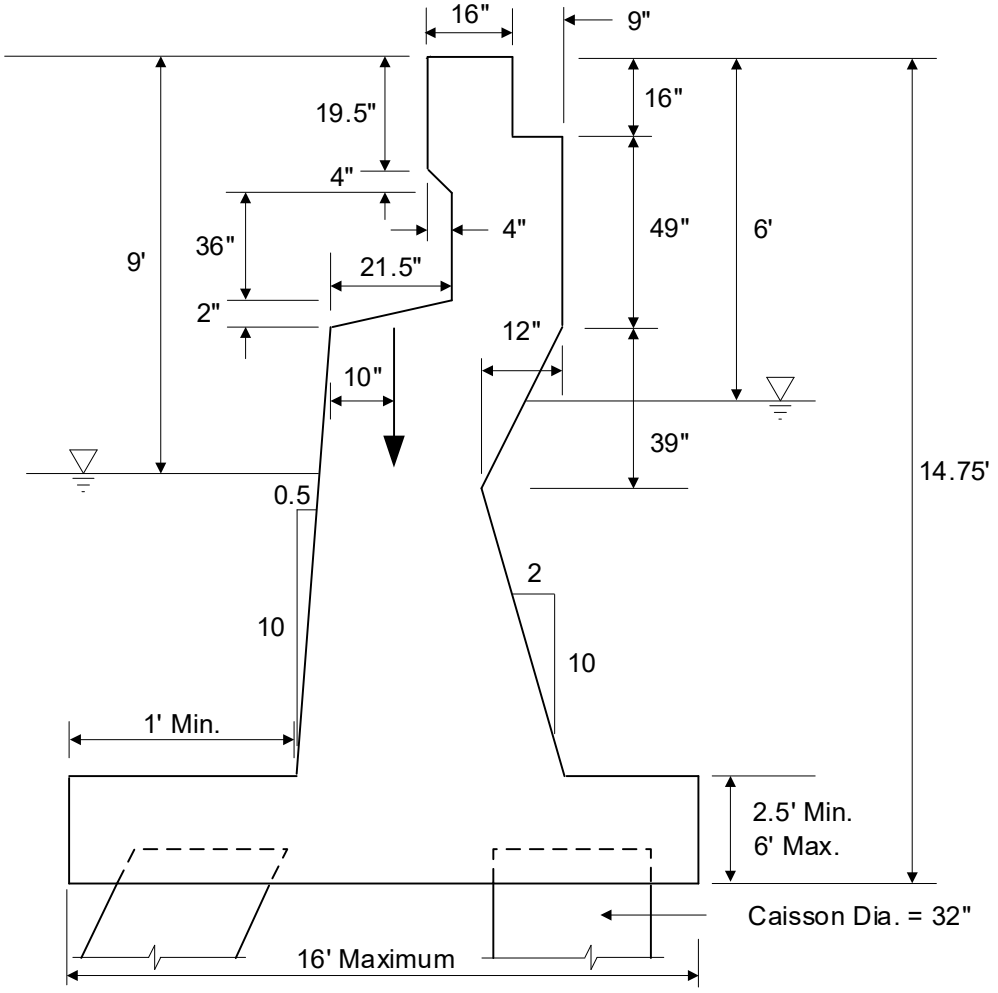

Figure 8.13-1 Example 12 Abutment Geometry

CONFIGURATION

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CONTROL

Sys of Units	Type of Run	Footing Datum
US	D	B

ABUTMENT TYPE II

Height (ft)	Top Width (in)	Seat Width (in)	Seat Slope Height (in)	Seat Face Height (in)	Corbel Width (in)	Corbel Height (in)	Corbel Slope Height (in)	Paving Notch Width (in)	Paving Notch Height (in)
14.75	16.0	21.5	2.0	36.0	4.0	19.5	4.0	9.0	16.0

Backwall Height (in)	Stem Notch Width (in)	Stem Notch Height (in)	Front Face Horizontal Component	Front Face Vertical Component	Back Face Horizontal Component	Back Face Vertical Component
49.0	12.0	39.0	0.50	10.00	2.00	10.00

Bearing X Locn (in)	Bearing Y Locn (in)	Front Water Level (ft)	Back Water Level (ft)	Architectural Treatment Thickness (in)	Backwall/ Stem Bar Alignment
10.0	none	9.00	6.00	0.0	Y

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
2.50	1.00	0.00	15.04	6.00	none	none	16.00

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
2.00	3.00	1.00

CAISSON

Caisson Diameter (in)	Caisson Embedment (in)	Service Axial Capacity (kip)	Strength Axial Capacity (kip)	Service Lateral Capacity (kip)	Strength Lateral Capacity (kip)	Allowed Uplift (kip)
32.0	12.0	N/A	802.00	N/A	0.00	0.00

PILE/CAISSON LAYOUT DESIGN

Toe to First Row (ft)	Minimum Heel to Last Row (ft)	Minimum Spacing (ft)	Maximum Spacing (ft)	Row Placement	Pile Spacing Rounding (ft)	Row Distances Rounding (ft)
2.17	2.17	10.70	15.00	E	0.00	0.00

Design Batt Horizontal Component	Design Batt Vertical Component	Last Row % Batter (%)	Optimize	Pile/ Caisson Cost ($/pile)	Footing Cost ($/yd^3)
3.00	12.00	0.0	C	1000.00	460.00

MATERIALS

Backwall f'c (ksi)	Stem f'c (ksi)	Footing f'c (ksi)	fy (ksi)	Reinforcement Epoxy Coated Backwall	Stem	Footing
3.000	3.000	3.000	60.000	N	N	N

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	Concrete Density For Ec (lb/ft^3)
33.25	120.0	135.0	35.0	150.0	145.0

Architectural Treatment Density (lb/ft^3)	fu (ksi)
150.0	90.000

MISCELLANEOUS REINFORCEMENT DATA

Aggregate Size (in)	Development Correction	Backwall Exposure Class	Stem Exposure Class	Footing Exposure Class
0.50	0.95	2	2	1

REINFORCEMENT COVER

Backwall Back Vertical (in)	Stem Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)	Toe End (in)	Heel End (in)
3.0	3.0	3.0	4.4	3.0	4.4	2.0	2.0

BAR SPACING FOR DESIGN

Backwall Maximum Bar Diam (in)	Stem Maximum Bar Diam (in)	Footing Maximum Bar Diam (in)	Hooked Footing Bars	User Requested Minimum Bar Spacing (in)	Bar Spacing Increment (in)
1.41	1.41	1.41	N	6.00	3.00

LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
1.00	1.00	1.00	2.50	2.50	1.60	0.00

LOADS ON ABUTMENTS

DC (kip/ft)	DW (kip/ft)	PL (kip/ft)	Vertical WSUP (kip/ft)	Horizontal WSUP (kip/ft)	WL (kip/ft)	TU (kip/ft)	Backwall Vertical LL (kip/ft)	Backwall Horizontal LL (kip/ft)
4.80	3.08	0.51	-0.48	n/a	0.00	0.68	0.23	none

Horizontal WSUB (kip/ft)	FR (kip/ft)	Horizontal WSUP SER-I (kip/ft)	Horizontal WSUP STR-III (kip/ft)	Horizontal WSUP STR-V (kip/ft)	Horizontal WSUB SER-I (kip/ft)	Horizontal WSUB STR-III (kip/ft)	Horizontal WSUB STR-V (kip/ft)
n/a	0.00	0.09	0.43	0.12	0.00	0.00	0.00

SPECIAL LIVE LOAD

Downward LL (kip/ft)	Upward LL (kip/ft)	BR (kip/ft)	CE (kip/ft)	STR 1 Factor	STR 1P Factor	STR 2 Factor	STR 3 Factor	STR 5 Factor	EXT 1 Factor	SER 1 Factor
0.31	-0.17	0.08	0.09	1.75	1.35	1.35	0.00	1.35	0.50	1.00

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
1	0	1

OUTPUT OF RESULTS

Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Footing Flexure	Reinf Summary
1	1	1	1	1	1	1

Crack Control	Shear Results	Development Length
1	1	1

OUTPUT OF INTERMEDIATE DATA

Unfactored **Forces**	Load Factors	Moment/Axial Interaction	Internal Footing Forces	Intermediate Bearing Resist**ance** Values	Detailed Stem Cutoff Load Values
1	1	1	1	0	1

Minimum Reinf**orcement** Check	**Intermediate Settlement Data**
0	**0**

8.14 EXAMPLE 13 (DESIGN)

Example 13 is a retaining wall on a spread footing. The geometry is shown in the following figure. Earthquake loads were considered in this problem. The footing is founded on two layers of soil.

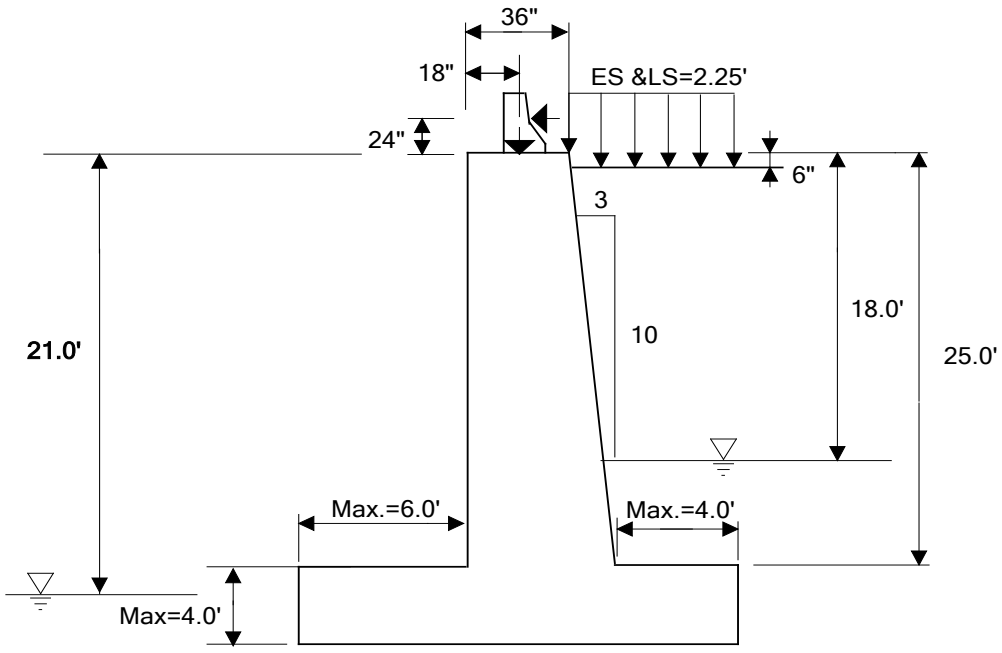

Figure 8.14-1 Example 13 Retaining Wall Geometry

CONFIGURATION

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CONTROL

Sys of Units	Type of Run	Footing Datum
US	D	T

RETAINING WALL

Height (ft)	Top Width (in)	Front Face Horizontal Component	Front Face Vertical Component	Back Face Horizontal Component	Back Face Vertical Component
25.00	36.0	none	none	3.00	10.00

Exposed Stem Height (in)	Backfill Horizontal Component	Backfill Vertical Component	Backfill Slope Height (ft)	Front Water Level (ft)	Back Water Level (ft)	Type of Wall	Architectural Treatment Thickness (in)
6.0	none	none	none	21.00	18.00	C	0.0

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
0.00	0.00	0.00	none	4.00	6.00	4.00	none

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
2.00	3.00	1.00

SPREAD

Design Optim	Cost of Concrete ($/yd^3)	Cut or Fill	Cost of Fill ($/yd^3)	Cost of Cut ($/yd^3)	Ground Elev (ft)	Ground Slope Type	Ground Slope Vert	Ground Slope Horiz
V	none	none	none	none	none	none	none	none

MATERIALS

Backwall f'c (ksi)	Stem f'c (ksi)	Footing f'c (ksi)	fy (ksi)	Reinforcement Backwall	Epoxy Coated Stem	Epoxy Coated Footing
NA	3.000	3.000	60.000	NA	Y	Y

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	Concrete Density For Ec (lb/ft^3)
33.25	120.0	135.0	35.0	150.0	145.0

Architectural Treatment Density (lb/ft^3)	fu (ksi)
150.0	90.000

SOIL

Stem Top to Soil Layer (ft)	Footing Length (Parallel) (ft)	Footing Near Slope	Soil Level At Toe (ft)	Allow Settle (in)	Bearing Cap Resistance Factor	Sliding Resist Factor	No. Soil Layers
25.00	100.00	N	2.50	1.00	0.50	1.00	2

Soil Layer Number	Soil Layer Thick (ft)	Undrained Shear Strength (ksf)	Mass Unit Weight/ Density (lb/ft^3)	Saturated Unit Weight/ Density (lb/ft^3)	Elastic Modulus (ksf)	Poissons Ratio
1	5.00	none	120.00	135.00	775.00	0.30
2	5.00	none	120.00	135.00	850.00	0.33

Soil Layer Number	Cohesion (ksf)	Effective Friction Angle (deg)	Ncq	N Gamma q
1	2.10	30.00	n/a	n/a
2	3.20	35.00	n/a	n/a

Apply	Precast or	Reduction

Inclination Factors Y	Cast-in-Place C	Coefficients RC(BC) Layer 1	Layer 2
		none	none

CONSOLIDATION SETTLEMENT

Layer Number	Void Ratio	Compr Index	Recomp Index	Second Comp Index	Init Effect Stress (ksi)	Max Past Effect Stress Top (ksi)	Prim Consol (year)	Serv Life (year)	Max Past Effect Stress Bottom (ksi)
1	0.30	0.00	0.00	0.000	0.01	0.02	1.0	10.0	0.04
2	0.70	0.10	0.01	0.001	0.02	0.04	1.0	10.0	0.06

MISCELLANEOUS REINFORCEMENT DATA

Aggregate Size (in)	Development Correction	Backwall Exposure Class	Stem Exposure Class	Footing Exposure Class
0.75	1.00	none	2	1

REINFORCEMENT COVER

Backwall Back Vertical (in)	Stem Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)	Toe End (in)	Heel End (in)
none	3.0	3.0	4.0	4.0	5.0	2.0	2.0

BAR SPACING FOR DESIGN

Backwall Maximum Bar Diam (in)	Stem Maximum Bar Diam (in)	Footing Maximum Bar Diam (in)	Hooked Footing Bars	User Requested Minimum Bar Spacing (in)	Bar Spacing Increment (in)
none	1.41	1.41	N	6.00	3.00

LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
1.00	1.00	1.00	2.25	2.25	2.25	2.25

LOADS ON RETAINING WALLS

CT (kip/ft)	Y Distance to CT (in)	Parapet Dead Load (kip/ft)	X Distance to Parapet (in)	Noise Wall Dead Load (kip/ft)	X Distance to Noise Wall (in)
1.50	24.0	0.10	18.0	0.00	0.0

Wind on External Structure (kip/ft)	Y Distance to Wind on External Structure (in)	Wind on External Structure SER-I (kip/ft)	STR-III (kip/ft)	STR-V (kip/ft)
n/a	0.0	none	none	none

Wind on Substructure (Wall)		
SER-I (kip/ft)	**STR-III (kip/ft)**	**STR-V (kip/ft)**
none	**none**	**none**

EARTHQUAKE LOADS

Response Modification	Soil Pressure Factor	Phi Factor Foundation	Vertical EQ Soil	Horizontal Superstructure Force (kip/ft)	Horizontal External Structure Force (kip/ft)
2.00	1.00	0.70	N/A	none	none

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
1	0	1

OUTPUT OF RESULTS

Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Footing Flexure	Reinf Summary
1	1	1	1	1	1	1

Crack Control	Shear Results	Development Length
1	1	1

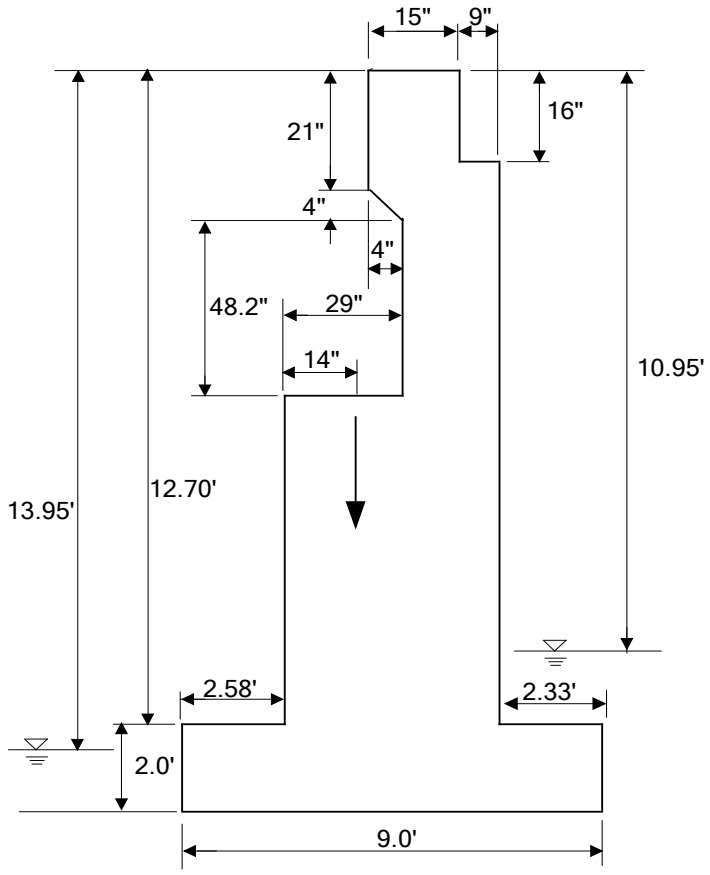
OUTPUT OF INTERMEDIATE DATA

Unfactored **Forces**	Load Factors	Moment/Axial Interaction	Internal Footing Forces	Intermediate Bearing Resist**ance** Values	Detailed Stem Cutoff Load Values
1	1	1	1	1	1

Minimum Reinf**orcement** Check	**Intermediate Settlement Data**
0	**1**

8.15 EXAMPLE 14

Example 14 is a type 1 abutment on spread footing. The structure geometry is shown in the following figure. The abutment is to be analyzed. The earthquake is considered for this problem.



Rebar Layout :

Stem: #8 @ 12" for entire height
Footing Perpendicular Direction: top and bottom: #8 @ 12"

Figure 8.15-1 Example 14 Abutment Geometry

```
                    CONFIGURATION

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CONTROL

Sys of Units	Type of Run	Footing Datum
US	A	T

ABUTMENT TYPE I

Height (ft)	Top Width (in)	Seat Width (in)	Seat Slope Height (in)	Seat Face Height (in)	Corbel Width (in)	Corbel Height (in)	Corbel Slope Height (in)
12.70	15.0	29.0	0.0	48.2	4.0	21.0	4.0

Paving Notch Width (in)	Paving Notch Height (in)	Bearing X Locn (in)	Bearing Y Locn (in)	Front Water Level (ft)	Back Water Level (ft)	Architectural Treatment Thickness (in)	Backwall/ Stem Bar Alignment
9.0	16.0	14.0	none	13.95	10.95	0.0	N/A

FOOTING

Min Footing Thick (ft)	Min Toe Proj (ft)	Min Heel Proj (ft)	Min Footing Width (ft)	Max Footing Thick (ft)	Max Toe Proj (ft)	Max Heel Proj (ft)	Max Footing Width (ft)
2.00	2.58	2.33	none	none	none	none	none

Footing Thick Increment (in)	Footing Width Increment (in)	Stem Shift Increment (in)
2.00	3.00	1.00

MATERIALS

Backwall f'c (ksi)	Stem f'c (ksi)	Footing f'c (ksi)	fy (ksi)	Reinforcement Epoxy Coated Backwall	Stem	Footing
3.500	3.000	3.000	50.000	N	N	N

Backfill Friction Angle (deg)	Backfill Dry Density (lb/ft^3)	Backfill Saturated Density (lb/ft^3)	Minimum Equivalent Fluid Press (lb/ft^3)	Concrete Density For DL (lb/ft^3)	For Ec (lb/ft^3)
33.25	120.0	135.0	35.0	150.0	145.0

Architectural Treatment Density (lb/ft^3)	fu (ksi)
150.0	65.000

SOIL

Stem Top to Soil Layer (ft)	Footing Length (Parallel) (ft)	Footing Near Slope	Soil Level At Toe (ft)	Allow Settle (in)	Bearing Cap Resistance Factor	Sliding Resist Factor	No. Soil Layers
14.70	50.20	N	2.00	1.00	0.50	0.85	1

Soil Layer Number	Soil Layer Thick (ft)	Undrained Shear Strength (ksf)	Mass Unit Weight/ Density (lb/ft^3)	Saturated Unit Weight/ Density (lb/ft^3)	Elastic Modulus (ksf)	Poissons Ratio
1	10.00	none	120.00	135.00	500.00	0.30

Soil Layer Number	Cohesion (ksf)	Effective Friction Angle (deg)	Ncq	N Gamma q
1	1.00	30.00	n/a	n/a

Apply Inclination Factors	Precast or Cast-in-Place	Reduction Coefficients RC(BC) Layer 1	Layer 2
Y	C	none	none

CONSOLIDATION SETTLEMENT

Layer Number	Void Ratio	Compr Index	Recomp Index	Second Comp Index	Init Effect Stress (ksi)	Max Past Effect Stress Top (ksi)	Prim Consol (year)	Serv Life (year)	Max Past Effect Stress Bottom (ksi)
1	0.80	0.10	0.02	0.002	0.01	0.01	0.1	5.0	0.01

MISCELLANEOUS REINFORCEMENT DATA

Aggregate Size (in)	Development Correction	Backwall Exposure Class	Stem Exposure Class	Footing Exposure Class
1.00	1.00	2	2	2

REINFORCEMENT COVER

Backwall Back Vertical (in)	Stem Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)	Toe End (in)	Heel End (in)
3.0	3.0	3.0	4.0	4.0	5.0	2.0	2.0

BAR SIZE

Backwall Back Vertical (US bar)	Footing Perpend Top (US bar)	Footing Parallel Top (US bar)	Footing Perpend Bottom (US bar)	Footing Parallel Bottom (US bar)	Footing Perp Top Bar Type	Footing Perp Bot Bar Type
8	8	none	8	none	Straight	Straight

BAR SPACING FOR ANALYSIS

Backwall Back Vertical (in)	Footing Top Perpend (in)	Footing Top Parallel (in)	Footing Bottom Perpend (in)	Footing Bottom Parallel (in)
12.0	12.0	0.0	12.0	0.0

STEM REINFORCING BARS

Range Number	Bar Size (US bar)	Bar Spacing (in)	Group Offset (in)	End Location (ft)
1	8	12.00	0.00	12.70

LOAD CONTROL

Ductility Factor	Redundancy Factor	Importance Factor	Temp LS (ft)	Final LS (ft)	Temp ES (ft)	Final ES (ft)
1.00	1.00	1.00	2.00	2.00	0.00	0.00

LOADS ON ABUTMENTS

DC (kip/ft)	DW (kip/ft)	PL (kip/ft)	Vertical WSUP (kip/ft)	Horizontal WSUP (kip/ft)	WL (kip/ft)	TU (kip/ft)	Backwall Vertical LL (kip/ft)	Backwall Horizontal LL (kip/ft)
11.40	1.00	none	0.00	n/a	0.21	0.37	0.00	none

Horizontal WSUB (kip/ft)	FR (kip/ft)	Horizontal WSUP SER-I (kip/ft)	Horizontal WSUP STR-III (kip/ft)	Horizontal WSUP STR-V (kip/ft)	Horizontal WSUB SER-I (kip/ft)	Horizontal WSUB STR-III (kip/ft)	Horizontal WSUB STR-V (kip/ft)
n/a	0.00	0.12	0.55	0.16	0.00	0.00	0.00

DESIGN LIVE LOAD

Downward LL (kip/ft)	Upward LL (kip/ft)	BR (kip/ft)	CE (kip/ft)
3.50	0.00	0.16	0.00

PERMIT LIVE LOAD

Downward LL (kip/ft)	**Upward LL (kip/ft)**	**BR (kip/ft)**	**CE (kip/ft)**
0.00	**0.00**	**0.00**	**0.00**

EARTHQUAKE LOADS

Response Modification	Soil Pressure Factor	Phi Factor Foundation	Vertical EQ Soil	Horizontal Superstructure Force (kip/ft)	Horizontal External Structure Force (kip/ft)
1.00	1.00	0.70	N/A	1.50	none

OUTPUT OF INPUT DATA

Input File Echo	Input Commands	Input Summary
1	0	1

OUTPUT OF RESULTS

Footing Geometry	Output Legend	Factored Forces	Footing Stability	Footing Control Forces	Footing Flexure	Reinf Summary
1	1	1	1	1	1	1

Crack Control	Shear Results	Development Length
1	1	1

OUTPUT OF INTERMEDIATE DATA

Unfactored **Forces**	Load Factors	Moment/Axial Interaction	Internal Footing Forces	Intermediate Bearing Resist**ance** Values	Detailed Stem Cutoff Load Values
1	1	1	1	1	1

Minimum Reinf**orcement** Check	**Intermediate Settlement Data**
1	**1**

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TECHNICAL QUESTIONS AND REVISION REQUESTS

This chapter contains a reply form to make it easier for users to convey their questions, problems or comments to the proper unit within the Department. General procedures for using this form are given. Users should keep the form in the manual as a master copy which can be reproduced as needed. It is also included as a Word template as part of the program installation.

Technical questions related to the interpretations of the design specifications as implemented in this program, why certain assumptions are made, applicability and limitations of this program, and other questions not related to the operation of this program can be directed to the appropriate person in PennDOT using the form or the information provided on the form. Please review the information provided in this User's Manual and the references given in Chapter 1 before submitting this form for processing or calling for assistance.

The form can also be used to report suspected program malfunctions that may require revisions to the program or to request revisions that may be required due to changes in specifications and for the enhancement of the program. Unexpected or incorrect output, rejection of input data, endless program cycling, and program abortion are examples of program malfunctions. Users are requested to review their input data and the program User's Manual before submitting the form for processing.

The form may also be used to submit suggestions for improving the User's Manual for this program. Suggestions might include typographical error correction, clarification of confusing sections, expansion of certain sections, changes in format, and the inclusion of additional information, diagrams, or examples.

The completed form should be sent to the **Highway Applications Division via** e-mail.

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ABLRFD
TECHNICAL QUESTION / REVISION REQUEST

This form is to be used to ask questions on technical issues related to this engineering program, report suspected program malfunctions, or to request revisions to the program or its documentation. Users are requested to review their input data and the program User's Manual before submitting this form.

CONTACT PERSON: _____ DATE: _____
ORGANIZATION: _____ PHONE: _____
E-MAIL ADDRESS: _____ PROGRAM VERSION: _____

Define your problem and attach samples and/or documentation you feel would be helpful in correcting the problem. If the input data is more than 4 or 5 lines, Licensees should provide the input data file as an e-mail attachment. If you require more space, use additional 8½ x 11 sheets of plain paper.

FORWARD COMPLETED FORM TO: Pennsylvania Office of Administration
Infrastructure and Economic Development
Bureau of Solutions Management
Highway Applications Division
E-MAIL: PenndotBisEngineer@pa.gov
PHONE: (717) 783-8822

FOR DEPARTMENT USE ONLY

RECEIVED BY: _____ ASSIGNED TO: _____ DATE: _____

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