USER'S MANUAL FOR

COMPUTER PROGRAM ABUT5

LFD

ABUTMENT AND RETAINING WALL

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Version 5.4.0.0

Prepared by:

Pennsylvania Department of Transportation
Bureau of Information Systems
Engineering Unit

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SUMMARY OF NOVEMBER 1982 REVISIONS

The program has been revised as follows:

1. Minor bugs found during the first year's use of the program were fixed.

2. Two new input items, MAX FTG WIDTH and PARAPET OR EXTERNAL LOAD, were added. Input Form 1 was revised.

3. The user can enter the limit on the maximum footing width for a design. The previous restriction of "footing width cannot be greater than the stem height" was removed and replaced by the user specified limit on the maximum footing width.

4. A retaining wall can be analyzed for a transverse parapet loading or an abutment can be analyzed for an external horizontal load, which cannot be entered elsewhere on the input form.

5. The program was revised as per 1981 AASHTO Interim Specifications Bridges. The critical section for shear in a footing on piles is now considered at a distance "d" from the face of the stem.

6. Moments and shears at critical sections in the footing are now printed for different AASHTO Group Loading

SUMMARY OF JANUARY 1984 REVISIONS – VERSION 4.0

The program was extensively revised to allow for Load Factor Design. The following changes were made:

1. Either Load Factor Design or Service Load Design can be specified as a method of design.

2. The Input Form was rearranged allowing the user to enter the first three lines for problem identification.

3. Output from the program was revised to accommodate Load Factor Design and to provide the user with maximum useful data for verification.

SUMMARY OF JUNE 1989 REVISIONS – VERSION 4.1

The BRADD-2 version of this program was refined and implemented as a stand-alone program. The following revisions were made:

1. Stability analysis of walls with sloping backfills is performed using the user-defined equivalent vertical and horizontal fluid pressures or using the curves given in Pennsylvania Department of Transportation Design Manual Part 4. The calculation of horizontal pressure due to live load surcharge is applied to the entire height of the abutment or retaining wall in accordance with Pennsylvania Department of Transportation Design Manual Part 4, Section B.5.

2. The program's pile spacing design logic was revised to investigate a variety of possible patterns. The optimum pattern is automatically selected as the footing with the least pile density. The user may optionally choose the optimum to be the footing with the smallest cross sectional area or the least cost.

3. The logic for designing a spread footing was refined to include adjustments to the toe/heel ratio in order to obtain a more economical design.

4. Output from the program was reformatted to fit on 8 ½ X 11 inch paper.

5. Serviceability is checked when the Load Factor Design Method is used and reinforcement greater than 40 ksi is specified.

6. The calculation of the area of steel for stem sections using the Load Factor Design Method was refined. If all factored loads are well within the strength curve, then the program reduces the area of steel.

7. Optional reinforcement design for both stem and footing was added. This option allows the user to specify desired rebar spacings with the program choosing the optimum reinforcement size for the given spacings.

8. The input items PILE OPT, LATERAL PILE CAPAC, Kv, PILE COST, FTG COST and BACKWALL LIVE LOAD were added. All input items are printed exactly as they are read by the program. When the program detects an error in any of the input items, an appropriate message is printed with the annotation *** ERROR ***. Any defaults assumed by the program are printed with the annotation *** NOTE ***. For an analysis problem, warnings are printed if any of the design criteria is not met, and the program will not design the reinforcement.

9. The input forms were revised to incorporate the above revisions.

10. Example Problems were revised giving detailed explanation of input items.

SUMMARY OF AUGUST 1991 REVISIONS – VERSION 4.2

The program has been revised as follows:

1. A temporary construction loading condition was added. This loading includes fill height to the abutment seat, live load surcharge, uplift, and wind on substructure, if applicable. The minimum factors of safety used for stability checks are reduced and the pile capacity is increased for this temporary condition.

2. The program now allows alternating battered and vertical piles in the last row (towards heel). A new input item was added to indicate if the program is to consider alternating battered piles in the last row.

3. The minimum reinforcement size is now #4 bar in the stem.

4. The balancing moment for a footing on piles should be the moment about the front row of piles. The program has been incorrectly printing the moment about the toe of the footing. The moment about the front row of piles is now printed.

5. An error correction was made to the calculation of the effects due to an external horizontal load on an abutment. For abutments with a backwall (Types I and II), the external horizontal distance was incorrectly being measured from the abutment seat instead of the top of backwall.

6. An error correction was made to exclude the weight of concrete in the backwall and include the wind on substructure for the temporary construction loading condition.

7. An error correction was made to avoid an endless loop in the pile footing design. Also, minor changes were needed to make the footing analysis results from the microcomputer version match the results from the mainframe version.

8. A correction was made to assure that the starting footing size for a design problem is not smaller than the starting size stated in the method of solution.

SUMMARY OF JULY 1996 REVISIONS – VERSION 5.0

The program has been revised as follows:

1. A modification was made to allow a specific toe dimension to be held constant for a design problem

2. The live load surcharge is now applied from the back face of the top of the wall for all ground configurations behind the wall. The input item TOP WALL TO BEG LL SURCH is no longer used to determine the application of live load surcharge.

3. Two conditions are considered when applying the effect of the vertical component of live load surcharge. The first condition assumes no vertical component for live load surcharge. The second condition assumes a vertical effect over the entire heel.

4. The pile design and analysis logic has been revised to reflect the intent of DM4 and current design practice. A new input item PERCENT ROW BATTERED has been added. For lateral resistance in piles, the program will only consider bending capacity when all piles in all rows are vertical. For battered piles, all lateral resistance must be provided by the horizontal component of the axial capacity of the battered piles. No bending of piles is allowed in a battered pile footing.

5. An error correction was made in the calculation of the theoretical cutoff location for stem back face vertical reinforcement.

6. Several error corrections were made, particularly in the area of Service Load Design, based on comments received from the New York Department of Transportation.

7. A new input item OVRSTR has been added. This item is used to indicate whether the allowable soil pressure or axial pile capacity is to be increased by the overstress percentage factor for each AASHTO load group.

8. A new input item BACKWALL LIVE LOAD HORZ has been added. This allows the user to apply a horizontal force due to live load acting directly on the backwall.

9. A seismic loading condition has been added. New input items SEISMIC LOAD and ALLOW PILE UPLIFT have been added for this loading condition, which is designated as load Group VII.

10. For the stem design, the vertical component of live load surcharge over the projection of the battered back face is ignored.

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11. For a pile footing, the default for the current input item BAR LOC has been changed to place bottom footing bars below the top of piles. To place bottom footing bars above the top of piles, the user must now enter an "N" for BAR LOC.

12. An error correction was made in the calculation of cracking moment. The area of steel is neglected as per AASHTO. Previously, the transformed section properties were used.

13. The minimum area of steel in the top of the footing has been changed to 0.31 sq. in. (#5 @ 12") or 50% of the steel in the bottom as per SOL 431-91-14.

14. For a retaining wall with sloping backfill, the vertical component of earth pressure acting at the free end of the heel is now included when calculating the moment and shear in the heel.

15. The calculations for the effect of buoyancy have been changed. Previously the program applied a buoyancy force acting upward at the center of footing and considered the saturated weight of soil over the heel. Now the program does not apply the buoyancy force at the center of the footing and considers the effective (buoyant) weight of soil over the heel. This is done regardless of the type of footing.

16. The critical sections for shear in the footing are now considered at the face of the stem when there is tension in the top of the footing. The critical sections for shear in the footing are considered at a distance "d" from the face of the stem when there is compression in the top of the footing.

17. A new input option (80% RULE) has been added for an analysis of a footing on piles to check the 80-20 rule for the lateral resistance of a pile group having battered and vertical piles.

18. The User's Manual has been corrected and revised. The complete manual has been reprinted.

SUMMARY OF DECEMBER 1996 REVISIONS – VERSION 5.1

The program has been revised as follows:

1. A program error was corrected in calculating the allowable soil pressure for a spread footing for different AASHTO Group Loadings. The program was always applying the overstress factor for the temporary loading condition (1.25) for all AASHTO Group Loadings.

2. The calculations for the effect of buoyancy have been revised again (Revision 15 of the July 1996 Revisions gave unconservative designs in some cases). The program now considers the weight of water over the toe, the horizontal pressure due to water in front of the abutment, the weight of saturated soil above the heel and a linear uplift pressure on the base of the footing.

3. A new input item called WATER LEVEL FRONT has been added.

SUMMARY OF MAY 1998 REVISIONS – VERSION 5.2

The program has been revised as follows:

1. Previous versions of the program limited the toe projection to a maximum of 2 feet for a pile footing design. The program was revised to increment the toe projection for each design footing width from the minimum toe projection (input value or a default of 1 ft.) until it exceeds one of the following: 1.) the input maximum toe projection; 2.) the design footing width minus the stem thickness at the base minus the minimum heel projection (1 ft.); or 3.) one-half the design footing width. The toe projection increment was changed from 1 inch to 3 inches to reduce program execution time. Also, the minimum heel projection for pile footings was changed from 2 ft. to 1 ft. to match the LRFD Abutment and Retaining Wall program.

2. The revision described above can result in several acceptable designs for a particular footing size with different stem locations. Therefore, when given two acceptable designs with equal footing cross sectional areas and equal pile densities, the program will select the design with the larger projection to minimize structure backfill.

3. The pile design procedure was enhanced to allow the pile rows to be placed as close to the toe as allowed for design pile arrangements f three or more rows. The first and last rows are placed at the minimum distance (1.5 ft.) from the toe and the heel edges of the footing, respectively. The remaining rows are then spaced using the minimum distance between rows (3 ft.) from the first row.

4. A new input item, PILE ROW OPT, was added to the control the pile row placement for design. The user can choose to try the design pile arrangements with evenly spaced rows, rows placed toward the toe (as described above) or both.

5. The program has always applied certain assumptions about the backwall dimensions for Abutment Type II when computing backwall section thicknesses. Namely, (BW1 + BW2) > (H2 + H3 + H4); and (H3 + H4) < (H2 + H3 + H4)/2 (refer to Figure 4.1.2). A warning message is now printed if either of these conditions is violated.

6. The lateral resistance of pile groups with all vertical piles was corrected to apply the overstress factor when "Y" is entered for OVRSTR. The lateral resistance of pile groups with battered piles using the 80% rule was also corrected to apply the overstress factor when applicable.

7. An input error message is now printed when a zero or blank is entered for HEIGHT OF BACKWALL BATTER for Abutment Type II. Previously, this would result in a run-time error causing the program to terminate.

8. Footing design parameters (i.e., the minimum and maximum values for footing width and thickness; and for toe and heel projections) are printed for design problems.

9. Corrected the axial pile capacity for seismic loading so that the overstress factor of 1.33 is not applied when a "Y" entered for OVRSTR since the capacity for seismic loading should use the ultimate axial pile capacity divided by a factor of 1.3.

10. The default value for OVRSTR has been changed to "Y".

11. A message was added to the optimum rebar design output for the vertical reinforcement in the back face of the stem to remind the user that the design applies to the stem only. Backwall reinforcement should be designed based on the STEM DESIGN output for Sections 1 and 2. This message is printed for Abutment Types I and II when backwall live loads are entered.

12. The example problems have been updated with the above revisions.

SUMMARY OF JUNE 1999 REVISIONS – VERSION 5.3

The program has been revised as follows:

1. The calculation of the default value of equivalent fluid pressure for a saturated soil is changed. It is now calculated based on the active earth pressure due to the buoyant unit weight of soil and the hydrostatic pressure of water. Previously it assumed a value of 39 lbs/ft^2. Refer to the method of Solution Section 3.1.2 and the description of EQUIV FLUID PRES SAT in Section 4.2.

2. The program has been revised to print the dates in either the MM/YYYY or the MM/DD/YYYY format.

3. The User's Manual has been revised for the above change. An explanation of the Lateral Resistance of a Pile Group and other clarifications are also added.

SUMMARY OF MAY 2005 REVISIONS – VERSION 5.4.0.0

The program has been revised as follows:

1. The program source code was converted to current PENNDOT programming standards compatible with Windows XP. (Revision 002)

2. The pedestal design procedure was corrected to select the controlling bearing pressure under the pedestal considering the correct overstress factor. Previously, the program selected the maximum bearing pressure for all load cases, but sometimes applied an incorrect overstress factor when determining whether it exceeds the allowable pressure. This could result in a pedestal footing design with excessive bearing pressure for certain load cases. (Revision 003)

3. The allowable bearing pressure, including the overstress factor, was added to the Stability Analysis output table for all footing types. Actual pressures, which exceed the allowable, are now indicated by an asterisk. (Revision 004)

4. Program output messages were reformatted and categorized as Notes, Warnings and Specification Failures to make them easier to identify and read. In addition, output section headings were added to better identify where the messages apply. (Revision 005)

5. The program has been converted to a Windows DLL. (Revision 006)

6. A note (“THE LATERAL RESISTANCE IS GREATER THAN 150% OF THE DRIVING FORCE (SUM H) A REDUCED BENDING CAPACITY MAY BE USED.”) printed after the pile pattern when the lateral resistance of a pile pattern is greater than 150% of the horizontal force was removed. It is no longer applicable. (Revision 007)

7. A Formatted Output Tables section was added to Chapter 6 of the User’s Manual to provide a sample of the output format. (Revision 008)

8. The DM-4 reference for the horizontal and vertical components of earth pressures calculation for sloped backfill was corrected from Table 5.8.1.3P(A) to Figure 5.5.2E in the “Constants, Assumption and Limitations” section (Section 3.12, Item 4) of the User’s Manual. (Revision 009)

9. A clarification for the use of a 2% allowance when checking soil pressures for spread footing and pedestal footing designs was added to the “Constants, Assumption and Limitations” section (Section 3.12, Item 18) of the User’s Manual. (Revision 010)

ABUTMENT AND RETAINING WALL

10. Several typographical errors were corrected from the initial release of the electronic (Adobe PDF) ABUT5 User's Manual.

1 GENERAL DESCRIPTION

1.1 PROGRAM IDENTIFICATION

PROGRAM TITLE: Abutment and Retaining Wall

PROGRAM NAME: ABUT5

VERSION: 5.4.0.0

SUBSYSTEM: Substructure

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ABSTRACT:

The Abutment and Retaining Wall program designs or analyzes a reinforced concrete bridge abutment or a wing wall by the Load Factor Design Method. The program analyzes the substructure for stability and designs the stem and footing for reinforcement required at various sections. A spread footing or a footing on piles or a footing on pedestals can be designed or analyzed. The design is in accordance with the 1992 AASHTO Standard Specifications for Highway Bridges and the Pennsylvania Department of Transportation Design Manual Part 4. As an option, the Service Load Design method can also be specified.

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2 PROGRAM DESCRIPTION

2.1 GENERAL

The Abutment and Retaining Wall program designs or analyzes a reinforced concrete bridge abutment or a wing wall by the Load Factor (LFD) method. The program analyzes the substructure for stability and designs the stem and footing for reinforcement required at various sections. For a spread footing, the width and thickness of the footing are designed. For a footing on piles, the width and thickness of the footing and optimum pile pattern are given by the program. A footing on pedestal can also be designed for pedestal dimensions. The geometry of the stem conforms to the Pennsylvania Department of Transportation Bridge Design Standards, BD-600 Series. The design is in accordance with the 1992 AASHTO Standard Specifications for Highway Bridges as amended by the Pennsylvania Department of Transportation Design Manual Part 4. The Service Load Design method can also be an optional method of design.

For the purpose of this manual, the 1992 AASHTO Standard Specifications for Highway Bridges will be referred to as AASHTO Specifications, and the Pennsylvania Department of Transportation Design Manual Part 4 will be referred to as DM4.

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3 METHOD OF SOLUTION

3.1 GENERAL

The program employs the principles of statics for structural analysis and uses either the Load Factor Design Method or the Service Load Design Method for computing reinforcement required at various sections of the stem and footing. For an analysis problem, the program performs the stability analysis, checks the adequacy of foundation and determines the required reinforcement at various sections in the stem and footing for an existing substructure. For a design problem, the program determines the size of the footing such that the substructure is adequately safe against overturning, sliding and soil (or pile) bearing capacity, and computes the reinforcement at various sections in the length of the substructure. The program uses Group Loadings I, II, III, IV, V and VI as specified in the ASHTO Specifications as well as a seismic loading condition (in lieu of AASHTO Group VII) and a temporary construction loading (defined as Group T).

The following sections describe the procedures used in various phases of the program.

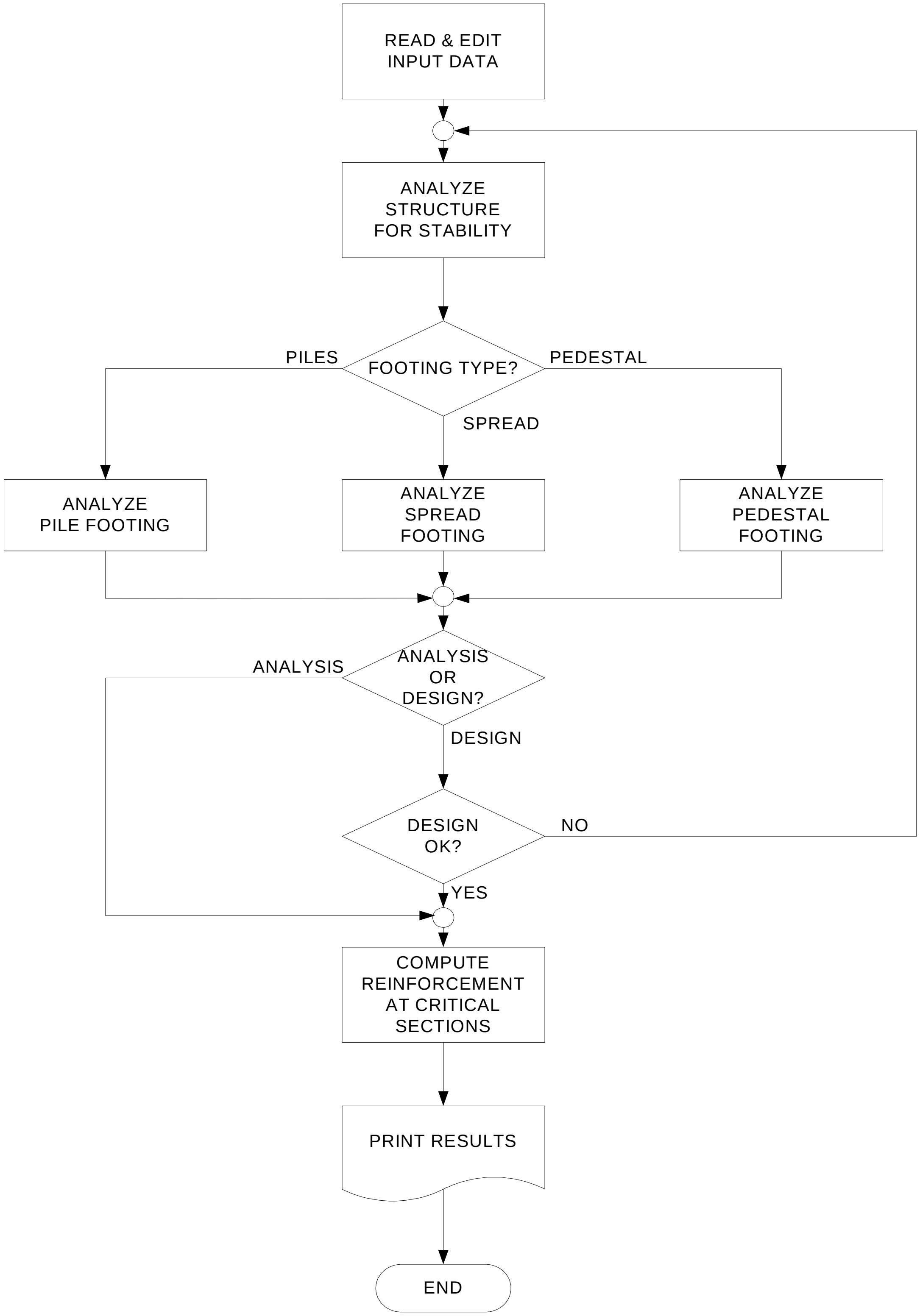


Figure 3.1.1 Program Flow Chart

3.2 APPLICATION OF LOADS

The substructure is analyzed for two types of loads: Vertical Loads and Horizontal Loads. Refer to Figure 5.6.1 on page 5-26, Section 5.6 for an explanation of various load application. The following individual loads are considered:

3.2.1 Vertical Loads

1) The weight of the structure. The density of concrete is assumed as 150 lbs/ft^3.

2) The weight of the fill material over the heel projection. The weight of the fill material over the toe projection is neglected. If a permanent water level is indicated behind the stem, the weight of fill material below the water level is calculated by:

$$W = \gamma_{SAT} V$$

Where: $W = weight\ of\ fill\ material\ below\ water\ level$

$\gamma_{SAT} = density\ of\ saturated\ soil$

$V = volume\ of\ fill\ material\ below\ water\ level$

The density of saturated soil (γ_{SAT}) is based on an assumed void ratio (volume of voids divided by volume of solid matter, *e*) of 0.3 and it is calculated by:

$$\gamma_{SAT} = \gamma_{dry} + \left[\frac{e}{1+e}\right]\gamma_{WAT}$$

Where: $\gamma_{DRY} = density\ of\ dry\ soil\ which\ is\ assumed\ as\ 120\ lbs/ft^3$

$\gamma_{WAT} = density\ of\ water\ which\ is\ assumed\ as\ 62.5\ lbs/ft^3$

3) The vertical component of the lateral earth pressure from a sloping backfill.

4) The dead load reaction from the superstructure.

5) The live load reaction from the superstructure.

6) The live load acting on the backwall, if applicable.

7) The weight of water over the toe projection is considered.

8) External load, if applicable.

9) The live load surcharge equivalent to a specified height of ill material. Two conditions are considered when applying the effect of the vertical component of live load surcharge. The first condition assumes no vertical component for live load surcharge. The second condition assumed a vertical effect over the entire heel.

10) Wind on superstructure acting upward.

11) The uplift due to buoyancy. The buoyancy force acting on the base of the footing is calculated by assuming a linear hydrostatic pressure due to the variation of water levels in the front and back of the substructure. Refer to Figure 3.2.1 on page 3-5.

3.2.2 Horizontal Loads

1) The horizontal component of lateral earth pressure including the water pressure due to the presence of water level.

2) Lateral earth pressure due to live load surcharge. This is applied to the entire back face of the stem up to the top of the backwall whenever a live load surcharge is considered.

3) Wind on live load acting at 6 feet above the top of the structure.

4) Wind on superstructure acting at the center of gravity of the exposed area of the superstructure elevation.

5) Wind on substructure acting at the mid point of the stem height up to the abutment seat.

6) Live load traction acting 6 feet above the top of the deck slab.

7) Centrifugal force acting 6 feet above the top of the deck slab.

8) Frictional force due to the thermal expansion of the superstructure acting at the bearing line.

9) External load, if applicable.

10) Load due to braking forces from the live load acting on the backwall, if applicable.

11) Load due to seismic forces from superstructure acting at the bearing line.

12) The horizontal component of water pressure due to the presence of water over the toe.

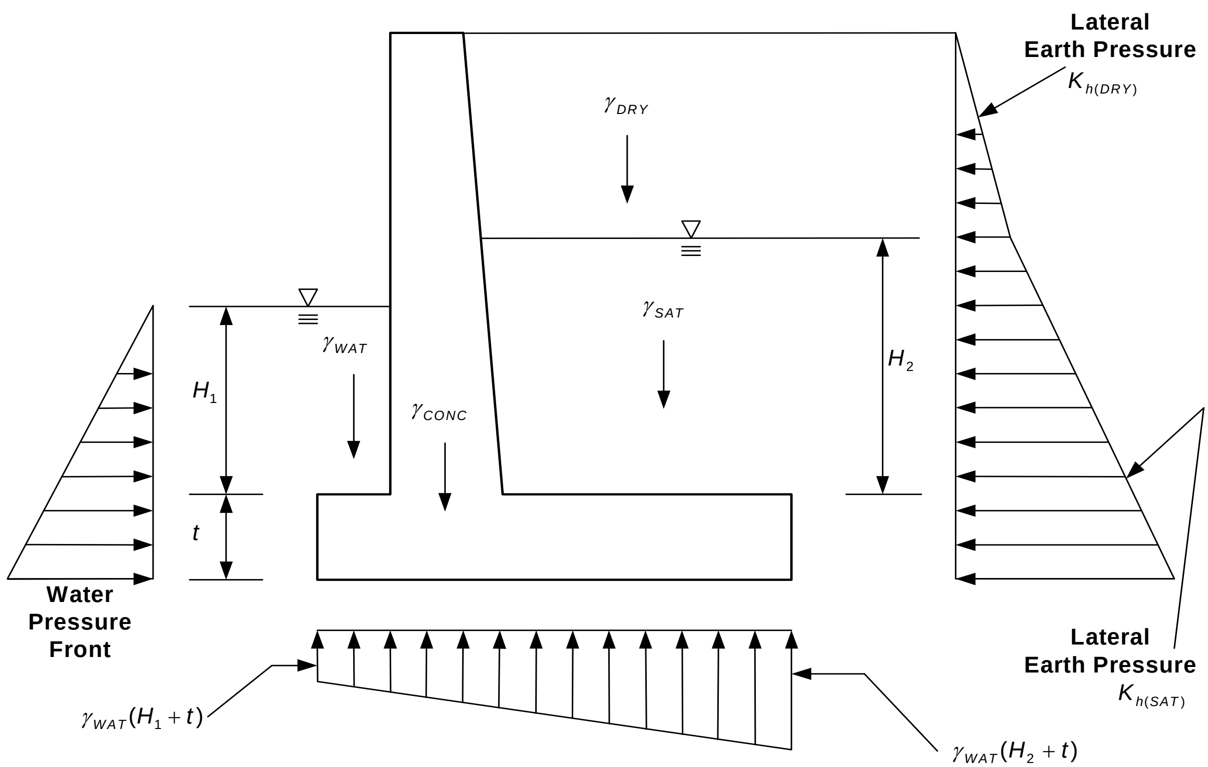


Figure 3.2.1 Effects of Water Levels

3.2.3 AASHTO Group Loadings

The following equation is used for various combinations of loads acting on the substructure:

$$Group(N) = \gamma\ [\beta_D \bullet D + \beta_L \bullet (L + I) + \beta_C \bullet CF + \beta_E \bullet B + \beta_W \bullet W + \beta_{WL} \bullet WL$$
$$+ \beta_{LF} \bullet LF + \beta_T \bullet T + \beta_{EQ} \bullet EQ]$$

Where N is the group number and γ and β are load factors. Groups I, II, III, IV, V and VI are used by the program. The seismic loading equation defined in DM4, Appendix A, Section 4.7.2 is used in lieu of AASHTO Group VII. Additionally, a temporary construction loading is used and has been given the designation T. The gamma and beta factors sued by the program are shown in Table 3.2.1 on page 3-7. Factored loads are used to design the stem and footing sections if the Load Factor Design is specified.

Service loads are used in determining the stability of the substructure whether the Load factor design is specified or the Service Load design is specified. Service loads are used to design the stem and footing sections if the Service Load Design is specified. For Service Load Design, the allowable stresses for different AASHTO Group Loadings are increased by Overstress % shown in Table 3.2.1 on page 3-7. The overstress percent factors (Overstress % divided by 100) are also used to check the allowable foundation pressure and pile loads under different AASHTO Group Loadings. However, these overstress percent factors are not used for checking stability (factors of safety).

For Load Factor Design of stem sections, two sets of factored loads are computed for each group. One based on a beta factor of 0.75 for Dead Load for designing a section for minimum axial load and maximum moment and another based on a beta factor of 1.0 for Dead Load for designing a section for maximum axial load and minimum moment. Out of these combinations, the following four combinations are selected for stem design. These are:

Minimum axial load and corresponding moment	$(\beta_D = 0.75)$
Maximum moment and corresponding axial load	$(\beta_D = 0.75)$
Maximum axial load corresponding moment	$(\beta_D = 1.0)$
Minimum moment and corresponding axial load	$(\beta_D = 1.0)$

Load Factor Design

β Factors

Group	γ	D	L+I	CF	E	B	W	WL	LF	T	EQ
I	1.3	1	1.67	1	1.3	1	0	0	0	0	0
II	1.3	1	0	0	1.3	1	1	0	0	0	0
III	1.3	1	1	1	1.3	1	0.3	1	1	0	0
IV	1.3	1	1	1	1.3	1	0	0	0	1	0
V	1.25	1	0	0	1.3	1	1	0	0	1	0
VI	1.25	1	1	1	1.3	1	0.3	1	1	1	0
VII	1	1	0	0	1	1	0	0	0	0	1
T	1.3	1(1)	1.3(2)	0	1.3	1	1(1)	0	0	0	0

Service Load Design

β Factors

Group	γ	D	L+I	CF	E	B	W	WL	LF	T	EQ	Overstress %
I	1	1	1	1	1	1	0	0	0	0	0	100
II	1	1	0	0	1	1	1	0	0	0	0	125
III	1	1	1	1	1	1	0.3	1	1	0	0	125
IV	1	1	1	1	1	1	0	0	0	1	0	125
V	1	1	0	0	1	1	1	0	0	1	0	140
VI	1	1	1	1	1	1	0.3	1	1	1	0	140
VII	1	1	0	0	1	1	0	0	0	0	1	133(3)
T	1	1(1)	1(2)	0	1	1	1(1)	0	0	0	0	125

(1) Neglects effects due to superstructure.

(2) Live Load surcharge only.

(3) This value is 230.769 for soil bearing pressure and axial pile loads.
See item 12 in Section 3.10. Also, see the description for input parameter OVRSTR.

Table 3.2.1 Load Factor and Service Load Coefficients

3.3 STABILITY ANALYSIS

Any retaining structure must be safe against overturning about the toe of the footing, against sliding on the footing base, and against crushing of foundation material or overloading of piles at the point of maximum pressure. This requires a stability analysis of the substructure. Service loads are used in checking the stability of the substructure.

The vertical and horizontal loads acting on the substructure are computed. The vertical loads are due to the weight of concrete, weight of water over toe, soil over the heel projection of the footing, dead load and live load reactions from the superstructure, live load surcharge over the heel of the footing, upward forces due to wind, upward force due to buoyancy and any additional load such as due to approach slab, pavement, etc. The horizontal loads are due to the soil pressure, water level over toe, live load surcharge earth pressure, wind on superstructure, wind on substructure, wind on live load, friction at bearing due to change in temperature, live load traction, centrifugal force due to live load and seismic force acting at the bearing. These loads and their locations are computed per foot length of the structure in the longitudinal direction. Also computed are moments due to these loads about the toe of the footing or the front row of piles.

Out of these loads and moments, the sums of vertical loads, horizontal loads and their moments for each AASHTO Group Loading, the seismic loading, and the temporary construction loading are computed. Also computed is the location of the resultant force for each Group Loading. Two separate tables of these values are computed, one that includes the vertical component of live load surcharge and another that does not include the vertical component of live load surcharge.

For the seismic loading condition, the vertical loads are due to the weight of concrete, soil over the heel of projection the footing, dead load reactions from the superstructure and any additional load such as due to approach slab, pavement, etc. The horizontal loads are due to the lateral earth pressure and the seismic force coming from the superstructure and acting at the bearing.

For the temporary construction loading condition (designated as Group T), the vertical loads included weight of concrete up to the construction join and soil over the heel projection up to the level of the construction joint. The horizontal loads for this temporary construction loading condition are pressure due to soil up to the construction joint, wind on substructure and live load surcharge horizontal force up to the full stem height. A construction joint is assumed at the base of the backwall. The temporary construction loading condition for a retaining wall assumes a level backfill at the elevation where the sloping backfill meets the back face of the stem.

The factor of safety against overturning is then computed by the formula:

$$F.S. = \frac{M_V}{M_h}$$

Where: $M_V = sum\ of\ moments\ due\ to\ vertical\ loads$

$M_h = sum\ of\ moments\ due\ to\ horizontal\ loads$

The factor of safety against sliding for a spread footing is computed by the formula:

$$F.S. = \frac{\mu V}{H}$$

Where: $H = sum\ of\ horizontal\ loads$

$V = sum\ of\ vertical\ loads$

$\mu = coefficient\ of\ friction\ of\ soil$

For a footing on pedestals, instead of factor of safety against sliding, the ratio of the sum of vertical loads to the sum of horizontal loads is computed.

The above factors of safety are computed for each AASHTO Group Loading, the seismic loading and the temporary construction loading using the service loads.

The minimum factors of safety used for stability checks used are as follows:

Spread Footing:

Overturning about toe	- 2.0 for soil foundation
	- 1.75 for rock foundation
	- 1.5 for temporary loading
	- 1.1 for seismic loading
Sliding at the base	- 1.5
	- 1.3 for temporary loading
	- 1.1 for seismic loading

Sliding is not checked for footings embedded in rock.

Pile Footing:

Overturning about the front row of piles	-	1.75
	-	1.5 for temporary loading
	-	1.1 for seismic loading

Overturning is not checked when piles are embedded 12 inches or more.

Pedestal Footing:

Overturning about toe of base slab	-	1.75
	-	1.5 for temporary loading
	-	1.1 for seismic loading
Overturning about toe of pedestal	-	1.75
	-	1.5 for temporary loading
	-	1.1 for seismic loading
Ratio of vertical loads to horizontal loads	-	2.0
	-	1.5 for temporary loading
	-	1.1 for seismic loading

3.4 SPREAD FOOTING

Whether the spread footing is analyzed for an existing structure or it is designed for a new structure, the basic computations are the same. The design differs from an analysis in determining the size of the footing. For an analysis problem, the width, projections and thickness of the footing are entered by the user and they are not changed by the program. Whereas, for a design problem, the program tries to find the most economical footing size within the limits given by the user and criteria set for by the AASHTO Specifications and DM4.

For an analysis problem, the program begins with the given dimensions and computes the soil pressure, shear stress and the area of reinforcement at critical section. The critical sections for shear and flexure are defined on page 3-21.

Soil pressure under the footing is computed based on the assumption that the footing is indefinitely stiff and the soil reaction has a straight-line distribution. Refer to any standard textbook on foundation design for this method.

For a design problem, the spread footing design is considered satisfactory when the following requirements are met:

1) The factor of safety against overturning is adequate.

2) The factor of safety against sliding is sufficient.

3) The maximum soil pressure is within the allowable limits (± 2%) and the resultant force falls within ± 1" of the kern area (there is no appreciable uplift).

The kern area for a spread footing is assumed to be the middle one-third of the footing width for a footing on soil and the middle one-half of the footing width for a footing on rock.

For a design problem, the program begins with the minimum toe and heel projections. The toe projection is initially set to 1 foot and the heel projection is set close to 2 feet such that the base slab width is a multiple of 3 inches. An iteration process is then performed, looping through the following steps:

- Step 1. The program performs a stability analysis computing the factor of safety against overturning about the toe of the footing and the factor of safety against sliding on the footing base. The maximum soil pressure under the footing is computed. The eccentricity (distance from the center of the base slab width) of the resultant force is computed and the difference between the eccentricity and the maximum allowable eccentricity (half the width of kern area) is found.

- Step 2. The program checks the computed values against the allowables. If all of the requirements listed above are met, then an acceptable footing width has been found and the program will proceed to check the thickness required for flexure and shear (Step 5). If the maximum soil pressure at the toe of the footing exceeds the allowable, the program skips to Step 4.

- Step 3. The heel projection is increased by one inch, decreasing the toe projection accordingly. If a maximum value was specified for the heel projection and this value is exceeded or the toe projection becomes less than the minimum (1 foot) then the program skips to Step 4. Otherwise, the program loops back to Step 1.

- Step 4. The footing width is increased by three inches. The heel projection is set equal to the minimum (2 feet). If a maximum value was specified for the toe projection and this value is exceeded, the toe projection is set equal to the maximum and the heel projection increased accordingly. If the maximum footing width is exceeded the program skips to Step 6. Otherwise, the program loops back to Step 1.

- Step 5. The shear strength and the thickness required for flexure are computed at critical sections in the footing. If the factored shear exceeds the shear strength of the section or the thickness required for flexure is greater than the thickness provided, the program skips to Step 6. If the shear strength and the thickness required for flexure are satisfactory, then the results are saved and the program goes to Step 7. Refer to DESIGN OF SECTION on page 3-24 for the method used for designing critical sections in the footing.

- Step 6. The footing thickness is increased by 3 inches and the footing width is reset to the minimum. If the footing thickness exceeds 3 feet, no design could be found within the maximum width specified and the program terminates with an appropriate message. Otherwise, the whole process beginning with the STABILITY ANALYSIS (Step 1) is repeated.

- Step 7. If a second design has been found, the program compares the footing cross sectional areas of the two designs and prints the results for the footing with the least area. If only one successful design has been found, the program increases the footing thickness by 3 inches and resets the footing width to the minimum and the design process is repeated starting with Step 1.

The design procedure described above optimizes the footing dimensions as much as practical such that at least two of the three design criteria are at the maximum allowable.

3.5 PILE FOOTING

The procedure used for analysis and design of a footing on piles differs from the procedure described above. Whether it is an analysis or design, the program computes the factor of safety against overturning about the front row of piles. The program also computes the pile loads and the lateral resistance of the pile group. Shear stresses and areas of reinforcement at critical sections are also computed. Refer to page 3-21 for critical sections. For an analysis problem, the above items are computed and printed out.

The pile loads are computed based on the elastic theory using the following equation:

$$Q_m = \frac{Q}{n} + \frac{M_y\, x_m}{\sum(n_i\, x_i^2)}$$

Where:
- Q_m = Axial load on given pile (compression is positive).
- Q = Total vertical load acting at the centroid of the pile group.
- n = Total number of piles in the group.
- M_y = Moment about the centroid of the pile group.
- x_i = Distance of each pile from the centroid of the pile group.
- x_m = Distance of the pile row, measured from the centroid of the pile group, for which Q_m is calculated.
- n_i = Number of piles in row I (reciprocal of pile spacing in row i).

x_i or x_m is positive to the left of the centroid of the pile group.

Refer to Figure 3.5.1 on page 3-14.

For a design problem, the pile footing design must satisfy the following criteria:

1) There must be no uplift on any pile under any loading condition except the seismic condition. This means that the resultant vertical force must lie between the extreme pile rows. For the seismic loading condition, there may be uplift in the last half of the pile rows and the uplift in any individual pile may not exceed the allowable pile uplift capacity entered as an input item.

2) The Pile load must be within the allowable limits.

3) The lateral resistance of the pile group must be adequate. Refer to page 3-9 for the minimum safety factor used by the program for stability.

For a design problem, the program begins with a minimum footing thickness of 2.5 feet or user defined minimum and a minimum toe projection of 1-foot. The footing width is set equal to the maximum of either 6 feet, a 1-foot toe projection plus the stem width at the bottom plus a 1-foot heel projection, or 50 percent of the stem height. This satisfies the criteria that the minimum distance between pile rows should be 3 feet and each pile row must be at least 1.5 foot from the edge of the footing. To obtain the optimum design, the program uses the following procedure:

- Step 1. The program performs a stability analysis computing the factor of safety against overturning about the front row (towards toe) of piles.

- Step 2. If the piles are not embedded 12 inches or more into the footing (indicated by input option), the factor of safety against overturning is checked. If this factor of safety is greater than the minimum safety factor for overturning, the program proceeds with the next check. If the factor of safety is less than the minimum, the footing width is increased by 3 inches and the program repeats Step 1. If the piles are specified as embedded 12 inches or more into the footing, the factor of safety against overturning is not checked for the design.

- Step 3. To determine the optimum pile pattern, various pile arrangements are considered so that pile spacings from one row to another row will be a multiple of each other. A minimum of 2 and a maximum of 5 rows of piles are allowed in a design. Refer to Figure 3.5.2 on page 3-5 for a description of all pile pattern combinations. The program will sequentially try each arrangement in the order given in Figure 3.5.2. Various pattern configurations are illustrated in Figure 3.5.3 on page 3-17.

  In this step, the program establishes the next pile pattern to be tried (pattern 1-1 the first time through). When all pile patterns have been tried for this footing, the program skips to Step 9. Otherwise, the program continues with Step 4.

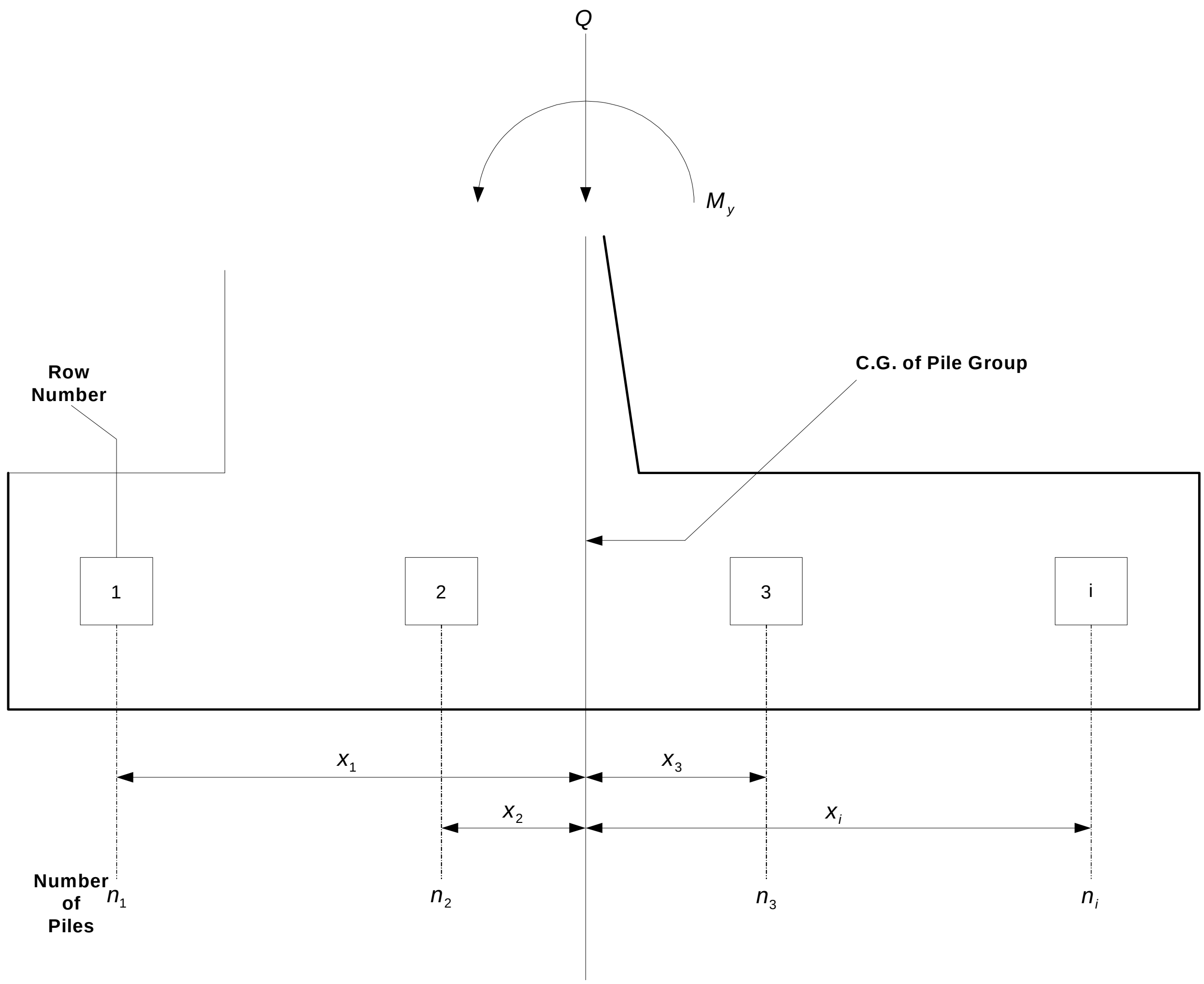


Figure 3.5.1 Pile Loads

- Step 4. For the given pile pattern, the spacing required to produce the maximum allowable pile load is computed. If this spacing is less than the minimum pile spacing, the pattern is rejected and the program returns to select the next pattern in Step 3. If the spacing is greater than the minimum, the lateral resistance is checked as per Step 5. The pile rows are spaced by one or both of two methods. The first and last rows are placed at the minimum distance (1.5 ft.) from the toe and the heel edges of the footing, respectively. Remaining rows either can be spaced evenly between the first and last rows or spaced using the minimum distance between rows (3ft.) from first row. If both methods are used, the evenly spaced pile arrangement is analyzed first.

- Step 5. When computing lateral resistance, the program starts by assuming all vertical piles (no battering). For this condition, the horizontal capacity of each pile is based on the input item LATERAL PILE CAPAC. The total load that can be resisted by bending of vertical piles only is computed. If this resistance is greater than the horizontal load, no battering of piles is required and the program skips to Step 7.

- Step 6. If the total load that can be resisted by bending of piles only is less than the horizontal load, the program tries to increase the resistance by battering piles. For this case, the program will check the following battering conditions in this order: First row (front) - 50%, then 100%; Middle rows (one at a time) - 25%, 50%, 75%, then 100%; Last row (back) - 25%, then 50%. For a combination of battered and vertical piles, there is no bending of vertical piles and all resistance must come from the battered piles. The lateral resistance for the battered piles is based only on the horizontal component of axial pile capacity. If the total lateral resistance is greater than the horizontal load, no further battering of piles is required, and the program returns to Step 4 to recalculate the spacing based on battered piles. If the pile capacity and lateral resistance for the pile spacing of this pattern is acceptable, the program continues with Step 7.

- Step 7. The shear strength and the thickness required for flexure are computed at critical sections in the footing. Refer to DESIGN OF SECTION on page 3-24 for the method used for designing critical sections in the footing. If the factored shear exceeds the shear strength of the section or the thickness required is greater than the thickness provided, the program returns to select the next pile pattern in Step 3. Otherwise, the areas of reinforcement required at critical sections and pile density are computed. The pile density is the number of piles per foot of footing length.

2 Rows	1-1	2-1	3-1	4-1	5-1			
3 Rows	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 Rows	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 Rows	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	

Figure 3.5.2 Pile Patterns

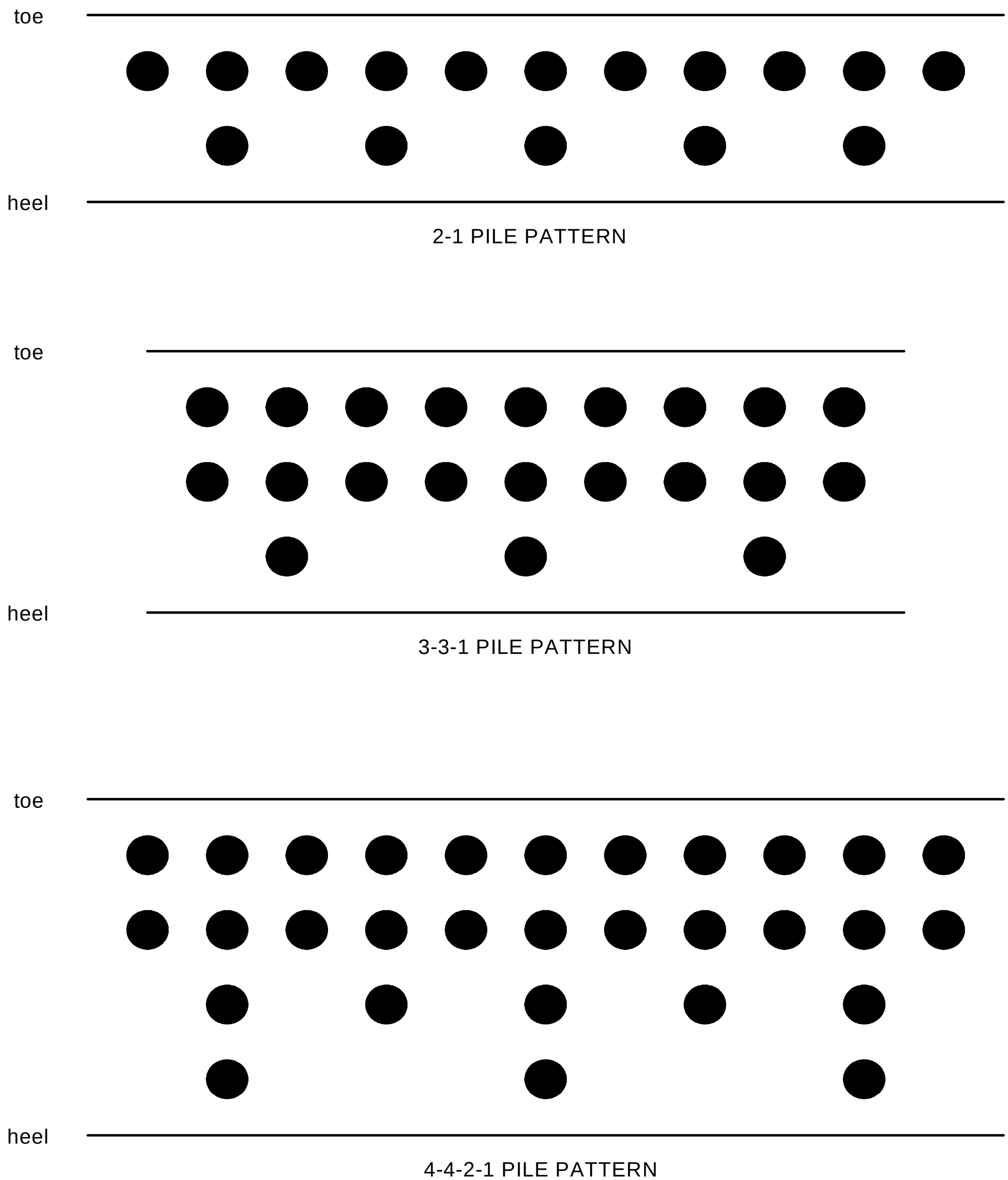


Figure 3.5.3 Pile Pattern Configurations

For an analysis problem, the program performs Steps 1, 2, 5 and 7. In Step 5, the lateral resistance is computed based on the entered pile pattern. If all entered piles are vertical, the lateral resistance is computed by multiplying the LATERAL PILE CAPAC with the number of piles. If the entered pile pattern consists of vertical and battered piles, the lateral resistance is computed by adding the horizontal component of axial pile capacity of all battered piles. As an option, the program computes the lateral resistance of battered piles by adding the horizontal components of pile loads (axial) of all battered piles.

- Step 8. If this is the first acceptable design, it is saved. Otherwise, this design is compared against the previously saved design, and the better design is saved. When comparing designs, the program generally saves the design with the lesser pile density. For designs with the same pile density, the program will save the one that has the smaller footing cross sectional area. The order of these comparisons can optionally be reversed by invoking an input option (PILE OPT = "F"), i.e., the program would optimize on footing cross sectional area first and pile density second. Another option (PILE OPT = "C") provides a cost analysis based on the user supplied cost per pile and cost per cubic yard of footing. When the cost comparison option is selected, the least expensive design is saved. Additionally, if the two designs have the same pile density and the same cross sectional area, the design with the larger toe projection is saved minimizing structure backfill. The program returns to Step 3 to try to find a better design.

- Step 9. All pattern arrangements have been tried for this footing. The footing thickness is increased by 3 inches. If the footing thickness does not exceed 4 feet, the program loops back to Step 1. If the footing thickness becomes greater than 4 feet, the program continues with Step 10.

- Step 10. The footing thickness is set back to the user defined minimum or 2.5 feet. The toe projection is increased by 3 inches. If a maximum toe projection was entered and the new toe projection exceeds the maximum; or the new toe projection exceeds one half the footing width; or the heel projection becomes less than the minimum (1 foot), then the program continues with Step 11. Otherwise, the program loops back to Step 1.

- Step 11. The toe projection is set back to the minimum of 1 foot. The footing width is increased by 3 inches. If a maximum value was specified for the heel projection and this value is exceeded, the heel projection is set equal to the maximum and the toe projection increased accordingly. If the maximum footing width is exceeded or if the footing width is more than 3.5 feet wider than the narrowest footing for which an acceptable design was found, the program goes on to Step 12. Otherwise the program loops back to Step 1.

- Step 12. If an acceptable design was found, the results are printed out. Otherwise, the program terminates and an appropriate message is printed out.

3.5.1 Lateral Resistance of Pile Group

The lateral resistance of a pile group is calculated based on the type of problem (Analysis or Design) and the method used. It is also based on the axial and lateral capacities of the pile entered by the user. For an analysis problem, there are two methods allowed, the method described below for a design problem and the 80% Rule. For an analysis problem, the program as a default calculates the lateral resistance as described below for a design problem. For a design problem, the 80% Rule option is not available.

For a design problem, the program assumes that if the pile group consists of all vertical piles, the lateral resistance is provided by bending (allowable deflection) of vertical piles. If the pile group consists of vertical and battered piles, the program assumes that: all of the applied horizontal force is resisted by the axial forces in the battered piles; the axial force in the battered pile can reach up to its axial capacity; and the vertical piles in the group do not provide any resistance to the applied horizontal force. For a design problem, if the pile group consists of all vertical piles, the lateral resistance is calculated by multiplying the number of vertical piles with the lateral pile capacity entered by the user. For a design problem, if the pile group consists of vertical and battered piles, the lateral resistance is calculated by multiplying the horizontal component of the axial pile capacity entered by the user with the number of battered piles in the group.

For an analysis problem, if the user specifies the 80% Rule, the lateral resistance is assumed to be provided by the horizontal components of the actual axial loads in the battered piles and the bending (allowable deflection) of vertical piles. For this method, the total lateral resistance provided by battering of piles and bending of vertical piles must be greater than the applied horizontal force. In addition, at least 80% of the applied horizontal force should be resisted by the horizontal components of the actual axial loads in the battered piles. The program calculates and prints the percentage of applied horizontal force resisted by the battered piles for each Group Loading.

The following example illustrates the calculation of lateral resistance for three cases. Assume that the pile group (10 feet long footing) consists of two rows of piles with piles spaced at 5 feet in the front row and piles spaced at 10 feet in the rear row. The axial capacity of the pile is 140 kips and the lateral capacity of the pile is 3 tons (6 kips). For a given lateral force (63 kips) applied to the pile group, the axial load in the front row pile is 77 kips and in the rear row pile is 54 kips. The pile batter is 3 on 12, i.e. the angle β made by the axis of the battered pile with the horizontal is 75.96 degrees.

<u>Case 1</u>: All piles are vertical.

Lateral Resistance of Pile Group = (No of Vertical Piles) (Lateral Pile Capacity)

= (3)(6) = 18 kips (Not enough)

Case 2: Front row of piles are battered, rear row piles are vertical.

Lateral Resistance of Pile Group = (No of battered Piles) (cos β) (Axial Pile Capacity)

= (2)(0.243)(140) = 67.91 kips (OK)

Case 3: Same as Case 2, but use the 80% Rule.

Lateral Resistance of Pile Group = Resistance by Battered Piles

+ Resistance by Vertical Piles

= (No of Battered Piles) (cos β)(Front Pile Load)

+ (No of Vertical Piles) (Lateral Pile Capacity)

= (2)(0.243)(77) + (1)(6)

= 37.35 + 6

= 43.35 kips < 63 kips (Not Good)

Percent Resistance by Battered Piles = (Resistance by Battered Piles/Applied Force)(100)

= (37.35/63)(100)

= 59.29% < 80 % (Not Good)

3.6 PEDESTAL FOOTING

A pedestal footing is analyzed or designed in the same manner as a spread footing with some exceptions in the design criteria for the footing and the design of the pedestal itself. For an analysis or a design of the footing, refer to the method of solution of a spread footing. Exceptions include computations of ratio of the vertical loads to the horizontal loads and the pressure on pedestals under the footing. In addition, the footing is assumed as a continuous beam spanning over the clear spacing of pedestals. For critical sections in the footing, refer to page 3-21.

For an analysis problem, the factor of safety against overturning about the toe of the pedestal, the ratio of the vertical load to the horizontal load and the soil pressure at the base of the pedestal are computed and printed out. For a design problem, the pedestal is designed for the thickness and the width. Pedestal spacing (clear) and pedestal height are specified by the user.

First, the maximum pressure on the pedestal under the footing is checked. Pedestal thickness is increased by one inch until the pressure on the pedestal becomes less than the allowable. Next, the program starts with an offset of the pedestal at the back (heel) equal to the footing thickness and an offset of the pedestal at the front (toe) equal to 1 foot and checks the factor of safety against overturning of the substructure about the toe of the pedestal and the soil pressure under the pedestal. If it is not safe against overturning or the soil pressure under the pedestal is excessive, first the pedestal width is incremented by decreasing the back offset until both the conditions (safe against overturning and soil pressure under pedestal less than allowable) are satisfied or the back offset becomes 1 foot. If the substructure is not safe against overturning or the soil pressure under the pedestal is still excessive, the pedestal width is incremented by moving the toe of the pedestal forward but keeping the back offset and front offset of the pedestal at the footing level equal to 1 foot. The pedestal width is incremented by three inches every time until the factor of safety against overturning becomes equal to or more than the minimum factor of safety and the soil pressure under the pedestal becomes less than or equal to the allowable soil pressure.

The shear stress and the flexural reinforcement in the footing are computed next. For this, the total vertical load acting on the structure is assumed to act uniformly distributed over the width of the footing. If the shear stress exceeds the allowable or if the thickness required for flexure is more than the thickness provided, the footing thickness is increased by 3 inches and the whole process beginning with the STABILITY ANALYSIS is repeated. Refer to DESIGN OF SECTION on page 3-24 for the method used for designing critical sections in the footing.

3.7 STEM REINFORCEMENT DESIGN

The geometry of the stem is defined by the user and it is not changed by the program both for the analysis as well as design problems. The stem is designed for reinforcement required at sections shown in Figure 3.8.1 on page 3-5.

For a given section, the vertical and horizontal loads (See APPLICATION OF LOADS on page 3-2) acting on the section are determined and the moments, shears and axial forces are computed for different AASHTO Group Loadings by using appropriate gamma and beta factors according to the method of design specified.

If Load Factor Design is specified, two sets of factored moments and axial forces are computed: one based on $\beta_D = 0.75$ and the other based on $\beta_D = 1.0$. Four critical sets of moment and axial force are chosen as described in AASHTO Group Loadings on page 3-6.

The section is then designed for reinforcement required for combined axial force and bending moment, and checked for shear. Refer to DESIGN OF SECTION on page 3-24 for the method used for designing critical sections in the stem. In calculating the moment due to a vertical load acting at the bearing line of an abutment, an eccentricity of 2 inches in either direction is considered to compensate for incidental field adjustment in the location of bearings. In addition, the moment due to forces such as wind, temperature change, etc., which can act in both directions, are either added or subtracted to get the appropriate net moment for a given combination.

3.8 FOOTING REINFORCEMENT DESIGN

The size of the footing to satisfy the stability, foundation pressure, pile pattern, etc. is determined as explained in the earlier sections. Once the overall size of the footing is determined, then the program designs the critical sections for reinforcement. The locations of critical sections checked for bending and shear are shown in Figure 3.8.1 on page 3-5. Note that the critical sections for shear in the footing are taken at the face of the stem when there is tension in the top of the footing. The critical sections for hear in the footing are taken at a distance “d” from the face of the stem when there is compression in the top of the footing. The distance “d” is the effective depth of the section under consideration. The critical section for bending in the footing on pedestals is taken at the face of the pedestal for negative moment (one that causes tension on the top of the footing) and at the center of pedestal spacing for positive moment (one that causes tension on the bottom of the footing).

The longitudinal reinforcement in a footing on piles is computed assuming the footing acting as a continuous slab spanning over the piles. The maximum bending moment is computed based on $WL^2/10$, where W is the uniform load equal to the total vertical load divided by the footing area and L is the center to center spacing of piles. The longitudinal reinforcement is computed for each pile row using the pile spacing in that row and assuming that only 50% bending occurs in the longitudinal direction. The maximum reinforcement required for any pile row is used as the longitudinal reinforcement.

The longitudinal reinforcement in a footing on pedestals is computed assuming the footing acting as a continuous beam spanning over the pedestals. The maximum bending moment in a section over the pedestal is computed based on $WL^2/10$, where W is the uniform load equal to the total vertical load divided by the footing area and L is the clear spacing between pedestals. The maximum bending moment between the pedestals is computed based on $3WL^2/40$.

The longitudinal reinforcement is not computed for a spread footing.

The transverse reinforcement in a spread footing or a footing on piles is computed assuming the footing acting as a cantilever fixed at the stem. For computation of moments and shears in the footing, the pile load is assumed to be a uniformly distributed line load over the pile spacing in that row.

For a footing on pedestals, the bending in the transverse direction is not considered, and therefore, the transverse reinforcement is not computed.

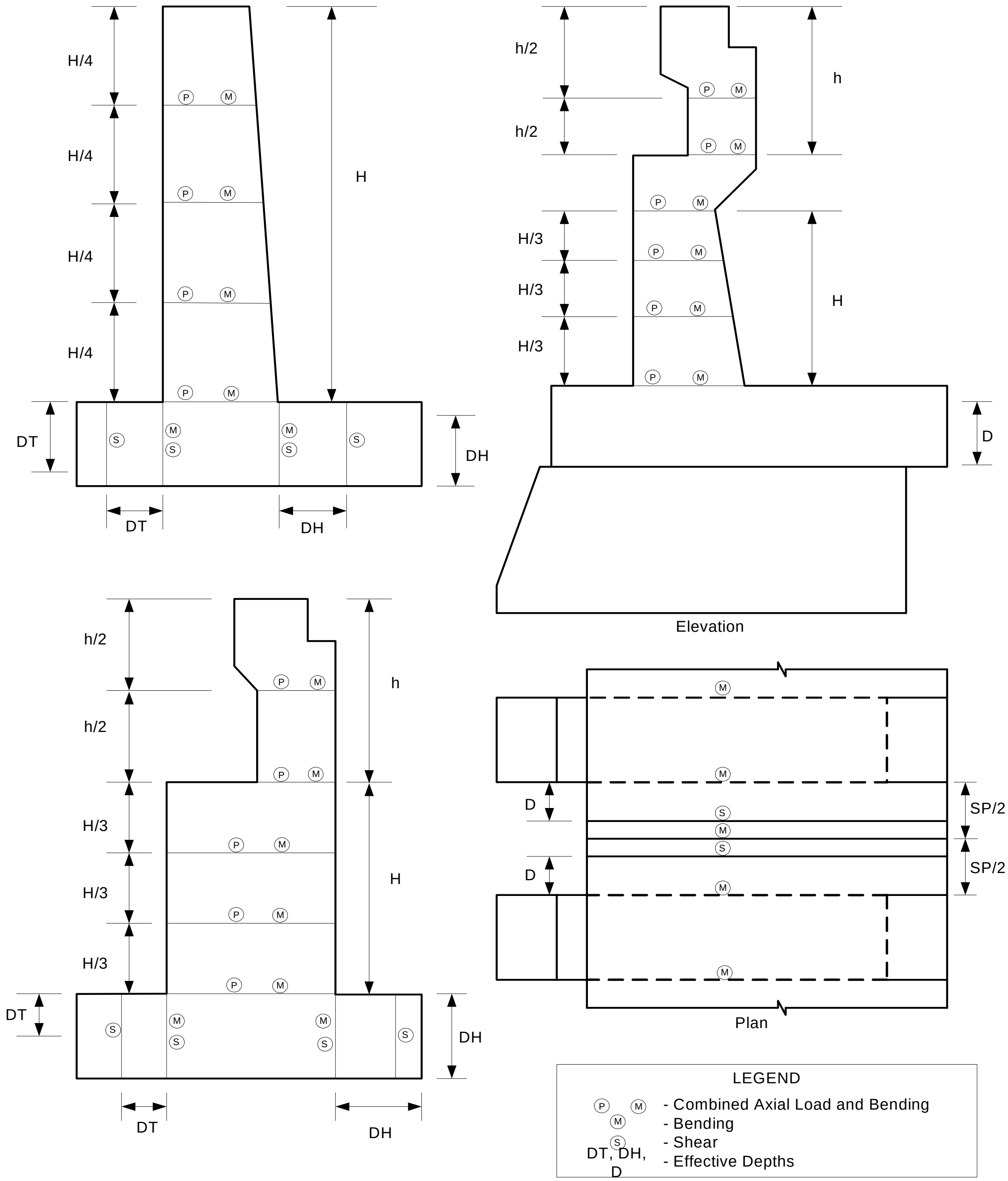


Figure 3.8.1 Critical Sections

3.9 DESIGN OF SECTION

A section in the stem is designed for reinforcement required to resist the combined axial force and bending moment and then checked for shear. The critical section for moment in the footing is designed for reinforcement required to resist the bending moment only. The critical section for shear in the slab is also checked. The method used for computing flexural reinforcement and checking shear depends on the method of design specified.

3.9.1 Load Factor Design

For this method, a section is first designed for bending only as a singly reinforced beam and then if axial force exists, it is checked for combined axial force and bending, neglecting compression reinforcement.

First, out of all factored moments, the maximum factored moment, M_f, is determined. Then the area of reinforcement required, A_s, is computed solving the following quadratic equation:

$$\frac{\phi f_y^2}{1.7 f_c' \, b} A_s^2 - \phi \, f_y \; d \; A_s + M_f = 0$$

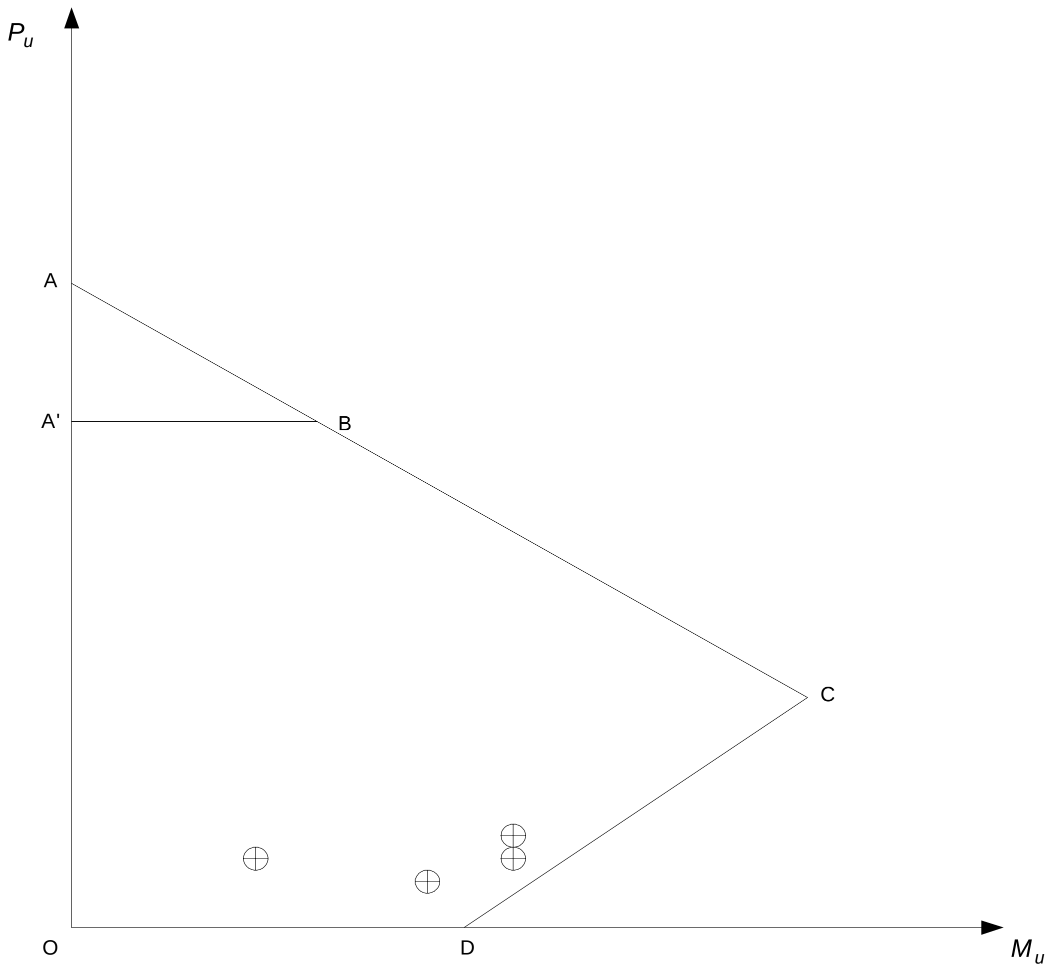
This is the same equation given in AASHTO Article 8.16.3.2.1 with M_f is substituted for ϕM_n.

A_s obtained from solving this equation is the area of reinforcement required by analysis, say $A_s(req)$.

If the section is subject to combined axial force and bending moment, a strength curve (load moment interaction) for the section is constructed as shown in Figure 3.9.1 on page 3-5. The key points of the strength curve are computed in accordance with AASHTO Article 8.16.4. The factored loads are then checked against corresponding strengths.

If any of the factored loads falls outside the strength curve, then A_s is increased by 0.01 in^2 and another strength curve is constructed. Each load is checked against corresponding strength and the whole procedure is repeated until A_s provided is such that all load points fall within the strength curve.

If all factored loads are within the strength curve, then A_s is decreased by 0.01 in^2 and another strength curve is constructed. Each load is checked against corresponding strength and the whole procedure is repeated until A_s provided is such that at least one point falls on or very near the curve and all other load points are still within the strength curve. The A_s obtained from this process becomes the area of reinforcement required by analysis, $A_s(req)$.



O	- Origin
A	- Pure Compression P_o
A'	- $0.80P_o$
B	- Horizontal line thru A'
C	- Balanced M_b and P_b
D	- Pure Flexure M_o
⊕	- Factored Loads

Figure 3.9.1 Strength Curve

Next, the minimum reinforcement requirement is checked. For this, the cracking moment, M_{cr}, and the ultimate moment, ϕM_n, are computed for a section provided with A_s from the following equations:

$$M_{cr} = \frac{f_r\ I}{y_b}$$

$$\phi\ M_n = \phi\ A_s\ f_y \left[d - \frac{A_2\ f_y}{1.70\ f_c'\ b} \right]$$

Where I is the moment of inertia of the section, $f_r = 7.5\sqrt{f_c'}$ and y_b is the distance of NA from the extreme fiber in tension. This calculation for ultimate moment ϕM_n assumes no axial force.

If ϕM_n is greater than $1.2M_{cr}$, then A_s provided satisfies the minimum reinforcement requirement. If ϕM_n is less than $1.2M_{cr}$, then A_s is incremented by 0.01 in^2 until ϕM_n becomes greater than $1.2M_{cr}$ or A_s provided is greater than $1.33A_s(req)$ whichever occurs first.

Next the ultimate shear capacity without shear reinforcement is computed by:

$$\phi\ V_c = \phi\ \left(2\sqrt{f_c'}\right) b_w\ d$$

If ϕV_c is less than the maximum factored shear, V_u, a message is printed out.

3.9.2 Service Load Design

For this method, the service moment, M, and the service axial load, N, are converted into an equivalent moment, N_e about the c.g. of reinforcement by the following formula:

$$N_e = M + N(t/2 - c)$$

Where: t = total depth of section

c = cover, c.g. of reinforcement to outer face.

First it is determined whether the section under consideration is under-reinforced (equivalent moment N_e is less than balanced moment) or over-reinforced (equivalent moment is greater than balanced moment).

The depth of neutral axis, X, for an under-reinforced section is computed solving the cub equation:

$$\frac{f_{sa}b}{6n}x^2 - \frac{f_{sa}bd}{2n}x^2 - N_e x + N_e d = 0$$

Where, f_{sa} is the allowable tensile stress in steel, b is the width of the section, n is the modular ratio and d is the effective depth of the section.

The depth of neutral axis for an over-reinforced section is computed solving the quadratic equation:

$$\frac{f_{ca}b}{6}x^2 - \frac{f_{ca}bd}{2}x + N_e = 0$$

Where, f_{ca} is the allowable compressive stress in the concrete.

The area of flexural reinforcement, A_s, is then determined from:

$$A_s = \frac{N_e}{f_s j d} - \frac{N}{f_s}$$

Where:
$$k = x/d$$
$$j = 1 - k/3$$
$$f_s = actual\ steel\ stress$$
$$= f_{sa}\ if\ under-reinforced\ section\ equation\ is\ used$$
$$= \frac{f_{ca}(1-k)n}{k}\ if\ over-reinforced\ section\ equation\ is\ used$$

For each section, A_s is computed for all load groups and the maximum A_s is determined. The A_s obtained from this process becomes the area of reinforcement required by analysis, $A_s(req)$.

Next, the minimum reinforcement requirement is checked. For this, the cracking moment, M_{cr}, and the moment strength, ϕM_n, are computed for a section provided with A_s from the following equations:

$$M_{cr} = \frac{f_r I}{y_b}$$

$$\phi M_n = \phi A_s f_y \left[d - \frac{A_s f_y}{1.70 f_c' b} \right]$$

Where, I is the moment of inertia of the section, $f_r = 7.5\sqrt{f'_c}$ and y_b is the distance of NA from the extreme fiber in tension. This calculation for moment strength ϕM_n assumes no axial force.

If ϕM_n is greater than $1.2M_{cr}$, then A_s provided satisfies the minimum reinforcement requirement. If ϕM_n is less than $1.2M_{cr}$, then A_s is incremented by 0.01 in^2 until ϕM_n becomes greater than $1.2M_{cr}$ or A_s provided is greater than $1.33A_s(req)$ whichever occurs first.

3.9.3 Reinforcement Design Optimization

Once the area of reinforcement required at a section is determined, the program tries to determine the optimum bar size and spacing based on the following procedure:

Given the five trial spacings input by the user, the program determines the necessary bar sizes considering both required area of reinforcement and serviceability criteria for crack control as per AASHTO 8.16.8. Each spacing and corresponding bar size is examined and rated on the following criteria:

1. Designs using large rebar sizes or inconvenient small spacings are penalized.

2. Designs that use less steel are favored.

3. Designs using larger spacings for ease of construction are favored.

The designs are then sorted according to minimum penalty and all five designs are listed in the output from most desirable to least optimal.

In the back face of the stem, one cutoff is utilized, providing two separate designs for vertical reinforcement.

3.10 CONSTANTS, ASSUMPTIONS AND LIMITATIONS

Certain assumptions, limitations and constants used in the program are listed here for reference. For details on specifications, refer to the AASHTO Specifications and DM4.

1) One-foot length of the substructure is considered for both analysis and design.

2) For Load Factor Design the stability check is done using service loads.

3) Any fill over the toe projection is disregarded.

4) The horizontal and vertical components of the earth pressure for a sloping backfill are either defined by the user or calculated by the program using the curves given in DM4 Figure 5.5.2E. The program assumes Soil Type 1.

5) The weight and pressure from water on the toe are considered. The uplift force due to buoyancy is applied at the base of the footing for a spread footing on soil and for footings on piles and pedestals. The uplift force due to buoyancy on a spread footing on rock is neglected.

6) Modular ratio, n, is computed as per AASHTO Article 8.15.3.4. For the calculation of n, E_s is assumed as 29,000,000 psi and E_c is calculated by $E_c = (145)^{1.5}(33)\sqrt{f'_c}$. Where f'_c is the specified compressive strength of concrete in psi.

7) The program does not check punching shear for a footing on piles.

8) For the computation of an effective depth of a section, a #8 bar is assumed.

9) The minimum reinforcement spacing is 6 inches. Maximum spacing is 18 inches.

10) The minimum reinforcement size is #5 bar in the footing and #4 bar in the stem.

11) A 2-inch cover is considered for serviceability. Any additional cover is considered sacrificial. The allowable stresses for serviceability will not be less than the allowable stresses for Service Load Design.

12) The soil bearing pressure and axial pile load for seismic loading (AASHTO Group VII) are checked by comparing the actual soil pressure and axial pile load to the ultimate soil bearing and axial pile capacities divided by a factor of 1.3. The ultimate capacity is defined as 3.0 times the allowables entered as input. This is equivalent to allowing an overstress of 230.769% for AASHTO Group VII Service Load Design.

13) For the temporary loading condition, the axial pile capacity or the allowable bearing pressure for spread footings on rock will always be increased by the overstress percentage factor of 1.25 regardless of the input indicator OVRSTR.

14) For a retaining wall, the live load surcharge will begin at the back face of the wall for all ground configurations behind the wall as stated in DM4.

15) For compliance with the seismic loading condition, the top reinforcement in footings will not be less than 50% of the area of bottom reinforcement or #5 bars @ 12 inches in both the transverse and longitudinal directions.

16) Shear capacity of the stem is based on monolithic construction. If a shear key is provided, the shear capacity of the key should be investigated by the designer.

17) When computing the thicknesses of the backwall design sections for Abutment Type II, the following assumptions are made concerning the backwall dimensions: (BW1 + BW2) > (H2 + H3 + H4); and (H3 + H4) < (H2 + H3 + H4)/2 (refer to Figure 5.2.2). A warning message is printed if either of these conditions is violated.

18) During the footing design process, a 2% allowance is used when checking actual soil pressures under spread footings and under pedestals against the input allowable soil pressure. If overstress factors are used (OVRSTR = Y), the 2% allowance is not applied.

4 GETTING STARTED

4.1 INSTALLATION

This program is delivered on a CD, which contains the installation program (Setup.exe), compressed program files, installation and operation instructions (GettingStarted.pdf), and the license agreement (LicenseAgreement.pdf). Running Setup.exe installs the executable program (BSP.exe), example problem input files (*.DAT), and the BSP User's Manual (BSPUsersManual.pdf). The program runs as a 32-bit application and is supported on Windows 9x, NT, 2000 and XP operating systems.

The original delivery CD should be stored in a safe place. The label on the front of the CD case insert contains useful information, which may be required by PENNDOT for requesting future versions of the program, i.e., enhancements, modifications, or error corrections. A backup copy of the original CD should be made and used for installation and running the program. You may want to print the software license agreement, record the license number in the space provided for Agreement Number, and keep it in a safe place along with your CD.

Refer to the installation instructions provided on the CD cover and in GettingStarted.pdf when running Setup.exe.

The following files should be installed in the destination folder:

1. ABUT5.exe – Executable program (FORTRAN console application).
2. ABUT5UsersManual.pdf – Program User's Manual (PDF Format).
3. ABUT5RevisionRequestForm.dot – Revision Request form (MS WORD template).
4. *.dat – Example problem input file.

4.2 PREPARING INPUT

The program requires an ASCII input file. The input file consists of a series of data lines. Each data line consists of a number of fixed length data fields. The data entered in the data files is read by the program using a fixed format (i.e., data type, location of decimal point). For numerical data, the format can be overridden by entering a decimal point as part of the data field. Otherwise, the decimal point is inserted at the appropriate location when the data is read. Chapter 5 of the User's Manual includes descriptions of the input and input forms to facilitate data preparation. 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 ENGINEERING ASSISTANT

ABUT5 is a FORTRAN console application program. It 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 Program\PennDOT, or by double-clicking the shortcut icon on the desktop. To run the program n a command window, the user must specify the directory in which the program has been installed or change to the directory.

The program will first 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. Next, 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 gives the option of overwriting the existing file or entering a new output file output file name. If no output file name is entered, a default output file will be used. The program will then execute.

To cancel the program during execution, press <Ctrl C> or <Ctrl Break>.

When the program execution is completed, the output will be displayed on the screen if the user requested it. To cancel this review, enter "Q" to quit.

The user can view the output file from within EngAsst or using a text editor.

5 INPUT DATA REQUIREMENTS

5.1 GENERAL

Input Forms 1 and 2 (Figure 5.1.1 and Figure 5.1.2 respectively) have been prepared to facilitate data preparation for execution of this program. For a given run, only one problem may be processed. To facilitate data preparation, refer to Figure 5.2.1 thru Figure 5.2.5 and example problems given in this manual. All dimensions and distances are in feet except as noted. All loads are in kips.

Any number of PROBLEM IDENTIFICATION lines may be entered of which the program will print the first three lines on the output. CRITERIA and DIMENSIONS data must be entered. REBAR DESIGN data is optional and should only be entered when REBAR DES = “Y” on the CRITERIA data. SEISMIC LOADING CONDITION and LOADING data must be entered for all problems. If LOADING is not applicable for a given problem, a blank line should be entered. The blank LOADING data line may be omitted if it is the last line of input. PEDESTAL DIMENSIONS and PILE PATTERN are optional depending on the type of problem.

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Form 1 of 2

ABUT5
ABUTMENT AND RETAINING WALL

	PROJECT IDENTIFICATION
1	2
#	
#	
#	

CRITERIA

DESIGN METHOD	A OR D	TYPE	FTG TYPE	PILE D	EMBEDDED	PILE ROWS	R OR S	EQUIV FLUID PRESSURE DRY	EQUIV FLUID PRESSURE SAT	COEFF OF FRICTION	BACKFILL SLOPE	ALLOW SOIL PRESS OR AXIAL PILE CAPAC	WATER LEVEL BACK	TOP FTG TO TOP EMBANK	WATER LEVEL FRONT	TOP WALL TO TOP BACKFILL	LIVE LOAD SURCH	TOP FTG TO ROCK SURFACE	F'C BACK WALL	F'C STEM	F'C FTG	REBAR GRADE	PILE BATTER	PILE OPT	LATERAL PILE CAPAC	K v	REBAR DES	OVTSTR	80% RULE	PILE ROW OPT
1	3	4	5	6	9	10	11	12	15	18	20	23	28	32	36	40	44	48	53	57	61	65	67	69	70	73	76	77	78	79

DIMENSIONS

TOP OF (BACK) WALL TO TOP OF FOOTING	TOP THICKNESS	PROJECTION TOE	PROJECTION HEEL	MAX PROJ T OR H	MAX PROJ TOE OR HEEL	MAX FTG WIDTH	H1	H2	H3	H4	W 1	W 2	W 3	BW1	BW 2	FRONT FACE TO DL REACT	BRIDGE SEAT WIDTH	HEIGHT OF BACKWALL BATTER	BACK BATTER	FOOTING THICKNESS	PILE COST	FTG COST
1	5	8	12	16	17	21	25	28	32	35	39	42	45	48	52	56	60	64	68	70	73	77

REBAR DESIGN

TRIAL REBAR SPACING 1	2	3	4	5	BAR LOC	BW EXPOS	STEM EXPOS	FTG EXPOS	MIN As	STEM REBAR COVER BACK VERT	STEM REBAR COVER BACK HORIZ	STEM REBAR COVER FRONT VERT	STEM REBAR COVER FRONT HORIZ	FOOTING REBAR COVER TOP LONG	FOOTING REBAR COVER TOP TRANS	FOOTING REBAR COVER BOTTOM LONG	FOOTING REBAR COVER BOTTOM TRANS
1	3	5	7	9	11	12	13	14	15	19	23	27	31	35	39	43	47

NOTE: REBAR DESIGN DATA IS OPTIONAL. ENTER ONLY WHEN REBAR DES = Y.

PREPARED BY..

DATE ..../........../..........

SHEET ...... OF ......

Figure 5.1.1 Input Form 1 of 2

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
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Form 2 of 2

ABUT5
ABUTMENT AND RETAINING WALL

LOADING

DL REACT	LL REACT	WIND ON LL	WIND ON SUPER	WIND ON SUB	UPWARD WIND	LONG FORCE FROM L L	CENTER FORCE	TEMP FORCE	PARAPET OR EXTERNAL				BACKWALL LIVE LOAD		SEISMIC LOAD	ALLOW PILE UPLIFT
									HORZ	DIST	VERT	DIST	VERT	HORZ		
1	5	9	13	17	21	25	29	33	37	41	45	49	53	57	61	65
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

PEDESTAL DIMENSIONS

SPACING	THICKNESS	TOE TO PED FRONT	HEEL TO PED BACK	PED WIDTH	FRONT HEIGHT	TOTAL HEIGHT
1	5	8	12	16	20	24
.	.	.	.	.	.	.

NOTE: PEDESTAL DIMENSIONS DATA IS OPTIONAL. ENTER ONLY WHEN FTG TYPE = 3.

PILE PATTERN

ROW NO	PILE BATTER	DISTANCE BETWEEN ROWS	PILE SPACING	PERCENT ROW BATTERED
1	3	5	10	15
	.	.	.	.
	.	.	.	.
	.	.	.	.
	.	.	.	.

NOTE: PILE PATTERN DATA IS OPTIONAL. ENTER ONLY WHEN FTG TYPE = 2 AND A OR D = A (ANALYSIS)

PREPARED BY... DATE ..../........../.......... SHEET ...... OF ......

Figure 5.1.2 Input Form 2 of 2

5.2 PROBLEM IDENTIFICATION

Any number of lines may be used to enter user comments for problem identification. The first column of each line must contain an asterisk to indicate that this is a user comment. These comment lines may be placed anywhere within the input data and the first three lines will be printed on the output for identification.

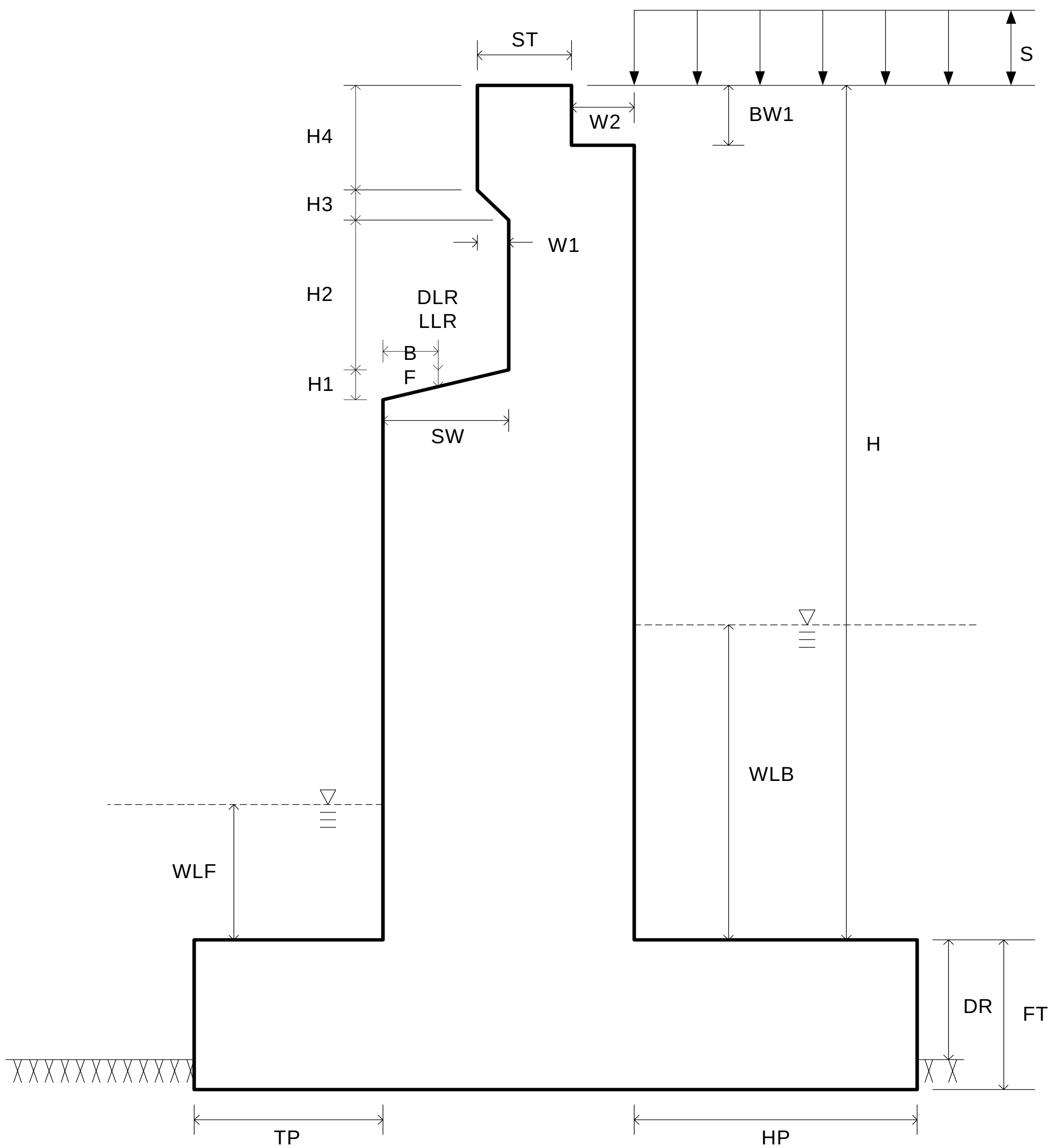
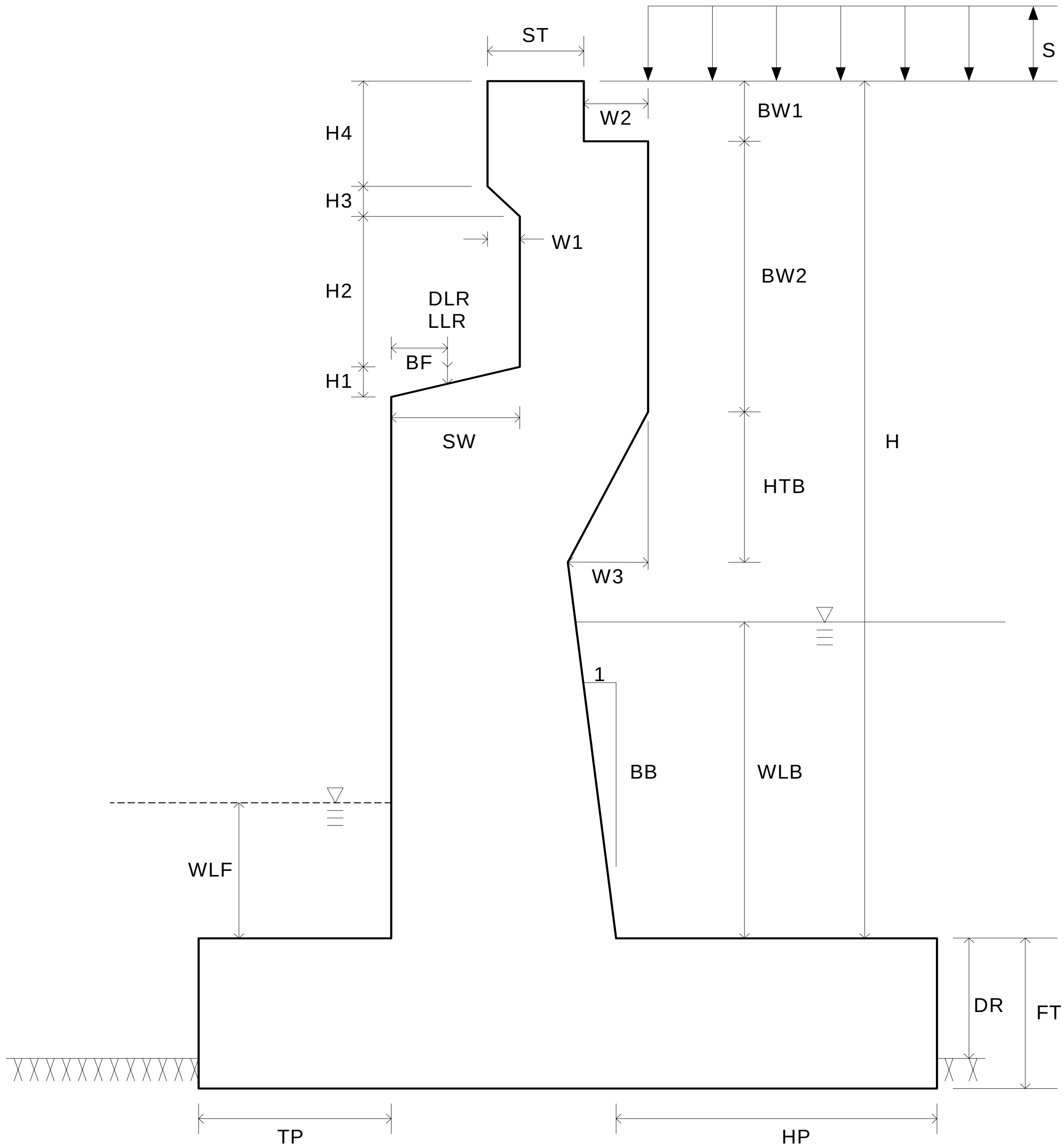


Figure 5.2.1 Input Dimensions - Abutment Type I



NOTE: The progam assumes that (BW1 + BW2) > (H2 + H3 + H4); and (H3 + H4) < (H2 + H3 + H4)/2 when computing the thicknesses of the backwall design sections.

Figure 5.2.2 Input Dimensions - Abutment Type II

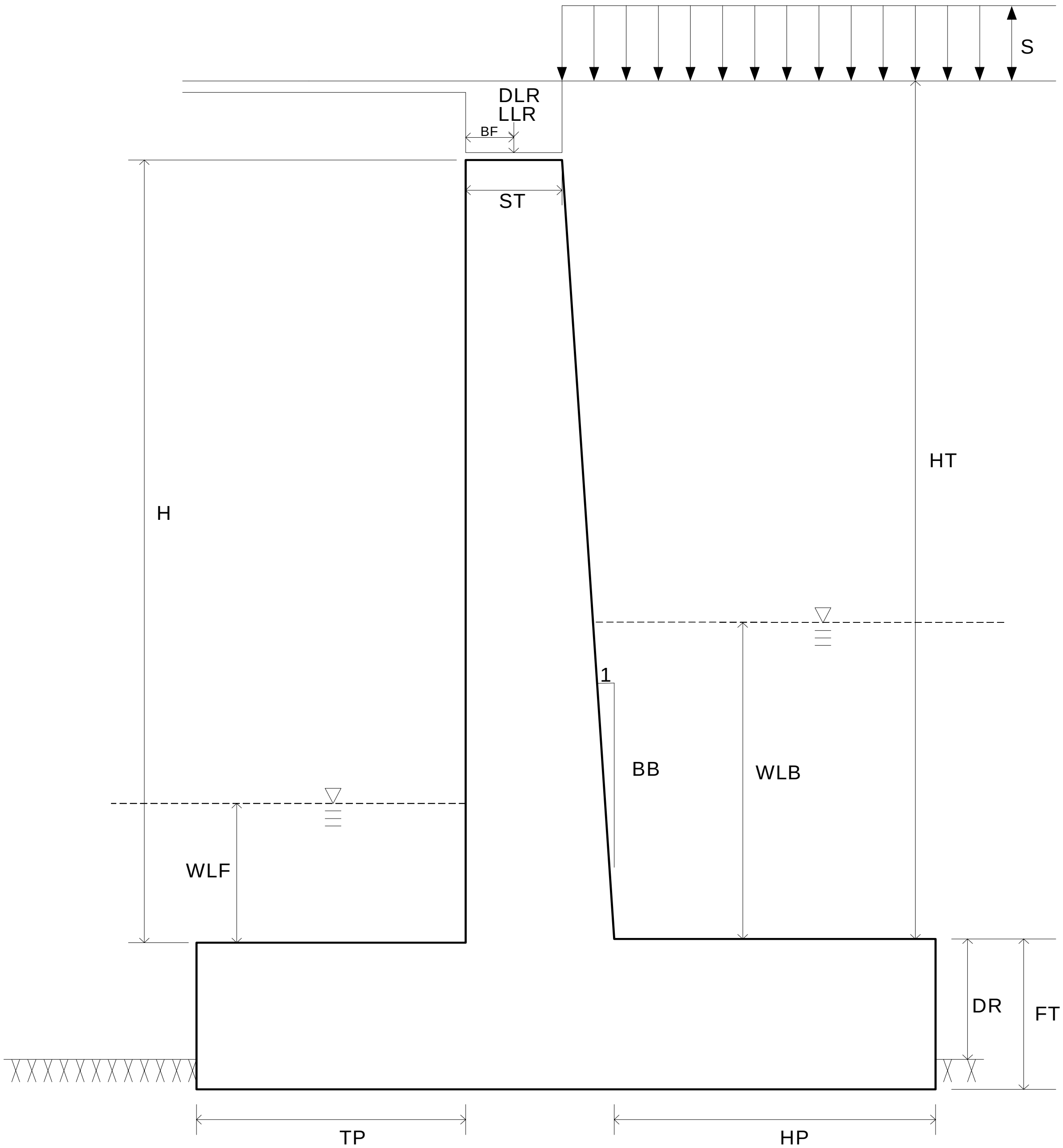


Figure 5.2.3 Input Dimensions - Abutment W/O Backwall

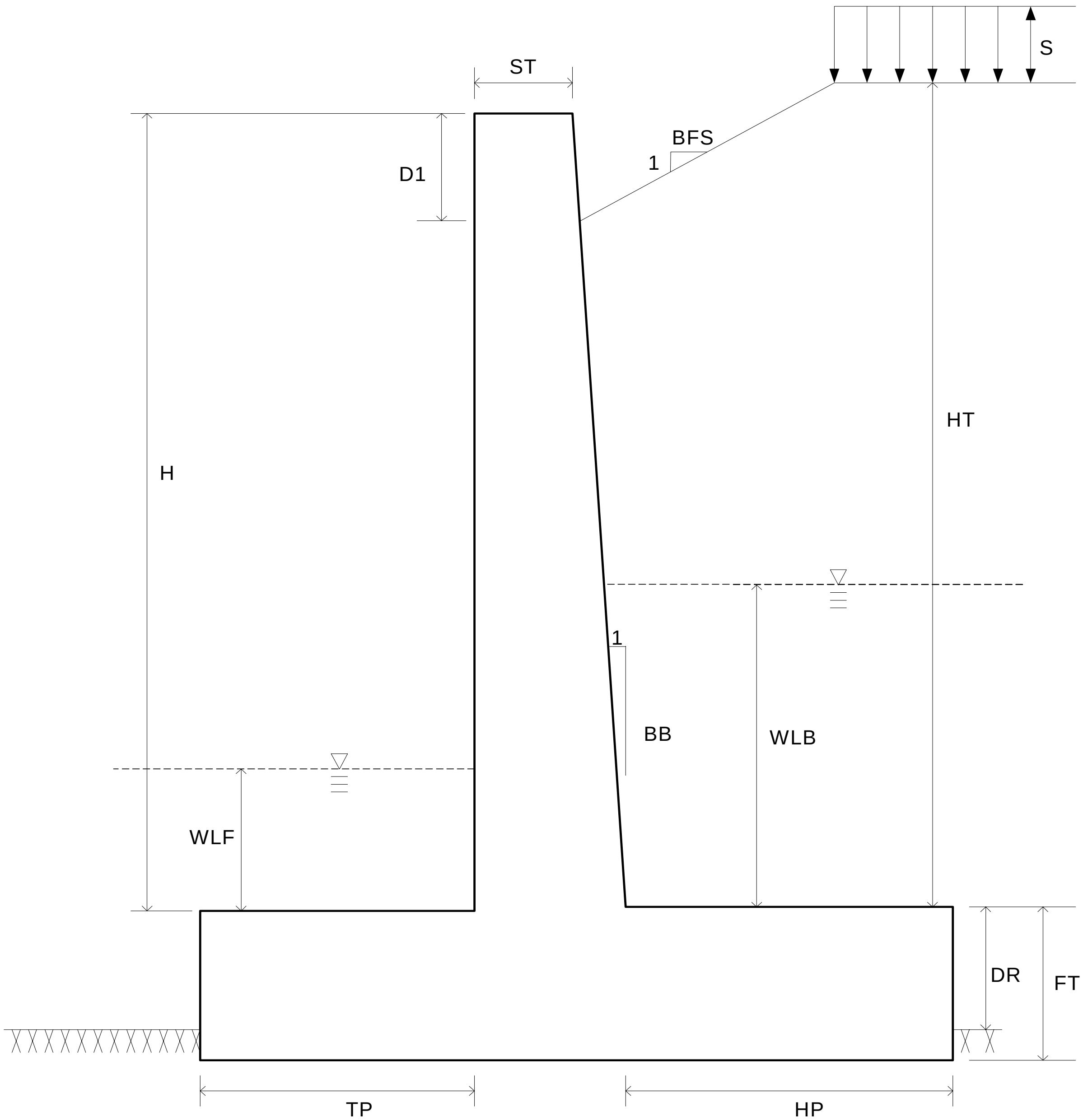


Figure 5.2.4 Input Dimensions - Retaining Wall with Level Backfill

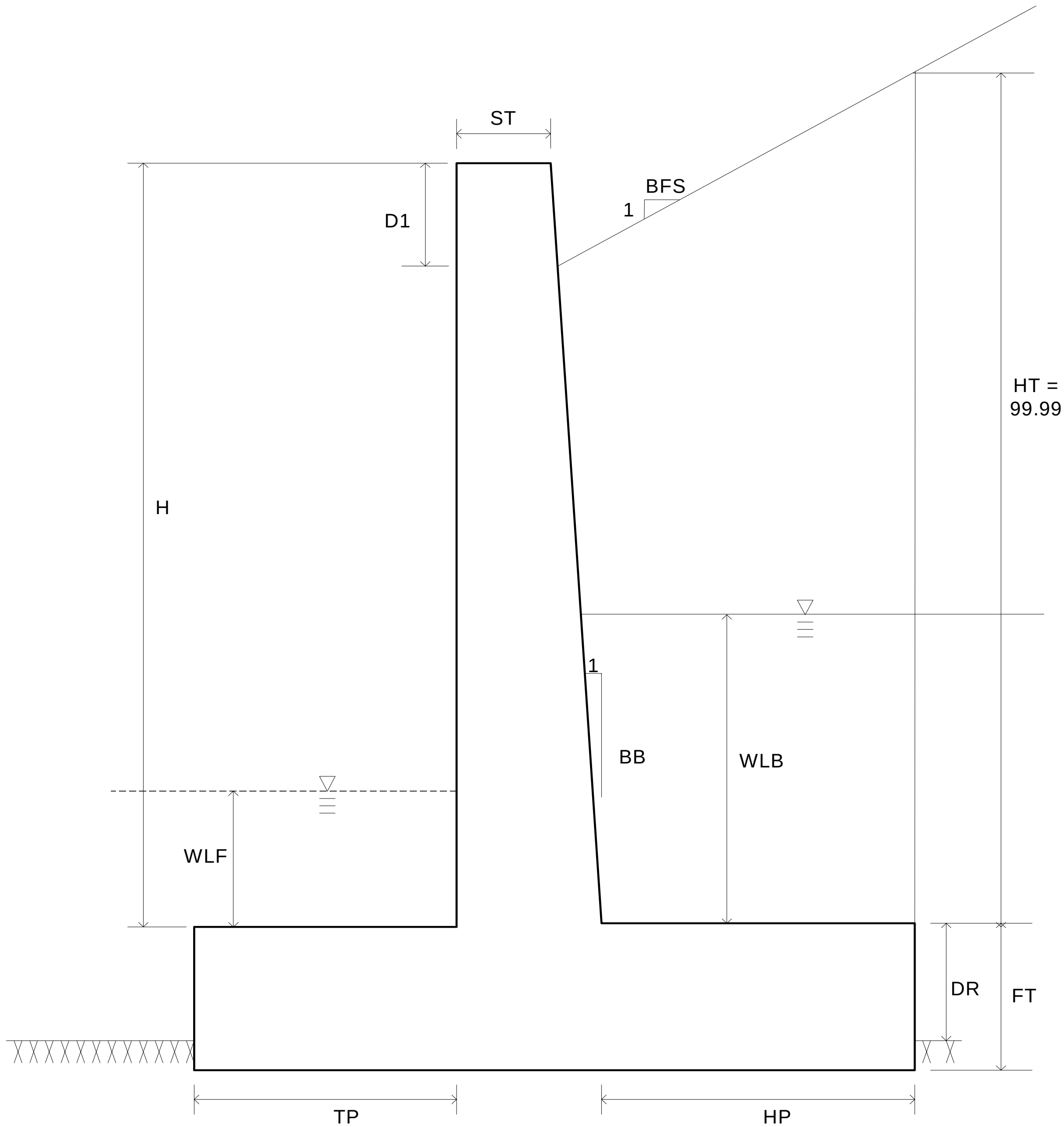


Figure 5.2.5 Input Dimensions - Retaining Wall with Continuously Sloping Backfill

5.3 CRITERIA

DESIGN METHOD

Enter LF if Load Factor Design is requested.

Enter SL if Service Load Design is requested.

A OR D

Type of problem being run. Enter “A” for an analysis problem or “D” for a design problem. Refer to the METHOD OF SOLUTION for what the program will do for a given type of problem.

TYPE

Describe the type of substructure by entering one of the following codes:

1 – Abutment Type I

2 – Abutment Type II

3 – Retaining Wall

4 – Abutment without Backwall

Refer to Figure 5.2.1 thru Figure 5.2.5 and Figure 5.3.1for various substructure types.

FTG TYPE

Enter one of the following codes to describe the type of footing:

1 – Spread Footing

2 – Pile Footing

3 – Pedestal Footing

Refer to Figure 5.3.1 on page 5-12 for types of footing.

PILE D

The diameter or depth of a pile in inches. This is the dimension of a pile parallel to the transverse directions of the substructure. Refer to Figure 5.3.1 on page 5-12 for an illustration. Enter this data only if “2” has been entered for FTG TYPE. Otherwise, leave blank. This data is used in calculating the shear at critical sections in a footing on piles in accordance with AASHTO 4.4.11.3.2.

EMBEDDED

For a design problem with a pile footing, specify whether the piles are embedded or not embedded sufficiently into the footing. Enter “Y” if the piles are embedded 12 inches or more into the footing. Enter “N” if the piles are not embedded at least 12 inches into the footing. If the piles are specified as embedded, the program will not check the factor of safety against overturning for the design.

For a design problem with a spread footing founded on rock, specify whether the toe of the footing is embedded in sound rock. Enter “Y” if embedded or “N” if not embedded. If the footing is specified as embedded, the program will not check the factor of safety against sliding for the design.

Leave blank for an analysis or a design with pedestal footing.

PILE ROWS

The number of rows of piles for an analysis problem. Enter this data only if “A” has been entered for A or D and “2” has been entered for FTG TYPE. Otherwise, leave blank.

R OR S

For a spread footing, specify whether it is founded on rock or soil. This data is used to set factors for stability analysis of the substructure. Refer to Section 3.3 for various factors of safety used by the program. This item also determines whether the allowable bearing pressure will automatically be increased by the overstress percentage factor for the temporary loading condition (See Section 3.3). Leave blank for a footing on piles or on pedestals. Enter “S” if the foundation is on soil. Enter “R” if the foundation is on rock.

EQUIV FLUID PRESSURE

The horizontal earth pressure (K_h) expressed as an equivalent fluid pressure, lbs/ft^2. Refer to DM4 Section B.5 for this value based on soil type, backfill slope and backfill height.

For a sloping backfill, the program also uses a vertical component of lateral earth pressure (K_v) entered at the end of this line of data.

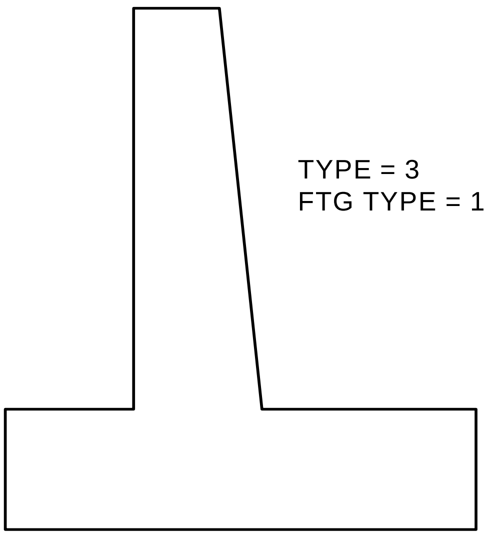
The following two value of K_h are to be entered.

DRY

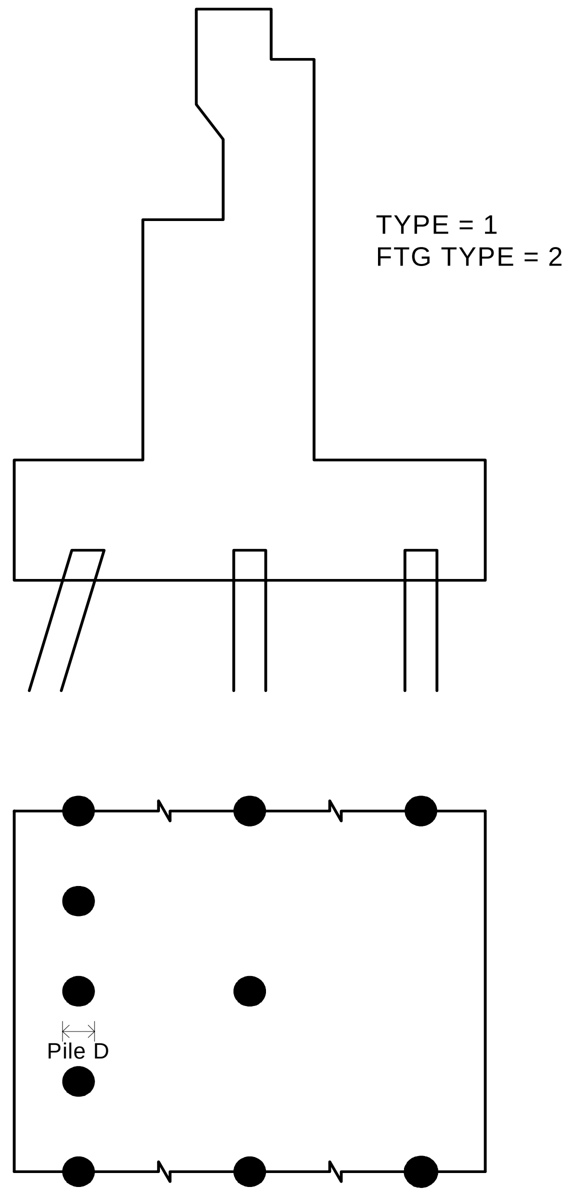
The equivalent fluid pressure for a dry soil, $K_{h(DRY)}$.

Enter this value if temporary shoring is required to retain the soil during construction. The value should be computed using the curves or tables given in DM4 Section B.5 using the type of soil behind the backfill.

If this data is not entered, the program will assume a value of 35 lbs/ft^2 for a level backfill or compute the value for a sloping backfill using the curve for Soil Type 1 given in DM4 Section B.5.

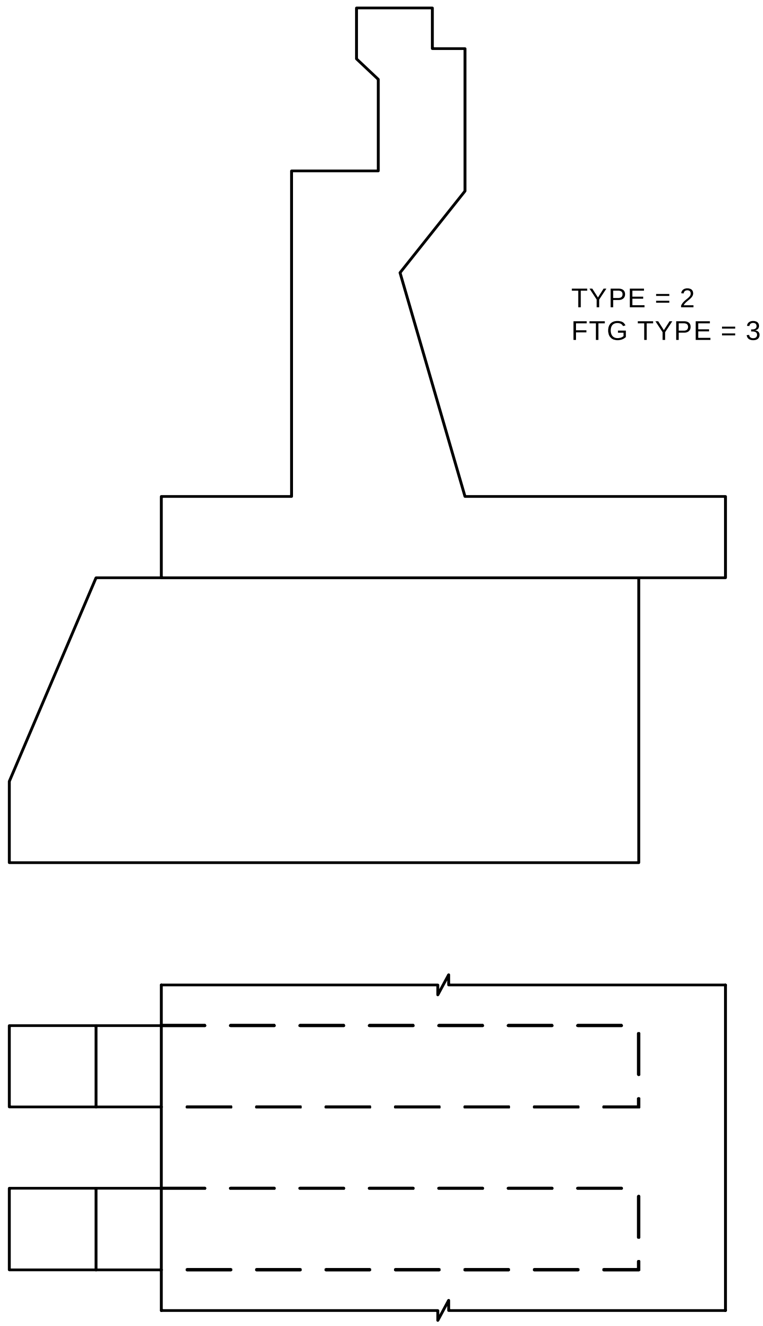


Retaining Wall on Spread Footing



Abutment Type I on Pile Footing

Figure 5.3.1 Types of Structures and Foundations



Abutment Type II on Pedestal Footing

Figure 5.3.2 Types of Structures and Foundations (cont.)

SAT

The equivalent fluid pressure for a saturated soil, $K_{h(SAT)}$.

If a value of EQUIV FLUID PRESSURE – DRY was entered, and if the value of WATER LEVEL BACK, described later, is entered greater than zero, calculate the equivalent fluid pressure for a saturated soil using the following equation:

$$K_{h(SAT)} = \frac{K_{h(DRY)}}{\gamma_{DRY}}(\gamma_{SAT} - \gamma_{WAT}) + \gamma_{WAT}$$

Where: $K_{h(DRY)} = equivalent\ fluid\ pressure\ for\ dry\ soil$

$\gamma_{DRY} = unit\ weight\ of\ dry\ soil, lbs/ft^2$

$\gamma_{SAT} = unit\ weight\ of\ saturated\ soil, lbs/ft^2$

$\gamma_{WAT} = unit\ weight\ of\ water, lbs/ft^2$

If this data is not entered, and if the value of WATER LEVEL BACK, described later, is entered greater than zero, the program will calculate the value of $K_{h(SAT)}$ using the equation given above. In calculating the value of $K_{h(SAT)}$, the program uses the value of $K_{h(DRY)}$ as input or calculated before and assumes the values of γ_{DRY} and γ_{WAT} as 120 lbs/ft^2 and 62.5 lbs/ft^2 respectively. γ_{SAT} is calculated as described in Section 3.2.1.

COEFF OF FRICTION

Enter the coefficient of friction of the foundation material. The normal range for this data varies from 0.33 for silty clay, 0.60 for gravel or sand to 0.99 for rock. Refer to the tables given in DM4 for this value based on the given type of soil.

This data must be entered for a spread footing, and is used to compute the horizontal resistance. For a pile footing or pedestal footing, leave this blank.

BACKFILL SLOPE

Enter the slope of the backfill expressed as 1' vertical to horizontal equal to this value in feet. This may generally be a case in a retaining wall. If the backfill is level, as in the case of Abutment Type I and II, and abutment without a backwall, leave this blank. This data is used for the computation of the equivalent fluid pressure for a sloping backfill shown as BFS in Figure 5.2.4 on page 5-8 and Figure 5.2.5 on page 5-9.

ALLOWABLE SOIL PRESS OR AXIAL PILE CAPAC

Enter the allowable soil pressure in kips per square foot for a spread footing or pedestal footing or the axial capacity of a pile in kips for a pile footing. Axial pile capacity must be entered for a design or analysis of a pile footing. The program uses the horizontal component of the axial pile capacity to calculate the lateral resistance of the pile group consisting of vertical and battered piles.

WATER LEVEL BACK

If the substructure is to be analyzed for a permanent water level at the back of the substructure, enter the height of water above the heel in feet shown as WLB in Figure 5.2.1 thru Figure 5.2.5. Leave blank if there is no water at the back of the substructure (dry condition). If the water level is below the top of the footing, enter a negative value. The difference between the value entered here and the value entered for WATER LEVEL FRONT cannot be greater than 3 feet. In no case should the water level be above the top of backwall batter, bottom of embankment slope, or height of stem. A realistic water level would be at the lowest weep hole or foundation drain invert elevation. This value is used to calculate the weight of saturated soil above the heel, the horizontal pressure due to saturated soil below the water level and the upward hydrostatic pressure (buoyancy effect) at the bottom of the heel. When this data is entered, the program uses the EQUIV FLUID PRES – SAT for horizontal earth pressure up to the water level. For soil above the water level, the program uses EQUIV FLUID PRES – DRY for horizontal earth pressure.

TOP FTG TO TOP EMBANK

Enter the distance from the top of footing to the top of final ground (“level” part of embankment for retaining walls) in feet. Show as HT in Figure 5.2.3 and Figure 5.2.4. If left blank, the program assumes this equal to the height of the stem including backwall. For an abutment without a backwall, this value (depth of superstructure) is usually greater than the stem height and thus must be entered. This is taken at the design height of the wall.

For a retaining wall with a continuously sloping back fill (Figure 5.2.5), this value should be entered as 99.99.

WATER LEVEL FRONT

If the substructure is to be analyzed for a permanent water level at the front of the substructure, enter the height of water above the toe in feet shown as WLF in Figure 5.2.1 thru Figure 5.2.5. Leave blank if there is no water at the front of the substructure (dry condition). If the water level is below the top of the footing, enter a negative value. This value is used to calculate the weight of water above the toe, the horizontal pressure due to presence of water in front of the substructure and the upward hydrostatic pressure (buoyancy effect) at the bottom of the toe. The value entered here cannot be greater than the value entered for WATER LEVEL BACK. Also, the difference between WATER LEVEL BACK and WATER LEVEL FRONT can not be greater than 3 feet.

TOP WALL TO TOP BACKFILL

For the analysis of a retaining wall, enter the vertical distance from the top of the wall to a point where the backfill intersects the back face of the stem in feet shown as D1 in Figure 5.2.4 on page 5-8 and Figure 5.2.5 on page 5-9. Enter this only if the backfill is below the top of the back face of the stem. Otherwise, leave blank. This value must be zero or blank for a design.

LIVE LOAD SURCH

Enter the live load surcharge for both the permanent and temporary loading condition, expressed as a height of fill in feet, acting on the substructure shown as S in Figure 5.2.1 thru Figure 5.2.5. Normally, a live load surcharge of 2 or 3 feet is applied for highway bridges. Enter zero or leave blank if no live load surcharge is to be applied.

The program considers two conditions when applying a vertical force due to surcharge. The first condition assumes no vertical component for live load surcharge. The second condition assumes vertical pressure due to surcharge over the entire heel. For a retaining wall, the vertical pressure over the heel due to the surcharge will begin at the back face of the wall for all ground configurations behind the wall as stated in DM4.

TOP FTG TO ROCK SURFACE

If a spread footing (FTG TYPE = “1”) is founded on rock and if the rock surface is above the bottom surface of the heel, enter the distance from the top of the footing to the rock surface in feet shown as DR in Figures Figure 5.2.1 thru Figure 5.2.5. Leave blank for FTG TYPE “2” or “3” or when R OR S is “S”. The program calculates the lateral earth pressure down to the top of rock elevation. If the user feels that the rock is NOT capable of resisting lateral earth pressure, leave this blank. When this distance is left blank or is entered greater than the footing thickness, the program will assume the lateral earth pressure acting from the bottom of the footing. Entering zero will mean that the total thickness of footing is embedded in rock.

F’C BACKWALL

The compressive strength of the concrete in psi used for the backwall. Enter for the Abutment Types I and II. When left blank, the program uses 3500 psi.

F’C STEM

The compressive strength of the concrete in psi used for the stem. When left blank, the program uses 3000 psi.

F’C FOOTING

The compressive strength of the concrete in psi used for the footing. When left blank, the program uses 3000 psi.

REBAR GRADE

The reinforcement bar grade. Enter “40”, “50” or “60”. The program uses this data to determine yield stress, fy or allowable tensile stress, fs. For service load design the program uses fs = 20,000 psi for grade 40 or 50 and fs = 24,000 for grade 60 reinforcement.

If left blank, the program assumes grade 60 bars.

PILE BATTER

For a design problem of footing on piles, enter a pile batter to be used in developing the horizontal resistance. Enter the horizontal component of the pile batter expressed as “X on 12”, where X is the horizontal component and 12 is the vertical component of the batter.

If left blank, the program will use a pile batter of “3 on 12” for a design problem.

Leave blank for an analysis problem.

PILE OPT

For a design problem of footing on piles, if it is desired to optimize to find the footing with the minimum cross sectional area, enter an “F”. If it is desired to optimize based on a cost analysis, enter a “C”. PILE COST and FTG COST must be entered when optimizing based on a cost analysis.

If left blank, the program will optimize to determine the footing with the minimum pile density.

Leave blank for an analysis problem or for a spread or pedestal footing.

LATERAL PILE CAPAC

Enter the maximum allowable lateral load per pile for vertical piles, **in tons**. This data must be entered when FTG TYPE is entered as “2” (pile footing). This value is used to calculate the lateral resistance of the pile group when <u>all</u> piles are vertical or when the 80% Rule option is used for analysis. This value does <u>not</u> affect the lateral resistance of the pile group consisting of vertical and battered piles when the 80% Rule option is not used.

Leave blank for a pedestal or spread footing.

Kv

The vertical earth pressure expressed as an equivalent fluid pressure in pounds per square foot. Refer to DM4 Section B.5 for this value based on soil type, backfill slope and backfill height. This is Rankine active earth pressure coefficient.

If this data is not entered, the program will use a value of 0.0 for a level backfill or compute a value for a sloping backfill using the curve for Soil Type 1 given in DM4 Section B.5.

Enter this value if temporary shoring is required to retain the soil during construction. This value should be computed using the curves or tables given in DM4 section B.5 using the type of soil behind the backfill.

REBAR DES

Enter “Y” if optional reinforcing design data is to be entered. When “Y” is specified, a line of REBAR DESIGN data must be entered after the DIMENSIONS data. When “Y” is not specified, skip the REBAR DESIGN data and enter the line of LOADING data after the DIMENSIONS data.

OVRSTR

Enter “Y” or leave blank if the ALLOW SOIL PRES or AXIAL PILE CAPAC is to be increased by the overstress percent factor for each AASHTO group load. The program uses the Overstress % shown in Table 3.2.1 on page 3-7. The allowable soil pressure or axial pile capacity will not be increased for the seismic loading condition. The lateral pile capacity of vertical piles will not be increased by the overstress percent factor. For the temporary loading condition, the allowable soil pressure or axial pile capacity will be increased by 125% regardless of what is entered here.

Enter “N” if the allowable soil pressure or pile capacity is not to be increased for each AASHTO group load.

For a spread footing or footing on pedestals, the allowable soil pressure should only be increased for each AASHTO group load if the entered value of allowable soil pressure is calculated based on shear failure and not for a settlement control.

80% RULE

This option is provided to check the 80-20 rule of the older design specification, which stated that in a pile group consisting of vertical and battered piles, at least 80% of horizontal force should be resisted by battering of piles and the 20% of horizontal force might be resisted by bending of vertical piles.

This option is available for analysis only. The program **does not** use the 80-20 rule for design.

Enter “N” or leave blank if the above check is not required for analysis or if all piles are vertical or if this is a design run.

For an analysis of a footing on piles, enter “Y” if the program should calculate the lateral resistance of the pile group consisting of vertical and battered piles by adding the horizontal components of actual pile loads (axial) of all battered piles. If “Y” is entered here, the program will indicate the lateral resistance as a percent of applied horizontal loads.

PILE ROW OPT

This option controls how the pile rows are placed across the footing width for each design pile arrangement trial. The program provides two pile row placement methods. Both methods place the first and last rows at the minimum distance (1.5 ft) from their respective footing edges. The remaining rows can either be spaced evenly between the first and last rows or be placed as close to the toe as allowed using the minimum distance between pile rows (3 ft). One or both of the pile placement methods can be selected. If both methods are used, the program will space the piles evenly first. If both placement methods result in a successful design, the footing with the evenly space pile rows is saved.

Enter one of the following pile row placement options:

T – Places rows as close to the toe as allowed

E – Places rows evenly spaced between the first and last pile rows.

B – Tries both row placement methods for each design pile arrangement.

If left blank, option “B” will be used.

Leave blank for an analysis problem or for a spread or pedestal footing.

5.4 DIMENSIONS

This line describes the geometry and other dimensions used for structural analysis. Refer to Figure 5.2.1, Figure 5.2.2, Figure 5.2.3, Figure 5.2.4 or Figure 5.2.5, depending on the substructure TYPE entered. All dimensions are in feet.

TOP OF (BACK) WALL TO TOP OF FOOTING

Enter the stem height including the height of the backwall in feet. This is measured from the top of the wall or backwall to the top of the footing. This distance is shown as H or HT in Figure 5.2.1 thru Figure 5.2.5. This is the design height of a wall with a varying height.

TOP THICKNESS

The thickness of the wall or backwall at the top in feet. Show as ST in Figures Figure 5.2.1 thru Figure 5.2.5. This data must be entered for an analysis problem. For a design problem, if this is left blank or entered less than the minimum thickness specified in DM4, the program uses the top thickness of 1.5 feet for a retaining wall or an abutment without a back wall and 1.25 feet for an abutment with a backwall.

TOE PROJECTION

For an analysis problem, enter the toe projection of the footing in feet shown as TP in Figures Figure 5.2.1 thru Figure 5.2.5.

For a design problem, a value can be entered here to specify a minimum toe projection or a fixed toe projection. To specify a minimum toe projection, enter the value of the minimum toe projection in feet and enter an “M” for T OR H. To fix the toe projection at a particular value, enter the negative of that value in feet and an “M” for T OR H. For example, entering “-1.75” here and an “M” for T OR H will force the program to produce a design with a toe projection of 1.75 feet.

HEEL PROJECTION

For an analysis problem only, enter the heel projection of the footing in feet shown as HP in Figures Figure 5.2.1 thru Figure 5.2.5.

Leave blank for a design problem.

MAX PROJ

For a design problem, if any of the footing projections is to be restricted because of an obstruction such as a utility line or other structure or because of any other reason, enter the appropriate code and the projection. The program will increase both projections in a manner described in the METHOD OF SOLUTION until either a satisfactory design is obtained or the restricted projection equals the maximum value specified, whichever occurs first. In the later case, the program proceeds with keeping the restricted projection constant and increasing the other projection until a satisfactory design is obtained. Only one projection can be restricted.

A minimum value for the toe projection can also be specified by entering “M” for T OR H (See below). In this case, the program will design a footing with a toe projection that is at least as long as the minimum specified. The toe projection can also be fixed at a particular value, as described previously under TOE PROJECTION. Note that if a minimum toe projection is specified, a maximum projection cannot be specified for either the toe or heel.

Leave items T OR H and TOE OR HEEL blank for an analysis problem.

T OR H

Enter “T” if the toe projection is to be restricted.
Enter “H” if the heel projection is to be restricted.

Enter “M” if a minimum value is to be used for the toe projection or if a fixed value is to be used for the toe projection, as previously described under TOE PROJECTION.

TOE OR HEEL

The value of the restricted toe or heel projection in feet.

MAX FTG

For a design problem, specify the maximum footing width up to which the program should try to find a design footing width for given loadings in feet. If this limit is not specified for a design problem, the program will assign a value equal to the stem height (H) or the embankment height (HT) whichever is greater. The program will also not allow this value greater than 3 times H.

The following nine (9) dimensions up to BW2 apply to Abutment Types I and II only. Leave blank for a retaining wall or an abutment without a backwall. Refer to Figure 5.2.1 or Figure 5.2.2 as appropriate. The same symbols are used on the Input Form 1 and Figures Figure 5.2.1 and Figure 5.2.2.

H1, H2, H3, and H4

Heights of the backwall in feet. Must be entered for the Abutment Types I and II.

W1, W2, and W3

The widths of projections of the backwall in feet. Refer to Figures Figure 5.2.1 and Figure 5.2.2. Leave W3 blank for the Abutment Type I.

BW1

The depth of the pavement notch in feet. Must be entered for both abutment types.

BW2

The distance from the bottom of the pavement notch to the beginning of the backwall batter for the Abutment Type II in feet. Leave blank for the Abutment Type I.

FRONT FACE TO D.L. REACTION

The distance from the front face of the stem to the centerline of bearing or the dead load reaction in feet shown as BF in Figure 5.2.1, Figure 5.2.2 and Figure 5.2.3. This data must be entered if the BEAM DEAD LOAD REACTION or the BEAM LIVE LOAD REACTION, explained later in Loading Data, is entered. Leave blank for the retaining wall.

BRIDGE SEAT WIDTH

The width of the bridge seat for the Abutment Types I and II in feet shown as SW in the Figure 5.2.1 and Figure 5.2.2. Leave blank for the retaining wall and the abutment without a backwall.

HEIGHT OF BACKWALL BATTER

The height of backwall batter for the Abutment Type II in feet shown as HTB in Figure 5.2.2 on page 5-6. A value greater than zero must be entered for Abutment Type II. Leave blank for other substructure types.

BACK BATTER

Enter the batter of the back face of the stem shown as BB in Figure 5.2.2 thru Figure 5.2.5. The batter expressed as 1 foot horizontal to vertical distance equal to the BACK BATTER for the back face of the stem for the Abutment Type II or retaining wall or abutment without backwall. Normal range for this data is between 10 and 12 feet, however, any reasonable batter can be given. Leave blank if the back face is vertical.

FOOTING THICKNESS

Enter the actual thickness of the footing for an analysis problem or the minimum thickness the program can start with for a design problem in feet shown as FT in Figure 5.2.1 thru Figure 5.2.5. For a design problem, if this is left blank or entered less than the minimum thickness required for a given type of foundation, the program will start with the minimum thickness of 2.0 feet for a spread footing or 2.5 feet for a footing on piles as specified in DM4.

PILE COST

When PILE OPT is entered as “C” for optimizing a pile footing based on a cost analysis, enter the approximate cost per pile, in dollars. Leave blank otherwise.

FTG COST

When PILE OPT is entered as “C” for optimizing a pile footing based on a cost analysis, enter the approximate cost per cubic yard of pile cap (footing), in dollars. Leave blank otherwise.

5.5 REBAR DESIGN

Enter this line only if the REBAR DES is entered as “Y” in the CRITERIA data.

TRIAL REBAR SPACING

Enter up to five trial rebar spacings, in inches, to be used for optimum reinforcing design.
The normal range for this data varies from 3 inches to 18 inches, inclusive.

If left blank, the program will assume the following spacings: 6 inches, 9 inches, 12 inches, 15 inches and 18 inches.

BAR LOC

Enter "N" if the reinforcement is to be placed above the piles. Enter "Y" if the reinforcement is to be placed at the bottom of the footing. Enter this data only if FTG TYPE is entered as "2" (pile footing).

If left blank, the program will assume the bars are located at the bottom of the footing.

The following three values are used to determine the applicable "z" value in calculating the allowable stress in flexural reinforcement for checking serviceability criteria for crack control.

BW EXPOS

Enter "N" or 'S" to indicate NORMAL or SEVER exposure conditions for the backwall reinforcement. If left blank, the program assumes severe exposure.

STEM EXPOS

Enter "N" or "S" to indicate NORMAL or SEVERE exposure conditions for the stem reinforcement. If left blank, the program assumes severe exposure.

FTG EXPOS

Enter "N" or "S" to indicate NORMAL or SEVER exposure conditions for the footing reinforcement. If left blank, the program assumes normal exposure.

MIN As

Enter, in square inches per linear foot, the minimum area of steel reinforcing to be used. If left blank, the program assumes 0.125 in^2 per linear foot.

The following eight values describe the rebar covers. Enter the distances from the extreme tension fiber to the tension steel centroid, in inches.

STEM BACK VERT

Enter the distance from the back of the stem to the rear face vertical reinforcement. If left blank, the program assumes 3.5 inches.

STEM BACK HORIZ

Enter the distance from the back of the stem to rear face horizontal reinforcement. If left blank, the program assumes 4.5 inches.

STEM FRONT VERT

Enter the distance from the front of the stem to the front face vertical reinforcement. If left blank, the program assumes 3.5 inches.

STEM FRONT HORIZ

Enter the distance from the front of the stem to the front face horizontal reinforcement. If left blank, the program assumes 2.5 inches.

FOOTING TOP LONG

Enter the distance from the top of the footing to the longitudinal reinforcement. If left blank, the program assumes 4.5 inches.

FOOTING TOP TRANS

Enter the distance from the top of the footing to the transverse reinforcement. If left blank, the program assumes 3.5 inches.

FOOTING BOTTOM LONG

Enter the distance from the bottom of the footing to the longitudinal reinforcement. If left blank, the program assumes 5.5 inches.

If FTG TYPE is entered as “2” (pile footing) and if BAR LOC is entered as “N” (reinforcement above piles), this value is added to the 12 inches embedded pile depth.

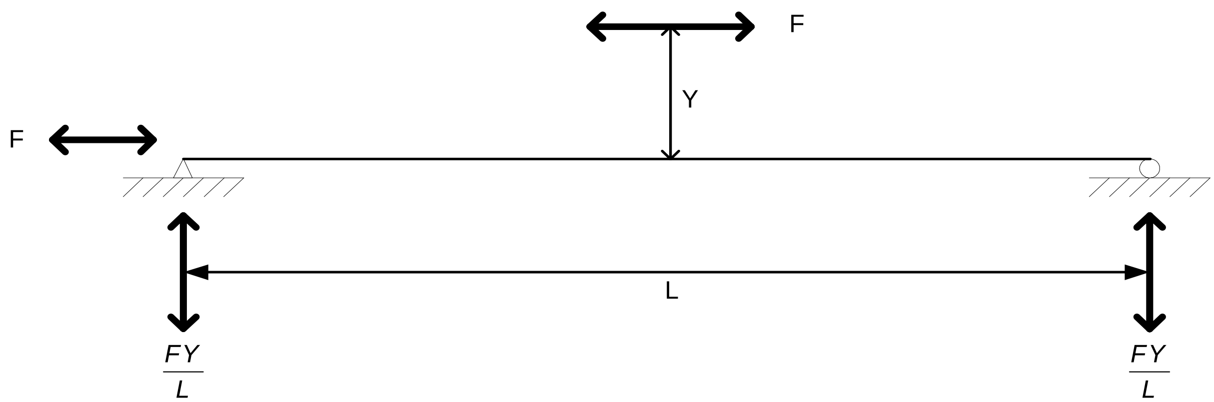
FOOTING BOTTOM TRANS

Enter the distance from the bottom of the footing to the transverse reinforcement. If left blank, the program assumes 4.5 inches.

If FTG TYPE is entered as “2” (pile footing) and if BAR LOC is entered as “N” (reinforcement above piles), this value is added to the 12 inch embedded pile depth.

5.6 LOADING

This line describes different loads acting on the substructure. Refer to Figure 5.6.1 on page 5-26. All loads are in kips per foot length of the abutment. All loads except PARAPET OR EXTERNAL load must be entered as loads acting at the centerline of bearing. The horizontal loads (such as wind on live load, centrifugal force and live load traction) which act above the bearing line must be converted as forces transmitted to the substructure through the bearings acting perpendicular to the length of the abutment.



The above figure shows how a horizontal force *F* acting at a distance *Y* above bearings is transmitted to the substructure. The vertical component, $\frac{FY}{L}$, is negligible.

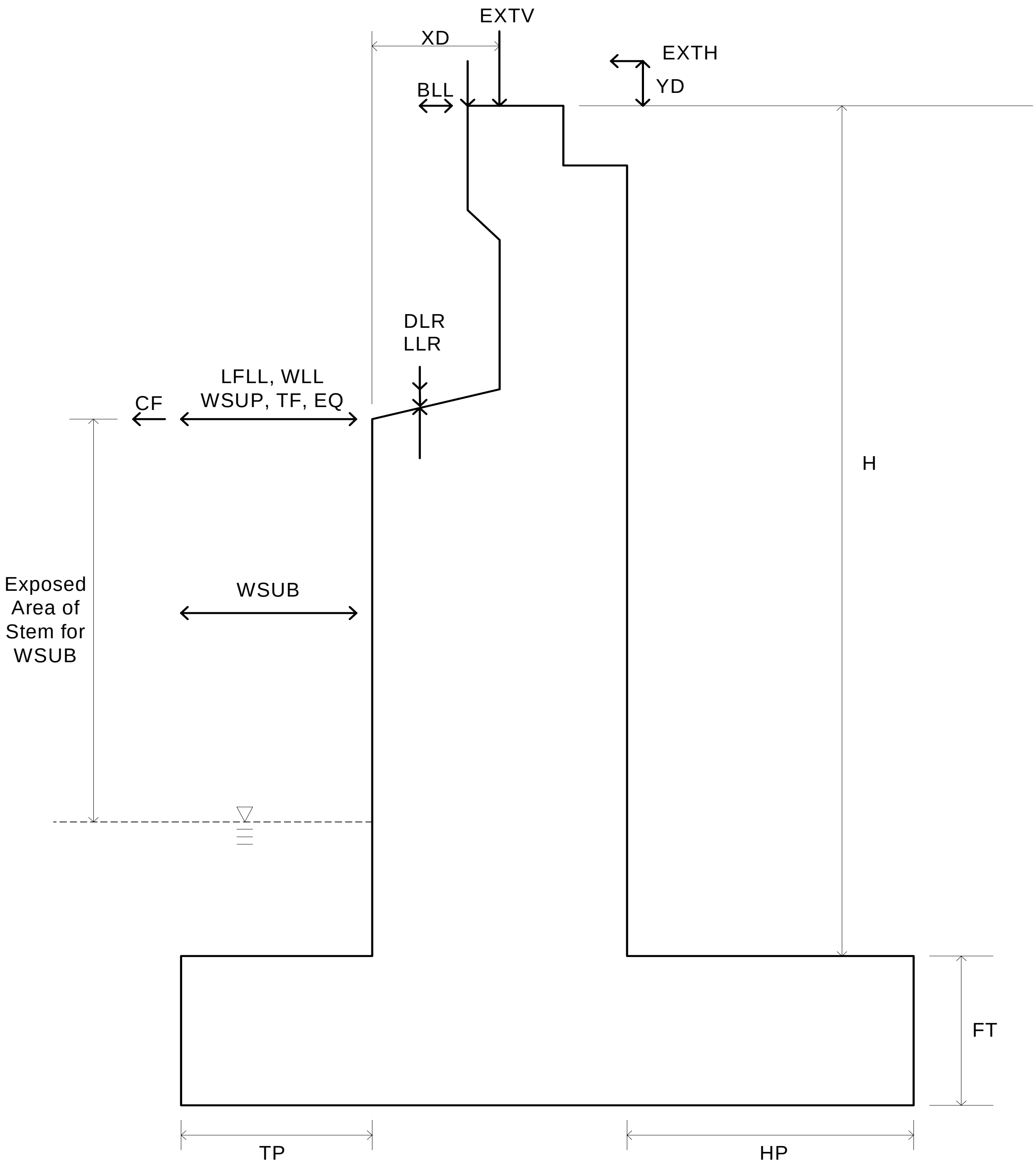


Figure 5.6.1 Loading Input

DL REACT

The vertical load due to superstructure dead load shown as DLR in Figure 5.6.1 on page 5-26.

LL REACT

The vertical load due to superstructure live load (Do not include impact) shown as LLR in Figure 5.6.1 on page 5-26.

WIND ON LL

The horizontal load due to the wind acting on live load and transmitted to the substructure through bearings shown as WLL in Figure 5.6.1 on page 5-26.

WIND ON SUPER

The horizontal load due to the wind acting on the exposed area of superstructure and transmitted to the substructure through bearings shown as WSUP in Figure 5.6.1 on page 5-26.

WIND ON SUB

The horizontal load due to the wind acting on the exposed area of stem shown as WSUB in Figure 5.6.1 on page 5-26.

UPWARD WIND

The vertical load, acting upward, due to the wind acting on the superstructure and transmitted to the substructure through bearings shown as WUP in Figure 5.6.1 on page 5-26.

LONG FORCE FROM LL

The horizontal load due to live load traction acting on the superstructure and transmitted to the substructure through bearings shown as LFLL in Figure 5.6.1 on page 5-26.

CENTR FORCE

The horizontal centrifugal force acting on the superstructure and transmitted to the substructure through bearings shown as CF in Figure 5.6.1 on page 5-26.

TEMP FORCE

The horizontal force due to friction at expansion bearing or force due to thermal movement of elastomeric bearing shown as TF in Figure 5.6.1 on page 5-26.

PARAPET OR EXTERNAL

Enter loads due to a parapet on a wing wall or other loads acting on the abutment, which cannot be described elsewhere. If a parapet is used as a traffic barrier, enter the weight of parapet as a vertical load and the transverse load for which the parapet is design as a horizontal load.

HORZ

Enter the value of horizontal load per foot length of the substructure. This is considered as a live load for AASHTO Group Loadings shown as EXTH in Figure 5.6.1 on page 5-26.

DIST

The distance of the line of action of horizontal load from the top of the wall in feet shown as YD in Figure 5.6.1 on page 5-26.

VERT

Enter the value of vertical load per foot length of the substructure shown as EXTV in Figure 5.6.1 on page 5-26. This is considered as a dead load for AASHTO Group Loading.

DIST

The distance of the line of action of vertical load from the front face of the stem in feet shown as XD in Figure 5.6.1 on page 5-26.

BACKWALL LIVE LOAD

Enter the loads acting directly on the backwall shown as BLL in Figure 5.6.1 on page 5-26. These loads are only used when designing the backwall sections (top two sections of Abutment Type I or II) of the stem. LL REACT and LONG FORCE FROM LL are used when designing the sections of stem below the backwall.

VERT

Enter the vertical force due to live load acting directly on the backwall.

HORZ

Enter the horizontal force due to live load acting directly on the backwall.

SEISMIC LOAD

The horizontal elastic seismic force to be used in the seismic loading condition acting at the bearing shown as EQ in Figure 5.6.1 on page 5-26. The seismic (earthquake) force, EQ, as listed in Section 3.2.3 (page 3-6), must be equal to the force EQF as described in DM4, Appendix A, Section 4.7.2. Determination of this force may require a seismic analysis of the superstructure by a computer program such as SEISAB or other appropriate methods.

For the seismic loading condition, the value entered here is used for the design of the footings, piles, and pedestals. For design of the abutment stem, one-half of the value entered here is used, based on the requirements of DM4, Appendix A, Section 4.7.1.

If SEISMIC LOAD is not entered, the program will not consider the seismic (Group VII) load case.

ALLOW PILE UPLIFT

Enter the allowable tension in a pile for a seismic loading condition (AASHTO Group VII) – kips. All piles must be anchored into the footings to transfer at least ten percent of the allowable pile load for a loading condition, which may cause tension in a pile.

5.7 PEDESTAL DIMENSIONS

This line describes the dimensions of the pedestal foundation. Enter this line only if the FTG TYPE is entered as "3" in the CRITERIA line. Refer to Figure 5.7.1 on page 5-30. All dimensions are in feet.

SPACING

Enter the clear distance between the pedestals in feet shown as SPAC in Figure 5.7.1 on page 5-30. Enter this data both for analysis and design problems.

THICKNESS

Enter the thickness of the pedestal for an analysis problem in feet shown as TH in Figure 5.7.1 on page 5-30. Leave blank for a design problem.

For a design problem, the program determines this thickness.

TOE TO PED FRONT

Enter the projection at the top of pedestal from the footing toe for an analysis problem in feet shown as PT Figure 5.7.1 on page 5-30. Leave blank for a design problem.

For a design problem, the program determines this projection.

HEEL TO PED BACK

Enter the offset of the pedestal back from the footing heel for an analysis problem in feet shown as PB in Figure 5.7.1 on page 5-30. Leave blank for a design problem.

For a design problem, the program determines this offset.

PED WIDTH

Enter the width at the base of the pedestal for an analysis problem in feet shown as W in Figure 5.7.1 on page 5-30. Leave blank for a design problem.

For a design problem, the program determines the width of the pedestal.

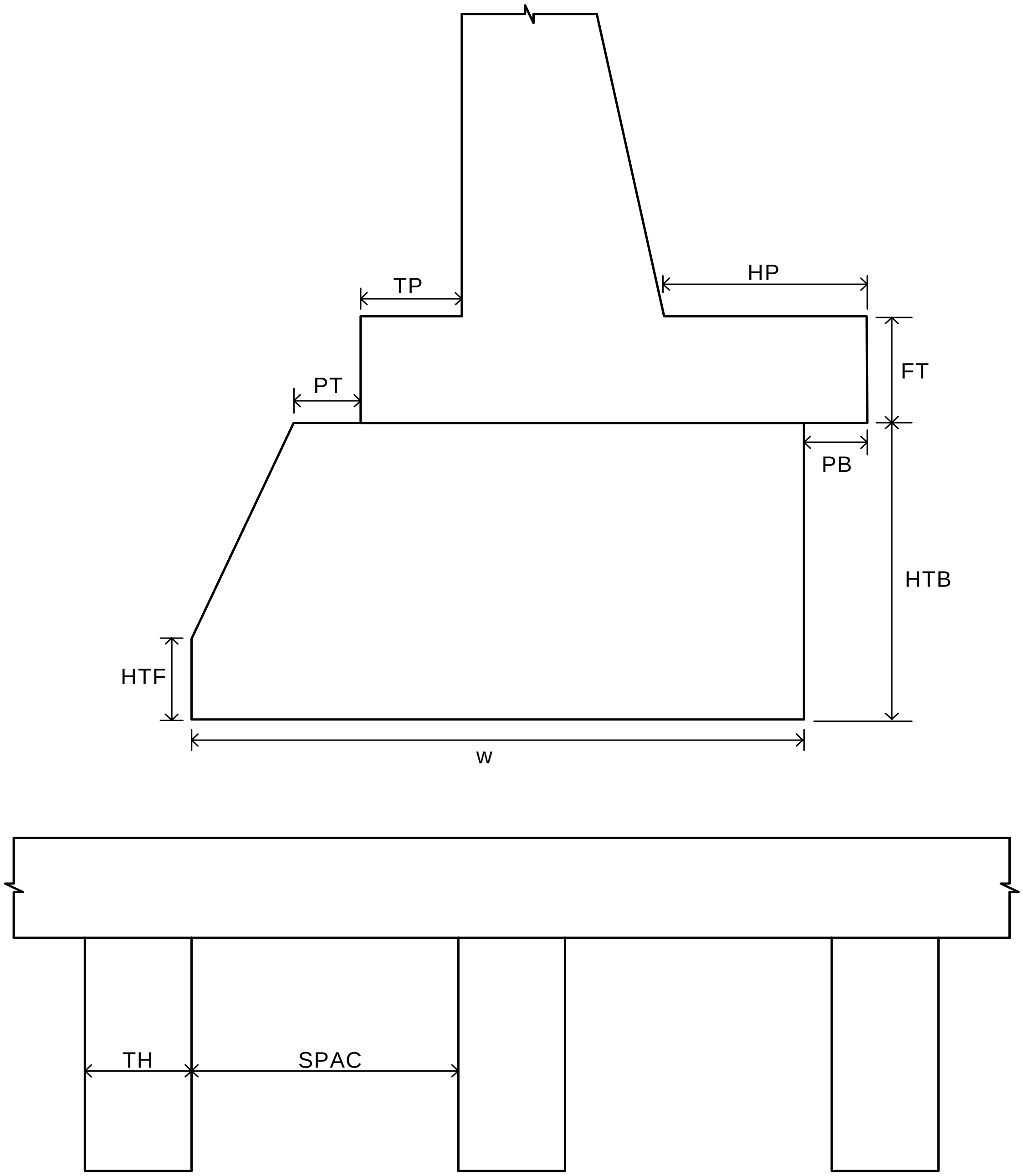


Figure 5.7.1 Pedestal Dimensions

FRONT HEIGHT

Enter the height of the vertical facing at the front of the pedestal in feet shown as HTF in Figure 5.7.1 on page 5-30. Enter this data both for analysis and design problems.

TOTAL HEIGHT

Enter the total height of the pedestal both for analysis and design problems in feet shown as HTB in Figure 5.7.1 on page 5-30.

5.8 PILE PATTERN

This line describes the pile pattern for an analysis problem for a pile footing. Enter this data only if FTG TYPE is entered as “2” in the criteria line and if it is an analysis problem. Refer to Figure 5.8.1 on page 5-32. All dimensions are in feet. Rows are numbered from the toe to the heel of the footing in a sequential order starting with 1. Maximum of five rows are allowed. Enter one line of data for each row. A minimum of two rows must be entered.

ROW NO

Enter the row number for which the pile geometry is entered. Last row number entered must agree with PILE ROWS entered in the CRITERIA line.

PILE BATTER

Enter the horizontal component of the pile batter expressed (shown as X in Figure 5.8.1 on page 5-32) as “X on 12”, where X is the horizontal component and 12 is the vertical component of the batter, if piles are battered in the row being described. Leave blank if piles are vertical.

DISTANCE BETWEEN ROWS

Enter the distance (normal to pile rows) from the previous pile row to the pile row being described in feet. If this is the first pile row, enter the distance from the toe edge of the footing shown as D1 in Figure 5.8.1 on page 5-32.

PILE SPACING

Enter the center-to-center distance between two piles in the pile row being described in feet. The program assumes that all piles are spaced equal distance in a given pile row.

PERCENT ROW BATTERED

Enter the percentage of battered piles in the row being described. When PILE BATTER is entered for the row being described, the default is 100.0%. When PILE BATTER is not entered for the row being described, the default is 0.0%. Battered piles in the last row (back) should not exceed 50.0%.

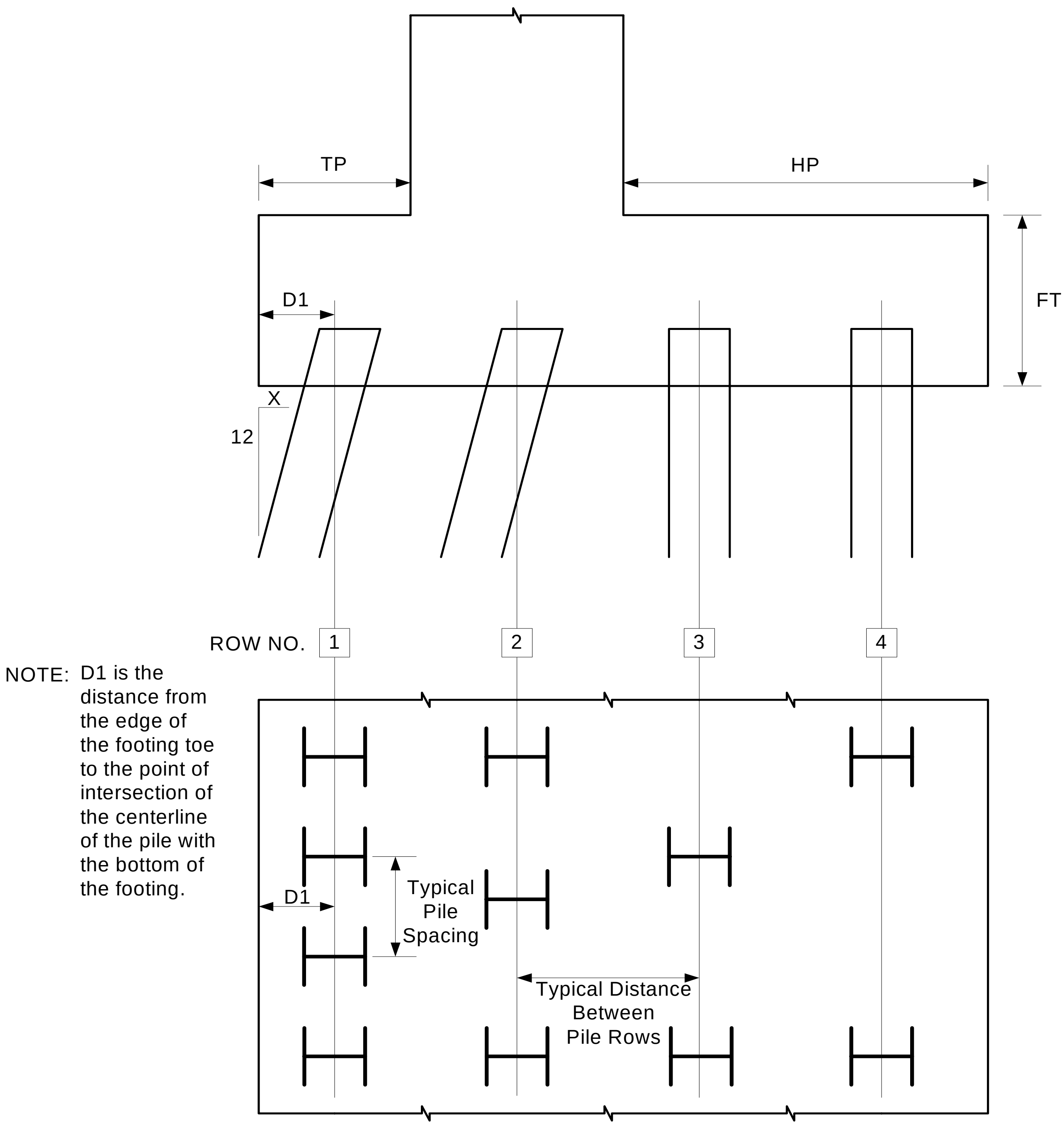


Figure 5.8.1 Pile Pattern

6 OUTPUT DESCRIPTION

6.1 GENERAL

The printed output consists of a repeat of all the input values exactly as read by the program, error messages, default values used by the program and the following computed values. Only the output that is applicable to a given type of problem is printed. All values are per foot length of the substructure.

The moments, forces, and pile loads printed are either based on service loads or factored loads as indicated on the output.

6.2 STABILITY ANALYSIS

The following computed values are printed for the stability analysis of the substructure.

AASHTO GROUP

The group number of the AASHTO Group Loadings. Group Loadings I, II, III, IV, V and VI are printed. The seismic loading is in lieu of group VII and "T" designates the temporary construction loading condition.

SUM V

The sum of vertical loads. Refer to APPLICATION OF LOADS on page 3-3 in the METHOD OF SOLUTION section of this manual for what vertical loads are considered in a given Group Loading – kips.

BAL. MOMENT

The moment of vertical loads acting on the substructure for a given Group Loading about the toe of the footing for a spread footing or a pedestal footing or about the front row of piles for a pile footing – kip-ft.

SUM H

The sum of horizontal loads. Refer to APPLICATION OF LOADS on page 3-3 in the METHOD OF SOLUTION section of this manual for what horizontal loads are considered in a given Group Loading – kips.

O.T. MOMENT

The moment of horizontal loads acting on the substructure for a given Group Loading about the toe of the footing for a spread footing or a pedestal footing or about the front row of piles for a pile footing – kip-ft.

TOE TO RESULT

The distance of the resultant force acting at the base of the footing for a spread footing or a pedestal footing from the toe of the footing – feet.

FRONT ROW TO RESULT

The distance of the resultant force acting at the base of the footing for a pile footing from the front row of piles – feet.

FOOTING PRESSURE TOE

The subgrade reaction at the toe end of the spread footing. An asterisk (*) is printed next to this value when it exceeds the allowable soil pressure. If “N” is entered for OVRSTR (overstress factors not applied), an exclamation point (!) is printed next to this value when it exceeds the allowable soil pressure within a 2% tolerance. – $kips/ft^2$.

FOOTING PRESSURE HEEL

The subgrade reaction at the heel end of the spread footing. An asterisk (*) is printed next to this value when it exceeds the allowable soil pressure. If “N” is entered for OVRSTR (overstress factors not applied), an exclamation point (!) is printed next to this value when it exceeds the allowable soil pressure within a 2% tolerance. – $kips/ft^2$.

FOOTING PRESSURE ALLOW

The allowable soil pressure including appropriate load group overstress factor when applicable – kips.

PRES. ON PEDESTAL TOE

The pressure between concrete surfaces at the top of the pedestal at the toe end of the footing. An asterisk (*) is printed next to this value when it exceeds the allowable axial pile load. If “N” is entered for OVRSTR (overstress factors not applied), an exclamation point (!) is printed next to this value when it exceeds the allowable axial pile load within a 2% tolerance. – $kips/ft^2$.

PRES. ON PEDEDSTAL HEEL

The pressure between concrete surfaces at the top of the pedestal at the heel end of the footing. An exclamation point (!) is printed next to this value when it exceeds the allowable compressive concrete stress within a 2% tolerance. An asterisk (*) is printed next to this value when it exceeds the allowable compressive concrete stress by more than 2%. – $kips/ft^2$.

PRES. ON PEDESTAL ALLOW

The allowable compressive concrete stress (0.4 f'_c) between the footing and the pedestal – kips/ft^2.

PRES. UNDER PED. TOE

The subgrade reaction at the toe end at the base of the pedestal. An asterisk (*) is printed next to this value when it exceeds the allowable axial pile load. If “N” is entered for OVRSTR (overstress factors not applied), an exclamation point (!) is printed next to this value when it exceeds the allowable axial pile load within a 2% tolerance. – kips/ft^2.

PRES. UNDER PED. HEEL

The subgrade reaction at the heel end at the base of the pedestal. An asterisk (*) is printed next to this value when it exceeds the allowable axial pile load. If “N” is entered for OVRSTR (overstress factors not applied), an exclamation point (!) is printed next to this value when it exceeds the allowable axial pile load within a 2% tolerance. – kips/ft^2.

PRES. UNDER PED. ALLOW

The allowable soil pressure including appropriate load group overstress factor when applicable – kips.

PILE LOAD FRONT

The axial load on each pile in the front row of a pile footing. An asterisk (*) is printed next to this value when it exceeds the allowable axial pile load. If “N” is entered for OVRSTR (overstress factors not applied), an exclamation point (!) is printed next to this value when it exceeds the allowable axial pile load within a 2% tolerance. – kips.

PILE LOAD BACK

The axial load on each pile in the back row of a pile footing. An asterisk (*) is printed next to this value when it exceeds the allowable axial pile load. If “N” is entered for OVRSTR (overstress factors not applied), an exclamation point (!) is printed next to this value when it exceeds the allowable axial pile load within a 2% tolerance. – kips.

PILE LOAD ALLOW

The allowable axial load on each pile including appropriate load group overstress factor when applicable – kips.

LATERAL RESISTANCE

The lateral resistance of the pile group – kips. For a pile group consisting of vertical piles only, this is the resistance offered by the lateral deflection of vertical piles. For a pile group with one or more battered piles, this is the resistance offered by the horizontal component of the axial pile capacity of battered piles only. The value printed here is the lateral resistance of the pile group multiplied by the overstress percentage factor for a given AASHTO Group. This heading and value are not printed when a “Y” is entered for 80% RULE for an analysis problem.

%BATTER RESISTANCE

The ratio of the horizontal component of axial loads in battered piles to the applied horizontal load (SUM H) expressed as a percent - %. This heading and value are printed only when a “Y” is entered for 80% RULE for an analysis problem.

If there are no battered piles, and if “Y” was entered for 80% RULE, this heading and value are not printed. Instead the lateral resistance of vertical piles is printed under the heading LATERAL RESISTANCE.

F.S. @ FOOTING

The factors of safety about the footing base.

O.T.

The factor of safety against overturning of the substructure about the toe of the footing for a spread footing or a pedestal footing or about the front row of piles for a pile footing.

SLIDING OR V/H

The factor of safety against sliding on the footing base of a spread footing. For a pedestal footing, this is the ratio of the vertical loads above the footing base.

F.S. @ PEDESTAL

The factors of safety about the pedestal base.

O.T.

The factor of safety against overturning the whole substructure including the pedestal about the pedestal toe.

V/H

The ratio of the vertical loads to the horizontal loads for a pedestal footing of all loads acting above the pedestal base.

6.3 FOOTING ANALYSIS

AASHTO GROUP

The group number of the AASHTO Group Loadings. Group Loadings I, II, III, IV, V and VI are printed. The seismic loading is in lieu of group VII and "T" designates the temporary construction loading condition.

TOE MOMENT

The moment in the footing at a section in the toe projection at the face of the stem – kip-ft. A positive toe moment causes a tension in the extreme bottom fiber.

TOE SHEAR

The shear in the toe projection of the footing at the critical section for shear as indicated under @ - kips. A positive shear is a force acting upward. If the critical section is greater than the toe projection, this is printed as zero.

@

If there is tension in the top of the footing, an "F" is printed to indicate that the critical section is at the face of the stem. If there is compression in the top of the footing, a "D" is printed to indicate that the critical section is at a distance equal to the effective depth "d" from the face of the stem.

HEEL MOMENT

The moment in the footing at a section in the heel projection at the face of the stem – kip-ft. A positive heel moment causes a tension in the extreme top fiber.

HEEL SHEAR

The shear in the heel projection of the footing at the critical section for shear as indicated under @ - kips. A positive shear is a force acting downward. If the critical section is greater than the heel projection, this is printed as zero.

@

If there is tension in the top of the footing, an "F" is printed to indicate that the critical section is at the face of the stem. If there is compression in the top of the footing, a "D" is printed to indicate that the critical section is at a distance equal to the effective depth "d" from the face of the stem.

6.4 FOOTING DESIGN

The following values are printed.

FOOTING WIDTH

The width of the footing – feet.

FOOTING THICKNESS

The thickness of the footing – feet.

TOE PROJ

The toe projection of the footing – feet. If it is a design problem, this is the design value.

HEEL PROJ

The heel projection of the footing – feet. If it is a design problem, this is the design value.

EFFECTIVE DEPTH – TOE

The distance from the top of the slab to the centroid of the bottom reinforcement in the toe projection of the footing – feet. This is the same as distance “d” mentioned in the description of TOE SHEAR.

EFFECTIVE DEPTH - HEEL

The distance from the bottom of the slab to the centroid of the top reinforcement in the heel projection of the footing – feet.

ULT SHEAR TOE

The maximum factored shear in toe for Load Factor Design – kips.

SHEAR STRESS TOE

The maximum shear stress in toe for Service Load Design – ksi.

SHEAR CAP TOE

The ultimate shear capacity of the toe selection for Load Factor Design – kips.

ALLOWABLE SHEAR TOE

The maximum allowable shear stress in the toe section for Service Load Design – ksi.

ULT SHEAR HEEL

The maximum factored shear in heel for a Load Factor Design – kips.

SHEAR STRESS HEEL

The maximum shear stress in heel for a Service Load Design – ksi.

SHEAR CAP HEEL

The ultimate shear capacity of the heel section for Load Factor Design – kips.

ALLOWABLE SHEAR HEEL

The maximum allowable shear stress in the heel section for Service Load Design – ksi.

TRANSVERSE REINFORCEMENT – TOE-BOT

The area of bottom reinforcement required in the toe projection of spread footing or footing on piles – in^2.

TRANSVERSE REINFORCEMENT – HEEL-TOP

The area of top reinforcement required in the heel projection of the spread footing or footing on piles – in^2.

LONGITUDINAL REINF

The area of longitudinal reinforcement required in the footing on piles – in^2.

LONGITUDINAL REINFORCEMENT POS-BOT

The area of longitudinal reinforcement required at the bottom of the footing on pedestals – in^2.

LONGITUDINAL REINFORCEMENT NEG-TOP

The area of longitudinal reinforcement required at the bottom of the footing on pedestals – in^2.

PEDESTAL DIMENSIONS

The width, thickness, offsets and heights of the pedestal are printed for a pedestal footing – feet.

LONGITUDINAL MOMENT CALCULATIONS

For a pile footing, the maximum uniform load – kips/ft, maximum pile spacing – feet, and maximum longitudinal moment – kip-ft. For a pedestal footing, the maximum uniform load – kips/ft, clear distance between pedestals – feet and maximum longitudinal moment, positive and negative – kip-ft.

MAXIMUM SHEAR

For a pedestal footing, the maximum shear at a distance “d” from the face of the pedestal – kips.

PILE PATTERN

For a pile footing, the batter of piles, if any, distance of the pile row from tow – feet, the pile spacings – feet, and the percent of battered piles for each row of piles. Also, the distance of the c.g. of pile group from toe – feet, the moment of inertia of pile group – ft^4, and pile density – piles/ft.

6.5 DESIGN OF STEM SECTIONS

For each critical section (see Figure 3.8.1 on page 3-23), in the stem the following values are printed out.

SECTION LOCATION

Self-explanatory.

AASHTO GROUP (FACTORED) or (SERVICE)

The group number of the AASHTO Group Loadings. Group Loading I, II, II, IV, V and VI are printed. The seismic loading is in lieu of group VII and "T" designates the temporary construction loading conditions.

MOMENT (BD = 1.0)

The moment at a section – kip-ft. If factored moment is printed, this value is based on a beta factor for dead load equal to 1.0.

AXIAL FORCE (BD = 1.0)

The axial load at a section – kips. If factored axial force is printed, this value is based on a beta factor for dead load equal to 1.0.

MOMENT (BD = 0.75)

Factored moment at a section based on a beta factor for dead load equal to 0.75 – kip-ft. This value is printed out only for a Load Factor Design.

AXIAL (BD = 0.75)

Factored axial force at a section based on a beta factor for dead load equal to 0.75 – kip-ft. This value is printed out only for a Load Factor Design.

SHEAR

The shear force at a section – kips.

SECTION THICKNESS

The thickness of the section – feet.

ULTIMATE SHEAR

The maximum factored shear at a section for Load Factor Design – kips.

SHEAR STRESS

The maximum shear stress at a section for a Service Load Design – ksi.

SHEAR CAPACITY

The ultimate shear capacity of the section for a Load Factor Design – kips.

ALLOWABLE SHEAR

The maximum allowable shear stress in the section for a Service Load Design – ksi.

BACK FACE REINF

The area of reinforcement required at a section at the back face of stem – in^2.

6.6 SUMMARY OF STEEL DESIGN

Steel design information is provided for both footing and stem, with the computer selected optimum designs. The rebar size, actual area of steel – in^2/ft and allowable and actual stress – ksi are given for each possible rebar spacing based on both required area of steel and serviceability as per AASHTO 8.16.8.

FOOTING DESIGN/ANALYSIS

A table of rebar information is given for top and bottom transverse reinforcement. For a footing on piles or pedestals, top and bottom longitudinal reinforcement information is also given.

STEM DESIGN/ANALYSIS

For each critical section (see Figure 3.8.1 on page 3-23) in the stem, a table of rebar information is given for vertical reinforcement on back face.

OPTIMUM REBAR DESIGN

Each spacing and corresponding bar size as described above is examined and rated. The designs are sorted according to minimum penalty and all designs are listed in the order from most desirable to least optimal. In the back face of the stem, one cutoff may be utilized providing two separate designs for vertical reinforcement.

6.7 FORMATTED OUTPUT TABLES

The following pages contain the format (i.e., the title, output parameters, units, field widths and decimal locations) for each of the output tables described 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 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 command, the program will print different combinations of these output tables.

Input Summary:

```
                     LFD Abutment and Retaining Wall

PROGRAM P4354040                                              ii/ii/iiii ii:ii
VERSION i.i.0.ii          LAST UPDATED ii/ii/iiii        DOCUMENTATION ii/iiii

INPUT: aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa

aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa


                              ANALYSIS OF
                               DESIGN OF
                    ABUTMENT WITH BACKWALL TYPE I
                    ABUTMENT WITH BACKWALL TYPE II
                            RETAINING WALL
                       ABUTMENT WITHOUT BACKWALL

                       TYPE OF FOOTING : SPREAD
                      TYPE OF FOOTING : ON PILES
                     TYPE OF FOOTING : ON PEDESTALS

                                                                 EQUIV FLUID
DESIGN                   FTG    PILE            PILE              PRESSURE
METHOD   A OR D   TYPE   TYPE     D    EMBEDDED ROWS   R OR S     DRY   SAT
  aa       a       i      i     xx.x     a        i      a       xx.x  x.xx

                      ALLOW SOIL   WATER  TOP FTG   WATER    TOP WALL   LIVE
COEFF OF  BACKFILL  PRESS OR AXIAL LEVEL  TO TOP    LEVEL     TO TOP    LOAD
FRICTION    SLOPE     PILE CAPAC    BACK  EMBANK    FRONT    BACKFILL   SURCH
  x.xx       ii         xxx.xx     xx.xx   xx.xx    xx.xx     xx.xx    xx.xx

TOP FTG  F'C                                   LATERAL                    PILE
TO ROCK  BACK   F'C    F'C  REBAR   PILE  PILE  PILE      REBAR  OVR  80%   ROW
SURFACE  WALL   STEM   FTG  GRADE  BATTER  OPT  CAPAC  Kv  DES   STR  RULE  OPT
xxx.xx  xxxx.  xxxx.  xxxx.   xx.    x.x    a   xx.x  xx.x  a     a    a     a

  TOP OF
(BACK)WALL                                        MAX
TO TOP OF     TOP      PROJECTION          MAX    FTG
 FOOTING   THICKNESS   TOE   HEEL  T OR H  PROJ  WIDTH   H1      H2    H3    H4
  xx.xx      x.xx     xx.xx xx.xx    a    xx.xx  xx.xx  x.xx  xx.xx  x.xx xx.xx

                            FRONT           HEIGHT
                            FACE   BRIDGE     OF
                            TO DL   SEAT   BACKWALL  BACK   FOOTING  PILE  FTG
 W1   W2   W3   BW1   BW2   REACT   WIDTH   BATTER  BATTER THICKNESS COST  COST
x.xx x.xx x.xx xx.xx xx.xx  xx.xx   xx.xx                    x.xx    iiii  iii

     TRIAL
 REBAR SPACING  BAR   BW    STEM    FTG    MIN
 1  2  3  4  5  LOC  EXPOS  EXPOS  EXPOS   As
ii ii ii ii ii   a     a      a      a    x.xxx

     STEM REBAR COVER           FOOTING REBAR COVER
 VERT  HORIZ   VERT  HORIZ    LONG  TRANS   LONG  TRANS
xx.xx  xx.xx  xx.xx  xx.xx   xx.xx  xx.xx  xx.xx  xx.xx


                                          LONG
                     WIND   WIND          FORCE
 DL     LL    WIND    ON     ON   UPWARD  FROM   CENTR  TEMP
REACT  REACT  ON LL  SUPER   SUB   WIND    LL    FORCE  FORCE
xx.xx  xx.xx  xx.xx  xx.xx  xx.xx  xx.xx  xx.xx  xx.xx  xx.xx
```

```
                                BACKWALL            ALLOW
   PARAPET OR EXTERNAL          LIVE LOAD  SEISMIC   PILE
HORZ   DIST   VERT   DIST   VERT   HORZ   LOAD   UPLIFT
xx.xx  xx.xx  xx.xx  xx.xx  xx.xx  xx.xx  xx.xx    xx.xx

                    TOE TO  HEEL TO
   PEDESTAL          PED      PED    PED    FRONT   TOTAL
SPACING  THICKNESS  FRONT    BACK   WIDTH  HEIGHT  HEIGHT
 xx.xx      x.xx    xx.xx    xx.xx  xx.xx   xx.xx   xx.xx

             DISTANCE           PERCENT
ROW   PILE   BETWEEN    PILE      ROW
NO   BATTER    ROWS    SPACING  BATTERED
ii     x.x    xxx.xx   xxx.xx    xxx.x
                  .
                  .
ii     x.x    xxx.xx   xxx.xx    xxx.x
```

Reinforcement Summary:

```
                              REINFORCEMENT SUMMARY
                              ---------------------
                               REBAR SPACINGS (in):
                                        x.
                                        x.
                                       xx.
                                       xx.
                                       xx.

                     REBAR COVERS (in):   (C.G. OF BAR TO OUTER FACE)
                             STEM                     FOOTING
                     BACK         FRONT           TOP         BOTTOM
                  VERT  HORIZ   VERT  HORIZ  LONG   TRANS  LONG   TRANS
                  x.xx  xx.xx  xx.xx  xx.xx xx.xx   xx.xx xx.xx   xx.xx

                              BACK WALL -- aaaaaa
                  EXPOSURES:  STEM ------- aaaaaa
                              FOOTING ---- aaaaaa

                  MINIMUM AREA OF STEEL PER FOOT: x.xxx SQUARE INCHES
```

Footing Design Parameters (Design run only):

```
                         FOOTING DESIGN PARAMETERS (ft.)

  FOOTING WIDTH     FOOTING THICKNESS   TOE PROJECTION      HEEL PROJECTION
   MIN    MAX          MIN    MAX          MIN    MAX          MIN    MAX

  xx.xx  xx.xx        xx.xx  xx.xx        xx.xx  xx.xx        xx.xx  xx.xx
```

Stability Analysis – Spread Footings:

STABILITY ANALYSIS (SERVICE LOADS) - WITH VERTICAL COMPONENT OF LL SURCHARGE

AASHTO GROUP	SUM V	BAL. MOMENT	SUM H	O.T. MOMENT	TOE TO RESULT	FOOTING PRESSURE TOE	HEEL	ALLOW	F.S.@FOOTING O.T.	SLIDING
1	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
2	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
3	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
4	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
5	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
6	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
T	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx

! - BEARING PRESSURE UNDER FOOTING EXCEEDS ALLOWABLE SOIL PRESSURE BUT IS WITHIN 2% TOLERANCE
* - BEARING PRESSURE UNDER FOOTING EXCEEDS ALLOWABLE SOIL PRESSURE

STABILITY ANALYSIS (SERVICE LOADS) - WITHOUT VERTICAL COMPONENT OF LL SURCHARGE

AASHTO GROUP	SUM V	BAL. MOMENT	SUM H	O.T. MOMENT	TOE TO RESULT	FOOTING PRESSURE TOE	HEEL	ALLOW	F.S.@FOOTING O.T.	SLIDING
1	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
2	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
3	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
4	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
5	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
6	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
T	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx

! - BEARING PRESSURE UNDER FOOTING EXCEEDS ALLOWABLE SOIL PRESSURE BUT IS WITHIN 2% TOLERANCE
* - BEARING PRESSURE UNDER FOOTING EXCEEDS ALLOWABLE SOIL PRESSURE

Stability Analysis – Pile Footings:

STABILITY ANALYSIS (SERVICE LOADS) - WITH VERTICAL COMPONENT OF LL SURCHARGE

AASHTO GROUP	SUM V	BAL. MOMENT	SUM H	O.T. MOMENT	FRONT ROW TO RESULT	PILE LOAD FRONT	BACK	ALLOW	LAT. RESIST	F.S. O.T.
1	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xxx.xxa	xxx.xxa	xxx.xx	xxx.xx	x.xx
2	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xxx.xxa	xxx.xxa	xxx.xx	xxx.xx	x.xx
3	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xxx.xxa	xxx.xxa	xxx.xx	xxx.xx	x.xx
4	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xxx.xxa	xxx.xxa	xxx.xx	xxx.xx	x.xx
5	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xxx.xxa	xxx.xxa	xxx.xx	xxx.xx	x.xx
6	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xxx.xxa	xxx.xxa	xxx.xx	xxx.xx	x.xx
T	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xxx.xxa	xxx.xxa	xxx.xx	xxx.xx	x.xx

! - PILE LOAD EXCEEDS AXIAL CAPACITY BUT IS WITHIN 2% TOLERANCE
* - PILE LOAD EXCEEDS AXIAL PILE CAPACITY

STABILITY ANALYSIS (SERVICE LOADS) - WITHOUT VERTICAL COMPONENT OF LL SURCHARGE

AASHTO GROUP	SUM V	BAL. MOMENT	SUM H	O.T. MOMENT	FRONT ROW TO RESULT	PILE LOAD FRONT	PILE LOAD BACK	PILE LOAD ALLOW	LAT. RESIST	F.S. O.T.
1	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xxx.xxa	xxx.xxa	xxx.xx	xxx.xx	x.xx
2	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xxx.xxa	xxx.xxa	xxx.xx	xxx.xx	x.xx
3	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xxx.xxa	xxx.xxa	xxx.xx	xxx.xx	x.xx
4	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xxx.xxa	xxx.xxa	xxx.xx	xxx.xx	x.xx
5	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xxx.xxa	xxx.xxa	xxx.xx	xxx.xx	x.xx
6	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xxx.xxa	xxx.xxa	xxx.xx	xxx.xx	x.xx
T	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xxx.xxa	xxx.xxa	xxx.xx	xxx.xx	x.xx

! - PILE LOAD EXCEEDS AXIAL CAPACITY BUT IS WITHIN 2% TOLERANCE
* - PILE LOAD EXCEEDS AXIAL PILE CAPACITY

Stability Analysis – Pedestal Footings:

STABILITY ANALYSIS (SERVICE LOADS)
STRUCTURE ABOVE PEDESTAL - WITH VERTICAL COMPONENT OF LL SURCHARGE

AASHTO GROUP	SUM V	BAL. MOMENT	SUM H	O.T. MOMENT	TOE TO RESULT	PRES. ON PEDESTAL TOE	PRES. ON PEDESTAL HEEL	PRES. ON PEDESTAL ALLOW#	F.S.@FOOTING O.T.	F.S.@FOOTING V/H
1	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
2	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
3	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
4	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
5	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
6	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
T	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx

- ALLOWABLE COMPRESSIVE CONCRETE STRESS (KSF) BETWEEN FOOTING AND PEDESTAL, 0.4*f'c
! - CONCRETE STRESS BETWEEN FOOTING AND PEDESTAL EXCEEDS ALLOWABLE BUT IS WITHIN 2% TOLERANCE
* - CONCRETE STRESS BETWEEN FOOTING AND PEDESTAL EXCEEDS ALLOWABLE

STABILITY ANALYSIS (SERVICE LOADS)
STRUCTURE ABOVE PEDESTAL - WITHOUT VERTICAL COMPONENT OF LL SURCHARGE

AASHTO GROUP	SUM V	BAL. MOMENT	SUM H	O.T. MOMENT	TOE TO RESULT	PRES. ON PEDESTAL TOE	PRES. ON PEDESTAL HEEL	PRES. ON PEDESTAL ALLOW#	F.S.@FOOTING O.T.	F.S.@FOOTING V/H
1	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
2	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
3	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
4	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
5	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
6	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx
T	xx.xx	xxx.xx	xx.xx	xxx.xx	xx.xx	xx.xxa	xx.xxa	xxx.xx	xx.xx	x.xx

- ALLOWABLE COMPRESSIVE CONCRETE STRESS (KSF) BETWEEN FOOTING AND PEDESTAL, 0.4*f'c
! - CONCRETE STRESS BETWEEN FOOTING AND PEDESTAL EXCEEDS ALLOWABLE BUT IS WITHIN 2% TOLERANCE
* - CONCRETE STRESS BETWEEN FOOTING AND PEDESTAL EXCEEDS ALLOWABLE

```
      STABILITY ANALYSIS (SERVICE LOADS)
      STRUCTURE INCLUDING PEDESTAL - WITH VERTICAL COMPONENT OF LL SURCHARGE
                  (SUM V, SUM H AND MOMENT ARE PER PEDESTAL)

   AASHTO        BAL.           O.T.   TOE TO   PRES. UNDER PED.    F.S.@PEDESTAL
   GROUP  SUM V  MOMENT  SUM H  MOMENT  RESULT  TOE    HEEL   ALLOW   O.T.   V/H
     1    XX.XX  XXX.XX  XX.XX  XXX.XX  XX.XX  XX.XXa XX.XXa  XXX.XX  XX.XX  XX.XX
     2    XX.XX  XXX.XX  XX.XX  XXX.XX  XX.XX  XX.XXa XX.XXa  XXX.XX  XX.XX  XX.XX
     3    XX.XX  XXX.XX  XX.XX  XXX.XX  XX.XX  XX.XXa XX.XXa  XXX.XX  XX.XX  XX.XX
     4    XX.XX  XXX.XX  XX.XX  XXX.XX  XX.XX  XX.XXa XX.XXa  XXX.XX  XX.XX  XX.XX
     5    XX.XX  XXX.XX  XX.XX  XXX.XX  XX.XX  XX.XXa XX.XXa  XXX.XX  XX.XX  XX.XX
     6    XX.XX  XXX.XX  XX.XX  XXX.XX  XX.XX  XX.XXa XX.XXa  XXX.XX  XX.XX  XX.XX
     T    XX.XX  XXX.XX  XX.XX  XXX.XX  XX.XX  XX.XXa XX.XXa  XXX.XX  XX.XX  XX.XX

      ! - BEARING PRESSURE UNDER PEDESTAL EXCEEDS ALLOWABLE BUT IS
          WITHIN 2% TOLERANCE
      * - BEARING PRESSURE UNDER PEDESTAL EXCEEDS ALLOWABLE SOIL PRESSURE


      STABILITY ANALYSIS (SERVICE LOADS)
      STRUCTURE INCLUDING PEDESTAL - WITHOUT VERTICAL COMPONENT OF LL SURCHARGE
                  (SUM V, SUM H AND MOMENT ARE PER PEDESTAL)

   AASHTO        BAL.           O.T.   TOE TO   PRES. UNDER PED.    F.S.@PEDESTAL
   GROUP  SUM V  MOMENT  SUM H  MOMENT  RESULT  TOE    HEEL   ALLOW   O.T.   V/H
     1    XX.XX  XXX.XX  XX.XX  XXX.XX  XX.XX  XX.XXa XX.XXa  XXX.XX  XX.XX  XX.XX
     2    XX.XX  XXX.XX  XX.XX  XXX.XX  XX.XX  XX.XXa XX.XXa  XXX.XX  XX.XX  XX.XX
     3    XX.XX  XXX.XX  XX.XX  XXX.XX  XX.XX  XX.XXa XX.XXa  XXX.XX  XX.XX  XX.XX
     4    XX.XX  XXX.XX  XX.XX  XXX.XX  XX.XX  XX.XXa XX.XXa  XXX.XX  XX.XX  XX.XX
     5    XX.XX  XXX.XX  XX.XX  XXX.XX  XX.XX  XX.XXa XX.XXa  XXX.XX  XX.XX  XX.XX
     6    XX.XX  XXX.XX  XX.XX  XXX.XX  XX.XX  XX.XXa XX.XXa  XXX.XX  XX.XX  XX.XX
     T    XX.XX  XXX.XX  XX.XX  XXX.XX  XX.XX  XX.XXa XX.XXa  XXX.XX  XX.XX  XX.XX

      ! - BEARING PRESSURE UNDER PEDESTAL EXCEEDS ALLOWABLE BUT IS
          WITHIN 2% TOLERANCE
      * - BEARING PRESSURE UNDER PEDESTAL EXCEEDS ALLOWABLE SOIL PRESSURE
```

Footing Analysis – Spread Footings:

```
   FOOTING ANALYSIS (SERVICE LOADS) - WITH VERTICAL COMPONENT OF LL SURCHARGE
   FOOTING ANALYSIS (FACTORED LOADS) - WITH VERTICAL COMPONENT OF LL SURCHARGE

   AASHTO SUM   BAL.   SUM   O.T.  TOE TO  FOOTING PRES.
   GROUP   V   MOMENT   H   MOMENT RESULT    TOE    HEEL
     1   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
     2   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
     3   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
     4   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
     5   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
     6   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
     T   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX

   AASHTO      TOE      TOE        HEEL     HEEL
   GROUP      MOMENT   SHEAR @    MOMENT   SHEAR @
     1        XXX.XX   XX.XX a    XXX.XX   XX.XX a
     2        XXX.XX   XX.XX a    XXX.XX   XX.XX a
     3        XXX.XX   XX.XX a    XXX.XX   XX.XX a
     4        XXX.XX   XX.XX a    XXX.XX   XX.XX a
     5        XXX.XX   XX.XX a    XXX.XX   XX.XX a
     6        XXX.XX   XX.XX a    XXX.XX   XX.XX a
     T        XXX.XX   XX.XX a    XXX.XX   XX.XX a
```

```
FOOTING ANALYSIS (SERVICE LOADS) - WITHOUT VERTICAL COMPONENT OF LL SURCHARGE
FOOTING ANALYSIS (FACTORED LOADS) - WITHOUT VERTICAL COMPONENT OF LL SURCHARGE
AASHTO SUM   BAL.   SUM   O.T.  TOE TO  FOOTING PRES.
GROUP   V   MOMENT   H   MOMENT RESULT    TOE    HEEL
  1   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  2   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  3   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  4   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  5   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  6   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  T   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX

AASHTO     TOE      TOE        HEEL     HEEL
GROUP     MOMENT   SHEAR @    MOMENT   SHEAR @
  1       XXX.XX   XX.XX a    XXX.XX   XX.XX a
  2       XXX.XX   XX.XX a    XXX.XX   XX.XX a
  3       XXX.XX   XX.XX a    XXX.XX   XX.XX a
  4       XXX.XX   XX.XX a    XXX.XX   XX.XX a
  5       XXX.XX   XX.XX a    XXX.XX   XX.XX a
  6       XXX.XX   XX.XX a    XXX.XX   XX.XX a
  T       XXX.XX   XX.XX a    XXX.XX   XX.XX a
```

Footing Analysis – Pile Footings:

```
FOOTING ANALYSIS (SERVICE LOADS) - WITH VERTICAL COMPONENT OF LL SURCHARGE
FOOTING ANALYSIS (FACTORED LOADS) - WITH VERTICAL COMPONENT OF LL SURCHARGE

AASHTO SUM   BAL.   SUM   O.T.  ROW 1     PILE LOAD
GROUP   V   MOMENT   H   MOMENT TO RES   FRONT  BACK
  1   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  2   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  3   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  4   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  5   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  6   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  T   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX

AASHTO     TOE      TOE        HEEL     HEEL
GROUP     MOMENT   SHEAR @    MOMENT   SHEAR @
  1       XXX.XX   XX.XX a    XXX.XX   XX.XX a
  2       XXX.XX   XX.XX a    XXX.XX   XX.XX a
  3       XXX.XX   XX.XX a    XXX.XX   XX.XX a
  4       XXX.XX   XX.XX a    XXX.XX   XX.XX a
  5       XXX.XX   XX.XX a    XXX.XX   XX.XX a
  6       XXX.XX   XX.XX a    XXX.XX   XX.XX a
  T       XXX.XX   XX.XX a    XXX.XX   XX.XX a

FOOTING ANALYSIS (FACTORED LOADS) - WITHOUT VERTICAL COMPONENT OF LL SURCHARGE

AASHTO SUM   BAL.   SUM   O.T.  ROW 1     PILE LOAD
GROUP   V   MOMENT   H   MOMENT TO RES   FRONT  BACK
  1   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  2   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  3   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  4   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  5   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  6   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
  T   XX.XX XXX.XX XX.XX XXX.XX XX.XX  XXX.XX XXX.XX
```

```
AASHTO     TOE       TOE        HEEL     HEEL
GROUP     MOMENT    SHEAR @    MOMENT   SHEAR @
  1       xxx.xx    xx.xx a    xxx.xx   xx.xx a
  2       xxx.xx    xx.xx a    xxx.xx   xx.xx a
  3       xxx.xx    xx.xx a    xxx.xx   xx.xx a
  4       xxx.xx    xx.xx a    xxx.xx   xx.xx a
  5       xxx.xx    xx.xx a    xxx.xx   xx.xx a
  6       xxx.xx    xx.xx a    xxx.xx   xx.xx a
  T       xxx.xx    xx.xx a    xxx.xx   xx.xx a
```

Footing Analysis – Pedestal Footings:

```
   FOOTING ANALYSIS (SERVICE LOADS)
   FOOTING ANALYSIS (FACTORED LOADS)
   STRUCTURE ABOVE PEDESTAL - WITH VERTICAL COMPONENT OF LL SURCHARGE

                                  MOMENT     MOMENT    SHEAR AT DIST
         AASHTO          UNIFORM  BETWEEN     OVER      D FROM FACE
         GROUP    SUM V   LOAD   PEDESTALS  PEDESTAL    OF PEDESTAL
            1     xx.xx   xx.xxx  xxx.xx     xxx.xx        xx.xx
            2     xx.xx   xx.xxx  xxx.xx     xxx.xx        xx.xx
            3     xx.xx   xx.xxx  xxx.xx     xxx.xx        xx.xx
            4     xx.xx   xx.xxx  xxx.xx     xxx.xx        xx.xx
            5     xx.xx   xx.xxx  xxx.xx     xxx.xx        xx.xx
            6     xx.xx   xx.xxx  xxx.xx     xxx.xx        xx.xx
            T     xx.xx   xx.xxx  xxx.xx     xxx.xx        xx.xx
```

Footing Design Summary – Spread Footings:

```
FOOTING DESIGN - WITH AND WITHOUT VERTICAL COMPONENT OF LL SURCHARGE

FOOTING   FOOTING                               EFFECTIVE DEPTH
WIDTH    THICKNESS   TOE PROJ   HEEL PROJ          TOE     HEEL
xx.xx      x.xx       xx.xx      xx.xx           x.xxx    x.xxx

ULT SHEAR   SHEAR CAP   ULT SHEAR   SHEAR CAP   TRANSVERSE REINFORCEMENT
   TOE         TOE         HEEL        HEEL         TOE-BOT    HEEL-TOP
 xx.xxx      xx.xxx      xx.xxx      xx.xxx          x.xx       x.xx
```

Footing Design Summary – Pile Footings:

```
FOOTING DESIGN - WITH AND WITHOUT VERTICAL COMPONENT OF LL SURCHARGE

FOOTING   FOOTING                               EFFECTIVE DEPTH
WIDTH    THICKNESS   TOE PROJ   HEEL PROJ          TOE     HEEL
xx.xx      x.xx       xx.xx      xx.xx           x.xxx    x.xxx

ULT SHEAR  SHEAR CAP  ULT SHEAR  SHEAR CAP  TRANS REINFORCEMENT  LONGITUDINAL
   TOE        TOE        HEEL       HEEL    TOE-BOT   HEEL-TOP   REINFORCEMENT
 xx.xxx     xx.xxx     xx.xxx     xx.xxx    x.xx      x.xx            x.xx

LONGITUDINAL MOMENT CALCULATIONS - WITH VERTICAL COMPONENT OF LL SURCHARGE
GROUP  a GOVERNS

MAX UNIFORM LOAD (w)          = xxx.xxx K/FT
MAX UNIFORM SERVICE LOAD (w) = xxx.xxx K/FT
MAX PILE SPACING              =   xx.xx FEET
MAX LONGITUDINAL MOMENT       =  xxx.xx K-FT
MAX LONG. MOMENT (SERVICE)    =  xxx.xx K-FT
```

```
                          PILE PATTERN
                          ------------
          ROW      BATTER     DISTANCE    SPACING   % BATTERED
           i     x.x ON 12     xx.xx       xx.xx      xxx.x
           i        VERT       xx.xx       xx.xx      xxx.x

     C.G. OF PILES xx.xx FT. FROM TOE    I OF PILES PER FOOT xx.xxx
     PILE DENSITY x.xxxx PILES PER FOOT
```

Footing Design Summary – Pedestal Footings:

```
FOOTING DESIGN - WITH AND WITHOUT VERTICAL COMPONENT OF LL SURCHARGE

FOOTING   FOOTING                         EFFECTIVE DEPTH
WIDTH   THICKNESS   TOE PROJ   HEEL PROJ     POS    NEG
xx.xx     x.xx       xx.xx      xx.xx       x.xxx   x.xxx

ULTIMATE   SHEAR  LONGITUDINAL REINFORCEMENT
 SHEAR   CAPACITY     POS-BOT   NEG-TOP
xx.xxx    xx.xxx       x.xxx     x.xxx


                             PEDESTAL DIMENSIONS
                             -------------------
                               OFFSET    OFFSET    FRONT   TOTAL
          WIDTH  THICKNESS   FROM TOE  FROM HEEL  HEIGHT  HEIGHT
          xx.xx    xx.xx      xx.xx      xx.xx    xx.xx   xx.xx


LONGITUDINAL MOMENT CALCULATIONS - WITH VERTICAL COMPONENT OF LL SURCHARGE
POSITIVE (BOTTOM) - GROUP  a GOVERNS
NEGATIVE (TOP) - GROUP  a GOVERNS

MAX UNIFORM LOAD (w)          =  xx.xxx K/FT
MAX UNIFORM SERVICE LOAD (w) =  xx.xxx K/FT
MAX LONGITUDINAL MOMENT       =  xxx.xx K-FT
MAX LONG. MOMENT (SERVICE)    =  xxx.xx K-FT

LONGITUDINAL MOMENT CALCULATIONS - WITH VERTICAL COMPONENT OF LL SURCHARGE
POSITIVE (BOTTOM) - GROUP  a GOVERNS
NEGATIVE (TOP) - GROUP  a GOVERNS

MAX UNIFORM LOAD (w)          =  xx.xxx K/FT
MAX UNIFORM SERVICE LOAD (w) =  xx.xxx K/FT
MAX LONGITUDINAL MOMENT       =  xxx.xx K-FT
MAX LONG. MOMENT (SERVICE)    =  xxx.xx K-FT

MAXIMUM SHEAR AT A DISTANCE D FROM THE FACE OF PEDESTAL
WITH VERTICAL COMPONENT OF LL SURCHARGE - GROUP  a GOVERNS

MAXIMUM SHEAR AT PEDESTAL     =   xx.xx K
```

Stem Design:

```
                              STEM ANALYSIS
                              -------------

DESIGN OF STEM SECTION AT xx.xx FT FROM TOP

AASHTO GROUP (SERVICE)    1      2      3      4      5      6      T
MOMENT                 xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx
AXIAL FORCE            xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx
SHEAR                  xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx

AASHTO GROUP (FACTORED)   1      2      3      4      5      6      T
MOMENT (BD=1.0)        xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx
AXIAL FORCE (BD=1.0)   xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx
MOMENT (BD=0.75)       xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx
AXIAL FORCE (BD=0.75)  xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx
SHEAR                  xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx xxx.xx

 SECTION   ULTIMATE    SHEAR   BACK FACE
THICKNESS    SHEAR    CAPACITY    REINF
 xx.xxx     xx.xxx     xx.xxx     xx.xxx
```

Reinforcement Design Summary:

```
                SUMMARY OF STEEL DESIGN
                -----------------------

                     FOOTING DESIGN

              Top longitudinal reinforcement:

    REBAR    REBAR     ACTUAL   ALLOWABLE   ACTUAL
   SPACING   SIZE        As       STRESS    STRESS
    (in)              (sq in/ft)  (ksi)     (ksi)
     6        ii        x.xxx     xxx.xxx   xxx.xxx a
     9        ii        x.xxx     xxx.xxx   xxx.xxx a
    12        ii        x.xxx     xxx.xxx   xxx.xxx a
    15        ii        x.xxx     xxx.xxx   xxx.xxx a
    18        ii        x.xxx     xxx.xxx   xxx.xxx a

             Bottom longitudinal reinforcement:

    REBAR    REBAR     ACTUAL   ALLOWABLE   ACTUAL
   SPACING   SIZE        As       STRESS    STRESS
    (in)              (sq in/ft)  (ksi)     (ksi)
     6        ii        x.xxx     xxx.xxx   xxx.xxx a
     9        ii        x.xxx     xxx.xxx   xxx.xxx a
    12        ii        x.xxx     xxx.xxx   xxx.xxx a
    15        ii        x.xxx     xxx.xxx   xxx.xxx a
    18        ii        x.xxx     xxx.xxx   xxx.xxx a

              Top transverse reinforcement:

    REBAR    REBAR     ACTUAL   ALLOWABLE   ACTUAL
   SPACING   SIZE        As       STRESS    STRESS
    (in)              (sq in/ft)  (ksi)     (ksi)
     6        ii        x.xxx     xxx.xxx   xxx.xxx a
     9        ii        x.xxx     xxx.xxx   xxx.xxx a
    12        ii        x.xxx     xxx.xxx   xxx.xxx a
    15        ii        x.xxx     xxx.xxx   xxx.xxx a
    18        ii        x.xxx     xxx.xxx   xxx.xxx a
```

```
               Bottom transverse reinforcement:

      REBAR    REBAR     ACTUAL  ALLOWABLE   ACTUAL
     SPACING   SIZE        As      STRESS    STRESS
      (in)              (sq in/ft)  (ksi)     (ksi)
       6        ii        x.xxx    xxx.xxx   xxx.xxx a
       9        ii        x.xxx    xxx.xxx   xxx.xxx a
      12        ii        x.xxx    xxx.xxx   xxx.xxx a
      15        ii        x.xxx    xxx.xxx   xxx.xxx a
      18        ii        x.xxx    xxx.xxx   xxx.xxx a

S - INDICATES THAT SERVICEABILITY CRITERIA GOVERNS
* - INDICATES THAT AREA SELECTED IS LESS THAN REQUIRED BUT WITHIN TOLERANCE


                        STEM DESIGN


          Vertical reinforcement on back face:

      REBAR    REBAR     ACTUAL  ALLOWABLE   ACTUAL
     SPACING   SIZE        As      STRESS    STRESS
      (in)              (sq in/ft)  (ksi)     (ksi)

At Section #i, xx.xx feet from the top:
       6        ii        x.xxx    xxx.xxx   xxx.xxx a
       9        ii        x.xxx    xxx.xxx   xxx.xxx a
      12        ii        x.xxx    xxx.xxx   xxx.xxx a
      15        ii        x.xxx    xxx.xxx   xxx.xxx a
      18        ii        x.xxx    xxx.xxx   xxx.xxx a

S - INDICATES THAT SERVICEABILITY CRITERIA GOVERNS
* - INDICATES THAT AREA SELECTED IS LESS THAN REQUIRED BUT WITHIN TOLERANCE



          OPTIMUM REBAR DESIGN
          --------------------


FOOTING:


 Top longitudinal reinforcement:
     Spacing       Rebar

       12.            ii
       18.            ii
       15.            ii
        9.            ii
        6.            ii
Bottom longitudinal reinforcement:
     Spacing       Rebar

       12.            ii
       18.            ii
       15.            ii
        9.            ii
        6.            ii
```

```
  Top transverse reinforcement:
     Spacing       Rebar

       12.            ii
       18.            ii
       15.            ii
        9.            ii
        6.            ii
 Bottom transverse reinforcement:
     Spacing       Rebar

       12.            ii
       18.            ii
       15.            ii
        9.            ii
        6.            ii


STEM:


  Here is the design of the vertical reinforcement
  in the back face of the stem.   For this design,
  the  spacing and rebar size are the same for the
  entire height of the wall.

  Vertical reinforcement on back of stem:
     Spacing       Rebar

       12.            ii
       18.            ii
       15.            ii
        9.            ii
        6.            ii

STEEL DESIGNS LISTED FROM MOST DESIRABLE TO LEAST OPTIMAL
```

7 EXAMPLE PROBLEMS

7.1 GENERAL

Four example problems have been included to aid users prepare data for their problems. Refer to INPUT DATA REQUIREMENTS for example problems as well as your specific problem. Example 1 and 2 are design problems and examples 3 and 4 are analysis problems.

7.2 EXAMPLE PROBLEM 1

7.2.1 Problem Description

This is an example of the design of an Abutment Type I on a pile footing using the Load Factor Design method. Figure 7.2.1 on page 7-3 shows the sketch of the structure.

7.2.2 Input

The following input lines are entered. Refer to the complete input data sheets shown in Figure 7.2.3 on page 7-5.

1. PROBLEM IDENTIFICATION

   One line of descriptive information has been entered.

2. CRITERIA

   a. DESIGN METHOD is “LF” for load factor design.

   b. A OR D is “D” for a design.

   c. TYPE is “1” for an Abutment Type I.

   d. FTG TYPE is “2” for a pile footing.

   e. PILE D is entered as 12.0 for HP12x53 piles.

f. EMBEDDED is “Y” indicating that the piles will be embedded at least 12 inches into the footing.

g. EQUIV FLUID PRESSURE DRY and SAT have been left blank, so the program will assume a default value of 35.0 for DRY and calculate a value for SAT since the backfill is level.

h. ALLOW SOIL PRESS OR AXIAL PILE CAPAC is entered as 5.0 kips/ft^2, which is the established bearing capacity of the given soil.

i. WATER LEVEL is entered as 1.75 feet – the permanent water level.

j. LIVE LOAD SURCH is the equivalent 2.0 feet height of fill, which is normally applied for highway bridges.

k. The compressive strengths of the concrete to be used are 3500 psi, 3000 psi and 3000 psi respectively for F’C BACKWALL, F’C SYSTEM AND F’C FTG (footing).

l. 50 grade steel is to be used (REBAR GRADE).

m. PILE OPT has been left blank, so the program will optimize to find the footing with the minimum pile density.

n. LATERAL PILE CAPAC has been entered as 3 tons.

o. REBAR DES is “Y” indicating that the REBAR DESIGN input should be read.

3. DIMENSIONS

Refer to the sketch in Figure 7.2.1 on page 7-3. All of the input items on this line of data are taken directly from the sketch. Note that the maximum toe projection is limited to 1.75 feet due to an adjacent pipeline running in front of the structure.

4. REBAR DESIGN

BAR LOC is “N” because the reinforcement is to be placed above the piles.

5. LOADING

Refer to Figure 7.2.2 on page 7-4 for the calculations used to compute the loading data.

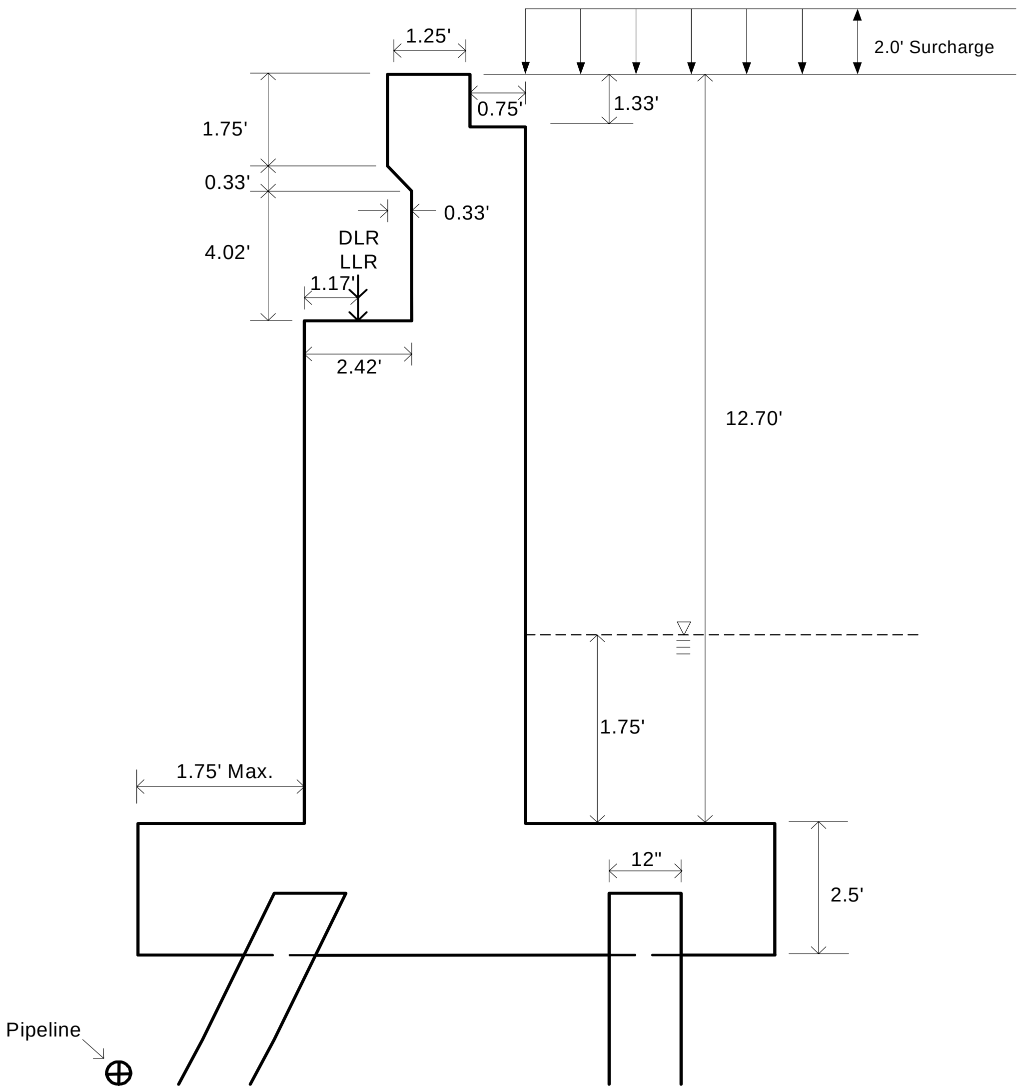


Figure 7.2.1 Example 1 - Sketch

Beam Length:	103.67'	Skew :	45 Degrees
Deck Width:	32.0'	Super Structure Depth (Beam + Slab + Para):	8.67'
Out-Out Parapets:	35.5'		
Abutment Length:	50.2'		

Dead Loads:

Beams:	$0.883\ x\ 6\ x\ 51.83$	$= 274.6$
Slab:	$0.625\ x\ 35.5\ x\ 51.83\ x\ 0.15$	$= 172.5$
Sup DL:	$0.03\ x\ 32.0\ x\ 51.83$	$= 49.8$
Forms:	$0.015\ x\ 35.5\ x\ 51.83$	$= 27.6$
Curb + Para:	$0.53\ x\ 2\ x\ 51.83$	$= 54.9$
End Dia:	$5.38\ x\ 3\ (Full\ Depth)$	$= 16.1$
End Dia:	$2.373\ x\ 12/10\ x\ 2\ (Partial\ Depth)$	$= 5.7$
Int Dia:	$2.373\ x\ 5$	$= 11.9$
Haunch	$1.29\ x\ 6$	$= 7.7$
		620.8 kips

$$DL\ \ REACT = 620.8/50.2 = 12.4\ kips/ft$$

Live Load: $Reaction = 65.5\ x\ 3\ x\ 0.9\ (3\ lanes) \quad = 176.9\ kips$

$$LL\ \ REACT = 176.9/50.2 = 3.5\ kips/ft$$

Wind on LL:

Lateral: Lateral Wind Load on Live Load = 0.10 kips/ft

$0.1\,x\ 103.67 = 10.4\ kips\ x\ \cos(45) \quad = 7.3\ kips$

Long: Longitudinal Wind Load on Live Load = 0.04 kips/ft

$0.04\ x\ 103.67 = 4.2\ kips\ x\ \cos(45) \quad = 3.0\ kips$

$$WIND\ ON\ \ LL = 10.3/50.2 = 0.21 kips/ft$$

Wind on Superstructure:

Lateral: $0.05\ x\ 8.67\ x\ 51.83 = 22.4\ kips\ x\ 0.707 \quad = 15.9\ kips$

Long: $0.012\ x\ 8.67\ x\ 51.83 = 5.39\ kips\ x\ 0.707 \quad = 3.8\ kips$

$$WIND\ ON\ \ SUPER = 19.7/50.2 = 0.39\ kips/ft$$

Longitudinal Force Due LL: Uniform Lane Load = 0.64 kips/ft
Concentrated Load for Lane Load = 18 kips

5% of Total Live Load (Lane Load) Reaction x cos(skew)

$$0.05\ x\ 0.9\ (3\ lanes)\ x\ [(103.67\ x\ 0.64)/2 + 18] = 6.91 kips\ x\ 0.707 = 4.9\ kips$$

$$LONG FORCE FROM LL = 4.9/50.2 = 0.10\ kips/ft$$

Longitudinal Temperature Force: $Delta = 0.0036\,x\ 103.67 = 0.3732$

Per Beam: (Shear Modulus/Pad Thickness) (Pad Area) (Delta)

Per Beam: $(0.110/1.875)\ (9\ x\ 22)\ (0.3732) = 4.335\ kips$

Total: $4.335\ x\ 6\ x\ \cos(45) \quad = 18.4\ kips$

$$TEMP\ FORCE = 18.4/50.2 = 0.37\ kips/ft$$

Neglect Wind on Substructure.
Neglect Upward Wind.
No Centrifugal Force.

Figure 7.2.2 Example 1 - Calculations

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Form 1 of 2

ABUT5
ABUTMENT AND RETAINING WALL

PROJECT IDENTIFICATION
EXAMPLE PROBLEM 1 - DESIGN OF ABUTMENT TYPE I ON PILES BY LFD
#
#

CRITERIA

DESIGN METHOD (1)	A OR D (3)	TYPE (4)	FTG TYPE (5)	PILE D (6)	EMBEDDED (9)	PILE ROWS (10)	R OR S (11)	EQUIV FLUID PRESSURE DRY (12)	EQUIV FLUID PRESSURE SAT (15)	COEFF OF FRICTION (18)	BACKFILL SLOPE (20)	ALLOW SOIL PRESS OR AXIAL PILE CAPAC (23)	WATER LEVEL BACK (28)	TOP FTG TO TOP EMBANK (32)	WATER LEVEL FRONT (36)	TOP WALL TO TOP BACKFILL (40)	LIVE LOAD SURCH (44)	TOP FTG TO ROCK SURFACE (48)	F'C BACK WALL (53)	F'C STEM (57)	F'C FTG (61)	REBAR GRADE (65)	PILE BATTER (67)	PILE OPT (69)	LATERAL PILE CAPAC (70)	K v (73)	REBAR DES (76)	OVTSTR (77)	80% RULE (78)	PILE ROW OPT (79)
LF	D	1	2	12.0	Y			.	.		.	140.40	1.75	.	.	.	2.00	.	3500	3000	3000	50	.		3.0	.	Y			

DIMENSIONS

TOP OF (BACK) WALL TO TOP OF FOOTING (1)	TOP THICKNESS (5)	PROJECTION TOE (8)	PROJECTION HEEL (12)	MAX PROJ T OR H (16)	MAX PROJ TOE OR HEEL (17)	MAX FTG WIDTH (21)	H1 (25)	H2 (28)	H3 (32)	H4 (35)	W 1 (39)	W 2 (42)	W 3 (45)	BW1 (48)	BW 2 (52)	FRONT FACE TO DL REACT (56)	BRIDGE SEAT WIDTH (60)	HEIGHT OF BACKWALL BATTER (64)	BACK BATTER (68)	FOOTING THICKNESS (70)	PILE COST (73)	FTG COST (77)
12.70	1.25	.	.	T	1.75	.	.	4.02	0.33	1.75	0.33	0.75	.	1.33	.	1.17	2.42	.		2.50		

REBAR DESIGN

TRIAL REBAR SPACING 1 (1)	2 (3)	3 (5)	4 (7)	5 (9)	BAR LOC (11)	BW EXPOS (12)	STEM EXPOS (13)	FTG EXPOS (14)	MIN As (15)	STEM REBAR COVER BACK VERT (19)	STEM BACK HORIZ (23)	STEM FRONT VERT (27)	STEM FRONT HORIZ (31)	FOOTING REBAR COVER TOP LONG (35)	FOOTING TOP TRANS (39)	FOOTING BOTTOM LONG (43)	FOOTING BOTTOM TRANS (47)
					N				.	.	.	.	.	.	.	.	.

NOTE: REBAR DESIGN DATA IS OPTIONAL. ENTER ONLY WHEN REBAR DES = Y.

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SHEET ...... OF ......

Figure 7.2.3 Example 1 - Input

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF INFORMATION SYSTEMS

Form 2 of 2

ABUT5
ABUTMENT AND RETAINING WALL

LOADING

DL REACT	LL REACT	WIND ON LL	WIND ON SUPER	WIND ON SUB	UPWARD WIND	LONG FORCE FROM L L	CENTER FORCE	TEMP FORCE	PARAPET OR EXTERNAL HORZ	PARAPET OR EXTERNAL DIST	PARAPET OR EXTERNAL VERT	PARAPET OR EXTERNAL DIST	BACKWALL LIVE LOAD VERT	BACKWALL LIVE LOAD HORZ	SEISMIC LOAD	ALLOW PILE UPLIFT
1	5	9	13	17	21	25	29	33	37	41	45	49	53	57	61	65
12.40	3.50	0.21	0.31	.	.	0.10	.	0.37	.	.	.	.	.	.	.	.

PEDESTAL DIMENSIONS

SPACING	THICKNESS	TOE TO PED FRONT	HEEL TO PED BACK	PED WIDTH	FRONT HEIGHT	TOTAL HEIGHT
1	5	8	12	16	20	24
.	.	.	.	.	.	.

NOTE: PEDESTAL DIMENSIONS DATA IS OPTIONAL. ENTER ONLY WHEN FTG TYPE = 3.

PILE PATTERN

ROW NO	PILE BATTER	DISTANCE BETWEEN ROWS	PILE SPACING	PERCENT ROW BATTERED
1	3	5	10	15
	.	.	.	.
	.	.	.	.
	.	.	.	.
	.	.	.	.

NOTE: PILE PATTERN DATA IS OPTIONAL. ENTER ONLY WHEN FTG TYPE = 2 AND A OR D = A (ANALYSIS)

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Figure 7.2.3 Example 1 - Input (cont.)

7.3 EXAMPLE PROBLEM 2

7.3.1 Problem Description

This is an example of the design of an abutment without a backwall on a spread footing using the Load Factor Design method. Figure 7.3.1 on page 7-9 shows the sketch of the structure.

7.3.2 Input

The following input lines are entered. Refer to the completed input data sheets shown in Figure 7.3.2 on page 7-10.

1. PROBLEM IDENTIFICATION

   Three lines of descriptive information have been entered.

2. CRITERIA

   a. DESIGN METHOD is “LF” for a load factor design.

   b. A OR D is “D” for a design.

   c. TYPE is “4” for an abutment without a backwall.

   d. FTG TYPE is “1” for a spread footing.

   e. R OR S is “S” for a footing founded on soil.

   f. EQIV FLUID PRESSURE DRY has been entered as 35.0 and the program will calculate a value for EQUIV FLUID PRESSURE SAT.

   g. COEFF OF FRICTION has been determined to be 0.45 for the given soil based on Table 5.8.1.5P(A) in DM4.

   h. ALLOW SOIL PRESS OR AXIAL PILE CAPAC is entered as 5.0 kips/ft^2, which is the established bearing capacity of the given soil.

   i. WATER LEVEL BACK is entered as 5.15 feet – the permanent water level in back of the abutment.

j. TOP FTG TO TOP EMBANK is 11.80 feet. This is equal to the stem height (10.0') plus the depth of superstructure (1.8').

k. WATER LEVEL FRONT is entered as 2.5 feet – the permanent water level in front of the abutment.

l. LIVE LOAD SURCH is the equivalent 2.0 feet height of fill, which is normally applied for highway bridges.

m. The compressive strengths of the concrete to be used are 3000 psi both F'C STEM and F'C FTG (footing). Note that F'C BACKWALL has been left blank because there is no backwall.

n. 50 grade steel is to be used (REBAR GRADE).

3. DIMENSIONS

Refer to the sketch in Figure 7.3.1 on page 7-9. All of the input items on this line of data are taken directly from the sketch. Note that a MAX FTG WIDTH of 15.00' has been entered. The program will stop if the design of the footing exceeds 15.0 feet.

4. LOADING

The various loads on this structure are calculated similar to the calculations shown for Example Problem 1.

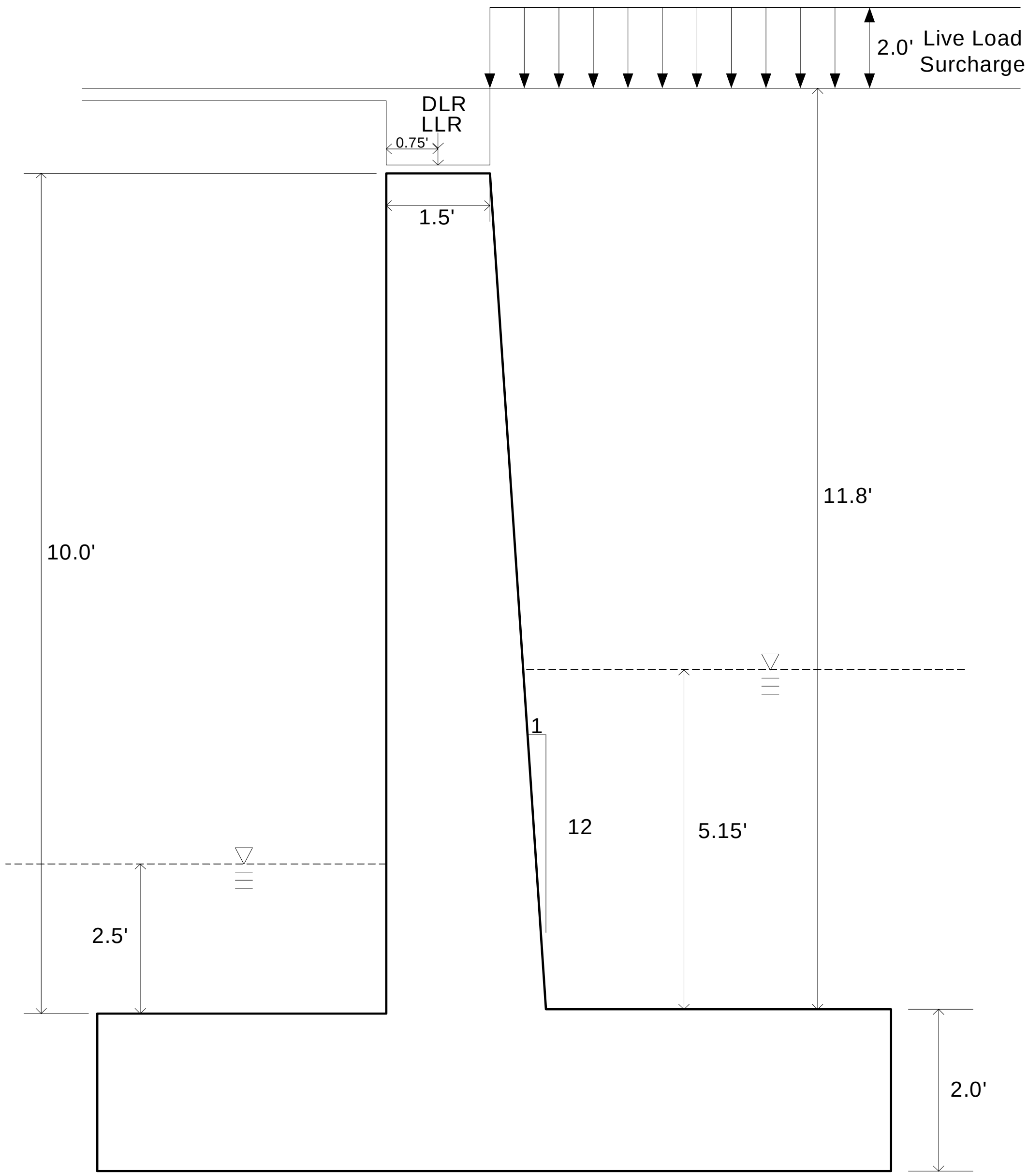

Figure 7.3.1 Example 2 - Sketch

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
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Form 1 of 2

ABUT5

ABUTMENT AND RETAINING WALL

PROJECT IDENTIFICATION

1	2
#	EXAMPLE PROBLEM 2 - LOAD FACTOR DESIGN TYPE
#	DESIGN OF ABUTMENT W/O BACKWALL ON SPREAD FOOTING
#	

CRITERIA

DESIGN METHOD	A OR D	TYPE	FTG TYPE	PILE D	EMBEDDED	PILE ROWS	R OR S	EQUIV FLUID PRESSURE DRY	EQUIV FLUID PRESSURE SAT	COEFF OF FRICTION	BACKFILL SLOPE	ALLOW SOIL PRESS OR AXIAL PILE CAPAC	WATER LEVEL BACK	TOP FTG TO TOP EMBANK	WATER LEVEL FRONT	TOP WALL TO TOP BACKFILL	LIVE LOAD SURCH	TOP FTG TO ROCK SURFACE	F'C BACK WALL	F'C STEM	F'C FTG	REBAR GRADE	PILE BATTER	PILE OPT	LATERAL PILE CAPAC	K v	REBAR DES	OVTSTR	80% RULE	PILE ROW OPT
1	3	4	5	6	9	10	11	12	15	18	20	23	28	32	36	40	44	48	53	57	61	65	67	69	70	73	76	77	78	79
LF	D	4	1	.			S	35.0	39.0	45	.	5.00	5.15	11.80	2.50	.	2.00	.		3000	3000	50	.		.	.				

DIMENSIONS

TOP OF (BACK) WALL TO TOP OF FOOTING	TOP THICKNESS	PROJECTION TOE	PROJECTION HEEL	MAX PROJ T OR H	MAX PROJ TOE OR HEEL	MAX FTG WIDTH	H1	H2	H3	H4	W 1	W 2	W 3	BW1	BW 2	FRONT FACE TO DL REACT	BRIDGE SEAT WIDTH	HEIGHT OF BACKWALL BATTER	BACK BATTER	FOOTING THICKNESS	PILE COST	FTG COST
1	5	8	12	16	17	21	25	28	32	35	39	42	45	48	52	56	60	64	68	70	73	77
10.00	1.50	.	.		12.00	.	.	.	.	.	.	.	.	.	.	0.75	.	.	12	2.00		

REBAR DESIGN

TRIAL REBAR SPACING 1	2	3	4	5	BAR LOC	BW EXPOS	STEM EXPOS	FTG EXPOS	MIN As	STEM REBAR COVER BACK VERT	STEM REBAR COVER BACK HORIZ	STEM REBAR COVER FRONT VERT	STEM REBAR COVER FRONT HORIZ	FOOTING REBAR COVER TOP LONG	FOOTING REBAR COVER TOP TRANS	FOOTING REBAR COVER BOTTOM LONG	FOOTING REBAR COVER BOTTOM TRANS
1	3	5	7	9	11	12	13	14	15	19	23	27	31	35	39	43	47
									.	.	.	.	.	.	.	.	.

NOTE: REBAR DESIGN DATA IS OPTIONAL. ENTER ONLY WHEN REBAR DES = Y.

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Figure 7.3.2 Example 2 - Input

Form 2 of 2

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF INFORMATION SYSTEMS

ABUT5
ABUTMENT AND RETAINING WALL

LOADING

DL REACT	LL REACT	WIND ON LL	WIND ON SUPER	WIND ON SUB	UPWARD WIND	LONG FORCE FROM L L	CENTER FORCE	TEMP FORCE	PARAPET OR EXTERNAL HORZ	PARAPET OR EXTERNAL DIST	PARAPET OR EXTERNAL VERT	PARAPET OR EXTERNAL DIST	BACKWALL LIVE LOAD VERT	BACKWALL LIVE LOAD HORZ	SEISMIC LOAD	ALLOW PILE UPLIFT
1	5	9	13	17	21	25	29	33	37	41	45	49	53	57	61	65
5.38	3.44	0.10	0.12	0.30	0.17	0.13	.	0.79	.	.	.	.	.	.	.	.

PEDESTAL DIMENSIONS

SPACING	THICKNESS	TOE TO PED FRONT	HEEL TO PED BACK	PED WIDTH	FRONT HEIGHT	TOTAL HEIGHT
1	5	8	12	16	20	24
.	.	.	.	.	.	.

NOTE: PEDESTAL DIMENSIONS DATA IS OPTIONAL. ENTER ONLY WHEN FTG TYPE = 3.

PILE PATTERN

ROW NO	PILE BATTER	DISTANCE BETWEEN ROWS	PILE SPACING	PERCENT ROW BATTERED
1	3	5	10	15
	.	.	.	.
	.	.	.	.
	.	.	.	.
	.	.	.	.

NOTE: PILE PATTERN DATA IS OPTIONAL. ENTER ONLY WHEN FTG TYPE = 2 AND A OR D = A (ANALYSIS)

PREPARED BY.. DATE ..../........../.......... SHEET ...... OF ......

Figure 7.3.2 Example 2 - Input (cont.)

7.4 EXAMPLE PROBLEM 3

7.4.1 Problem Description

This is an example of the analysis of a retaining wall on a pile footing using the Service Load method. Figure 7.4.1 on page 7-15 shows the sketch of the structure. Please note that the analysis shows that this retaining wall fails the lateral resistance check and thus could not be used as a good design. This example is selected for illustration purpose only.

7.4.2 Input

The following input lines are entered. Refer to the complete input data sheets shown in Figure 7.4.2 on page 7-16.

1. PROBLEM IDENTIFICATION

   Two lines of descriptive information have been entered.

2. CRITERIA

   a. DESIGN METHOD is “SL” for service load method.

   b. A OR D is “A” for analysis

   c. TYPE is “3” for a retaining wall.

   d. FTG TYPE is “2” for a pile footing.

   e. PILE D is entered as 12.0 for twelve-inch diameter circular piles.

   f. PILE ROWS is 2 for two rows of piles.

   g. EQUIV FLUID PRESSURE DRY and SAT have deliberately been left blank. The program will automatically computer the values for these items based on the table for Soil Type 1 in DM4.

   h. BACKFILL SLOPE is entered as 2.0 for a 2:1 slope.

   i. WATER LEVEL is entered as 1.75 feet – the permanent water level.

j. TOP FTG TO TOP EMBANK is 14.00 feet. This is measured as shown in Figure 7.4.1 on page 7-15.

k. TOP WALL TO TOP BACKFILL is 1.00 feet. This is measured from the top of the wall down to the toe of the slope and is shown in Figure 7.4.1 on page 7-15.

l. LIVE LOAD SURCH is the equivalent 1.0 feet height of fill.

m. The compressive strengths of the concrete to be used are 3000 psi both F'C STEM and F'C FTG (footing), the defaults when left blank.

n. 60 grade steel is desired (REBAR GRADE) which is the default when not entered.

o. LATERAL PILE CAPAC is entered as 3 tons.

p. Kv has deliberately been left blank. The program will automatically compute this value based on the tables for soil type 1 in DM4.

q. REBAR DES is "Y" to denote that the optional REBAR DESIGN line of data will be entered for this problem.

r. 80% RULE is "Y" to denote that the program should calculate the lateral resistance of the pile group by adding the horizontal components of pile loads (axial) of all battered piles and indicate the lateral resistance as a percent of applied horizontal loads.

3. DIMENSIONS

Refer to the sketch in Figure 7.4.1 on page 7-15. All of the input items on this line of data are taken directly from the sketch.

4. REBAR DESIGN

This data has been entered because the reinforcement is to be placed above the piles and the values for the rebar covers in the bottom of the footing are not the same as the defaults. BAR LOC is "N" and FOOTING REBAR COVER BOTTOM LONG and TRANS have been entered as 4.5 and 3.5 respectively. All other items on this line have been let blank and the defaults will be assumed.

5. LOADING

There is a railing attached to the top of the wall and it must be applied as an external load.

a. PARAPET OR EXTERNAL VERT has been entered as 0.05 kips because the weight of railing is 50 lbs/ft.

b. PARAPET OR EXTERNAL DIST has been entered as 0.67 feet, placing the load at 8 inches from the front face of the wall

6. PILE PATTERN

This structure is to be founded on two rows of piles with the front row battered 3 on 12 and piles spaced as shown at the bottom of Figure 7.4.1 on page 7-15. Two lines of input are entered, one for each row of piles.

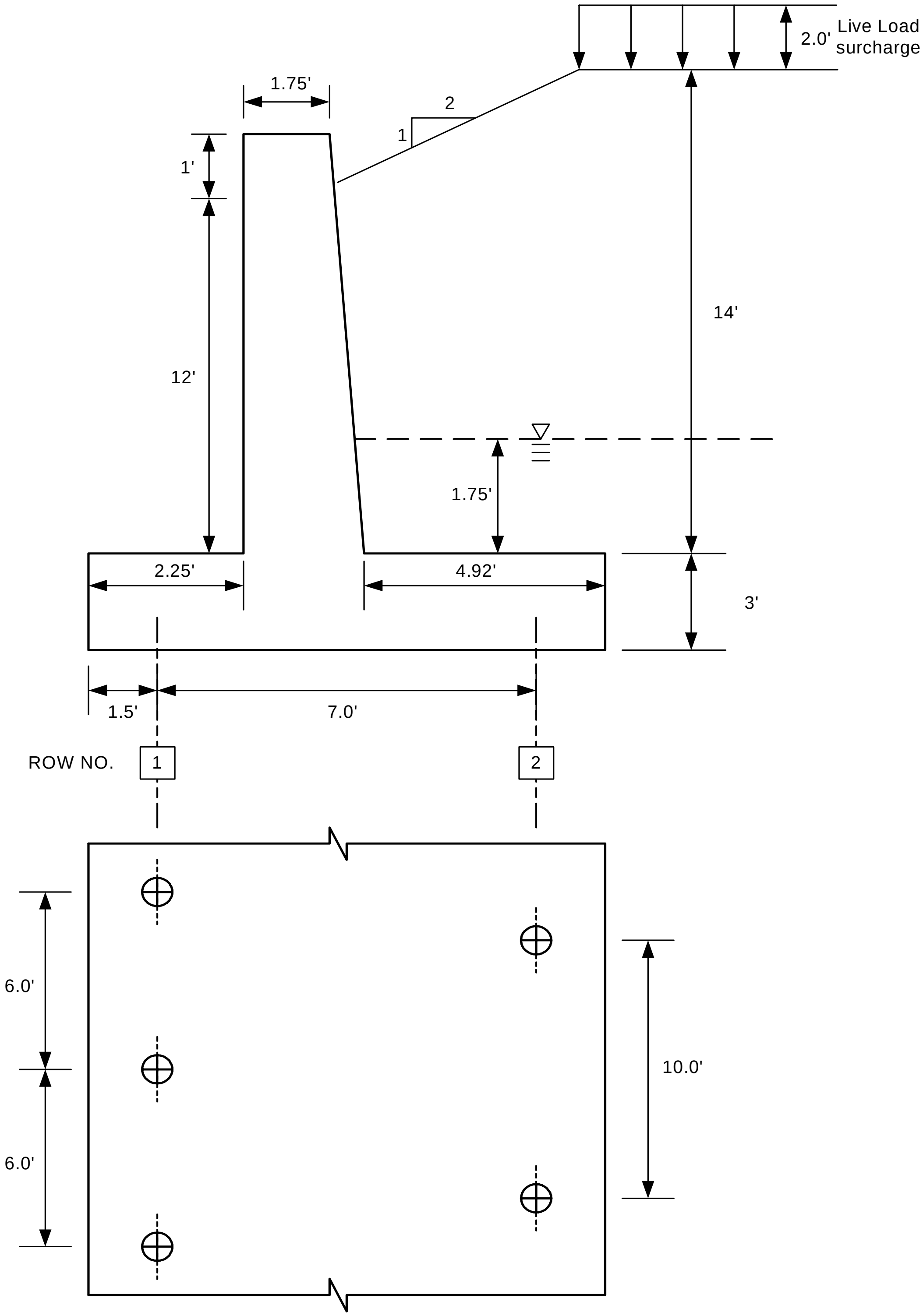

Figure 7.4.1 Example 3 - Sketch

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
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Form 1 of 2

ABUT5
ABUTMENT AND RETAINING WALL

PROJECT IDENTIFICATION

1	2
#	EXAMPLE PROBLEM 3 - ANALYSIS PROBLEM
#	ANALYSIS OF WINGWALL ON PILES BY SERVICE LOAD DESIGN
#	

CRITERIA

DESIGN METHOD	A OR D	TYPE	FTG TYPE	PILE D	EMBEDDED	PILE ROWS	R OR S	EQUIV FLUID PRESSURE DRY	EQUIV FLUID PRESSURE SAT	COEFF OF FRICTION	BACKFILL SLOPE	ALLOW SOIL PRESS OR AXIAL PILE CAPAC	WATER LEVEL BACK	TOP FTG TO TOP EMBANK	WATER LEVEL FRONT	TOP WALL TO TOP BACKFILL	LIVE LOAD SURCH	TOP FTG TO ROCK SURFACE	F'C BACK WALL	F'C STEM	F'C FTG	REBAR GRADE	PILE BATTER	PILE OPT	LATERAL PILE CAPAC	K v	REBAR DES	OVTSTR	80% RULE	PILE ROW OPT
1	3	4	5	6	9	10	11	12	15	18	20	23	28	32	36	40	44	48	53	57	61	65	67	69	70	73	76	77	78	79
SL	A	3	2	1.20	2						2.0	1400.0	1.75	14.00		1.00	2.00								3.0		Y	Y	Y	

DIMENSIONS

TOP OF (BACK) WALL TO TOP OF FOOTING	TOP THICKNESS	PROJECTION TOE	PROJECTION HEEL	MAX PROJ T OR H	MAX PROJ TOE OR HEEL	MAX FTG WIDTH	H1	H2	H3	H4	W 1	W 2	W 3	BW1	BW 2	FRONT FACE TO DL REACT	BRIDGE SEAT WIDTH	HEIGHT OF BACKWALL BATTER	BACK BATTER	FOOTING THICKNESS	PILE COST	FTG COST
1	5	8	12	16	17	21	25	28	32	35	39	42	45	48	52	56	60	64	68	70	73	77
13.00	1.75	2.25	4.92																12	3.00		

REBAR DESIGN

TRIAL REBAR SPACING 1	2	3	4	5	BAR LOC	BW EXPOS	STEM EXPOS	FTG EXPOS	MIN As	STEM REBAR COVER BACK VERT	STEM REBAR COVER BACK HORIZ	STEM REBAR COVER FRONT VERT	STEM REBAR COVER FRONT HORIZ	FOOTING REBAR COVER TOP LONG	FOOTING REBAR COVER TOP TRANS	FOOTING REBAR COVER BOTTOM LONG	FOOTING REBAR COVER BOTTOM TRANS
1	3	5	7	9	11	12	13	14	15	19	23	27	31	35	39	43	47
					N											4.50	3.50

NOTE: REBAR DESIGN DATA IS OPTIONAL. ENTER ONLY WHEN REBAR DES = Y.

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Figure 7.4.2 Example 3 - Input

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ABUT5
ABUTMENT AND RETAINING WALL

LOADING

DL REACT	LL REACT	WIND ON LL	WIND ON SUPER	WIND ON SUB	UPWARD WIND	LONG FORCE FROM L L	CENTER FORCE	TEMP FORCE	PARAPET OR EXTERNAL				BACKWALL LIVE LOAD		SEISMIC LOAD	ALLOW PILE UPLIFT
									HORZ	DIST	VERT	DIST	VERT	HORZ		
1	5	9	13	17	21	25	29	33	37	41	45	49	53	57	61	65
.	.	.	.	.	.	.	.	.	.	.	0.05	0.67	.	.	.	.

PEDESTAL DIMENSIONS

SPACING	THICKNESS	TOE TO PED FRONT	HEEL TO PED BACK	PED WIDTH	FRONT HEIGHT	TOTAL HEIGHT
1	5	8	12	16	20	24
.	.	.	.	.	.	.

NOTE: PEDESTAL DIMENSIONS DATA IS OPTIONAL. ENTER ONLY WHEN FTG TYPE = 3.

PILE PATTERN

ROW NO	PILE BATTER	DISTANCE BETWEEN ROWS	PILE SPACING	PERCENT ROW BATTERED
1	3	5	10	15
1	3.0	1.50	6.00	100.0
2	.	7.00	10.00	.
	.	.	.	.
	.	.	.	.

NOTE: PILE PATTERN DATA IS OPTIONAL. ENTER ONLY WHEN FTG TYPE = 2 AND A OR D = A (ANALYSIS)

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Figure 7.4.2 Example 3 - Input (cont.)

7.5 EXAMPLE PROBLEM 4

7.5.1 Problem Description

This is an example of the analysis of an abutment without a backwall on a pedestal footing using the Load Factor Design method. Figure 7.5.1 on page 7-20 shows the sketch of the structure.

7.5.2 Input

The following input lines are entered. Refer to the complete input data sheets shown in Figure 7.5.2 on page 7-21.

1. PROBLEM IDENTIFICATION

   Three lines of descriptive information have been entered.

2. CRITERIA

   a. DESIGN METHOD is “LF” for load factor design.

   b. A OR D is “A” for an analysis.

   c. TYPE is “4” for an abutment without a backwall.

   d. FTG TYPE is “3” for a pedestal footing.

   e. EQUIV FLUID PRESSURE DRY has been entered as 35.0. There is no water level, so SAT is not entered.

   f. ALLOW SOIL PRESS OR AXIAL PILE CAPAC is entered as 10.0 kips/ft^2, which is the established bearing capacity of the surface on which the pedestal sits.

   g. TOP FTG TO TOP EMBANK is 11.06 feet. This is equal to the stem height (7.57’) plus the depth of superstructure (3.49’).

   h. LIVE LOAD SURCH is the equivalent 2.0 feet height of fill, which is normally applied for highway bridges.

   i. The compressive strengths of the concrete to be used are 3000 psi both F’C STEM and F’C FTG (footing). Note that F’C BACKWALL has been left blank because there is no backwall.

j. 50-grade steel is to be used (REBAR GRADE).

3. DIMENSIONS

Refer to the sketch in Figure 7.5.1 on page 7-20. All of the input items on this line of data are taken directly from the sketch.

4. LOADING

The various loads on this structure are calculated similar to the calculations illustrated for Example Problem 1.

5. PEDESTAL DIMENSIONS

This line of data must be entered because this is an analysis problem. Refer to the sketch in Figure 7.5.1 on page 7-21. All of the input items on this line of data are taken directly from the sketch.

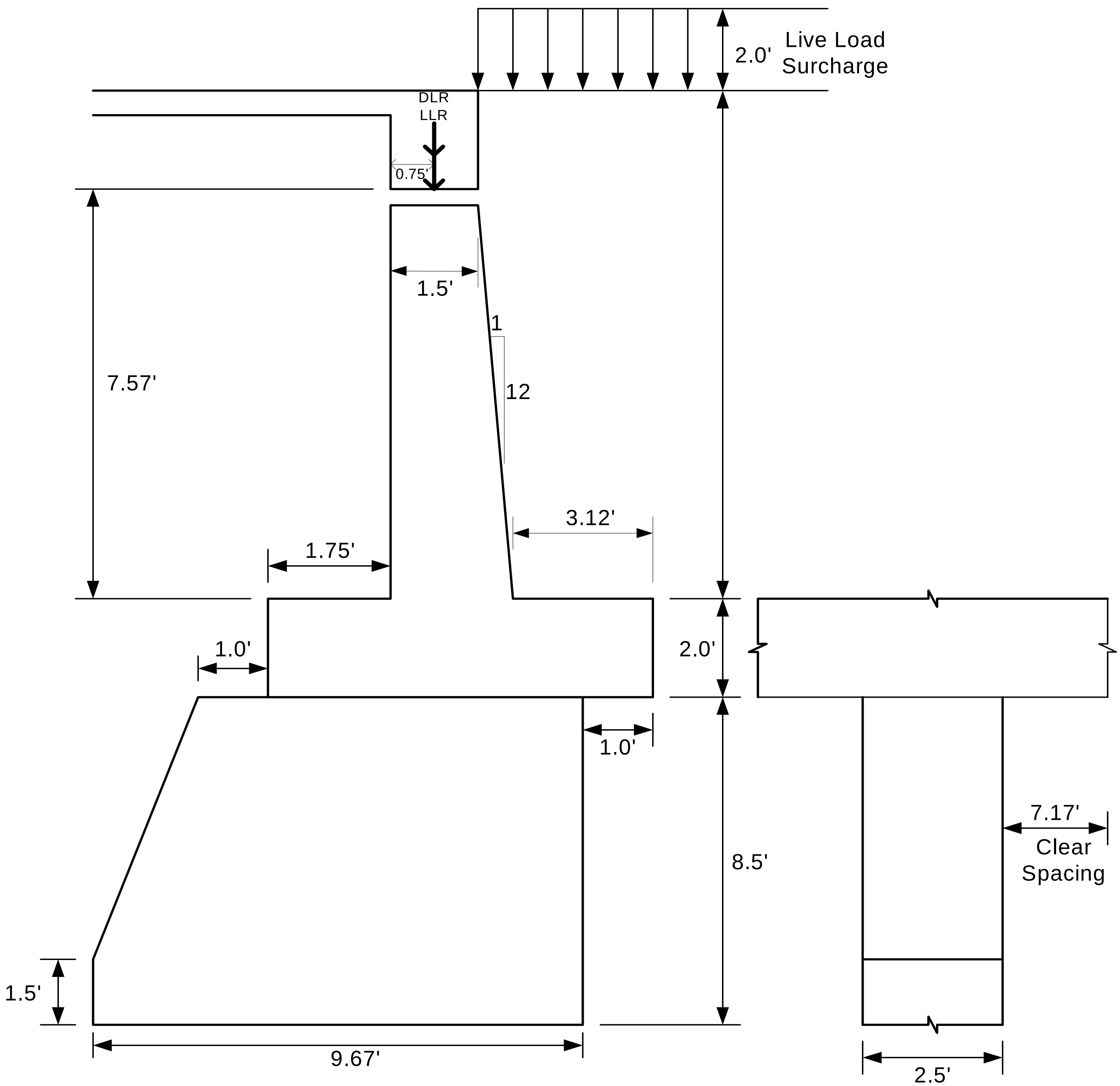

Figure 7.5.1 Example 4 - Sketch

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
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Form 1 of 2

ABUT5
ABUTMENT AND RETAINING WALL

PROJECT IDENTIFICATION

1	2
#	EXAMPLE PROBLEM 4 ANALYSIS PROBLEM
#	ABUTMENT W/O BACKWALL ON PEDESTALS
#	LOAD FACTOR METHOD

CRITERIA

DESIGN METHOD	A OR D	TYPE	FTG TYPE	PILE D	EMBEDDED	PILE ROWS	R OR S	EQUIV FLUID PRESSURE DRY	EQUIV FLUID PRESSURE SAT	COEFF OF FRICTION	BACKFILL SLOPE	ALLOW SOIL PRESS OR AXIAL PILE CAPAC	WATER LEVEL BACK	TOP FTG TO TOP EMBANK	WATER LEVEL FRONT	TOP WALL TO TOP BACKFILL	LIVE LOAD SURCH	TOP FTG TO ROCK SURFACE	F'C BACK WALL	F'C STEM	F'C FTG	REBAR GRADE	PILE BATTER	PILE OPT	LATERAL PILE CAPAC	K v	REBAR DES	OVTSTR	80% RULE	PILE ROW OPT
1	3	4	5	6	9	10	11	12	15	18	20	23	28	32	36	40	44	48	53	57	61	65	67	69	70	73	76	77	78	79
LF	A	4	3					35.0				10.00		11.06			2.00		30	00	3000	50								

DIMENSIONS

TOP OF (BACK) WALL TO TOP OF FOOTING	TOP THICKNESS	PROJECTION TOE	PROJECTION HEEL	T OR H	MAX PROJ TOE OR HEEL	MAX FTG WIDTH	H1	H2	H3	H4	W 1	W 2	W 3	BW1	BW 2	FRONT FACE TO DL REACT	BRIDGE SEAT WIDTH	HEIGHT OF BACKWALL BATTER	BACK BATTER	FOOTING THICKNESS	PILE COST	FTG COST
1	5	8	12	16	17	21	25	28	32	35	39	42	45	48	52	56	60	64	68	70	73	77
7.57	1.50	1.67	3.20													0.75			12	2.00		

REBAR DESIGN

TRIAL REBAR SPACING 1	2	3	4	5	BAR LOC	BW EXPOS	STEM EXPOS	FTG EXPOS	MIN As	STEM REBAR COVER BACK VERT	STEM REBAR COVER BACK HORIZ	STEM REBAR COVER FRONT VERT	STEM REBAR COVER FRONT HORIZ	FOOTING REBAR COVER TOP LONG	FOOTING REBAR COVER TOP TRANS	FOOTING REBAR COVER BOTTOM LONG	FOOTING REBAR COVER BOTTOM TRANS
1	3	5	7	9	11	12	13	14	15	19	23	27	31	35	39	43	47

NOTE: REBAR DESIGN DATA IS OPTIONAL. ENTER ONLY WHEN REBAR DES = Y.

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Figure 7.5.2 Example 4 - Input

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ABUT5
ABUTMENT AND RETAINING WALL

LOADING

DL REACT	LL REACT	WIND ON LL	WIND ON SUPER	WIND ON SUB	UPWARD WIND	LONG FORCE FROM L L	CENTER FORCE	TEMP FORCE	PARAPET OR EXTERNAL HORZ	PARAPET OR EXTERNAL DIST	PARAPET OR EXTERNAL VERT	PARAPET OR EXTERNAL DIST	BACKWALL LIVE LOAD VERT	BACKWALL LIVE LOAD HORZ	SEISMIC LOAD	ALLOW PILE UPLIFT
1	5	9	13	17	21	25	29	33	37	41	45	49	53	57	61	65
2.75	2.86	0.08	0.15	0.30	0.15	0.11	.	0.65	.	.	.	.	.	.	.	.

PEDESTAL DIMENSIONS

SPACING	THICKNESS	TOE TO PED FRONT	HEEL TO PED BACK	PED WIDTH	FRONT HEIGHT	TOTAL HEIGHT
1	5	8	12	16	20	24
7.17	2.00	1.00	1.00	11.00	1.50	8.50

NOTE: PEDESTAL DIMENSIONS DATA IS OPTIONAL. ENTER ONLY WHEN FTG TYPE = 3.

PILE PATTERN

ROW NO	PILE BATTER	DISTANCE BETWEEN ROWS	PILE SPACING	PERCENT ROW BATTERED
1	3	5	10	15
	.	.	.	.
	.	.	.	.
	.	.	.	.
	.	.	.	.

NOTE: PILE PATTERN DATA IS OPTIONAL. ENTER ONLY WHEN FTG TYPE = 2 AND A OR D = A (ANALYSIS)

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Figure 7.5.2 Example 4 - Input (cont.)

8 TECHNICAL QUESTIONS AND REVISION REQUESTS

This chapter contains reply forms to make it easier for users to convey their questions, problems or comments to the proper unit within the Department. General procedures for using these forms are given. Users should keep the forms in the manual as master copies, which can be reproduced as needed. They are also included as a Word template on the disk that has been provided for the program.

8.1 TECHNICAL QUESTIONS

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 this form or the information provided on this 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 completed form should be sent to the Bridge Quality Assurance Division (see form for complete address).

8.2 REVISION REQUESTS

This form is to be used to report suspected program malfunctions that may require revisions to the program. It can also be used 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 this form for processing.

This 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 Engineering Unit via mail, fax, or e-mail.

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ABUT5
TECHNICAL QUESTIONS

This form is to be used to ask questions on technical issues related to this engineering program. Questions on the interpretations of the design specifications as implemented in this program, why certain assumptions are made by the program and other questions not related to the operation of this program may be submitted using this form or by calling the telephone number listed in this form. Users are requested to read the User's Manual, LFD Specifications and DM-4 before submitting this form or calling to ask questions.

CONTACT PERSON: ____ DATE: ____________________
ORGANIZATION: ____ PHONE: ____________________
E-MAIL ADDRESS: ____ FAX: ____________________
PROGRAM VERSION: _________

Clearly state your question(s) and attach documentation you feel would be helpful in answering your question(s). If you require more space, use additional 8½ x 11 sheets of plain paper.

FORWARD COMPLETED FORM TO: Pennsylvania Dept. of Transportation
Bridge Quality Assurance Division
P.O. Box 3560
Harrisburg, PA 17105-3560
PHONE: (717) 787-2881
FAX: (717) 787-2882

FOR DEPARTMENT USE ONLY

RECEIVED BY: ________________ ASSIGNED TO: ___________________ DATE: _____________

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ABUT5
REVISION REQUEST

This form is to be used to 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: ____ FAX: ____________________
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 on a diskette. If you require more space, use additional 8½ x 11 sheets of plain paper.

FORWARD COMPLETED FORM TO: Pennsylvania Department of Transportation
Bureau of Information Systems, Engineering Unit
P. O. Box 8213, Harrisburg, PA 17105-8213
PHONE: (717) 783-8822
FAX: (717) 705-5529
E-MAIL: penndotbisengineer@state.pa.us

FOR DEPARTMENT USE ONLY

RECEIVED BY: ________________ ASSIGNED TO: ____________________ DATE: _____________