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MANUAL	LRFD Bridge Design Manual	**DEVELOPED BY**	Bridge Office
SUBJECT	Title Page Table of Contents Section 14: Joints and Bearings		

An update to the MnDOT Bridge Office *LRFD Bridge Design Manual* is available for download in *Adobe* PDF (Portable Document Format) at http://www.dot.state.mn.us/bridge/. This Web site should be checked regularly for updates.

INSTRUCTIONS:
(for two-sided printing)

1. Remove from the manual:
   - Title Page
   - Table of Contents pages ix and xii
   - Entire Section 14

2. Print and insert in the manual:
   - Title Page
   - Table of Contents pages ix and xii
   - Section 14

Note: The "NOVEMBER 2017" update includes the following revisions:

- Updated the elastomeric bearing guidance and tables to reflect material hardness change from 55 to 60 durometers.
- Updated the elastomeric bearing guidance and tables to standardize the number of laminates for prestressed concrete beam bearings.
- Updated the elastomeric bearing guidance to match AASHTO changes regarding the minimum compressive load.
- Replaced the reference to knock-off studs with new reference to 3/8" x 3/8" bar.
- Clarified guidance on design of the bearing plate and curved plate.
- Added notes explaining our current practice of using cotton duck pads rather than plain elastomeric pads.

- Replaced article on pot bearings with similar article on disc bearings.
- Revised guidance, tables, and examples regarding curved plate and bearing plate design from the previous method of designing for max service stress equal to $0.55F_y$ to LRFD strength design for flexure limited to F_y.
- Added a bullet to the bridge fixity guidance regarding bridges on a slope tending to move downhill.
- Added note to consider creep movement for post-tensioned concrete bridges.
- Added guidance on where a 1/8" plain pad is to be used.
- Added note stating that pot bearings are not to be used on roadway bridges.
- Added guidance for prestressed concrete beam bridges on slopes > 3%.
- Updated the fixed elastomeric bearing example.
- Updated the expansion elastomeric bearing example.
- Made numerous editorial changes.
- Changed some of the existing guidance from passive to active voice.

Direct all ***technical questions*** regarding this transmittal to:

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MANUAL

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MINNESOTA DEPARTMENT OF TRANSPORTATION

Bridge Office

LRFD Bridge Design Manual

MnDOT BRIDGE OFFICE

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APPENDIX A. MEMOS

14. JOINTS AND BEARINGS

Expansion joints and bearings provide mechanisms to accommodate movements of bridges without generating excessive internal forces. This section provides guidance on joint and bearing selection and the movement and loads that must be used in their designs.

14.1 Bridge Movements and Fixity

To determine movements for bearings and joints, the point of fixity must be established for the bridge or bridge segment. The point of fixity is the neutral point on the bridge that does not move horizontally as the bridge experiences temperature changes. Use the following guidance concerning bridge fixity:

1) For single span structures, fix the bearings at the low end of the bridge.
2) For typical two-span structures, fix the bearings at the pier. For bridges with tall or flexible piers that are located on slopes, the superstructure may tend to move toward the downhill end, causing maintenance problems at the uphill end due to a wider joint than anticipated. For these bridges, consider providing fixed bearings at the downhill abutment.
3) For structures with three or more spans, investigate the longitudinal stiffness of the bridge. The longitudinal stiffness is a function of the interaction between pier stiffnesses, bearing types and joint locations. Consider the following:
    a) The number and location of expansion joints is determined based on a maximum joint opening of 4 inches at the ends of the bridge. When joint openings exceed 4 inches, two options are available:
        i) The preferred option is to provide additional joints at the piers to split the superstructure into segments.
        ii) Provide modular expansion joints at bridge ends only.
    b) For each bridge or bridge segment, provide fixed bearings at a minimum of two piers to provide increased resistance to longitudinal movements.
    c) Provide fixed bearings at all tall pier locations. Tall or flexible piers deflect prior to mobilizing the translational capacity of the bearing.
    d) Bridges with tall or flexible piers that are located on slopes may tend to move toward the downhill end, causing maintenance problems at the uphill end due to a wider joint than anticipated. For these bridges, consider providing fixed bearings at the downhill abutment.
    e) A combination of fixed, expansion, guided, and limited expansion bearings can be provided at the piers to accommodate the movements for the bridge or bridge segments.

f) Based on the point of fixity of each segment, the maximum movements can be determined for the design of joints and bearings.

14.2 Expansion Joints [14.5.3.2]

Minnesota bridges with parapet type abutments typically have strip seal expansion joints at the abutments to isolate superstructure movements from the abutments. When the maximum joint openings at the abutments exceed 4 inches additional joints are needed at piers or modular joints are required at the abutments.

Do not use elastomeric compression seal expansion joints.

14.2.1 Thermal Movements [Table 3.4.1-1]

Design joint openings for movements associated with a temperature range of 150°F (-30°F to 120°F). For strip seal expansion joints on typical bridges, use a load factor for movement of 1.0. (Note that this value differs from the LRFD Specification based on past performance of joints in Minnesota.) For strip seal expansion joints on non-typical bridges and for all modular expansion joints, use a load factor for movement of 1.2 per LRFD Article 3.4.1. See BDM Article 3.10.1 for the definition of typical and non-typical bridges.

The coefficients of thermal expansion are:

[5.4.2.2]
[6.4.1]

- Concrete: 6.0×10^{-6} per °F
- Steel: 6.5×10^{-6} per °F

14.2.2 Strip Seal Expansion Joints

For movements of up to 4 inches, use strip seal expansion devices. Design joints to have a minimum opening of $^{1}/_{2}$ inch between the steel elements (extrusions) of the joint.

[14.5.3.2]

To provide a reasonably smooth roadway surface, the maximum width of expansion openings is limited to 4 inches (measured perpendicular to joint) on roadway bridges. The maximum width for pedestrian bridges is 5 inches. Detail cover plates on sidewalks, medians, and pedestrian bridges to cover the opening.

The standard strip seal device is a Type 4.0, which has a movement capacity of 4 inches. Bridges on a horizontal curve or with a skew over 30° must accommodate "racking" or transverse movements as well. For these situations use a Type 5.0 strip seal (5 inch capacity). Type 5.0 strip seals can also be used on pedestrian bridges.

For skews less than 30°:

- For expansion distance less than 150'-0", dimension opening at 2 inches at all temperatures.
- For expansion distance greater than or equal to 150'-0", dimension opening at $1^1/_2$ inches at 90°F. Also determine and show dimension at 45°F, checking that the opening at -30°F does not exceed 4 inches. If so, reduce accordingly at 45°F and 90°F.

For skews greater than or equal to 30°:

- Dimension opening at $1^1/_2$ inches at 90°F. Also determine and show dimension at 45°F, checking that the opening at -30°F does not exceed 4 inches. If so, reduce accordingly at 45°F and 90°F.

14.2.3 Modular Expansion Joints

When dividing a bridge into segments will not reduce the joint movement to less than 4 inches, use modular expansion joints. Provide a joint setting schedule with modular joints that lists the opening the joint should have at different construction temperatures. Show joint openings for a temperature range from 45°F to 90°F in 15°F increments.

Note that conventional modular joints are one-directional units. Bridges with skews or horizontal curvature may require the use of "swivel" modular joints. These accommodate lateral movement as well as longitudinal movements.

14.2.4 Expansion Joint Detailing

Show the elevation at the top of the extrusion at crown break points, gutter lines, and the start and end of curved sections. Dimension the lengths for straight and curved portions of the expansion joint.

For skews up to 20°, detail expansion joint as straight from edge of deck to edge of deck. See Figure 14.2.4.1.

For skews greater than 20° and up to 50°, detail expansion joint opening as straight between the top inside edge of barriers. Kink the joint opening at top inside edge of barriers so it is normal with outside edge of deck. See Figure 14.2.4.1.

For skews greater than 50°, curve the expansion joint ends. Use a 2'-0" radius for new bridges. A minimum radius of 1'-6" is allowed on bridge rehabilitation/reconstruction projects. Terminate the curved section 6 inches from gutter line. See Figure 14.2.4.1.

Use bend-up details for all bridges with curbs or barriers. For bridges with skewed joints, verify that the bend-up details in the barrier do not project out of the front face of the barrier.

Use snowplow protection for expansion joint devices (Bridge Details Part II Fig. 5-397.628) when joints are skewed greater than 15° and less than 50°.

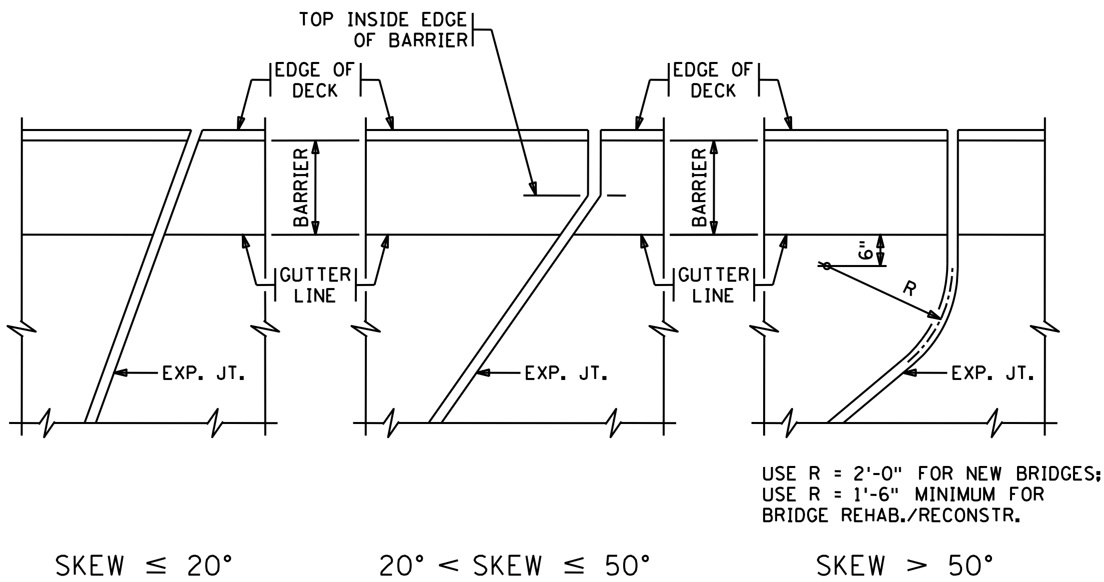

Figure 14.2.4.1
Expansion Joint Details

14.3 Bearings

The purpose of a bridge bearing is to transmit loads from the superstructure to the substructure while facilitating translation and rotation. Four types of bearings are typically used:

1) Expansion Bearing:
   - Transfers vertical load
   - Allows lateral movement in two directions
   - Allows longitudinal rotation
2) Guided Expansion Bearing:
   - Transfers vertical load and lateral load in one direction
   - Allows lateral movement in one direction
   - Allows longitudinal rotation
3) Limited Expansion Bearing:
   - Transfers vertical load and lateral load
   - Allows limited lateral movement in one direction
   - Allows longitudinal rotation

4) Fixed Bearing:
   - Transfers vertical load and lateral load
   - Resists lateral movement
   - Allows longitudinal rotation

All of Minnesota is located in Seismic Zone 1. See Article 3.7 of this manual for Seismic Zone 1 requirements for fixed and expansion bearings.

14.3.1 Loads and Movements

Design bearings for movements associated with a temperature range of 150°F (-30°F to 120°F) and a base construction temperature of 45°F.

Design elastomeric bearings for service loads and without Dynamic Load Allowance (IM).

[14.6.1]

Uplift at bearings is not permitted. Check bearings for uplift using the Strength I load combination with the minimum load factor for dead load.

For post-tensioned concrete bridges, consider the movement due to concrete creep for design of the bearings and expansions joints.

14.3.2 Bearing Details

Identify the type of bearing used at each support location on the superstructure framing plan.

For bearing components, the length is measured parallel to the centerline of the beam and the width is measured perpendicular to the centerline of the beam.

Check the dimensions of the bearing. Check that bearings have adequate clearance to other bearings (pier locations), are consistent with the beam end details (pier and abutment locations), and have adequate clearance to vertical faces of supporting elements. For fixed bearings, provide a minimum of 1 inch clear from the face of the bearing seat to the bearing pad or masonry plate. For expansion bearings, increase this minimum dimension to 3 inches.

Locate bearing anchor rods to permit field drilling of holes and provide 2 inch minimum clearance to reinforcement in bridge seat.

Bearings typically provide a modest amount of lateral restraint. However, designers must consider whether or not additional restraint needs to be provided. Typically, this additional restraint is provided by reinforced concrete guide lugs in the substructure or slotted hole fixed bearing assemblies adjacent to the center beam at expansion piers and abutments for bridges on large skews or curves. A 1 inch clear dimension must be provided between elements for either of these restraint methods. Provide additional restraint for pedestrian bridges.

The service life of bearings is less than the anticipated service life of a bridge. To simplify future maintenance operations and potential replacement, provide adequate clearance for the installation of jacks (at least 6 inches) and also provide a jacking load path. The load path may involve properly designed and detailed diaphragms or a suitable superstructure element.

When the slope of steel beam or plate girder superstructures exceeds 3%, incorporate tapered sole plates into the bearings. When the slope of prestressed beam superstructures exceeds 3%, incorporate tapered bearing plates into the bearings, using standard detail B309 as a guide.

For bridge bearings that have a masonry plate (e.g. - new disc bearings or existing lubricated bronze plate bearings being replaced in kind), include a 1/8 inch 60 durometer plain elastomeric pad between the bridge seat and new masonry plate to provide proper load distribution.

14.3.3 Elastomeric Bearings

Use of elastomeric bearings is preferred over other types of bearings. Fixed and expansion elastomeric bearing types are used most frequently.

MnDOT’s standard elastomeric bearings include:

- Detail B304: Fixed bearing used on bridge repair projects for replacement of existing bearings where there is insufficient height available for a curved plate bearing assembly, consisting of a steel reinforced elastomeric pad with bearing plate and anchor rods, sized to match the height of the existing bearing.
- Detail B305: Fixed bearing used at integral abutments or at piers with continuity diaphragms consisting of a plain elastomeric pad.
- Detail B309: Fixed bearing used at integral abutments or at piers with continuity diaphragms when grades exceed 3%, consisting of a plain elastomeric pad with a tapered bearing plate.
- Detail B310: Fixed bearing for prestressed concrete beams consisting of a plain elastomeric pad with a curved plate to allow rotation, and anchor rods for fixity.
- Detail B311: Expansion bearing for prestressed concrete beams consisting of a steel reinforced elastomeric pad with a curved plate to allow rotation.

- Detail B354: Fixed bearing for steel beams consisting of a plain elastomeric pad with a curved plate to allow rotation, and anchor rods for fixity.
- Detail B355: Expansion bearing for steel beams consisting of a steel reinforced elastomeric pad with a curved plate to allow rotation.

Note that the use of plain elastomeric pads is currently limited per Memo to Designers (2012-01) due to issues of excessive pad deformation. For all fixed curved plate bearing assemblies (Details B310 and B354), plain elastomeric bearing pads are replaced with cotton-duck bearing pads of the same size as required for a plain pad. However, the guidance regarding plain elastomeric pads within this article has been retained until a final policy decision is made regarding their use.

14.3.3.1 Design

Use the tables found in Article 14.7 of this manual whenever possible for consistency and economy among bearing designs.

Design elastomeric bearings using Method A of the AASHTO LRFD Specifications.

[Table 14.7.6.2-1] Design using an elastomer hardness of 60 durometers. The minimum shear modulus (G) for this material is 130 psi. The maximum shear modulus is 200 psi.

Except for special designs, use steel with a yield strength F_y equal to 36 ksi for all bearing assembly plates.

For MnDOT bridges with curved plate bearings, rotations need not be considered in the design.

For maximum compressive stress checks, use the minimum shear modulus value.

Holes are not permitted in elastomeric bearings.

14.3.3.1.1 Size and Stability

Although not an AASHTO requirement, MnDOT has historically used the following limits for the shape factor, S, for plain pads and internal laminates of steel reinforced pads with good success:

$$5.0 \le S \le 10.0$$

For fixed bearings, use $^1/_2$ inch or $^3/_4$ inch thickness plain pads. For expansion bearings, use $^3/_8$ inch, $^1/_2$ inch, or $^3/_4$ inch thickness internal laminates with $^1/_8$ inch thick steel reinforcing plates and $^1/_4$ thick cover layers.

Round dimensions for elastomeric bearings to the nearest 2 inch increment. For "RB", "M", and "MN" series prestressed beams, the minimum length (A) is 12 inches and the minimum width (B) is 24 inches. For "MW" series prestressed beams, the minimum length (A) is 16 inches and the minimum width (B) is 36 inches. For steel beams, the minimum length (A) is 8 inches. The width (B) shall not be less than the bottom flange width and not more than 2 inches greater than the bottom flange width for steel beams.

Based on the past performance of elastomeric bearings, MnDOT places a limit on the plan aspect ratio of a bearing. The length (A) is limited by the following equation:

$$B \leq 2.5 \cdot A$$

[14.7.6.3.6]

Additionally, the total elastomer thickness for the bearing (h_{rt}) must be no more than $^1/_3$ of the bearing pad length and width:

$$h_{rt} \leq \frac{A}{3} \text{ and } \frac{B}{3}$$

14.3.3.2 Fixed Bearings

[14.7.6.3.2]

Design fixed elastomeric bearings for a maximum compressive stress of 0.880 ksi. This includes a 10% increase for fixity.

Provide transverse fixity for $^2/_3$ of beams at fixed piers or fixed abutments for widths along skew greater than 70'-0".

14.3.3.3 Expansion Bearings

[14.7.6.3.2]

Design expansion elastomeric bearings to be steel-reinforced, with a maximum compressive stress equal to the lesser of 1.25GS or 1.25 ksi.

[14.7.6.3.4]

[Table 3.4.1-1]

In order to accommodate shear deformation in the pad due to thermal movement, the total height or thickness of elastomer (h_{rt}) must be greater than twice the maximum design movement. The LRFD Specifications list a load factor of 1.2 to be used for thermal movement calculations. However, based on past performance of bearings, use a load factor of 1.3 with half the design temperature range (75°F) when computing movement Δ_s for the shear deformation check.

Timely delivery of elastomeric bearings has been an issue in the past. In an effort to improve availability and encourage fabricators/contractors to stockpile pads, the number of laminates has been standardized into two groupings for "RB", "M", and "MN" series prestressed beam expansion elastomeric bearings. Where possible:

- For design movements $\Delta_s \leq 1.00''$, use a 12" x 24" pad with 3 – ½" thick laminates
- For pads where $1.00'' <$ design movement $\Delta_s \leq 1.75''$, use a 12" x 24" pad with 6 – ½" laminates

14.3.3.3.1 Minimum Compressive Load [C14.8.3.1]

LRFD Article C14.8.3.1 states that bearings should be anchored securely to the support to prevent their moving out of place. It further states that elastomeric bearings may be left without anchorage provided adequate friction is available and that a design coefficient of friction equal to 0.20 may be assumed between elastomer and concrete or steel. The minimum horizontal resistance to slippage of the bearing is:

$$H_{bres} = 0.20 \cdot P_{min}$$

The factored horizontal shear force H_{bu} generated in the bearing due to temperature movement is:

[14.6.3.1]

$$H_{bu} = G \cdot A_{pad} \cdot \frac{\Delta_u}{h_{rt}}$$

Equating H_{bres} and H_{bu} and solving for the minimum compressive load, P_{min} results in:

$$P_{min} \geq 5 \cdot G \cdot A_{pad} \cdot \frac{\Delta_u}{h_{rt}}$$

For the minimum compressive load check, use the maximum shear modulus value (0.200 ksi). For calculation of Δ_u, LRFD Article 3.4.1 specifies a load factor of 1.2. However, based on past performance of bearings, use a load factor of 1.0 with half the design temperature range (75°F) to calculate Δ_u.

If the check is not satisfied, revise the number and/or thickness of the laminates as needed. If the requirement still cannot be met, the standard curved plate expansion bearing assemblies (B311 and B355) contain a 3/8" x 3/8" bar welded to the bearing plate. This can be considered as a mechanism that secures the pads.

14.3.4 Disc Bearings

Use disc bearings where the loads are too high or the movements and rotations are too large to be readily accommodated with elastomeric bearings.

To reduce the possibility of generating large lateral forces in wide bridges supported on disc bearings, do not use guided or fixed bearings for beam lines outside of the center 45 feet of the bridge (distance measured along the substructure).

Due to a variety of preferences among disc bearing fabricators, explicit bearing details are not provided in the plans. Instead, provide a schematic of the bearings and all applicable design loads and movements in the plans. Using the provided data, the fabricator will determine the size of all of the bearing components, from the masonry plate to the sole plate.

Contact bearing fabricators to determine estimated bearing assembly heights for inclusion in the bridge plan. Also provide the appropriate standard plan note (see Appendix 2-C.J) in the bridge plan regarding the estimated bearing assembly heights and adjustments to seat elevations.

Fixed disc bearings allow for limited rotation, but no movement.

Guided expansion disc bearings allow for free movement in one direction and provide rotational capacity. However, movement perpendicular to the free movement direction is restrained. For curved bridges, assume the free movement direction to be along a chord connecting the ends of the beam. Guide bars must resist a minimum of 15% of the vertical service limit state load applied to the bearing.

Expansion disc bearings provide for rotation and unguided movement in all horizontal directions.

For computation of movement for design of disc bearings, use a load factor of 1.2.

14.3.5 Other Types of Bearings

Pot Bearings

Do not use pot bearings on roadway bridges.

Steel Bearings

This type of bearing does not contain elastomeric components to accommodate horizontal movement. Rather, horizontal movement takes place at the interface of a machined masonry plate and a lubricated bronze plate. Bridge Details Part I B351, B352, and B353 detail fixed, expansion, and guided expansion steel bearings respectively. They have all been archived, but can be retrieved if necessary for a repair plan. Note that these bearings are used for bridge repair projects only and are not for new construction.

Modify the standard bearings as necessary to accommodate unusually wide flanges or to provide movement capacities greater than those permitted with the standard details.

Check the clearances on the guide bars for curved bridges.

To reduce the possibility of generating large lateral forces in wide bridges supported on steel bearings, do not use guided or fixed bearings for beam lines outside of the center 45'-0" of the bridge (distance measured along the substructure).

Bearings for Railroad Bridges

Due to the extremely large loads associated with railroad bridges, spherical bearings, rocker bearings, disc bearings, or pot bearings are normally required. Rocker bearings may be considered for other applications where there is a combination of large load and large movement.

14.4 Curved Plate Design

Width

For prestressed concrete beams, set the width (H) equal to the bearing pad width (B) plus 2 inches. The width may change slightly (2 inches to 4 inches) for special designs. For steel beams, set the width equal to the bearing pad width (B).

Thickness

Use the LRFD design method for determining the curved plate thickness. Although AASHTO LRFD allows the nominal flexural resistance of a section to be taken as the plastic moment of a section, MnDOT limits the nominal flexural resistance to the yield moment. For steel elements in flexure use a resistance factor, ϕ_f, equal to 1.0.

[6.5.4.2]

The all-around weld, together with the friction between plates, causes the curved plate and bearing plate to act compositely. Therefore, the thickness for design can be considered to include the curved plate thickness plus the bearing plate thickness. The minimum thickness for curved plates is $1^1/_4$ inches. When greater thickness is required, increase plate thickness in $^1/_4$ inch increments.

Length

The minimum length (G) for the curved plate is $4^1/_2$ inches. The next permitted length is 6 inches, after which the length may be increased by increments of 2 inches up to a maximum of 12 inches. If, when designing the bearing plate, the required bearing plate thickness exceeds 2 inches, increase the length of the curved plate to reduce the length of the cantilever for the bearing plate design. Increase the curved plate length until the required bearing plate thickness alone and the required plate thickness for the curved plate based on composite design are approximately equal.

Radius

The radius of curved plates is to be no less than 16 inches. Check contact stresses to make sure that an adequate radius is provided. Based on past satisfactory performance of curved plate bearing

[14.7.1.4]

assemblies, use LRFD Equations C14.7.1.4-1 and C14.7.1.4-2 for determination of curved plate radius. If the resulting radius exceeds 24 inches, a special design must be completed using LRFD Equation 14.7.1.4-1 and steel with a yield strength F_y equal to 50 ksi.

14.5 Bearing Plate Design

Width

For prestressed concrete beams, set the width (E) equal to the curved plate width (H) plus 1 inch for expansion bearings. For fixed bearings, set the width (E) equal to the beam bottom flange width plus 8 inches. For steel beams, set the width (E) equal to the curved plate width (B) plus 2 inches for expansion bearings and plus 10 inches for fixed bearings.

Length

Set the length of the bearing plate (C) 2 inches larger than the bearing pad length (A).

Thickness

Use the LRFD design method for determining the bearing plate thickness. Although AASHTO LRFD allows the nominal flexural resistance of a section to be taken as the plastic moment of a section, MnDOT limits the nominal flexural resistance to the yield moment. For steel elements in

[6.5.4.2]

flexure use a resistance factor, ϕ_f, equal to 1.0.

The minimum thickness for bearing plates is $1^1/_2$ inches. When greater thickness is required, increase plate thickness in $^1/_4$ inch increments.

14.6 Sole Plate Design (Steel Beams)

Width

Set the width of the sole plate 2 inches larger than the curved plate width (B). The width cannot be equal to the beam flange width because of the fillet weld used to attach the sole plate to the flange. Increase the sole plate width by 1 inch if this occurs.

Length

The minimum length is 6 inches. Also, the length shall not be less than the curved plate length (G).

Thickness

The minimum sole plate thickness is $1^{1}/_{4}$ inches. When greater thickness is required, increase plate thickness in $^{1}/_{8}$ inch increments.

When the bearing pad width exceeds the bottom flange width, the sole plate must be designed as a cantilever to resist the load from the pad that extends outside the flange. Use the LRFD design method. Although AASHTO LRFD allows the nominal flexural resistance of a section to be taken as the plastic moment of a section, MnDOT limits the nominal flexural resistance to the yield moment. For steel elements in flexure use a resistance factor, ϕ_f, equal to 1.0.

[6.5.4.2]

14.7 Tables

The following tables contain standard curved plate bearing designs for prestressed concrete and steel beam superstructures based on the guidance given in this manual.

Table 14.7.1	Fixed Curved Plate Bearing Assembly for Prestressed Concrete Beams (B310)
Table 14.7.2	Expansion Curved Plate Bearing Assembly for Prestressed Concrete Beams (B311)
Table 14.7.3	Elastomeric Bearing Pad Thickness for Expansion Curved Plate Bearing Assembly for Prestressed Concrete Beams (B311)
Table 14.7.4	Fixed Curved Plate Bearing Assembly for Steel Beams (B354)
Table 14.7.5	Expansion Curved Plate Bearing Assembly for Steel Beams (B355)
Table 14.7.6	Elastomeric Bearing Pad Thickness for Expansion Curved Plate Bearing Assembly for Steel Beams (B355)

The curved plate thicknesses, the bearing plate thicknesses, and the steel beam sole plate thicknesses given in the tables were designed for the LRFD Strength I limit state by applying the live load factor of 1.75 to the maximum service load determined for the elastomeric pad design. This ensures a conservative design for the plates without knowing the exact mix of dead load and live load.

Use the tables whenever possible to increase consistency and economy among bearing designs. When calculated loads and/or movements fall outside the limits given in the table, two options are available to designers:

[14.7.1.4]

1) Complete a special elastomeric bearing design. For this case, use LRFD Equation 14.7.1.4-1 for determination of curved plate radius. Also, use steel with a yield strength equal to 50 ksi for the curved plate. Modify the B-Detail by specifying that the curved plate shall comply with MnDOT Spec. 3310.
2) Use a disc bearing.

Table 14.7.1
Fixed Curved Plate Bearing Assembly for "RB", "M", and "MN" Series Prestressed Concrete Beams (B310) ①

Max Service DL+LL (kips)	Bearing Pad Size (in)		Plain Pad Thickness (in)	Shape Factor	Bearing Plate Size (in) ③			Curved Plate Size (in) ③			Minimum Radius (in)
	A	B			C	E	F	G	H	J	
253	12	24	1/2	8.0	14	②	1 1/2	4 1/2	26	1 1/4	16
295	14	↓	↓	8.8	16	↓	↓	6	↓	↓	↓
337	16	↓	↓	9.6	18	↓	2	↓	↓	↓	↓
380	18	↓	3/4	6.9	20	↓	↓	8	↓	↓	↓
422	20	↓	↓	7.3	22	↓	2 1/4	↓	↓	↓	20

① Table does not apply to "MW" series beams. A special design is required.

② 34" for all "RB" series beams.
34" for all "M" series I-beams.
38" for all "MN" series I-beams.

③ Plates are conservatively designed for $1.75 \cdot (\text{Max Service DL} + \text{LL})$.

Table 14.7.2
Expansion Curved Plate Bearing Assembly for "RB", "M", and "MN" Series Prestressed Concrete Beams (B311) ①

Max Service DL+LL (Kips)	Bearing Pad Size (in)		Laminate Thickness (in)	Max. Number of Laminates ②	Shape Factor	Bearing Plate Size (in) ③			Curved Plate Size (in) ③			Minimum Radius (in)
	A	B				C	E	F	G	H	J	
300	12	24	1/2	7	8.0	14	27	1 1/2	4 1/2	26	1 1/4	16
360	12	↓	↓	7	8.0	14	↓	1 3/4	↓	↓	↓	↓
420	14	↓	↓	8	8.8	16	↓	↓	6	↓	↓	19

① Table does not apply to "MW" series beams. A special design is required.

② See Table 14.7.3 for determination of required number of laminates.

③ Plates are conservatively designed for $1.75 \cdot (\text{Max Service DL} + \text{LL})$.

Table 14.7.3
Elastomeric Bearing Pad Thickness for Expansion Curved Plate Bearing Assembly for Prestressed Concrete Beams (B311) ①②

Interior Laminate Thickness (in)	D (in) ③	Number of Laminates	Total Elastomer Thickness, h_{rt} (in) ③	Maximum Movement Δ_s (in) ④
$^1/_2$"	$2^1/_2$	3 ⑤	2	1
	$4^3/_8$	6 ⑤	$3^1/_2$	$1^3/_4$
	5	7	4	2
	$5^5/_8$	8	$4^1/_2$	$2^1/_4$

① Table does not apply to "MW" series beams. A special design is required. Table is based on requirements of AASHTO LRFD Bridge Design Specifications Article 14.7.6.3.4: $h_{rt} \geq 2\Delta_s$. Engineer must also check that the minimum compressive load requirement (discussed in Article 14.3.3.3.1) is satisfied. Specifically:

$$P_{min} \geq 5 \cdot G \cdot A_{pad} \cdot \frac{\Delta_u}{h_{rt}}$$

where P_{min} is the minimum factored load ($0.9 \cdot DC + 1.75 \cdot LL_{min}$), G is equal to the maximum shear modulus value (0.200 ksi), A_{pad} is the plan area of the bearing pad, and Δ_u is the movement of the bearing pad from the undeformed state using a 75°F temperature

② Engineer must also check the elastomeric bearing pad for compression deflection based on the requirements from AASHTO LRFD Bridge Design Specifications Articles 14.7.6.3.3 and 14.7.5.3.6.

③ Pad thickness D includes h_{rt} and $^1/_8$" steel reinforcement plates. Total elastomer thickness h_{rt} includes interior laminates plus $^1/_4$" cover layers.

④ Maximum movement Δ_s is the movement of the bearing pad from the undeformed state to the point of maximum deformation. Use a 75°F temperature change with a 1.3 load factor for calculation of maximum movement.

⑤ For "RB", "M", and "MN" series prestressed beam expansion elastomeric bearings, the number of laminates has been standardized for the movements that are most often encountered.

- If $\Delta_s \leq 1.00$", use 3 – ½" laminates.
- If 1.00" < $\Delta_s \leq 1.75$", use 6 – ½" laminates.

Table 14.7.4 – Fixed Curved Plate Bearing Assembly for Steel Beams (B354)

Beam Flange Min. Width (in)	Beam Flange Max. Width (in)	Max. Service DL+LL (kips)	Bearing Pad Size (in)		Plain Pad Thick. (in)	Shape Factor	Bearing Plate Size (in) ①			Curved Plate Size (in) ①			Min. Radius (in)	Sole Plate Size (in)		
			A	B			C	E	F	G	B	H		Length	Width	Thick.
12	14	81	8	14	1/2	5.1	10	24	1 1/2	4 1/2	14	1 1/4	16	6	16	1 1/4
↓	↓	116	10	↓	↓	5.8	12	↓	↓	↓	↓	↓	↓	↓	↓	↓
↓	↓	147	12	↓	↓	6.5	14	↓	↓	↓	↓	↓	↓	↓	↓	↓
↓	↓	172	14	↓	↓	7.0	16	↓	1 3/4	↓	↓	↓	↓	↓	↓	↓
14	16	97	8	16	1/2	5.3	10	26	1 1/2	4 1/2	16	1 1/4	16	6	18	1 1/4
↓	↓	140	10	↓	↓	6.2	12	↓	↓	↓	↓	↓	↓	↓	↓	↓
↓	↓	168	12	↓	↓	6.9	14	↓	↓	↓	↓	↓	↓	↓	↓	↓
↓	↓	197	14	↓	↓	7.5	16	↓	1 3/4	↓	↓	↓	↓	↓	↓	↓
↓	↓	225	16	↓	↓	8.0	18	↓	↓	6	↓	↓	17	↓	↓	↓
16	18	113	8	18	1/2	5.5	10	28	1 1/2	4 1/2	18	1 1/4	16	6	20	1 1/4
↓	↓	158	10	↓	↓	6.4	12	↓	↓	↓	↓	↓	↓	↓	↓	↓
↓	↓	190	12	↓	↓	7.2	14	↓	↓	↓	↓	↓	↓	↓	↓	↓
↓	↓	221	14	↓	↓	7.9	16	↓	1 3/4	↓	↓	↓	↓	↓	↓	↓
↓	↓	253	16	↓	↓	8.5	18	↓	2	6	↓	↓	↓	↓	↓	↓
↓	↓	285	18	↓	↓	9.0	20	↓	↓	8	↓	↓	19	8	↓	↓
18	20	130	8	20	1/2	5.7	10	30	1 1/2	4 1/2	20	1 1/4	16	6	22	1 1/4
↓	↓	176	10	↓	↓	6.7	12	↓	↓	↓	↓	↓	↓	↓	↓	↓
↓	↓	211	12	↓	↓	7.5	14	↓	↓	↓	↓	↓	↓	↓	↓	↓
↓	↓	246	14	↓	↓	8.2	16	↓	1 3/4	↓	↓	↓	↓	↓	↓	↓
↓	↓	281	16	↓	↓	8.9	18	↓	2	6	↓	↓	↓	↓	↓	↓
↓	↓	316	18	↓	↓	9.5	20	↓	↓	8	↓	↓	18	8	↓	↓
↓	↓	352	20	↓	↓	10.0	22	↓	2 1/4	↓	↓	↓	22	↓	↓	↓

Table 14.7.4 *(Cont.)* **– Fixed Curved Plate Bearing Assembly for Steel Beams (B354)**

Beam Flange Min. Width (in)	Beam Flange Max. Width (in)	Max. Service DL+LL (kips)	Bearing Pad Size (in)		Plain Pad Thick. (in)	Shape Factor	Bearing Plate Size (in) ①			Curved Plate Size (in) ①			Min. Radius (in)	Sole Plate Size (in)		
			A	B			C	E	F	G	B	H		Length	Width	Thick.
20	22	193	10	22	$\frac{1}{2}$	6.9	12	32	$1\frac{1}{2}$	$4\frac{1}{2}$	22	$1\frac{1}{4}$	16	6	24	$1\frac{1}{4}$
↓	↓	232	12	↓	↓	7.8	14	↓	↓	↓	↓	↓	↓	↓	↓	↓
↓	↓	271	14	↓	↓	8.6	16	↓	$1\frac{3}{4}$	↓	↓	↓	↓	↓	↓	↓
↓	↓	309	16	↓	↓	9.3	18	↓	2	6	↓	↓	↓	↓	↓	↓
↓	↓	348	18	↓	↓	9.9	20	↓	↓	8	↓	↓	17	8	↓	↓
↓	↓	387	20	↓	$\frac{3}{4}$	7.0	22	↓	$2\frac{1}{4}$	↓	↓	↓	21	↓	↓	↓
↓	↓	426	22	↓	↓	7.3	24	↓	$2\frac{1}{2}$	↓	↓	↓	25	↓	↓	↓
22	24	211	10	24	$\frac{1}{2}$	7.1	12	34	$1\frac{1}{2}$	$4\frac{1}{2}$	24	$1\frac{1}{4}$	16	6	26	$1\frac{1}{4}$
↓	↓	253	12	↓	↓	8.0	14	↓	↓	↓	↓	↓	↓	↓	↓	↓
↓	↓	295	14	↓	↓	8.8	16	↓	$1\frac{3}{4}$	↓	↓	↓	↓	↓	↓	↓
↓	↓	337	16	↓	↓	9.6	18	↓	2	6	↓	↓	↓	↓	↓	↓
↓	↓	380	18	↓	$\frac{3}{4}$	6.9	20	↓	↓	8	↓	↓	↓	8	↓	↓
↓	↓	422	20	↓	↓	7.3	22	↓	$2\frac{1}{4}$	↓	↓	↓	20	↓	↓	↓
↓	↓	464	22	↓	↓	7.7	24	↓	$2\frac{1}{2}$	↓	↓	↓	24	↓	↓	↓
24	26	274	12	26	$\frac{1}{2}$	8.2	14	36	$1\frac{1}{2}$	$4\frac{1}{2}$	26	$1\frac{1}{4}$	16	6	28	$1\frac{1}{4}$
↓	↓	320	14	↓	↓	9.1	16	↓	$1\frac{3}{4}$	↓	↓	↓	↓	↓	↓	↓
↓	↓	366	16	↓	↓	9.9	18	↓	2	6	↓	↓	↓	↓	↓	↓
↓	↓	411	18	↓	$\frac{3}{4}$	7.1	20	↓	↓	8	↓	↓	↓	8	↓	↓
↓	↓	457	20	↓	↓	7.5	22	↓	$2\frac{1}{4}$	↓	↓	↓	19	↓	↓	↓
↓	↓	503	22	↓	↓	7.9	24	↓	$2\frac{1}{2}$	↓	↓	↓	23	↓	↓	↓

① Plates are conservatively designed for 1.75 · Max Service DL+ LL

Table 14.7.5 – Expansion Curved Plate Bearing Assembly for Steel Beams (B355)

Beam Flange Min. Width (in)	Beam Flange Max. Width (in)	Max. Service DL+LL (kips)	Bearing Pad Size (in)		Laminate Thick. (in)	Max. Number of Laminates ①	Shape Factor	Bearing Plate Size (in) ②			Curved Plate Size (in) ②			Min. Radius (in)	Sole Plate Size (in)		
			A	B				C	E	F	G	B	H		Length	Width	Thick.
12	14	123	8	14	3/8	5	6.8	10	16	1 1/2	4 1/2	14	1 1/4	16	6	16	1 1/4
↓	↓	175	10	↓	↓	7	7.8	12	↓	↓	↓	↓	↓	↓	↓	↓	↓
↓	↓	210	12	↓	↓	9	8.6	14	↓	1 3/4	↓	↓	↓	21	↓	↓	↓
14	16	147	8	16	3/8	5	7.1	10	18	1 1/2	4 1/2	16	1 1/4	16	6	18	1 1/4
↓	↓	200	10	↓	↓	7	8.2	12	↓	↓	↓	↓	↓	↓	↓	↓	↓
↓	↓	240	12	↓	↓	9	9.1	14	↓	1 3/4	↓	↓	↓	19	↓	↓	↓
16	18	172	8	18	3/8	5	7.4	10	20	1 1/2	4 1/2	18	1 1/4	16	6	20	1 1/4
↓	↓	225	10	↓	↓	7	8.6	12	↓	↓	↓	↓	↓	↓	↓	↓	↓
↓	↓	270	12	↓	↓	9	9.6	14	↓	1 3/4	↓	↓	↓	17	↓	↓	↓
↓	↓	315	14	↓	1/2	8	7.9	16	↓	↓	6	↓	↓	23	↓	↓	↓
18	20	198	8	20	3/8	5	7.6	10	22	1 1/2	4 1/2	20	1 1/4	16	6	22	1 1/4
↓	↓	250	10	↓	↓	7	8.9	12	↓	↓	↓	↓	↓	↓	↓	↓	↓
↓	↓	300	12	↓	↓	9	10.0	14	↓	1 3/4	↓	↓	↓	↓	↓	↓	↓
↓	↓	350	14	↓	1/2	8	8.2	16	↓	↓	6	↓	↓	22	↓	↓	↓
20	22	275	10	22	3/8	7	9.2	12	24	1 1/2	4 1/2	22	1 1/4	16	6	24	1 1/4
↓	↓	330	12	↓	1/2	↓	7.8	14	↓	1 3/4	↓	↓	↓	↓	↓	↓	↓
↓	↓	385	14	↓	↓	8	8.6	16	↓	↓	6	↓	↓	21	↓	↓	↓
22	24	300	10	24	3/8	7	9.4	12	26	1 1/2	4 1/2	24	1 1/4	16	6	26	1 1/4
↓	↓	360	12	↓	1/2	↓	8.0	14	↓	1 3/4	↓	↓	↓	↓	↓	↓	↓
↓	↓	420	14	↓	↓	8	8.8	16	↓	↓	6	↓	↓	20	↓	↓	↓
24	26	390	12	26	1/2	7	8.2	14	28	1 3/4	4 1/2	26	1 1/4	16	6	28	1 1/4
↓	↓	455	14	↓	↓	8	9.1	16	↓	↓	6	↓	↓	19	↓	↓	↓

① See Table 14.7.6 for determination of required number of laminates.

② Plates are conservatively designed for 1.75 · Max Service DL+ LL

Table 14.7.6
Elastomeric Bearing Pad Thickness for Expansion Curved Plate Bearing Assembly for Steel Beams (B355)①②

Interior Laminate Thickness (in)	D (in) ③	Number of Laminates ④	Total Elastomer Thickness, h_{rt} (in) ③	Maximum Movement (in) ⑤
3/8"	1 1/8	1	7/8	7/16
	1 5/8	2	1 1/4	5/8
	2 1/8	3	1 5/8	13/16
	2 5/8	4	2	1
	3 1/8	5	2 3/8	1 3/16
	3 5/8	6	2 3/4	1 3/8
	4 1/8	7	3 1/8	1 9/16
	4 5/8	8	3 1/2	1 3/4
	5 1/8	9	3 7/8	1 15/16
	5 5/8	10	4 1/4	2 1/8
	6 1/8	11	4 5/8	2 5/16
1/2"	1 1/4	1	1	1/2
	1 7/8	2	1 1/2	3/4
	2 1/2	3	2	1
	3 1/8	4	2 1/2	1 1/4
	3 3/4	5	3	1 1/2
	4 3/8	6	3 1/2	1 3/4
	5	7	4	2
	5 5/8	8	4 1/2	2 1/4
	6 1/4	9	5	2 1/2
	6 7/8	10	5 1/2	2 3/4
	7 1/2	11	6	3

① Table is based on requirements of AASHTO LRFD Article 14.7.6.3.4: $h_{rt} \geq 2\Delta_s$. Engineer must also check that the minimum compressive load requirement (discussed in Article 14.3.3.3.1 of this manual) is satisfied:

$$P_{min} \geq 5 \cdot G \cdot A_{pad} \cdot \frac{\Delta_u}{h_{rt}}$$

where P_{min} is the minimum factored load ($0.9 \cdot DC + 1.75 \cdot LL_{min}$), G is equal to the maximum shear modulus value (0.200 ksi), A_{pad} is the plan area of the bearing pad, and Δ_u is the movement of the bearing pad from the undeformed state using a 75°F temperature change with a 1.0 load factor.

② Engineer must also check the elastomeric bearing pad for compression deflection based on the requirements from AASHTO LRFD Bridge Design Specifications Articles 14.7.6.3.3 and 14.7.5.3.6.

③ Pad thickness D includes h_{rt} and 1/8" steel reinforcement plates. Total elastomer thickness h_{rt} Includes interior laminates plus 1/4" cover layers.

④ Engineer must also check that $S_i^2/n < 22$ to meet requirements of AASHTO LRFD Article 14.7.6.3.4.

⑤ Maximum movement Δ_s is the movement of the bearing pad from the undeformed state to the point of maximum deformation. Use a 75°F temperature change with a 1.3 load factor for calculation of maximum movement.

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14.8 Design Examples

Two design examples follow. The first is a fixed elastomeric bearing. The second is an expansion elastomeric bearing.

14.8.1 Fixed Elastomeric Bearing Design Example [14.7.6]

Note that the use of plain elastomeric pads is currently limited per Memo to Designers (2012-01) due to issues of excessive pad deformation. For all fixed curved plate bearing assemblies (Details B310 and B354), plain elastomeric bearing pads are replaced with cotton-duck bearing pads of the same size as required for a plain pad. However, the following design example has been retained until a final policy decision is made regarding their use.

This example illustrates the design of a fixed curved plate elastomeric bearing for a prestressed concrete beam bridge. The bearing is based on Bridge Details Part I B310. The elastomeric bearing pad is designed using Method A (LRFD Article 14.7.6). Figure 14.8.1.1 shows the bearing components.

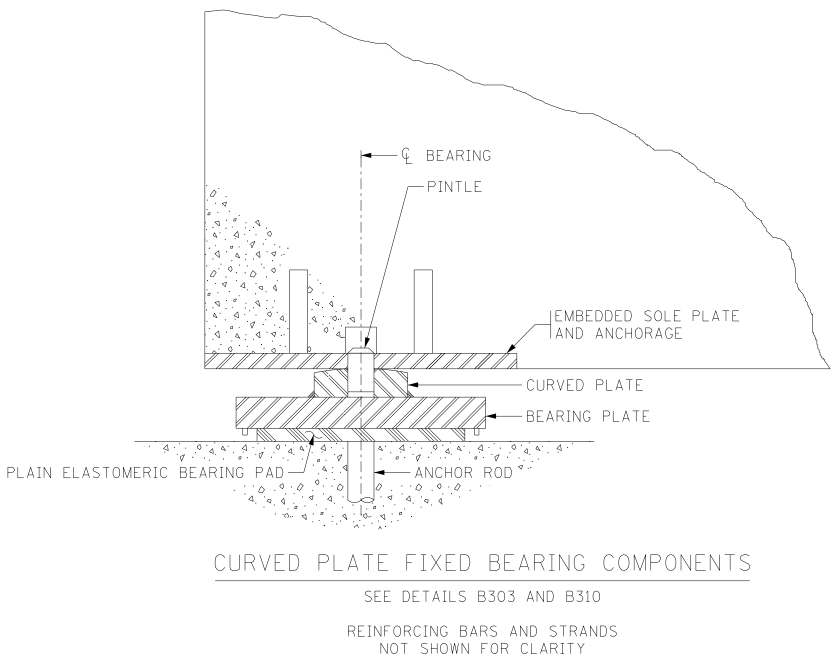


Figure 14.8.1.1

After the maximum reaction is calculated, the bearing design should be selected from the standard tables found in BDM Article 14.7. If a standard design will not work due to unusual loads or geometric constraints, a custom design will be required.

This example will outline the procedure to custom design a fixed elastomeric bearing. First, design the elastomeric pad. Next determine the steel plate requirements for the rest of the bearing assembly.

A. Design Elastomeric Bearing Pad [14.7.6]

The prestressed beam for this example is an MN63, which has a bottom flange width equal to 30 inches. The design loads are given as follows:

Dead Load = P_{dl} = 156 kips

Maximum Live Load = 97.6 kips (Does not include IM)

Minimum Live Load $= P_{llmin} = 0$ kips

Combining the loads results in the following:

Maximum service limit state load $P_s = P_{dl} + P_{llmax}$
$= 156 + 97.6 = 253.6$ kips

Minimum strength limit state load $P_{umin} = 0.9 \cdot P_{dl} + 1.75 \cdot P_{llmin}$
$= 0.9 \cdot 156 + 1.75 \cdot 0$
$= 140.4$ kips
Therefore, there is no uplift.

[Table 14.7.6.2-1]

MnDOT Spec. 3741 specifies an elastomeric pad with a hardness of 60 durometers. Per LRFD Table 14.7.6.2-1, the shear modulus G for design ranges from 0.130 to 0.200 ksi.

The minimum bearing pad dimensions for a prestressed beam are:
Length A = 12 in
Width B = 24 in

Assuming a plain pad thickness D = 0.50 in,

[14.7.5.1]

$$\text{Shape factor } S = \frac{A \cdot B}{2 \cdot D \cdot (A + B)} = \frac{12 \cdot 24}{2 \cdot 0.5 \cdot (12 + 24)} = 8.0$$

[14.7.6.3.2]

The allowable compressive stress σ_{sall} for plain pads is the smaller of:

$\sigma_{sall} = 1.00 \cdot G \cdot S$
$= 1.00 \cdot 0.130 \cdot 8.0$
$= 1.04$ ksi
or $\sigma_{sall} = 0.80$ ksi. < <u>GOVERNS</u>

The allowable is increased by 10% for a fixed bearing because shear deformation is prevented.

$\sigma_{sallfixed} = 1.10 \cdot 0.80 = 0.88$ ksi

Then the maximum service limit state stress is:

$$\text{Actual } \sigma_S = \frac{P_S}{A \cdot B} = \frac{253.6}{12 \cdot 24} = 0.88 \text{ ksi} = 0.88 \text{ ksi} \quad \underline{\text{OK}}$$

There are two geometric checks on the bearing pad to ensure that it has good proportions. First, in plan, the length of the long side can be no more the 2.5 times the length of the short side. Second, the height of the elastomeric portion can be no more than $^1/_3$ the length of the short side of the pad.

$$2.5 \cdot A = 2.5 \cdot 12 = 30 \text{ in} \geq 24 \text{ in} \quad \underline{\text{OK}}$$

[14.7.6.3.6]

$$\frac{A}{3} = \frac{12}{3} = 4 \text{ in} > 0.50 \text{ in} = h_{rt} \quad \underline{\text{OK}}$$

Therefore, use a 12″ x 24″ x ½″ plain pad.

B. Curved Plate Design

Set the curved plate width 2 inches wider than the bearing pad.

$$H = B + 2 = 24 + 2 = 26 \text{ in}$$

The all-around weld, together with the friction between plates, causes the curved plate and bearing plate to act compositely. Therefore, the thickness for design can be considered to include the curved plate thickness plus the bearing plate thickness.

Begin by checking the thickness for a curved composite plate with a length of 4.5 inches. If, when designing the bearing plate, the required bearing plate thickness exceeds 2 inches, increase the length of the curved plate to reduce the length of the cantilever for the bearing plate design. Increase the curved plate length until the required bearing plate thickness alone and the required plate thickness for the curved plate based on composite design are approximately equal.

$$\text{Curved Plate Length} = G = 4.5 \text{ in}$$

The radius of the contact surface is the first parameter to determine for the curved plate. The radius of the curved plate is a function of the yield strength of the steel and the load intensity.

The sole plate width minus the chamfers at each side is greater than the length of the curved plate. Then the contact length of the sole plate with the curved plate is equal to the length of the curved plate minus the pintles and the associated bevels around each of the pintles. See Figure 14.8.1.2.

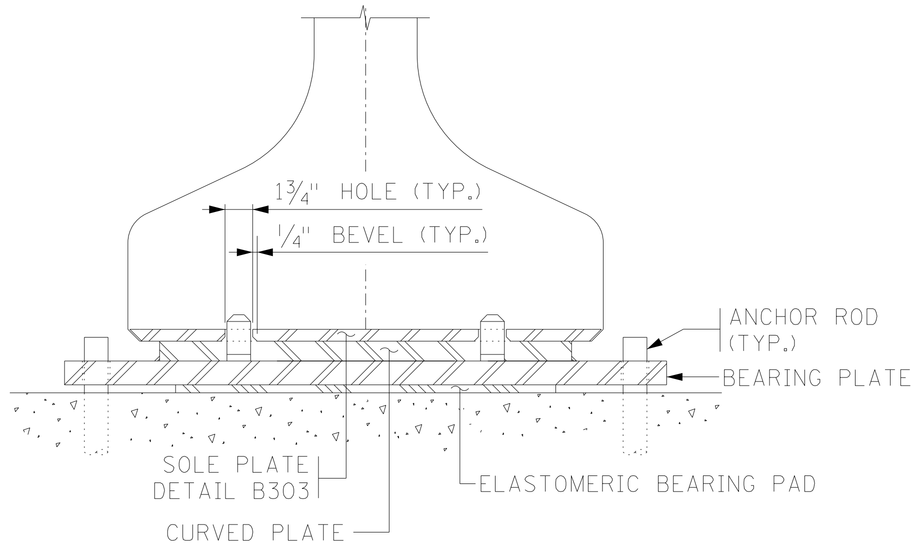


Figure 14.8.1.2

Contact length L_{sp} is equal to

$$L_{sp} = 26 - 2 \cdot (2.25) = 21.50 \text{ in}$$

[14.7.1.4]

Based on past satisfactory performance of curved plate bearing assemblies, the minimum radius permitted is determined with LRFD Equation C14.7.1.4-1 and C14.7.1.4-2. Start by assuming the diameter d is 25 inches or less, so use the first equation. Rearranging the equation to solve for diameter results in the following:

$$d_{min} = \frac{20 \cdot p}{0.6 \cdot (F_y - 13)} = \frac{20 \cdot \left(\frac{P_s}{L_{sp}}\right)}{0.6 \cdot (F_y - 13)} = \frac{20 \cdot \left(\frac{253.6}{21.50}\right)}{0.6 \cdot (36 - 13)}$$

$$= 17.1 \text{ in} < 25.0 \text{ in}$$

The assumption was correct. Then the radius R_{min} = 8.55 inches.

The radius of curved plates is to be no less than 16 inches. Therefore, specify the minimum radius for the curved plate to be 16 inches.

The required thickness of the curved composite plate is based on a simple model in which a uniform pressure is applied to the bottom of the plate and the reaction is a line load. See Figure 14.8.1.3. Use strength limit state loads for flexural design of the steel plates.

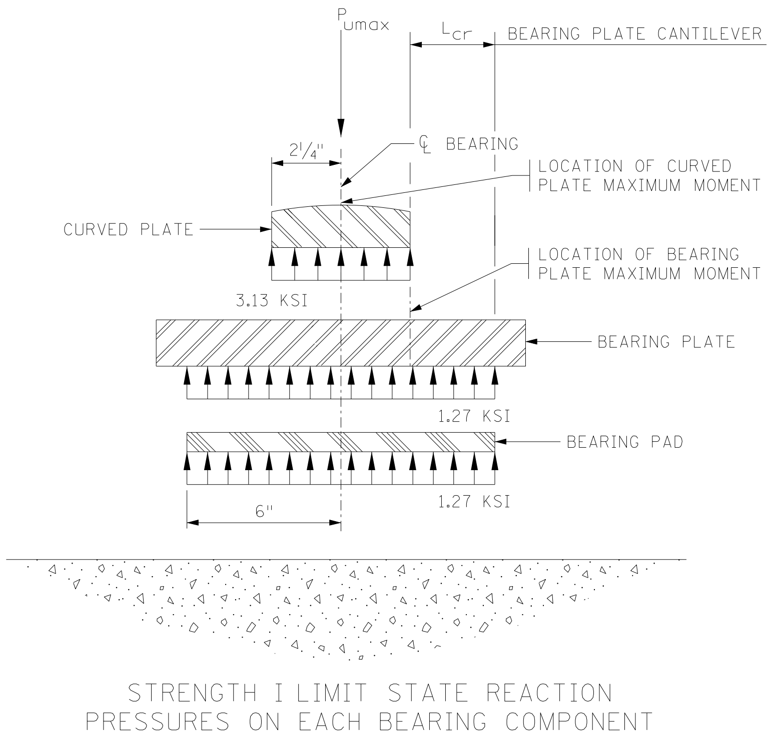


Figure 14.8.1.3

Maximum strength limit state load $P_{umax} = 1.25 \cdot P_{dl} + 1.75 \cdot P_{llmax}$

$= 1.25 \cdot 156 + 1.75 \cdot 97.6$

$= 365.8$ kips

Pressure on the composite plate is:

$$\sigma_{cp} = \frac{P_{umax}}{G \cdot H} = \frac{365.8}{4.5 \cdot 26} = 3.13 \text{ ksi}$$

Maximum moment on the composite plate is:

$$M_{ucp} = \sigma_{cp} \cdot \frac{G}{2} \cdot \frac{G}{4} \cdot H = 3.13 \cdot \frac{4.5}{2} \cdot \frac{4.5}{4} \cdot 26 = 206.0 \text{ kip-in}$$

[6.12.2.2.7]

Consider the plate to be fully laterally supported. The AASHTO LRFD specifications allow the nominal flexural resistance of a rectangular section to be taken as the plastic moment. However, MnDOT limits the nominal resistance to the yield moment. Find the required composite plate thickness such that the yield moment, M_y, of the section will have adequate capacity to resist the design moment, M_{ucp}.

[6.5.4.2]

For steel elements in flexure, $\phi_f = 1.0$.

The flexural resistance, M_r, of the composite plate section is:

$$M_r = \phi_f M_{ncp} = \phi_f M_y = \phi_f S_{cp} F_y$$

The section modulus of the composite plate is:

$$S_{cp} = \frac{H \cdot J^2}{6}$$

where J = thickness of composite plate

Then by substitution:

$$M_r = \phi_f \cdot \left(\frac{H \cdot J^2}{6}\right) \cdot F_y$$

Set the flexural resistance of the composite plate section equal to the design moment:

$$M_{ucp} = \phi_f \cdot \left(\frac{H \cdot J^2}{6}\right) \cdot F_y$$

Solve for composite plate thickness:

$$J \geq \sqrt{\frac{6 \cdot M_{ucp}}{\phi_f \; F_y \cdot H}} = \sqrt{\frac{6 \cdot 206.0}{1.0 \cdot 36 \cdot 26}} = 1.15 \text{ in}$$

The standard curved plate thickness is 1¼ inches, so composite action does not need to be considered. Use a 1¼ thick curved plate.

C. Bearing Plate Design

Per Detail B310, the length (C) is set at 2 inches longer than the pad length. This provides room for the keeper bar to be attached to the bottom of the bearing plate. The width (E) is set 8 inches greater than the beam bottom flange width. This provides room on each side for the anchor rods.

$$E = b_f + 8 = 30 + 8 = 38 \text{ in}$$

$$C = A + 2 = 12 + 2 = 14 \text{ in}$$

The bearing plate is assumed to act as a cantilever (See Figure 14.8.1.3) that carries the maximum strength limit state load to the curved plate. The cantilever length is half the difference in length between the bearing pad and the curved plate.

$$\sigma_{bp} = \frac{P_{umax}}{A \cdot B} = \frac{365.8}{12 \cdot 24} = 1.27 \text{ ksi}$$

$$L_{cr} = \frac{A}{2} - \frac{G}{2} = \frac{12}{2} - \frac{4.5}{2} = 3.75 \text{ in}$$

$$M_{ubp} = \sigma_{bp} \cdot \frac{{L_{cr}}^2}{2} \cdot E = 1.27 \cdot \frac{3.75^2}{2} \cdot 38 = 339.3 \text{ kip-in}$$

[6.12.2.2.7]

Again, the AASHTO LRFD Specifications allow the nominal flexural capacity to be set equal to the plastic moment of the plate. However, MnDOT limits the nominal capacity of the plate to the yield moment. Find the required bearing plate thickness such that the yield moment, M_y, of the section will have adequate capacity to resist the design moment, M_{ubp}.

The flexural resistance, M_r, of the bearing plate section is:

$$M_r = \phi_f M_{nbp} = \phi_f M_y = \phi_f S_{bp} F_y$$

The section modulus of the bearing plate is:

$$S_{bp} = \frac{E \cdot F^2}{6}$$

where F = thickness of bearing plate

Then by substitution:

$$M_r = \phi_f \cdot \left(\frac{E \cdot F^2}{6} \right) \cdot F_y$$

Set the flexural resistance of the bearing plate section equal to the design moment:

$$M_{ubp} = \phi_f \cdot \left(\frac{E \cdot F^2}{6} \right) \cdot F_y$$

Solve for bearing plate thickness:

$$\text{Min. } F = \sqrt{\frac{6 \cdot M_{ubp}}{\phi_f \ F_y \cdot E}} = \sqrt{\frac{6 \cdot 339.3}{1.0 \cdot 36 \cdot 38}} = 1.22 \text{ in}$$

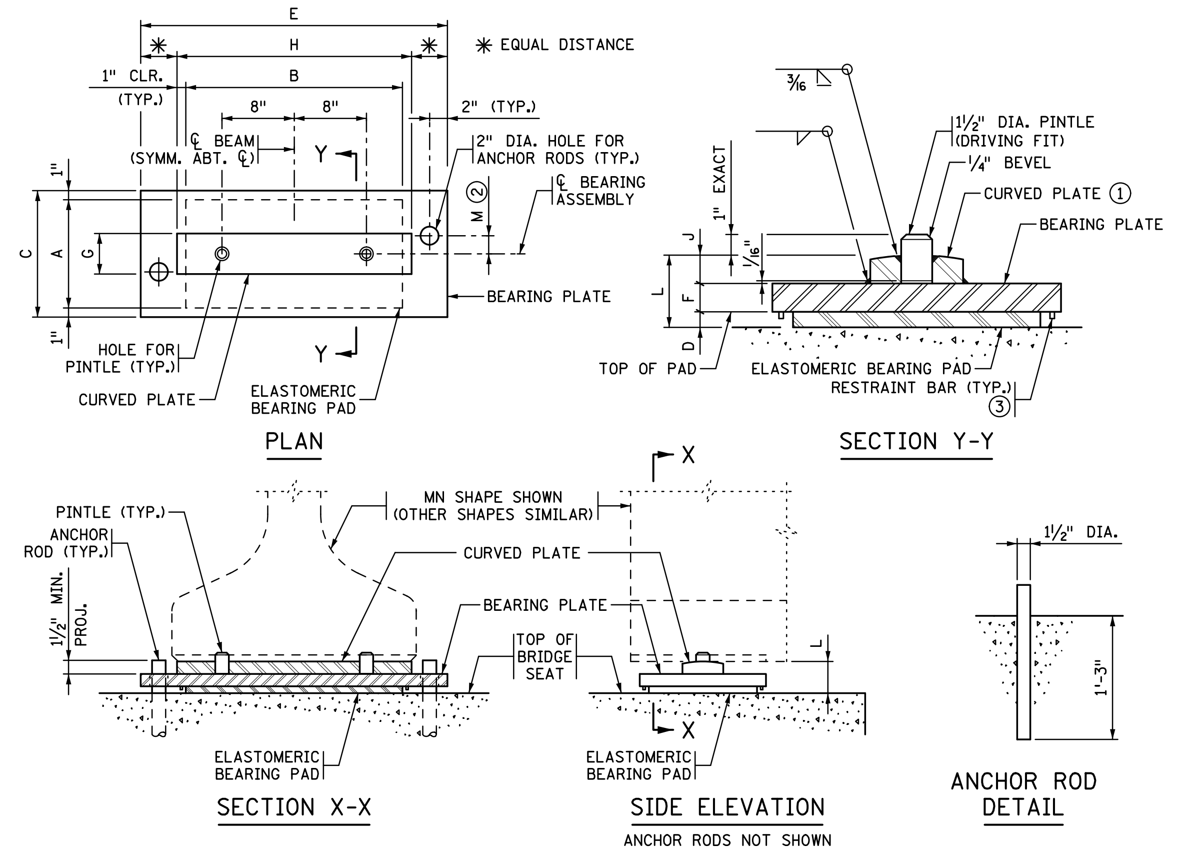
The standard bearing plate thickness is 1½ inches, so use a 1½ thick bearing plate.

D. Anchor Rods/Pintles

The Detail B310 standard set of two $1^{1}/_{2}$ inch anchor rods has a factored load capacity of 72.4 kips and the set of two pintles has a factored load capacity of 100.6 kips. For many projects, such as the superstructure assumed for this design example, the capacity of the anchor rods and pintles will be adequate by inspection. For projects where two or more piers are fixed or where significant longitudinal forces are anticipated, evaluate the capacity of the anchor rods and pintles.

The anchor rod offset dimension (M) is to be calculated such that the anchor rods are located along the beam centerline of bearing. In this case, the skew is zero, so $M = 0$ inches.

The bearing design is summarized in Figures 14.8.1.4 and 14.8.1.5.



TABLE

ASSEMBLY TYPE	LOCATION	BEAM SIZE	BEARING PAD SIZE			SHAPE FACTOR	BEARING PLATE SIZE			CURVED PLATE SIZE				ANCHOR ROD OFFSET		ASSY. HEIGHT	RESTRAINT PATTERN ③
			A	B	D		C	E	F	G	H	J	R ①	+/- ②	M	L	
F1	PIER	MN63	12"	24"	½"	8.0	14"	38"	1½"	4½"	26"	1¼"	16"		0"	3¼"	A-1

NOTES:

PROVIDE ELASTOMERIC MATERIALS AND PAD CONSTRUCTION PER SPEC. 3741.

PROVIDE STEEL PLATES PER SPEC. 3306.

PROVIDE ANCHOR RODS PER SPEC. 3306. GALVANIZE PER SPEC. 3394.

PROVIDE PINTLES PER SPEC. 3309.

GALVANIZE STRUCTURAL STEEL BEARING ASSEMBLY AFTER FABRICATION PER SPEC. 3394, EXCEPT AS NOTED.

PAYMENT FOR BEARING ASSEMBLY INCLUDES ALL MATERIAL ON THIS DETAIL.

① THE MIN. RADIUS IS 16" UNLESS OTHERWISE SPECIFIED IN THE TABLE. THE MAX. RADIUS IS 24". FINISH TO 250 MICRO. THE FINISHED THICKNESS OF THE PLATE MAY BE 1/16" LESS THAN SHOWN.

② "+" DENOTES OFFSET AS SHOWN.
"-" DENOTES OFFSET OPPOSITE OF SHOWN.

③ REFER TO BEARING PAD RESTRAINT SHEET FOR ADDITIONAL INFORMATION AND DETAILS.

DESIGN DATA:

MAX. FACTORED SHEAR RESISTANCE:
- 50.3 KIPS PER 1½" DIA. PINTLE
- 36.2 KIPS PER 1½" DIA. ANCHOR ROD

APPROVED: SEPTEMBER 22, 2011	STATE OF MINNESOTA DEPARTMENT OF TRANSPORTATION	REVISED	DETAIL NO.
Nancy Daubenberger STATE BRIDGE ENGINEER	CURVED PLATE BEARING ASSEMBLY (PRESTRESSED CONCRETE BEAMS) (FIXED)	11-06-2013 11-03-2015 01-05-2017 11-02-2017	B310

Figure 14.8.1.4

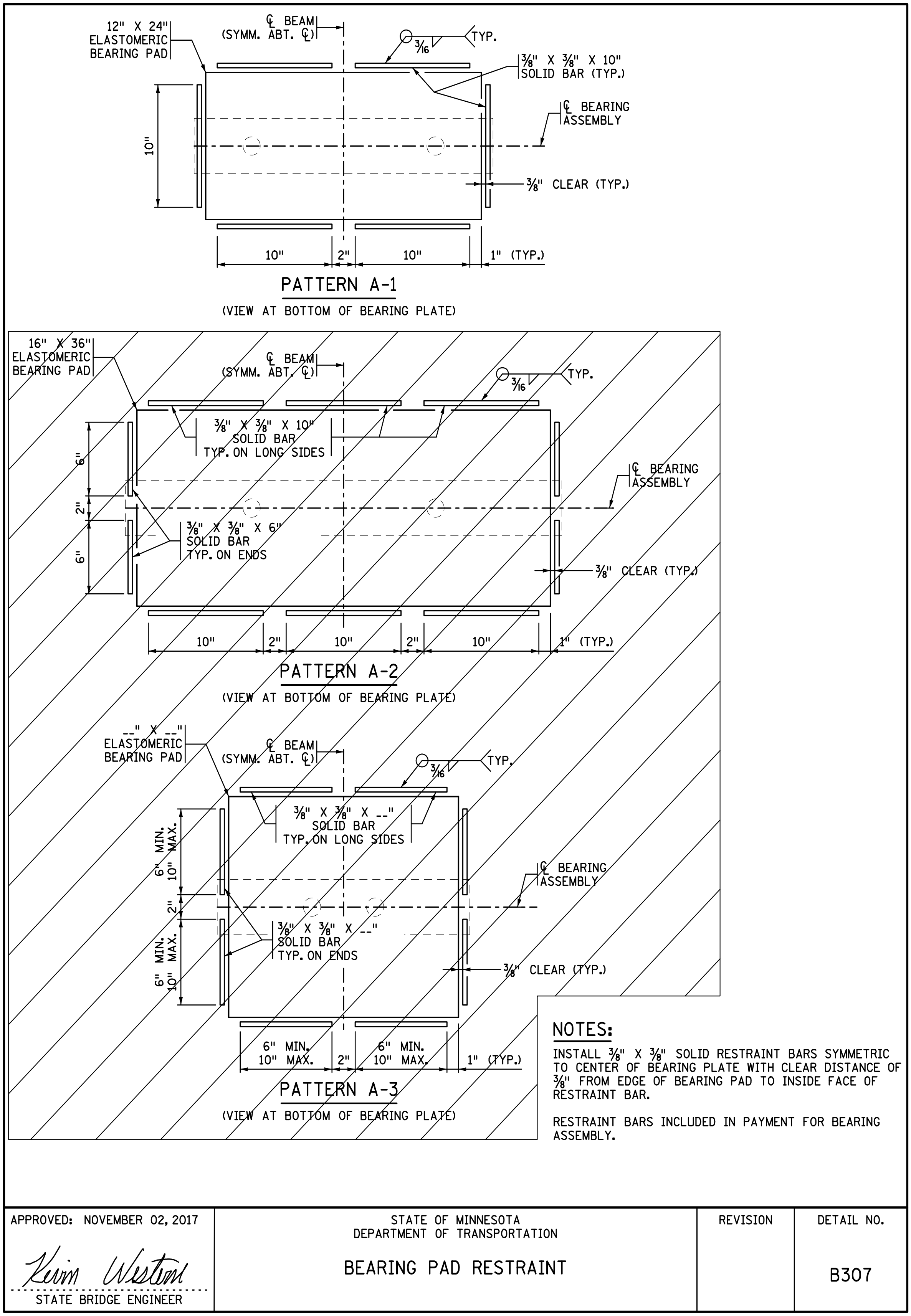


Figure 14.8.1.5

14.8.2 Expansion Elastomeric Bearing Design Example [14.7.6]

This example illustrates the design of an expansion curved plate elastomeric bearing for a steel plate girder bridge. The bearing is based on Bridge Details Part I, B355. The elastomeric bearing pad is designed using Method A (LRFD Article 14.7.6). Figure 14.8.2.1 labels the primary components for this type of bearing.

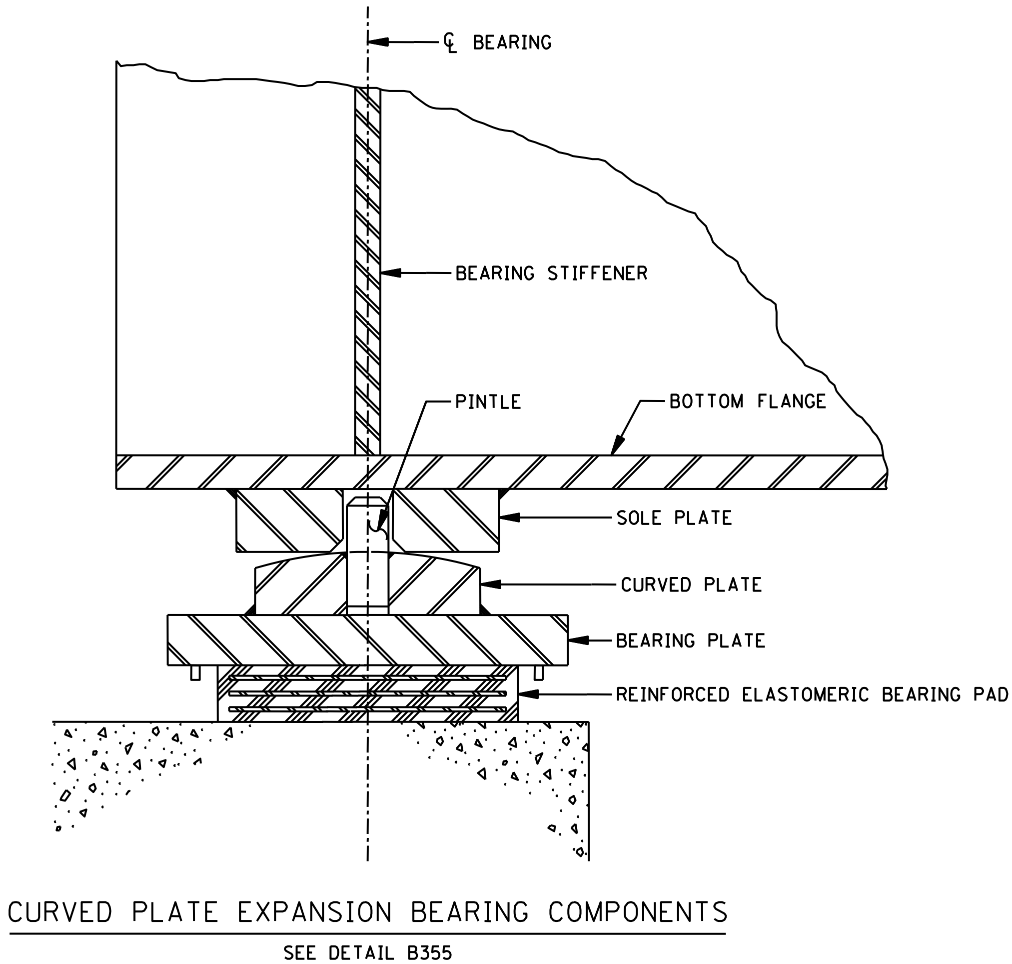


Figure 14.8.2.1

After the maximum reaction is calculated, the bearing design should be selected from standard bearing tables in Article 14.7 of this manual. If a standard design will not work due to unusual loads or geometric constraints, a custom design will be required.

This example will outline the procedure to custom design an expansion elastomeric bearing. First determine the size of the pad required. Next determine the steel plate requirements for the rest of the assembly.

Two movements are accommodated with this type of bearing, rotation and horizontal translation. The rotation takes place at the interface between the sole plate and the curved plate. The horizontal translation takes place in the reinforced elastomeric bearing pad.

A. Design Reinforced Elastomeric Bearing Pad

The bearing pad needs sufficient plan area to ensure that compression stresses are below the limit. It also needs sufficient thickness to accommodate the horizontal translation. Begin by determining the design movements and loads for the bearing.

Design Movements

The bearing is located at the abutment of a two-span steel plate girder bridge with equal spans of 152'-0". Fixity is assumed at the pier.

Expansion length = L_{exp} = 152 ft

[6.4.1] Coefficient of thermal expansion for steel $= \alpha_{steel} = 0.0000065$

Design temperatures:

Base Construction Temperature: $T_{constr} = 45\,°F$

Low Temperature: $T_{low} = -30\,°F$

High Temperature: $T_{high} = 120\,°F$

Temperature Fall: $T_{fall} = T_{constr} - T_{low} = 75\,°F$

Temperature Rise: $T_{rise} = T_{high} - T_{constr} = 75\,°F$

Movement for minimum compressive stress check (Load Factor $= 1.0$)

$$\Delta_u = 1.0 \cdot T_{fall} \cdot \alpha_{steel} \cdot L_{exp} = 1.0 \cdot 75 \cdot 0.0000065 \cdot 152 \cdot 12 = 0.89 \text{ in}$$

Movement for shear deformation check (Load Factor $= 1.3$)

$$\Delta_s = 1.3 \cdot T_{fall} \cdot \alpha_{steel} \cdot L_{exp} = 1.3 \cdot \Delta_u = 1.3 \cdot 0.89 = 1.16 \text{ in}$$

Design Loads

The design loads for the bearing are given as follows:

Dead load $= P_{dl} = 117$ kips

Maximum live load (without IM) $= P_{ll_{max}} = 108$ kips

Minimum live load (without IM) $= P_{ll_{min}} = -15$ kips

The bearing is sized using the maximum service limit state load:

$$P_{smax} = P_{dl} + P_{llmax} = 117 + 108 = 225 \text{ kips}$$

The minimum compressive load check is made with Strength I limit state load:

$$P_{umin} = 0.9 \cdot P_{dl} + 1.75 \cdot P_{llmin} = 0.9 \cdot 117 + 1.75 \cdot (-15) = 79.1 \text{ kips}$$

Size Elastomeric Bearing Pad

[Table 14.7.6.2-1]

MnDOT Spec. 3741 specifies an elastomeric pad with a hardness of 60 durometers. Per LRFD Table 14.7.6.2-1, the shear modulus G for design ranges from 0.130 to 0.200 ksi.

In order to accommodate shear deformation in the pad due to thermal movement, the total thickness of elastomer must be at least twice the design movement. The movement Δ_s with the 1.3 multiplier is used for this check.

[Eq. 14.7.6.3.4-1]

Minimum $h_{rt} = 2 \cdot \Delta_s = 2 \cdot 1.16 = 2.32$ in

Thickness of cover elastomer laminate, $h_{cover} = 0.25$ in

Try an internal elastomer laminate thickness, $h_{ri} = 0.375$ in

Thickness of steel plates, $h_s = 0.125$ in

Determine the number of internal laminates, n, required:

$$n = \frac{\text{Min } h_{rt} - 2 \cdot h_{cover}}{h_{ri}} = \frac{2.32 - 2 \cdot 0.25}{0.375} = 4.85$$

Use 5 internal laminates.

Number of steel plates, $n_s = n + 1 = 6$

Total elastomer thickness:

$$h_{rt} = 2 \cdot (h_{cover}) + n \cdot (h_{ri}) = 2 \cdot (0.25) + 5 \cdot (0.375) = 2.375 \text{ in}$$

Height of reinforced elastomeric pad, $D = h_{rt} + n_s \cdot h_s$
$= 2.375 + 6 \cdot 0.125 = 3.125$ in

For preliminary pad sizing, assume the pad allowable compression is 1.25 ksi. Round the pad width and length dimensions to even inch dimensions. For steel beams, the width (B) must be at least the bottom flange width and not more than 2 inches greater than the bottom flange width. In this case, the bottom flange width is 20 inches.

Try a pad width, B = 20 in

Solve for the minimum pad length (A):

$$A_{min} = \frac{P_{smax}}{1.25 \cdot B} = \frac{225}{1.25 \cdot 20} = 9.00 \quad \text{in}$$

Try a pad length, A = 10 in

Shape Factor Check

Check the shape factor of the internal laminate:

$$S_i = \frac{A \cdot B}{2 \cdot (A + B) \cdot h_{ri}} = \frac{10 \cdot 20}{2 \cdot (10 + 20) \cdot 0.375} = 8.89$$

$5.0 \leq S_i = 8.89 \leq 10.0$ OK

[14.7.6.1]

Check that shape factor requirements of AASHTO LRFD Art. 14.7.6.1 are met:

For this check, if cover layer thickness is greater than or equal to internal laminate thickness, n may be increased 0.5 for each cover layer.

Then

$$\frac{S_i^2}{n} = \frac{8.89^2}{5 + 0.5 + 0.5} = 13.17 < 22 \quad \underline{\text{OK}}$$

Compute the shape for the cover layers for later use in the deflection computations.

[14.7.5.1]

$$S_c = \frac{A \cdot B}{2 \cdot (A + B) \cdot h_{ri}} = \frac{10 \cdot 20}{2 \cdot (10 + 20) \cdot 0.25} = 13.33$$

Pad Dimensional Checks

Check that the bearing satisfies aspect ratio checks. The total elastomeric thickness, h_{rt}, must be less than $^1/_3$ the length of the pad's shortest side.

[14.7.6.3.6]

$$\frac{A}{3} = \frac{10}{3} = 3.33 \text{ in} > 2.375 \text{ in} \quad \underline{\text{OK}}$$

Also check that maximum pad dimension (B) is no greater than 2.5 times the smallest pad dimension (A):

$2.5 \cdot A = 2.5 \cdot 10 = 25 \text{ in} > 20 \text{ in}$ OK

[14.7.6.3.2] **Maximum Compressive Stress Check**

Now check the maximum compressive stress in the pad. Use the minimum shear modulus for this computation (G_{min} = 0.130 ksi).

The allowable compressive stress σ_{sall} is the smaller of:

$$\sigma_{sall} = 1.25 \cdot G_{min} \cdot S_i$$
$$= 1.25 \cdot 0.130 \cdot 8.89$$
$$= 1.44 \text{ ksi}$$

or σ_{sall} = 1.25 ksi. <u>GOVERNS</u>

Then the maximum service limit state stress is:

Actual $\sigma_s = \frac{P_s}{A \cdot B} = \frac{225}{10 \cdot 20} = 1.13$ ksi < 1.25 ksi <u>OK</u>

[14.7.6.3.3] **Compressive Deflection**
[14.7.5.3.6]

To ensure that joints and appurtenances perform properly, the vertical deflection in elastomeric bearings is checked. Due to the nonlinear behavior of the elastomer, the movement associated with live load is computed by subtracting the dead load deflection from the total load deflection.

Begin by determining the average vertical compressive stress in the bearings under dead load alone and under total load.

$$\sigma_{dl} = \frac{P_{dl}}{A \cdot B} = \frac{117}{10 \cdot 20} = 0.585 \text{ ksi}$$

$$\sigma_{tl} = \frac{P_{tl}}{A \cdot B} = \frac{225}{10 \cdot 20} = 1.125 \text{ ksi}$$

Using the stress strain figure for 60 durometer reinforced bearings shown in AASHTO LRFD Figure C14.7.6.3.3-1, the strain was estimated in the interior laminates and the cover layers and summarized in Table 14.8.2.1.

Table 14.8.2.1 Estimated Strains

Laminate	Load	S	Stress (ksi)	Estimated Compressive Strain ε (%)
Interior	Dead Load	8.89	0.585	2.6%
	Total Load	8.89	1.125	4.2%
Cover	Dead Load	13.33	0.585	2.2%
	Total Load	13.33	1.125	3.7%

The initial compressive deflection of a single interior laminate under total load is:

[14.7.6.3.3]

$$\Delta_{tlhri} = \varepsilon \cdot h_{ri} = 0.042 \cdot h_{ri} < 0.090 \cdot h_{ri} \quad \underline{\text{OK}}$$

With five interior laminates and two cover layers the deflection under total load is:

$$\Delta_{tl} = 5 \cdot \varepsilon_{ri} \cdot h_{ri} + 2 \cdot \varepsilon_{cover} \cdot h_{rcover}$$

$$= 5 \cdot 0.042 \cdot 0.375 + 2 \cdot 0.037 \cdot 0.25 = 0.097 \text{ in}$$

The deflection under dead load is:

$$\Delta_{dl} = 5 \cdot \varepsilon_{ri} \cdot h_{ri} + 2 \cdot \varepsilon_{cover} \cdot h_{rcover}$$

$$= 5 \cdot 0.026 \cdot 0.375 + 2 \cdot 0.022 \cdot 0.25 = 0.060 \text{ in}$$

[Table 14.7.6.2-1]

The deflection due to creep is:

$$\Delta_{cr} = 0.35 \cdot \Delta_{dl} = 0.35 \cdot 0.060 = 0.021 \text{ in}$$

[C14.7.5.3.6]

The difference between the two deflections is the estimated live load deflection. The total deflection due to live load plus creep should be no greater than $^1/_8$ inch.

$$\Delta_{ll} = \Delta_{tl} - \Delta_{dl} = 0.097 - 0.060 = 0.037 \text{ in}$$

$$\Delta_{ll} + \Delta_{cr} = 0.037 + 0.021 = 0.058 \text{ in} < 0.125 \text{ in} \quad \underline{\text{OK}}$$

Minimum Compressive Load Check

Using the equation derived in BDM Article 14.3.3.3.1:

$$\text{Req'd. } P_{umin} \geq 5 \cdot G_{max} \cdot A_{pad} \cdot \frac{\Delta_u}{h_{rt}}$$

$$= 5 \cdot 0.200 \cdot 10 \cdot 20 \cdot \frac{0.89}{2.375} = 74.9 \text{ kips}$$

Actual P_{umin} = 79.1 kips > 74.9 kips OK

[14.7.5.3.5] **Check Service and Fatigue of Steel Reinforcement Plates**

Check the service and fatigue limit states for the steel plates. At the service limit state the following equation must be satisfied:

$$h_s \geq \frac{3 \cdot h_{max} \cdot \sigma_s}{F_y}$$

The yield strength of the steel plates (F_y) is 36 ksi.

$$h_{max} = h_{ri} = 0.375 \text{ in}$$

$$\sigma_s = 1.13 \text{ ksi}$$

$$\text{Min. } h_s = \frac{3 \cdot h_{max} \cdot \sigma_s}{F_y} = \frac{3 \cdot 0.375 \cdot 1.13}{36} = 0.035 \text{ in} < 0.125 \text{ in} \quad \underline{\text{OK}}$$

At the fatigue limit state, the following equation must be satisfied:

$$h_s \geq \frac{2 \cdot h_{max} \cdot \sigma_L}{\Delta_{FTH}}$$

[Table 6.6.1.2.5-3] where, $\Delta_{FTH} = 24$ ksi (Category A steel detail).

Note that the live load used for this check is not based on reactions from the fatigue truck and is not factored according to the fatigue limit state. Rather, it is the maximum live load for the service limit state with a load factor equal to 1.0.

$$\sigma_L = \frac{P_{llmax}}{A \cdot B} = \frac{108}{10 \cdot 20} = 0.540 \text{ ksi}$$

Minimum steel plate thickness for this check is

$$\text{Min. } h_s = \frac{2 \cdot h_{max} \cdot \sigma_L}{\Delta_{FTH}} = \frac{2 \cdot 0.375 \cdot 0.540}{24} = 0.017 < 0.125 \text{ in} \quad \underline{\text{OK}}$$

Use a 10" x 20" x 3 1/8" bearing pad, composed of two 1/4 inch cover laminates, five 3/8 inch interior laminates, and six 1/8 inch steel plates.

B. Curved Plate Design

The thickness of the plate is H. The curved plate has a width (B), which is equal to the width of the bearing pad. The length (G) is determined in an iterative process with the thickness. Begin by checking the thickness for a curved composite plate with a length of 4.5 inches. If, when designing the bearing plate, the required bearing plate thickness exceeds 2 inches, increase the length of the curved plate to reduce the length of the cantilever for the bearing plate design. Increase the curved plate length until the required bearing plate thickness alone and the required composite plate thickness for the curved plate design become approximately equal.

Try a 20" x 4.5" curved plate ($B = 20 \text{ in}, \ G = 4.5 \text{ in}$).

First, determine the radius of the contact surface. The radius of the curved plate is a function of the yield strength of the steel and the load intensity.

The contact length of the sole plate with the curved plate is equal to the curved plate width minus the pintles and bevels. Refer to Figure 14.8.2.2.

Contact length L_{sp} is equal to

$$L_{SP} = 20 - 2 \cdot (1.75) - 2 \cdot (0.25) - 2 \cdot (0.25) = 15.50 \text{ in}$$

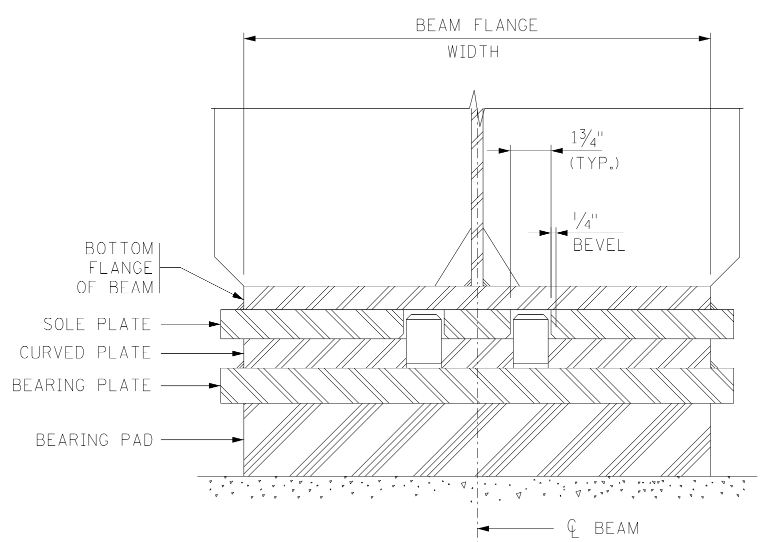


Figure 14.8.2.2

[14.7.1.4] Based on past satisfactory performance of curved plate bearing assemblies, the minimum radius permitted is determined with LRFD Equation C14.7.1.4-1 and C14.7.1.4-2. Start by assuming the diameter d is 25 inches or less, so use the first equation. Rearranging the equation to solve for diameter results in the following:

$$d_{min} = \frac{20 \cdot p}{0.6 \cdot (F_y - 13)} = \frac{20 \cdot \left(\frac{P_s}{L_{sp}}\right)}{0.6 \cdot (F_y - 13)} = \frac{20 \cdot \left(\frac{225}{15.50}\right)}{0.6 \cdot (36 - 13)} = 21.0 \text{ in} < 25.0 \text{ in}$$

The assumption was correct. Then the radius R_{min} = 10.5 in

The radius of curved plates is to be no less than 16 inches. Therefore, specify the minimum radius for the curved plate to be 16 inches.

Use strength limit state loads for flexural design of the curved plate.

The maximum Strength I limit state load, P_{umax}, is:

$$P_{umax} = 1.25 \cdot P_{dl} + 1.75 \cdot P_{llmax}$$

$$= 1.25 \cdot 117 + 1.75 \cdot (108) = 335.3 \text{ kips}$$

Pressure on the composite plate is:

$$\sigma_{cp} = \frac{P_{u\,max}}{G \cdot B} = \frac{335.3}{4.5 \cdot 20} = 3.73 \text{ ksi}$$

Maximum moment on the composite plate is:

$$M_{ucp} = \sigma_{cp} \cdot \frac{G}{2} \cdot \frac{G}{4} \cdot B = 3.73 \cdot \frac{4.5}{2} \cdot \frac{4.5}{4} \cdot 20 = 188.8 \text{ kip-in}$$

[6.12.2.2.7] Consider the plate to be fully laterally supported. The AASHTO LRFD Specifications allow the nominal flexural resistance of a rectangular section to be taken as the plastic moment. However, MnDOT limits the nominal resistance to the yield moment. Find the required composite plate thickness such that the yield moment, M_y, of the section will have adequate capacity to resist the design moment, M_{ucp}.

[6.5.4.2] For steel elements in flexure, $\phi_f = 1.0$.

The flexural resistance, M_r, of the composite plate section is:

$$M_r = \phi_f \cdot M_{ncp} = \phi_f \cdot M_y = \phi_f \cdot S_{cp} \cdot F_y$$

The section modulus of the composite plate is:

$$S_{cp} = \frac{B \cdot H^2}{6}$$

where H = thickness of composite plate

Then by substitution:

$$M_r = \phi_f \cdot \left(\frac{B \cdot H^2}{6} \right) \cdot F_y$$

Set the flexural resistance of the composite plate section equal to the design moment:

$$M_{ucp} = \phi_f \cdot \left(\frac{B \cdot H^2}{6} \right) \cdot F_y$$

Solve for composite plate thickness:

$$H \geq \sqrt{\frac{6 \cdot M_{ucp}}{\phi_f \ F_y \cdot B}} = \sqrt{\frac{6 \cdot 188.8}{1.0 \cdot 36 \cdot 20}} = 1.25 \text{ in}$$

The standard curved plate thickness is 1¼ inches, so composite action does not need to be considered. Use a 1¼ thick curved plate.

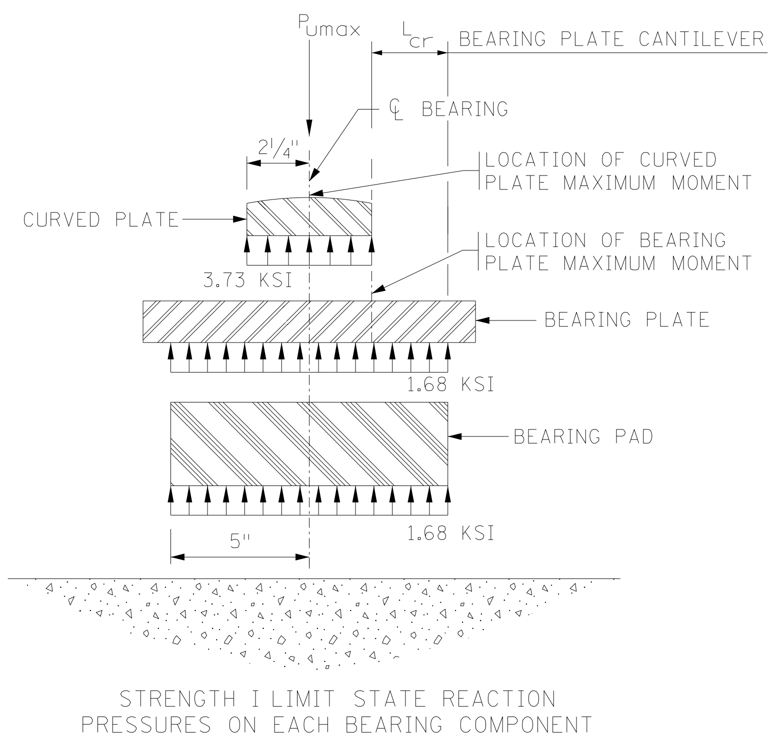


Figure 14.8.2.3

C. Bearing Plate Design

Now determine the thickness of the bearing plate. The bearing plate has plan dimensions that are slightly larger than the bearing pad to provide adequate space for the attachment of the keeper bar. One inch is provided on all sides for this purpose.

Bearing Plate width, E = 22 in

Bearing Plate length, C = 12 in

The bearing plate is assumed to act as a cantilever that carries the bearing pad pressure back to the curved plate. See Figure 14.8.2.3.

The cantilever length is half the difference in length between the bearing pad and the curved plate.

$$\sigma_{bp} = \frac{P_{umax}}{A \cdot B} = \frac{335.3}{10 \cdot 20} = 1.68 \text{ ksi}$$

$$L_{cr} = \frac{A}{2} - \frac{G}{2} = \frac{10}{2} - \frac{4.5}{2} = 2.75 \text{ in}$$

$$M_{ubp} = \sigma_{bp} \cdot \frac{L_{cr}^2}{2} \cdot E = 1.68 \cdot \frac{2.75^2}{2} \cdot 22 = 139.8 \text{ kip-in}$$

Again, the AASHTO LRFD specifications allow the nominal flexural capacity to be set equal to the plastic moment of the plate. However, MnDOT limits the nominal capacity of the plate to the yield moment. Find the required bearing plate thickness such that the yield moment, M_y, of the section will have adequate capacity to resist the design moment, M_{ubp}.

The flexural resistance, M_r, of the bearing plate section is:

$$M_r = \phi_f \cdot M_{nbp} = \phi_f \cdot M_y = \phi_f \cdot S_{bp} \cdot F_y$$

The section modulus of the bearing plate is:

$$S_{bp} = \frac{E \cdot F^2}{6}$$

where F = thickness of bearing plate

Then by substitution:

$$M_r = \phi_f \cdot \left(\frac{E \cdot F^2}{6} \right) \cdot F_y$$

Set the flexural resistance of the bearing plate section equal to the design moment:

$$M_{ubp} = \phi_f \cdot \left(\frac{E \cdot F^2}{6} \right) \cdot F_y$$

Solve for bearing plate thickness:

$$F \geq \sqrt{\frac{6 \cdot M_{ubp}}{\phi_f \ F_y \cdot E}} = \sqrt{\frac{6 \cdot 139.8}{1.0 \cdot 36 \cdot 22}} = 1.03 \text{ in}$$

The standard bearing plate thickness is 1½ inches, so use a 1½ thick bearing plate.

D. Sole Plate Constraints

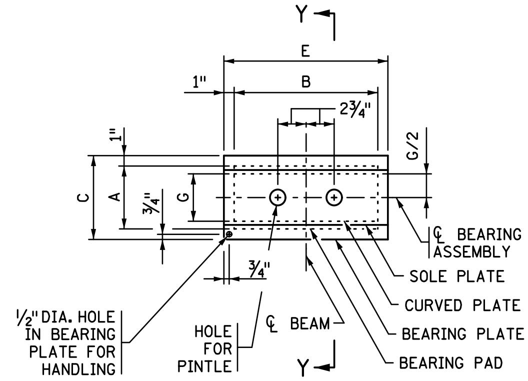
Set the sole plate width 2 inches greater than the curved plate width and check that it is sufficiently wider than the beam bottom flange to allow welding.

Sole plate width $= 20 + 2 = 22$ in > 20 in flange <u>OK</u>

The sole plate length must be 6 inches minimum, but not less than the curved plate length. Therefore, set sole plate length equal to 6 inches.

The minimum sole plate thickness is $1^1/_4$ inches. When the bearing pad width exceeds the bottom flange width, the sole plate must be designed as a cantilever to resist the load from the pad that extends outside the flange. For our case, the bottom flange width equals the pad width, so set sole plate thickness equal to $1^1/_4$ inches.

The bearing design is summarized in Figures 14.8.2.4 and 14.8.2.5.



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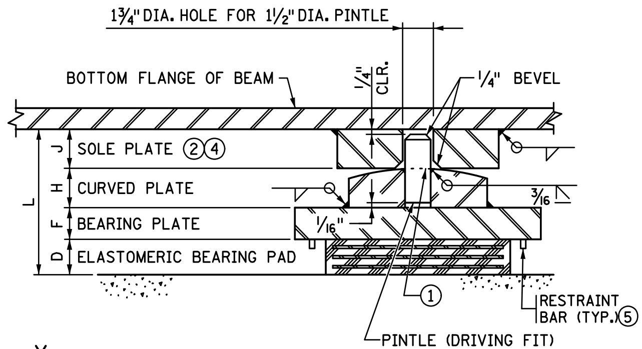
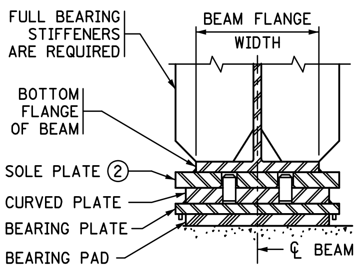
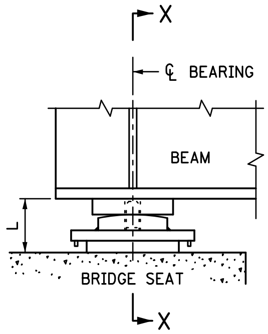


SECTION Y-Y

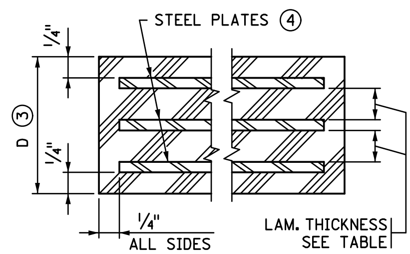
ENLARGED BEARING ASSEMBLY



SECTION X-X



SIDE ELEVATION



SECTION THROUGH BEARING PAD

TABLE																							
ASSEMBLY TYPE	LOCATION	BEAM FLANGE WIDTH	BEARING PAD SIZE			STEEL PLATES		LAMINATES		SHAPE FACTOR	BEARING PLATE SIZE			CURVED PLATE SIZE				SOLE PLATE SIZE			PINTLE DIA.	ASSY. HEIGHT	RESTRAINT PATTERN ⑤
			A	B	D	NO.	THICK.	NO.	THICK.		C	E	F	G	B	H	R ①	WID.	LEN.	J ②		L	
E	ABUT.	20"	10"	20"	3⅛"	6	⅛"	5	⅜"	8.89	12"	22"	1½"	4½"	20"	1¼"	16"	22"	6"	1¼"	1½"	7⅛"	A-3

NOTES:

PROVIDE ELASTOMERIC MATERIALS AND PAD CONSTRUCTION PER SPEC. 3741.

PROVIDE STEEL PLATES PER SPEC. 3306 EXCEPT THE SOLE PLATE. PROVIDE SOLE PLATE WITH THE SAME MATERIAL SPECIFICATION AS THE STEEL BEAMS.

PROVIDE PINTLES PER SPEC. 3309.

GALVANIZE STRUCTURAL STEEL BEARING ASSEMBLY AFTER FABRICATION PER SPEC. 3394, EXCEPT AS NOTED.

PAYMENT FOR BEARING ASSEMBLY INCLUDES ALL MATERIAL ON THIS DETAIL EXCEPT THE SOLE PLATE. THE SOLE PLATE IS INCLUDED IN THE WEIGHT OF STRUCTURAL STEEL.

① THE MIN. RADIUS IS 16" UNLESS OTHERWISE SPECIFIED IN THE TABLE. THE MAX. RADIUS IS 24". FINISH TO 250 MICRO. THE FINISHED THICKNESS OF THE PLATE MAY BE 1/16" LESS THAN SHOWN.

② WHEN THE SOLE PLATE IS TAPERED, DIMENSIONS "J" AND "L" ARE THICKNESS OF SOLE PLATE AND BEARING ASSEMBLY AT CENTERLINE OF BEARING.

③ THE TOTAL THICKNESS SHOWN INCLUDES THE STEEL PLATES.

④ DO NOT GALVANIZE THIS PLATE.

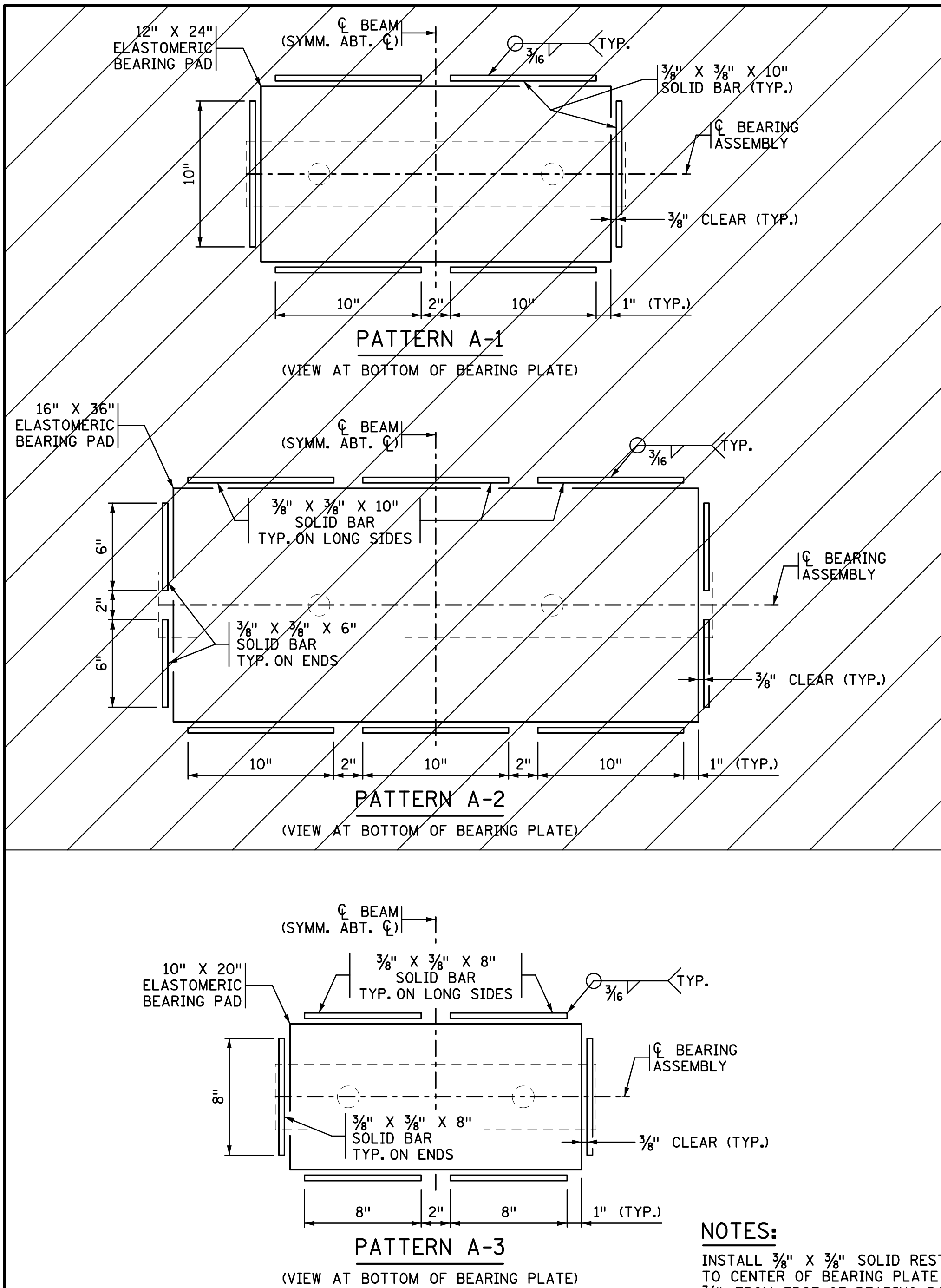
⑤ REFER TO BEARING PAD RESTRAINT SHEET FOR ADDITIONAL INFORMATION AND DETAILS.

DESIGN DATA:

MAX. FACTORED SHEAR RESISTANCE:
- 50.3 KIPS PER 1½" DIA. PINTLE

APPROVED: NOVEMBER 22, 2002	STATE OF MINNESOTA DEPARTMENT OF TRANSPORTATION	REVISED	DETAIL NO.
Daniel L. Dorgan STATE BRIDGE ENGINEER	CURVED PLATE BEARING ASSEMBLY (STEEL BEAMS) (EXPANSION)	08-10-2006 12-17-2008 11-03-2015 11-02-2017	B355

Figure 14.8.2.4



NOTES:

INSTALL 3/8" X 3/8" SOLID RESTRAINT BARS SYMMETRIC TO CENTER OF BEARING PLATE WITH CLEAR DISTANCE OF 3/8" FROM EDGE OF BEARING PAD TO INSIDE FACE OF RESTRAINT BAR.

RESTRAINT BARS INCLUDED IN PAYMENT FOR BEARING ASSEMBLY.

MODIFIED:	
PATTERN A-3	

APPROVED: NOVEMBER 02, 2017	STATE OF MINNESOTA DEPARTMENT OF TRANSPORTATION	REVISION	DETAIL NO.
Kevin Western STATE BRIDGE ENGINEER	BEARING PAD RESTRAINT		B307 MODIFIED

Figure 14.8.2.5