USER'S MANUAL FOR

LRFD BEARING PAD DESIGN AND ANALYSIS
(BPLRFD)

pennsylvania
DEPARTMENT OF TRANSPORTATION

Version 1.11.0.0

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USER'S MANUAL FOR
COMPUTER PROGRAM BPLRFD
LRFD BEARING PAD DESIGN AND
ANALYSIS VERSION 1.11.0.0

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September, 2023

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LRFD BEARING PAD DESIGN AND ANALYSIS

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SUMMARY OF OCTOBER 1998 REVISIONS – VERSION 1.1

BPLRFD Version 1.1 contains the following revisions:

1. Added two (2) new input parameters (Minimum Pad Thickness and Maximum Pad Length) to the GEO command to provide the user with additional design constraints for cases such as dapped prestressed beams.

2. Added three (3) new input parameters (DL1 Rotation Movement, DL2 Rotations Movement and LL Rotations Movement) to the EXP command to account for longitudinal movement due to dead load and live load rotations. These longitudinal movements are added to the thermal movement and the creep and shrinkage movement to determine the required pad thickness to satisfy the shear deformation and Method A anchorage design criteria.

3. Corrected the interior and exterior edge distances for prestressed beam with two pads in the system parameter files in accordance with BD-659 for SI units.

4. Corrected several input parameter upper and lower limits in the User's Manual to match the limits in the parameter file.

5. The example problems have been revised for the new input parameters and the User's Manual has been reprinted.

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SUMMARY OF SEPTEMBER 2000 REVISIONS – VERSION 1.2

BPLRFD Version 1.2 contains the following revisions:

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

2. The program has been converted to Digital Visual Fortran Version 6.0B compiler as a Win 32 application. It will run on Windows 95, Windows 98 and Windows NT Version 4.0 operating systems. It will not run under DOS 6.22 or below operating systems.

3. Geometry constraint checks were added for analysis runs.

4. A new input command, TOL, was added for entering construction rotational tolerances about the longitudinal and transverse axes of the bearing pad. The TOL command can be used for both simple span bearings and continuous span bearings. The command consists of two parameters, the construction tolerance about the transverse axis of the pad and the construction tolerance about the longitudinal axis of the pad, with the allowable input range of 0.0 to 0.005 radians. In previous versions of BPLRFD, a construction tolerance of 0.005 radians was automatically applied for simple spans of 30 m (100 ft). For continuous spans, the user had control over the application of the 0.005 radians construction tolerance by using parameters 2 and 3 of the CON command. These parameters have been removed from the CON command.

5. The exterior edge distance for prestressed box beams with two pads have been changed in the system parameter files in accordance with BD-653M for US units.

6. The program was revised to limit the design of pads with anchor dowels to expansion lengths of less than or equal to 15 m (50 ft) in accordance with DM-4 Section 14.7.6.4. A warning message is printed for analysis runs when this limit is violated.

7. The minimum thickness of the cover layer of a laminated pad was changed from 5mm to 7 mm(0.125" to 0.25").

8. The minimum dead load reaction is used when determining the required pad thickness for rotation. Previously the maximum dead load reaction was used.

9. The default for the "Minimum Pad Thickness" parameter of the GEO command was changed to 50 mm (2"). This was done to take advantage of the additional rotational capacity by laminated pads with this minimum thickness for spans less than 30 m or 100 ft (see DM-4 Section C14.7.5.3.1aP). In effect, this would eliminate any plain pad design. If a plain pad design is desired, an input value less than 30 mm (1.25") must be entered.

10. Consideration of creep shrinkage movement in the shear deformation check has been eliminated since the direction of movement is opposite from the longitudinal movement due to end rotation (see DM-4 Section

C14.7.5.3.4). Consequently, the "Shrinkage and Creep Movement" parameter of the EXP command was eliminated.

11. A new parameter, "Temperature Range for Substructure Design", was added and the "Temperature Range" parameter was renamed to "Temperature Range for Bearing Design" for the EXP command. The temperature range for bearing design is used to compute the thermal movement that is used to check the shear deformation criteria (see Section 3.8 of this manual) and to check the Method A anchorage criteria (see Section 3.8 of this manual). The temperature range for substructure design is used to compute the thermal movement that is used to compute the shear force induced by shear deformation (see Section 3.11 of this manual).

12. The two-pad design procedure for box beams was revised to allow pad location to vary from one-quarter of the Beam Bottom Width by an increment of 25 mm (1") toward the beam edge. This will allow pads that exceed initial geometric constraints to be analyzed again at a more favorable location. The maximum interior edge distances for prestressed box beams with two pads have been changed in the system parameter files to allow the pad location to move toward the edge of the beam controlled only by the minimum exterior distance.

13. A new input parameter, "Pad Location", was added to the ANA command. This parameter locates the pads for a two-pad bearing as the perpendicular distance from the edge of the beam to the centroid of each pad. This will allow a two-pad bearing with the pads located at points other than the beam width quarter points to be analyzed.

14. Two-pad designs using rectangular pads are now available for prestressed spread box beams.

15. The Method A anchorage check is done for two cases, dead load only and dead load plus live load.

16. A new parameter, "Minimum Live Load Reaction", was added to the LRX command. This parameter is used to compute the allowable shear force for the dead load plus live load case for the Method A anchorage check.

17. The example problems have been revised for the new input commands and parameters. The User's Manual has been revised to reflect the above program changes and all recent DM-4 revisions to the bearing pad criteria. The entire manual has been reprinted.

NOTE: Due to several input changes, input files created for Version 1.1 or earlier will not run under Version 1.2 without some minor modifications.

SUMMARY OF JULY 2005 REVISIONS - VERSION 1.3.0.0

Since the release of BPLRFD Version 1.2 several revision requests and user requested enhancements have been received. This release of BPLRFD Version 1.3.0.0 contains the following revisions:

1. The program has been enhanced to allow input files to be in a different directory than program executable. (Revision 009)

2. The file extension for the parameter definition file that contains various values for input parameters has been changed from .pdf to .pd to avoid association with Adobe Acrobat files. (Revision 011)

3. The contact information for Revision Requests in Chapter 9 has been updated. (Revision 012)

4. Construction or Pier Flexibility value is now included in the calculation of the Total DL+LL value for the Shear Deformations for Bearing Design output table. (Revision 013)

5. The minimum Live Load Reaction is now used to calculate the allowable horizontal shear force. The proper shear force is now used to display the correct message regarding the DL+LL Method A anchorage requirement under the "Detailed Specification Checks" section of the output. (Revision 014)

6. Several minor pagination revisions to the output file have been made. (Revision 015 and 021)

7. Additional compiler settings have been activated to trap divide by zero errors. (Revision 016)

8. Before exiting, the program will pause and require the user to press the enter key. This will allow the user to scroll back to view the runtime messages. (Revision 017)

9. A copyright notice has been added to the program output for use during beta testing. (Revision 018)

10. A design history file is now created for all design runs of the program and is intended for use in troubleshooting design failures. (Revision 020)

11. The DM-4 reference in Chapter 5 Section 5.8 has been changed to the correct section number. (Revision 022)

12. The interior minimum layer thickness for box beams has been changed to 0.375 in for US units for consistency in the system parameter file. (Revision 023)

13. The program has been converted to be a Windows DLL (Revision 025)

14. The User's Manual has been converted into Microsoft Word. (Revision 026)

15. The Engineering Assistant and BPLRFD User's Manual have been modified to allow negative LL reactions on the LRX command. (Revision 029)

16. The images used by Engineering Assistant now contain caption text to help identify the image. (Revision 031)

17. The example input files have been modified to eliminate all input warnings. (Revision 036)

18. The hole size for single pads with dowel rods has been increased to 2.375" or 60 mm. This is because, for adjacent box beams, a 1.25" (32 mm) hole is not large enough to allow for drilling a 2" (50 mm) hole in the substructure unit as specified in BD-656M. (Revision 038)

19. Bearing pads with holes are no longer allowed for analysis or design with prestressed spread box beams. Pads with holes are only allowed for prestressed adjacent box beams. (Revision 039)

SUMMARY OF SEPTEMBER 2007 REVISIONS - VERSION 1.4.0.0

Since the release of BPLRFD Version 1.3.0.0 several revision requests and user requested enhancements have been received. This release of BPLRFD Version 1.4.0.0 contains the following revisions and enhancements.

General Program Revisions

1. A new structure type for prestressed bulb-tee beams has been added to permit the program to handle larger allowable edge distances. Previously the input for a prestressed bulb-tee beam had to be entered using the prestressed I-beam structure type which used a smaller allowable edge distance which cause an inability to find a valid pad design (Request 055).

Input Revisions

2. The rotation parameters on the TOL command have been modified to issue a warning when a value is entered larger than the upper limit. Previously the program would stop with an error if the upper limit was exceeded (Request 043, 054).

3. The program has been revised to allow more than 256 characters on an input command line (Request 044).

User Manual Revisions

4. The User's Manual was modified to indicate when out of plane rotation values can be entered on the LLR command "Live Load Rotation About Longitudinal Axis of Pad" parameter (Request 048).

5. A typographical error has been corrected in reference to DM-4 in Section 6.6.5 of the User's Manual (Request 051).

6. A typographical error has been corrected in reference to DM-4 in Section 3.1 of the User's Manual (Request 056).

7. Typographical errors have been corrected in the Summary of Revisions for version 1.2 and in Section 3.9 of the User's Manual (Request 057).

Engineering Assistant Revisions

8. The superstructure type field on the CTL command in EngAsst has been revised so the Steel I-beam type is number 4 (Request 045).

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SUMMARY OF JANUARY 2010 REVISIONS - VERSION 1.5.0.0

Since the release of BPLRFD Version 1.4.0.0 several revision requests and user requested enhancements have been received. This release of BPLRFD Version 1.5.0.0 contains the following revisions and enhancements.

User's Manual Revisions

1. Chapter 9 of the user's manual has been updated for issues regarding the PennDOT Bureau Name. Two instances of "Engineering Unit" and one instance of "Bureau of Information Systems" have been replaced by "Engineering Software Section" and "Bureau of Business Solutions and Services", respectively (Request 063).

Input Revisions

2. The lower limits of the LRX command parameters 1 and 2, Maximum and Minimum Dead Load Reaction, have been changed from 0 kip to 0.1 kip to resolve a divide by zero error (Request 058).

3. Acceptable entries for the CTL command parameter 4, Superstructure Type, have been revised to only accept "IP", "BA", "BS", "IS", and "BT". The superstructure type must be entered as one of the five 2-letter options, as the numerical entries (1 through 5) are no longer supported by the program. **Pre-existing input files must be modified to accept the new 2-letter format** (Request 059 and Request 068).

4. As a result of a decision by the AASHTO Subcommittee on Bridges and Structures to no longer publish SI unit specifications, the program only supports US customary (US) units. The only acceptable entry for the CTL command parameter 1, System of Units, is "US" (Request 067).

Output Revisions

5. BPLRFD will now produce PDF versions of all output files in addition to the text-only files (Request 066).

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SUMMARY OF JANUARY 2013 REVISIONS - VERSION 1.6.0.0

Since the release of BPLRFD Version 1.5.0.0 several revision requests and user requested enhancements have been received. This release of BPLRFD Version 1.6.0.0 contains the following revisions and enhancements.

General Program Revisions

1. The program has been revised to include the Method B anchorage check for laminated bearing pads for expansion bearings. This check is done in addition to the existing Method A anchorage check. (Requests 076, 083)

2. The program has been revised to now indicate when a hole is not required in the output when a hole diameter is entered by the user. Previously, when a hole was not required, there was no message in the output confirming a hole was not required. (Request 080)

Input Revisions

3. The Minimum Live Load Reaction parameter on the LRX command has been revised to only be required for Continuous Spans. For Simple Spans the program will now automatically compute one-half the Maximum Live Load Reaction for this input parameter as per DM-4 14.7.6.4. Previously, the Minimum Live Load Reaction was required to be entered for Simple Spans. (Request 081)

Parameter File Revisions

4. The Maximum Pad Thickness has been increased to 8 inches. (Request 078)

5. The maximum compressive stress for steel reinforced elastomeric pads has been increased to 1.25 ksi. (Request 079)

Program Source Revisions

6. The BPLRFD program has been updated to the Intel Fortran Composer XE 2011 Compiler. (Request 073)

User's Manual Revisions

7. A typographical error in Section 3.14 of the Users Manual has been corrected. (Request 074)

8. The Compressive strain section of the UM has been updated to now indicate that the program utilizes coefficients for calculating compressive strain. (Request 077)

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SUMMARY OF APRIL 2015 REVISIONS - VERSION 1.7.0.0

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

General Program Revisions

1. The method of calling the engineering program DLL from the Engineering Assistant has been changed for compatibility with EngAsst v2.5.0.0 which uses Microsoft's .NET Framework, version 4.5. Because of this, BPLRFD will no longer work with EngAsst v2.4.0.6 or v2.4.0.9 unless the EngAsst "Edit / Run EXE – Command Window" option is selected. BPLRFD will no longer work with EngAsst v2.4.0.0 and earlier. (Request 088)

2. The BPLRFD program has been updated to compile with Intel Fortran XE 2013 SP1 Update 4 using Visual Studio 2012 Update 4. (Request 85)

Input Revisions

3. The upper limit and the default for the Maximum Pad Length parameter on the GEO command has been increased to 24 inches. Previously, the Maximum Pad Length was limited to 20 inches. (Request 087)

Output Revisions

4. The page layout of the output file has been enhanced to allow for more characters per page width and more lines per page in the PDF output file. The new layout has 91 characters per page width and 74 lines per page. (Request 092)

Program Source Revisions

5. The program has been revised to no longer apply the beta factor to plain bearing pads for the Method A design approach in accordance with the 2012 PennDOT Design Manual 4 and the 2010 AASHTO Bridge Design Specifications. (Request 091)

6. The program has been revised to summarize the Method A and Method B anchorage check results in the Recommended Pad Size output table for Design runs, and in the Inputted Pad Size table for Analysis runs. When either the Method A or Method B anchorage check fails a **District** Bridge Engineer warning is now printed indicating that a restraint system is required. Previously, the output could sometimes erroneously indicate that a restraint system was not required even though Method A anchorage was not satisfied. (Request 094)

Engineering Assistant Revisions

7. The Engineering Assistant field help has been updated to show complete information from Chapters 5 and 6 of the BPLRFD Users Manual. (Request 082)

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SUMMARY OF MAY 2018 REVISIONS - VERSION 1.8.0.0

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

General Programming Revisions

1. Minor program changes have been incorporated to allow BPLRFD to continue to be run from the PennDOT BRADD software (Request 095).

2. The program is now compiled with Intel Visual Fortran Parallel Studio XE 2017 Update 5 using Visual Studio 2017 (Request 103).

Program Input Revisions

3. The program now provides the user with the option to design a single pad for a box beam (BPD command). Previously, the program would start with a two pad design and only try a single pad design if a two pad design could not be found. As a result, it was often not possible to have the program design a single pad (Request 102).

4. The lower and upper limits of the ELASTOMER THICKNESS OF PLAIN PAD parameter on the ANA command have been changed to 0.75" and 1.25" respectively, and will cause a warning if a value outside of these bounds is entered. These limits correspond to the limits on plain pad thickness in DM-4 14.7.6.3.1aP. Additionally, the default value for MINIMUM PAD THICKNESS on the GEO command now depends on the pad type, with a default of 0.75" for plain pads and 2" for laminated pads (Request 108).

5. An input parameter for laminated bearing pad shim thickness has been added to the ANA command. **NOTE: this change requires revisions to all existing laminated pad analysis input files to select a shim thickness** (Request 112).

User's Manual Revisions

6. The command and parameter descriptions in User Manual Chapters 5 and 6 and the program configuration files for EngAsst have been revised to be consistent with the functioning of the program (Request 096).

7. User Manual Chapter 5 and the program configuration files for EngAsst were reviewed for documentation of commands and parameters that are no longer used by the program. There are no commands or parameters that are no longer used, so no changes to the User's Manual or configuration files were necessary (Request 097).

8. User Manual Chapter 4 has been revised to reflect the supported versions of Microsoft Windows and to property describe the Windows Start Menu folder containing the installed program (Request 100).

LRFD BEARING PAD DESIGN AND ANALYSIS

Specification Checking Revisions

9. A tolerance of 0.01" has been added to the minimum elastomer thickness comparison for shear and rotation to prevent BPLRFD from rejecting a bearing pad when the provided thickness is 0.01” smaller than the required thickness (Request 098).

10. The compressive stress resistance of the bearing pads specified in DM-4 14.7.6.3.2, is no longer divided by a beta factor. The beta factor was removed from the compressive stress resistance equation in the 2012 DM-4 but was never implemented in BPLRFD until now (Request 101).

11. The program has been revised to be consistent the AASHTO LRFD Specification, 7th Edition, and DM-4 2015 (Request 104).

12. The Method B anchorage check is no longer done for pads with dowels, because this check should be similar to the Method A anchorage check, which is only done for pads without dowels (Request 107).

13. The Method B anchorage check is no longer done for plain bearing pads, because the Method B specification checks only apply to steel-reinforced elastomeric bearings. In many cases, the Method B check was leading to program crashes for plain pads (Request 108).

14. The program will now remove the area of the hole in the bearing pad (when a hole is specified) for applied stress and compressive stress resistance calculations. In addition, the program will now always consider a hole in the bearing pad (for a single pad configuration) at the fixed end for the design of bearing pads for prestressed adjacent box beams (Request 109).

15. The program was not generating an error during analysis runs when the shape factor of a bearing pad layer is less than 3. The coefficients in the equation for calculation of strain in a bearing pad are interpolated from a table of values for shape factors from 3 to 12. The User's Manual has always stated that pads with a shape factor less than 3 would result in the program stopping, but this check has not been present for analysis runs. The program will now stop with a specification check failure for the analysis of bearing pads with a shape factor less than 3 (Request 111).

SUMMARY OF JUNE 2019 REVISIONS - VERSION 1.9.0.0

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

Program Input Revisions

1. Several new input consistency checks have been added to the ANA command to ensure consistency between the BPD command and ANA command, particularly when creating analysis input files from design run output (Request 113).

2. An input value for elastomer shear modulus has been added to the BPD command. This value can be used to supersede the shear modulus values corresponding to the pad hardness for Method B calculations (Request 120).

Program Output Revisions

3. The echo of the information from the system parameter file to the output file has been revised to add units to the values as well as adding more description to some of the values (Request 105).

4. The program design and analysis output now includes units for all values where it is appropriate (Request 106).

5. A warning will no longer print if the span length applicability limit from DM-4 14.7.6.4P is exceeded for the analysis of a bearing pad with a dowel at the fixed end of a box beam (Request 114).

6. The output for HORIZONTAL SHEAR FORCE DUE TO THERMAL MOVEMENT FOR SUBSTRUCTURE DESIGN now includes units and an advisory that the shear force is the total shear force from both pads when two pads are present (Request 115).

Specification Checking Revisions

7. The user now has the option to design or analyze the bearing pads using design Method B from the LRFD Specifications Section 14.7.5. The user also has the option in a single run to first attempt a design using Method A, then, if a design cannot be found, attempt the design using Method B (Request 072).

8. The minimum shim steel thickness has been changed to 0.1196", equivalent to the actual thickness of 11 gauge carbon steel (Request 121).

User's Manual Revisions

9. The description of the TOL command and its parameters have been clarified to indicate that the input values should also include rotation due to dead loads (Request 116).

LRFD BEARING PAD DESIGN AND ANALYSIS

10. The contact information and revision request forms in Chapter 9 of the User's Manual have been revised and consolidated into a single form (Requests 119 and 122).

SUMMARY OF MARCH 2020 REVISIONS - VERSION 1.10.0.0

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

General Program Revisions

1. The program now computes a rotational stiffness value of the bearing pad that will be used by PSLRFD v2.14.0.0 and higher to check girder stability during construction (Request 124).

2. For Method B analysis or design, the specified shear modulus is used to compute an upper and lower range of shear modulus values. The least favorable of the range of values is used for each computation (Request 125).

Programming Revisions

3. The program is now complied with Intel Visual Fortran Parallel Studio XE 2019 Update 5 and Visual Studio XE 2019 (Request 123).

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SUMMARY OF SEPTEMBER 2023 REVISIONS - VERSION 1.11.0.0

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

General Program Revisions

1. **The program now computes and reports the moment transferred to the substructure due to the deformation of an elastomeric element based on the LRFD Specifications Equation 14.6.3.2-3 (Request 127).**

2. **The program has been updated to address the change of approval authority from Chief Bridge Engineer (CBE) to District Bridge Engineer (DBE) (Requests 128 and 134).**

3. **An error in the source code was fixed to ensure that all dead and live load combinations are calculated to determine the maximum shear strain due to axial load for Method B calculations (Request 129).**

4. **A discrepancy between the User's Manual and the BPLRFD.PD file regarding the Minimum Pad Thickness has been resolved (Request 135).**

Programming Revisions

5. **An x64 build option has been added to BPLRFD to match the programs used by APRAS. (Request 132).**

User's Manual Revisions

6. **The consideration of beam dapping and sole plates has been added to the description in section 5.9 of the UM and the Help files for the TOL tab and the corresponding commands, tolLong and tolTrans. (Request 130).**

7. **The fax number has been removed from Chapter 9 of the User's Manual and the revision request template because it is no longer monitored. (Request 133).**

8. **Windows 8.1 operating system has been removed from the User's Manual as a supported operating system. (Request 137).**

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1 GENERAL DESCRIPTION

1.1 PROGRAM IDENTIFICATION

Program Title:	LRFD Bearing Pad Design and Analysis
Program Name:	BPLRFD
Version:	1.11.0.0
Subsystem:	Superstructure
Authors:	Pennsylvania Department of Transportation and Michael Baker International

ABSTRACT:

The LRFD Bearing Pad Design and Analysis Program (BPLRFD) performs an analysis and specifications check, in accordance with the AASHTO LRFD Bridge Design Specifications and the Pennsylvania Department of Transportation Design Manual Part 4, for elastomeric bearing pads used in simple and continuous span structures. As result of a decision by the AASHTO Subcommittee on Bridges and Structures to no longer publish SI unit specifications, the program only supports US customary (US) units. The circular or rectangular pad types included are plain pads, plain pads with a hole, laminated pads and laminated pads with a hole.

The user enters the beam type, and the program determines the minimum edge distances and the required number of pads. The beam types considered are prestressed I-beams, prestressed spread box beams, prestressed adjacent box beams and steel I-beams. For all pad types used with adjacent box beams and for circular pads used with spread box beams, the program assumes two pads at each end of the beam for design. The design procedure considers the effects of the vertical load, horizontal longitudinal movement, beam rotation due to live load, construction tolerances, and pier flexibility for continuous beams.

1.2 ABBREVIATIONS

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

AASHTO	-	American Association of State Highway and Transportation Officials.
BD Standards	-	Bridge Design Standards, BD-600M Series (Publication 218M), 2016 Edition, Pennsylvania Department of Transportation
BPLRFD	-	LRFD Bearing Pad Design and Analysis program.
DM-4	-	Pennsylvania Department of Transportation Design Manual Part 4, **December** 2019 Edition. This publication can be ordered from: Pennsylvania Department of Transportation Publication Sales P.O. Box 2028 Harrisburg, PA 17105 This publication can also be downloaded free of charge from PennDOT's website.
LRFD Specifications	-	AASHTO LRFD Bridge Design Specifications, **Eighth** Edition, **2017**, published by: American Association of State Highway and Transportation Officials 444 North Capitol Street, N.W., Suite 249 Washington, D.C. 20001
PennDOT	-	Pennsylvania Department of Transportation.
US	-	Customary United States units of measurement.

2 PROGRAM DESCRIPTION

2.1 GENERAL

The purpose of this program is to provide a tool for bridge engineers to analyze and design elastomeric bearing pads for simple and continuous span structures. BPLRFD performs an analysis and specifications check in accordance with the AASHTO LRFD Bridge Design Specifications and the Pennsylvania Department of Transportation Design Manual Part 4 using either Method A or Method B. As result of a decision by the AASHTO Subcommittee on Bridges and Structures to no longer publish SI unit specifications, the program only supports US customary (US) units.

2.2 PROGRAM FUNCTIONS

BPLRFD performs the following functions:

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

2. Analysis - BPLRFD computes the stresses and strains in each elastomer layer due to the vertical loads and the shear deformation in each elastomer layer due to the horizontal longitudinal movement. It also computes the total elastomer thickness required to satisfy the total rotation. Then the program checks conformance to the LRFD Specifications and DM-4 including geometry, allowable stresses, thickness required for movement, and rotation, Method A and Method B anchorage, stability, and shim plate thickness (for laminated pads only).

3. Design - The design procedure is based on computing the minimum total elastomer volume with a minimum pad length or diameter. The program will first try to design a plain pad. If the program is unable to successfully design a plain pad, it will try to design a laminated pad. The successful design must meet all LRFD Specifications and DM-4 checks.

4. Output - The output from BPLRFD includes a summary of the input and the results from the design or analysis. The design output includes the pad length, pad width (or pad diameter for circular pad), the number of layers, the interior and cover layer thicknesses, the number of shims, the total thickness of elastomer, and the total bearing thickness including shims. The analysis and design output includes specification checking for geometry, dead load stress, live load stress, total stress, Method A and Method B anchorage, shim thickness, rotation due to live load, rotation due to construction tolerance, stability, and pad deflection. All computed values are printed to an output file for review by the user. For design runs, a history file is created for use in troubleshooting design failures.

2.3 ASSUMPTIONS AND LIMITATIONS

The following is a list of basic assumptions and limitations for BPLRFD:

1. The program assumes no uplift in the dead load and live load reactions. Therefore, all dead load and live load reactions should produce compression in the pad.

2. The program will design or analyze one or two bearing pads per end of beam.

3. The program assumes that skew angle between the centerline of bearings and centerline of beam is the PennDOT skew angle. For PennDOT, a positive skew is measured counterclockwise from the centerline of girder. For AASHTO, a positive skew is measured counterclockwise from a line perpendicular to the centerline of girder. As shown in Figure 1, AASHTO skew angle (θ_A) is negative and PennDOT skew angle (θ_P) is positive.

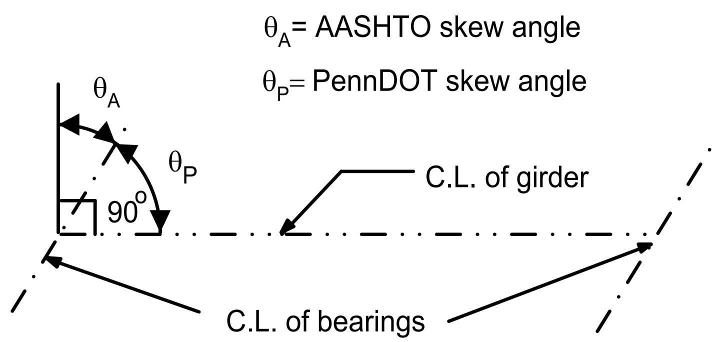

Figure 2.3-1 Skew Angle

4. For a bearing pad design run, the program assumes that a single bearing pad at the fixed end of a prestressed adjacent box beam will always have a hole in it for a dowel, regardless of the expansion length of the beam. If there are two pads at the fixed end, no holes are assumed or allowed. For analysis runs, the presence of a hole in the pad at the fixed end is determined from the program input on the ANA command.

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3 METHOD OF SOLUTION

The primary purpose of this program is to design or analyze elastomeric bearing pads for simple span or continuous span bridges. The analysis and specification checks are performed in accordance with the LRFD Specifications and DM-4. This chapter provides detailed information regarding the method of solution used in the program.

The solution algorithm for the bearing pad design is an iterative procedure that tests all combinations of pad length and layer thicknesses between minimum and maximum values. After several different pads have been designed, the program selects the pad having the minimum volume of elastomer with the minimum pad length or diameter. For an analysis run, however, the geometrical and physical properties of the elastomeric bearing pads are known and the program simply performs the specification checks according to the LRFD Specifications and DM-4.

3.1 NOTATION

The following are the meanings of equation notations used in various expressions throughout this document. These notations may not necessarily agree with the notations used in the LRFD Specifications or DM-4. For each notation, the corresponding units are presented in parentheses. Definitions of abbreviations are presented in Section 1.2.

A = pad plan area (in^2)
B = bottom width of beam (in)
CR = creep factor applied to dead load strain (LRFD Specifications Table 14.7.5.2-1)
D = gross diameter of a circular bearing pad (in)
D_H = hole diameter for a dowel (in)
DL_{max} = maximum dead load compressive force acting on each bearing pad (kip)
DL_{min} = minimum dead load compressive force acting on each bearing pad (kip)
F_s = approximate shear force induced by shear deformation (kip)
F_y = yield strength of steel reinforcement (ksi)
G_H = high end of range of shear modulus of elastomer (ksi)
G_L = low end of range of shear modulus of elastomer (ksi)
h_s = thickness of the steel reinforcement (in)
H_D = maximum total pad thickness to satisfy stability for a circular bearing pad (in)
H_L = maximum total pad thickness to satisfy transverse stability for a rectangular bearing pad (in)
H_W = maximum total pad thickness to satisfy longitudinal stability for a rectangular bearing pad (in)
L = gross length of rectangular bearing parallel to the longitudinal axis of the bridge when skew equals 90 degrees (in)
LL_{max} = maximum live load compressive force acting on each bearing pad (kip)
LL_{min} = minimum live load compressive force acting on each bearing pad (kip)
P = total compressive force acting on each bearing pad (kip)
S = shape factor
S_c = laminated pad shape factor for cover layer elastomer thickness
S_i = laminated pad shape factor for interior layer elastomer thickness
S_p = plain pad shape factor
SPC = pad spacing (when two pads per beam end are used) (in)
t_c = thickness of cover layer elastomer for a laminated pad (in)
t_i = thickness of interior layer elastomer for a laminated pad (in)
t_p = elastomer thickness for a plain pad (in)
T = total elastomer thickness of a laminated pad (in)
T_r = total elastomer thickness required to accommodate rotation (in)
W = gross width of rectangular bearing perpendicular to the longitudinal axis of the bridge when skew equals 90 degrees (in)

α_L = end beam rotation about an axis perpendicular to the longitudinal axis of the bridge (radians)

α_W = end beam rotation about an axis parallel to the longitudinal axis of the bridge (radians)

α_L' = end beam rotation about an axis perpendicular to the longitudinal axis of the bearing pad (radians)

α_W' = end beam rotation about an axis parallel to the longitudinal axis of the bearing pad (radians)

δ_{DL} = compressive deflection due to long-term dead load (in)

δ_{LL} = compressive deflection due to live load (in)

δ_T = compressive deflection due to long-term total load (in)

Δ_F = horizontal movement due to construction/pier flexibility (in)

ΔF_{TH} = constant amplitude fatigue threshold for Category A as specified in LRFD Specifications Table 6.6.1.2.5-3 (ksi)

$\Delta_{t(DL)}$ = total horizontal longitudinal movement due to dead load for bearing design (in)

$\Delta_{t(DL+LL)}$ = total horizontal longitudinal movement due to dead load plus live load for bearing design (in)

$\Delta_{t(substr)}$ = total horizontal longitudinal movement for substructure design (in)

ε_c = elastomer compressive strain in cover layer

ε_{cDL} = elastomer compressive strain in cover layer due to dead load

ε_{cT} = elastomer compressive strain in cover layer due to total load

ε_i = elastomer compressive strain in an interior layer

ε_{iDL} = elastomer compressive strain in an interior layer due to dead load

ε_{iT} = elastomer compressive strain in an interior layer due to total load

ε_p = elastomer compressive strain in a plain pad

ε_{pDL} = elastomer compressive strain in a plain pad due to dead load

ε_{pT} = elastomer compressive strain in a plain pad due to total load

θ = angle between a line perpendicular to the centerline of beam and a line perpendicular to the L dimension of the bearing pad (see Figures 3.6-1 and 3.6-2)

π = ratio of the circumference of a circle to its diameter; equals approximately 3.141592654

σ_s = allowable stress in the steel reinforcement (ksi)

σ_{max} = maximum allowable compressive stress in any elastomer layer (ksi)

σ_{MD} = compressive stress in any elastomer layer due to minimum dead load (ksi)

σ_{MDL} = compressive stress in any elastomer layer due to minimum dead load plus minimum live load (ksi)

ϕ = allowable compressive stress factor for laminated and plain pads as specified in DM-4 Article 14.7.6.3.2; equals 1.0 for expansion bearings and 1.1 for fixed laminated bearings

3.2 SYSTEM PARAMETER INITIALIZATION

The program reads in system parameters used by the program from the system parameter files. These parameters are dependent on user input values. BPLRFDU.SPF is the system parameter file for US units (see Section 3.14). These parameters, in addition to the user input, are used by the program to design and/or analyze the bearing pad. The following sections describe the design and analysis process.

3.3 DESIGN PROCEDURE

The design procedure is based on finding the minimum elastomer volume with the minimum pad length or diameter. The iterative design procedure is illustrated in Figures 1 through 12.

For simple span structures, the process starts by designing the expansion end using a plain pad without any hole for anchorage. The design begins with the default number of pads, minimum pad length or diameter, and minimum pad thickness for the specified beam type.

When designing bearing pads used with adjacent box beams and spread box beams, the user chooses whether the program assumes one or two pads per end of beam. If using two pads, the distance between the pads is as specified in the system parameter file. Also, if using two pads, the program first tries to find a two pad solution. If the program cannot find a good design with two pads, the design is attempted with one pad, with no hole in the pad. If this design fails and the design is for an adjacent box beam less than or equal to 50 feet long, the program tries to find a design with a single pad with a dowel through it. If the user chooses a single pad for a box beam, the design procedure only tries a single pad. No two pad solutions are attempted if the user chooses a single pad.

For design of bearing pads for prestressed adjacent box beams, the program always assumes a dowel through the pad at the fixed end of the beam, when designing for the one pad configuration. Because of this, for simple span design runs, even though the expansion end is always designed first, the compressive resistance is calculated both with and without a hole in the bearing pad to ensure that the length and width of the bearing pad designed for the expansion end will work at the fixed end, as well.

For all other beam types, the program uses one pad per end of beam.

The starting default values are stored in the system parameter file. The maximum values for pad length or diameter and elastomer thicknesses are also read from the system parameter file.

Figures 1, 2, and 3 outline the design procedure for rectangular plain and laminated expansion bearing pads. Figures 4, 5, and 6 outline the design procedure for rectangular plain and laminated fixed bearing pads. Figures 7, 8, and 9 outline the design procedure for circular plain and laminated expansion bearing pads. Figures 10, 11, and 12 outline the design procedure for circular plain and laminated fixed bearing pads.

For rectangular pads:

> The design of the expansion bearing (Figure 1) is performed first. The program sets the pad length and thickness using the default values from the system parameter file. It then computes the required width based on the compressive stress equations. The computed width is compared to the maximum available width based on the bottom flange width and the minimum edge distance. If the computed width is larger

than the available width, the program increments the pad thickness. The thickness is incremented until it exceeds the maximum thickness stored in the system parameter file. Once the maximum thickness is reached, the program increments the pad length. If the pad length exceeds the maximum pad length, the program will stop the plain pad design and proceed with a laminated pad design. The increment of pad length and thickness are stored in the system parameter files. The program uses only the calculated value of width for each pad length and thickness combination, because the desired solution is the minimum volume of the pad.

The design iterations for laminated pads (Figures 2 and 3) are similar to the plain pads except for the pad thickness iteration. For laminated pads, both the cover and interior layers are incremented until successful designs are obtained. The thickness increments of both the cover layers and the interior layers are stored in the system parameter files. After all designs are stored, the program selects the design having the minimum elastomer volume.

For prestressed box beam two-pad designs, the pads are initially positioned at the quarter points of the bottom beam width. If the pads do not satisfy all specification checks, the pads are moved toward the outer edge of the beam, and the specification checks are again performed. This continues until the pads either satisfy all specification checks or the actual exterior edge distance is less than the minimum at which point the pad thickness is incremented and the design process continues. If the two-pad design is not successful, a single pad is tried. For adjacent beam superstructures, if the one-pad design is not successful and the expansion length is less than the anchor dowel span limit from the system parameter file, the program assumes a hole is provided in the pad for an anchorage dowel. When a dowel is provided for anchorage, the program assumes that the dowel will stop the beam from sliding on the pad, and therefore, the program does not check Method A anchorage or Method B anchorage.

If the design is successful at the expansion end, with or without a hole, the program will proceed with the pad design for the fixed end. For the design of the fixed end, the program uses the same pad length and width dimensions as determined for the expansion end. With the given length and width of the pad, the program tries to design a plain pad as illustrated in Figure 4.

If a plain pad design is not successful, the program designs a laminated pad as illustrated in Figures 5 and 6. The fixed end design computes the required elastomer thickness for a pad with the same length and width as that used for the expansion end. In addition to the pad length and width, the program also uses the same criteria for anchorage with dowels and the number of pads at the fixed end as was used at the expansion end.

For continuous span structures, the expansion and fixed end bearings are designed independently. The program designs only one pad (fixed or expansion) per run. The procedure for both the expansion and fixed end bearings is similar to the design procedure discussed above for the expansion end bearing in a simple span structure.

For circular pads:

The design of the expansion bearing (Figure 7) is performed first. The program sets the minimum pad diameter using the default minimum diameter, bottom flange width, and maximum edge distances from the system parameter file. The diameter is then compared to the maximum available diameter based on the bottom flange width of the beam and the minimum edge distance. If the diameter is less than the maximum available diameter, the program will perform the checks for the bearing pad, such as compressive stress, longitudinal movement, rotation, and stability. If one of the above checks fails, or, if the diameter is greater than the maximum available diameter, the program increments the pad thickness. The pad thickness is incremented until it exceeds the maximum thickness stored in the system parameter file. Once the thickness exceeds the maximum pad thickness, the program will increment the pad diameter. If the pad diameter exceeds the maximum available diameter, the program will stop the plain pad design and proceed with a laminated pad design. The increment of pad length and thickness are stored in the system parameter files.

The design iterations for laminated pads (Figures 8 and 9) are similar to the plain pads except for the pad thickness iteration. For laminated pads, both the cover and interior layers are incremented until successful designs are obtained. The thickness increments of both the cover layer and the interior layer are stored in the system parameter files. After all designs are stored, the program selects the design having the minimum elastomer volume.

For prestressed box beam two-pad designs, the pads are initially positioned at the quarter points of the bottom beam width. If the pads do not satisfy all specification checks, the pads are moved toward the outer edge of the beam, and the specification checks are again performed. This continues until the pads either satisfy all specification checks or the actual exterior edge distance is less than the minimum at which point the pad thickness is incremented and the design process continues. If the two-pad design is not successful, a single pad is tried. For adjacent beam superstructures, if the one-pad design is not successful and the expansion length is less than the anchor dowel span limit from the system parameter file, the program assumes a hole is provided in the pad for an anchorage dowel. When a dowel is provided for anchorage, the program assumes that the dowel will stop the beam from sliding on the pad, and therefore, the program does not check Method A anchorage or Method B anchorage.

If the design is successful at the expansion end, with or without a hole, the program will proceed with the pad design for the fixed end. For the design of the fixed end, the program uses the same pad diameter as determined for the expansion end. With the given diameter of the pad, the program tries to design a plain pad as illustrated in Figure 10.

If a plain pad design is not successful, the program designs a laminated pad as illustrated in Figures 11 and 12. The fixed end design computes the required elastomer thickness for a pad with the same diameter as that used for the expansion end. In addition to the pad diameter, the program also uses the same criteria for anchorage with dowels and the number of pads at the fixed end as was used at the expansion end.

For continuous span structures, the expansion and fixed end bearings are designed independently. The program will design only one pad (fixed or expansion) per run. The procedure for both the expansion and fixed end bearings is similar to the design procedure discussed above for the expansion end bearing in a simple span structure.

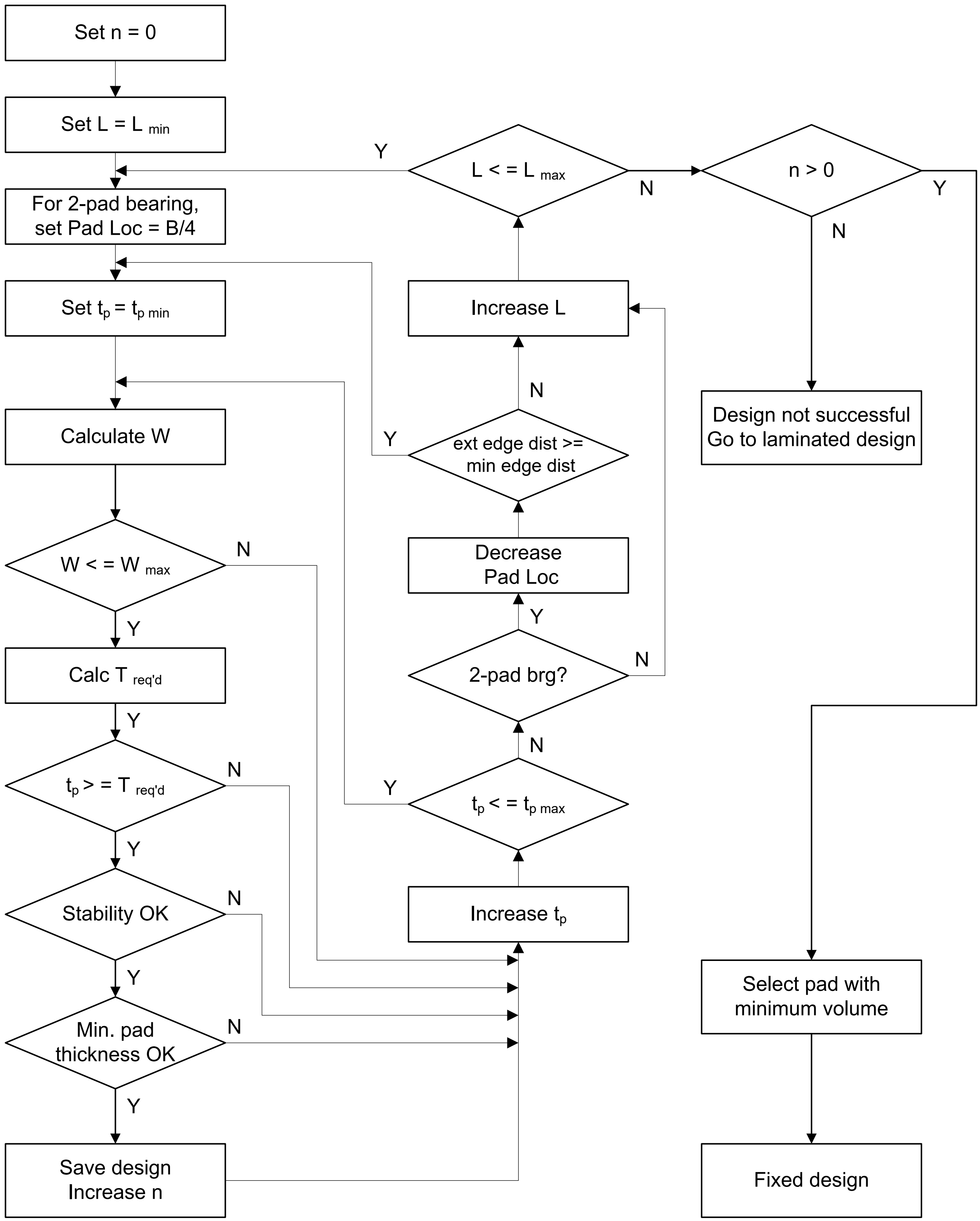


Figure 3.3-1 Rectangular Plain Pad for Expansion Bearing or Fixed Bearing of Continuous Span (Method A)

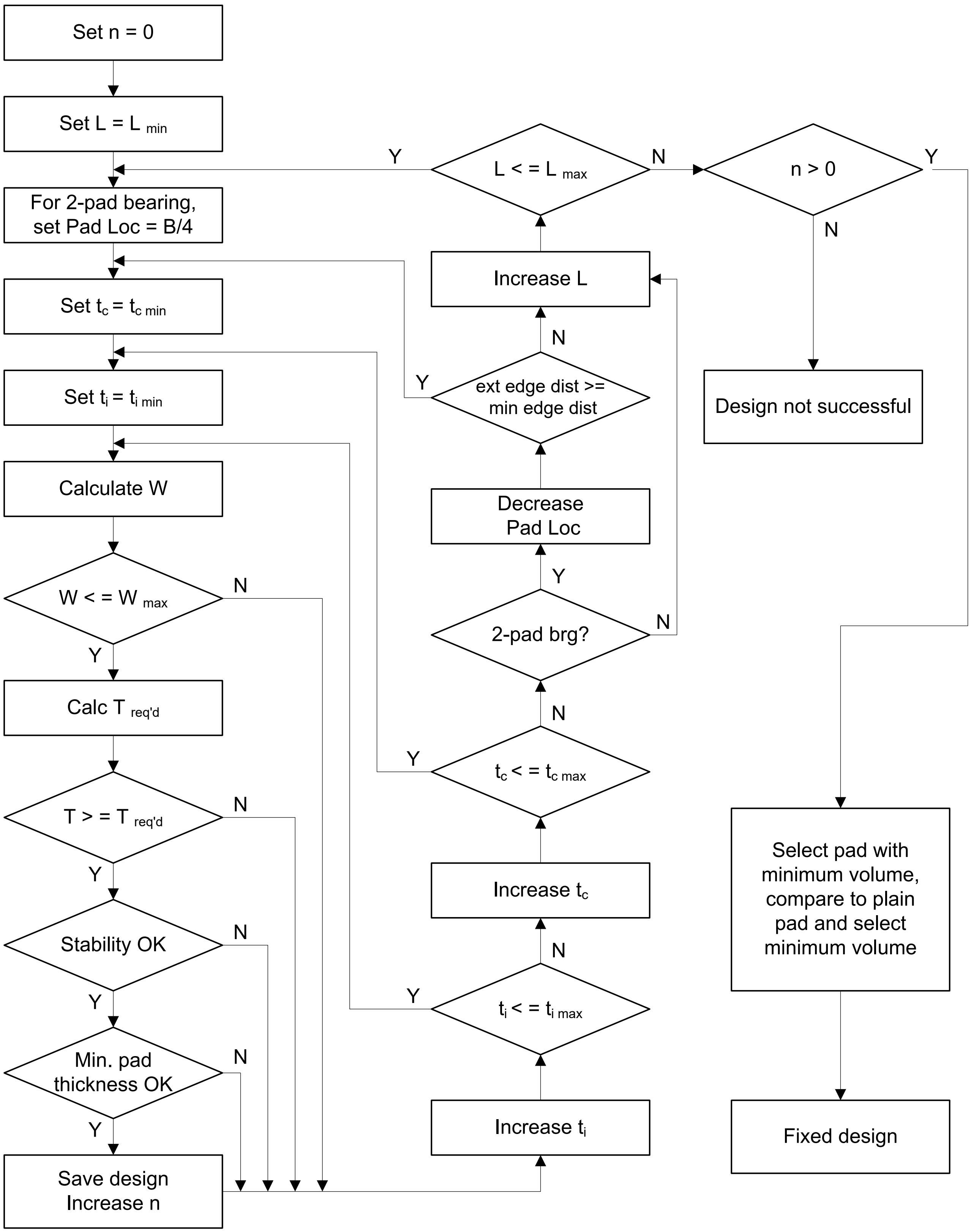


Figure 3.3-2 Rectangular Laminated Pad for Expansion Bearing or Fixed Bearing of Continuous Span (Method A)

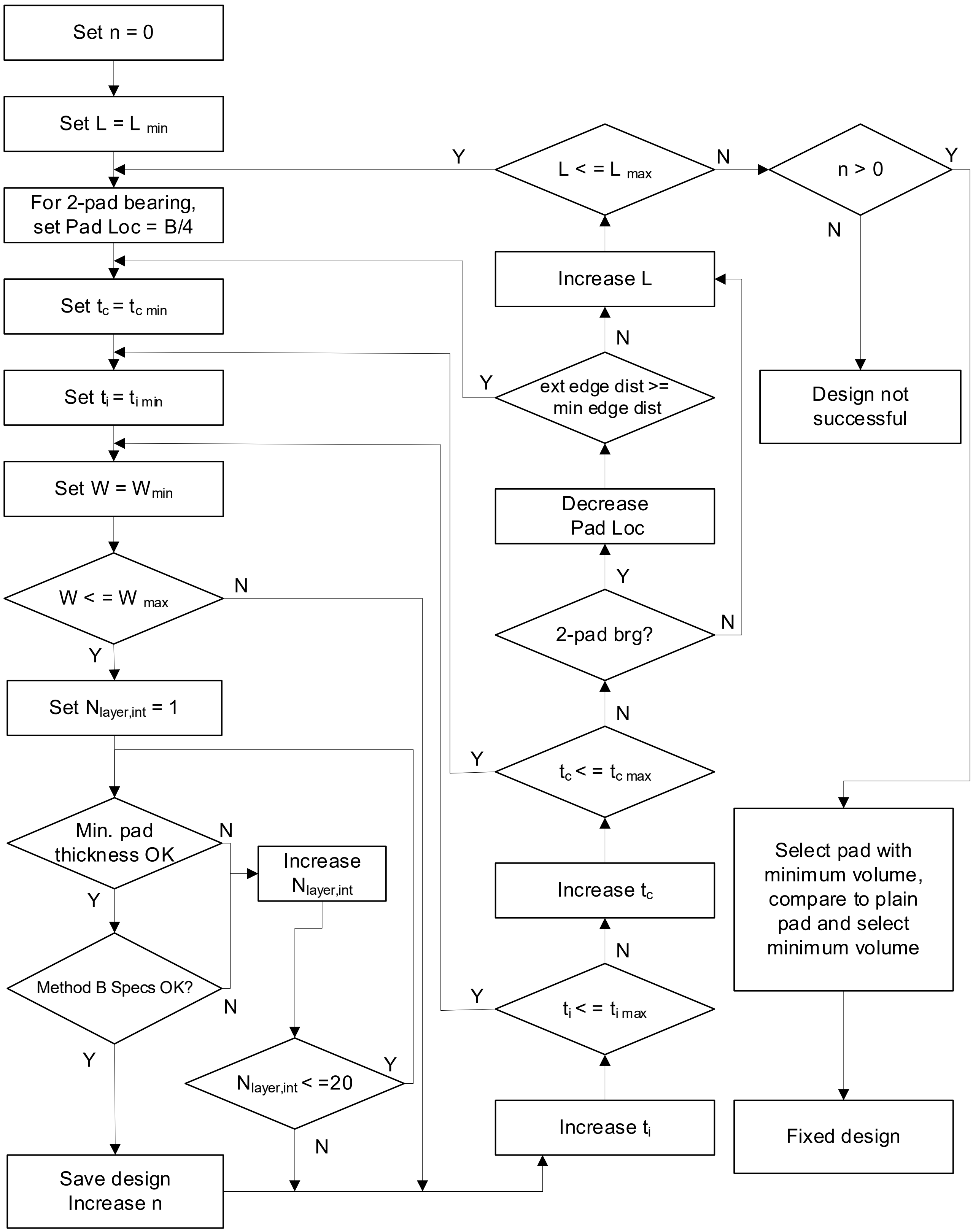


Figure 3.3-3 Rectangular Laminated Pad for Expansion Bearing or Fixed Bearing of Continuous Span (Method B)

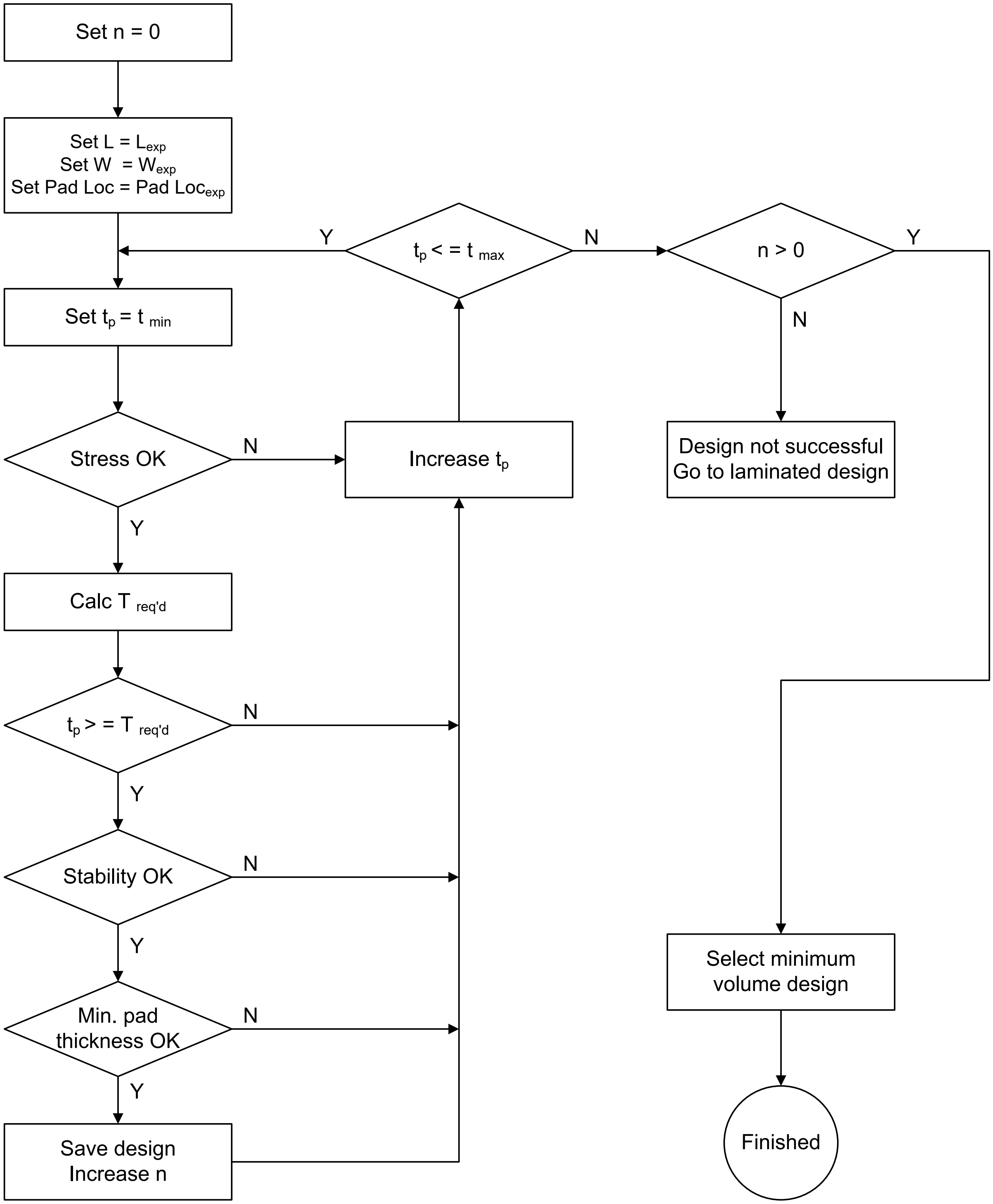


Figure 3.3-4 Rectangular Plain Pad for Fixed Bearing of Simple Span (Method A)

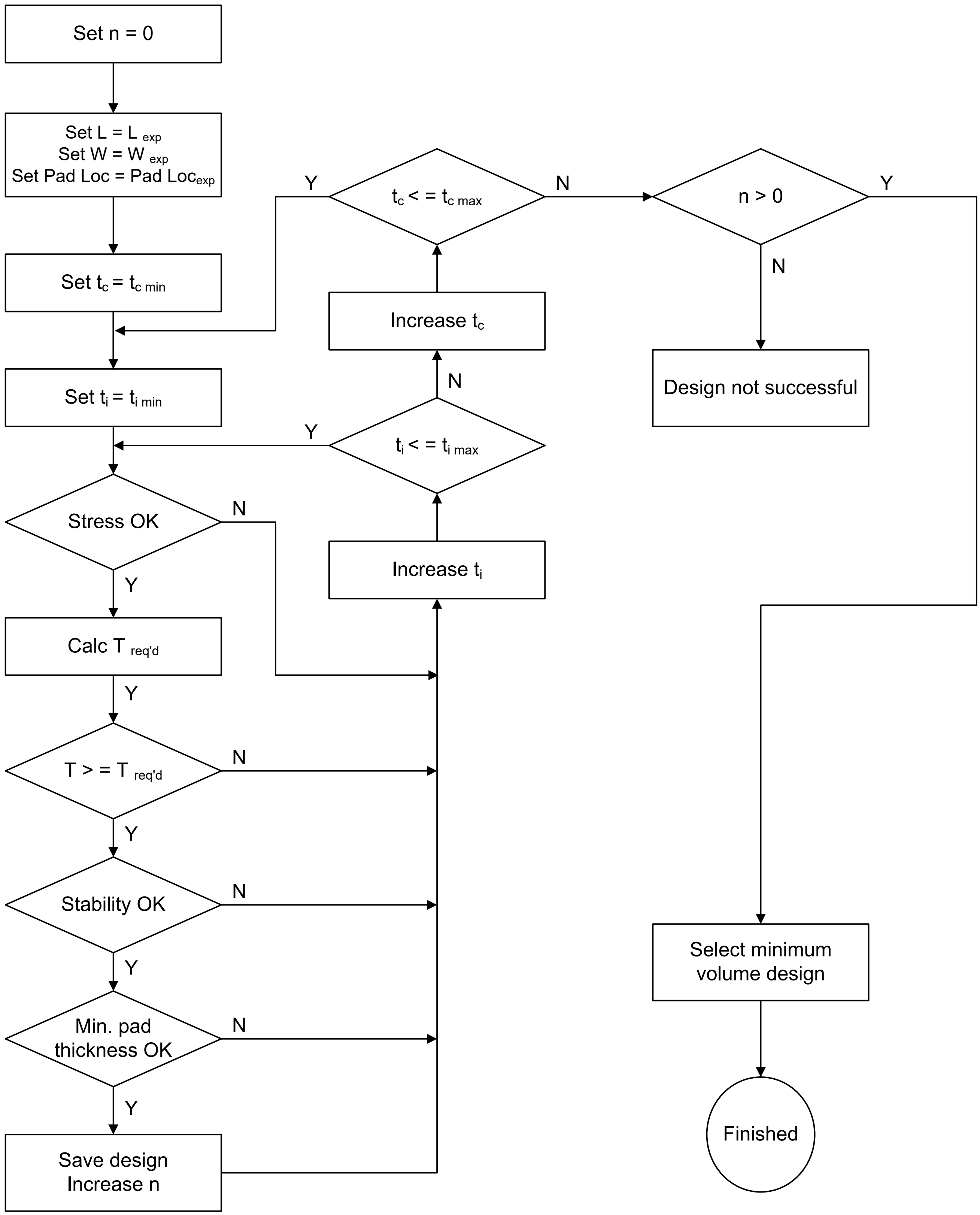


Figure 3.3-5 Rectangular Laminated Pad for Fixed Bearing of Simple Span (Method A)

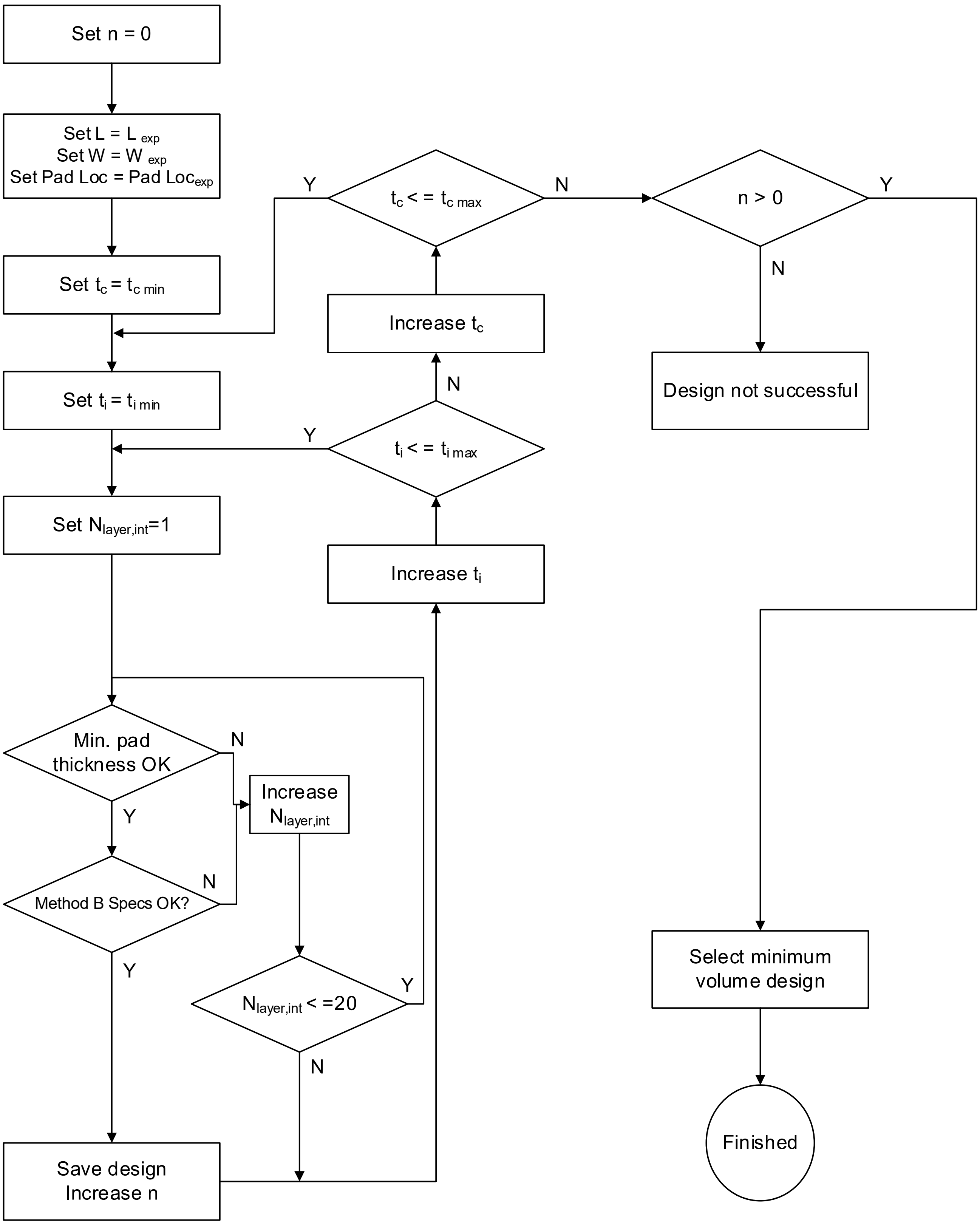


Figure 3.3-6 Rectangular Laminated Pad for Fixed Bearing of Simple Span (Method B)

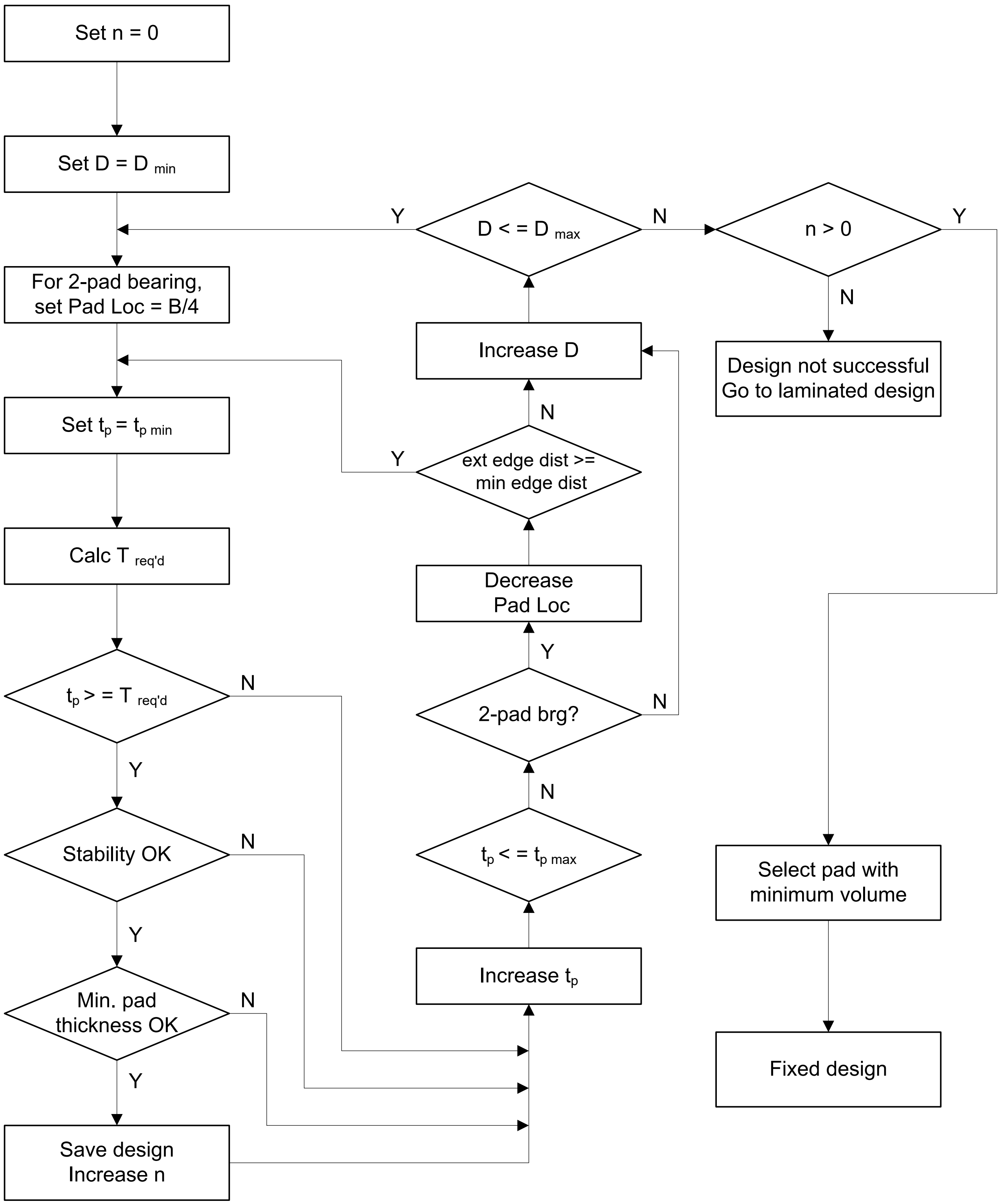


Figure 3.3-7 Circular Plain Pad for Expansion Bearing or Fixed Bearing of Continuous Span (Method A)

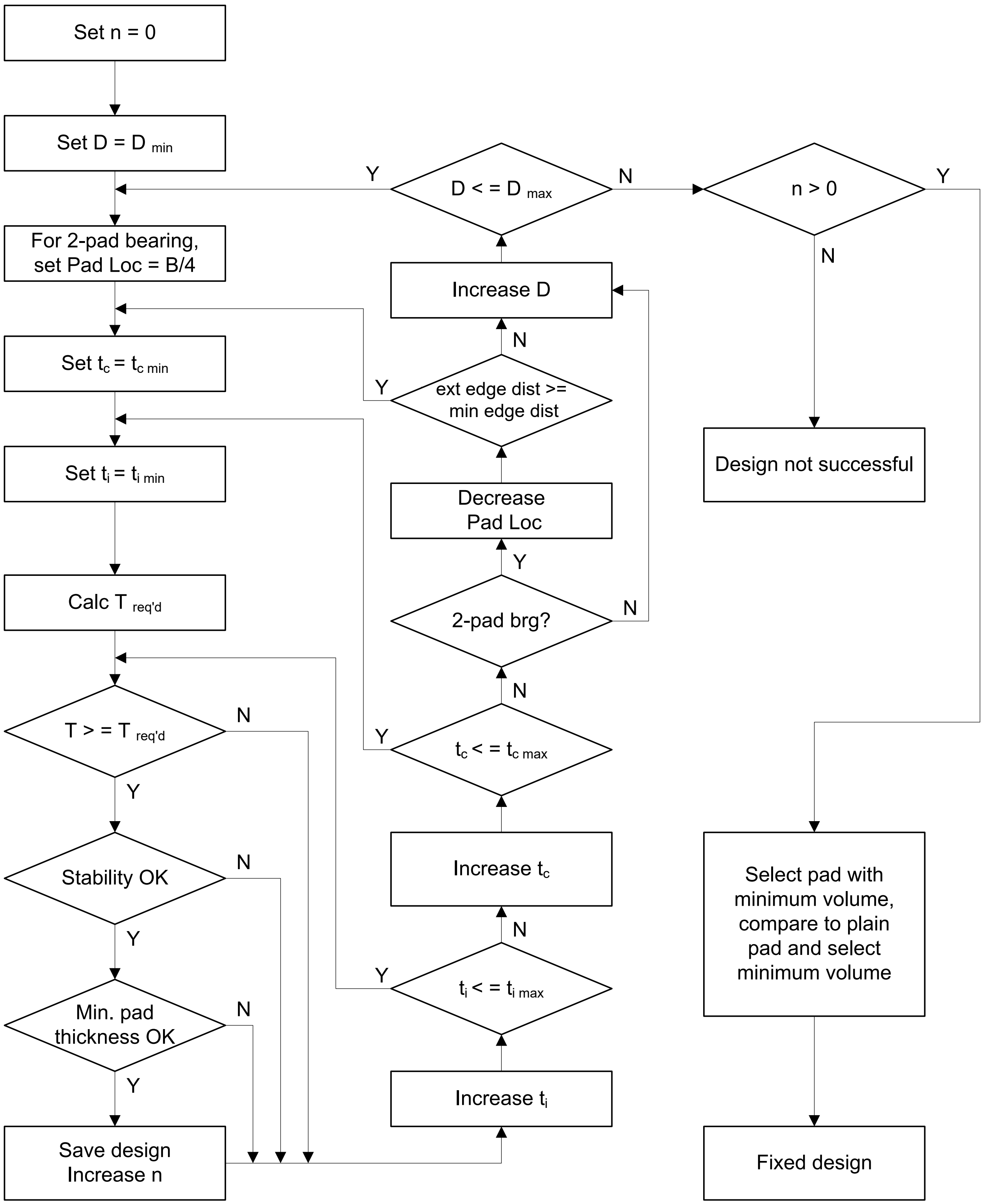


Figure 3.3-8 Circular Laminated Pad for Expansion Bearing or Fixed Bearing of Continuous Span (Method A)

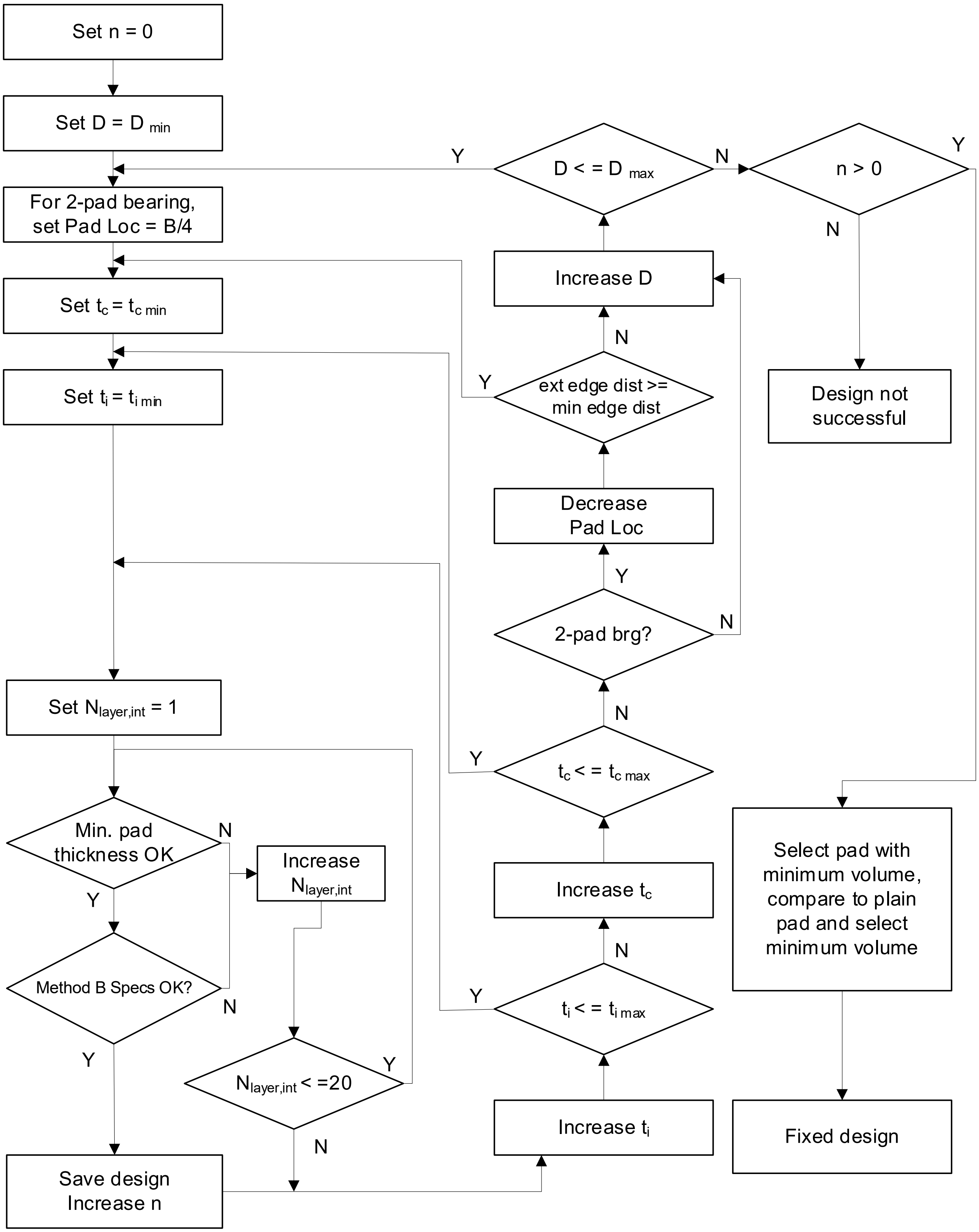


Figure 3.3-9 Circular Laminated Pad for Expansion Bearing or Fixed Bearing of Continuous Span (Method B)

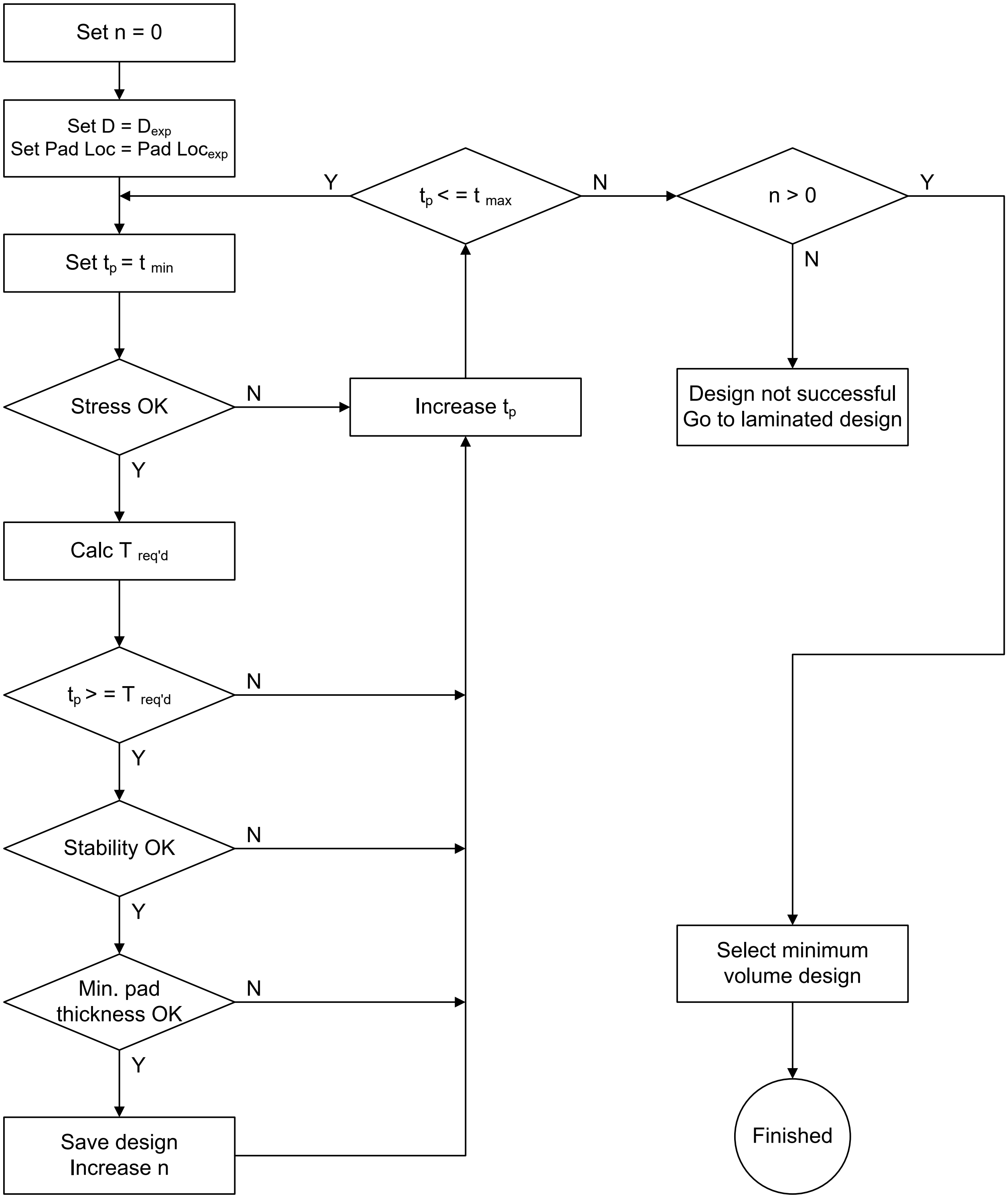


Figure 3.3-10 Circular Plain Pad for Fixed Bearing of Simple Span (Method A)

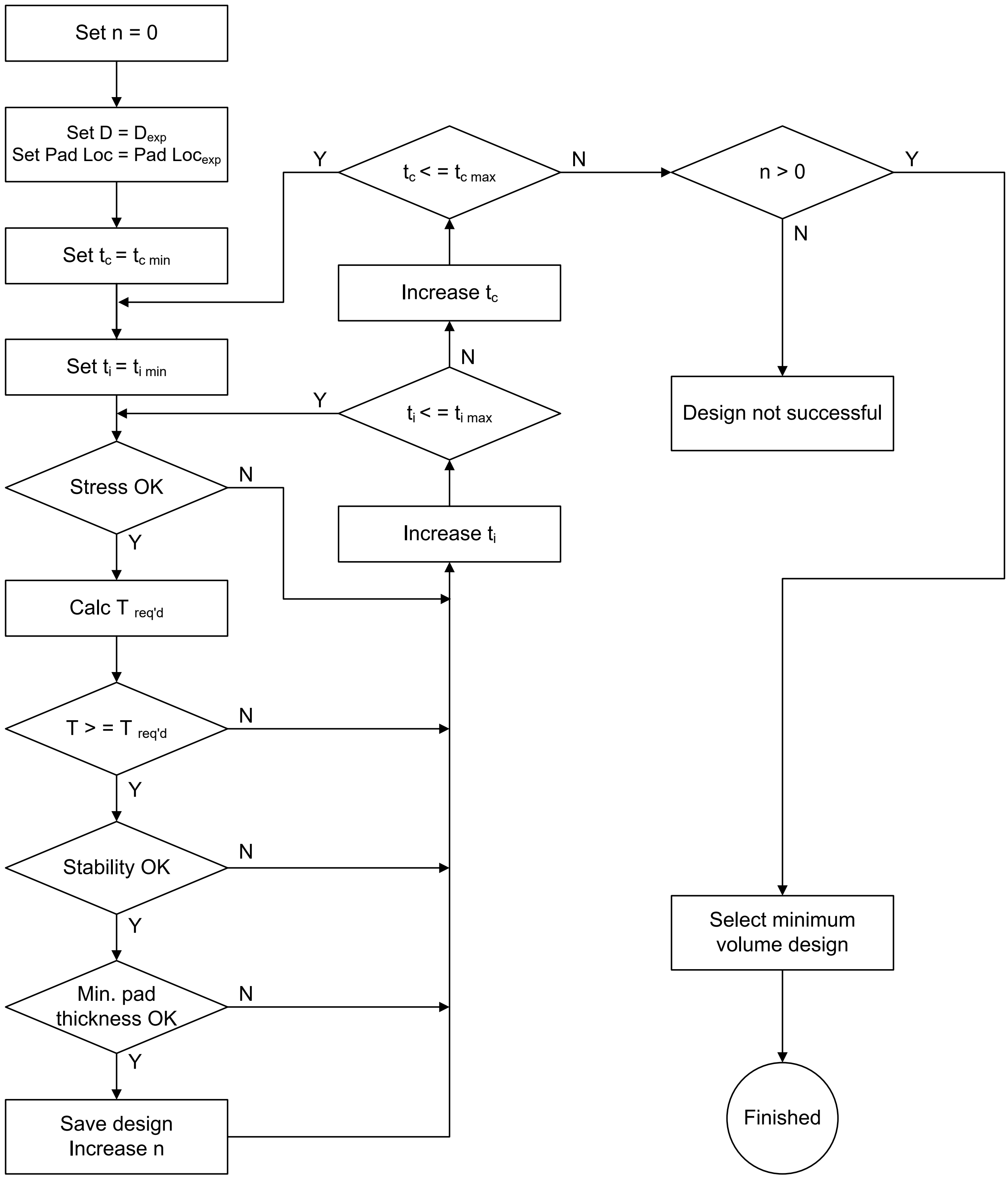


Figure 3.3-11 Circular Laminated Pad for Fixed Bearing of Simple Span (Method A)

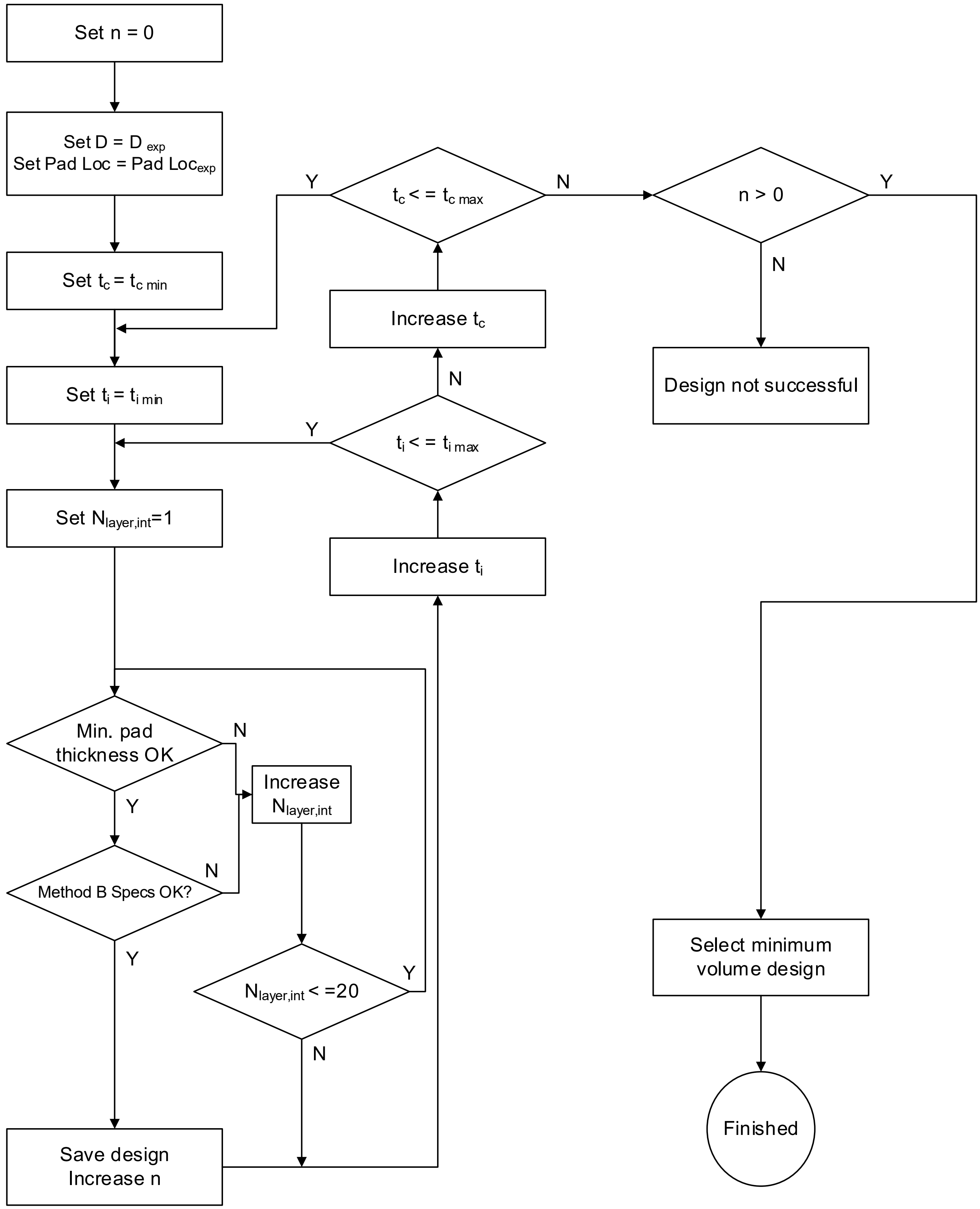


Figure 3.3-12 Circular Laminated Pad for Fixed Bearing of Simple Span (Method B)

3.4 ANALYSIS PROCEDURE

An analysis of a bearing pad is performed by comparing the computed values for a given pad to the allowable values. The following allowable values are checked when an analysis is performed:

Method A:

1. Pad geometry (pad length and width or pad diameter, edge distances).
2. Compressive stress.
3. Thickness required for shear deformation and rotation.
4. Stability.
5. Shim plate thickness.
6. Minimum pad thickness.
7. Method A and Method B Anchorage.
8. Compressive deflection.

Method B:

1. Pad geometry (pad length and width or pad diameter, edge distances).
2. Shear deformation.
3. Combined compression, rotation, and shear.
4. Stability.
5. Shim plate thickness.
6. Minimum pad thickness.
7. Method B Anchorage.
8. Compressive deflection.

3.5 LOADINGS

The bearing pad is designed or analyzed using dead load and live load values input by the user. These load reaction values should not be factored, because the Service I limit state is used in design and analysis. The live load value should not include the effects of impact.

3.6 PAD GEOMETRY (METHOD A DESIGN)

For rectangular pads only: the program starts the design process by assuming a length and thickness of pad. The program then uses the following equations (see Section 3.6.1 for derivations) to compute the pad width for a given trial length and elastomer layer thickness.

For a pad without a hole:

$$Q = \frac{G_L \varphi L^2}{2tP}$$

$$W = \frac{1 + \sqrt{1 + 4QL}}{2Q}$$

For a pad with a hole:

$$Q_a = G_L \varphi L^2$$

$$Q_b = -\left(G_L \varphi L \left(\frac{\pi D_H^2}{4}\right) + 2tP\right)$$

$$Q_c = -(2LtP + \pi D_H tP)$$

$$W = -\frac{Q_b + \sqrt{Q_b^2 - 4Q_a Q_c}}{2Q_a}$$

For laminated pads, t is maximum of the interior or cover layer thickness. For plain pads, t is the thickness of the pad.

The starting length and available thicknesses are stored in the system parameter file. The bearing pad length (L) can not exceed the default maximum length of bearing pad specified in the system parameter file. This bearing pad width (W) as well as the length (L) are also subjected to the restrictions imposed by the maximum and minimum edge distances as shown in Figure 1. The maximum and minimum edge distances are specified in the system parameter file. If the minimum width (W_{min}) is not satisfied, the design width is set to the minimum width.

For one rectangular pad per beam end:

$$L_{max} = \frac{B - 2d1_{min}}{\sin\theta} - \frac{W}{\tan\theta}$$

$$W_{max} = \frac{B - 2d1_{min}}{cos\,\theta} - L\,tan\,\theta$$

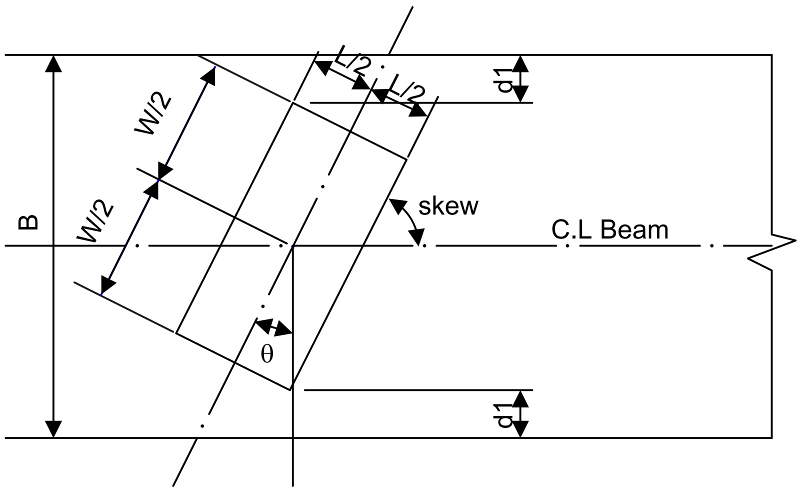
$$W_{min} = \frac{B - 2d1_{max}}{cos\,\theta} - L\,tan\,\theta$$

For two rectangular pads per beam end:

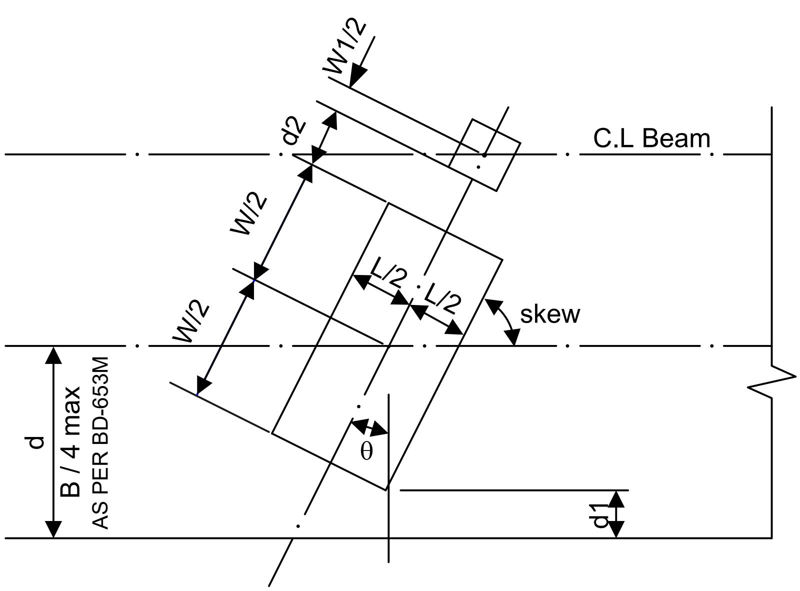
$$L_{max} = 2\left(\frac{d - d1_{min}}{\sin\theta} - \frac{W}{2\tan\theta}\right)$$

$$W_{max} = 2 * min\left(\frac{d - d1_{min}}{\cos\theta} - \frac{L}{2}\tan\theta\,, \frac{\left(\frac{B}{2} - d\right)}{\cos\theta} - \frac{W1}{2} - d2_{min}\right)$$

$$W_{min} = 2 * max\left(\frac{d - d1_{max}}{\cos\theta} - \frac{L}{2}\tan\theta\,, \frac{\left(\frac{B}{2} - d\right)}{\cos\theta} - \frac{W1}{2} - d2_{max}\right)$$



One Rectangular Pad Per Beam End



Two Rectangular Pads Per Beam End

Figure 3.6-1 Rectangular Bearing Pad

Where:

B = Beam Width

L = Pad Length

W = Pad Width

d = Pad Location

d1 = Exterior Edge Distance

d2 = Interior Edge Distance

W1 = Width of Elastomeric Sponge Washer

$\theta = 90^{\circ} - \text{skew}$

For circular pads, the program starts the design process by assuming a diameter and thickness of pad. The starting diameter and available thicknesses are stored in the system parameter file. The bearing pad diameter (D) can not exceed the default maximum diameter of bearing pad specified in the system parameter file. This bearing pad diameter (D) is also subjected to the restrictions imposed by the maximum and minimum edge distances as shown in Figure 2. The maximum and minimum edge distances are specified in the system parameter file. If the starting diameter is less than the minimum diameter, the starting diameter is set to the minimum.

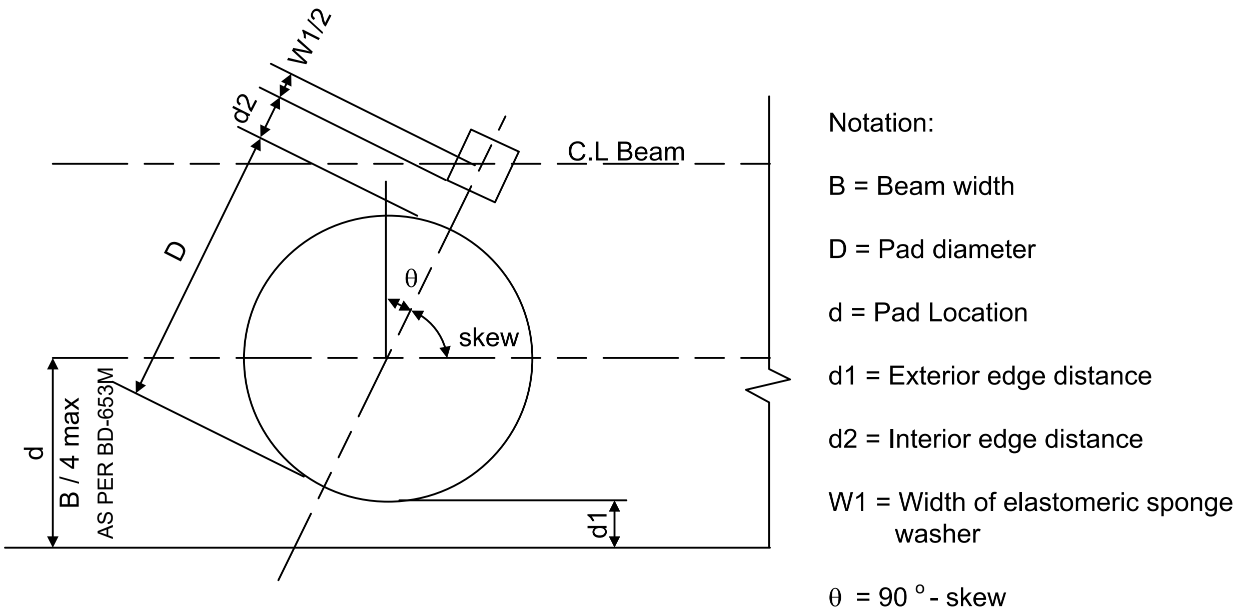


Figure 3.6-2 Two Circular Bearing Pads Per Beam End

For one circular pad per beam end:

$$D_{max} = B - 2\,d1_{min}$$

$$D_{min} = B - 2\,d1_{max}$$

For two circular pads per beam end:

$$D_{max} = 2\ Min\left(d - d1_{min},\ \ \frac{\left(\frac{B}{2} - d\right)}{\cos\theta} - \frac{W1}{2} - d2_{min} \right)$$

$$D_{min} = 2\ Max\left(d - d1_{max},\ \ \frac{\left(\frac{B}{2} - d\right)}{\cos\theta} - \frac{W1}{2} - d2_{max} \right)$$

3.6.1 Equation Derivations for Rectangular Pads Only

The following is a derivation of the Q factor for determining the pad width, W, for pads without a hole:

$$S = shape\ factor = \frac{LW}{2t(L+W)}\ without\ hole$$

$$F_{all} = allowable\ stress = G_L S \varphi$$

$$F_{act} = actual\ stress = \frac{P}{LW}$$

Setting F_{act} equal to F_{all} yields:

$$\frac{P}{LW} = G_L S \varphi$$

Substituting the equation for the shape factor and rearranging terms yields:

$$\frac{P}{LW} = \frac{G_L \varphi LW}{2t(L+W)}$$

$$L + W = \frac{G_L \varphi L^2 W^2}{2tP}$$

$$\frac{G_L \varphi L^2}{2tP} W^2 - W - L = 0$$

$$Q = \frac{G_L \varphi L^2}{2tP}$$

The following is a derivation of the Q factor for determining the pad width, W, for pads with a hole:

$$S = shape\ factor = \frac{LW - \left(\frac{\pi}{4}\right) D_H^2}{t(2L + 2W + \pi D_H)}\ with\ hole$$

$$F_{all} = allowable\ stress = G_L S \varphi$$

$$F_{act} = actual\ stress = \frac{P}{LW}$$

Setting F_{act} equal to F_{all} yields:

$$\frac{P}{LW} = G_L S \varphi$$

Substituting the equation for the shape factor and rearranging terms yields:

$$\frac{P}{LW} = \frac{G_L \varphi \left(LW - \left(\frac{\pi}{4}\right) D_H^2\right)}{t(2L + 2W + \pi D_H)}$$

$$t(2L + 2W + \pi D_H) = \frac{G_L \varphi LW \left(LW - \left(\frac{\pi}{4}\right) D_H^2\right)}{P}$$

$$\frac{G_L \varphi L^2 W^2}{P} - \frac{G_L \varphi LW \pi D_H^2}{4P} = 2Lt + 2Wt + \pi D_H t$$

Multiplying both sides by P and rearranging terms yields:

$$G_L \varphi L^2 W^2 - \left(\frac{G_L \varphi L \pi D_H^2}{4} + 2tP\right) W - 2LtP - \pi D_H tP = 0$$

Let:

$$Q_a = G_L \varphi L^2$$

$$Q_b = -\left(\frac{G_L \varphi L \pi D_H^2}{4} + 2tP\right)$$

$$Q_c = -(2LtP + \pi D_H tP)$$

to solve the following quadratic equation for W:

$$Q_a W^2 + Q_b W + Q_c = 0$$

3.7 COMPRESSIVE STRESS (METHOD A DESIGN)

The compressive stress is computed and checked as follows:

$$\sigma = \frac{DL_{max} + LL_{max}}{A} \leq \phi\sigma_{max}$$

For bearing pads with holes, the area of the pad and the compressive stress resistance are both calculated by taking the hole area into account. That is, the pad area is equal to the gross area of the pad less the area of the hole, so the presence of the hole will serve to reduce the area of the pad as well as the compressive resistance.

3.8 PAD THICKNESS FOR SHEAR DEFORMATION AND ANCHORAGE (METHOD A DESIGN)

The minimum pad thickness required to satisfy the shear deformation and Method A anchorage design criteria is calculated by taking the maximum of the following equations:

Based on shear deformation, LRFD Specifications Equation 14.7.5.3.2-1:

$$h_{rt} = 2\Delta_s = 2\left(\Delta_{t(DL+LL)} + \Delta_F\right)$$

Based on Method A anchorage, DM-4 Section 14.7.6.4P and LRFD Specifications Equation 14.6.3.1-2:

$$h_{rt} = max\left(\frac{5G_H\left(\Delta_{t(DL)} + \Delta_F\right)}{\sigma_{MD}}, \frac{5G_H\left(\Delta_{t(DL+LL)} + \Delta_F\right)}{\sigma_{MDL}}\right)$$

where: h_{rt} = total elastomer thickness

Δ_S = total shear deformation of the elastomer (see LRFD Specifications and DM-4 14.7.5.3.2)

$\Delta_{t(DL+LL)}$ = [(Expansion length) * (Coefficient of thermal expansion of the beam) * (Temperature range for bearing design)] + (DL1 rotation longitudinal movement) + (DL2 rotation longitudinal movement) + (LL rotation longitudinal movement)

$\Delta_{t(DL)}$ = [(Expansion length) * (Coefficient of thermal expansion of the beam) * (Temperature range for bearing design)] + (DL1 rotation longitudinal movement) + (DL2 rotation longitudinal movement)

Δ_F = 0 for simple spans

= horizontal movement input value for continuous spans to account for construction/pier flexibility (CON input command)

G_H = shear modulus of the elastomer. As per DM-4 14.6.3.1-2, use the highest value of G for the elastomer hardness selected.

σ_{MD} = stress due to minimum dead load

σ_{MDL} = stress due to minimum dead load + minimum live load

For rectangular pads:

$$\sigma_{MD} = \frac{DL_{min}}{LW}$$

$$\sigma_{MDL} = \frac{DL_{min} + LL_{min}}{LW}$$

For circular pads:

$$\sigma_{MD} = \frac{DL_{min}}{\frac{\pi D^2}{4}} = \frac{4DL_{min}}{\pi D^2}$$

$$\sigma_{MDL} = \frac{(DL_{min} + LL_{min})}{\frac{\pi D^2}{4}} = \frac{4(DL_{min} + LL_{min})}{\pi D^2}$$

The anchorage equation is derived by setting the unfactored shear force induced by the shear deformation (AASHTO LRFD Equation 14.6.3.1-2) equal to 20% of the minimum dead load reaction or 20% of the minimum dead load plus minimum live load reactions, as required in DM-4 14.7.6.4P, as follows:

Shear force due to the deformation of the bearing pad:

$$Shear\ Force = H_{bu} = G_H A \frac{\Delta_u}{h_{rt}} \quad (AASHTO\ LRFD\ Equation\ 14.6.3.1 - 2)$$

where: G_H = shear modulus of the elastomer. As per DM-4 14.6.3.1-2, use the highest value of G for the elastomer hardness selected.

A = plan area of the bearing pad

Δ_u = factored shear deformation (as per DM-4, factored for service)

h_{rt} = total elastomer thickness

Equating the shear force to 20% of the reaction results in:

$$G_H A \frac{\Delta_u}{h_{rt}} = \frac{P}{5}$$

moving the area term to the right and the factor of five to the left,

$$5G_H \frac{\Delta_u}{h_{rt}} = \frac{P}{A}$$

substituting the terms for stress (σ_{MD} and σ_{MDL}) for P/A and substituting the appropriate deformation expressions (either DL($\Delta_{t(DL)}$+Δ_F) or DL+LL($\Delta_{t(DL+LL)}$+Δ_F)) results in:

$$5G_H \frac{\left(\Delta_{t(DL)} + \Delta_F\right)}{h_{rt}} = \sigma_{MD}$$

$$5G_H \frac{\left(\Delta_{t(DL+LL)} + \Delta_F\right)}{h_{rt}} = \sigma_{MDL}$$

a final rearrangement to solve for h_{rt} gives the original anchorage expressions above:

$$h_{rt} = 5G_H \frac{\left(\Delta_{t(DL)} + \Delta_F\right)}{\sigma_{MD}}$$

$$h_{rt} = 5G_H \frac{\left(\Delta_{t(DL+LL)} + \Delta_F\right)}{\sigma_{MDL}}$$

The maximum of these two values is reported in the program output.

Refer to EXP command (Section 5.10) for the input data of temperature range, DL1 rotation longitudinal movement, DL2 rotation longitudinal movement, and LL rotation longitudinal movement; and refer to system parameter files for the coefficient of thermal expansion of a beam.

3.9 PAD THICKNESS FOR ROTATION (METHOD A DESIGN)

Strain in the pad layer is calculated by the following equations in accordance with DM-4, C14.7.5.3.6:

$$\varepsilon_c\ ,\ \varepsilon_i\ ,\ \varepsilon_p = A\ \sigma^2 + B\ \sigma \qquad \text{(percent, DM-4 Equation C14.7.5.3.6-1)}$$

where: A = coefficient from DM-4 Table C14.7.5.3.6-1P (stored in the system parameter file (see Section 3.16))

B = coefficient from DM-4 Table C14.7.5.3.6-1P (stored in the system parameter file (see Section 3.16))

σ = P/A (compressive stress to be considered)

The coefficients A and B are functions of pad hardness and S, where S is the shape factor. The shape factor is computed using the following equations:

$$S = \frac{LW}{2t(L+W)}\ for\ rectangular\ pad\ without\ hole$$

$$S = \frac{LW - \left(\frac{\pi}{4}\right) D_H^2}{t(2L + 2W + \pi D_H)}\ for\ rectangular\ pad\ with\ hole$$

$$S = \frac{D}{4t}\ for\ circular\ pad\ without\ hole$$

$$S = \frac{D - D_H}{4t}\ for\ circular\ pad\ with\ hole$$

To evaluate the strain, the calculated value of S is used as follows:

If S < 3: For analysis: The program prints an error message and stops.
For design: The program iterates to choose another pad size.

If S > 12: For both analysis and design: The program uses S = 12 to calculate the strain in the pad layer.

If 3 ≤ S ≤ 12: For both analysis and design: The program calculates the strain in the pad layer by linearly interpolating the strains computed for each of the two nearest (lower and higher) S value curves to the actual S value of the pad layer.

Pad thickness is calculated using the following equations:

$$T_r = \frac{TMP - 4\varepsilon_C t_c}{2\varepsilon_i} + 2t_c$$ for laminated pads

$$T_r = \frac{TMP}{2\varepsilon_p}$$ for plain pads

For rectangular pads:

where: TMP = either TMP_x or TMP_z

TMP_x = pad compression due to rotation about the transverse axis of the pad.

TMP_z = pad compression due to rotation about the longitudinal axis of the pad.

$$TMP_X = L\left(\alpha_{W'(LL)} + \alpha_{W(relative)}\right)$$

$$TMP_Z = W'\left(\alpha_{L'(LL)} + \alpha_{L(relative)}\right)$$

where: $\alpha_{w'(LL)}$ = Live load rotation about transverse axis of pad (see LLR command)

$\alpha_{w(relative)}$ = The sum of construction rotational tolerance, dead load rotation, and any other relative rotation between the bottom of the beam bearing surface and beam seat, all about the transverse axis of the pad (see TOL command)

$\alpha_{L'(LL)}$ = Live load rotation about the longitudinal axis of the pad (see LLR command)

$\alpha_{L(relative)}$ = The sum of construction rotational tolerance, dead load rotation, and any other relative rotation between the bottom of the beam bearing surface and beam seat, all about the longitudinal axis of the pad (see TOL command)

W' = W (for one bearing pad case)

W' = 2W + SPC (for two pad case; see Figure 1)

SPC = $\frac{B-2d}{cos\,\theta} - W$ (for two pad case; see Figure 1)

For circular pads:

$$TMP = \sqrt{\left(D'\left(\alpha_{L'(LL)} + \alpha_{L(relative)}\right)\right)^2 + \left(D'\left(\alpha_{W'(LL)} + \alpha_{W(relative)}\right)\right)^2}$$

where: D' = D (for one bearing pad case)

= 2D + SPC (for two pad case; see Figure 1)

SPC = $\frac{B-2d}{\cos\theta} - D$ (for two pad case; see Figure 1)

$\alpha_{w'(LL)}$ = Live load rotation about transverse axis of pad (see LLR command)

$\alpha_{w(relative)}$ = The sum of construction rotational tolerance, dead load rotation, and any other relative rotation between the bottom of the beam bearing surface and beam seat, all about the transverse axis of the pad (see TOL command)

$\alpha_{L'(LL)}$ = Live load rotation about the longitudinal axis of the pad (see LLR command)

$\alpha_{L(relative)}$ = The sum of construction rotational tolerance, dead load rotation, and any other relative rotation between the bottom of the beam bearing surface and beam seat, all about the longitudinal axis of the pad (see TOL command)

Rotation of a bearing pad is illustrated in Figure 1.

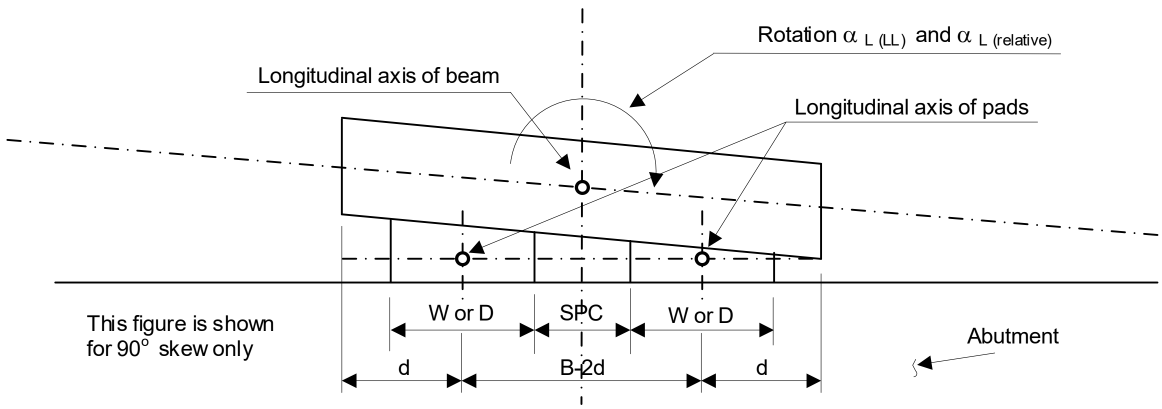


Figure 3.9-1 Rotation of Bearing Pad (Section Through Beam and Pads)

The strain is based on the load that causes the beam rotation being considered. The rotation due to construction tolerance, dead load, and any other relative rotation between the bottom of the beam bearing surface and the beam seat ($\alpha_{(relative)}$) is considered with minimum dead load. The rotations due to live load and $\alpha_{(relative)}$ are considered with minimum dead load plus live load. The live load and $\alpha_{(relative)}$ rotations are user-input values. The maximum pad thickness required for rotation is based on the combinations of beam skew (minimum and maximum) and beam rotation ($\alpha_{(relative)}$ and live load) about each axis of the pad.

3.10 STABILITY REQUIREMENTS (METHOD A DESIGN)

The maximum total pad thickness (elastomer layers plus shims) permitted to satisfy stability is calculated as follows:

For rectangular pads:

$$H_L = \frac{L}{ss}$$

$$H_W = \frac{W}{ss}$$

For circular pads:

$$H_D = \frac{D}{ss}$$

where: ss = 3 for rectangular laminated pads
ss = 5 for rectangular plain pads
ss = 4 for circular laminated pads
ss = 6 for circular plain pads

3.11 BEARING ROTATIONAL STIFFNESS

The bearing rotational stiffness calculations will only be done for P/S I-Beams and P/S Bulb Tees with a single, rectangular pad orientated with the beam. This rotational stiffness can be used to evaluate the lateral stability of a prestressed girder seated on bearing pads during construction, using the procedures documented in the PCI Girder Subcommittee report titled “Recommended Practices for Lateral Stability of Precast, Prestressed Concrete Bridge Girders. The rotational stiffness is computed by the following formula:

$$K_z = \frac{3G_{bp}I_{brg}}{T(1+\alpha_{cr})}\left(A_r + B_{trn}{S_{brg}}^2\right) \quad \text{(single bearing)}$$

Where;

$K_z =$ rotational stiffness (in-kips/rad)

$G_{bp} =$ shear modulus (ksi) (reduced by 15% when Method B is used per LRFD A14.7.5.2, lower limit used for Method A)

$I_{brg} =$ moment of inertia of bearing $= \frac{L_{brg}{W_{brg}}^3}{12}$ (in^4)

$T =$ total elastomer thickness (in)

$\alpha_{cr} =$ creep factor (dimensionless)

$A_r = 1$ dimensionless constant from NCHRP Report 596

$B_{trn} =$ dimensionless value from NCHRP Report 596

$S_{brg} =$ interior layer shape factor (dimensionless)

The equation for B_{trn} is given by:

$$B_{trn} = (0.24 - 0.024\lambda) + (1.15 - 0.89\lambda)\left(1 - e^{-0.64\frac{W_{brg}}{L_{brg}}}\right)$$

Where;

$\lambda =$ compressibility index (dimensionless)

$W_{brg} =$ bearing pad width (in)

$L_{brg} =$ bearing pad length (in)

The equation for the compressibility index is given by:

$$\lambda = S_{brg}\sqrt{3\frac{G_{bp}}{K_{bp}}}$$

Where;

$K_{bp} =$ bulk modulus and is taken as 450 ksi per LRFD C14.7.5.3.3

3.12 HORIZONTAL SHEAR FORCE AND MOMENTS FOR SUBSTRUCTURE DESIGN (METHOD A AND METHOD B DESIGN)

The analysis of an expansion end pad includes the calculation of the unfactored shear force on the pad as a result of the elastomer's resistance to shear deformation for substructure design.

$$F_S = \frac{G_H \, A \, \Delta_{t(\text{substr.})}}{T}$$

where: $\Delta_{t(\text{substr})}$ = [(Expansion length) * (Coefficient of thermal expansion of the beam) * (Temperature range for substructure design)]

For two pad case, A is equal to the total plan area of both pads. For plain pads, T is equal to t_p.

The horizontal force due to thermal movement only is computed. Horizontal force effects due to beam end rotation and pier flexibility, as applicable, should be accounted for separately. For abutments, horizontal force effects due to beam end rotation act in a direction opposite to earth and thermal effects, and therefore should be disregarded.

For unconfined elastomeric bearings and pads, the moment transmitted to the substructure by bearings shall be taken as (LRFD Specifications Equation 14.6.3.2-3):

$$M_u = 1.60(0.5 E_c I)\frac{\theta_s}{h_{rt}}$$

where: I = moment of inertia of plan shape of bearing (in4)

E_c = effective elastic modulus of elastomeric bearing in compression (ksi)

θ_s = maximum service limit state rotation angle (radians)

h_{rt} = total elastomer thickness (in)

3.13 SHIM PLATE THICKNESS (METHOD A DESIGN)

The analysis of a laminated pad at the expansion end includes the calculation and checking of the thickness of the steel reinforcement (shims) due to the shear deformation of the pad. The program checks the thickness of the reinforcement according to DM-4. The thickness of the reinforcement, h_S, shall satisfy:

At the service limit state:

$$h_s \geq k_{hole} \frac{h_{avg}(1.7\ ksi)}{0.55 F_y}$$

At the fatigue limit state:

$$h_s \geq k_{hole} \frac{2 h_{avg} \sigma_L}{\Delta F_{TH}}$$

At PennDOT minimum:

$$h_s \geq 0.1196\ inch$$

where: h_{avg} = the average thickness of the two layers of the elastomer bonded to the reinforcement; in this program, the thickness of the interior elastomer layer is used.

k_{hole} = 1 if there is no hole in the reinforcement.

$= \frac{2 * Gross\ Width}{Net\ Width}$ if a hole exists in the reinforcement.

σ_L = service average compressive stress due to live load (in this program, the maximum live load stress is used)

0.1196" = actual thickness of 11 gauge carbon steel

3.14 MINIMUM PAD THICKNESS REQUIREMENT (METHOD A AND METHOD B DESIGN)

The minimum total pad thickness (elastomeric layer plus shims) permitted must be greater than or equal to the minimum pad thickness entered by the user on the GEO command (Section 5.6), within a tolerance of 0.01".

3.15 COMPRESSIVE DEFLECTION (METHOD A AND METHOD B DESIGN)

The analysis of a pad includes the calculation of the compressive deflection of the pad due to the unfactored maximum dead load, the unfactored live load and the unfactored total load. The calculations are as follows:

Plain pad:

$$\delta_T = t_p\left(CR\varepsilon_{pDL} + \varepsilon_{pT}\right)$$
$$\delta_{LL} = t_p\left(\varepsilon_{pT} - \varepsilon_{pDL}\right)$$
$$\delta_{DL} = \delta_T - \delta_{LL}$$

Laminated pad:

$$\delta_T = \left(T - 2t_c\right)\left(CR\varepsilon_{iDL} + \varepsilon_{iT}\right) + 2t_c\left(CR\varepsilon_{cDL} + \varepsilon_{cT}\right)$$
$$\delta_{LL} = \left(T - 2t_c\right)\left(\varepsilon_{iT} - \varepsilon_{iDL}\right) + 2t_c\left(\varepsilon_{cT} - \varepsilon_{cDL}\right)$$
$$\delta_{DL} = \delta_T - \delta_{LL}$$

For laminated pads, the compressive deflection is calculated by converting the compressive stress into strain based on Equation DC14.7.5.3.6-1

3.16 METHOD B ANCHORAGE (METHOD A AND METHOD B DESIGN)

The analysis and design of an expansion pad that is laminated now includes the Method B anchorage check from A14.7.5.4 in addition to the Method A anchorage check. For Method A design runs, the program will issue a **District** Bridge Engineer warning if the Method B anchorage check criteria is not satisfied, but will not consider the check as part of the design algorithm. For Method B design runs, this check will be considered as part of the design algorithm. For Method A and Method B analysis runs, the program will check Method B anchorage criteria and issue a **District** Bridge Engineer warning if the criteria is not met. The calculations are as follows:

$$\frac{\theta_s}{n} < \frac{3\varepsilon_a}{S_i}$$

Where:

θ_s	=	Total maximum service limit state design rotation angles (DL+1.75*LL) (rad.)
ε_a	=	Total maximum service limit state axial strain of the interior layer (DL+1.75*LL) (in/in)
n	=	number in interior layers of elastomer. If the thickness of the exterior layer of elastomer is >= ½ the interior elastomer layer thickness, then value of n is increased by ½ for each exterior layer
S_i	=	shape factor of the *i*th internal layer of the bearing (See 3.6.1, 3.6.9)

If the left term is smaller than the right term, then the Method B anchorage criteria is considered satisfied. However, if the left term is greater than or equal to the right term, then a **District** Bridge Engineer's warning message is printed indicating that an external restraint system is required to secure the bearing against horizontal movement.

3.17 METHOD B DESIGN

The user also has the option of designing or analyzing laminated bearing pads with the Method B procedure described in section 14.7.5 of the LRFD Specifications. A major difference between Method A and Method B is that Method B can only be used for steel-reinforced bearing pads. Plain pads cannot be designed with Method B.

The design algorithm for bearing pads using Method B is also a bit different than the algorithm followed for Method A. The Method A procedure rearranges many of the design equations in order to directly find the required pad thickness. The Method B equations cannot be easily rearranged in this way, so the program adds a loop to iterate over the number of interior layers, up to 20 layers. Method B also adds an iteration loop over the pad width. Method A directly calculates the required pad width using the compressive stress check.

For both Method A and Method B, the program also iterates over the pad length, cover layer thickness, and interior layer thickness

For Method B, the required shim thickness is independent of the number of interior layers, so this is calculated before the iteration loop so the total thickness of the trial pad can be calculated before checking the other design equations. This eliminates many thin pads from consideration. Also, once a given pad passes all specification check for a given number of interior layers, the program does not add more layers. The governing pad is the pad with the smallest elastomer volume.

The program mostly uses the Method B Specification checks from the AASHTO LRFD Specifications. The only DM-4 specification followed for the Method B checks is the minimum shim thickness of 0.1196" (versus 0.0625" in the LRFD Specifications).

The program Method B design algorithm is as follows:

Expansion End:

1. Specify a length, width, interior layer thickness, and cover layer thickness for the current trial pad.

2. Calculate the required shim thickness, based on the applied stress. AASHTO equation 14.7.5.3.5-1 is used for the service limit state check, and a minimum shim thickness of 0.1196" is used. AASHTO equation 14.7.5.3.5-2 is used for the fatigue check.

3. Start with one interior layer and calculate the total pad thickness. If this is less than the user-entered or default pad thickness, add an interior layer.

4. If the minimum thickness requirement has been met, check the shear deformation requirements of A14.7.5.3.2 (if at any time in the design process a specification check fails, the trial pad is rejected and the number of interior

layers is increased by one). The shear deformation only includes thermal movement and the user input pier flexibility movement. The thermal movement is multiplied by 0.65 and a load factor of 1.2 as per AASHTO.

5. If the shear deformation check passes, the program then does the combined compression, rotation, and shear check (A14.7.5.3.3).

6. The shear strain due to axial load is calculated using the maximum combination of dead load stress and 1.75*live load stress. Also, D_a uses the values specified in LRFD Specifications Equations 14.7.5.3.3-4 and -5, not the refined calculation given in the LRFD Specifications commentary.

7. The shear strain due to rotation uses the D_r values specified in LRFD Specifications Equations 14.7.5.3.3-7 and -9, not the refined calculation given in the LRFD Specifications commentary. In addition, for circular pads, the rotations about each axis are resolved into a single values, as is done elsewhere in the program. For rectangular pads, the rotations are considered separately.

   For cases with two pads, when calculating the shear strain due to rotation about the longitudinal axis of the pad, the length (L) term in equation 14.7.5.3.3-6 or diameter (D) term in equation 14.7.5.3.3-8 is calculated to the outer edge of the two pad group (not the length or diameter of a single pad). See Figure 1.

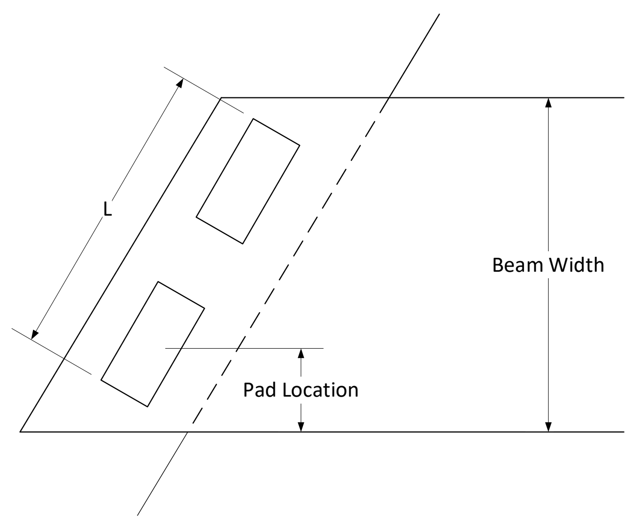


Figure 3.16-1 Pad Length for Two Pad Configuration

8. The shear strain due to shear deformation includes shear deformation from thermal movement (multiplied by 0.65 and 1.2 as described above), user input pier flexibility, and horizontal movement due to rotation from dead and live loads for all specification conditions. This is different than the shear deformation check above in Step 4.

9. If the the static shear strain due to axial load is less than 3.0 and the combined shear strain due to axial load, rotation, and shear deformation is less than 5.0, the bearing pad passes the shear strain check (LRFD Specifications Equations 14.7.5.3.3-1 and -2).

10. Next, the stability (A14.7.5.3.4) of the bearing pad is checked. The bridge deck is always assumed to free to translate horizontally, making this check more conservative for cases where the deck is not free to translate. The stress checked here is the maximum combination of dead and live load stresses. The live load stress is not multiplied by 1.75 in this case.

11. The Method B anchorage check is done (LRFD Specifications Section 14.7.5.4). Originally, the Method B anchorage check implemented in BPLRFD only checked one combination: input dead load rotation + input live load rotation on the left side of LRFD Specifications Equation 14.7.5.4-1, compared to the strain due to input minimum dead load reaction combined with the strain due to the input maximum live load on the right.

    Because of the nonlinearity of the strain response of the bearing pad, two more combinations are checked. Input dead load rotation only on the left, compared to the strain due to the input minimum dead load reaction on the right, and input dead load + input live load rotation on the left and the strain due to the input minimum dead load reaction plus the input minimum live load reaction. The strain is determined using the method in DC14.7.5.3.6. Again, because of the nonlinearity of the response, the strain is determined from the total stress, not individual dead load + individual live load. The minimum dead load + maximum live load combination is retained to match the original BPLRFD check.

12. If no good design is found after these checks, another interior layer is added and process started again.

Fixed End:

For the design of the fixed end pad, the length and width (or diameter) are set to be the same as the expansion end. The cover and interior layer thicknesses are iterated, as well as the number of layers. The same order of checks is followed as described for the expansion end, but the shear deformation and anchorage checks are skipped for all Method B Specification options. The shear deformation strain value in the combined shear strain check is set to zero (as the fixed end pad is assumed to be restrained), but the rest of the shear strain values are calculated as described above.

3.18 SYSTEM PARAMETER FILE

The Bearing Pad Design and Analysis Program reads a system parameter file for the following: the strain equation coefficients; shear modulus; creep factor; stability factors; maximum thickness for laminated pads; minimum and maximum thickness for plain pads; minimum and maximum pad layer thicknesses and lengths; reinforcement (shim) thickness and strengths; rotation construction tolerances; minimum and maximum edge distances; and dowel hole diameter.

```
! Use "!" as comments. No comments are permitted on a data line before the data.
! Words enclosed in brackets {} are keywords and should not be modified.
! Data lines are read using spaces as delimiters.
! Reference LRFD Specifications, DM-4, and PennDOT BD drawings
!
{MODULUS}
!
! Shear Modulus and Creep Factor are as per AASHTO Table 14.7.6.2-1
!
!              Shear Modulus     Creep
!  Hardness    Low     High      Factor
! (Shore A)   (psi)   (psi)
     50         95.    130.       .250
     60        130.    200.       .350
!
{COEFF}
!
! Coefficients A and B are as per DM-4 Table C14.7.5.3.6-1P
!
!   Hard-   --------------- Shape Factors ---------------
!   ness       3       4       5       6       9       12
!
     50     -18.0   -4.20   -1.40   -0.69   -0.7    -1.00    ! Coefficient A (1/ksi^2)
     50      22.7    12.3    8.4     5.9     5.2     5.0     ! Coefficient B (1/ksi)
     60     -7.30   -2.80   -1.60   -0.9    -0.78   -0.99    ! Coefficient A (1/ksi^2)
     60      15.9    10.2    7.3     5.3     4.6     4.5     ! Coefficient B (1/ksi)
!
!
{ALLOWABLE STRESS}
!
! Allowable compressive stress for bearing pad as per DM-4 14.7.6.3.2
!
!   Laminated Pad            Plain Pad
!     (psi)                   (psi)
      1250.0                  800.0
!
!
{STABILITY}
!
!  Factors for stability check as per DM-4 14.7.6.3.6
! (denominators of equations in DM-4 14.7.6.3.6)
!
!  DO NOT CHANGE THE "TYPE" DESIGNATION. P and L are the only two accepted.
!
! Type  length   width   diameter
   P      5        5        6        ! Plain
   L      3        3        4        ! Laminated
!
!
```

```
{MAX_LAMINATED_THK}
!
! Maximum thickness for laminated bearing pads (inches) as per DM-4 14.7.6.3.6-7P
! Note that this is greater than the "generally not exceed" value of 6" in DM-4 C14.7.6.3.1aP
! BPREV135 - Note that this is equal to the "generally not exceed" value of 8" in DM-4
! C14.7.6.3.1aP
!
 8.00
!
!
{PLAIN_THK}
!
! Min. and max. thick. of plain bearing pads (inches) as per DM-4 14.7.6.3.1aP
!    Minimum     Maximum
       0.75       1.25
!
!
{STRUCT_PARAM}
!                     (all units are inches)
!                DO NOT CHANGE THE "STRUCT TYPE" DESIGNATIONS. Changing
!                them here does not change them inside the program.
! STRUCT
!   TYPE  DMINIT  DMAXIT  DMINCT DMAXCT  DMINL DMAXL DMIND DMAXD
    1     .375    .625    .25    .25     4.0   24.   4.0   40.   ! P/S  I
    2     .375    .625    .25    .25     4.0   24.   4.0   40.   ! P/S Spr Box
    3     .375    .625    .25    .25     4.0   24.   4.0   40.   ! P/S Adj Box
    4     .375    .625    .25    .25     4.0   24.   4.0   40.   ! Steel
    5     .375    .625    .25    .25     4.0   24.   4.0   40.   ! P/S Bulb Tee
!
!
{NOTES}
!
! Parameter description for the STRUCT_PARAM section:
! The next parameters are used for controlling the thickness of
! the elastomer layers for a design.
!
! DMINIT - Default minimum interior layer elastomer thickness (*)
! DMAXIT - Default maximum interior layer elastomer thickness (*)
! DMINCT - Default minimum cover layer elastomer thickness (*)
! DMAXCT - Default maximum cover layer elastomer thickness (*)
! DMINL  - Default minimum length of bearing pad
! DMAXL  - Default maximum length of bearing pad
! DMIND  - Default minimum diameter of circular bearing pad
! DMAXD  - Default maximum diameter of circular bearing pad
!
!    (*) Values are as per DM-4 14.7.6.3.1aP
!
!    Note that 0.500 is used for DMINIT for box beams to reduce the
!    total pad volume, since for box beams, the plan area usually does
!    not control.
!
! Structure type description  for the STRUCT_PARAM section:
!     1 - Prestressed I-beam
!     2 - Prestressed Spread Box-beam
!     3 - Prestressed Adjacent Box-beam
!     4 - Steel I-beam superstructure, rolled shape or plate-girder
!     5 - Prestressed Bulb Tee Beam
!
!
{INCREMENT}
!
!    Length   Width    --------- Thickness of Pad ------------
!    of Pad   of Pad   Inter.layer    Cover layer   Plain pad
!     (in)     (in)       (in)           (in)         (in)
      1.0      1.0       .125           .125         .125
!
```

```
{SHIMS}
!
!    Minimum          Yield Strength        Constant Amplitude
!   Thickness            of Shim            Fatigue Threshold
!     (in)                (psi)                   (psi)
     0.1196              36000.0                 24000.0
!
!  The minimum thickness is per (DM-4 14.7.5.3.5), and is equal to the actual thickness
!    of 11 gauge carbon steel
!  Yield strength is based on M270 Grade 36 steel (AASHTO LRFD Table 6.4.1-1)
!  Constant amplitude fatigue threshold for Category A (AASHTO LRFD Table 6.6.1.2.5-3)
!
!
{ANCHOR DOWEL SPAN LIMIT}
!
! Span limit for anchor dowels as per DM-4 14.7.6.4P
!    Maximum
!  Span Length
!     (in)
     600.0
!
!
{HOLE DIAM}
    2.375
!
! Hole diameter in inches.
!
!
{THERMAL COEF}
! Coefficient of thermal expansion of the beam:
!   P/S beam      Steel beam
    .0000060      .0000065
!
!
! From here till the end of the file are the definitions of the
! maximum and minimum edge distances for P/S ADJACENT BOX BEAM,
! P/S SPREAD BOX BEAM, P/S I BEAM, and STEEL BEAM as per BD-653M.
!
!
{P/S ADJ. BOX, ONE RECT. PAD PER BEAM END}
!
!   Beam
!  Bottom      Maximum     Minimum
!   Width     Edge Dist.  Edge Dist.
!   (in)        (in)       (in)
     36          6.5        1.0
     48         10.0        1.0
!
!
{P/S ADJ. BOX, TWO RECT. PADS PER BEAM END}
!
!   Beam      ----- EXTERIOR -----   ---------- INTERIOR ---------
!  Bottom      Maximum    Minimum     Maximum    Minimum    Washer
!   Width     Edge Dist. Edge Dist.  Edge Dist. Edge Dist.  Width
!   (in)        (in)      (in)         (in)      (in)       (in)
     36         3.25      1.0          5.0        0.0        5.0
     48         5.0       1.0         12.0        0.0        5.0
!
!
{P/S ADJ. BOX, ONE CIRC. PAD PER BEAM END}
!
!   Beam
!  Bottom      Maximum     Minimum
!   Width     Edge Dist.  Edge Dist.
!   (in)        (in)       (in)
     36          6.5        1.0
```

```
     48         10.0        1.0
!
!
{P/S ADJ. BOX, TWO CIRC. PADS PER BEAM END}
!
!   Beam      ----- EXTERIOR -----   ---------- INTERIOR ---------
!  Bottom      Maximum    Minimum     Maximum    Minimum    Washer
!   Width     Edge Dist. Edge Dist.  Edge Dist. Edge Dist.  Width
!   (in)        (in)      (in)         (in)      (in)       (in)
     36         3.25      1.0          5.0        0.0        5.0
     48         5.0       1.0         12.0        0.0        5.0
!
!
{P/S SPR. BOX, ONE RECT. PAD PER BEAM END}
!
!   Beam
!  Bottom      Maximum     Minimum
!   Width     Edge Dist.  Edge Dist.
!   (in)        (in)       (in)
     36          6.5        1.0
     48         10.0        1.0
!
!
{P/S SPR. BOX, TWO RECT. PADS PER BEAM END}
!
!   Beam      ----- EXTERIOR -----   ---------- INTERIOR ---------
!  Bottom      Maximum    Minimum     Maximum    Minimum    Washer
!   Width     Edge Dist. Edge Dist.  Edge Dist. Edge Dist.  Width
!   (in)        (in)      (in)         (in)      (in)       (in)
     36         3.25       1.0          5.0       0.0        5.0
     48          5.0       1.0         12.0       0.0        5.0
!
!
{P/S SPR. BOX, ONE CIRC. PAD PER BEAM END}
!
!   Beam
!  Bottom      Maximum     Minimum
!   Width     Edge Dist.  Edge Dist.
!   (in)        (in)       (in)
     36          6.5        1.0
     48         10.0        1.0
!
!
{P/S SPR. BOX, TWO CIRC. PADS PER BEAM END}
!
!   Beam      ----- EXTERIOR -----   ---------- INTERIOR ---------
!  Bottom      Maximum    Minimum     Maximum    Minimum    Washer
!   Width     Edge Dist. Edge Dist.  Edge Dist. Edge Dist.  Width
!   (in)        (in)      (in)         (in)      (in)       (in)
     36         3.25      1.0          5.0        0.0        5.0
     48         5.0       1.0         12.0        0.0        5.0
!
! Washer width is the width of the elastomeric sponge washer provided
! for the dowel rod at CL of brg./CL beam intersection as per BD-653M.
!
!
{P/S I, RECT. PAD}
!
!    Minimum       Maximum
!   Edge Dist.    Edge Dist.
!      (in)         (in/in)
       1.0           0.1
!
! Maximum edge dist. shown above is the coefficient multiplied by the
! bottom width of the beam to obtain the actual maximum edge distance
! as per BD-653M.
```

```
!
!
{P/S I, CIRC. PAD}
!
!    Minimum       Maximum
!   Edge Dist.    Edge Dist.
!     (in)          (in/in)
       1.0           0.1
!
! Maximum edge dist. shown above is the coefficient multiplied by the
! bottom width of the beam to obtain the actual maximum edge distance
! as per BD-653M.
!
!
! Steel Beams
!
!  The edge distances for steel beams are computed by the program as
!  25% greater than the bottom flange width of the beam.
!
!
{P/S BULB, RECT. PAD}
!
!    Minimum       Maximum
!   Edge Dist.    Edge Dist.
!     (in)          (in/in)
       1.0          0.15
!
! Maximum edge dist. shown above is the coefficient multiplied by the
! bottom width of the beam to obtain the actual maximum edge distance
! as per BD-659M
!
!
{P/S BULB, CIRC. PAD}
!
!    Minimum       Maximum
!   Edge Dist.    Edge Dist.
!     (in)          (in/in)
       1.0          0.15
! << EOF >
```

4 GETTING STARTED

4.1 INSTALLATION

This program is delivered via download from the Department's website. Once payment has been received by PennDOT you will receive a confirmation e-mail with instructions on how to download the software. The download file is a self-extracting installation file for the licensed PennDOT engineering software. The engineering program runs as a 32-bit application and is supported on Windows 10 operating systems (32 bit and 64 bit versions) **and Windows 11**.

Your license number, license key and registered company name, found in the e-mail received from the Department, are required to be entered when installing the program and must be entered exactly as shown in the e-mail. The license number, license key and registered company name will also be needed when requesting future versions of the program (i.e., enhancements, modifications, or error corrections), and requesting program support. A backup copy of the program download and e-mail instructions should be made and used for future installations. You may want to print the software license agreement, record the license number, license key and registered company name and keep it in a safe place.

To install the program, follow the installation instructions provided with the original e-mail from the Department.

The following files will be installed in the program destination folder, which defaults to "C:\Program Files\PennDOT\BPLRFD v<version_number>\" **for 32-bit operating systems** or "C:\Program Files (x86)\PennDOT\BPLRFD v<version number>\" for 64-bit operating systems:

1. BPLRFD.exe, BPLRFD_DLL.dll - Executable program and Dynamic Link Library.
2. BPLRFD.pd - Parameter definition file.
3. BPLRFD Users Manual.pdf - Program User's Manual (PDF Format).
4. BPLRFDRevReq.dotx - Revision Request form (MS Word template).
5. GettingStarted.pdf - A document describing installation and running of the program
6. LicenseAgreement.pdf - The program license agreement
7. MSVCR71.dll - Runtime Dynamic Link Library

The program example problem files (ex*.dat) will be installed in the program example folder, which defaults to "C:\PennDOT\BPLRFD v<version_number> Examples\". Users must have write access in order to run the input files from this folder.

4.2 PREPARING INPUT

The engineering program requires an ASCII input file. The input file consists of a series of command lines. Each command line defines a set of input parameters that are associated with that command. A description of the input commands can be found in Chapter 5 of the User's Manual. The input can be created using Engineering Assistant, described below, or any text editor.

4.3 ENGINEERING ASSISTANT

The Engineering Assistant (EngAsst) is a Windows application developed by the Pennsylvania Department of Transportation (PennDOT) to provide a graphical user interface (GUI) for PennDOT's engineering programs. The data for the input to the engineering program is presented in a user-friendly format, reflecting the implied structure of the data, showing each record type on a separate tab page in the display and showing each field on each record with a defining label.

With EngAsst the user can create a new input file, modify an existing input file, import input files, run the associated engineering program and view the output in a Windows environment. The help and documentation are provided, including text descriptions of each field, relevant images, and extended help text at both the record/tab level and the field level. Access to all parts of the Engineering Program User's Manual, where available, is also provided within EngAsst.

EngAsst is not included with this software. It requires a separate license that can be obtained through the Department's standard Engineering Software licensing procedures. Order forms can be obtained from program support website at http://penndot.engrprograms.com.

4.4 RUNNING THE PROGRAM WITHOUT ENGASST

The engineering programs are FORTRAN console application programs. They may be run from a command window, by double-clicking on the program icon from Windows Explorer, by selecting the shortcut from the Start menu under "PennDOT BPLRFD <version number>", or by double-clicking the shortcut icon on the desktop. To run the program in a command window, the user must specify the directory in which the program has been installed or change to the directory.

The program will prompt for an input file name, and the user should then enter the appropriate input file name. The input file must be created before running the program. The program will then prompt for whether the output should be reviewed on the screen. The user should enter Y if the output is to be reviewed on the screen after execution or N if the output is not to be reviewed on the screen. The program will then prompt for the name of the output file in which the output is to be stored, and the user should then enter the desired output file name. If a file with the specified output file name already exists, the program will ask the user whether to overwrite the existing file. The user should enter Y if the existing file is to be overwritten or N if the existing file is not to be overwritten. If the user enters N to specify that the existing file is not to be overwritten, the program will prompt the user for another output file name. The program will then execute.

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

When the program completes execution, the user is prompted to “Press <ENTER> to exit program.” This allows the user to view the last messages written to the screen when the program was started by double-clicking on the program icon from Windows Explorer.

The user can view the *.OUT output file with a text editor and the *.PDF output file with Adobe Acrobat or any other PDF viewing programs.

5 INPUT DESCRIPTION

5.1 INPUT DATA REQUIREMENTS

Before running BPLRFD, the user must create an input file. The input file consists of a series of command lines. Each command line defines a set of input parameters that are associated with that command. The program interprets each command line and checks the input parameters to insure that the input data is of the correct type and within the allowable ranges set by the program.

The syntax of a command line is given as:

```
KWD   parm1,   parm2,   ,   ,   parm5,   ,
```

where KWD is a 3 character keyword representing a command, and
parm1, parm2.... are the parameter values associated with the KWD

If a command line begins with an exclamation point (!), then it is treated as a comment line that is not used by the program. Comment lines can be inserted by the user to provide descriptions and clarifications. The following are two examples of a comment line:

```
!   THE FOLLOWING COMMAND LINE IS ONLY USED FOR CONTINUOUS BEAM.
!   PENNDOT SKEW ANGLE DESIGNATION IS USED IN THIS INPUT.
```

To temporarily make a command line void, the user can use an exclamation point (!) to transform the command line into a comment line. For an input line to be treated as a comment line, the exclamation point must be put in column 1 of the input line. For example, in the following case, the program will use the input data on the second line but will not use the input data on the first line:

```
!   BPD   50, 0., L, R, B, F
BPD   50, 0., L, R, S, F
```

A command line must not exceed 256 characters in length. Command lines can be continued on any number of data lines in the input file by placing a hyphen (-) at the end of each data line to be continued, and by placing any remaining parameters on the following lines starting in column 4 of each continuation line. The limit of 256 characters includes all characters and parameters on all continuation lines of a given command line.

The first three columns of each command line are reserved for keywords that define the command type. Columns 4 through 256 are to be used to input the parameters associated with a command. One or more spaces are recommended between the keyword and the input parameters to improve readability.

The parameters associated with each command must be entered in the order they appear in the command description tables. The user must place commas to separate the parameters on the command line. Blank spaces cannot be used to separate parameters. The parameter field width is not restricted; however, the total number of characters cannot exceed 256.

The default value for a parameter is assigned by the program by placing a comma without any value for the parameter. For example, in the command syntax example shown below, the default values will be assigned to parameters parm3 and parm4.

```
KWD   parm1,   parm2,   ,   ,   parm5
```

If the user places a comma and there is no default value, the program will return an error status. If a comma is entered after the command keyword, the program will assign the default value to the first parameter. If the user does not enter all the parameters for a command, the program will assign default values for those parameters not entered. That is, the user is not required to place commas at the end of a command line. If the above example required seven parameters, parm6 and parm7 would also be assigned default values by the program.

The default values are stored in a parameter definition file, which can be changed only by the Department's system manager. The parameter definition file stores the parameter descriptions, types of data, units, upper and lower limits, error or warning status if the upper or lower limits are exceeded, and the default values for each parameter. The parameter definition file differs from the system parameter files in that it stores the default values and descriptions of the user input parameters, while the system parameter files store the parameters that a user does not need to enter each time, such as the allowable stresses, modulus of elasticity, and coefficients for calculating the strains.

Any numerical value, within the upper and lower limits, can be entered for a parameter. The status codes, shown in parentheses below the lower and upper limits, indicate the status if an input item exceeds the lower or upper limits. The status code, (E), indicates an error. The status code, (W), indicates a warning. The status code, (**D**), indicates a warning that can be accepted/ignored only upon the approval of the Department's **District** Bridge Engineer.

In the following sections, all available commands and associated parameters are described with two tables for each command. The first table contains the keyword for a particular command along with a description of the command. The second table gives all the parameters associated with the given command, parameter description, units, limits, and default values.

and default values.

The program will process all input and will check for errors and warnings. If the number of errors exceeds 25 during input processing, the program will terminate immediately. After all input is processed, the program checks if any errors were found. If an error was found, the program will terminate. If warnings are found, the program will continue to process. If the number of warnings exceeds 200 during input processing for a single run, the program will terminate immediately. The user should review all warnings in the output file to insure that the input data is correct. Warnings are an indication that the input value has exceeded normally acceptable limits for that parameter.

5.2 ORDER OF COMMANDS

If the user wants to control the number of lines printed on a page or the number of lines to be left blank at the top of each page, the CFG (configure) command should be the first command. The CFG command is optional and the program will use default values if the CFG command is not entered. The first required command is one or more TTL (title) commands. As many as ten TTL commands may be entered by the user. The first TTL command is printed in the header at the top of each output page. A maximum of ten TTL commands is printed on the first page of the output. The second required command after the title commands is the CTL (control) command. The CTL command is used to specify the system of units which is required for checking the range of the input data. The CTL command also includes other major control parameters such as Design/Analysis, Simple/Continuous, and Superstructure Type.

The remaining commands can be entered in any order.

The recommended order of the commands is shown in Table 1. The commands are shown in alphabetical order in Table 2. The section headings in these tables refer to the section number of this chapter where these commands are described. Figure 1 shows the overall view of a typical input file with these commands.

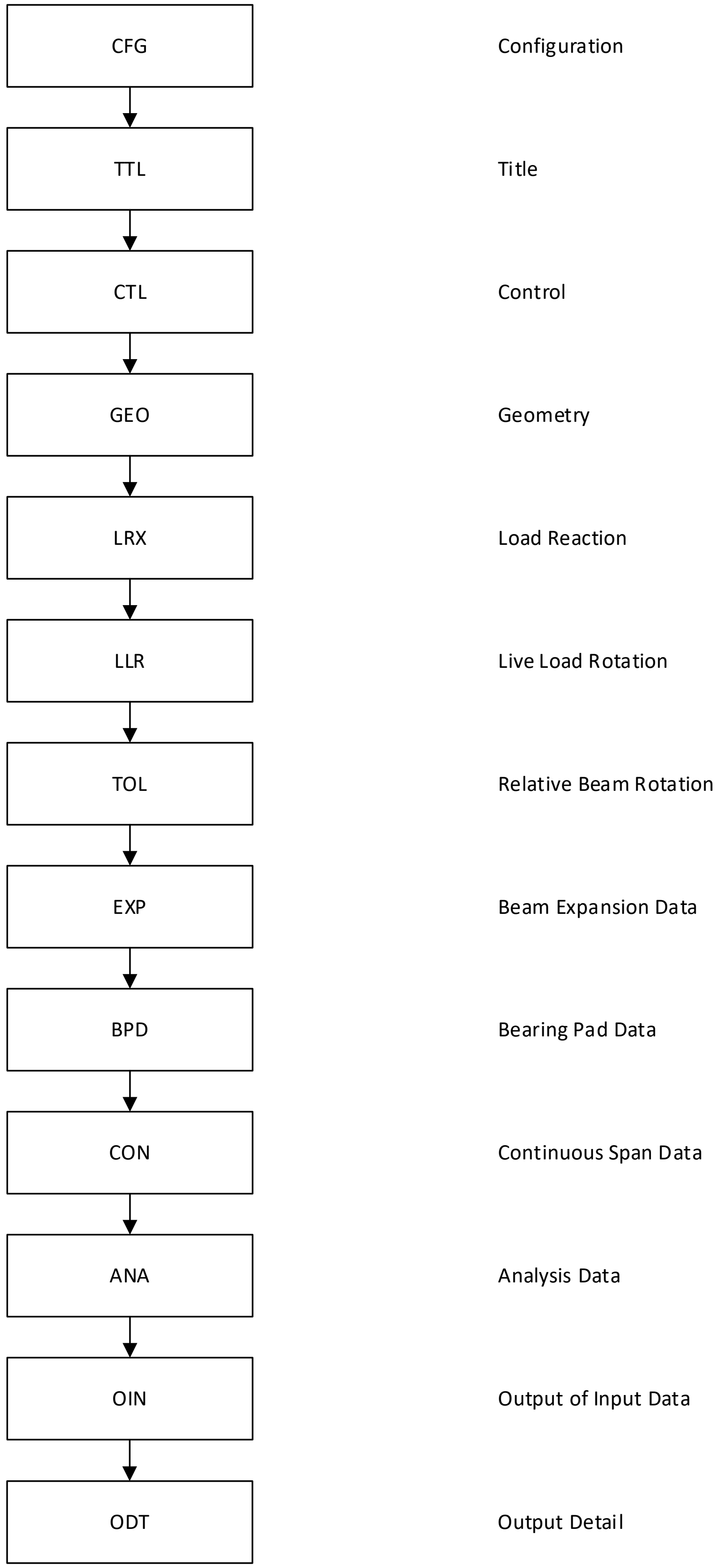


Figure 5.2-1 Overall View of Input File

Table 5.2-1 Recommended Order of Commands

Keyword	Command Description	Comments	Section
CFG	Configuration	Optional for both design and analysis	5.3
TTL	Title	At least one TTL command is required for both design and analysis	5.4
CTL	Control	Required before other structure commands (other than CFG and TTL commands) for both design and analysis	5.5
GEO	Geometry	Required for both design and analysis	5.6
LRX	Load Reaction	Required for both design and analysis	5.7
LLR	Live Load Rotation	Required for both design and analysis	5.8
TOL	Relative Beam Rotation	Required for both design and analysis	5.9
EXP	Beam Expansion Data	Required for both design and analysis	5.10
BPD	Bearing Pad Data	Required for both design and analysis	5.11
CON	Continuous Span Data	Required for continuous beams only	5.12
ANA	Analysis Data	Required for analysis only	5.13
OIN	Output of Input Data	Optional for both design and analysis	5.14
ODT	Output Detail	Optional for both design and analysis	5.15

Table 5.2-2 Commands in Alphabetical Order

Keyword	Command Description	Comments	Section
ANA	Analysis Data	Required for analysis only	5.13
BPD	Bearing Pad Data	Required for both design and analysis	5.11
CFG	Configuration	Optional for both design and analysis	5.3
CON	Continuous Span Data	Required for continuous beams only	5.12
CTL	Control	Required before other structure commands (other than CFG and TTL commands) for both design and analysis	5.5
EXP	Beam Expansion Data	Required for both design and analysis	5.10
GEO	Geometry	Required for both design and analysis	5.6
LLR	Live Load Rotation	Required for both design and analysis	5.8
LRX	Load Reaction	Required for both design and analysis	5.7
ODT	Output Detail	Optional for both design and analysis	5.15
OIN	Output of Input Data	Optional for both design and analysis	5.14
TOL	Relative Beam Rotation	Required for both design and analysis	5.9
TTL	Title	At least one TTL command is required for both design and analysis	5.4

5.3 CFG – CONFIGURATION COMMAND

KEYWORD	COMMAND DESCRIPTION
CFG	CONFIGURATION - This command is used for configuring the program output from a given PC and printer setup. Only one CFG command may be used. If this command is not entered, each parameter listed below will be automatically set to its default value. This command is optional for both design and analysis.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Number of Lines Per Page	Enter the number of printable lines per output page.	--	50 (W)	74 (W)	74
2. Number of Top Blank Lines	Enter the number of lines to be left blank at the top of each output page.	--	0 (E)	5 (W)	0

5.4 TTL – TITLE COMMAND

KEYWORD	COMMAND DESCRIPTION
TTL	TITLE - As many as ten TTL commands may be entered by the user. The first TTL command is printed in the header at the top of each output page. A maximum of ten TTL commands can be entered and are printed on the first page of the output. The input file must have at least one TTL command.

PARAMETER	DESCRIPTION
1. Title	Enter any descriptive information about the project. Title information can be entered anywhere between Column 4 and Column 79.

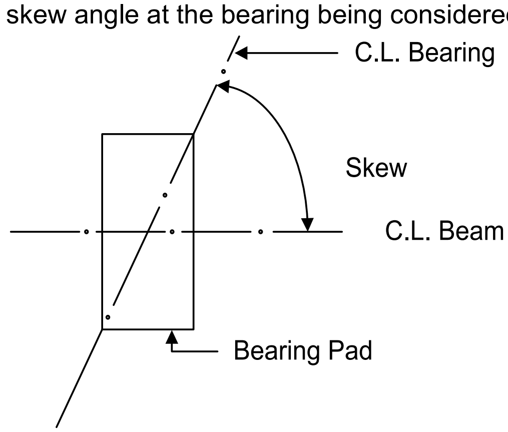
5.5 CTL – CONTROL COMMAND

KEYWORD	COMMAND DESCRIPTION
CTL	CONTROL - This command is used to set the control parameters for the input. The input file must have one and only one CTL command. The CTL command must be entered before any other structure command other than the CFG and TTL commands. This command is required for both design and analysis.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. System of Units	Enter: US - U.S. customary units.	--	US (E)	--	US
2. Run Type	Enter: A - Given the bearing pad size and configuration, perform specification check in accordance with the LRFD Specifications and DM-4. D - Designs bearing pads for the given loading and bridge geometry in accordance with the LRFD Specifications and DM-4.	--	A, D (E)	--	--
3. Span Type	Enter: S - Simple span. C - Continuous span.	--	S, C (E)	--	--
4. Superstructure Type	Enter: IP - Prestressed I-beam. BS - Prestressed spread box beam. BA - Prestressed adjacent box beam. IS - Steel I-beam. BT - Prestressed bulb tee beam.	--	IP, BS, BA, IS, BT (E)	--	--
5. Design / Analysis Method	Enter: A - Use AASHTO Method A (Section 14.7.6) for design and analysis B - Use AASHTO Method B (Section 14.7.5) for design and analysis AB - Attempt design using Method A. If design fails, attempt design again using Method B NOTE: Method B can only be used for laminated pads. Plain pads cannot be designed or analyzed with Method B. Selection AB is only valid for DESIGN runs of the program.	--	A, B, AB (E)	--	A

5.6 GEO – GEOMETRY COMMAND

KEYWORD	COMMAND DESCRIPTION
GEO	GEOMETRY - This command is used to define the bridge geometry information. Only one GEO command can be used. This command is required for both design and analysis.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Expansion Length	Enter the expansion length, as follows: For simple span structures, enter the span length, center-to-center of bearings. For expansion bearings of continuous span structures, enter the total expansion length, from centerline of the bearing being designed or analyzed to the center of the theoretical fixed point of the bridge. For fixed end bearings of continuous span structures, enter 0.	ft	0. (E)	300. (W)	--
2. Beam Bottom Width	Enter the width of the bottom of the beam.	in	6. (W)	48. (W)	--
3. Maximum Skew	Enter the maximum skew angle measured from the centerline of the beam to the centerline of the bearing. When the centerline of the bridge is perpendicular to the centerline of bearing, this value is 90°. For simple span structures, enter the greater skew angle (if the skews at fixed end and expansion end are different). For continuous span structures, enter the skew angle at the bearing being considered. 	degree	25. (E)	90. (E)	--

5.6 GEO - GEOMETRY COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
4. Minimum Skew	Enter the minimum skew angle measured from the centerline of the beam to the centerline of the bearing. This value must not be greater than the maximum skew angle. For simple span structures, enter the smaller skew angle (if the skews at fixed end and expansion end are different). For continuous span structures, enter the skew angle at the bearing being considered.	degree	25. (E)	90. (E)	--
5. Minimum Pad Thickness	Enter the user specified minimum total pad thickness (elastomeric layers plus shims) required. This input item is provided to the user for those cases where a minimum thickness of pad is necessary, such as for dapped prestressed beams. For design, enter the minimum total pad thickness required for all pad designs. For analysis, the total pad thickness entered on the ANA command will be compared to this value. If this is left blank, the program will default to a minimum pad thickness of 0.75" for design or analysis of plain pads (as per DM-4 14.7.6.3.1aP). The program will default to a minimum pad thickness of 2" for design or analysis of laminated pads (as recommended in DM-4 C14.7.6.3.1aP). Note that if this input is left blank, during the design process, when the program is considering plain pads, the minimum thickness will be 0.75" and when considering laminated pads the minimum thickness will be 2".	in	0. (E)	8. (E)	0.75" (Plain) 2.0" (lamin-ated)
6. Maximum Pad Length	For design, enter the maximum pad length (rectangular pad) or maximum pad diameter (circular pad) allowed for all pads designed. For analysis, leave blank.	in	0. (E)	24. (E)	24.

5.7 LRX – LOAD REACTION COMMAND

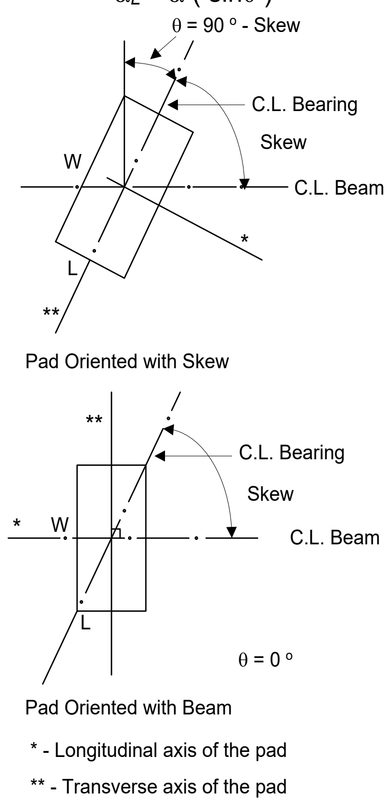
KEYWORD	COMMAND DESCRIPTION
LRX	LOAD REACTION - This command is used to input the load reactions. All load reactions are assumed to be compressive forces and no uplift force is considered. Only one LRX command can be used. The load reactions input by the user for use in BPLRFD include the beam reactions for maximum and minimum dead and live loads. These are the load reactions per each girder and must be obtained from the superstructure design. This command is required for both design and analysis.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Maximum Dead Load Reaction	Enter the maximum unfactored total dead load reaction.	kips	0.1 (E)	300. (W)	--
2. Minimum Dead Load Reaction	Enter the minimum unfactored permanent dead load reaction.	kips	0.1 (E)	300. (W)	--
3. Maximum Live Load Reaction	Enter the maximum unfactored live load reaction. This live load reaction should not include the effects of impact.	kips	0. (E)	300. (W)	--
4. Minimum Live Load Reaction	Enter the minimum unfactored live load reaction for continuous span superstructures. This live load reaction should not include the effects of impact. Leave blank for simple span superstructures.	kips	-300. (W)	300. (W)	--[1]

[1] For Simple spans, this value defaults to one-half the Maximum Live Load Reaction as per SC14.7.6.4P. For Continuous spans, there is no default.

5.8 LLR – LIVE LOAD ROTATION COMMAND

KEYWORD	COMMAND DESCRIPTION
LLR	LIVE LOAD ROTATION - This command is used to enter the beam end rotations due to live load. Only one LLR command can be used. Live load rotation about the transverse axis of a beam can be evaluated according to DM-4 Equation 14.7.6.3.5-4 or using output from Department's CBA, STLRFD, or PSLRFD programs. This command is required for both design and analysis.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Live Load Rotation About Transverse Axis of Pad	Enter the live load rotation about the transverse axis of the bearing pad (See the diagram below). LL rotation about pad transverse axis: $\alpha_w = \alpha\ (\cos\theta)$	rad	0. (E)	0.08727[1] (E)	--
2. Live Load Rotation About Longitudinal Axis of Pad	Enter the live load rotation about the longitudinal axis of the bearing pad (See the diagram). LL rotation about pad longitudinal axis: $\alpha_L = \alpha\ (\sin\theta)$  	rad	0. (E)	0.08727[1] (E)	--

Notes:

1 0.08727 is equivalent to 5°.

5.9 TOL – RELATIVE BEAM ROTATION COMMAND

KEYWORD	COMMAND DESCRIPTION
TOL	RELATIVE BEAM ROTATION - This command is used to enter the relative rotation between the bottom of the beam bearing surface and beam seat. The relative rotation should include: 1) construction rotational tolerances 2) rotations due to dead load 3) any other relative rotation between the bottom of the beam bearing surface and the beam seat The relative beam rotation will be added to the live load rotations to check rotational requirements. The relative rotation between the bottom of the beam bearing surface and beam seat accounts for conditions when the beam seat is not sloped to match the slope of the beam bearing surface. Required for both simple and continuous spans as well as for both design and analysis. Only one TOL command can be used. **If beams are dapped or have sole plates, the dead load rotation should be taken up by the sole plate or dap. Therefore, the user may not have to include dead load rotations on the TOL command.**

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Total Relative Rotation About Transverse Axis of Bearing Pad	Enter the total relative rotation of the bottom of the beam bearing surface and the beam seat about the transverse axis of the bearing pad. The total relative rotation should include: 1) construction rotational tolerances 2) rotations due to dead load 3) any other relative rotation between the bottom of the beam bearing surface and beam seat Refer to DM-4 Article 14.7.6.3.5.	rad	0. (E)	0.015 (W)	--
2. Total Relative Rotation About Longitudinal Axis of Bearing Pad	Enter the total relative rotation of the bottom of the beam bearing surface and the beam seat about the longitudinal axis of the bearing pad. The total relative rotation should include: 1) construction rotational tolerances 2) rotations due to dead load 3) any other relative rotation between the bottom of the beam bearing surface and beam seat Refer to DM-4 Article 14.7.6.3.5.	rad	0. (E)	0.015 (W)	--

5.10 EXP – BEAM EXPANSION DATA COMMAND

KEYWORD	COMMAND DESCRIPTION
EXP	BEAM EXPANSION DATA - This command is used to specify the beam expansion properties, such as temperature change range, dead load rotation longitudinal movement and live load rotation longitudinal movement. Only one EXP command can be used. This command is required for both design and analysis.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Temperature Range for Bearing Design	Enter the temperature range for bearing design (see DM-4 Article 3.12.2.1) which is used to calculate of thermal movement.	deg(F°)	0. (E)	100. (W)	--
2. Temperature Range for Substructure Design	Enter the temperature range for substructure design (see DM-4 Article 3.12.2.1) which is used to calculate the thermal movement for calculating the shear force induced by shear deformation (see Section 3.11).	deg(F°)	0. (E)	100. (W)	--
3. DL1 Rotation Movement	Enter the longitudinal beam movement resulting from the beam rotation due to placement of the total non-composite dead load on the beam.	in	0. (E)	1.5 (W)	--
4. DL2 Rotation Movement	Enter the longitudinal beam movement resulting from the beam rotation due to placement of the total composite dead load on the beam.	in	0. (E)	1.5 (W)	--
5. LL Rotation Movement	Enter the longitudinal beam movement resulting from the beam rotation due to placement of the total live load on the beam.	in	0. (E)	1.5 (W)	--

5.11 BPD – BEARING PAD DATA COMMAND

KEYWORD	COMMAND DESCRIPTION
BPD	BEARING PAD DATA - This command is used to specify the hardness, type, shape and the hole diameter of the bearing pad. It also specifies whether the bearing pad being considered is at the expansion or fixed end of the beam. Only one BPD command can be used. This command is required for both design and analysis.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Pad Hardness	Enter the hardness specification for the elastomer for Method A or Method AB as defined on the CTL command.	Duro-meter	50 (E)	60 (E)	50[1]
2. Hole Diameter in Bearing Pad	For design, enter the hole diameter to be used for prestressed adjacent box beams at the fixed end of the beam, and, if necessary, to meet anchorage requirements at the expansion end of the beam. If 0 in is entered, the program will use a hole diameter of 2.375 in to accommodate the drilling of a 2 in hole in the substructure unit as specified in BD-656M. For analysis, enter the diameter of the hole in the pad, and enter HOLE IN BEARING PAD as Y on the ANA command. If 0 in is entered here, and Y is entered for HOLE IN BEARING PAD on the ANA command, the program will use a hole diameter of 2.375 in to accommodate the drilling of a 2 in hole in the substructure unit as specified in BD-656M. Holes can only be used for bearing pads with prestressed adjacent box beams. If a value other than 0.0 is entered for this parameter for any other superstructure type, the program will stop with an error.	in	0. (E)	2.5 (E)	0.
3. Pad Type	Enter the bearing pad type: For design: P - Consider plain pad first, and if the plain pad fails, then consider laminated pads. L - Consider only a laminated pad. For analysis: P - Analyze a plain pad. L - Analyze a laminated pad.	--	P, L (E)	--	--
4. Pad Shape	Enter the bearing pad shape: R - Design or analyze a rectangular pad. C - Design or analyze a circular pad.	--	R, C (E)	--	--

Notes:
[1] Default for Method A or Method AB only.

5.11 BPD - BEARING PAD DATA COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
5. Pad Orientation	Enter the bearing pad orientation: B - If the bearing pad is oriented with the beam. See LLR command. S - If the bearing pad is oriented with the skew. See LLR command.	--	B, S (E)	--	--
6. Expansion/ Fixed	Enter the bearing pad movement type, as follows: For design of bearings for simple span structures, leave blank. The program will design the expansion end first and then design the fixed end. For design of bearings for continuous span structures OR analysis of bearing pads for either simple or continuous span structures: F - Design or analyze a fixed bearing. E - Design or analyze an expansion bearing.	--	E, F (E)	--	--
7. Number of Pads for Box Design	For the design of bearing pads for adjacent box beams or spread box beams, enter the number of pads to consider. For the design of bearing pads for other superstructure types, leave this input value blank. For the analysis of bearing pads for all superstructure types, leave this input value blank. If "2" is entered, the program will first try to design a two pad solution. If a two pad solution cannot be found, the program will then try to find a one pad solution with no hole in the pad. If this design cannot be found, and the superstructure is an adjacent box beam with a length less than or equal to 50 feet, the program will then try a one pad solution with a dowel.	--	1 (E)	2 (E)	2 (for design of box beam pads)

5.11 BPD - BEARING PAD DATA COMMAND (Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
8. Elastomer Shear Modulus	Enter the shear modulus at 73°F for the elastomer, to be used for Method B calculations. This value must be entered for bearing pads designed or analyzed with AASHTO Method B. This value will be ignored for Method A. This parameter allows for a more precise entry of shear modulus. AASHTO Section C14.7.5.2 states that hardness correlates only very loosely with shear modulus.	ksi	0.080 (W)	0.175 (W)	--

5.12 CON – CONTINUOUS SPAN DATA COMMAND

KEYWORD	COMMAND DESCRIPTION
CON	CONTINUOUS SPAN DATA - This command is used to enter additional pier movement due to construction loads or applied pier loads. This command is only used when designing or analyzing a bearing pad for a continuous span. Only one CON command can be used.

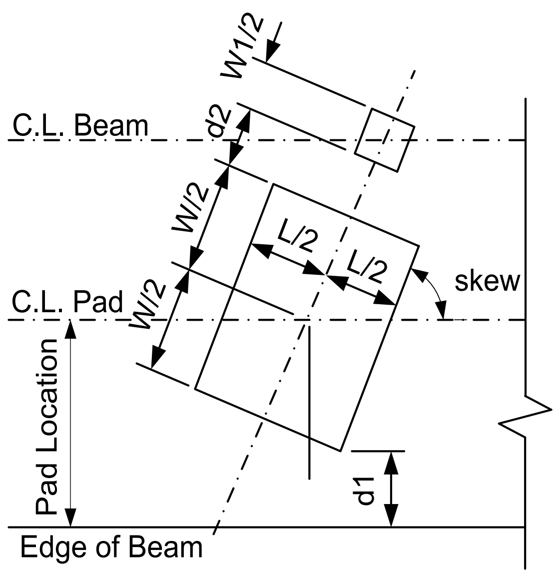
PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Construction Pier Flexibility	Enter the horizontal movement to account for construction/pier flexibility.	in	0. (E)	10. (W)	--

5.13 ANA – ANALYSIS DATA COMMAND

KEYWORD	COMMAND DESCRIPTION
ANA	ANALYSIS DATA - Use this command only if A is entered for the run type parameter in the CTL command. This command is used to specify the size and configuration of bearing pad to be analyzed. Only one ANA command can be used. This command is required for analysis only.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Pad Diameter	Enter the diameter of the pad to be analyzed. Leave blank for a rectangular pad.	in	0. (E)	48. (W)	--
2. Pad Length	Enter the length of the pad to be analyzed. See LLR command for pad orientation. Leave blank for a circular pad.	in	0. (E)	48. (W)	--
3. Pad Width	Enter the width of the pad to be analyzed. See LLR command for pad orientation. Leave blank for a circular pad.	in	0. (E)	48. (W)	--
4. Elastomer Thickness of Plain Pad	Enter the elastomer thickness of a plain pad. Leave blank for a laminated bearing pad.	in	0.75 (W)	1.25 (W)	--
5. Elastomer Thickness of Interior Layer	Enter the elastomer thickness of a single interior layer for a laminated pad. Leave blank for a plain bearing pad.	in	0. (E)	1. (W)	--
6. Elastomer Thickness of Cover Layer	Enter the elastomer thickness of a single cover layer for a laminated pad. Leave blank for a plain bearing pad.	in	0. (E)	1. (W)	--
7. Number of Layers	Enter the total number of layers of elastomeric material in a bearing pad. (Note: Both the interior and cover layers are to be included for a laminated pad.) Enter 1 for a plain bearing pad.	--	1 (plain pad) 3 (laminated pad) (E)	20 (W)	1 (plain pad) 3 (laminated pad)
8. Number of Bearing Pads	Enter the number of bearing pads per beam end.	--	1 (E)	2 (E)	--
9. Hole in Bearing Pad	Specify if there is a hole in the bearing pad. If Y is entered here, also enter the size of the hole with the HOLE DIAMETER IN BEARING PAD parameter of the BPD command. Only bearing pads for adjacent box beams can have holes. If this parameter is entered as 'Y' for any other superstructure type, the program will stop with an error.	--	Y, N (E)	--	--

5.13 ANA - ANALYSIS DATA COMMAND(Cont.)

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
10.Pad Location	Enter the perpendicular distance from the centroid of pad to the edge the beam to locate the pad when 2 pads per beam end are specified. Leave blank if only one pad per beam is used. 	in	0. (E)	MXLOC[1] (W)	MXLOC
11.Shim Thickness	Enter the actual thickness of the steel shims used as reinforcement for the pad. Leave this value blank for a plain pad.	in	0.1196 (W)	0.50 (W)	--

Notes:

[1] MXLOC is equal one fourth of the Beam Bottom Width (Parameter 3 of the GEO command).

5.14 OIN – OUTPUT OF INPUT DATA COMMAND

KEYWORD	COMMAND DESCRIPTION
OIN	OUTPUT OF INPUT DATA - This command allows the user to control the output of the input data. Only one OIN command can be used. This command is optional for both design and analysis.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Input File Echo	Enter: 0 - Do not print input file echo. 1 - Print input file echo.	--	0 (E)	1 (E)	0
2. Input Commands	Enter: 0 - Do not print input commands. 1 - Print input commands.	--	0 (E)	1 (E)	0
3. Input Summary	Enter: 0 - Do not print input summary. 1 - Print input summary.	--	0 (E)	1 (E)	1

5.15 ODT – OUTPUT DETAIL COMMAND

KEYWORD	COMMAND DESCRIPTION
ODT	OUTPUT DETAIL - This command is used to control the level of output detail. Only one ODT command can be used. This command is optional for both design and analysis.

PARAMETER	DESCRIPTION	UNITS	LOWER LIMIT	UPPER LIMIT	Default
1. Detailed Specification Checks	Enter: 0 - Do not print the detailed specification checks. 1 - Print the detailed specification checks.	--	0 (E)	1 (E)	0
2. Results	Enter: 0 - Do not print the results. 1 - Print the results.	--	0 (E)	1 (E)	1

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6 DETAILED INPUT DESCRIPTION

This chapter provides a detailed description of some of the input parameters, which were described in Chapter 5, but may need further explanation or commentary. The numbering scheme used in this chapter is as follows. The section number for a command corresponds to the same section number in Chapter 5. The parameter being described is preceded by a section number, whose last extension number refers to the parameter number in the corresponding command in Chapter 5. For example, Section 6.7.2 Minimum Dead Load Reaction corresponds to Section 5.7 LRX - Load Reaction Command, parameter 2. Only the commands and parameters for which detailed description is given are included in this chapter.

6.6 GEO – GEOMETRY COMMAND

6.6.1 Expansion Length

The expansion length is the distance from the bearing being investigated to the nearest point of fixity. The program uses the expansion length to compute the thermal movement of the bridge at the bearing pad (see Section 3.8 of this manual for further details) and to check against the DM-4 Section 14.7.6.4 span limit requirement for use of anchor dowels.

6.6.3 Maximum Skew

The maximum skew is used to compute the available lengths and widths for the pad (see Section 3.6 of this manual for further details) and to compute the pad compression due to rotation (see Section 3.9 of this manual for further details).

The skew angle value to be entered is the absolute value of the PennDOT skew angle. For PennDOT, a positive skew is measured counterclockwise from the centerline of beam. For AASHTO, a positive skew is measured counterclockwise from a line perpendicular to the centerline of beam. As shown in Figure 1, AASHTO skew angle (θ_A) is negative and PennDOT skew angle (θ_P) is positive.

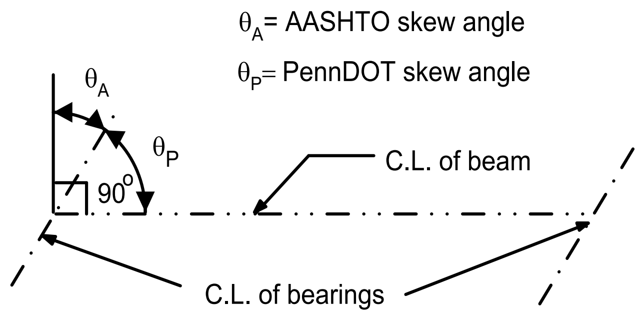

Figure 6.6-1 Skew Angle

6.6.4 Minimum Skew

Similar to the maximum skew, the minimum skew is used to compute the available lengths and widths for the pad (see Section 3.6 of this manual for further details) and to compute the pad compression due to rotation (see Section 3.9 of this manual for further details).

6.6.6 Maximum Pad Length

Maximum pad length (rectangular pads) or maximum pad diameter (circular pads) allowed as specified by the user. This input item is provided to the user for those cases where a maximum pad length or diameter is necessary, such as for dapped prestressed beams.

6.7 LRX – LOAD REACTION COMMAND

The load reactions input by the user for use in BPLRFD include the beam reactions for maximum and minimum dead and live loads. These are the load reactions per each girder and must be obtained from the superstructure design.

6.7.1 Maximum Dead Load Reaction

The maximum dead load reaction is unfactored, and is used, together with the maximum live load reaction, to check the allowable compressive stress of the bearing pad. The maximum dead load reaction should be the maximum total dead load applied to the bearing.

6.7.2 Minimum Dead Load Reaction

The minimum dead load reaction is unfactored, and is used to check the Method A anchorage and rotational requirements (see Section 3.8). The minimum dead load reaction should be the dead load without the future wearing surface, utilities, or other non-permanent dead load included.

6.7.3 Maximum Live Load Reaction

The maximum live load reaction is unfactored, should not include the effects of impact, and is used to check compressive stress of the bearing pad and the fatigue requirement of the shim plates (if applicable). The maximum live load reaction should be based on the design live load for the Service I limit state. Thus, for PennDOT, this corresponds to the live load reaction produced by the PHL-93 live loading.

6.7.4 Minimum Live Load Reaction

The minimum live load reaction is unfactored and should not include the effects of impact. It is used to compute the live load stress for the Method A anchorage check. The minimum live load reaction should be based on the design live load for the Service I limit state. Thus, for PennDOT, this corresponds to the live load reaction produced by the PHL-93 live loading.

6.8 LLR – LIVE LOAD ROTATION COMMAND

6.8.1 Live Load Rotation About Transverse Axis of Pad

The live load rotation about the transverse axis of the pad is used to compute the pad compression due to rotation (see Section 3.9 of this manual for further details).

For straight bridges (PennDOT skew at 90 degrees), this value should be equal to the live load rotation either evaluated according to DM-4 Equation 14.7.6.3.5-4 or given in the output from the Department's CBA, STLRFD, or PSLRFD programs.

For skewed bridges (PennDOT skew less than 90 degrees) with the pad oriented with the beam (see BPD command, Section 5.11 of this manual), this value should be equal to the live load rotation either evaluated according to DM-4 Equation 14.7.6.3.5-4 or given in the output from the Department's CBA, STLRFD, or PSLRFD programs.

For skewed bridges with the pad oriented with the skew, this value should be equal to the vector component of the live load rotation either evaluated according to DM-4 Equation 14.7.6.3.5-4 or given in the output from the Department's CBA, STLRFD, or PSLRFD programs.

For all single span bridges, either straight or skewed, the maximum live load rotation along the centerline of beam should not be greater than 0.004 radians. This value is based on the combination of the maximum live load deflection criteria, DM-4 Part B Section 2.5.2.6.2, and the live load rotation calculation, DM-4 Equation 14.7.6.3.5-4. This value is a maximum regardless of the span length.

6.8.2 Live Load Rotation About Longitudinal Axis of Pad

The live load rotation about the longitudinal axis of the pad is used to compute the pad compression due to rotation (see Section 3.9 of this manual for further details).

For straight bridges (PennDOT skew at 90 degrees), this value should be equal to zero.

For skewed bridges (PennDOT skew less than 90 degrees) with the pad oriented with the beam (see BPD command, Section 5.11 of this manual), this value should be equal to zero for beam rotation from DM-4 Equation 14.7.6.3.5-4 or output from the Department’s CBA, STLRFD or PSLRFD programs. However, it is possible to enter a value greater than zero to account for skewed steel bridges which undergo out-of-plane rotations.

For skewed bridges with the pad oriented with the skew, this value should be equal to the vector component of the live load rotation either evaluated according to DM-4 Equation 14.7.6.3.5-4 or given in the output from the Department's CBA, STLRFD, or PSLRFD programs.

For all single span bridges, either straight or skewed, the maximum live load rotation along the centerline of beam should not be greater than 0.004 radians. This value is based on the combination of the maximum live load deflection criteria, DM-4 Part B Section 2.5.2.6.2, and the live load rotation calculation, DM-4 Equation 14.7.6.3.5-4. This value is a maximum regardless of the span length.

6.10 EXP – BEAM EXPANSION DATA COMMAND

6.10.1 Temperature Range for Bearing Design

The temperature range for bearing design can be found in DM-4 Table 3.12.2.1-1. It is used to calculate the thermal movement for the shear deformation check and the Method A anchorage check (see Section 3.8 of this manual for further details).

6.10.2 Temperature Range for Substructure Design

The temperature range for substructure design can be found in DM-4 Table 3.12.2.1-1. Typically, the temperature fall is used. It is used to calculate the thermal movement used for the calculation of the shear force induced by shear deformation (see Section 3.11 of this manual for further details).

HORIZONTAL SHEAR FORCE FOR SUBSTRUCTURE

The analysis of an expansion end pad includes the calculation of the unfactored shear force on the pad as a result of the elastomer's resistance to shear deformation for substructure design.

$$F_S = \frac{G_H A \Delta_t}{T}$$

Where: $\Delta_{t(substr)}$ = [(Expansion length) X (Coefficient of thermal expansion of the beam) X (Temperature range for substructure design)]

For a two pad case, A is equal to the total plan area of both pads. For plain pads, T is equal to tp.

The horizontal force due to thermal movement only is computed. Horizontal force effects due to beam end rotation and pier flexibility, as applicable, should be accounted for separately. For abutments, horizontal force effects due to beam end rotation act in a direction opposite to earth and thermal effects, and therefore should be disregarded.

6.10.3 DL1 Rotation Movement

The total non-composite dead load longitudinal movement is included when computing the minimum pad thickness required to satisfy the shear deformation design criteria (see Section 3.8 of this manual for further details). For details on how to calculate this longitudinal movement, see Section 6.10.5. For prestressed concrete beams, movement due to the girder weight can typically be neglected because the beams are usually lifted from the support points near the ends of the beam during erection.

6.10.4 DL2 Rotation Movement

The total composite dead load longitudinal movement is included when computing the minimum pad thickness required to satisfy the shear deformation design criteria (see Section 3.8 of this manual for further details). For details on how to calculate this longitudinal movement, see Section 6.10.5.

6.10.5 LL Rotation Movement

The total live load longitudinal movement is included when computing the minimum pad thickness required to satisfy the shear deformation design criteria (see Section 3.8 of this manual for further details). Recommendations on how to calculate longitudinal movement follows.

6.10.5.1 Simple Spans

The LL Rotation Movement is used in conjunction with the Minimum LL Reaction for the shear deformation and Method A anchorage checks. Basing the LL Rotation Movement on maximum rotation is conservative. The longitudinal movement due to either dead load or live load rotation for **simple spans** can be calculated using the following method:

Let $\theta = \frac{16}{5}\frac{\Delta}{L}$ (See DM-4 Article 14.7.6.3.5)

where:

- θ = rotation due to the midspan deflection from either non-composite dead load, composite dead load, or live load (radians).
- Δ = midspan deflection due to either non-composite dead load, composite dead load, or live load (in).
- L = span length (in).

$$LONGITUDINAL\ MOVEMENT = \left(\frac{2A}{D}\right)\delta$$

Let $\delta = D\sin\theta = D\,\theta$

$$LONGITUDINAL\ MOVEMENT = \left(\frac{2A}{D}\right) D\,\theta = 2A\,\theta$$

where: D = depth of beam, either composite or non-composite (in).

A = distance from the bottom of the beam to the neutral axis of either the composite or the non-composite section (see Figure 1) (in).

δ = longitudinal movement at top of beam section (composite or non-composite) due to rotation θ (in).

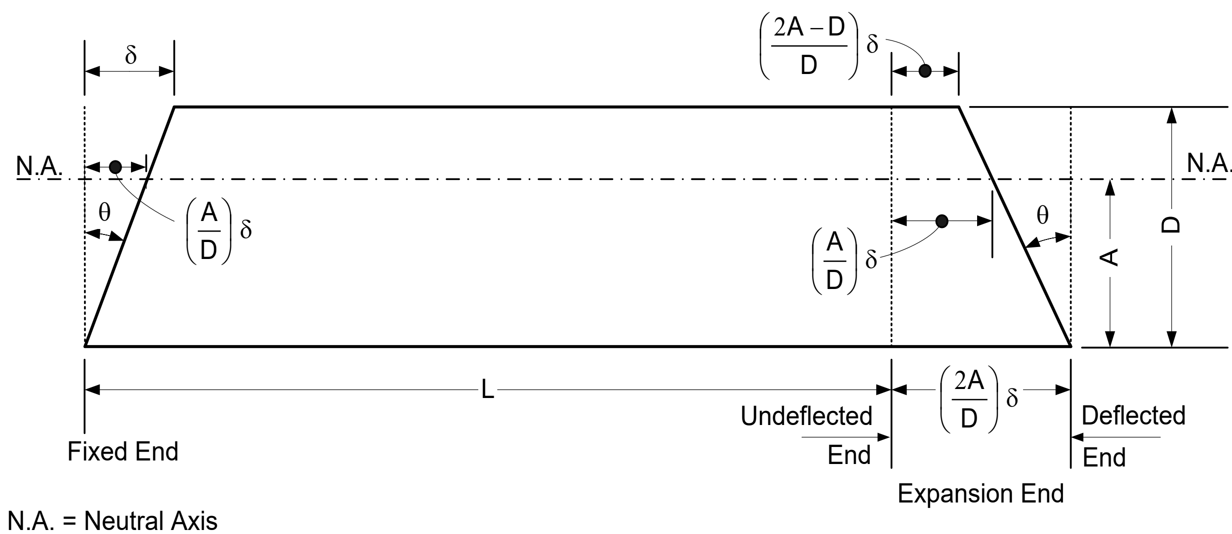

Figure 6.10-1 Longitudinal Movement from Beam Rotation

6.10.5.2 Continuous Spans

Longitudinal movement at the bottom of beam for continuous bridges should be computed as indicated below or by a rational method. The cumulative effects of longitudinal movement at individual bearing locations must be considered (e.g., longitudinal movements become additive for spans located away from the center of the theoretical fixed point of the bridge).

- Continuous Steel Beam Bridges: The methodology in determining the cumulative effects of longitudinal movement due to all permanent non-composite and composite dead loads can be cumbersome and complex. Some finite element computer programs provide dead load movement data directly and this data can be used for the design of bearings. As an alternative to the need for developing a complex solution, dead load longitudinal movements in the bearing pads may be neglected for the bearing pad design provided that shear deformations are relieved in accordance with the procedure described in DM-4, Section 14.7.5.3.4. This procedure may also be used where computed dead load longitudinal movements result in an unsuccessful design of the bearing pads.

Longitudinal movement due to live load may be computed at individual bearing locations using simple span methodology. The longitudinal movement due to live load may be approximated as the live load movement of the longest individual span leading up to the point of design from the theoretical point of fixity.

- Prestressed Concrete Bridges Made Continuous for Live Load: Longitudinal movement due to non-composite dead loads may be based on simple span methodology (provided that the deck pouring sequence is performed in accordance with DM-4, Section 5.14.1.2.7fP). When using simple span methodology, one-half the computed non-composite dead load longitudinal movement may be used for the bearing design because the bearings at each end of the beam are unfixed at this stage of construction.

Longitudinal movement due to permanent composite dead load may be computed using simple span methodology. The longitudinal movement of each span leading up to the point of design from the theoretical point of fixity should be combined to account for the cumulative action.

Longitudinal movement due to live load may be computed at individual bearing locations using simple span methodology. The longitudinal movement due to live load may be approximated as the live load movement of the longest individual span leading up to the point of design from the theoretical point of fixity.

6.11 BPD – BEARING PAD DATA COMMAND

6.11.5 Pad Orientation

For straight bridges (PennDOT skew at 90 degrees), all bearing pads should be set oriented with the beam.

For skewed bridges (PennDOT skew less than 90 degrees), the bearing pads should be set as follows: for both prestressed I-beams and steel beams, orient the pads with the beams; for both adjacent box beams and spread box beams, orient the pads with the skew.

6.12 CON – CONTINUOUS SPAN DATA COMMAND

6.12.1 Construction Pier Flexibility

Construction / Pier flexibility should include horizontal movement due to applied pier forces and construction conditions.

The program adds the construction pier flexibility movement to the thermal movement when computing the minimum pad thickness required to satisfy the shear deformation design criteria (see Section 3.8 of this manual for further details). If the computed construction pier flexibility movement will decrease the shear deformation of the bearing, enter 0.0.

6.14 OIN – OUTPUT OF INPUT DATA COMMAND

A summary of the defaults for this command is presented in Table 1. Also presented in Table 1 is a list of the output tables printed with each parameter.

Table 6.14-1 Summary of Defaults for OIN Command

PARAMETER	OUTPUT TABLES INCLUDED	DEFAULTS	
		ANALYSIS RUN	DESIGN RUN
1. Input File Echo	INPUT DATA FILE ECHO	0	0
2. Input Commands	COMMAND LINE INPUT	0	0
3. Input Summary	SPAN AND LOAD DATA CONTINUOUS SPAN ONLY ANALYSIS DATA DATA VALUES FROM THE PARAMETER FILE	1	1

6.15 ODT – OUTPUT DETAIL COMMAND

A summary of the defaults for this command is presented in Table 1. Also presented in Table 1 is a list of the output tables printed with each parameter.

Table 6.15-1 Summary of Defaults for ODT Command

PARAMETER	OUTPUT TABLES INCLUDED	DEFAULTS	
		ANALYSIS RUN	DESIGN RUN
1. Detailed Specification Checks	DESIGN OF EXPANSION END PAD - PLAIN DESIGN OF EXPANSION END PAD - LAMINATED ANALYSIS OF EXPANSION END PAD - PLAIN ANALYSIS OF EXPANSION END PAD - LAMINATED DESIGN OF FIXED END PAD - PLAIN DESIGN OF FIXED END PAD - LAMINATED ANALYSIS OF FIXED END PAD - PLAIN ANALYSIS OF FIXED END PAD - LAMINATED DESIGN OF EXPANSION CIRCULAR PAD - PLAIN DESIGN OF EXPANSION CIRCULAR PAD - LAMINATED ANALYSIS OF EXPANSION CIRCULAR PAD - PLAIN ANALYSIS OF EXPANSION CIRCULAR PAD - LAMINATED DESIGN OF FIXED CIRCULAR PAD - PLAIN DESIGN OF FIXED CIRCULAR PAD - LAMINATED ANALYSIS OF FIXED CIRCULAR PAD - PLAIN ANALYSIS OF FIXED CIRCULAR PAD - LAMINATED	0	0
2. Results	BEARING PAD DESIGN DATA RECOMMENDED PAD SIZE BEARING PAD ANALYSIS DATA INPUTTED PAD SIZE	1	1

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7 OUTPUT DESCRIPTION

7.1 GENERAL OUTPUT INFORMATION

Information is provided for describing output table controls, page format, page numbering, and page header. In general, the page format is built into the program and cannot be changed by the user for either the .OUT output file or the .PDF output file. The one exception is that the user can specify the number of blank lines to be printed at the top of each page before the page header is printed. This formatting change will be reflected in both the .OUT and .PDF output files accordingly.

7.1.1 Output Table Controls

The output table controls are specified using a number of input commands and parameters to control which output reports will be printed. These controls are specified using two different input commands, according to which type of output they represent. These two kinds of output are input data and detailed output. The commands and their defaults are discussed in Sections 6.14 and 6.15.

7.1.2 Page Format

There is a maximum of 91 columns in the output files. Columns 1, 2, 3, and 4 have been left blank to provide a margin on the left side of the page. This has been done to make the output files less dependent on the output device capabilities. The output is therefore limited to 87 characters, column 5 to column 91. The user can specify the number of lines to be left blank at the top of the page with the CFG command.

7.1.3 Page Numbering

The program assigns page numbers and determines when a new page should begin. There are certain rules built into the program to determine when a new page should begin. The program will attempt to fit up to the number of lines specified on the CFG command on each page. Internally, the program keeps track of how many lines are left on the page and adjusts according to the number of lines in the heading of the output table and a minimum number of data lines required after the heading.

7.1.4 Page Header

After the cover page, header information is printed at the top of each page. A sample header is shown in Figure 1.

```
LRFD Bearing Pad Design and Analysis, Version 1.2                 PAGE   2
Input File: Ex1.dat                                   09/24/2000  09:49:15
--------------------------------------------------------------------------
                                Example 1
                                  INPUT
--------------------------------------------------------------------------
```

Figure 7.1-1 Page Header

Information printed in the header includes:

1. Program Title, Version Number - the program name and version number is located at the top left corner of the header.
2. Page Number - the page number appears at the top right corner of the header.
3. Input File - the name of the input data file used to create this output is shown at the beginning of the second line.
4. Date and Time - the data and time of the program execution for this problem is printed at the right side of the second line.
5. A separator line is printed between program specific header information and user specified header information.
6. The next header line contains the first title line input by the user via the TTL command. This should be a general descriptive line used to describe the problem to be run.
7. The next header line contains the type of output specified by the user.
8. The final header line is another separator line.

7.1.5 Units

The desired system of units is entered by the user on the CTL command. "US" is entered for U.S. customary units. As result of a decision by the AASTHO Subcommittee on Bridges and Structures to longer publish SI unit specifications, SI units are no longer supported by the program. The system of units presented in the output corresponds with the desired system of units entered by the user. Presented in Table 1 is a summary of the basic units of measure used by this program. Units for values in the output are as presented in Table 1, unless otherwise indicated in the program output.

Table 7.1-1 Units

Variable	Unit of Measure US (U.S. Customary Units)
AREA	in^2
DEFLECTION	in
DEPTH	in
DISTANCE	in
FORCE	kips
LENGTH	in
MASS	N/A
REACTION	kips
ROTATION	radians
SHEAR MODULUS	psi
SKEW	radians
STRAIN	in/in
STRESS	ksi
THICKNESS	in
WEIGHT	lbf
WIDTH	in

7.1.6 Sign Conventions

Presented in Table 2 is a summary of the sign conventions used by this program.

Table 7.1-2 Sign Conventions

Variable	Sign Convention
REACTION	A reaction acting in the upward direction is positive.
LOAD	A load acting in the downward direction is positive.
SHEAR	A shear force acting upward on the right face of the free body in equilibrium is positive.
DEFLECTION	A downward deflection is positive.
AXIAL FORCE	A force causing tension is positive.
STRESS	A compressive stress is positive.

7.2 COVER PAGE

The first page of the output is the cover page. The following information is shown at the top of the cover page:

1. Program Title - LRFD Bearing Pad Design and Analysis
2. Program Name - BPLRFD
3. Version ii.nn - where ii represents the numeric designation for major revisions and enhancements to the program and nn represents the numeric designation for minor revisions.
4. Last Updated - this is the date the program was last revised.
5. Documentation - this is the date the User's Manual was last revised.
6. License Number - this is a unique number assigned to all licensees per the License Agreement.

The middle section of the cover page is reserved for the first 10 TTL commands input by the user. This information typically should describe the bridge, location, stationing, span length, type of structure, and any other information the user would need to identify the output.

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7.3 INPUT DATA OUTPUT

The input data consists of an echo of the input file, summary of input commands, and input summary tables. Each of these can individually be turned on or off. A summary of the output tables included is given in Section 6.14.

7.3.1 Input File Echo

The input file echo (parameter 1) is a listing of the input commands and comments as entered by the user. The user can refer to this section to trace input errors and warnings by comparing the input data to the input descriptions provided in Chapter 5. The input file can contain 256 characters in a single line, but the output is limited to 75 characters on a single line. If the input line contains more than 75 characters, the input file echo will be wrapped to the next row. Other than this limitation, the echo of the input file should appear the same as the input data file.

7.3.2 Input Commands

This section (parameter 2) is a summary that includes a detailed description of each input parameter for all input commands entered by the user. The summary of input commands is in a vertical format. Two examples of the input commands are shown in Figure 1.

```
COMMAND:  CTL
  SYSTEM OF UNITS                    US
  DESIGN/ANALYSIS                     D
  SIMPLE/CONTINUOUS                   S
  STRUCTURE TYPE                     IS
  DESIGN/ANALYSIS METHOD              A            (default)

COMMAND:  GEO
  SPAN LENGTH                      50.0 ft
  BEAM BOTTOM WIDTH                 5.0 in
          %WARNING - <GEO>:
              Real value out of range
              The value entered for BEAM BOTTOM WIDTH is
               less than the lower range limit.
              Value Entered: 5.
              Valid values are between 6. and 48.
  MAXIMUM SKEW ANGLE               90.0 deg
  MINIMUM SKEW ANGLE               90.0 deg
  MINIMUM PAD THICKNESS             2.0 in         (default)
  MAXIMUM PAD LENGTH                20. in         (default)
```

Figure 7.3-1 CTL and GEO Summary of Input Commands

The summary of input commands includes the following information:

1. Command keyword.
2. Input parameter description.
3. Value of the input parameter as entered or the default value as stored in the program. The value is displayed to the same number of significant figures as entered by the user or as stored in the input

parameter file. The word (default) is placed to the right of the units when default values are used. An asterisk (*) indicates the input value is optional and was not entered.

4. Units (US) if applicable.
5. Any warnings or errors encountered with respect to the input data.

Input values may be optional or required. Required input is input that is entered by the user or set to the default value stored in the program. Default values are indicated with the text (default) placed to the right of the units. If there is no default value stored in the program and the user does not enter a value, an error message is displayed.

Any warnings or errors encountered while processing the input data will be reflected with the appropriate input command under the summary of input commands. If this level of input data output is turned off, the warnings will still appear; though without the added benefit of the warnings and errors being grouped with the corresponding input command. The program has several different input warning and error messages. After encountering warnings or errors, the program also prints a message to the screen advising the user to review the output file for explanations of the warnings and errors.

7.3.3 Input Summary

The input summary consists of tables that include summaries of all input parameters in horizontal tabular format. A more complete description of all input items can be found in Chapters 5 and 6.

One example of an input summary table is shown in Figure 2.

The input summary tables contain the following information:

1. A description of the input data.
2. Input parameter header containing an abbreviated parameter description and units.
3. Input parameter values. The input values are shown to a fixed number of decimal places because of the tabular format. The actual input value may be rounded to fit the output format. Refer to the summary of input commands for the actual value input by the user.

```
                            SPAN AND LOAD DATA
                            ------------------
                                DESIGN/
DESIGN/   SPAN  SUPERSTRUCTURE ANALYSIS  EXP.   BEAM BOT   MAX.   MIN.
ANALYSIS  TYPE       TYPE       METHOD  LENGTH   WIDTH     SKEW   SKEW
                                         (ft)     (in)    (deg)  (deg)
   D       S     STEEL I-BEAM     A      50.00   20.000    90.0   90.0

MIN PAD   MAX PAD    MAX DL     MIN DL     MAX LL     MIN LL
 THICK    LENGTH    REACTION   REACTION   REACTION   REACTION
 (in)      (in)      (kips)     (kips)     (kips)     (kips)
  ***     20.000      24.10      21.70      15.20       7.60

NOTE: The Minimum LL Reaction has been changed to 0.5*Maximum LL Reaction
      per DC14.7.6.4P.

*** MINIMUM PAD THICKNESS on the GEO command has been left blank, which
    indicates that the program should use default values for the minimum
    pad thickness. When designing or analyzing plain pads, the minimum
    pad thickness is taken as 0.75". (DM-4 14.7.6.3.1aP) When designing
    or analyzing laminated pads, the minimum pad thickness is taken as
    2", as suggested in DM-4 C14.7.6.3.1aP.

                                CONSTRUCTION TOLERANCE, DEAD LOAD,
---- LL  ROTATION ----             AND OTHER RELATIVE ROTATION
 ABOUT PAD   ABOUT PAD                ABOUT PAD    ABOUT PAD
LONGITUDINAL TRANSVERSE              LONGITUDINAL  TRANSVERSE
   AXIS        AXIS                     AXIS          AXIS
  (rad.)      (rad.)                   (rad.)        (rad.)
 0.00000     0.00320                  0.00000       0.00300

  TEMPERATURE RANGE FOR
  BEARING   SUBSTRUCTURE     ROTATION MOVEMENT
  DESIGN       DESIGN        DL1      DL2     LL
  (Fdeg)       (Fdeg)       (in)     (in)    (in)
  100.0         78.0        0.050    0.080   0.100

  PAD       HOLE     PAD    PAD       PAD       BEARING   # PADS FOR    ELASTOMER
HARDNESS  DIAMETER  TYPE  SHAPE  ORIENTATION    TYPE    BOX DESIGN  SHEAR MODULUS*
 (duro)     (in)                                                        (ksi)
   50      0.000     P      R         B           E         n/a          n/a
```

Figure 7.3-2 Input Summary Table

7.3.4 Data Values from the Parameter File

The data values from the parameter file are values that are read from an ASCII text parameter file based on several input items such as expansion length, elastomer pad hardness, and superstructure type.

An example of a set of data values from the parameter file is shown in Figure 3.

```
                         DATA VALUES FROM THE PARAMETER FILE
                         -----------------------------------
    AASHTO Table 14.7.6.2-1 - Correlated Material Properties
                  Shear Modulus        Creep
     Hardness     Low      High        Factor
     (Shore A)   (psi)     (psi)
     50           95.0    130.0       0.2500

       DM-4 Table C14.7.5.3.6-1P - Constants for Strain Equation
                      ---------------- Shape Factors ---------------
   Hardness  Constant    3       4       5       6       9      12
     50          A    -18.00   -4.20   -1.40   -0.69   -0.70   -1.00  (1/ksi^2)
     50          B     22.7    12.3     8.4     5.9     5.2     5.0   (1/ksi)

       Stability Factors (denominators of equations in DM-4 14.7.6.3.6):
           Plain Pad
             Length       =       5.000
             Width        =       5.000
           Laminated Pad
             Length       =       3.000
             Width        =       3.000

       Maximum total pad thickness (laminated) (DM-4 14.7.6.3.6-7P) =     8.0000 in
       Maximum thickness of a plain pad (DM-4 14.7.6.3.1aP) =     1.2500 in
       Minimum thickness of a plain pad (DM-4 14.7.6.3.1aP) =     0.7500 in

       Minimum interior layer thickness =     0.3750 in
       Maximum interior layer thickness =     0.6250 in
       Minimum cover layer thickness    =     0.2500 in
       Maximum cover layer thickness    =     0.2500 in

       Minimum shim thickness (actual) (DM-4 14.7.5.3.5) =      0.1196 in
       Shim yield strength                                =     36000.0 psi
       Constant amplitude fatigue threshold (Category A) =     24000.0 psi

       Edge Distances:
          Minimum exterior   =    -5.0000 in
          Maximum exterior   =     2.0000 in

     NOTE: For steel superstructures, the edge distances are computed by the program,
           based on a maximum edge distance equal to 25% of the bottom flange width.
           A negative value for edge distance indicates the pad is wider than the
           bottom flange width.
```

Figure 7.3-3 Data Values from the Parameter File

7.4 DETAILED SPECIFICATION CHECK OUTPUT

The detailed output consists of the detailed design output, the detailed analysis output, a summary of the design data, and the recommended or inputted pad sizes. A summary of the output tables for each control is given in Section 6.15. The user can suppress all detailed output by setting every parameter to zero.

7.4.1 Design of Expansion End Pad - Plain

This table presents the properties of a plain rectangular bearing pad designed for the expansion end of the bridge. The following information is reported in the DESIGN OF EXPANSION END PAD - PLAIN output table.

1. Acceptable Pad Size: - message denoting that the design found by the program passes all specification checks.
2. EXPANSION END: - end of the girder for which the program designed the reported bearing pad.
3. Use two pads, each pad should be: - denotes that the program has determined that two bearing pads are required for this end of the bridge.
4. Pad Length - total length of the bearing pad.
5. Pad Width - total width of the bearing pad.
6. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
7. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
8. Total Elastomer Thickness - total thickness of bearing pad.
9. Provide a hole in the pad for dowel, hole diameter - if the program determines that a dowel rod is necessary for the bearing, provide a hole this size to accept the dowel.

7.4.2 Design of Expansion End Pad - Laminated

This table presents the properties of a laminated rectangular bearing pad designed for the expansion end of the bridge. The following information is reported in the DESIGN OF EXPANSION END PAD - LAMINATED output table.

1. Acceptable Pad Size: - message denoting that the design found by the program passes all specification checks.
2. EXPANSION END: - end of the girder for which the program designed the reported bearing pad.
3. Use one pad with dimensions of: - denotes that a single pad is required for this end of the bridge.
4. Use two pads, each pad should be: - denotes that the program has determined that two bearing pads are required for this end of the bridge.
5. Design/Analysis Method - denotes which design method was used by the program.
6. Pad Length - total length of the bearing pad.
7. Pad Width - total width of the bearing pad.
8. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
9. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
10. Total Elastomer Thickness - total thickness of all elastomer layers.
11. Number of Elastomer Layers - number of elastomer layers needed.
12. Thickness of Interior Elastomer Layers - required thickness of each interior layer.
13. Thickness of Cover Elastomer Layers - required thickness for each cover layer.
14. Thickness of Shim Plates - required thickness of each shim plate.
15. Total Bearing Pad Thickness - includes total thickness of all elastomer layers and all shim plates.
16. Provide a hole in the pad for dowel, hole diameter - if the program determines that a dowel rod is necessary for the bearing, provide a hole this size to accept the dowel.

7.4.3 Analysis of Expansion End Pad - Plain

This table presents the specification checks for a plain rectangular bearing pad for the expansion end of the bridge. The following information is reported in the ANALYSIS OF EXPANSION END PAD - PLAIN output table.

1. Pad Length - total length of the bearing pad.
2. Pad Width - total width of the bearing pad.
3. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
4. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
5. Total Pad Elastomer Thickness - total thickness of all elastomer layers.
6. Total Bearing Pad Thickness - total bearing pad thickness.
7. Number of Pads Per End - the total number of pads required at the end of the bridge.

Check geometry constraints

8. Maximum Permissible Length of Pad - maximum length of the pad that can be used, given the geometrical layout of the bearing pad and beam size.
9. Maximum Permissible Width of Pad - maximum width of the pad that can be used, given the geometrical layout of the bearing pad and beam size.
10. Minimum Exterior Edge Distance - minimum distance from the edge of the bearing pad to the edge of the beam.
11. Maximum Exterior Edge Distance - maximum distance from the edge of the bearing pad to the edge of the beam.
12. Minimum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the minimum distance from the edge of the pad to the edge of the elastomeric sponge washer.
13. Maximum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the maximum distance from the edge of the pad to the edge of the elastomeric sponge washer.
14. Width of Elastomeric Sponge Washer - for situations that require two bearing pads at the end of a beam, this is the width of the elastomeric sponge washer.
15. <<< Pad Exceeds Maximum Permissible Length >>> - prints when bearing pad length exceeds maximum permissible.
16. <<< Pad Exceeds Maximum Permissible Width >>> - prints when bearing pad width exceeds maximum permissible.
17. <<< Pad Size Satisfies Geometry Constraints >>> - prints when bearing pad satisfies all geometrical constraints.

Check compressive stresses

18. Pad Area - cross sectional area of the bearing pad.
19. Stress Due to Maximum Dead Load - stresses due to maximum dead load reaction.

20. Stress Due to Minimum Dead Load - stresses due to minimum dead load reaction.
21. Stress Due to Live Load - stresses due to maximum live load reaction.
22. Stress Due to Total Load - total stresses due to maximum dead load and maximum live load reactions acting on bearing pad.
23. ERROR - Computing Compressive Stress... - prints when the program encounters an error when computing the compressive stress in the pad. Review input data for errors.
24. Shape Factor for Plain Pad - computed shape factor for plain bearing pad.
25. Allowable Stress - allowable compressive stress on bearing pad.
26. ERROR - Computing Allowable Compressive Stress... - prints when the program encounters an error when computing the compressive stress capacity of the pad. Review input data for errors.
27. <<< Stress Exceeds Allowable Stress >>> - prints when bearing pad fails the compressive stress criteria.
28. <<< Pad Satisfies Stress Criteria >>> - prints when bearing pad satisfies all compressive stress criteria.
29. <<< Shape factor less than 3, strain cannot be calculated >>> - prints when the plain pad shape factor is less than three, which means that the coefficients used to calculate the strain in the bearing pad cannot be calculated (DM-4 C14.7.5.3.6).
30. <<< Shape factor greater than 12; use S=12 to calculate strain >>> - prints when the plain pad shape factor is greater than 12, which means that the coefficients used to calculate the strain in the bearing pad will be conservatively calculated using a value of 12 rather than the actual shape factor (DM-4 C14.7.5.3.6).
31. <<< Shape factor is between 3 and 12; shape factor OK >>> - prints when the plain pad shape factor is between 3 and 12 so the coefficients used to calculate the strain in the bearing pad can be calculated as per DM-4 C14.7.5.3.6.

Compute horizontal shear

32. Horizontal Shear Force - computed total horizontal shear force acting on all bearing pads at the expansion end. Computed for both dead load only and dead load plus live load cases.
33. Allowable Horizontal Shear Force for Method A anchorage - computed allowable total horizontal shear to satisfy the Method A anchorage requirements of DM-4 Section 14.7.6.4 (also see Section 3.11 of this manual). Only printed when dowel is not used. Computed for both dead load only and dead load plus live load cases.
34. <<< Pad Satisfies Method A Anchorage Requirements >>> - prints when the Method A anchorage requirement is satisfied and dowel not used.
35. <<< Pad DOES NOT Satisfies Method A Anchorage Requirements >>> - prints when the horizontal shear force exceeds the allowable and a dowel not used.
36. <<< Method A anchorage (DM-4 14.7.6.4P) not checked because a hole has been provided for a dowel >>> - prints when a hole is present, indicating that a dowel is being used.

Check shear deformation and rotation

37. Thickness Required for Method A Anchorage - the pad thickness required to accommodate Method A anchorage.

38. <<< Pad Satisfies Method A Anchorage Requirements >>> - prints when the pad satisfies thickness required for Method A anchorage.
39. <<< Pad Does Not Satisfy Method A Anchorage >>> - prints when the pad does not satisfy thickness required for Method A anchorage.
40. <<< Method A anchorage (DM-4 14.7.6.4P) not checked because a hole has been provided for a dowel >>> - prints when a hole is present, indicating that a dowel is being used.
41. Thickness Required for Shear Deformation - the pad thickness required to accommodate all shear deformations.
42. Strain in Pad due to Dead Load - the strain in the pad due to the maximum dead load reaction.
43. Strain in Pad due to Total Load - the strain in the pad due to the maximum total load reaction.

Compute thickness required for rotation

44. Rotation About the Transverse Axis of Bearing Pad - the following table shows the combinations of rotations and skews that need to be satisfied about the transverse axis of this bearing pad.

    Rotation Combination - the combination of rotations checked:

    Construction Tolerance - the construction rotational tolerances entered by the user.

    Construction Tolerance + Live Load - the construction tolerance value plus the rotation due to live load entered by the user.

    End Rotation - the rotation corresponding to the rotation combination.

    Effective Skew - the skew of the bearing pad. Both maximum and minimum skews are checked.

    Strain - strain in the bearing pad due to rotation combination.

    Thickness Required - thickness of pad required due to the strain in the bearing pad.

45. Rotation About the Longitudinal Axis of Bearing Pad - the following table shows the combinations of rotations and skews that need to be satisfied about the longitudinal axis of this bearing pad.

    Rotation Combination - the combination of rotations checked:

    Construction Tolerance - the construction rotational tolerances entered by the user.

    Construction Tolerance + Live Load - the construction tolerance value plus the rotation due to live load entered by the user.

    End Rotation - the rotation corresponding to the rotation combination.

    Effective Skew - the skew of the bearing pad. Both maximum and minimum skews are checked.

    Strain - strain in the bearing pad due to rotation combination.

    Thickness Required - thickness of pad required due to the strain in the bearing pad.

46. Required minimum elastomer thickness for shear and rotation - minimum thickness needed based on shear deformation and rotation criteria above.
47. Provided elastomer thickness - the provided elastomer thickness of the bearing pad. The comparison of the required and provided elastomer thicknesses considers a tolerance of 0.01 inch.
48. <<< Pad is Too Thin >>> - prints when the pad thickness is less than the required thickness.
49. <<< Pad is Too Thick >>> - prints when the pad thickness is greater than the maximum allowed.
50. Thickness is less than the minimum allowable thickness - prints when the pad thickness is less than the minimum allowed.

51. <<< Pad Satisfies Thickness Criteria >>> - prints when the pad satisfies all the above thickness criteria.

Check stability

52. Stability Factor for Length - stability factor from parameter file set based on pad type.
53. Stability Factor for Width - stability factor from parameter file set based on pad type.
54. Maximum Thickness to Satisfy Longitudinal Stability - pad length divided by length stability factor.
55. Maximum Thickness to Satisfy Transverse Stability - pad width divided by width stability factor.
56. <<< Pad Thickness Exceeds LONGITUDINAL Stability >>> - prints when the pad thickness exceeds longitudinal stability criteria.
57. <<< Pad Thickness Exceeds TRANSVERSE Stability >>> - prints when the pad thickness exceeds transverse stability criteria.
58. <<< Pad Satisfies LONGITUDINAL Stability Criteria >>> - prints when the pad thickness satisfies the longitudinal stability criteria.
59. <<< Pad Satisfies TRANSVERSE Stability Criteria >>> - prints when the pad thickness satisfies the transverse stability criteria.

Compute compressive deflection

60. Dead Load Deflection (include creep) - compressive dead load deflection of bearing pad, including deflection due to creep.
61. Live Load Deflection (exclude creep) - compressive live load deflection of bearing pad, excluding deflection due to creep.
62. Total Load Deflection (include creep) - compressive total load deflection of bearing pad, including deflection due to creep from dead load only.

7.4.4 Analysis of Expansion End Pad - Laminated

This table presents the specification checks for a laminated rectangular bearing pad for the expansion end of the bridge. The following information is reported in the ANALYSIS OF EXPANSION END PAD - LAMINATED output table.

1. Pad Length - total length of the bearing pad.
2. Pad Width - total width of the bearing pad.
3. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
4. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
5. Interior Layer Thickness - thickness of each interior layer.
6. Cover Layer Thickness - thickness of each cover layer.
7. Total Number of Elastomer Layers - total number of elastomer layers for the bearing pad.
8. Total Pad Elastomer Thickness - total thickness of all elastomer layers in the bearing pad.
9. Thickness of Shim Plates - thickness of each shim plate.
10. Total Bearing Pad Thickness - total bearing pad thickness.
11. Number of Pads Per End - the total number of pads required at the end of the bridge.

Check geometry constraints

12. Maximum Permissible Length of Pad - maximum length of the pad that can be used, given the geometrical layout of the bearing pad and beam size.
13. Maximum Permissible Width of Pad - maximum width of the pad that can be used, given the geometrical layout of the bearing pad and beam size.
14. Minimum Exterior Edge Distance - minimum distance from the edge of the bearing pad to the edge of the beam.
15. Maximum Exterior Edge Distance - maximum distance from the edge of the bearing pad to the edge of the beam.
16. Minimum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the minimum distance from the edge of the pad to the edge of the elastomeric sponge washer.
17. Maximum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the maximum distance from the edge of the pad to the edge of the elastomeric sponge washer.
18. Width of Elastomeric Sponge Washer - for situations that require two bearing pads at the end of a beam, this is the width of the elastomeric sponge washer.
19. <<< Pad Exceeds Maximum Permissible Length >>> - prints when bearing pad length exceeds maximum permissible.
20. <<< Pad Exceeds Maximum Permissible Width >>> - prints when bearing pad width exceeds maximum permissible.

21. <<< Pad Size Satisfies Geometry Constraints >>> - prints when bearing pad satisfies all geometrical constraints.

Check compressive stresses (Method A Specification Check)

22. Pad Area - cross sectional area of the bearing pad.
23. Stress Due to Maximum Dead Load - stresses due to maximum dead load reaction.
24. Stress Due to Minimum Dead Load - stresses due to minimum dead load reaction.
25. Stress Due to Live Load - stresses due to maximum live load reaction.
26. Stress Due to Total Load - total stresses due to maximum dead load and maximum live load reactions acting on bearing pad.
27. ERROR - Computing Compressive Stress... - prints when the program encounters an error when computing the compressive stress in the pad. Review input data for errors.
28. Shape Factor for Interior Layer - computed shape factor for interior layer of bearing pad.
29. Shape Factor for Cover Layer - computed shape factor for cover layer of bearing pad.
30. Allowable Stress - allowable compressive stress on bearing pad.
31. ERROR - Computing Allowable Compressive Stress... - prints when the program encounters an error when computing the compressive stress capacity of the pad. Review input data for errors.
32. <<< Stress Exceeds Allowable Stress >>> - prints when bearing pad fails the compressive stress criteria.
33. <<< Pad Satisfies Stress Criteria >>> - prints when bearing pad satisfies all compressive stress criteria.
34. <<< Interior layer shape factor less than 3, strain cannot be calculated >>> - prints when the interior layer shape factor is less than three, which means that the coefficients used to calculate the strain in the bearing pad cannot be calculated (DM-4 C14.7.5.3.6).
35. <<< Interior layer shape factor greater than 12; use S=12 to calculate strain >>> - prints when the interior layer shape factor is greater than 12, which means that the coefficients used to calculate the strain in the bearing pad will be conservatively calculated using a value of 12 rather than the actual shape factor (DM-4 C14.7.5.3.6).
36. <<< Interior layer shape factor is between 3 and 12; shape factor OK >>> - prints when the interior layer shape factor is between 3 and 12 so the coefficients used to calculate the strain in the bearing pad can be calculated as per DM-4 C14.7.5.3.6.
37. <<< Cover layer shape factor less than 3, strain cannot be calculated >>> - prints when the cover layer shape factor is less than three, which means that the coefficients used to calculate the strain in the bearing pad cannot be calculated (DM-4 C14.7.5.3.6).
38. <<< Cover layer shape factor greater than 12; use S=12 to calculate strain >>> - prints when the cover layer shape factor is greater than 12, which means that the coefficients used to calculate the strain in the bearing pad will be conservatively calculated using a value of 12 rather than the actual shape factor (DM-4 C14.7.5.3.6).
39. <<< Cover layer shape factor is between 3 and 12; shape factor OK >>> - prints when the cover layer shape factor is between 3 and 12 so the coefficients used to calculate the strain in the bearing pad can be calculated as per DM-4 C14.7.5.3.6.

Compute horizontal shear (Method A Specification Check)

40. Horizontal Shear Force - computed total horizontal shear force acting on all bearing pads at the expansion end. Computed for both dead load only and dead load plus live load cases.
41. Allowable Horizontal Shear Force for Method A anchorage - computed allowable total horizontal shear to satisfy Method A anchorage requirements of DM-4 Section 14.7.6.4 (also see Section 3.11 of this manual). Only printed when dowel is not used. Computed for both dead load only and dead load plus live load cases.
42. <<< Pad Satisfies Method A Anchorage Requirements >>> - prints when Method A anchorage requirement is satisfied and dowel not used.
43. <<< Pad DOES NOT Satisfies Method A Anchorage Requirements >>> - prints when the horizontal shear force exceeds the allowable and a dowel not used.
44. <<< Method A anchorage (DM-4 14.7.6.4P) not checked because a hole has been provided for a dowel >>> - prints when a hole is present, indicating that a dowel is being used.

Check shim thickness (Method A Specification Check)

45. Minimum Shim Thickness per Service Limit State - the minimum shim thickness based on the service limit state.
46. Minimum Shim Thickness per Fatigue Limit State - the minimum shim thickness based on the fatigue limit state.
47. Minimum Thickness Required by PennDOT - the minimum thickness based on restrictions in DM-4.
48. Shim Thickness - the shim thickness that corresponds to the maximum shim thickness of the three options given above.
49. <<< Shim DOES NOT Satisfy Stress Criteria >>> - prints when the shims do not satisfy the thickness criteria for the service or fatigue limit states.
50. <<< Shim Satisfies Stress Criteria >>> - prints when the shims satisfy the thickness criteria for the service and fatigue limit states.
51. <<< Shim DOES NOT satisfy PennDOT minimum thickness criteria >>> - prints when the actual shim thickness is less than the PennDOT minimum.
52. <<< Shim satisfies PennDOT minimum thickness criteria >>> - prints when the actual shim thickness is greater than or equal to the PennDOT minimum.

Check shear deformation and rotation (Method A Specification Check)

53. Thickness Required for Method A Anchorage - the pad thickness required to accommodate Method A anchorage. Only prints when no hole is present.
54. <<< Pad Satisfies Method A Anchorage Requirement >>> - prints when the pad satisfies thickness required for Method A anchorage.
55. <<< Pad Does Not Satisfy Method A Anchorage >>> - prints when the pad does not satisfy thickness required for Method A anchorage.
56. <<< Method A anchorage (DM-4 14.7.6.4P) not checked because a hole has been provided for a dowel >>> - prints when a hole is present, indicating that a dowel is being used.

57. Thickness Required for Shear Deformation - the pad thickness required to accommodate all shear deformations.
58. Strain in Cover Layer Due to Dead Load - the strain in the cover layers of the bearing pad due to the maximum dead load reaction.
59. Strain in Interior Layer Due to Dead Load - the strain in the interior layers of the bearing pad due to the maximum dead load reaction.
60. Strain in Cover Layer Due to Total Load - the strain in the cover layers of the bearing pad due to the maximum total load reaction.
61. Strain in Interior Layer Due to Total Load - the strain in the interior layers of the bearing pad due to the maximum total load reaction.

Compute thickness required for rotation (Method A Specification Check)

62. Rotation About the Transverse Axis of Bearing Pad - the following table shows the combinations of rotations and skews that need to be satisfied about the transverse axis of this bearing pad.

    Rotation Combination - the combination of rotations checked:

    Construction Tolerance - the construction rotational tolerances entered by the user.

    Construction Tolerance + Live Load - the construction tolerance value plus the rotation due to live load entered by the user.

    End Rotation - the rotation corresponding to the rotation combination.

    Effective Skew - the skew of the bearing pad. Both maximum and minimum skews are checked.

    Cover Strain - strain in the cover layers of the bearing pad due to rotation combination.

    Interior Strain - strain in the interior layers of the bearing pad due to rotation combination.

    Thickness Required - thickness of pad required due to the strain in the bearing pad.

63. Rotation About the Longitudinal Axis of Bearing Pad - the following table shows the combinations of rotations and skews that need to be satisfied about the longitudinal axis of this bearing pad.

    Rotation Combination - the combination of rotations checked:

    Construction Tolerance - the construction rotational tolerances entered by the user.

    Construction Tolerance + Live Load - the construction tolerance value plus the rotation due to live load entered by the user.

    End Rotation - the rotation corresponding to the rotation combination.

    Effective Skew - the skew of the bearing pad. Both maximum and minimum skew are checked.

    Cover Strain - strain in the cover layers of the bearing pad due to rotation combination.

    Interior Strain - strain in the interior layers of the bearing pad due to rotation combination.

    Thickness Required - thickness of pad required due to the strain in the bearing pad.

64. Required minimum elastomer thickness for shear and rotation - minimum thickness needed based on shear deformation and rotation criteria above.
65. Provided elastomer thickness - the provided elastomer thickness of the bearing pad. The comparison of the required and provided elastomer thicknesses considers a tolerance of 0.01 inch.
66. <<< Pad is Too Thin >>> - prints when the pad thickness is less than the required thickness.
67. << Pad is Too Thick >>> - prints when the pad thickness is greater than the maximum allowed.

68. Thickness of interior layer is less than the minimum allowable thickness - prints when the interior pad thickness is less than the minimum allowed.
69. Thickness of cover layer is less than the minimum allowable thickness - prints when the cover pad thickness is less than the minimum allowed.
70. <<< Pad Satisfies Thickness Criteria >>> - prints when the pad satisfies all the above thickness criteria.

Check stability (Method A Specification Check)

71. Stability Factor for Length - stability factor from parameter file set based on pad type.
72. Stability Factor for Width - stability factor from parameter file set based on pad type.
73. Maximum Thickness to Satisfy Longitudinal Stability - pad length divided by length stability factor.
74. Maximum Thickness to Satisfy Transverse Stability - pad width divided by width stability factor.
75. <<< Pad Thickness Exceeds LONGITUDINAL Stability >>> - prints when the pad thickness exceeds longitudinal stability criteria.
76. <<< Pad Thickness Exceeds TRANSVERSE Stability >>> - prints when the pad thickness exceeds transverse stability criteria.
77. <<< Pad Satisfies LONGITUDINAL Stability Criteria >>> - prints when the pad thickness satisfies the longitudinal stability criteria.
78. <<< Pad Satisfies TRANSVERSE Stability Criteria >>> - prints when the pad thickness satisfies the transverse stability criteria.

Shear Deformation - AASHTO LRFD 14.7.5.3.2 (Method B Specification Check)

79. Unfactored thermal movement - unfactored thermal movement calculated using the entire temperature range.
80. Construction Flexibility - horizontal movement entered by the user.
81. DC1 + DC2 + LL rotation movement - horizontal movements due to rotation entered by the user.
82. hrt - total elastomer thickness of the pad.
83. 2.0*deltaS - two times the total factored horizontal movement.
84. <<< Bearing pad PASSES Method B Shear Deformation check - OK >>> - prints when the pad passes the shear deformation check.
85. <<< Bearing pad FAILS Method B Shear Deformation check - NG >>> - prints when the pad fails the shear deformation check.

Shear strain due to axial load - AASHTO LRFD 14.7.5.3.3 (Method B Specification Check)

86. Maximum DL Stress - maximum dead load stress.
87. Maximum LL Stress - maximum live load stress.
88. Shape Factor, Internal - shape factor of an internal layer.
89. Shear modulus (G)- user-input shear modulus or minimum shear modulus value for the user input pad hardness.
90. Gamma(a,st) - maximum static shear strain caused by axial load
91. Gamma(a,st+1.75cy) - maximum total shear strain caused by static + 1.75 * cyclic axial load

Shear strain due to rotation - AASHTO LRFD 14.7.5.3.3 (Method B Specification Check)

92. LL Rotation about transverse axis - live load rotation about the pad transverse axis, entered by the user.
93. LL Rotation about longitudinal axis - live load rotation about the pad longitudinal axis, entered by the user.
94. DL + Toler about transverse axis - construction tolerance and dead load rotation about the pad transverse axis, entered by the user.
95. DL + Toler about longitudinal axis - construction tolerance and dead load rotation about the pad transverse axis, entered by the user.
96. Gamma(r,st+1.75cy, abt transv axis) - maximum total shear strain caused by static + 1.75 cyclic rotation, about the transverse axis of the pad
97. Gamma(r,st+1.75cy, abt long axis) - maximum total shear strain caused by static + 1.75 cyclic rotation, about the longitudinal axis of the pad

Shear strain due to shear deformation - AASHTO LRFD 14.7.5.3.3 (Method B Specification Check)

98. Unfactored thermal movement - unfactored thermal movement calculated using the entire temperature range.
99. Construction Flexibility - horizontal movement entered by the user.
100. DC1+DC2+1.75*LL mvmt due rot - total horizontal movement due to DC1 + DC2 + 1.75*LL rotational movements.
101. <<< Shear strain caused by static axial load, x.xxxx, <= 3.0 (AASHTO LRFD 14.7.5.3.3-2) - OK >>> - shear strain due to the static axial load is less than the limit of 3.0.
102. <<< Shear strain caused by static axial load, x.xxxx, <= 3.0 (AASHTO LRFD 14.7.5.3.3-2) - NG >>> - shear strain due to the static axial load exceeds the limit of 3.0.
103. <<< Combined shear strain, x.xxxx, <= 5.0 (AASHTO LRFD 14.7.5.3.3-1) - OK>>> - total combined shear strain is less than the limit of 5.0.
104. <<< Combined shear strain, x.xxxx, <= 5.0 (AASHTO LRFD 14.7.5.3.3-1) - NG>>> - total combined shear strain exceeds the limit of 5.0.

Stability of Elastomeric Bearings - AASHTO LRFD 14.7.5.3.4 (Method B Specification Check)

105. Shape Factor; Internal - shape factor of an internal layer.
106. Shear modulus (G) - user-input shear modulus or minimum shear modulus value for the user input pad hardness.
107. A (AASHTO LRFD 14.7.5.3.4-2) - variable, A, calculated as per AASHTO LRFD.
108. B (AASHTO LRFD 14.7.5.3.4-3) - variable, B, calculated as per AASHTO LRFD.
109. Bridge deck is assumed to be free to translate horizontally - statement of assumption made by BPLRFD
110. (GL * Sint)/(2.0*A - B) - specification check value calculated by the program.
111. <<< Bearing pad satisfies AASHTO LRFD 14.7.5.3.4-1, so stability is OK >>> - if 2.0*A < B, the bearing pad passes the stability check.
112. SigmaS - maximum sum of dead and live load stresses.

113. <<< Bearing pad satisfies AASHTO LRFD 14.7.5.3.4-4, so stability is OK >>> - total stress is less than or equal to the specification check values.

114. <<< Bearing pad FAILS AASHTO LRFD 14.7.5.3.4-4, so stability is NG >>>- total stress is greater than the specification check values.

Required Shim Thickness - AASHTO LRFD 14.7.5.3.5 (Method B Specification Check)

115. Shim yield strength - default yield strength for reinforcing shims

116. Const Ampl Ftg Thresh (A) - constant amplitude fatigue threshold for Category A

117. Minimum shim thickness - minimum allowed shim thickness

118. Combination - load combination being checked.

119. Stress - total stress used for the shim thickness calculation.

120. Required Shim Thickness - calculated shim thickness for the current load combination

121. <<< Shim thickness greater than or equal to minimum required - OK >>> - user input or designed shim thickness is greater than or equal to the required thickness

122. <<< Shim thickness greater than or equal to minimum required - NG >>> - user input or designed shim thickness is less than the required thickness.

Check total pad thickness against input or default minimum thickness (Method B Specification Check)

123. Calculated total pad thickness - calculated pad thickness.

124. Input/Default minimum pad thickness - minimum allowed pad thickness.

125. <<< Pad satisfies input MINIMUM THICKNESS criteria >>> - pad thickness is greater than or equal to the minimum required thickness.

126. <<< Pad thickness less than input MINIMUM THICKNESS >>> - pad thickness is less than the minimum required thickness.

Check Method B anchorage (Method A and Method B Specification Check)

127. Check Anchorage - AASHTO LRFD 14.7.5.4 – following table shows the values used for and the calculation of the Method B anchorage check. Only prints if no hole is present.

    Total Rotation – the total end rotation of the bearing pad

    Total Strain – the total axial strain of the interior layer

    No. of Layers – number of interior considered (will include one layer to account for the cover layers if the cover layer is greater than half the thickness of an interior layer)

    Shape Factor – shape factor of the interior elastomer layer

    Left Term – Left term of the A14.7.5.4-1 Equation

    Right Term – Right term of the A14.7.5.4-1 Equation

    These values are printed for three conditions: minimum dead load only, maximum dead load + minimum live load, minimum dead load + maximum live load.

128. <<< Pad satisfies Method B Anchorage criteria>>> – prints when the pad thickness meets the Method B Anchorage criteria.

129. <<< Pad DOES NOT satisfy Method B Anchorage criteria>>> – prints when the pad thickness does not meet the Method B Anchorage criteria.

130. <<< Method B anchorage (AASHTO LRFD 14.7.5.4) not checked because a hole has been provided for a dowel >>> - prints when a hole is present, indicating that a dowel is being used.

Compute compressive deflection (Method A and Method B Specification Check)

131. Dead Load Deflection (include creep) - compressive dead load deflection of bearing pad, including deflection due to creep.

132. Live Load Deflection (exclude creep) - compressive live load deflection of bearing pad, excluding deflection due to creep.

133. Total Load Deflection (include creep) - compressive total load deflection of bearing pad, including deflection due to creep from dead load only.

7.4.5 Design of Fixed End Pad - Plain

This table presents the properties of a plain rectangular bearing pad designed for the fixed end of the bridge. The following information is reported in the DESIGN OF FIXED END PAD - PLAIN output table.

1. Acceptable Pad Size: - message denoting that the design found by the program passes all specification checks.
2. FIXED END: - end of the girder for which the program designed the reported bearing pad.
3. Use two pads, each pad should be: - denotes that the program has determined that two bearing pads are required for this end of the bridge.
4. Pad Length - total length of the bearing pad.
5. Pad Width - total width of the bearing pad.
6. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
7. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
8. Total Elastomer Thickness - total thickness of bearing pad.
9. Provide a hole in the pad for dowel, hole diameter - if the program determines that a dowel rod is necessary for the bearing, provide a hole this size to accept the dowel.

7.4.6 Design of Fixed End Pad - Laminated

This table presents the properties of a laminated rectangular bearing pad designed for the fixed end of the bridge. The following information is reported in the DESIGN OF FIXED END PAD - LAMINATED output table.

1. Acceptable Pad Size: - message denoting that the design found by the program passes all specification checks.
2. FIXED END: - end of the girder for which the program designed the reported bearing pad.
3. Use two pads, each pad should be: - denotes that the program has determined that two bearing pads are required for this end of the bridge.
4. Pad Length - total length of the bearing pad.
5. Pad Width - total width of the bearing pad.
6. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
7. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
8. Total Elastomer Thickness - total thickness of all elastomer layers.
9. Number of Elastomer Layers - number of elastomer layers needed.
10. Thickness of Interior Elastomer Layers - required thickness of each interior layer.
11. Thickness of Cover Elastomer Layers - required thickness of each cover layer.
12. Thickness of Shim Plates - required thickness of each shim plate.
13. Total Bearing Pad Thickness - includes total thickness of all elastomer layers and all shim plates.
14. Provide a hole in the pad for dowel, hole diameter - if the program determines that a dowel rod is necessary for the bearing, provide a hole this size to accept the dowel.

7.4.7 Analysis of Fixed End Pad - Plain

This table presents the specification checks for a plain rectangular bearing pad designed for the fixed end of the bridge. The following information is reported in the ANALYSIS OF FIXED END PAD - PLAIN output table.

1. Pad Length - total length of the bearing pad.
2. Pad Width - total width of the bearing pad.
3. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
4. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
5. Total Pad Elastomer Thickness - total thickness of all elastomer layers.
6. Total Bearing Pad Thickness - total bearing pad thickness.
7. Number of Pads Per End - the total number of pads required at the end of the bridge.
8. Maximum Permissible Length of Pad - maximum length of the pad that can be used, given the geometrical layout of the bearing pad and beam size.
9. Maximum Permissible Width of Pad - maximum width of the pad that can be used, given the geometrical layout of the bearing pad and beam size.
10. Minimum Exterior Edge Distance - minimum distance from the edge of the bearing pad to the edge of the beam.
11. Maximum Exterior Edge Distance - maximum distance from the edge of the bearing pad to the edge of the beam.
12. Minimum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the minimum distance from the edge of the pad to the edge of the elastomeric sponge washer.
13. Maximum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the maximum distance from the edge of the pad to the edge of the elastomeric sponge washer.
14. Width of Elastomeric Sponge Washer - for situations that require two bearing pads at the end of a beam, this is the width of the elastomeric sponge washer.
15. <<< Pad Exceeds Maximum Permissible Length >>> - prints when bearing pad length exceeds maximum permissible.
16. <<< Pad Exceeds Maximum Permissible Width >>> - prints when bearing pad width exceeds maximum permissible.
17. <<< Pad Size Satisfies Geometry Constraints >>> - prints when bearing pad satisfies all geometrical constraints.
18. Pad Area - cross sectional area of the bearing pad.
19. Stress Due to Maximum Dead Load - stresses due to maximum dead load reaction.
20. Stress Due to Minimum Dead Load - stresses due to minimum dead load reaction.
21. Stress Due to Live Load - stresses due to maximum live load reaction.

22. Stress Due to Total Load - total stresses due to maximum dead load and maximum live load reactions acting on bearing pad.
23. ERROR - Computing Compressive Stress... - prints when the program encounters an error when computing the compressive stress in the pad. Review input data for errors.
24. Shape Factor for Plain Pad - computed shape factor for plain bearing pad.
25. Allowable Stress - allowable compressive stress on bearing pad.
26. ERROR - Computing Allowable Compressive Stress... - prints when the program encounters an error when computing the compressive stress capacity of the pad. Review input data for errors.
27. <<< Stress Exceeds Allowable Stress >>> - prints when bearing pad fails the compressive stress criteria.
28. <<< Pad Satisfies Stress Criteria >>> - prints when bearing pad satisfies all compressive stress criteria.
29. <<< Shape factor less than 3, strain cannot be calculated >>> - prints when the plain pad shape factor is less than three, which means that the coefficients used to calculate the strain in the bearing pad cannot be calculated (DM-4 C14.7.5.3.6).
30. <<< Shape factor greater than 12; use S=12 to calculate strain >>> - prints when the plain pad shape factor is greater than 12, which means that the coefficients used to calculate the strain in the bearing pad will be conservatively calculated using a value of 12 rather than the actual shape factor (DM-4 C14.7.5.3.6).
31. <<< Shape factor is between 3 and 12; shape factor OK >>> - prints when the plain pad shape factor is between 3 and 12 so the coefficients used to calculate the strain in the bearing pad can be calculated as per DM-4 C14.7.5.3.6.
32. Strain in Pad due to Dead Load - the strain in the pad due to the maximum dead load reaction.
33. Strain in Pad due to Total Load - the strain in the pad due to the maximum total load reaction.
34. Rotation About the Transverse Axis of Bearing Pad - the following table shows the combinations of rotations and skews that need to be satisfied about the transverse axis of this bearing pad.

    Rotation Combination - the combination of rotations checked:

    - Construction Tolerance - the construction rotational tolerances entered by the user.
    - Construction Tolerance + Live Load - the construction tolerance value plus the rotation due to live load entered by the user.

    End Rotation - the rotation corresponding to the rotation combination.

    Effective Skew - the skew of the bearing pad. Both maximum and minimum skews are checked.

    Strain - strain in the bearing pad due to rotation combination.

    Thickness Required - thickness of pad required due to the strain in the bearing pad.
35. Rotation About the Longitudinal Axis of Bearing Pad - the following table shows the combinations of rotations and skews that need to be satisfied about the longitudinal axis of this bearing pad.

    Rotation Combination - the combination of rotations checked:

    - Construction Tolerance - the construction rotational tolerances entered by the user.
    - Construction Tolerance + Live Load - the construction tolerance value plus the rotation due to live load entered by the user.

End Rotation - the rotation corresponding to the rotation combination.

Effective Skew - the skew of the bearing pad. Both maximum and minimum skews are checked.

Strain - strain in the bearing pad due to rotation combination.

Thickness Required - thickness of pad required due to the strain in the bearing pad.

36. Required minimum elastomer thickness for shear and rotation - minimum thickness needed based on shear deformation and rotation criteria above.
37. Provided elastomer thickness - the provided elastomer thickness of the bearing pad. The comparison of the required and provided elastomer thicknesses considers a tolerance of 0.01 inch.
38. <<< Pad is Too Thin >>> - prints when the pad thickness is less than the required thickness.
39. <<< Pad Does Not Satisfy Method A Anchorage >>> - prints when the pad does not satisfy thickness required for Method A anchorage.
40. <<< Pad is Too Thick >>> - prints when the pad thickness is greater than the maximum allowed.
41. Thickness is less than the minimum allowable thickness - prints when the pad thickness is less than the minimum allowed.
42. <<< Pad Satisfies Thickness Criteria >>> - prints when the pad satisfies all the above thickness criteria.
43. Stability Factor for Length - stability factor from parameter file set based on pad type.
44. Stability Factor for Width - stability factor from parameter file set based on pad type.
45. Maximum Thickness to Satisfy Longitudinal Stability - pad length divided by length stability factor.
46. Maximum Thickness to Satisfy Transverse Stability - pad width divided by width stability factor.
47. <<< Pad Thickness Exceeds LONGITUDINAL Stability >>> - prints when the pad thickness exceeds longitudinal stability criteria.
48. <<< Pad Thickness Exceeds TRANSVERSE Stability >>> - prints when the pad thickness exceeds longitudinal stability criteria.
49. <<< Pad Satisfies LONGITUDINAL Stability Criteria >>> - prints when the pad thickness satisfies the longitudinal stability criteria.
50. <<< Pad Satisfies TRANSVERSE Stability Criteria >>> - prints when the pad thickness satisfies the transverse stability criteria.
51. Dead Load Deflection (include creep) - compressive dead load deflection of bearing pad, including deflection due to creep.
52. Live Load Deflection (exclude creep) - compressive live load deflection of bearing pad, excluding deflection due to creep.
53. Total Load Deflection (include creep) - compressive total load deflection of bearing pad, including deflection due to creep from dead load only.

7.4.8 Analysis of Fixed End Pad - Laminated

This table presents the specification checks for a laminated rectangular bearing pad at the fixed end of the bridge. The following information is reported in the ANALYSIS OF FIXED END PAD - LAMINATED output table.

1. Pad Length - total length of the bearing pad.
2. Pad Width - total width of the bearing pad.
3. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
4. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
5. Interior Layer Thickness - thickness of each interior layer.
6. Cover Layer Thickness - thickness of each cover layer.
7. Total Number of Elastomer Layers - total number of elastomer layers for the bearing pad.
8. Total Pad Elastomer Thickness - total thickness of all elastomer layers in the bearing pad.
9. Thickness of Shim Plates - thickness of each shim plate.
10. Total Bearing Pad Thickness - total bearing pad thickness.
11. Number of Pads Per End - the total number of pads required at the end of the bridge.

Check geometry constraints

12. Maximum Permissible Length of Pad - maximum length of the pad that can be used, given the geometrical layout of the bearing pad and beam size.
13. Maximum Permissible Width of Pad - maximum width of the pad that can be used, given the geometrical layout of the bearing pad and beam size.
14. Minimum Exterior Edge Distance - minimum distance from the edge of the bearing pad to the edge of the beam.
15. Maximum Exterior Edge Distance - maximum distance from the edge of the bearing pad to the edge of the beam.
16. Minimum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the minimum distance from the edge of the pad to the edge of the elastomeric sponge washer.
17. Maximum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the maximum distance from the edge of the pad to the edge of the elastomeric sponge washer.
18. Width of Elastomeric Sponge Washer - for situations that require two bearing pads at the end of a beam, this is the width of the elastomeric sponge washer.
19. <<< Pad Exceeds Maximum Permissible Length >>> - prints when bearing pad length exceeds maximum permissible.
20. <<< Pad Exceeds Maximum Permissible Width >>> - prints when bearing pad width exceeds maximum permissible.

21. <<< Pad Size Satisfies Geometry Constraints >>> - prints when bearing pad satisfies all geometrical constraints.

Check compressive stresses (Method A Specification Check)

22. Pad Area - cross sectional area of the bearing pad.
23. Stress Due to Maximum Dead Load - stresses due to maximum dead load reaction.
24. Stress Due to Minimum Dead Load - stresses due to minimum dead load reaction.
25. Stress Due to Live Load - stresses due to maximum live load reaction.
26. Stress Due to Total Load - total stresses due to maximum dead load and maximum live load reactions acting on bearing pad.
27. ERROR - Computing Compressive Stress... - prints when the program encounters an error when computing the compressive stress in the pad. Review input data for errors.
28. Shape Factor for Interior Layer - computed shape factor for interior layer of bearing pad.
29. Shape Factor for Cover Layer - computed shape factor for cover layer of bearing pad.
30. Allowable Stress - allowable compressive stress on bearing pad.
31. ERROR - Computing Allowable Compressive Stress... - prints when the program encounters an error when computing the compressive stress capacity of the pad. Review input data for errors.
32. <<< Stress Exceeds Allowable Stress >>> - prints when bearing pad fails the compressive stress criteria.
33. <<< Pad Satisfies Stress Criteria >>> - prints when bearing pad satisfies all compressive stress criteria.
34. <<< Interior layer shape factor less than 3, strain cannot be calculated >>> - prints when the interior layer shape factor is less than three, which means that the coefficients used to calculate the strain in the bearing pad cannot be calculated (DM-4 C14.7.5.3.6).
35. <<< Interior layer shape factor greater than 12; use S=12 to calculate strain >>> - prints when the interior layer shape factor is greater than 12, which means that the coefficients used to calculate the strain in the bearing pad will be conservatively calculated using a value of 12 rather than the actual shape factor (DM-4 C14.7.5.3.6).
36. <<< Interior layer shape factor is between 3 and 12; shape factor OK >>> - prints when the interior layer shape factor is between 3 and 12 so the coefficients used to calculate the strain in the bearing pad can be calculated as per DM-4 C14.7.5.3.6.
37. <<< Cover layer shape factor less than 3, strain cannot be calculated >>> - prints when the cover layer shape factor is less than three, which means that the coefficients used to calculate the strain in the bearing pad cannot be calculated (DM-4 C14.7.5.3.6).
38. <<< Cover layer shape factor greater than 12; use S=12 to calculate strain >>> - prints when the cover layer shape factor is greater than 12, which means that the coefficients used to calculate the strain in the bearing pad will be conservatively calculated using a value of 12 rather than the actual shape factor (DM-4 C14.7.5.3.6).
39. <<< Cover layer shape factor is between 3 and 12; shape factor OK >>> - prints when the cover layer shape factor is between 3 and 12 so the coefficients used to calculate the strain in the bearing pad can be calculated as per DM-4 C14.7.5.3.6.

Check rotation (Method A Specification Check)

40. Strain in Cover Layer Due to Dead Load - the strain in the cover layers of the bearing pad due to the maximum dead load reaction.
41. Strain in Interior Layer Due to Dead Load - the strain in the interior layers of the bearing pad due to the maximum dead load reaction.
42. Strain in Cover Layer Due to Total Load - the strain in the cover layers of the bearing pad due to the maximum total load reaction.
43. Strain in Interior Layer Due to Total Load - the strain in the interior layers of the bearing pad due to the maximum total load reaction.

Compute thickness required for rotation (Method A Specification Check)

44. Rotation About the Transverse Axis of Bearing Pad - the following table shows the combinations of rotations and skews that need to be satisfied about the transverse axis of this bearing pad.

    Rotation Combination - the combination of rotations checked:

    Construction Tolerance - the construction rotational tolerances entered by the user.

    Construction Tolerance + Live Load - the construction tolerance value plus the rotation due to live load entered by the user.

    End Rotation - the rotation corresponding to the rotation combination.

    Effective Skew - the skew of the bearing pad. Both maximum and minimum skews are checked.

    Cover Strain - strain in the cover layers of the bearing pad due to rotation combination.

    Interior Strain - strain in the interior layers of the bearing pad due to rotation combination.

    Thickness Required - thickness of pad required due to the strain in the bearing pad.

45. Rotation About the Longitudinal Axis of Bearing Pad - the following table shows the combinations of rotations and skews that need to be satisfied about the longitudinal axis of this bearing pad.

    Rotation Combination - the combination of rotations checked:

    Construction Tolerance - the construction rotational tolerances entered by the user.

    Construction Tolerance + Live Load - the construction tolerance value plus the rotation due to live load entered by the user.

    End Rotation - the rotation corresponding to the rotation combination.

    Effective Skew - the skew of the bearing pad. Both maximum and minimum skews are checked.

    Cover Strain - strain in the cover layers of the bearing pad due to rotation combination.

    Interior Strain - strain in the interior layers of the bearing pad due to rotation combination.

    Thickness Required - thickness of pad required due to the strain in the bearing pad.

46. Required minimum elastomer thickness for shear and rotation - minimum thickness needed based on shear deformation and rotation criteria above.
47. Provided elastomer thickness - the provided elastomer thickness of the bearing pad. The comparison of the required and provided elastomer thicknesses considers a tolerance of 0.01 inch.
48. <<< Pad is Too Thin >>> - prints when the pad thickness is less than the required thickness.
49. <<< Pad Does Not Satisfy Method A Anchorage >>> - prints when the pad does not satisfy thickness required for Method A anchorage.

50. <<< Pad is Too Thick >>> - prints when the pad thickness is greater than the maximum allowed.
51. Thickness of interior layer is less than the minimum allowable thickness - prints when the interior pad thickness is less than the minimum allowed.
52. Thickness of cover layer is less than the minimum allowable thickness - prints when the cover pad thickness is less than the minimum allowed.
53. <<< Pad Satisfies Thickness Criteria >>> - prints when the pad satisfies all the above thickness criteria.

Check stability (Method A Specification Check)

54. Stability Factor for Length - stability factor from parameter file set based on pad type.
55. Stability Factor for Width - stability factor from parameter file set based on pad type.
56. Maximum Thickness to Satisfy Longitudinal Stability - pad length divided by length stability factor.
57. Maximum Thickness to Satisfy Transverse Stability - pad width divided by width stability factor.
58. <<< Pad Thickness Exceeds LONGITUDINAL Stability >>> - prints when the pad thickness exceeds longitudinal stability criteria.
59. <<< Pad Thickness Exceeds TRANSVERSE Stability >>> - prints when the pad thickness exceeds transverse stability criteria.
60. <<< Pad Satisfies LONGITUDINAL Stability Criteria >>> - prints when the pad thickness satisfies the longitudinal stability criteria.
61. <<< Pad Satisfies TRANSVERSE Stability Criteria >>> - prints when the pad thickness satisfies the transverse stability criteria.

Shear strain due to axial load - AASHTO LRFD 14.7.5.3.3 (Method B Specification Check)

62. Maximum DL Stress - maximum dead load stress.
63. Maximum LL Stress - maximum live load stress.
64. Shape Factor, Internal - shape factor of an internal layer.
65. Shear modulus (G) - user-input shear modulus or minimum shear modulus value for the user input pad hardness.
66. Gamma(a,st) - maximum static shear strain caused by axial load
67. Gamma(a,st+1.75cy) - maximum total shear strain caused by static + 1.75 * cyclic axial load

Shear strain due to rotation - AASHTO LRFD 14.7.5.3.3 (Method B Specification Check)

68. LL Rotation about transverse axis - live load rotation about the pad transverse axis, entered by the user.
69. LL Rotation about longitudinal axis - live load rotation about the pad longitudinal axis, entered by the user.
70. DL + Toler about transverse axis - construction tolerance and dead load rotation about the pad transverse axis, entered by the user.
71. DL + Toler about longitudinal axis - construction tolerance and dead load rotation about the pad transverse axis, entered by the user.
72. Gamma(r,st+1.75cy, abt transv axis) - maximum total shear strain caused by static + 1.75 cyclic rotation, about the transverse axis of the pad

73. Gamma(r,st+1.75cy, abt long axis) - maximum total shear strain caused by static + 1.75 cyclic rotation, about the longitudinal axis of the pad
74. <<< Shear strain caused by static axial load, x.xxxx, <= 3.0 (AASHTO LRFD 14.7.5.3.3-2) - OK >>> - shear strain due to the static axial load is less than the limit of 3.0.
75. <<< Shear strain caused by static axial load, x.xxxx, <= 3.0 (AASHTO LRFD 14.7.5.3.3-2) - NG >>> - shear strain due to the static axial load exceeds the limit of 3.0.
76. <<< Combined shear strain, x.xxxx, <= 5.0 (AASHTO LRFD 14.7.5.3.3-1) - OK>>> - total combined shear strain is less than the limit of 5.0.
77. <<< Combined shear strain, x.xxxx, <= 5.0 (AASHTO LRFD 14.7.5.3.3-1) - NG>>> - total combined shear strain exceeds the limit of 5.0.

Stability of Elastomeric Bearings - AASHTO LRFD 14.7.5.3.4 (Method B Specification Check)

78. Shape Factor; Internal - shape factor of an internal layer.
79. Shear modulus (G) - user-input shear modulus or minimum shear modulus value for the user input pad hardness.
80. A (AASHTO LRFD 14.7.5.3.4-2) - variable, A, calculated as per AASHTO LRFD.
81. B (AASHTO LRFD 14.7.5.3.4-3) - variable, B, calculated as per AASHTO LRFD.
82. Bridge deck is assumed to be free to translate horizontally - statement of assumption made by BPLRFD
83. (GL * Sint)/(2.0*A - B) - specification check value calculated by the program.
84. <<< Bearing pad satisfies AASHTO LRFD 14.7.5.3.4-1, so stability is OK >>> - if 2.0*A < B, the bearing pad passes the stability check.
85. SigmaS - maximum sum of dead and live load stresses.
86. <<< Bearing pad satisfies AASHTO LRFD 14.7.5.3.4-4, so stability is OK >>> - total stress is less than or equal to the specification check values.
87. <<< Bearing pad FAILS AASHTO LRFD 14.7.5.3.4-4, so stability is NG >>>- total stress is greater than the specification check values.

Required Shim Thickness - AASHTO LRFD 14.7.5.3.5 (Method B Specification Check)

88. Shim yield strength - default yield strength for reinforcing shims
89. Const Ampl Ftg Thresh (A) - constant amplitude fatigue threshold for Category A
90. Minimum shim thickness - minimum allowed shim thickness
91. Combination - load combination being checked.
92. Stress - total stress used for the shim thickness calculation.
93. Required Shim Thickness - calculated shim thickness for the current load combination
94. <<< Shim thickness greater than or equal to minimum required - OK >>> - user input or designed shim thickness is greater than or equal to the required thickness
95. <<< Shim thickness greater than or equal to minimum required - NG >>> - user input or designed shim thickness is less than the required thickness.

Check total pad thickness against input or default minimum thickness (Method B Specification Check)

96. Calculated total pad thickness - calculated pad thickness.
97. Input/Default minimum pad thickness - minimum allowed pad thickness.

98. <<< Pad satisfies input MINIMUM THICKNESS criteria >>> - pad thickness is greater than or equal to the minimum required thickness.
99. <<< Pad thickness less than input MINIMUM THICKNESS >>> - pad thickness is less than the minimum required thickness.

Compute compressive deflection (Method A and Method B Specification Check)

100. Dead Load Deflection (include creep) - compressive dead load deflection of bearing pad, including deflection due to creep.
101. Live Load Deflection (exclude creep) - compressive live load deflection of bearing pad, excluding deflection due to creep.
102. Total Load Deflection (include creep) - compressive total load deflection of bearing pad, including deflection due to creep from dead load only.

7.4.9 Design of Expansion Circular Pad - Plain

This table presents the properties of a plain circular bearing pad designed for the expansion end of the bridge. The following information is reported in the DESIGN OF EXPANSION CIRCULAR PAD - PLAIN output table.

1. Acceptable Pad Size: - message denoting that the design found by the program passes all specification checks.
2. EXPANSION END: - end of the girder for which the program designed the reported bearing pad.
3. Use two pads, each pad should be: - denotes that the program has determined that two bearing pads are required for this end of the bridge.
4. Pad Diameter - diameter of the bearing pad.
5. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
6. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
7. Total Elastomer Thickness - total thickness of the bearing pad.
8. Provide a hole in the pad for dowel, hole diameter - if the program determines that a dowel rod is necessary for the bearing, provide a hole this size to accept the dowel.

7.4.10 Design of Expansion Circular Pad - Laminated

This table presents the properties of a laminated circular bearing pad designed for the expansion end of the bridge. The following information is reported in the DESIGN OF EXPANSION CIRCULAR PAD - LAMINATED output table.

1. Acceptable Pad Size: - message denoting that the design found by the program passes all specification checks.
2. EXPANSION END: - end of the girder for which the program designed the reported bearing pad.
3. Use two pads, each pad should be: - denotes that the program has determined that two bearing pads are required for this end of the bridge.
4. Pad Diameter - diameter of the bearing pad.
5. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
6. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
7. Total Elastomer Thickness - total thickness of all elastomer layers.
8. Number of Elastomer Layers - number of elastomer layers needed.
9. Thickness of Interior Elastomer Layers - required thickness of each interior layer.
10. Thickness of Cover Elastomer Layers - required thickness for each cover layer.
11. Thickness of Shim Plates - required thickness of each shim plate.
12. Total Bearing Pad Thickness - includes total thickness of all elastomer layers and all shim plates.
13. Provide a hole in the pad for dowel, hole diameter - if the program determines that a dowel rod is necessary for the bearing, provide a hole this size to accept the dowel.

7.4.11 Analysis of Expansion Circular Pad - Plain

This table presents the specification checks for a plain circular bearing pad at the expansion end of the bridge. The following information is reported in the ANALYSIS OF EXPANSION CIRCULAR PAD - PLAIN output table.

1. Pad Diameter - diameter of the bearing pad.
2. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
3. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
4. Total Pad Elastomer Thickness - total thickness of all elastomer layers.
5. Total Bearing Pad Thickness - total bearing pad thickness.
6. Number of Pads Per End - the total number of pads required at the end of the bridge.
7. Maximum Permissible Diameter of Pad - maximum diameter of the pad that can be used, given the geometrical layout of the bearing pad and beam size.
8. Minimum Exterior Edge Distance - minimum distance from the edge of the bearing pad to the edge of the beam.
9. Maximum Exterior Edge Distance - maximum distance from the edge of the bearing pad to the edge of the beam.
10. Minimum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the minimum distance from the edge of the pad to the edge of the elastomeric sponge washer.
11. Maximum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the maximum distance from the edge of the pad to the edge of the elastomeric sponge washer.
12. Width of Elastomeric Sponge Washer - for situations that require two bearing pads at the end of a beam, this is the width of the elastomeric sponge washer.
13. <<< Pad Diameter Exceeds Maximum Permissible Diameter >>> - prints when bearing pad diameter exceeds maximum permissible diameter.
14. <<< Pad Size Satisfies Geometry Constraints >>> - prints when bearing pad satisfies all geometrical constraints.
15. Pad Area - cross sectional area of the bearing pad.
16. Stress Due to Maximum Dead Load - stresses due to maximum dead load reaction.
17. Stress Due to Minimum Dead Load - stresses due to minimum dead load reaction.
18. Stress Due to Live Load - stresses due to maximum live load reaction.
19. Stress Due to Total Load - total stresses due to maximum dead load and maximum live load reactions acting on bearing pad.
20. ERROR - Computing Compressive Stress... - prints when the program encounters an error when computing the compressive stress in the pad. Review input data for errors.
21. Shape Factor for Plain Pad - computed shape factor for plain bearing pad.

22. Allowable Stress - allowable compressive stress on bearing pad.
23. ERROR - Computing Allowable Compressive Stress... - prints when the program encounters an error when computing the compressive stress capacity of the pad. Review input data for errors.
24. <<< Stress Exceeds Allowable Stress >>> - prints when bearing pad fails the compressive stress checks.
25. <<< Pad Satisfies Stress Criteria >>> - prints when bearing pad satisfies all compressive stress criteria.
26. <<< Shape factor less than 3, strain cannot be calculated >>> - prints when the plain pad shape factor is less than three, which means that the coefficients used to calculate the strain in the bearing pad cannot be calculated (DM-4 C14.7.5.3.6).
27. <<< Shape factor greater than 12; use S=12 to calculate strain >>> - prints when the plain pad shape factor is greater than 12, which means that the coefficients used to calculate the strain in the bearing pad will be conservatively calculated using a value of 12 rather than the actual shape factor (DM-4 C14.7.5.3.6).
28. <<< Shape factor is between 3 and 12; shape factor OK >>> - prints when the plain pad shape factor is between 3 and 12 so the coefficients used to calculate the strain in the bearing pad can be calculated as per DM-4 C14.7.5.3.6.
29. Horizontal Shear Force - computed total horizontal shear force acting on all bearing pads at the expansion end. Computed for both dead load only and dead load plus live load cases.
30. Allowable Horizontal Shear Force for Method A anchorage - computed allowable total horizontal shear to satisfy Method A anchorage requirements of DM-4 Section 14.7.6.4 (also see Section 3.11 of this manual). Only printed when dowel is not used. Computed for both dead load only and dead load plus live load cases.
31. <<< Pad Satisfies Method A Anchorage Requirements >>> - prints when Method A anchorage requirement is satisfied and dowel not used.
32. <<< Pad DOES NOT Satisfies Method A Anchorage Requirements >>> - prints when the horizontal shear force exceeds the allowable and a dowel not used.
33. <<< Method A anchorage (DM-4 14.7.6.4P) not checked because a hole has been provided for a dowel >>> - prints when a hole is present, indicating that a dowel is being used.
34. Thickness Required for Method A Anchorage - the pad thickness required to accommodate Method A anchorage.
35. <<< Pad Satisfies Method A Anchorage Requirement >>> - prints when the pad satisfies thickness required for Method A anchorage.
36. <<< Pad Does Not Satisfy Method A Anchorage >>> - prints when the pad does not satisfy thickness required for Method A anchorage.
37. <<< Method A anchorage (DM-4 14.7.6.4P) not checked because a hole has been provided for a dowel >>> - prints when a hole is present, indicating that a dowel is being used.
38. Thickness Required for Shear Deformation - the pad thickness required to accommodate all shear deformations.
39. Strain in Pad due to Dead Load - the strain in the pad due to the maximum dead load reaction.

40. Strain in Pad due to Total Load - the strain in the pad due to the maximum total load reaction.
41. Rotation About Bearing Pad - the following table shows the combinations of rotations and skews that need to be satisfied for this bearing pad.

    Rotation Combination - the combination of rotations checked:

        Construction Tolerance - the construction rotational tolerances entered by the user.

        Construction Tolerance + Live Load - the construction tolerance value plus the rotation due to live load entered by the user.

    End Rotation - the rotation corresponding to the rotation combination.

    Effective Skew - the skew of the bearing pad. Both maximum and minimum skews are checked.

    Strain - strain in the bearing pad due to rotation combination.

    Thickness Required - thickness of pad required due to the strain in the bearing pad.
42. Required minimum elastomer thickness for shear and rotation - minimum thickness needed based on shear deformation and rotation criteria above.
43. Provided Elastomer Thickness - the provided elastomer thickness of the bearing pad. The comparison of the required and provided elastomer thickness considers a tolerance of 0.01 inch.
44. <<< Pad is Too Thin >>> - prints when the pad thickness is less than the required thickness.
45. <<< Pad is Too Thick >>> - prints when the pad thickness is greater than maximum allowed.
46. Thickness is less than the minimum allowable thickness - prints when the pad thickness is less than the minimum allowed.
47. <<< Pad Satisfies Thickness Criteria >>> - prints when the pad satisfies all the above thickness criteria.
48. Stability Factor for Diameter - stability factor from parameter file based on pad type.
49. Maximum Thickness to Satisfy Circular Pad Stability - pad diameter divided by diameter stability factor.
50. <<< Pad Thickness Exceeds Stability Criteria >>> - prints when the pad thickness exceeds stability criteria.
51. <<< Pad Satisfies Stability Criteria >>> - prints when the pad thickness satisfies the stability criteria.
52. Dead Load Deflection (include creep) - compressive dead load deflection of bearing pad, including deflection due to creep.
53. Live Load Deflection (exclude creep) - compressive live load deflection of bearing pad, excluding deflection due to creep.
54. Total Load Deflection (include creep) - compressive total load deflection of bearing pad, including deflection due to creep from dead load only.

7.4.12 Analysis of Expansion Circular Pad - Laminated

This table presents the specification checks for a laminated circular bearing pad at the expansion end of the bridge. The following information is reported in the ANALYSIS OF EXPANSION CIRCULAR PAD - LAMINATED output table.

1. Pad Diameter - total length of the bearing pad.
2. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
3. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
4. Interior Layer Thickness - thickness of each interior layer.
5. Cover Layer Thickness - thickness of each cover layer.
6. Total Number of Elastomer Layers - total number of elastomer layers for the bearing pad.
7. Total Pad Elastomer Thickness - total thickness of all elastomer layers in the bearing pad.
8. Thickness of Shim Plates - thickness of each shim plate.
9. Total Bearing Pad Thickness - total bearing pad thickness.
10. Number of Pads Per End - the total number of pads required at the end of the bridge.

Check geometry constraints

11. Maximum Permissible Diameter of Pad - maximum diameter of the pad that can be used, given the geometrical layout of the bearing pad and beam size.
12. Minimum Exterior Edge Distance - minimum distance from the edge of the bearing pad to the edge of the beam.
13. Maximum Exterior Edge Distance - maximum distance from the edge of the bearing pad to the edge of the beam.
14. Minimum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the minimum distance from the edge of the pad to the edge of the elastomeric sponge washer.
15. Maximum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the maximum distance from the edge of the pad to the edge of the elastomeric sponge washer.
16. Width of Elastomeric Sponge Washer - for situations that require two bearing pads at the end of a beam, this is the width of the elastomeric sponge washer.
17. <<< Pad Diameter Exceeds Maximum Permissible Diameter >>> - prints when bearing pad diameter exceeds maximum permissible diameter.
18. <<< Pad Size Satisfies Geometry Constraints >>> - prints when bearing pad satisfies all geometrical constraints.

Check compressive stresses (Method A Specification Check)

19. Pad Area - cross sectional area of the bearing pad.
20. Stress Due to Maximum Dead Load - stresses due to maximum dead load reaction.
21. Stress Due to Minimum Dead Load - stresses due to minimum dead load reaction.

22. Stress Due to Live Load - stresses due to maximum live load reaction.
23. Stress Due to Total Load - total stresses due to maximum dead load and maximum live load reactions acting on bearing pad.
24. ERROR - Computing Compressive Stress... - prints when the program encounters an error when computing the compressive stress in the pad. Review input data for errors.
25. Shape Factor for Interior Layer - computed shape factor for interior layer of bearing pad.
26. Shape Factor for Cover Layer - computed shape factor for cover layer of bearing pad.
27. Allowable Stress - allowable compressive stress on bearing pad.
28. ERROR - Computing Allowable Compressive Stress... - prints when the program encounters an error when computing the compressive stress capacity of the pad. Review input data for errors.
29. <<< Stress Exceeds Allowable Stress >>> - prints when bearing pad fails the compressive stress checks.
30. <<< Pad Satisfies Stress Criteria >>> - prints when bearing pad satisfies all compressive stress criteria.
31. <<< Interior layer shape factor less than 3, strain cannot be calculated >>> - prints when the interior layer shape factor is less than three, which means that the coefficients used to calculate the strain in the bearing pad cannot be calculated (DM-4 C14.7.5.3.6).
32. <<< Interior layer shape factor greater than 12; use S=12 to calculate strain >>> - prints when the interior layer shape factor is greater than 12, which means that the coefficients used to calculate the strain in the bearing pad will be conservatively calculated using a value of 12 rather than the actual shape factor (DM-4 C14.7.5.3.6).
33. <<< Interior layer shape factor is between 3 and 12; shape factor OK >>> - prints when the interior layer shape factor is between 3 and 12 so the coefficients used to calculate the strain in the bearing pad can be calculated as per DM-4 C14.7.5.3.6.
34. <<< Cover layer shape factor less than 3, strain cannot be calculated >>> - prints when the cover layer shape factor is less than three, which means that the coefficients used to calculate the strain in the bearing pad cannot be calculated (DM-4 C14.7.5.3.6).
35. <<< Cover layer shape factor greater than 12; use S=12 to calculate strain >>> - prints when the cover layer shape factor is greater than 12, which means that the coefficients used to calculate the strain in the bearing pad will be conservatively calculated using a value of 12 rather than the actual shape factor (DM-4 C14.7.5.3.6).
36. <<< Cover layer shape factor is between 3 and 12; shape factor OK >>> - prints when the cover layer shape factor is between 3 and 12 so the coefficients used to calculate the strain in the bearing pad can be calculated as per DM-4 C14.7.5.3.6.

Compute horizontal shear (Method A Specification Check)

37. Horizontal Shear Force - computed total horizontal shear force acting on all bearing pads at the expansion end. Computed for both dead load only and dead load plus live load cases.
38. Allowable Horizontal Shear Force for Method A anchorage - computed allowable total horizontal shear to satisfy Method A anchorage requirements of DM-4 Section 14.7.6.4 (also see Section 3.11 of this

manual). Only printed when dowel is not used. Computed for both dead load only and dead load plus live load cases.

39. <<< Pad Satisfies Method A Anchorage Requirements >>> - prints when Method A anchorage requirement is satisfied and dowel not used.
40. <<< Pad DOES NOT Satisfies Method A Anchorage Requirements >>> - prints when the horizontal shear force exceeds the allowable and a dowel not used.
41. <<< Method A anchorage (DM-4 14.7.6.4P) not checked because a hole has been provided for a dowel >>> - prints when a hole is present, indicating that a dowel is being used.

Check shim thickness (Method A Specification Check)

42. Minimum Shim Thickness per Service Limit State - the minimum shim thickness based on the service limit state.
43. Minimum Shim Thickness per Fatigue Limit State - the minimum shim thickness based on the fatigue limit state.
44. Minimum Thickness Required by PennDOT - the minimum thickness based on restrictions in DM-4.
45. Shim Thickness - the shim thickness that corresponds to the maximum shim thickness of the three options given above.
46. <<< Shim DOES NOT Satisfy Stress Criteria >>> - prints when the shims do not satisfy the thickness criteria for the service or fatigue limit states.
47. <<< Shim Satisfies Stress Criteria >>> - prints when the shims satisfy the thickness criteria for the service and fatigue limit states
48. <<< Shim DOES NOT satisfy PennDOT minimum thickness criteria >>> - prints when the actual shim thickness is less than the PennDOT minimum.
49. <<< Shim satisfies PennDOT minimum thickness criteria >>> - prints when the actual shim thickness is greater than or equal to the PennDOT minimum.

Check shear deformation and rotation (Method A Specification Check)

50. Thickness Required for Method A Anchorage - the pad thickness required to accommodate Method A anchorage.
51. <<< Pad Satisfies Method A Anchorage Requirement >>> - prints when the pad satisfies thickness required for Method A anchorage.
52. <<< Pad Does Not Satisfy Method A Anchorage >>> - prints when the pad does not satisfy thickness required for Method A anchorage.
53. <<< Method A anchorage (DM-4 14.7.6.4P) not checked because a hole has been provided for a dowel >>> - prints when a hole is present, indicating that a dowel is being used.
54. Thickness Required for Shear Deformation - the pad thickness required to accommodate all shear deformations.
55. Strain in Cover Layer Due to Dead Load - the strain in the cover layers of the bearing pad due to the maximum dead load reaction.
56. Strain in Interior Layer Due to Dead Load - the strain in the interior layers of the bearing pad due to the maximum dead load reaction.

57. Strain in Cover Layer Due to Total Load - the strain in the cover layers of the bearing pad due to the maximum total load reaction.
58. Strain in Interior Layer Due to Total Load - the strain in the interior layers of the bearing pad due to the maximum total load reaction.

Compute thickness required for rotation (Method A Specification Check)

59. Rotation About Bearing Pad - the following table shows the combinations of rotations and skews that need to be satisfied about this bearing pad.

    Rotation Combination - the combination of rotations checked:

    Construction Tolerance - the construction rotational tolerances entered by the user.

    Construction Tolerance + Live Load - the construction tolerance value plus the rotation due to live load entered by the user.

    End Rotation - the rotation corresponding to the rotation combination.

    Effective Skew - the skew of the bearing pad. Both maximum and minimum skews are checked.

    Cover Strain - strain in the cover layers of the bearing pad due to rotation combination.

    Interior Strain - strain in the interior layers of the bearing pad due to rotation combination.

    Thickness Required - thickness of pad required due to the strain in the bearing pad.

60. Required minimum elastomer thickness for shear and rotation - minimum thickness needed based on shear deformation and rotation criteria above.
61. Provided elastomer thickness - the provided elastomer thickness of the bearing pad. The comparison of the required and provided elastomer thicknesses considers a tolerance of 0.01 inch.
62. <<< Pad is Too Thin >>> - prints when the pad thickness is less than the required thickness.
63. <<< Pad is Too Thick >>> - prints when the pad thickness is greater than maximum allowed.
64. Thickness of interior layer is less than the minimum allowable thickness - prints when the interior pad thickness is less than the minimum allowed.
65. Thickness of cover layer is less than the minimum allowable thickness - prints when the interior pad thickness is less than the minimum allowed.
66. <<< Pad Satisfies Thickness Criteria >>> - prints when the pad satisfies all the above thickness criteria.

Check stability (Method A Specification Check)

67. Stability Factor for Diameter - stability factor from parameter file based on pad type.
68. Maximum Thickness to Satisfy Circular Pad Stability - pad length divided by length stability factor.
69. <<< Pad Thickness Exceeds Stability Criteria >>> - prints when the pad thickness exceeds stability criteria.
70. <<< Pad Satisfies Stability Criteria >>> - prints when the pad thickness satisfies stability criteria.

Shear Deformation - AASHTO LRFD 14.7.5.3.2 (Method B Specification Check)

71. Unfactored thermal movement - unfactored thermal movement calculated using the entire temperature range.
72. Construction Flexibility - horizontal movement entered by the user.
73. DC1 + DC2 + LL rotation movement - horizontal movements due to rotation entered by the user.
74. hrt - total elastomer thickness of the pad.

75. 2.0*deltaS - two times the total factored horizontal movement.
76. <<< Bearing pad PASSES Method B Shear Deformation check - OK >>> - prints when the pad passes the shear deformation check.
77. <<< Bearing pad FAILS Method B Shear Deformation check - NG >>> - prints when the pad fails the shear deformation check.

Shear strain due to axial load - AASHTO LRFD 14.7.5.3.3 (Method B Specification Check)

78. Maximum DL Stress - maximum dead load stress.
79. Maximum LL Stress - maximum live load stress.
80. Shape Factor, Internal - shape factor of an internal layer.
81. Shear modulus (G) - user-input shear modulus or minimum shear modulus value for the user input pad hardness.
82. Gamma(a,st) - maximum static shear strain caused by axial load
83. Gamma(a,st+1.75cy) - maximum total shear strain caused by static + 1.75 * cyclic axial load

Shear strain due to rotation - AASHTO LRFD 14.7.5.3.3 (Method B Specification Check)

84. LL Rotation about transverse axis - live load rotation about the pad transverse axis, entered by the user.
85. LL Rotation about longitudinal axis - live load rotation about the pad longitudinal axis, entered by the user.
86. DL + Toler about transverse axis - construction tolerance and dead load rotation about the pad transverse axis, entered by the user.
87. DL + Toler about longitudinal axis - construction tolerance and dead load rotation about the pad transverse axis, entered by the user.
88. Gamma(r,st+1.75cy, resolved) - maximum total shear strain caused by static + 1.75 cyclic rotation, about the transverse and longitudinal axes of the pad, resolved to a single rotation.

Shear strain due to shear deformation - AASHTO LRFD 14.7.5.3.3 (Method B Specification Check)

89. Unfactored thermal movement - unfactored thermal movement calculated using the entire temperature range.
90. Construction Flexibility - horizontal movement entered by the user.
91. DC1+DC2+1.75*LL mvmt due rot - total horizontal movement due to DC1 + DC2 + 1.75*LL rotational movements.
92. <<< Shear strain caused by static axial load, x.xxxx, <= 3.0 (AASHTO LRFD 14.7.5.3.3-2) - OK >>> - shear strain due to the static axial load is less than the limit of 3.0.
93. <<< Shear strain caused by static axial load, x.xxxx, <= 3.0 (AASHTO LRFD 14.7.5.3.3-2) - NG >>> - shear strain due to the static axial load exceeds the limit of 3.0.
94. <<< Combined shear strain, x.xxxx, <= 5.0 (AASHTO LRFD 14.7.5.3.3-1) - OK>>> - total combined shear strain is less than the limit of 5.0.
95. <<< Combined shear strain, x.xxxx, <= 5.0 (AASHTO LRFD 14.7.5.3.3-1) - NG>>> - total combined shear strain exceeds the limit of 5.0.

Stability of Elastomeric Bearings - AASHTO LRFD 14.7.5.3.4 (Method B Specification Check)

96. Shape Factor; Internal - shape factor of an internal layer.
97. Shear modulus (G) - user-input shear modulus or minimum shear modulus value for the user input pad hardness.
98. A (AASHTO LRFD 14.7.5.3.4-2) - variable, A, calculated as per AASHTO LRFD.
99. B (AASHTO LRFD 14.7.5.3.4-3) - variable, B, calculated as per AASHTO LRFD.
100. Bridge deck is assumed to be free to translate horizontally - statement of assumption made by BPLRFD.
101. (GL * Sint)/(2.0*A - B) - specification check value calculated by the program.
102. <<< Bearing pad satisfies AASHTO LRFD 14.7.5.3.4-1, so stability is OK >>> - if 2.0*A < B, the bearing pad passes the stability check.
103. SigmaS - maximum sum of dead and live load stresses.
104. <<< Bearing pad satisfies AASHTO LRFD 14.7.5.3.4-4, so stability is OK >>> - total stress is less than or equal to the specification check values.
105. <<< Bearing pad FAILS AASHTO LRFD 14.7.5.3.4-4, so stability is NG >>>- total stress is greater than the specification check values.

Required Shim Thickness - AASHTO LRFD 14.7.5.3.5 (Method B Specification Check)

106. Shim yield strength - default yield strength for reinforcing shims
107. Const Ampl Ftg Thresh (A) - constant amplitude fatigue threshold for Category A
108. Minimum shim thickness - minimum allowed shim thickness
109. Combination - load combination being checked.
110. Stress - total stress used for the shim thickness calculation.
111. Required Shim Thickness - calculated shim thickness for the current load combination
112. <<< Shim thickness greater than or equal to minimum required - OK >>> - user input or designed shim thickness is greater than or equal to the required thickness
113. <<< Shim thickness greater than or equal to minimum required - NG >>> - user input or designed shim thickness is less than the required thickness.

Check total pad thickness against input or default minimum thickness (Method B Specification Check)

114. Calculated total pad thickness - calculated pad thickness.
115. Input/Default minimum pad thickness - minimum allowed pad thickness.
116. <<< Pad satisfies input MINIMUM THICKNESS criteria >>> - pad thickness is greater than or equal to the minimum required thickness.
117. <<< Pad thickness less than input MINIMUM THICKNESS >>> - pad thickness is less than the minimum required thickness.

Check Method B anchorage (Method A and Method B Specification Check)

118. Check Anchorage - AASHTO LRFD 14.7.5.4 – following table shows the values used for and the calculation of the Method B anchorage check. Only prints if no hole is present.

    Total Rotation – the total end rotation of the bearing pad

    Total Strain – the total axial strain of the interior layer

No. of Layers – number of layers considered (will include one layer to account for the cover layers if the cover layer is greater than half the thickness of an interior layer)

Shape Factor – shape factor of the interior elastomer layer

Left Term – Left term of the A14.7.5.4-1 Equation

Right Term – Right term of the A14.7.5.4-1 Equation

These values are printed for three conditions: minimum dead load only, maximum dead load + minimum live load, minimum dead load + maximum live load.

119. <<< Pad satisfies Method B Anchorage criteria>>> – prints when the pad thickness meets the Method B Anchorage criteria.

120. <<< Pad DOES NOT satisfy Method B Anchorage criteria>>> – prints when the pad thickness does not meet the Method B Anchorage criteria.

121. <<< Method B anchorage (AASHTO LRFD 14.7.5.4) not checked because a hole has been provided for a dowel >>> - prints when a hole is present, indicating that a dowel is being used.

Compute compressive deflection (Method A and Method B Specification Check)

122. Dead Load Deflection (include creep) - compressive dead load deflection of bearing pad, including deflection due to creep.

123. Live Load Deflection (exclude creep) - compressive live load deflection of bearing pad, excluding deflection due to creep.

124. Total Load Deflection (include creep) - compressive total load deflection of bearing pad, including deflection due to creep from dead load only.

7.4.13 Design of Fixed Circular Pad - Plain

This table presents the properties of a plain circular bearing pad at the fixed end of the bridge. The following information is reported in the DESIGN OF FIXED CIRCULAR PAD - PLAIN output table.

1. Acceptable Pad Size: - message denoting that the design found by the program passes all specification checks.
2. FIXED END: - end of the girder for which the program designed the reported bearing pad.
3. Use two pads, each pad should be: - denotes that the program has determined that two bearing pads are required for this end of the bridge.
4. Pad Diameter - diameter of the bearing pad.
5. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
6. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
7. Total Elastomer Thickness - total thickness of all elastomer layers.
8. Provide a hole in the pad for dowel, hole diameter - if the program determines that a dowel rod is necessary for the bearing, provide a hole this size to accept the dowel.

7.4.14 Design of Fixed Circular Pad - Laminated

This table presents the properties of a laminated circular bearing pad designed for the fixed end of the bridge. The following information is reported in the DESIGN OF FIXED CIRCULAR PAD - LAMINATED output table.

1. Acceptable Pad Size: - message denoting that the design found by the program passes all specification checks.
2. FIXED END: - end of the girder for which the program designed the reported bearing pad.
3. Use two pads, each pad should be: - denotes that the program has determined that two bearing pads are required for this end of the bridge.
4. Pad Diameter - diameter of the bearing pad.
5. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
6. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
7. Total Elastomer Thickness - total thickness of all elastomer layers.
8. Number of Elastomer Layers - number of elastomer layers needed.
9. Thickness of Interior Elastomer Layers - required thickness of each interior layer.
10. Thickness of Cover Elastomer Layers - required thickness of each cover layer.
11. Thickness of Shim Plates - required thickness of each shim plate.
12. Total Bearing Pad Thickness - includes total thickness of all elastomer layers and all shim plates.
13. Provide a hole in the pad for dowel, hole diameter - if the program determines that a dowel rod is necessary for the bearing, provide a hole this size to accept the dowel.

7.4.15 Analysis of Fixed Circular Pad - Plain

This table presents the specification checks for a plain circular bearing pad at the fixed end of the bridge. The following information is reported in the ANALYSIS OF FIXED CIRCULAR PAD - PLAIN output table.

1. Pad Diameter - diameter of the bearing pad.
2. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
3. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
4. Total Pad Elastomer Thickness - total thickness of all elastomer layers.
5. Total Bearing Pad Thickness - total bearing pad thickness.
6. Number of Pads Per End - the total number of pads required at the end of the bridge.

Check geometry constraints

7. Maximum Permissible Diameter of Pad - maximum length of the pad that can be used, given the geometrical layout of the bearing pad and beam size.
8. Minimum Exterior Edge Distance - minimum distance from the edge of the bearing pad to the edge of the beam.
9. Maximum Exterior Edge Distance - maximum distance from the edge of the bearing pad to the edge of the beam.
10. Minimum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the minimum distance from the edge of the pad to the edge of the elastomeric sponge washer.
11. Maximum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the maximum distance from the edge of the pad to the edge of the elastomeric sponge washer.
12. Width of Elastomeric Sponge Washer - for situations that require two bearing pads at the end of a beam, this is the width of the elastomeric sponge washer.
13. <<< Pad Diameter Exceeds Maximum Permissible Diameter >>> - prints when bearing pad diameter exceeds maximum permissible diameter.
14. <<< Pad Size Satisfies Geometry Constraints >>> - prints when bearing pad satisfies all geometrical constraints.

Check compressive stresses

15. Pad Area - cross sectional area of the bearing pad.
16. Stress Due to Maximum Dead Load - stresses due to maximum dead load reaction.
17. Stress Due to Minimum Dead Load - stresses due to minimum dead load reaction.
18. Stress Due to Live Load - stresses due to maximum live load reaction.
19. Stress Due to Total Load - total stresses due to maximum dead load and maximum live load reactions acting on bearing pad.
20. ERROR - Computing Compressive Stress... - prints when the program encounters an error when computing the compressive stress in the pad. Review input data for errors.

21. Shape Factor for Plain Pad - computed shape factor for plain bearing pad.
22. Allowable Stress - allowable compressive stress on bearing pad.
23. ERROR - Computing Allowable Compressive Stress... - prints when the program encounters an error when computing the compressive stress capacity of the pad. Review input data for errors.
24. <<< Stress Exceeds Allowable Stress >>> - prints when bearing pad fails the compressive stress checks.
25. <<< Pad Satisfies Stress Criteria >>> - prints when bearing pad satisfies all compressive stress criteria.
26. <<< Shape factor less than 3, strain cannot be calculated >>> - prints when the plain pad shape factor is less than three, which means that the coefficients used to calculate the strain in the bearing pad cannot be calculated (DM-4 C14.7.5.3.6).
27. <<< Shape factor greater than 12; use S=12 to calculate strain >>> - prints when the plain pad shape factor is greater than 12, which means that the coefficients used to calculate the strain in the bearing pad will be conservatively calculated using a value of 12 rather than the actual shape factor (DM-4 C14.7.5.3.6).
28. <<< Shape factor is between 3 and 12; shape factor OK >>> - prints when the plain pad shape factor is between 3 and 12 so the coefficients used to calculate the strain in the bearing pad can be calculated as per DM-4 C14.7.5.3.6.

Check rotation

29. Strain in Pad due to Dead Load - the strain in the pad due to the maximum dead load reaction.
30. Strain in Pad due to Total Load - the strain in the pad due to the maximum total load reaction.

Compute thickness required for rotation

31. Rotation About Bearing Pad - the following table shows the combinations of rotations and skews that need to be satisfied for this bearing pad.

    Rotation Combination - the combination of rotations checked:

    Construction Tolerance - the construction rotational tolerances entered by the user.

    Construction Tolerance + Live Load - the construction tolerance value plus the rotation due to live load entered by the user.

    End Rotation - the rotation corresponding to the rotation combination.

    Effective Skew - the skew of the bearing pad. Both maximum and minimum skews are checked.

    Strain - strain in the bearing pad due to rotation combination.

    Thickness Required - thickness of pad required due to the strain in the bearing pad.

32. Required minimum elastomer thickness for shear and rotation - minimum thickness needed based on shear deformation and rotation criteria above.
33. Provided elastomer thickness - the provided elastomer thickness of the bearing pad. The comparison of the required and provided elastomer thicknesses considers a tolerance of 0.01 inch.
34. <<< Pad is Too Thin >>> - prints when the pad thickness is less than the required thickness.
35. <<< Pad Does Not Satisfy Method A Anchorage >>> - prints when the pad does not satisfy thickness required for Method A anchorage.
36. <<< Pad is Too Thick >>> - prints when the pad thickness is greater than maximum allowed.

37. Thickness is less than the minimum allowable thickness - prints when the pad thickness is less than the minimum allowed.
38. <<< Pad Satisfies Thickness Criteria >>> - prints when the pad satisfies all the above thickness criteria.

Check stability

39. Stability Factor for Diameter - stability factor from parameter file set based on pad type.
40. Maximum Thickness to Satisfy Circular Pad Stability - pad length divided by length stability factor.
41. <<< Pad Thickness Exceeds Stability Criteria >>> - prints if the pad thickness exceeds stability criteria.
42. <<< Pad Satisfies Stability Criteria >>> - prints when the pad thickness satisfies the longitudinal stability criteria.

Compute compressive deflection

43. Dead Load Deflection (include creep) - compressive dead load deflection of bearing pad, including deflection due to creep.
44. Live Load Deflection (exclude creep) - compressive live load deflection of bearing pad, excluding deflection due to creep.
45. Total Load Deflection (include creep) - compressive total load deflection of bearing pad, including deflection due to creep from dead load only.

7.4.16 Analysis of Fixed Circular Pad - Laminated

This table presents the specification checks for a laminated circular bearing pad at the fixed end of the bridge. The following information is reported in the ANALYSIS OF FIXED CIRCULAR PAD - LAMINATED output table.

1. Pad Diameter - total length of the bearing pad.
2. Pad Spacing - if two pads are needed, this value will print showing the required clear spacing between the pads.
3. Pad Location – if two pads are needed, the perpendicular distance from the edge of the beam to the centroid of the pad is printed.
4. Interior Layer Thickness - thickness of each interior layer.
5. Cover Layer Thickness - thickness of each cover layer.
6. Total Number of Elastomer Layers - total number of elastomer layers for the bearing pad.
7. Total Pad Elastomer Thickness - total thickness of all elastomer layers in the bearing pad.
8. Thickness of Shim Plates - thickness of each shim plate.
9. Total Bearing Pad Thickness - total bearing pad thickness.
10. Number of Pads Per End - the total number of pads required at the end of the bridge.

Check geometry constraints

11. Maximum Permissible Diameter of Pad - maximum diameter of pad that can be used, given the geometrical layout of the bearing pad and beam size.
12. Minimum Exterior Edge Distance - minimum distance from the edge of the bearing pad to the edge of the beam.
13. Maximum Exterior Edge Distance - maximum distance from the edge of the bearing pad to the edge of the beam.
14. Minimum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the minimum distance from the edge of the pad to the edge of the elastomeric sponge washer.
15. Maximum Interior Edge Distance - for situations that require two bearing pads at the end of a beam, this is the maximum distance from the edge of the pad to the edge of the elastomeric sponge washer.
16. Width of Elastomeric Sponge Washer - for situations that require two bearing pads at the end of a beam, this is the width of the elastomeric sponge washer.
17. <<< Pad Diameter Exceeds Maximum Permissible Diameter >>> - prints when bearing pad diameter exceeds maximum permissible diameter.
18. <<< Pad Size Satisfies Geometry Constraints >>> - prints when bearing pad satisfies all geometrical constraints.

Check compressive stresses (Method A Specification Check)

19. Pad Area - cross sectional area of the bearing pad.
20. Stress Due to Maximum Dead Load - stresses due to maximum dead load reaction.
21. Stress Due to Minimum Dead Load - stresses due to minimum dead load reaction.

22. Stress Due to Live Load - stresses due to maximum live load reaction.
23. Stress Due to Total Load - total stresses due to maximum dead load and maximum live load reactions acting on bearing pad.
24. ERROR - Computing Compressive Stress... - prints when the program encounters an error when computing the compressive stress in the pad. Review input data for errors.
25. Shape Factor for Interior Layer - computed shape factor for interior layer of bearing pad.
26. Shape Factor for Cover Layer - computed shape factor for cover layer of bearing pad.
27. Allowable Stress - allowable compressive stress on bearing pad.
28. ERROR - Computing Allowable Compressive Stress... - prints when the program encounters an error when computing the compressive stress capacity of the pad. Review input data for errors.
29. <<< Stress Exceeds Allowable Stress >>> - prints when bearing pad fails the compressive stress checks.
30. <<< Interior layer shape factor less than 3, strain cannot be calculated >>> - prints when the interior layer shape factor is less than three, which means that the coefficients used to calculate the strain in the bearing pad cannot be calculated (DM-4 C14.7.5.3.6).
31. <<< Interior layer shape factor greater than 12; use S=12 to calculate strain >>> - prints when the interior layer shape factor is greater than 12, which means that the coefficients used to calculate the strain in the bearing pad will be conservatively calculated using a value of 12 rather than the actual shape factor (DM-4 C14.7.5.3.6).
32. <<< Interior layer shape factor is between 3 and 12; shape factor OK >>> - prints when the interior layer shape factor is between 3 and 12 so the coefficients used to calculate the strain in the bearing pad can be calculated as per DM-4 C14.7.5.3.6.
33. <<< Cover layer shape factor less than 3, strain cannot be calculated >>> - prints when the cover layer shape factor is less than three, which means that the coefficients used to calculate the strain in the bearing pad cannot be calculated (DM-4 C14.7.5.3.6).
34. <<< Cover layer shape factor greater than 12; use S=12 to calculate strain >>> - prints when the cover layer shape factor is greater than 12, which means that the coefficients used to calculate the strain in the bearing pad will be conservatively calculated using a value of 12 rather than the actual shape factor (DM-4 C14.7.5.3.6).
35. <<< Cover layer shape factor is between 3 and 12; shape factor OK >>> - prints when the cover layer shape factor is between 3 and 12 so the coefficients used to calculate the strain in the bearing pad can be calculated as per DM-4 C14.7.5.3.6.
36. <<< Pad Satisfies Stress Criteria >>> - prints when bearing pad satisfies all compressive stress criteria.

Check rotation (Method A Specification Check)

37. Strain in Cover Layer Due to Dead Load - the strain in the cover layers of the bearing pad due to the maximum dead load reaction.
38. Strain in Interior Layer Due to Dead Load - the strain in the interior layers of the bearing pad due to the maximum dead load reaction.

39. Strain in Cover Layer Due to Total Load - the strain in the cover layers of the bearing pad due to the maximum total load reaction.
40. Strain in Interior Layer Due to Total Load - the strain in the interior layers of the bearing pad due to the maximum total load reaction.

Compute thickness required for rotation (Method A Specification Check)

41. Rotation About Bearing Pad - the following table shows the combinations of rotations and skews that need to be satisfied for this bearing pad.

    Rotation Combination - the combination of rotations checked:

    Construction Tolerance - the construction rotational tolerances entered by the user.

    Construction Tolerance + Live Load - the construction tolerance value plus the rotation due to live load entered by the user.

    End Rotation - the rotation corresponding to the rotation combination.

    Effective Skew - the skew of the bearing pad. Both maximum and minimum skews are checked.

    Cover Strain - strain in the cover layers of the bearing pad due to rotation combination.

    Interior Strain - strain in the interior layers of the bearing pad due to rotation combination.

    Thickness Required - thickness of pad required due to the strain in the bearing pad.

42. Required minimum elastomer thickness for shear and rotation - minimum thickness needed based on shear deformation and rotation criteria above.
43. Provided elastomer thickness - the provided elastomer thickness of the bearing pad. The comparison of the required and provided elastomer thicknesses considers a tolerance of 0.01 inch.
44. <<< Pad is Too Thin >>> - prints when the pad thickness is less than the required thickness.
45. <<< Pad Does Not Satisfy Method A Anchorage >>> - prints when the pad does not satisfy thickness required for Method A anchorage.
46. <<< Pad is Too Thick >>> - prints when the pad thickness is greater than maximum allowed.
47. Thickness of interior layer is less than the minimum allowable thickness - prints when the interior pad thickness is less than the minimum allowed.
48. Thickness of cover layer is less than the minimum allowable thickness - prints when the interior pad thickness is less than the minimum allowed.
49. <<< Pad Satisfies Thickness Criteria >>> - prints when the pad satisfies all the above thickness criteria.

Check stability (Method A Specification Check)

50. Stability Factor for Diameter - stability factor from parameter file based on pad type.
51. Maximum Thickness to Satisfy Circular Pad Stability - pad width divided by width stability factor.
52. <<< Pad Thickness Exceeds Stability Criteria >>> - prints if the pad thickness exceeds stability criteria.
53. <<< Pad Satisfies Stability Criteria >>> - prints when the pad thickness satisfies the longitudinal stability criteria.

Shear strain due to axial load - AASHTO LRFD 14.7.5.3.3 (Method B Specification Check)

54. Maximum DL Stress - maximum dead load stress.
55. Maximum LL Stress - maximum live load stress.
56. Shape Factor, Internal - shape factor of an internal layer.

57. Shear modulus (G)- user-input shear modulus or minimum shear modulus value for the user input pad hardness.
58. Gamma(a,st) - maximum static shear strain caused by axial load
59. Gamma(a,st+1.75cy) - maximum total shear strain caused by static + 1.75 * cyclic axial load

Shear strain due to rotation - AASHTO LRFD 14.7.5.3.3 (Method B Specification Check)

60. LL Rotation about transverse axis - live load rotation about the pad transverse axis, entered by the user.
61. LL Rotation about longitudinal axis - live load rotation about the pad longitudinal axis, entered by the user.
62. DL + Toler about transverse axis - construction tolerance and dead load rotation about the pad transverse axis, entered by the user.
63. DL + Toler about longitudinal axis - construction tolerance and dead load rotation about the pad transverse axis, entered by the user.
64. Gamma(r,st+1.75cy, resolved) - maximum total shear strain caused by static + 1.75 cyclic rotation, about the transverse and longitudinal axes of the pad, resolved to a single rotation.
65. <<< Shear strain caused by static axial load, x.xxxx, <= 3.0 (AASHTO LRFD 14.7.5.3.3-2) - OK >>> - shear strain due to the static axial load is less than the limit of 3.0.
66. <<< Shear strain caused by static axial load, x.xxxx, <= 3.0 (AASHTO LRFD 14.7.5.3.3-2) - NG >>> - shear strain due to the static axial load exceeds the limit of 3.0.
67. <<< Combined shear strain, x.xxxx, <= 5.0 (AASHTO LRFD 14.7.5.3.3-1) - OK>>> - total combined shear strain is less than the limit of 5.0.
68. <<< Combined shear strain, x.xxxx, <= 5.0 (AASHTO LRFD 14.7.5.3.3-1) - NG>>> - total combined shear strain exceeds the limit of 5.0.

Stability of Elastomeric Bearings - AASHTO LRFD 14.7.5.3.4 (Method B Specification Check)

69. Shape Factor; Internal - shape factor of an internal layer.
70. Shear modulus (G) - user-input shear modulus or minimum shear modulus value for the user input pad hardness.
71. A (AASHTO LRFD 14.7.5.3.4-2) - variable, A, calculated as per AASHTO LRFD.
72. B (AASHTO LRFD 14.7.5.3.4-3) - variable, B, calculated as per AASHTO LRFD.
73. Bridge deck is assumed to be free to translate horizontally - statement of assumption made by BPLRFD
74. (GL * Sint)/(2.0*A - B) - specification check value calculated by the program.
75. <<< Bearing pad satisfies AASHTO LRFD 14.7.5.3.4-1, so stability is OK >>> - if 2.0*A < B, the bearing pad passes the stability check.
76. SigmaS - maximum sum of dead and live load stresses.
77. <<< Bearing pad satisfies AASHTO LRFD 14.7.5.3.4-4, so stability is OK >>> - total stress is less than or equal to the specification check values.
78. <<< Bearing pad FAILS AASHTO LRFD 14.7.5.3.4-4, so stability is NG >>>- total stress is greater than the specification check values.

Required Shim Thickness - AASHTO LRFD 14.7.5.3.5 (Method B Specification Check)

79. Shim yield strength - default yield strength for reinforcing shims
80. Const Ampl Ftg Thresh (A) - constant amplitude fatigue threshold for Category A
81. Minimum shim thickness - minimum allowed shim thickness
82. Combination - load combination being checked.
83. Stress - total stress used for the shim thickness calculation.
84. Required Shim Thickness - calculated shim thickness for the current load combination
85. <<< Shim thickness greater than or equal to minimum required - OK >>> - user input or designed shim thickness is greater than or equal to the required thickness
86. <<< Shim thickness greater than or equal to minimum required - NG >>> - user input or designed shim thickness is less than the required thickness.

Check total pad thickness against input or default minimum thickness (Method B Specification Check)

87. Calculated total pad thickness - calculated pad thickness.
88. Input/Default minimum pad thickness - minimum allowed pad thickness.
89. <<< Pad satisfies input MINIMUM THICKNESS criteria >>> - pad thickness is greater than or equal to the minimum required thickness.
90. <<< Pad thickness less than input MINIMUM THICKNESS >>> - pad thickness is less than the minimum required thickness.

Compute compressive deflection (Method A and Method B Specification Check)

91. Dead Load Deflection (include creep) - compressive dead load deflection of bearing pad, including deflection due to creep.
92. Live Load Deflection (exclude creep) - compressive live load deflection of bearing pad, excluding deflection due to creep.
93. Total Load Deflection (include creep) - compressive total load deflection of bearing pad, including deflection due to creep from dead load only.

7.4.17 Bearing Pad Design Data

These tables present a summary of the input data that was used to design the bearing pads.

Reactions

1. Reactions, DL - maximum dead load reaction.
2. Reactions, LL - maximum live load reaction.
3. Reactions, Total - combination of maximum dead load and maximum live load reactions.

Shear Deformation for Bearing Design

1. Shear Deformations, Thermal - the shear deformations due to thermal effects. This value only prints when an expansion bearing has been designed.
2. Shear Deformations, Construction Flexibility - the shear deformation to account for construction or pier flexibility (see Section 5.12).
3. Shear Deformations, DL1 Rotation, DL2 Rotation, and LL Rotation Movements – the shear deformations due to horizontal movement induced by dead load and live load rotations.
4. Shear Deformations, Total DL and Total DL + LL - combination of all shear deformations for which the bearing is designed. This value only prints when an expansion bearing has been designed.

Shear Deformation for Substructure Design

1. Shear Deformations, Thermal - the shear deformations due to thermal effects. This value only prints when an expansion bearing has been designed.
2. Shear Deformations, Total DL and Total DL + LL - combination of all shear deformations for which the bearing is designed. This value only prints when an expansion bearing has been designed.

Rotations

1. Rotations, About Transverse Axis of Bearing Pad, LL - live load rotations about the transverse axis of the bearing pad.
2. Rotations, About Transverse Axis of Bearing Pad, Construction Tolerance - construction tolerance rotations about the transverse axis of the bearing pad.
3. Rotations, About Transverse Axis of Bearing Pad, Design - total rotation (construction tolerance plus live load) for which the bearing pad was designed.
4. Rotations, About Longitudinal Axis of Bearing Pad, LL - live load rotations about the longitudinal axis of the bearing pad.
5. Rotations, About Longitudinal Axis of Bearing Pad, Construction Tolerance - construction tolerance rotations about the longitudinal axis of the bearing pad.
6. Rotations, About Longitudinal Axis of Bearing Pad, Design - total rotation (construction tolerance plus live load) for which the bearing pad was designed.

7.4.18 Recommended Pad Size

This table presents a summary of the recommended pad sizes for design.

1. EXPANSION END - printed only for an expansion bearing.
2. FIXED END - printed only for a fixed bearing.
3. Use two pads, each pad should be - prints if two bearing pads should be used for this end of the bridge.
4. Pad Length - recommended length for a rectangular bearing.
5. Pad Width - recommended width for a rectangular bearing.
6. Pad Diameter - recommended diameter for a circular bearing.
7. Pad Spacing - required clear space between bearing pads if two bearing pads are recommended.
8. Pad Location – the perpendicular distance from the edge of the beam to the centroid of the pad printed if two pads are recommended.
9. Total Elastomer Thickness - recommended total thickness of all elastomer layers (or total thickness of bearing if a plain bearing is recommended).
10. Number of Elastomer Layers - number of elastomeric layers recommended. Only prints if a laminated bearing is recommended.
11. Thickness of Interior Elastomer Layers - recommended thickness of each interior elastomer layer. Only prints if a laminated bearing is recommended.
12. Thickness of Cover Elastomer Layers - recommended thickness of each cover elastomer layer. Only prints if a laminated bearing is recommended.
13. Thickness of Shim Plates - recommended thickness of each shim plate. Only prints if a laminated bearing is recommended.
14. Total Bearing Pad Thickness - total thickness of bearing pad including all elastomeric pads and all shim plates. Only prints if a laminated bearing is recommended.
15. Provide a hole in the pad for dowel, hole diameter - if a dowel is recommended, then a hole with this diameter should be provided to receive the dowel.
16. Rotational Stiffness (single Pad) – the rotational stiffness is used to evaluate the lateral stability of a prestressed I-girder seated on bearing pads during construction.
17. Horizontal shear force due to thermal movement for substructure design – the shear force induced by thermal movement shear deformation in the pad, which is applied to the substructure. This is followed by the maximum and minimum shear modulus.
18. Dowel not required, no hole provided – this message prints if the user entered a hole size when one is not required.
19. Bearing pad satisfies all Method A code checks... - this message prints if the design satisfies all Method A code checks.
20. Bearing pad satisfies all Method A code checks, HOWEVER, the pad VIOLATES geometry constraints... - this message prints if the design satisfies all Method A code checks but fails the geometry constraints.

21. Except for Method A anchorage and shim stresses!!! - this message prints if the design satisfies all Method A code checks except Method A anchorage and shim stresses.
22. Except Method A anchorage!!! - this message prints if the design satisfies all Method A code checks except Method A anchorage.
23. Except shim stresses!!! - this message prints if the design satisfies all code Method A checks except shim stresses.
24. Bearing pad satisfies Method B anchorage. –this message prints if the pad satisfies the Method B anchorage check. (Expansion End Pads only)
25. Bearing pad DOES NOT satisfy Method B anchorage. –this message prints if the pad does not pass the Method B anchorage check. (Expansion End Pads only)
26. Bearing pad VIOLATES at least one code check - this message prints along with one of the following to denote a code check failure:

    Bearing pad is overstressed.

    Bearing pad is too thick.

    Bearing pad is too thin.

    Bearing pad is unstable in diameter direction - only prints for circular bearings.

    Bearing pad is unstable in longitudinal direction - only prints for rectangular bearings.

    Bearing pad is unstable in transverse direction - only prints for rectangular bearings.

    Shape factor is less than 3.
27. Unable to complete the analysis due to an error, please check input - prints if an input error was encountered. Check input data and rerun the program.

7.4.19 Bearing Pad Analysis Data

This table presents a summary of the input data that was used to analyze the bearing pads.

1. Reactions, DL - maximum dead load reaction.
2. Reactions, LL - maximum live load reaction.
3. Reactions, Total - combination of maximum dead load and maximum live load reactions.
4. Shear Deformations, Thermal - the shear deformations due to thermal effects. This value only prints when an expansion bearing has been analyzed.
5. Shear Deformations, Construction or Pier Flexibility - the shear deformations due to construction allowances or pier flexibility. This value only prints when an expansion bearing has been analyzed.
6. Shear Deformations, DL1 Rotation, DL2 Rotation, and LL Rotation Movements – the shear deformations due to horizontal movement induced by dead load and live load rotations.
7. Shear Deformations, Total - combination of all shear deformations that the bearing is designed for. This value only prints when an expansion bearing has been analyzed.
8. Rotations, About Transverse Axis of Bearing Pad, LL - live load rotations about the transverse axis of the bearing pad.
9. Rotations, About Transverse Axis of Bearing Pad, Construction Tolerance - construction tolerance rotations about the transverse axis of the bearing pad.
10. Rotations, About Transverse Axis of Bearing Pad, Design - total rotation (construction tolerance plus live load) for which the bearing pad was designed.
11. Rotations, About Longitudinal Axis of Bearing Pad, LL - live load rotations about the longitudinal axis of the bearing pad.
12. Rotations, About Longitudinal Axis of Bearing Pad, Construction Tolerance - construction tolerance rotations about the longitudinal axis of the bearing pad.
13. Rotations, About Longitudinal Axis of Bearing Pad, Design - total rotation (construction tolerance plus live load) for which the bearing pad was designed.

7.4.20 Inputted Pad Size

This table presents a summary of the inputted pad size for analysis.

1. EXPANSION END - printed only for an expansion bearing.
2. FIXED END - printed only for a fixed bearing.
3. Using two pads, each with the following properties - prints if two bearing pads were analyzed for this end of the bridge.
4. Pad Length - inputted length for a rectangular bearing.
5. Pad Width - inputted width for a rectangular bearing.
6. Pad Diameter - inputted diameter for a circular bearing.
7. Pad Spacing - required space between bearing pads if two bearing pads are input.
8. Pad Location – the perpendicular distance from the edge of the beam to the centroid of the pad if two bearing pads are input.
9. Total Elastomer Thickness - inputted total thickness of all elastomer layers (or total thickness of bearing if a plain bearing is input).
10. Number of Elastomer Layers - number of elastomeric layers inputted. Only prints if a laminated bearing is input.
11. Thickness of Interior Elastomer Layers - inputted thickness of each interior elastomer layer. Only prints if a laminated bearing is input.
12. Thickness of Cover Elastomer Layers - inputted thickness of each cover elastomer layer. Only prints if a laminated bearing is input.
13. Thickness of Shim Plates - inputted thickness of each shim plate. Only prints if a laminated bearing is input.
14. Total Bearing Pad Thickness - total thickness of bearing pad including all elastomeric pads and all shim plates. Only prints if a laminated bearing is input.
15. Provide a hole in the pad for dowel, hole diameter - if a dowel is recommended, then a hole with this diameter should be provided to receive the dowel.
16. Rotational Stiffness (single pad) – the rotational stiffness is used to evaluate the lateral stability of a prestressed I-girder seated on bearing pads during construction.
17. Horizontal shear force due to thermal movement for substructure design – the shear force induced by thermal movement shear deformation in the pad, which is applied to the substructure. This is followed by the maximum and minimum shear modulus.
18. Bearing pad satisfies all Method A code checks... - this message prints if the pad satisfies all Method A code checks.
19. Bearing pad satisfies all Method A code checks, HOWEVER, the pad VIOLATES geometry constraints... - this message prints if the pad satisfies all Method A code checks but fails the geometry constraints.

20. Except for Method A anchorage and shim stresses!!! This message prints if the pad satisfies all Method A code checks except Method A anchorage and shim stresses.
21. Except Method A anchorage!!! This message prints if the pad satisfies all Method A code checks except Method A anchorage.
22. Except shim stresses!!! This message prints if the pad satisfies all Method A code checks except shim stresses.
23. Bearing pad satisfies Method B anchorage. –this message prints if the pad satisfies the Method B anchorage check. (Expansion End Pads only)
24. Bearing pad DOES NOT satisfy Method B anchorage. –this message prints if the pad does not pass the Method B anchorage check. (Expansion End Pads only)
25. Bearing pad VIOLATES at least one code check - this message prints along with one of the following to denote a code check failure:

    Bearing pad is overstressed.

    Bearing pad is too thick.

    Bearing pad is too thin.

    Bearing pad thickness is less than input minimum.

    Bearing pad is unstable in diameter direction - only prints for circular bearings.

    Bearing pad is unstable in longitudinal direction - only prints for rectangular bearings.

    Bearing pad is unstable in transverse direction - only prints for rectangular bearings.

    Shape factor is less than 3.
26. Unable to complete the analysis due to an error, please check input - prints if an input error was encountered. Check input data and rerun the program.

7.5 FORMATTED OUTPUT TABLES

The following pages contain the output from a typical design run of the program. The complete output available is not reflected in this output. Depending on such items as the type of run, specifications checked, and output commands and parameters chosen, the program will print different combinations of output.

Example of Input File Echo:

```
                                    EXAMPLE.DAT
                                    -----------
!
TTL Example
TTL DESIGN OF BEARING PADS FOR A SIMPLE SPAN STEEL BEAM
TTL
!
CTL US,D,S,IS
!
GEO 50.0,20.0,90.0,90.0,,20
!
. . .
```

Example of Input Commands:

```
                                  INPUT COMMANDS
                                  --------------

     COMMAND:  CFG
       NUMBER OF LINES PER PAGE            74
       NO. BLANK LINES @ PG TOP             0

     COMMAND:  CTL
       SYSTEM OF UNITS                     US
       DESIGN/ANALYSIS                      D
       SIMPLE/CONTINUOUS                    S
       STRUCTURE TYPE                      IS
       DESIGN/ANALYSIS METHOD               A             (default)

     COMMAND:  GEO
       EXPANSION LENGTH                  50.0 ft
       BEAM BOTTOM WIDTH                 20.0 in
       MAXIMUM SKEW ANGLE                90.0 deg
       MINIMUM SKEW ANGLE                90.0 deg
       MINIMUM PAD THICKNESS                * in     (computed, if necessary)
       MAXIMUM PAD LENGTH                  20 in

. . .
```

Example of Program Output:

```
                              SPAN AND LOAD DATA
                              ------------------
                               DESIGN/
 DESIGN/   SPAN  SUPERSTRUCTURE ANALYSIS  EXP.   BEAM BOT   MAX.   MIN.
 ANALYSIS  TYPE       TYPE       METHOD  LENGTH   WIDTH     SKEW   SKEW
                                          (ft)     (in)    (deg)  (deg)
    D       S     STEEL I-BEAM     A      50.00   20.000    90.0   90.0

 MIN PAD   MAX PAD    MAX DL     MIN DL     MAX LL     MIN LL
  THICK    LENGTH    REACTION   REACTION   REACTION   REACTION
  (in)      (in)      (kips)     (kips)     (kips)     (kips)
   ***     20.000      24.10      21.70      15.20       7.60

 NOTE: The Minimum LL Reaction has been changed to 0.5*Maximum LL Reaction
       per DC14.7.6.4P.

 *** MINIMUM PAD THICKNESS on the GEO command has been left blank, which
     indicates that the program should use default values for the minimum
     pad thickness. When designing or analyzing plain pads, the minimum
     pad thickness is taken as 0.75". (DM-4 14.7.6.3.1aP) When designing
     or analyzing laminated pads, the minimum pad thickness is taken as
     2", as suggested in DM-4 C14.7.6.3.1aP.

                               CONSTRUCTION TOLERANCE, DEAD LOAD,
 ---- LL  ROTATION ----           AND OTHER RELATIVE ROTATION
  ABOUT PAD   ABOUT PAD              ABOUT PAD    ABOUT PAD
 LONGITUDINAL TRANSVERSE            LONGITUDINAL  TRANSVERSE
    AXIS        AXIS                    AXIS         AXIS
   (rad.)      (rad.)                  (rad.)       (rad.)
  0.00000     0.00320                 0.00000      0.00300

   TEMPERATURE RANGE FOR
   BEARING   SUBSTRUCTURE     ROTATION MOVEMENT
   DESIGN       DESIGN        DL1     DL2     LL
   (Fdeg)       (Fdeg)        (in)    (in)    (in)
    80.0         58.0        0.095   0.028   0.103

   PAD       HOLE     PAD   PAD       PAD      BEARING   # PADS FOR    ELASTOMER
 HARDNESS  DIAMETER  TYPE  SHAPE  ORIENTATION    TYPE    BOX DESIGN  SHEAR MODULUS*
  (duro)     (in)                                                         (ksi)
    50      0.000     P      R         S           E          1            n/a

 * A value of "n/a" for this value indicates that this value does not apply for
   this run of the program because the user has entered "A" for the DESIGN/ANALYSIS
   METHOD on the CTL command. The program will use a shear modulus corresponding
   to the PAD HARDNESS value.

                        DATA VALUES FROM THE PARAMETER FILE
                        -----------------------------------
AASHTO Table 14.7.6.2-1 - Correlated Material Properties
             Shear Modulus     Creep
 Hardness     Low    High     Factor
(Shore A)    (psi)   (psi)
    50        95.0   130.0    0.2500

   DM-4 Table C14.7.5.3.6-1P - Constants for Strain Equation
                  ---------------- Shape Factors ---------------
Hardness  Constant    3       4       5       6       9      12
  50         A     -18.00   -4.20   -1.40   -0.69   -0.70   -1.00  (1/ksi^2)
  50         B      22.7    12.3     8.4     5.9     5.2     5.0   (1/ksi)
```

. . .

7.6 DESIGN HISTORY FILE

This filename (named <output file name>.HIS) is automatically created for design runs and is a trace of the bearing pad design process. This file does not have much formatting and is intended only as a troubleshooting aid for design failures. As such, this file is not intended to become part of the final design calculations.

8 EXAMPLE PROBLEMS

8.1 EXAMPLE PROBLEMS

This chapter contains a description of the example problems used to test and verify this program. Table 1 shows the example problem matrix, which lists each example problem and the key input items used to differentiate the problems. The actual input data file for each example problem is not listed in this manual but is included electronically along with the executable program.

Table 8.1-1 Example Problem Matrix

	Example Problem						
Input Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**
System of Units	US	US	US	US	US	US	US
Run Type	Design	Design	Analysis	Design	Design	Design	Design
Span Type	Simple	Simple	Simple	Continuous	Continuous	Simple	Simple
Superstructure Type	Steel I-beam	P/S Adjac. Box Beam	P/S Adjac. Box Beam	P/S Spread Box Beam	P/S Spread Box Beam	P/S I-beam	P/S I-beam
Design/Analysis Method	A	A	A	A	A	A	B
Expansion Length	50 ft.	33.56 ft.	33.56 ft.	200 ft.	0 ft.	98 ft.	100 ft.
Beam Bottom Width	20 in.	48 in.	48 in.	48 in.	48 in.	24 in.	26 in.
Maximum Skew	90°	75°	75°	80°	80°	60°	90°
Minimum Skew	90°	75°	75°	80°	80°	60°	90°
Minimum Pad Thickness	2.0 in.	2.0 in.	2.0 in.	2.0 in.	2.0 in.	2.0 in.	2.0 in.
Maximum Pad Length	20.0 in.	24.0 in.	24.0 in.	24.0 in.	24.0 in.	24.0 in.	20.0 in.
Max. Dead Load Reaction	24.1 Kips	24.59 Kips	24.59 Kips	120.0 Kips	120.0 Kips	72.6 Kips	138.7 Kips
Min. Dead Load Reaction	21.7 Kips	22.75 Kips	22.75 Kips	115.0 Kips	115.0 Kips	65.30 Kips	100.3 Kips
Max. Live Load Reaction	15.2 Kips	27.59 Kips	27.59 Kips	85.0 Kips	85.0 Kips	101.0 Kips	80.79 Kips
Min. Live Load Reaction	7.6 Kips	13.8 Kips	13.8 Kips	75.0 Kips	75.0 Kips	50.5 Kips	40.39 Kips
LL Rotation - Transv. Axis	0.0032	0.0018	0.0018	0.00295	0.00295	0.0021	0.00158
LL Rotation - Longit. Axis	0.0	0.0005	0.0005	0.00052	0.00052	0.0005	0.0
Const. Tolerance - Transv.	0.003 rad	0.0005 rad	0.003 rad	0.005 rad	0.005 rad	0.003 rad	0.005 rad
Const. Tolerance - Longit.	0.0 rad	0.0 rad	0.0 rad	0.003 rad	0.003 rad	0.0 rad	0.005 rad
Temp. Range Bearing Design	100°F	80°F	80°F	80 °F	80 °F	80 °F	80 °F
Temp. Range Substr. Design	78°F	58°F	58° F	58 °F	58 °F	58 °F	58 °F
DL1 Rotation Movement	0.05 in.	0.01 in.	0.01 in.	0.17 in.	0.0 in.	0.21 in.	0.392 in.
DL2 Rotation Movement	0.08 in.	0.06 in.	0.06 in.	0.03 in.	0.0 in.	0.05 in.	0.096 in.
LL Rotation Movement	0.1 in.	0.05 in.	0.05 in.	0.11 in.	0.0 in.	0.24 in.	0.132 in.
Pad Hardness/Shear Mod.	50	50	50	50	50	50	0.130 ksi
Hole Diameter in Brg. Pad	0.0 in.	0.0 in.	0.0 in.	0.0 in.	0.0 in.	0.0 in.	0.0 in.
Pad Type	Plain	Plain	Laminated	Plain	Plain	Laminated	Laminated
Pad Shape	Rect.	Circular	Rect.	Rect.	Rect.	Circular	Rect.
Pad Orientation	Beam	Skew	Skew	Skew	Skew	Beam	Beam
Expansion / Fixed	Expansion	Expansion	Expansion	Expansion	Fixed	Expansion	Expansion
Construction Pier Flex.	N/A	N/A	N/A	0.35 in.	0.0 in.	N/A	N/A
Pad Diameter	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pad Length	N/A	N/A	7.0 in.	N/A	N/A	N/A	N/A
Pad Width	N/A	N/A	13.0 in.	N/A	N/A	N/A	N/A
Elast. Thick. - Plain Pad	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Elast. Thick. - Inter. Layer	N/A	N/A	0.625 in.	N/A	N/A	N/A	N/A
Elast. Thick. - Cover Layer	N/A	N/A	0.25 in.	N/A	N/A	N/A	N/A
Number of Layers	N/A	N/A	4	N/A	N/A	N/A	N/A
Number of Bearing Pads	N/A	N/A	2	N/A	N/A	N/A	N/A
Hole in Bearing Pad	N/A	N/A	No	N/A	N/A	N/A	N/A
Pad Location	N/A	N/A	12	N/A	N/A	N/A	N/A

8.2 EXAMPLE 1

Example 1 is a design problem using US units. A plain rectangular bearing pad without a hole is designed for the expansion bearing of a simple span steel I-beam bridge. The expansion length is 50 feet and the beam bottom width is 20 inches. The maximum skew angle is 90 degrees, the minimum skew angle is 90 degrees, and the bearing pad is oriented with the beam. The maximum dead load reaction is 24.1 kips, the minimum dead load reaction is 21.7 kips, the maximum live load reaction is 15.2 kips, and the minimum live load reaction is 8.4 kips. The live load rotation about the transverse axis of the pad is 0.0032 radians, and the live load rotation about the longitudinal axis of the pad is 0.0 radians. Longitudinal beam movements due to non-composite dead load, superimposed dead load, and live load are 0.05 inches, 0.08 inches and 0.1 inches, respectively. The bearing pad hardness is 50 and the temperature range is 100°F. A construction rotational tolerance of 0.003 radians is considered about the transverse axis of the bearing pad. Presented in Figure 8.3-1 is a sketch showing the skew angle, centerline of beam, centerline of bearing, and pad orientation. Although this figure is based on Example 2 only, it serves to illustrate these bearing pad features for this example as well.

SPAN AND LOAD DATA

DESIGN/ ANALYSIS	SPAN TYPE	SUPERSTRUCTURE TYPE	DESIGN/ ANALYSIS METHOD	EXP. LENGTH (ft)	BEAM BOT WIDTH (in)	MAX. SKEW (deg)	MIN. SKEW (deg)
D	S	STEEL I-BEAM	A	50.00	20.000	90.0	90.0

MIN PAD THICK (in)	MAX PAD LENGTH (in)	MAX DL REACTION (kips)	MIN DL REACTION (kips)	MAX LL REACTION (kips)	MIN LL REACTION (kips)
***	20.000	24.10	21.70	15.20	7.60

NOTE: The Minimum LL Reaction has been changed to 0.5*Maximum LL Reaction per DC14.7.6.4P.

*** MINIMUM PAD THICKNESS on the GEO command has been left blank, which indicates that the program should use default values for the minimum pad thickness. When designing or analyzing plain pads, the minimum pad thickness is taken as 0.75". (DM-4 14.7.6.3.1aP) When designing or analyzing laminated pads, the minimum pad thickness is taken as 2", as suggested in DM-4 C14.7.6.3.1aP.

---- LL ROTATION ----		CONSTRUCTION TOLERANCE, DEAD LOAD, AND OTHER RELATIVE ROTATION	
ABOUT PAD LONGITUDINAL AXIS (rad.)	ABOUT PAD TRANSVERSE AXIS (rad.)	ABOUT PAD LONGITUDINAL AXIS (rad.)	ABOUT PAD TRANSVERSE AXIS (rad.)
0.00000	0.00320	0.00000	0.00300

TEMPERATURE RANGE FOR		ROTATION MOVEMENT		
BEARING DESIGN (Fdeg)	SUBSTRUCTURE DESIGN (Fdeg)	DL1 (in)	DL2 (in)	LL (in)
100.0	78.0	0.050	0.080	0.100

PAD HARDNESS (duro)	HOLE DIAMETER (in)	PAD TYPE	PAD SHAPE	PAD ORIENTATION	BEARING TYPE	# PADS FOR BOX DESIGN	ELASTOMER SHEAR MODULUS* (ksi)
50	0.000	P	R	B	E	n/a	n/a

* A value of "n/a" for this value indicates that this value does not apply for this run of the program because the user has entered "A" for the DESIGN/ANALYSIS METHOD on the CTL command. The program will use a shear modulus corresponding to the PAD HARDNESS value.

8.3 EXAMPLE 2

Example 2 is a design problem using US units. A plain circular bearing pad without a hole is designed for the expansion bearing of a simple span prestressed concrete adjacent box beam bridge. The expansion length is 33.56 feet and the beam bottom width is 48 inches. The maximum skew angle is 75 degrees, the minimum skew angle is 75 degrees and the bearing pad is oriented with the skew. The maximum dead load reaction is 24.59 kips, the minimum dead load reaction is 21.75 kips, the maximum live load reaction is 27.59 kips, and the minimum live load reaction is 15.75 kips. The live load rotation about the transverse axis of the pad is 0.0018 radians, and the live load rotation about the longitudinal axis of the pad is 0.0005 radians. Longitudinal beam movements due to non-composite dead load, superimposed dead load, and live load are 0.01 inches, 0.06 inches and 0.05 inches, respectively. The bearing pad hardness is 50 and the temperature range is 80°F. A construction rotational tolerance of 0.0005 radians is considered about the transverse axis of the bearing pad. Presented in Figure 1 is a sketch showing the skew angle, centerline of beam, centerline of bearing, and pad orientation for Example 2.

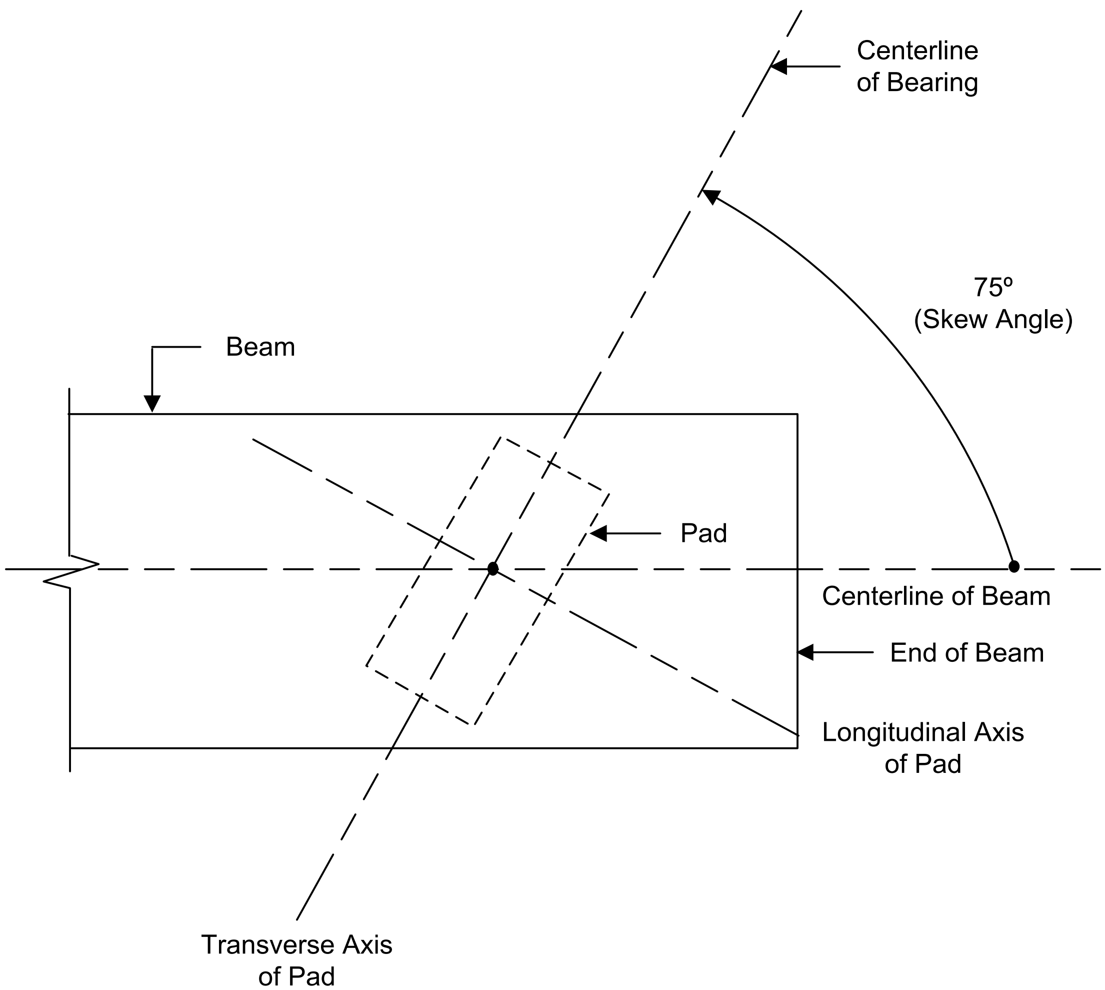

Figure 8.3-1 Bearing Pad Orientation for Example 2

SPAN AND LOAD DATA

DESIGN/ ANALYSIS	SPAN TYPE	SUPERSTRUCTURE TYPE	DESIGN/ ANALYSIS METHOD	EXP. LENGTH (ft)	BEAM BOT WIDTH (in)	MAX. SKEW (deg)	MIN. SKEW (deg)
D	S	PRESTR. ADJCNT	A	33.56	48.000	75.0	75.0

MIN PAD THICK (in)	MAX PAD LENGTH (in)	MAX DL REACTION (kips)	MIN DL REACTION (kips)	MAX LL REACTION (kips)	MIN LL REACTION (kips)
***	24.000	24.59	22.75	27.59	13.80

NOTE: The Minimum LL Reaction has been changed to 0.5*Maximum LL Reaction per DC14.7.6.4P.

*** MINIMUM PAD THICKNESS on the GEO command has been left blank, which indicates that the program should use default values for the minimum pad thickness. When designing or analyzing plain pads, the minimum pad thickness is taken as 0.75". (DM-4 14.7.6.3.1aP) When designing or analyzing laminated pads, the minimum pad thickness is taken as 2", as suggested in DM-4 C14.7.6.3.1aP.

---- LL ROTATION ----		CONSTRUCTION TOLERANCE, DEAD LOAD, AND OTHER RELATIVE ROTATION	
ABOUT PAD LONGITUDINAL AXIS (rad.)	ABOUT PAD TRANSVERSE AXIS (rad.)	ABOUT PAD LONGITUDINAL AXIS (rad.)	ABOUT PAD TRANSVERSE AXIS (rad.)
0.00050	0.00180	0.00000	0.00050

TEMPERATURE RANGE FOR		ROTATION MOVEMENT		
BEARING DESIGN (Fdeg)	SUBSTRUCTURE DESIGN (Fdeg)	DL1 (in)	DL2 (in)	LL (in)
80.0	58.0	0.010	0.060	0.050

PAD HARDNESS (duro)	HOLE DIAMETER (in)	PAD TYPE	PAD SHAPE	PAD ORIENTATION	BEARING TYPE	# PADS FOR BOX DESIGN	ELASTOMER SHEAR MODULUS* (ksi)
50	0.000	P	C	S	E	2	n/a

* A value of "n/a" for this value indicates that this value does not apply for this run of the program because the user has entered "A" for the DESIGN/ANALYSIS METHOD on the CTL command. The program will use a shear modulus corresponding to the PAD HARDNESS value.

8.4 EXAMPLE 3

Example 3 is an analysis problem using US units. Two laminated rectangular bearing pads without holes are analyzed for the expansion bearing of a simple span prestressed concrete adjacent box beam bridge. The expansion length is 33.56 feet and the beam bottom width is 48 inches. The maximum skew angle is 75 degrees, the minimum skew angle is 75 degrees, and the bearing pad is oriented with the skew. The maximum dead load reaction is 24.59 kips, the minimum dead load reaction is 21.75 kips, the maximum live load reaction is 27.59 kips, and the minimum live load reaction is 15.75 kips. The live load rotation about the transverse axis of the pad is 0.0018 radians, and the live load rotation about the longitudinal axis of the pad is 0.0005 radians. Longitudinal beam movements due to non-composite dead load, superimposed dead load, and live load are 0.01 inches, 0.06 inches and 0.05 inches, respectively. The bearing pad hardness is 50 and the temperature range is 80°F. A construction rotational tolerance of 0.003 radians is considered about the transverse axis of the bearing pad. The bearing pad measures 7 inches long by 13 inches wide with four layers of elastomeric material in the bearing pad. The elastomer thickness is 0.625 inches for the interior layer and 0.25 inches for the cover layer. The pads are located at the default one quarter of the bottom beam width. Presented in Figure 8.3-1 is a sketch showing the skew angle, centerline of beam, centerline of bearing, and pad orientation. Although this figure is based on Example 2 only, it serves to illustrate these bearing pad features for this example as well.

```
                              SPAN AND LOAD DATA
                              ------------------
                                  DESIGN/
DESIGN/   SPAN  SUPERSTRUCTURE ANALYSIS  EXP.   BEAM BOT   MAX.   MIN.
ANALYSIS  TYPE       TYPE       METHOD  LENGTH   WIDTH     SKEW   SKEW
                                         (ft)     (in)    (deg)  (deg)
   A       S    PRESTR. ADJCNT    A      33.56   48.000    75.0   75.0

MIN PAD   MAX PAD    MAX DL     MIN DL     MAX LL     MIN LL
 THICK    LENGTH    REACTION   REACTION   REACTION   REACTION
 (in)      (in)      (kips)     (kips)     (kips)     (kips)
  ***     24.000      24.59      22.75      27.59      13.80

NOTE: The Minimum LL Reaction has been changed to 0.5*Maximum LL Reaction
      per DC14.7.6.4P.

*** MINIMUM PAD THICKNESS on the GEO command has been left blank, which
    indicates that the program should use default values for the minimum
    pad thickness. When designing or analyzing plain pads, the minimum
    pad thickness is taken as 0.75". (DM-4 14.7.6.3.1aP) When designing
    or analyzing laminated pads, the minimum pad thickness is taken as
    2", as suggested in DM-4 C14.7.6.3.1aP.

                                  CONSTRUCTION TOLERANCE, DEAD LOAD,
---- LL  ROTATION ----               AND OTHER RELATIVE ROTATION
 ABOUT PAD   ABOUT PAD                 ABOUT PAD    ABOUT PAD
LONGITUDINAL TRANSVERSE               LONGITUDINAL  TRANSVERSE
   AXIS        AXIS                      AXIS          AXIS
  (rad.)      (rad.)                    (rad.)        (rad.)
 0.00050     0.00180                   0.00000       0.00300
```

```
TEMPERATURE RANGE FOR
BEARING   SUBSTRUCTURE     ROTATION MOVEMENT
DESIGN       DESIGN         DL1      DL2      LL
 (Fdeg)       (Fdeg)       (in)     (in)     (in)
  80.0         58.0        0.010    0.060    0.050

   PAD       HOLE     PAD    PAD       PAD       BEARING   # PADS FOR    ELASTOMER
HARDNESS  DIAMETER  TYPE  SHAPE  ORIENTATION    TYPE    BOX DESIGN  SHEAR MODULUS*
 (duro)     (in)                                                         (ksi)
   50       0.000     L      R         S          E          n/a          n/a
```

* A value of "n/a" for this value indicates that this value does not apply for this run of the program because the user has entered "A" for the DESIGN/ANALYSIS METHOD on the CTL command. The program will use a shear modulus corresponding to the PAD HARDNESS value.

8.5 EXAMPLE 4

Example 4 is a design problem using US units. A plain rectangular bearing pad without a hole is designed for the expansion bearing of a continuous span prestressed concrete spread box beam bridge. The expansion length is 200 feet and the beam bottom width is 48 inches. The maximum skew angle is 80 degrees, the minimum skew angle is 80 degrees, and the bearing pad is oriented with the skew. The maximum dead load reaction is 120 kips, the minimum dead load reaction is 115 kips, the maximum live load reaction is 85 kips, and the minimum live load reaction is 75 kips. The live load rotation about the transverse axis of the pad is 0.00295 radians, and the live load rotation about the longitudinal axis of the pad is 0.00052 radians. Longitudinal beam movements due to non-composite dead load, superimposed dead load, and live load are 0.17 inches, 0.03 inches and 0.11 inches, respectively. The bearing pad hardness is 50 and the temperature range is 80°F. The construction pier flexibility is 0.35 inches. Construction rotational tolerances of 0.005 radians about the pad’s transverse axis and 0.003 radians about the pad’s longitudinal axis are considered. Presented in Figure 8.3-1 is a sketch showing the skew angle, centerline of beam, centerline of bearing, and pad orientation. Although this figure is based on Example 2 only, it serves to illustrate these bearing pad features for this example as well.

```
                                 SPAN AND LOAD DATA
                                 ------------------
                                     DESIGN/
DESIGN/    SPAN   SUPERSTRUCTURE ANALYSIS   EXP.    BEAM BOT    MAX.    MIN.
ANALYSIS   TYPE        TYPE       METHOD   LENGTH    WIDTH      SKEW    SKEW
                                            (ft)      (in)     (deg)   (deg)
   D        C     PRESTR. SPREAD    A      200.00    48.000     80.0    80.0

MIN PAD    MAX PAD    MAX DL     MIN DL     MAX LL     MIN LL
 THICK     LENGTH    REACTION   REACTION   REACTION   REACTION
 (in)       (in)      (kips)     (kips)     (kips)     (kips)
  ***      24.000     120.00     115.00      85.00      75.00

*** MINIMUM PAD THICKNESS on the GEO command has been left blank, which
    indicates that the program should use default values for the minimum
    pad thickness. When designing or analyzing plain pads, the minimum
    pad thickness is taken as 0.75". (DM-4 14.7.6.3.1aP) When designing
    or analyzing laminated pads, the minimum pad thickness is taken as
    2", as suggested in DM-4 C14.7.6.3.1aP.

                                     CONSTRUCTION TOLERANCE, DEAD LOAD,
---- LL  ROTATION ----                  AND OTHER RELATIVE ROTATION
 ABOUT PAD   ABOUT PAD                     ABOUT PAD    ABOUT PAD
LONGITUDINAL TRANSVERSE                   LONGITUDINAL  TRANSVERSE
   AXIS         AXIS                          AXIS          AXIS
  (rad.)       (rad.)                        (rad.)        (rad.)
 0.00052      0.00295                       0.00300       0.00500

  TEMPERATURE RANGE FOR
  BEARING   SUBSTRUCTURE     ROTATION MOVEMENT
  DESIGN       DESIGN         DL1      DL2      LL
  (Fdeg)       (Fdeg)        (in)     (in)     (in)
   80.0         58.0         0.170    0.030    0.110
```

PAD HARDNESS (duro)	HOLE DIAMETER (in)	PAD TYPE	PAD SHAPE	PAD ORIENTATION	BEARING TYPE	# PADS FOR BOX DESIGN	ELASTOMER SHEAR MODULUS* (ksi)
50	0.000	P	R	S	E	2	n/a

* A value of "n/a" for this value indicates that this value does not apply for this run of the program because the user has entered "A" for the DESIGN/ANALYSIS METHOD on the CTL command. The program will use a shear modulus corresponding to the PAD HARDNESS value.

CONTINUOUS SPAN ONLY
CONSTRUCTION/PIER FLEXIBILITY (in)
0.350

8.6 EXAMPLE 5

Example 5 is a design problem using US units. A plain rectangular bearing pad without a hole is designed for the fixed bearing of a continuous span prestressed concrete spread box beam bridge. The beam bottom width is 48 inches. The maximum skew angle is 80 degrees, the minimum skew angle is 80 degrees, and the bearing pad is oriented with the skew. The maximum dead load reaction is 120 kips, the minimum dead load reaction is 115 kips, the maximum live load reaction is 85 kips, and the minimum live load reaction is 75 kips. The live load rotation about the transverse axis of the pad is 0.00295 radians, and the live load rotation about the longitudinal axis of the pad is 0.00052 radians. The bearing pad hardness is 50 and the temperature range is 80°F. Since the bearing is fixed, no longitudinal beam movement is considered. Construction rotational tolerances of 0.005 radians about the pad's transverse axis and 0.003 radians about the pad's longitudinal axis are considered. Presented in Figure 8.3-1 is a sketch showing the skew angle, centerline of beam, centerline of bearing, and pad orientation. Although this figure is based on Example 2 only, it serves to illustrate these bearing pad features for this example as well.

```
                                SPAN AND LOAD DATA
                                ------------------
                                    DESIGN/
DESIGN/   SPAN  SUPERSTRUCTURE ANALYSIS  EXP.   BEAM BOT   MAX.   MIN.
ANALYSIS  TYPE       TYPE       METHOD  LENGTH   WIDTH     SKEW   SKEW
                                         (ft)     (in)    (deg)  (deg)
   D       C    PRESTR. SPREAD    A      0.00    48.000    80.0   80.0

MIN PAD   MAX PAD    MAX DL     MIN DL     MAX LL     MIN LL
 THICK    LENGTH    REACTION   REACTION   REACTION   REACTION
 (in)      (in)     (kips)     (kips)     (kips)     (kips)
  ***     24.000    120.00     115.00      85.00      75.00

*** MINIMUM PAD THICKNESS on the GEO command has been left blank, which
    indicates that the program should use default values for the minimum
    pad thickness. When designing or analyzing plain pads, the minimum
    pad thickness is taken as 0.75". (DM-4 14.7.6.3.1aP) When designing
    or analyzing laminated pads, the minimum pad thickness is taken as
    2", as suggested in DM-4 C14.7.6.3.1aP.

                                CONSTRUCTION TOLERANCE, DEAD LOAD,
---- LL  ROTATION ----             AND OTHER RELATIVE ROTATION
 ABOUT PAD   ABOUT PAD                ABOUT PAD    ABOUT PAD
LONGITUDINAL TRANSVERSE              LONGITUDINAL  TRANSVERSE
   AXIS         AXIS                    AXIS          AXIS
  (rad.)       (rad.)                  (rad.)        (rad.)
 0.00052      0.00295                 0.00300       0.00500

  TEMPERATURE RANGE FOR
  BEARING   SUBSTRUCTURE     ROTATION MOVEMENT
  DESIGN       DESIGN         DL1     DL2     LL
  (Fdeg)       (Fdeg)        (in)    (in)    (in)
   80.0         58.0         0.000   0.000   0.000
```

PAD HARDNESS (duro)	HOLE DIAMETER (in)	PAD TYPE	PAD SHAPE	PAD ORIENTATION	BEARING TYPE	# PADS FOR BOX DESIGN	ELASTOMER SHEAR MODULUS* (ksi)
50	0.000	P	R	S	F	2	n/a

* A value of "n/a" for this value indicates that this value does not apply for this run of the program because the user has entered "A" for the DESIGN/ANALYSIS METHOD on the CTL command. The program will use a shear modulus corresponding to the PAD HARDNESS value.

CONTINUOUS SPAN ONLY

CONSTRUCTION/PIER FLEXIBILITY (in)
0.000

8.7 EXAMPLE 6

Example 6 is a design problem using US units. A laminated circular bearing pad without a hole is designed for the expansion bearing of a simple span prestressed concrete I-beam bridge. The expansion length is 98 feet, and the beam bottom width is 24 inches. The maximum skew angle is 60 degrees, the minimum skew angle is 60 degrees, and the bearing pad is oriented with the beam. The maximum dead load reaction is 72.6 kips, the minimum dead load reaction is 65.3 kips, the maximum live load reaction is 101.0 kips, and the minimum live load reaction is 48.0 kips. The live load rotation about the transverse axis of the pad is 0.0021 radians, and the live load rotation about the longitudinal axis of the pad is 0.0005 radians. Longitudinal beam movements due to non-composite dead load, superimposed dead load, and live load are 0.21 inches, 0.05 inches and 0.24 inches, respectively. The bearing pad hardness is 50 and the temperature range is 80°F. A construction rotational tolerance of 0.003 radians is considered about the transverse axis of the bearing pad. Presented in Figure 8.3-1 is a sketch showing the skew angle, centerline of beam, centerline of bearing, and pad orientation. Although this figure is based on Example 2 only, it serves to illustrate these bearing pad features for this example as well.

```
                              SPAN AND LOAD DATA
                              ------------------
                                  DESIGN/
DESIGN/   SPAN  SUPERSTRUCTURE ANALYSIS  EXP.   BEAM BOT   MAX.   MIN.
ANALYSIS  TYPE       TYPE       METHOD  LENGTH   WIDTH     SKEW   SKEW
                                         (ft)     (in)    (deg)  (deg)
   D       S    PRESTR. I-BEAM    A      98.00   24.000    60.0   60.0

MIN PAD   MAX PAD    MAX DL     MIN DL     MAX LL     MIN LL
 THICK    LENGTH    REACTION   REACTION   REACTION   REACTION
 (in)      (in)      (kips)     (kips)     (kips)     (kips)
  ***     24.000      72.60      65.30     101.00      50.50

NOTE: The Minimum LL Reaction has been changed to 0.5*Maximum LL Reaction
      per DC14.7.6.4P.

*** MINIMUM PAD THICKNESS on the GEO command has been left blank, which
    indicates that the program should use default values for the minimum
    pad thickness. When designing or analyzing plain pads, the minimum
    pad thickness is taken as 0.75". (DM-4 14.7.6.3.1aP) When designing
    or analyzing laminated pads, the minimum pad thickness is taken as
    2", as suggested in DM-4 C14.7.6.3.1aP.

                                CONSTRUCTION TOLERANCE, DEAD LOAD,
---- LL  ROTATION ----             AND OTHER RELATIVE ROTATION
 ABOUT PAD   ABOUT PAD                ABOUT PAD    ABOUT PAD
LONGITUDINAL TRANSVERSE              LONGITUDINAL  TRANSVERSE
   AXIS        AXIS                     AXIS          AXIS
  (rad.)      (rad.)                   (rad.)        (rad.)
 0.00050     0.00210                  0.00000       0.00300

  TEMPERATURE RANGE FOR
  BEARING   SUBSTRUCTURE     ROTATION MOVEMENT
  DESIGN       DESIGN        DL1     DL2     LL
  (Fdeg)       (Fdeg)       (in)    (in)    (in)
   80.0         58.0        0.210   0.050   0.240
```

PAD HARDNESS (duro)	HOLE DIAMETER (in)	PAD TYPE	PAD SHAPE	PAD ORIENTATION	BEARING TYPE	# PADS FOR BOX DESIGN	ELASTOMER SHEAR MODULUS* (ksi)
50	0.000	L	C	B	E	n/a	n/a

* A value of "n/a" for this value indicates that this value does not apply for this run of the program because the user has entered "A" for the DESIGN/ANALYSIS METHOD on the CTL command. The program will use a shear modulus corresponding to the PAD HARDNESS value.

8.8 EXAMPLE 7

Example 7 is a design problem using Method B with US units. A laminated rectangular bearing pad without a hole is designed for the expansion bearing of a simple span prestressed concrete I-beam bridge. The expansion length is 100 feet, and the beam bottom width is 26 inches. The maximum skew angle is 90 degrees, the minimum skew angle is 90 degrees, and the bearing pad is oriented with the beam. The maximum dead load reaction is 138.65 kips, the minimum dead load reaction is 100.3 kips, the maximum live load reaction is 80.79 kips, and the minimum live load reaction is 40.39 kips. The live load rotation about the transverse axis of the pad is 0.00158 radians, and the live load rotation about the longitudinal axis of the pad is 0.0 radians. Longitudinal beam movements due to non-composite dead load, superimposed dead load, and live load are 0.392 inches, 0.096 inches and 0.132 inches, respectively. The elastomer shear modulus is 0.130 ksi and the temperature range is 80°F. A construction rotational tolerance of 0.005 radians is considered about the transverse and longitudinal axes of the bearing pad. Presented in Figure 8.3-1 is a sketch showing the skew angle, centerline of beam, centerline of bearing, and pad orientation. Although this figure is based on Example 2 only, it serves to illustrate these bearing pad features for this example as well.

```
                                SPAN AND LOAD DATA
                                ------------------
                                    DESIGN/
DESIGN/    SPAN   SUPERSTRUCTURE ANALYSIS   EXP.   BEAM BOT   MAX.   MIN.
ANALYSIS   TYPE        TYPE       METHOD   LENGTH   WIDTH     SKEW   SKEW
                                            (ft)     (in)    (deg)  (deg)
   D        S     PRESTR. I-BEAM    B      100.00   26.000    90.0   90.0

MIN PAD   MAX PAD    MAX DL     MIN DL     MAX LL     MIN LL
 THICK    LENGTH    REACTION   REACTION   REACTION   REACTION
 (in)      (in)      (kips)     (kips)     (kips)     (kips)
 2.000    20.000     138.65     100.30      80.79      40.39

NOTE: The Minimum LL Reaction has been changed to 0.5*Maximum LL Reaction
      per DC14.7.6.4P.

                                    CONSTRUCTION TOLERANCE, DEAD LOAD,
---- LL  ROTATION ----                 AND OTHER RELATIVE ROTATION
 ABOUT PAD   ABOUT PAD                    ABOUT PAD    ABOUT PAD
LONGITUDINAL TRANSVERSE                  LONGITUDINAL  TRANSVERSE
   AXIS        AXIS                        AXIS          AXIS
  (rad.)      (rad.)                      (rad.)        (rad.)
 0.00000     0.00158                     0.00500       0.00500

  TEMPERATURE RANGE FOR
  BEARING   SUBSTRUCTURE     ROTATION MOVEMENT
  DESIGN       DESIGN        DL1      DL2      LL
  (Fdeg)       (Fdeg)       (in)     (in)     (in)
   80.0         58.0        0.392    0.096    0.132
```

PAD HARDNESS (duro)	HOLE DIAMETER (in)	PAD TYPE	PAD SHAPE	PAD ORIENTATION	BEARING TYPE	# PADS FOR BOX DESIGN	ELASTOMER SHEAR MODULUS* (ksi)
na	0.000	L	R	B	E	n/a	0.1300

* The user has provided an input value for ELASTOMER SHEAR MODULUS. This value will only be used for Method B calculations. For Method A calculations, the program uses shear modulus values corresponding to the PAD HARDNESS value.

9 TECHNICAL QUESTIONS AND REVISION REQUESTS

This chapter contains a reply form to make it easier for users to convey their questions, problems, or comments to the proper unit within the Department. General procedures for using these forms are given. Users should keep the forms in the manual as a master copy which can be reproduced as needed. It is also included as a Word template as part of the program installation

Technical questions related to the interpretations of the design specifications as implemented in this program, why certain assumptions are made, applicability and limitations of this program, and other questions not related to the operation of this program can be directed to the appropriate person in PennDOT using this form or the information provided on the form. Please review the information provided in this User's Manual and the references given in Chapter 1 before submitting this form for processing or calling for assistance.

The form can also be used to report suspected program malfunctions that may require revisions to the program or to request revisions that may be required due to changes in specifications and for the enhancement of the program. Unexpected or incorrect output, rejection of input data, endless program cycling, and program abortion are examples of program malfunctions. Users are requested to review their input data and the program User’s Manual before submitting the form for processing.

The form may also be used to submit suggestions for improving the User’s Manual for this program. Suggestions might include typographical error correction, clarification of confusing sections, expansion of certain sections, changes in format, and the inclusion of additional information, diagrams, or examples.

The completed form should be sent to the Engineering Software Section via fax or e-mail.

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BPLRFD
TECHNICAL QUESTION /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: ____ PROGRAM VERSION: _________

Define your problem and attach samples and/or documentation you feel would be helpful in correcting the problem. If the input data is more than 4 or 5 lines, Licensees should provide the input data file as an e-mail attachment. If you require more space, use additional 8½ x 11 sheets of plain paper.

FORWARD COMPLETED FORM TO: Pennsylvania Office of Administration
Infrastructure and Economic Development
Bureau of Solutions Management
Highway Applications Division
E-MAIL: PenndotBisEngineer@pa.gov
PHONE: (717) 783-8822

FOR DEPARTMENT USE ONLY

RECEIVED BY: ________________ ASSIGNED TO: ____________________ DATE: _____________

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