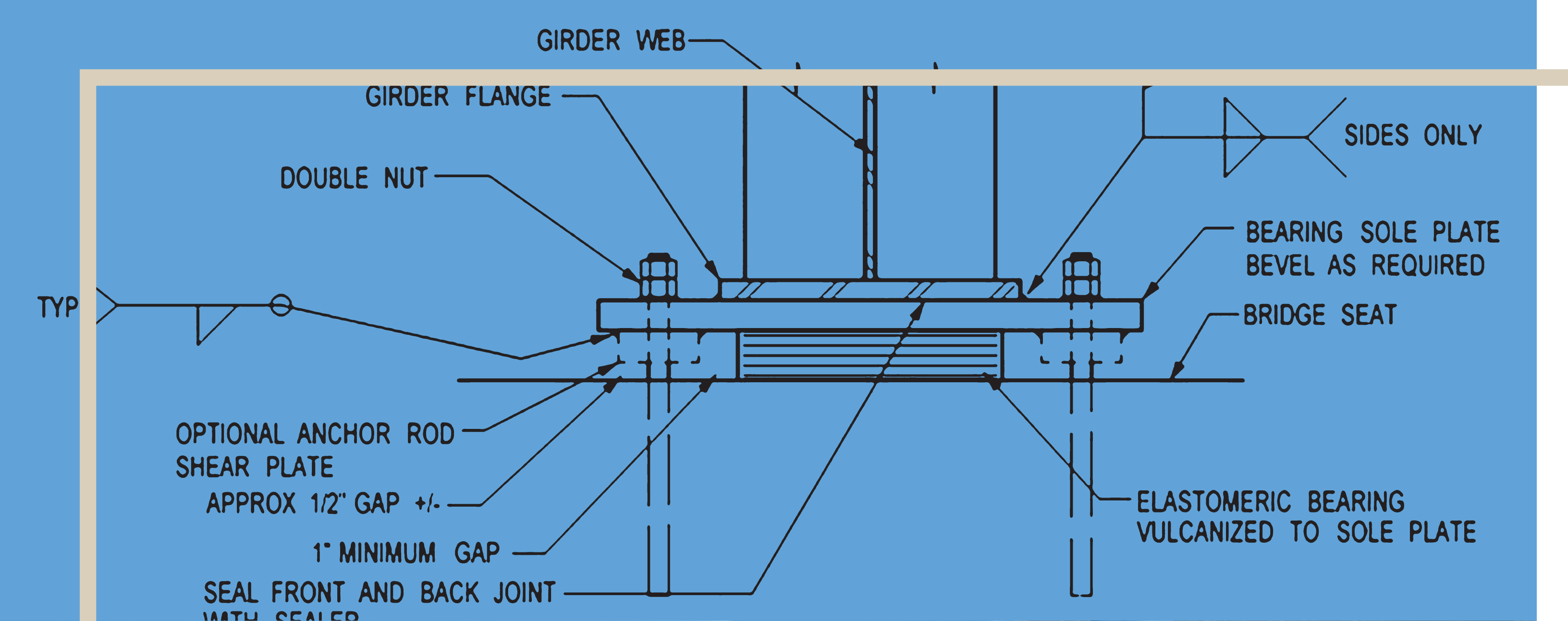

Steel Bridge Bearing Guidelines

G9.1—2022

American Association of State Highway and Transportation Officials
AASHTO

NSBA National Steel Bridge Alliance Founded 1995

AASHTO/NSBA STEEL BRIDGE COLLABORATION

American Association of State Highway and Transportation Officials

National Steel Bridge Alliance

Preface

This document presents guidelines developed by the AASHTO/NSBA Steel Bridge Collaboration. The primary goal of the Collaboration is to achieve steel bridge design and construction of the highest quality and value through standardization of the design, fabrication, construction, inspection, and long-term maintenance processes. Each document represents the consensus of a diverse group of professionals.

It is desired that Owners adopt and implement Collaboration documents in their entirety to facilitate the achievement of standardization. It is understood, however, that local statutes or preferences may prevent full adoption of the document. In such cases, Owners may adopt these guidelines with the exceptions they feel are necessary.

Cover photos courtesy of Michael Culmo, P.E., Rhode Island Department of Transportation.

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Steel Bridge Bearing Guidelines

Introduction

The purpose of these Guidelines is to present steel bridge bearing design guidelines and construction details that are cost-effective, functional, and durable. Four major types of bridge bearings are presented:

1. **Elastomeric Bearings**

   Section 1 primarily addresses steel-reinforced elastomeric pads; however, much of the content is directly applicable to fiberglass-reinforced, plain, and cotton duck pads as well.

2. **High Load Multi-Rotational (HLMR) Bearings**

   Section 2 addresses pot, disc, and spherical bearings.

3. **Steel Bearings**

   Bearings in Section 3 are limited to simple bearings made with steel plates used for fixed bearing lines, which are still considered by some bridge owners to be useful and effective.

4. **Seismic Isolation Bearings**

   Section 4 covers bearings used to reduce seismic forces in bridge substructures.

These bearing categories are sufficient to cover the vast majority of structures in the U.S. national bridge inventory. Special bridges may require different bearings.

These Guidelines are not intended as a stand-alone document and do not supersede the current editions of the *AASHTO LRFD Bridge Design Specifications* or the *LRFD Bridge Construction Specifications*.

This document contains many guidelines that are based on provisions of the *AASHTO LRFD Bridge Design Specifications* and *LRFD Bridge Construction Specifications*. Designers should note that changes made to these AASHTO specifications after the publication of this document may be in conflict with the guidelines contained herein. In this case, the provisions in the AASHTO specifications shall take precedence over the guidelines in this document.

These Guidelines do not supersede owner requirements for design and detailing of bearings. Owners may choose to adopt details from different bearing types for their owner standards (e.g., anchor rod details). Designers should obtain prior approval for the use of details and design recommendations included in these Guidelines that are not consistent with owner standards.

The layout of this document is similar to a typical two-column AASHTO bridge specification format. Guidelines are presented in the left column and commentary is provided in the right column. The commentary text is aligned vertically with the guideline text for easier reference, which explains spaces in the text in both columns. This format has proven to be useful for readers.

Abbreviated Table of Contents

The AASHTO/NSBA Steel Bridge Collaboration *G9.1—Steel Bridge Bearing Guidelines*, Second Edition contains the following sections and appendices:

1. General Information
2. Elastomeric Bearings
3. High Load Multi-Rotational (HLMR) Bearings
4. Steel Bearings
5. Seismic Isolation Bearings

Appendix A: Recommendations for Beam Rotation Calculations

Appendix B: Recommendations for Thermal Movement Calculations

Section 1: General Information

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SECTION 1:

GENERAL INFORMATION

1.1—BEARING TYPES

Over the history of steel bridge design, numerous types of bearings have been used. Some were found to function well, and others did not. Many were costly to fabricate and found to not be durable, especially when exposed to leaking deck expansion joints.

These Guidelines contain the most common steel bridge bearings in use in the United States at the time of adoption. The bearings presented herein are considered to be cost-effective, functional, and durable.

C1.1

Commonly-used steel bridge bearings can be divided into three general types: elastomeric bearings, high load multi-rotational bearings, and mechanical (steel) bearings.

The designer must determine which bearing type is best suited to cost-effectively accommodate the design requirements.

1.1.1—Elastomeric Bearings

Elastomeric bearings are based on the principle that the bearing can resist the vertical forces and deform to accommodate beam rotations and thermal movement.

Basic elastomeric bearings have no moving parts. Sliding surfaces are sometimes employed for bearings that are subjected to larger thermal movements.

Internal reinforcements typically are steel plates that are used to improve the structural performance of the bearing.

C1.1.1

There are three predominant elastomeric bearing types designed and supplied in the U.S.A.: plain pads, steel-reinforced, and cotton duck elastomeric bearings. Glass fiber-reinforced elastomeric bearings are similar to steel-reinforced elastomeric bearings, but due to the sudden failure characteristics of the fiberglass, the compressive stresses are limited. Glass fiber-reinforced bearings have not demonstrated economic advantages over steel-reinforced bearings and are not widely used.

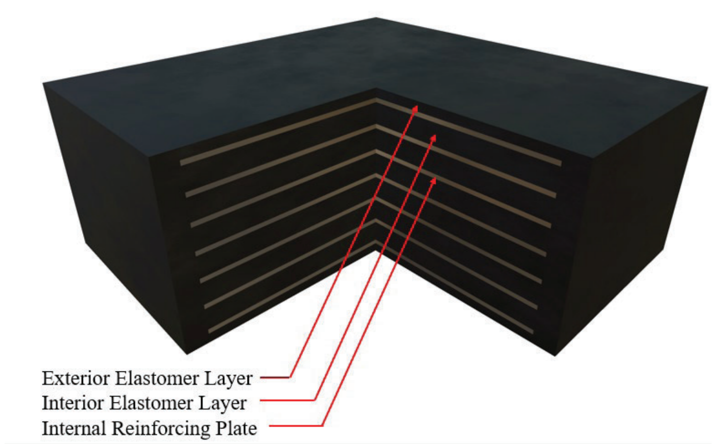

Figure 1.1.1-1. Cut-Away View of a Reinforced Elastomeric Bearing

1.1.2—High Load Multi-Rotational (HLMR) Bearings

High load multi-rotational (HLMR) bearings are mechanical bearing assemblies that resist vertical forces. Rotations are typically handled by a bearing element that can deform (similar to an elastomeric bearing). HLMR bearings can accommodate rotations in multiple directions. Thermal movement is typically accommodated with a sliding polytetrafluoroethylene (PTFE) surface.

C1.1.2

Pot, disc, and spherical bearings currently make up the readily available variety of HLMR bearings. Pot and disc bearings use an elastomeric element to accommodate rotation. Spherical bearings accommodate rotation via a curved sliding surface.

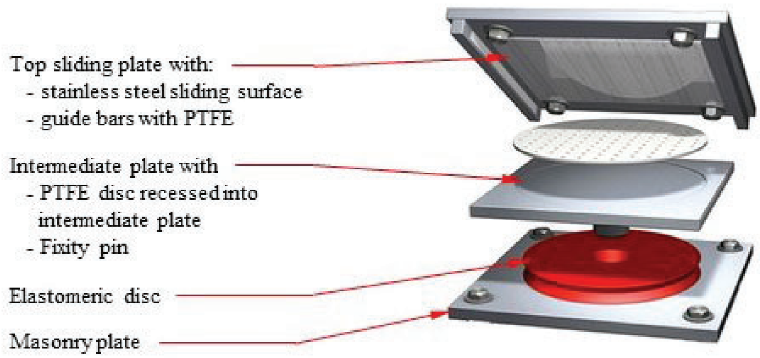

Figure 1.1.2-1. Exploded View of a High Load Multi-Rotational Bearing (Disc Bearing Shown)

1.1.3—Mechanical (Steel) Bearings

Steel bearings resist vertical load. In modern steel bearings, rotations are typically accommodated by machining a curved plate surface. In older designs, rotations were often accommodated by means of a rocker design featuring lugs and a pintle. Thermal movement can be accommodated with a sliding surface (similar to HLMR bearings).

C1.1.3

Steel bearings have been used over the entire history of steel bridge building. Some designs have functioned very well and are relatively cost-effective. Figure 1.1.3-1 depicts a fixed steel bearing with a convex sole plate that has proven to be cost-effective and durable.

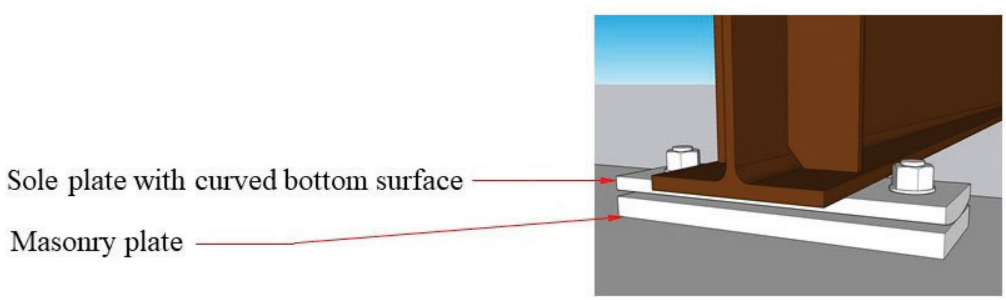

Figure 1.1.3-1. Simple Steel Bearing (Fixed Bearing Shown)

1.2—BEARING SELECTION AND APPLICABILITY

The first step in bearing selection is to determine all loads that are to be resisted by the bearings. The next step is to determine the required movements and rotations about all axes.

C1.2

Bridge bearings for multi-girder bridge types are typically subjected to vertical load, rotation about one axis, and longitudinal thermal movement.

Analysis of bridges that are very wide, highly skewed, curved or of unusual geometry may indicate the need to provide bearings with additional movements and rotations along other axes.

1.2.1—Preliminary Bearing Selection

The selection of bearing type is dependent on a number of factors, including:

1. vertical load
2. thermal movement
3. beam rotation

Table 14.6.2-1 of the 9th Edition of the *AASHTO LRFD Bridge Design Specifications* is a Bearing Suitability Table that can be used for preliminary bearing selection.

The preliminary selection for bearing types included in these Guidelines can also be made using the basic recommendations noted in Article 1.2.2.

C1.2.1

This approach is the basis for the majority of the provisions in these Guidelines.

1.2.2—Recommended Bearing Design Limitations

The limitations on each bearing type should be determined through the design process outlined in the *AASHTO LRFD Bridge Design Specifications*.

Table 1.2.2-1 depicts common recommended design limitations for the bearing types included in this document.

C1.2.2

Recommendations for the design of elements and connections are included in these Guidelines

The values in the table are based on the experience of the AASHTO/NSBA Steel Bridge Collaboration Task Group 9. The following notes are applicable to Table 1.2.2-1:

1. The values noted are not hard limitations. The values are common practical limits based on typical bearings designed in accordance with the *AASHTO LRFD Bridge Design Specifications.*
2. The base bearing element does not accommodate movement. When combined with a stainless steel/PTFE sliding surface, any reasonable movement can be accommodated.

3. Seismic isolation bearings have design values that are similar to HLMR bearings. Consult with bearing manufacturers for limitations for seismic isolation bearings.

Table 1.2.2-1. Recommended Bearing Design Limitations

Bearing Type	Load		Movement		Rotation	Costs	
	Min. (kip)	Max. (kip)	Min. (in.)	Max. (in.)	Rad.	Initial	Mainte-nance
Elastomeric Pads							
Plain (PEP)	0	100	0	0.5	0.01	Low	Low
Cotton Duck (CDP)	0	315	0	0.2	0.003	Low	Low
Fiberglass (FGP)	0	135	0	1.0	0.015	Low	Low
Steel-Reinforced Elastomeric	50	800	0	4	0.04	Low	Low
High Load Multi-Rotational Bearings (See C1.2.2 Note 3)	200	10,000+	0	See C1.2.2 Note 2	0.04	Moderate	Moderate

1.3—DURABILITY AND MAINTENANCE

Bridge bearings should be designed to last for the service life of the bridge. There are multiple strategies to achieve this.

- Specify corrosion protection for exposed steel surfaces of the bearing;
- Design the superstructure with a jointless deck over the bearing.

Elastomeric bearings should not need periodic maintenance.

Bearings that have sliding surfaces may require some maintenance during the service life of the bridge. Designers should detail the bearings such that the bridge can be jacked in order to remove the bearing.

C1.3

Elastomeric bearings are very durable. They have no moving parts that could wear out, and no exposed steel that could corrode. If steel masonry or sole plates are used, they should be provided with some form of corrosion protection.

1.4—BEARING PROTECTION STRATEGIES

All exposed steel surfaces of bearings should be protected from corrosion. The corrosion protection systems should be shop applied.

C1.4

Even if the superstructure is uncoated weathering steel, it is recommended that some form of corrosion protection be applied to the bearing plates. The three most common coatings being used are paint, metallizing, and hot-dip galvanizing. There is no one approach that is applicable to all situations as there are pros and cons to each protection system.

1.4.1—Painting

Painting may be used to protect steel plates for bearings that are not under deck expansion joints, or are in other non-corrosive environments.

Designers should use owner-approved paint systems.

Exposed elastomeric materials, as well as PTFE and stainless steel sliding surfaces, should not be painted.

C1.4.1

Painting can provide a level of corrosion protection equal to that of the steel framing above; however, this approach should only be considered for bearings not located under deck expansion joints. Expansion joints have historically been a source of leakage brought on by the punishing effects of tire traffic, resulting in a more severe corrosion environment.

There are many different painting systems used to protect the exposed steel on bearings.

The paint system is typically specified by the owner or consulting engineer. It is recognized that, with bearings being used on bridges in many different climates, certain paint systems work better in specific temperature or humidity ranges. Road salt usage or marine environments may dictate more robust painting systems. A common type specified by many owners is a three-coat system consisting of a zinc primer, epoxy mid-coat, and a urethane topcoat.

If an owner does not have a specific paint system for bearings, the designer should consult with bearing manufacturers and coating companies to specify the best system for a particular type of bridge and/or climate.

Elastomeric and PTFE materials are formulated to withstand exposure without a coating system. Stainless steel sliding surfaces are designed to be corrosion-resistant. Adding a coating system would increase friction and impair their ability to accommodate movements.

1.4.2—Metallizing

Metallizing can be used to protect exposed steel surfaces under deck expansion joints and in other highly corrosive environments.

C1.4.2

A higher level of corrosion protection may be desirable for bearings that may become exposed to severe corrosive environments. Deck expansion joints have historically produced leakage on the beam ends and bearings as they age.

Metallizing is a thermally-applied spray coating typically consisting of a sacrificial material such as zinc, aluminum, or both. The advantage with metallizing is that it can be applied to a specific area as not all metal surfaces are to be coated.

Another advantage is that there is no drying or cure time as with paint. Once the surface is sprayed, it is ready for service and the bearing plates are ready for final assembly.

While it is recognized by bearing manufacturers that metallizing is the most expensive protection system of the three discussed in this article, it has become more common due to its advantages over the other systems.

1.4.3—Hot-Dip Galvanizing

Hot-dip galvanizing can be used to protect exposed steel surfaces under deck expansion joints and in other highly-corrosive environments.

C1.4.3

Hot-dip galvanizing is a process where entire steel plates are dipped in molten zinc. All surfaces of the plates are coated with a relatively even amount of zinc. Hot-dip galvanizing provides multiple layers of zinc protection when compared to metallizing.

There are several reasons why hot-dip galvanizing should not be specified for certain bearing types including:

- There are parts of common HLMR bearings where it is not advisable to have a coating material applied as in the case of the surfaces that come in contact with the polyurethane material on a disc bearing.
- Threaded bolt holes can be a problem with hot-dip galvanizing as the zinc can fill the threads, requiring re-tapping of the hole after galvanizing.
- Hot-dip galvanizing of steel plates can lead to warping of the plates due to the intense heat in the galvanizing process. This can require extensive plate flattening which is costly and difficult to achieve.

1.5—TOLERANCES

Tolerances in bearing installation locations need to be specified and followed in order to facilitate the erection of the bridge. This Article and following Sub-Articles contain guidance on tolerances relative to bearings.

C1.5

For many bridges, it is critical to have the bearings set onto seats constructed precisely at the correct elevations. If seat elevations are not accurate, difficulty in fit-up can occur and girders may not be in contact with the bearings after the structure is fully erected. This is particularly an issue for curved or highly skewed bridges, which often have stiff cross frames.

1.5.1—Beam Seat Elevation Variance

Construction tolerances of the concrete beam seat under bearings can have a significant influence on the erection fit-up of the steel superstructure and the long-term performance of the bearing.

C1.5.1

Elevation tolerances are not well-defined. The *LRFD Bridge Construction Specifications* provide guidance for flatness of individual beam seats, but do not address elevation or slope tolerances.

Variations in beam seat elevations from one substructure element to the next typically do not result in girder fit-up problems. The deck haunch is used to accommodate fabrication and these elevation tolerances.

Relative elevation variations between adjacent bearings along a substructure unit can make installation of steel diaphragms between girders very difficult. In extreme cases, improper beam seat elevations can result in girders suspended above bearings while being supported by transverse diaphragms.

The designer should specify beam seat elevation tolerances while considering structural steel fit-up concerns and concrete finishing practices unless tolerances are specifically addressed in owner's specifications.

If beam seat tolerances are provided in owner specifications, the designer should evaluate the potential impacts during erection fit-up.

In absence of an owner-specified tolerance, the recommended elevation variation tolerance between adjacent beam seats is $\pm^{1}/_{16}$ in.

Some owners specify tolerances for beam seats while other owners permit the use of oversized holes in diaphragm connections to mitigate potential fit-up issues.

1.5.1.1—Mitigation for Out-of-Tolerance Beam Seats

If beam seat variations exceed the specified tolerance, the contractor should be allowed to propose a means to adjust the bearings to facilitate erection of the superstructure.

High beam seats may be able to be lowered by grinding of the concrete surface, provided that the minimum concrete cover over the seat reinforcing bars is maintained.

Low beam seats can be modified by adjusting the overall height of the bearing assembly. Minor adjustments to elastomeric bearings can be made by

C1.5.1.1

To reduce the possibility of seat elevation inaccuracy, the contractor may elect to build the bearing seat at a higher elevation with subsequent grinding to bring back into elevation tolerance. If bearing seats are built to a higher elevation, increase top concrete cover by the same amount.

The grinding should be executed in such a way as to not create a low point where moisture can collect near the bearing.

A thin high-durometer (80A–90A) elastomeric shim provides equivalent friction resistance, while not affecting the overall performance of the bearing.

placing a high-durometer elastomeric shim between the bearing and the beam seat.

Steel shims can be used to adjust the total bearing assembly height. The designer can specify a nominal thickness shim and allow the contractor to remove the shim, supplement it with additional shims, or replace it with a different thickness shim.

The use of steel shims is primarily applicable to bearings that are bolted in place (shim between faying surfaces) or bearings with anchor rods and masonry plates (shim under the masonry plate).

Example: The designer can detail a ½-in.-thick shim plate on the plans. If the beam seat elevation is ½ in. too high, the shim is simply eliminated. If the beam seat elevation is too low, additional shims can be added to make up the difference. It should be noted that this approach is not typical and should be reserved for projects where these issues could affect the project schedule, such as accelerated bridge construction (ABC) projects.

1.5.2—Transverse Erection Offset Tolerance

The erection of steel framing can result in minor variances in the horizontal location of the framing. The design details should allow for minor adjustment of the connection between the bearing and the framing in order to accommodate these variations.

Designers should specify a transverse erection eccentricity tolerance for the bearing assembly.

A transverse erection tolerance value of ±1 in. is recommended. This value should be noted on the plans or in the specifications.

The designer should verify that the bearing stiffeners can resist the offset eccentric moment caused by the tolerance. The detailing of the bearing should also accommodate this tolerance.

The effect of the offset on the design of the bearing can typically be ignored.

C1.5.2

Several of the details contained in these Guidelines do not include anchor rods, which limits the amount of adjustability.

Designers should consider wider beam sole plates and field welding.

The offset location of the bearing would cause a moment in the girder and bearing stiffeners (applied about the longitudinal axis of the girder).

If the transverse erection tolerance is exceeded in the field, it is not necessarily cause for rejection. In this case, the Contractor should submit calculations demonstrating the resistance of the bearing stiffeners with the actual offset. It is recommended that the designer forward the bearing reactions to the contractor for this calculation.

The offset of the beam on the bearing does not induce eccentric load into the bearing because the superstructure is essentially a rigid body.

1.5.2.1—Mitigation for Out-of-Center Bearings

Bearings detailed with field-welded connections to the beam can be offset and welded in place.

Bearings without anchor rods can be reset to be centered under the beam.

C1.5.2.1

This Article contains several options. The choice of the option should be based on the detailing of the bearing.

Bearings can be detailed with oversized anchor rod pockets (or blockouts) in the beam seat. The bearing can be installed prior to grouting the pocket. Once the bearing is centered on the beam, the anchor rods can be grouted in place.

1.5.3—Anchor Rod Location Tolerance

The horizontal location tolerance of anchor rod groups (for each bearing) should be specified on the plans. A transverse tolerance value of $\pm^1/_4$ in. is recommended for the group.

The horizontal location of each anchor rod within a group should be specified on the plans. A transverse tolerance value of $\pm^1/_{16}$ in. is recommended.

All tolerance measurements should be made from a common working point, globally for the groups and locally for the individual rods.

C1.5.3

If oversized grout pockets or pocket sleeves for anchor rods are used, the size of the pocket should account for the transverse tolerance.

The rod-to-rod tolerance is based on a masonry plate hole that is $^1/_8$ in. larger than the rod. The $\pm^1/_{16}$ in. tolerance is typically accomplished through the use of casting templates.

The recommendation to make all tolerance measurements from a common working point is made as opposed to center-to-center measurements, which can lead to a build-up of tolerance measurement inaccuracies.

1.6—REFERENCES

AASHTO. *AASHTO LRFD Bridge Design Specifications*, 9th Ed. LRFDBDS-9. American Association of State Highway and Transportation Officials, Washington, DC, 2020.

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Section 2: Elastomeric Bearings

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SECTION 2:

ELASTOMERIC BEARINGS

2.1—GENERAL

This Section is intended to assist in the design and detailing of elastomeric bridge bearings. The information included is intended to permit efficient fabrication, installation, and maintenance of these bearings.

C2.1

Elastomeric bearings have a low initial cost when compared to other bearing types, and require virtually no long-term maintenance.

These Guidelines contain design guidance for areas that are not specifically addressed in the *AASHTO LRFD Bridge Design Specifications*.

2.2—BASIC ASSUMPTIONS

These Guidelines make the following design and detailing assumptions for elastomeric bearings:

1. The bearings are normally vulcanized to a top plate or sole plate.
2. The bearings are attached to the girder by field welding or bolting.
3. Masonry plates and anchor rods are not normally required.
4. The bearing bears directly on the concrete substructure.
5. Lateral forces on expansion bearings are restrained by means of friction, keeper angles, or concrete keeper blocks (keys). Lateral forces on fixed bearings are restrained by anchor rods.

C2.2

Some bridge owners prefer to attach the bearings to the beam by welding and others prefer bolting. Both methods are acceptable (refer to individual owner requirements). Welded attachment allows for minor adjustment during installation and is often the most economical design. Bolting provides limited damage to coating systems and allows for easier removal in the future.

Several owners design expansion bearings without a connection to the girder. The bearing is held in place by friction alone. There have been isolated problems with elastomeric bearings slipping and/or walking out from under beams. Research has shown that paraffin used in natural rubber bearings to prevent ozone degradation can bleed out, causing a large drop in friction values. Several owners incorporate recesses and keeper assemblies to prevent the bearing from slipping; however, these methods are typically not cost-effective. This problem can also be solved by specifying polychloroprene for the elastomer, since paraffin is not required in polychloroprene bearings. (See Research Report 1304-3, *An Experimental Study of Elastomeric Bridge Bearings with Design Recommendations*, Muscarella and Yura, 1995.)

Several owners design short single-span bridges using expansion bearings only. This method theoretically reduces the movement at the expansion bearings by 50 percent.

2.3—DESIGN AND DETAILING RECOMMENDATIONS

2.3.1—Design

The design of elastomeric bearings is the responsibility of the design engineer. The design should follow the provisions of Section 14 of the *AASHTO LRFD Bridge Design Specifications*, which contain two distinct design methods:

In the *AASHTO LRFD Bridge Design Specifications* Article 14.7.6, Method A design is generally based on stresses imparted on the bearing under design loads and rotations.

In the *AASHTO LRFD Bridge Design Specifications* Article 14.7.5, Method B design is generally based on superposition of strains imparted on the bearing under design loads and rotations.

Owners currently use both Method A and Method B as outlined in the *AASHTO LRFD Bridge Design Specifications*. For specific information regarding the requirements of individual owners, refer to each owner's design procedures.

In general, the stress limits associated with Method A usually result in a bearing with a lower capacity than a bearing designed using Method B.

The increased capacity of bearings designed using Method B require additional testing and quality control.

2.3.1.1—Bearing Shapes

Elastomeric bearings can either be round or rectangular.

The following is general guidance on bearing shapes (based on the experience of the NSBA Collaboration members):

- Large rotations or large longitudinal movement: the recommended bearing shape is rectangular bearings with the larger plan dimension laid out perpendicular to the beam centerline.
- Large skew: the recommended bearing shape is round.

C2.3.1.1

The *AASHTO LRFD Bridge Design Specifications* allow the use of both round and rectangular bearings. Elastomeric bearings are typically rectangular or round. The decision to choose between these two shapes can be affected by the design parameters and design details.

Round bearings are best used for standardization of bearings by an agency since only one dimension can vary in plan. Round bearings are recommended for curved and larger skewed bridges since they can accommodate movement and rotations in multiple directions. They also usually require a narrower bridge seat on skewed bridges.

Rotation can cause large stresses at the front and rear of the bearing. Large movement can lead to tall bearings. Reducing the longitudinal dimension can facilitate the design. If movement is excessive, a sliding surface can be detailed in the bearing.

Rectangular bearings set on a large skew can lead to unnecessarily wide bridge seats (corner-to-corner width). Round bearings can be used to reduce the width. Skewed bridges also have different rotation characteristics. If a 3D analysis was to be performed, it would show that the axis of rotation is not along the centerline of bearing. Round bearings can accommodate rotation about any axis.

2.3.1.2—Bearing Sizes

The size of elastomeric bearings is a function of the design loads and movements. The design parameters are set by Section 14 of the *AASHTO LRFD Bridge Design Specifications*.

C2.3.1.2

2.3.1.3—Material Properties

The design of the bearings needs to be based on certain assumptions regarding material properties. The required properties of all materials should be noted in the contract documents.

The *AASHTO LRFD Bridge Design Specifications* include two distinct design methods for bearings. The two main properties that affect the design of an elastomeric bearing are the shear modulus, *G*, and the hardness (durometer). Designers should only specify shear modulus, *G*, or hardness (not both), depending on the design method employed.

Shear modulus, *G*, is a critically important material property in the design and performance of elastomeric bearings. The designer should use both the minimum and maximum values for *G* for a chosen hardness type, as specified in Article 14.7.5.2 (for Method B design) and Article 14.7.6.2 (for Method A design) of the *AASHTO LRFD Bridge Design Specifications*, to ensure that the designed bearing will be satisfactory for the full range of shear moduli.

The Method A design provisions are based on a specified hardness. The *AASHTO LRFD Bridge Design Specifications* provide ranges of shear moduli for different hardnesses that should be used in the design.

The Method B design provisions are based on a specified shear modulus. The shear modulus specified must be between 0.080 and 0.175 ksi. The equations for Method B are strain-based and less conservative; therefore, it is important to narrow the least favorable range.

C2.3.1.3

Recommendations for the design of elements and connections are included in these Guidelines.

The least favorable range of shear modulus values are provided in the *AASHTO LRFD Bridge Design Specifications* for 50-, 60-, and 70-durometer hardness. The shear modulus range is broad since the design approach for Method A is conservative. Bearings designed by Method A are specified by durometer hardness only, never by a shear modulus.

The compounding of elastomer includes many variables and it is unlikely that the same exact shear modulus can be achieved from batch to batch, so the least favorable range is ±15 percent of the specified shear modulus. Given the restrictions on the upper or lower allowable shear moduli, the designer should avoid specifying a shear modulus close to the upper or lower bound which could limit the acceptable range. From an economic standpoint, for any particular project, the designer should try to use one shear modulus for all designs.

2.3.1.4—Design Rotation and Movement

Elastomeric bearing assemblies with beveled sole plates should typically be designed for unfactored live load rotations, and an additional rotation representing a combination of uncertainties and construction tolerances as specified in Article 14.4.2.1 of the *AASHTO LRFD Bridge Design Specifications*.

If beveled sole plates are not specified, then the bearing design should also include dead load rotation and rotation due to the profile grade slope.

If an approximate (average) sole plate slope is specified, the bearing should be designed for a rotation equal to the difference between the theoretical sole plate slope and the specified sole plate slope. See Article 2.3.3 for more information on this approach to detailing sole plates.

C2.3.1.4

Bearing assemblies consist of the elastomeric bearing element, connection plates (if required), and a beveled or flat sole plate (if required). See Article 1.6 for details of typical bearing assemblies. Refer to Appendix A for information on calculating rotations.

The design rotations for uncertainties and construction tolerances are specified in Article 14.4.2.1 of the *AASHTO LRFD Bridge Design Specifications.* The specified design rotation for uncertainties and construction tolerances should be sufficient for virtually all situations. The value of 0.005 radians is a significant rotation. It is equivalent to a slope of $^1/_8$ inch in 24 inches. This tolerance level has proven to be attainable in the field. Specifying a larger rotation can increase the bearing cost unnecessarily.

The experience of many owners contributing to this document is that the 0.005 radian value produces bearings that are easily installed and perform well.

In theory, the bottom of the beveled sole plate would be parallel to the beam seat once construction was complete. In this case, the bearing would only experience live load rotation.

Some owners may require the designer to check the bearing for the temporary condition during construction before the end rotation of the beam end. This is not normally required, as elastomeric bearings are forgiving. Historically, this temporary condition has not been a problem.

Refer to Appendix A for information on the effect of beveled sole plates on bearing design rotations.

The bearings should be designed for longitudinal and lateral movements.

Longitudinal translation due to dead load girder rotation may need to be accounted for on beams with large rotations or for deep girders. This translation should be added to the design longitudinal movement. Refer to Appendix B for guidance on longitudinal and lateral movements.

The designer should specify on the plans a range of temperatures for setting the bearings based on the design of the bearings. Provisions should also be included for jacking the structure in order to reset the bearings if this range cannot be met during construction.

Owners have different requirements for design temperature ranges. A recommended specification for installation temperature range is the average ambient temperature for the bridge location plus or minus 10 degrees F. Larger values can be specified provided that the bearing is designed for the additional movement.

For example, the Massachusetts Department of Transportation's *LRFD Bridge Manual* includes the following text:

Design Temperature Range (DT) for structural steel members:

- 70 degrees F temperature rise (from an assumed ambient temperature of 50 degrees F)
- 100 degrees F temperature fall (from an assumed ambient temperature of 70 degrees F)

The variable ambient temperature assumption in the design accounts for an assumed temperature at installation of between 50 degrees F and 70 degrees F.

2.3.2—Sole Plate Connections

The connection of the sole plate to I-girders can be shop-welded, field-welded, or bolted depending on the circumstances of the bearing details. This Article and the following Sub-Articles explain the recommended connections for common bearing details. Field-welded connections should be made after the deck has been placed.

C2.3.2

The suggested welded connection shown on the Detail Sheets in Article 2.10 may be done in either the fabrication shop or the field. Care should be taken during field-welding operations, as uncontrolled welding heat can damage the elastomer (see Article 2.3.4).

Bolted connections with oversized holes allow for minor field adjustments of the bearing during installation. Bolting also requires less touchup painting on painted structures and simplifies future removal.

2.3.2.1—Bearings without Anchor Rods

Sole plates may be shop-welded, field-welded, or bolted for bearings without anchor rods.

C2.3.2.1

This recommendation is based on the assumption that the final location of the bearing on the bridge seat is not critical, and that minor variations in the horizontal location of the bearing due to construction erection tolerances are acceptable. The bearing will simply fall under the centerline of the final erected position of the girder.

See Drawing Numbers E 1.1 through E 2.1 in Article 2.10 for detailing options for elastomeric bearings without anchor rods.

2.3.2.2—Bearings with Anchor Rods

Sole plates should be field-welded for bearings with anchor rods.

C2.3.2.2

This recommendation is based on the assumption that the bottom of the bearing assembly is tied to and fixed by the location of the bearing, and that minor variations in the location of the sole plate relative to the beam due to construction erection tolerances are acceptable.

Welding allows for greater adjustment during installation and is more economical. The damage due to removal of the weld for future removal and maintenance can be reasonably repaired. Article 3.7 of the *AASHTO/AWS D1.5/D1.5M Bridge Welding Code* has information on weld removal and repair.

See Drawing Numbers E 2.2 though E 3.2 in Article 2.10 for detailing options for elastomeric bearings with anchor rods.

2.3.2.3—Bearings with Stainless Steel Sliding Surfaces

Sole plates with integral stainless steel sliding surfaces should be field-connected to the girder.

Seal welding of the stainless steel sheet to the sole plate may be considered prequalified when using the gas tungsten arc welding (GTAW) process.

C2.3.2.3

Field welding or field bolting should be considered for sole plates with stainless steel sliding surfaces since they can be damaged during shipping if attached to the girder in the shop.

The decision to use field welding or field bolting should consider the presence of anchor rods as described in Article 2.3.2.2.

See Drawing Numbers E 2.1 through E 2.5 in Article 2.10 for detailing options for elastomeric bearings with stainless steel sliding plates.

Welds should be completed by qualified welders using AWS A5.9 filler metals matching Base Metal Group B in Table 5.2 of AWS *D1.6/D1.6 M Structural Welding Code – Stainless Steel.* Welding parameters should be as recommended by the electrode manufacturer.

2.3.2.4—Commections to Box Girders

Connections to box girders should be bolted.

Box girder bearings with masonry plates and anchor rods can be detailed with an additional auxiliary bottom plate that is field-welded to the masonry plate.

C2.3.2.4

Box girder bearings should be attached by bolting since a welded sole plate requires an overhead weld with limited clearance.

The auxiliary bottom plate will accommodate field adjustments due to construction erection tolerances.

2.3.3—Sole Plate Details

The sole plate should extend transversely beyond the edge of the bottom flange of the girder a minimum of 1 in. on each side.

The minimum thickness of the sole plate should be 1½ in. after beveling if the field weld is directly over the elastomer. Beveled plates as thin as ¾ in. may be used if there is a lateral separation between the weld and the elastomer that would provide a 1½ in. separation between the weld and the elastomer.

C2.3.3

The sole plate extension is intended to allow sufficient room for welding. Fabricators will not overturn a girder in the shop to make a small weld; therefore, it is assumed that the girder will be upright when this weld is made in the shop or in the field. (See “E” Drawings in Article 2.10).

A thickness of 1½ in. exceeds the ¾-in. minimum thickness specified by the *AASHTO LRFD Bridge Design Specifications* to control plate distortion due to welding.

The designer should strive for a design with a limited number of different sole-plate bevels. The bearing designs can account for minor variations between different beam ends. A common sole plate can be detailed with a bevel slope equal to the average theoretical slope for all bearings in a similar group. Each bearing can then be designed to accommodate the difference between the theoretical slope and the average slope.

Detailing a common sole plate bevel is applicable to bridges with multiple spans that have similar geometry. If an average sole plate bevel is specified, the final slope of the bottom of the sole plate for each bearing should be shown on the plans. This recommendation is for use by construction inspectors and future bridge inspectors that may be assuming that the bottom of the sole plate should be level. Having a value shown on the plans (along with notes) should address this potential issue.

For bearings requiring sole plates with minor bevels (<0.01 radians), the designer may alternatively choose to use flat sole plates and design the bearing accounting for the theoretical sole plate bevel.

Using flat sole plates can result in a significant cost savings. The impact on the bearing design may be minor, which can be offset by the savings in machining of the sole. It can also result in a time savings in the bearing/beam fabrication process.

If an average sole plate bevel is specified, the final slope of the bottom of the sole plate (including tolerances) for each bearing should be shown on the plans.

The recommendation to show the sole plate slopes on the drawings is for use by construction inspectors and future bridge inspectors that may assume that the bottom of the sole plate should be level. Having a value shown on the plans (along with notes) should address this potential issue.

2.3.4—Bearing-to-Girder Connection

The bearing may be connected to the girder by field welding or field bolting.

C2.3.4

Welding and bolting are both acceptable; however, welding is the more economical option. If bolting is selected, oversized holes are recommended to facilitate field fit-up. Refer to each owner's standard details.

If welding is used, the welds should be in the horizontal position.

Overhead welds should be avoided due to limited clearance.

The temperature of the steel adjacent to the elastomer should be kept below 225 degrees F.

The *AASHTO LRFD Bridge Design Specifications* allow the temperature of the steel near the elastomer to be heated up to 400 degrees F. However, this temperature is above the temperature that is commonly used for vulcanizing and may cause separation of the elastomer from the sole plate. Temperature crayons or other heat-indicating devices should be specified for welding inspection.

The bearing should be detailed with at least 1½ in. of distance in any direction between the elastomer and any field welds.

The welds for the sole plate connection should only be along the longitudinal girder axis. Transverse joints should be sealed with an acceptable caulking material.

The longitudinal welds are made in the horizontal position, which is the position most likely to result in a quality fillet weld. Transverse welds require overhead welds and are very difficult to complete due to limited clearance.

The caulking of the underside transverse joint is intended to prevent corrosion between the sole plate and the bottom flange. Most owners use a silicone-based caulk; however, other materials may be used.

2.3.5—Masonry Plates and Anchor Rods

2.3.5.1—Expansion Bearings

Masonry plates are not normally required for elastomeric expansion bearings. The bearing can bear directly on the concrete substructure.

Masonry plates with anchor rods are not required for expansion bearings. Lateral forces are restrained by means of friction, concrete keeper blocks, or keeper angles. In certain cases, such as high movement expansion bearings, anchor rods may be required (see "E" Drawings in Article 2.10).

Keeper assemblies can be used to provide lateral restraint in lieu of masonry plates with anchor rods for bridges that are very wide or with high skews. Care should be taken with the layout of keeper blocks and keeper angles. Skewed bridges will tend to expand along an axis that runs from acute corner to acute corner. Bridges that are wider than they are long will expand more in the transverse direction than in the longitudinal direction.

C2.3.5.1

The bearing should be checked for sliding resistance. To prevent sliding, the maximum shear force in the bearing should be less than 20 percent of the dead load or any other loading that produces a smaller reaction. This criterion will be difficult to meet for bearings with high movement and low vertical load. An elastomeric bearing combined with a PTFE/stainless steel sliding surface should be considered for this case (see Article 2.3.6). Restraint for the elastomeric bearing should be considered for highly skewed bridges. The thermal movement of the superstructure at acute corners can create excessive movement in the bearing that could exceed the above stated 20 percent criterion and lead to slippage of the bearing relative to the substructure. See Article B2.2 for more information on this issue.

Eliminating masonry plates and anchor rods for expansion bearings greatly reduces the costs of the bearings. Concrete keeper blocks and keeper angles are less costly and easier to construct.

Bridges may be designed with expansion bearings at both ends of the girders if the center of gravity of the bridge is relatively centered between the bearing lines. Bridges with grades greater than 3 percent or where large braking forces can be expected (e.g., bridges located near intersections) should not be designed with two sets of expansion bearings. In these cases, a fixed bearing should be used on one end of the bridge.

The major component of a bridge that drives thermal expansion is the concrete bridge deck. This element is directly exposed to sunlight and usually achieves temperatures that are higher than the ambient temperature. On skewed and/or wide bridges, the concrete deck expands in two dimensions and is not influenced significantly by the alignment of the girders below. On these types of bridges, the location and alignment of the keeper assemblies needs to be carefully studied. Refer to Appendix B for more information on this issue.

2.3.5.2—Fixed Bearings

Masonry plates are not required for fixed elastomeric bearings. The bearing can bear directly on the concrete substructure.

C2.3.5.2

Economical fixed bearings can be detailed without masonry plates, while still providing lateral resistance (see Detail Sheets in Article 2.10).

2.3.5.3—Anchor Rods

Material for anchor rods should conform to ASTM F1554, and should be either threaded (with nuts) or swedged on the embedded portion of the rod. The design yield strength of this material may be specified as 36 ksi, 55 ksi, or 105 ksi, depending on the design. The yield strength should be given in the specifications or on the plans.

C2.3.5.3

The term "anchor bolts" should not be used because "bolt" implies that the rod has a hex head. This material is specifically designed for anchor rod applications. Other materials have been used, but do not offer the economies of materials that conform to ASTM F1554. The designer should offer options of swedging or threading the anchor as different suppliers supply one or both of these options.

Swedging is a process of indenting a rod through the use of a press force. Figure C2.3.5.3-1 shows swedged anchor rods.

Figure C2.3.5.3-1. Swedged Anchor Rods

2.3.6—Elastomeric Bearings with Sliding Surfaces

Bearings with sliding surfaces should only be used for situations where large movement does not permit the economical use of conventional elastomeric bearings. This will require the incorporation of a vulcanized steel load plate with an integral PTFE sliding material.

The introduction of a sliding surface does not necessarily require the use of anchor rods. The designer should investigate other means of providing lateral restraint.

C2.3.6

Sliding surfaces are more costly to fabricate than conventional elastomeric bearings and they introduce the need for potential future maintenance. Therefore, the use of this type of bearing should be limited to special situations.

Keeper blocks or keeper angles should be used to maintain alignment of the structure and provide lateral support. They have proven to be more cost-effective than anchor rod assemblies at each bearing.

Anchor rods, if used, should be investigated for the combined effects of shear and bending. A shear plate may be incorporated into the design to reduce the bending effects in the anchor rods.

The nature of this type of bearing requires that the anchorage forces be passed through a plane that is above the bridge seat. If bending forces in the anchor rods are large, then shear blocks should be added (see “E” Drawings in Article 2.10).

2.4—MANUFACTURING

Vulcanization is commonly used to manufacture steel reinforced elastomeric bearings and bearings with connected top and bottom plates.

Figure 2.4-1 shows an elastomeric bearing at the completion of fabrication.

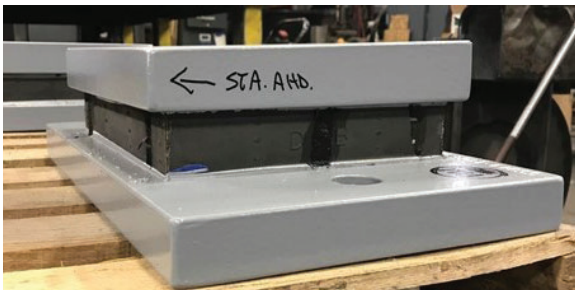

Figure 2.4-1. Fabricated Elastomeric Bearing. Note patched alignment grooves.

C2.4

Manufacturing techniques and abilities vary among steel reinforced elastomeric bearing manufacturers. The raw elastomer, polychloroprene or polyisoprene (natural rubber), is compounded with various additives to achieve the specified durometer or shear modulus and for long term durability. The elastomer is milled and, in the process, heated, then calendered into sheets. Calendering is a mechanical process by which elastomer is passed through a series of rollers to flatten and manufacture uniform sheets. The material is then cut into the approximate finished elastomeric bearing plan dimensions.

The internal steel laminates and any external load plates to be vulcanize bonded are abrasively treated to remove mill scale and roughen the surface, then treated with a compound to promote adhesion with the elastomer.

Alternate layers of elastomer and internal steel are stacked into a mold. Because heat and pressure are required during the vulcanization process, the elastomeric layers begin thicker than the final layer thickness and excess bleeds out. The elastomeric bearing is heated to the elastomer’s cure temperature and held under pressure until curing is complete. The time to achieve this varies with the size and thickness of the bearing, so often a thermocouple is used to verify the internal core temperature. If a beveled sole plate is required, the top of the mold must be equipped with an opposite bevel so that the bottom surface of the load plate is level.

After the elastomeric bearing is molded, the excess elastomer that has bled out is trimmed from the edges of the bearing and the load plate. If not galvanized prior to the molding process, external plates can then be coated for corrosion protection.

Mechanical devices can be used to align the internal steel laminates to maintain internal layer thickness and edge cover.

The grooves left by the alignment mechanisms that remain at the vertical edges from the molding process may be filled with an elastomeric caulk or vulcanize patched.

Patched alignment grooves on the sides of the bearing are shown in Figure 2.4-1.

2.5—QUALITY CONTROL TESTING

Elastomeric bearings are sampled and typically tested in accordance with AASHTO M 251.

In general, testing includes the following:

- Dimensional verification.
- Material properties including shear modulus or durometer.
- Compressive load test at 1.5 times the design service load. The load is held for five minutes, removed, and reapplied for a second period of five minutes.
- Creep and shear bond test. Figure 2.5-1 depicts a shear bond test.

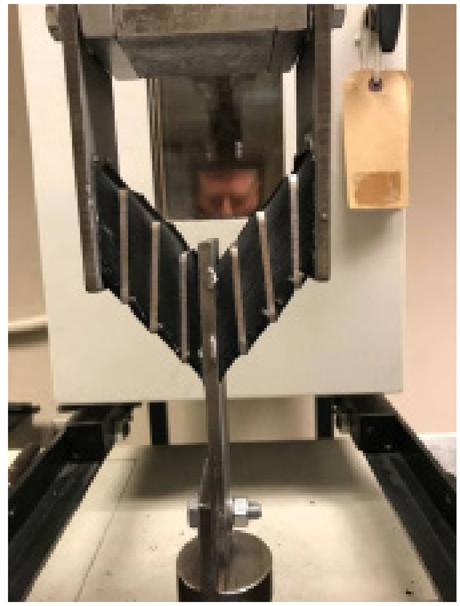

Figure 2.5-1. Shear Bond Test

2.6—MARKING

The designer should add the following notes to the plans:

"All bearings shall be marked prior to shipping. The marks shall include the bearing location on the bridge, and a direction arrow that points up-station. All marks shall be permanent and be visible after the bearing is installed."

C2.6

Problems have occurred in the field with the installation of bearings with beveled sole plates. It is not always obvious which orientation a bearing must take on a beam before the dead load rotation has been applied. This is especially true for bearings with minor bevels.

2.7—INSTALLATION PRACTICE

The installation practice of an elastomeric bearing should be based on the assumptions made during design. Designers should specify any special requirements for the installation of the bearing that may affect the bearing's performance.

Designers should assume a mean setting temperature range when calculating the design movement. The temperature setting range should be shown in the contract documents.

C2.7

The design movement of the bearing is normally not based on the entire expected temperature range. The design movement is normally taken from a mean temperature. It is not realistic to expect that the bearing will be installed at an exact mean temperature; therefore, the bearing should be designed for a movement that is equal to the mean, plus or minus a specified temperature range.

If construction is anticipated during temperature extremes, the bearing can be designed for a larger temperature range. Alternatively, the bridge can be designed and detailed for future jacking where the bearings can be reset. This should be noted in the contract documents.

Bearings designed with masonry plates and anchor rods should be detailed with an adjustable connection between the bearing assembly and the steel framing above. Field welding is an acceptable way to accomplish this.

It is not reasonable to assume that the anchor rods and steel framing will be constructed to a tolerance that would accommodate a simple bolted connection. Field welding allows for significant adjustment.

2.8—FIELD INSPECTION AND MAINTENANCE

Elastomeric bearings should be inspected during standard bridge inspection cycles. The following measures of proper performance can be checked during inspection:

- Over-translation
- Proper translation
- Sliding or “walking”
- Splitting, tearing, or excessive bulging

C2.8

Elastomeric bearings are relatively maintenance-free but should be inspected in accordance with the most recent procedures set forth by FHWA’s National Bridge Inspection Program or a more stringent state or local government policy.

Because the total sum thickness of internal steel shims may be unknown at the time of inspection, if the translation (deviation from vertical) is half the total height of the bearing (not including external load plates), the position of the bearing should be considered to be past the allowable one-way movement. For situations where the beam can slip infrequently to reach translation equilibrium on the bearing pad and not move the bearing pad from the substructure support, lateral translation of up to half the thickness of the pad should not be a reason for concern.

Normal operating temperature for most owners is approximately 50–70 degrees F in which the forward and back station vertical faces of the bearing are near vertical. Translation beyond expected or opposite of expected could mean that the bearing was set outside of the normal operating temperature and never reset.

Elastomeric bearings should be checked for evidence that the bearing has “walked out” from under the beam or girder.

A small amount of bulging, splitting, or tearing in steel reinforced elastomeric bearings will not necessarily reduce the serviceability of the bearing pad unless the internal reinforcement becomes subjected to an excessively-corrosive environment. Check the area where the pad is bonded to the sole and masonry plates, if applicable, for evidence of separation. Check for thickness variations that cannot be attributed to normal rotation of the bearing. Older elastomeric bearings may have been designed before the shape factor was included in the design. Therefore, check for excessive bulging (vertical faces of plain pads and vertical face of layers between steel laminates). Bulging can lead to splitting and/or rolling of the bearing elastomer.

- Sliding Surfaces

Any bearing with PTFE/stainless steel sliding elements should be inspected for fragments of PTFE on the surrounding surface, which would indicate damage to the stainless steel, or encroachment of the stainless steel edge onto or over the PTFE surface. The stainless steel should be examined for scratching, weld spatter, grout, paint, and any other type of debris. These items could cause damage to the PTFE and prevent proper function of the bearing. Examine the position of the stainless steel surface on the bearing to determine remaining movement capacity.

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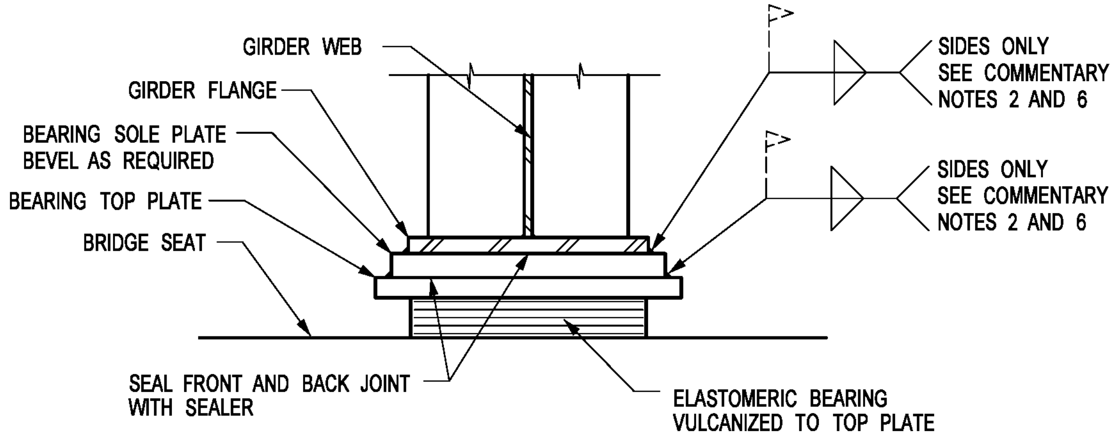
Muscarella, J. V. and Yura, J. A., Research Report FHWA/TX-98-1304-3, An Experimental Study of Elastomeric Bridge Bearings with Design Recommendations, University of Texas at Austin, Austin, TX, 1995.

2.10—RECOMMENDED DRAWING DETAILS

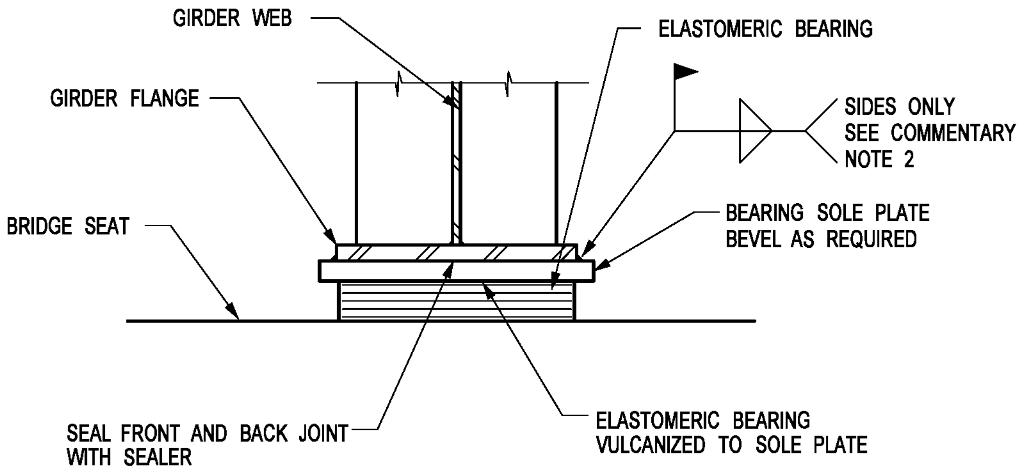
The following pages contain drawings that include recommended design and detailing guidance for elastomeric bearings. These drawings are not intended to supersede any standards established by the bridge Owner. The designer should obtain permission to use any detail that is in conflict with the Owner's standards.



OPTION A - SEPARATE BEVELED SOLE PLATE

COMMENTARY:

1. *LOWER BEARING COST THAN OPTION B BECAUSE THE TOP PLATE IS FLAT, WHICH FACILITATES THE VULCANIZING PROCESS. HOWEVER, TOTAL COST MAY BE HIGHER DUE TO NEED FOR MULTIPLE PLATES.*
2. *CARE MUST BE EXERCISED WITH THE FIELD WELDING. THE TEMPERATURE OF THE STEEL ADJACENT TO THE BEARING MUST BE KEPT TO BELOW 225 DEGREES F. TEMPERATURE CRAYONS MAY BE USED TO MONITOR THE STEEL TEMPERATURE DURING WELDING.*
3. *GOOD FOR BRIDGES WITH MANY DIFFERENT SOLE PLATES, SINCE THE SLOPE OF THE SOLE PLATE DOES NOT AFFECT THE MANUFACTURE OF THE BEARING.*
4. *LATERAL RESTRAINT BY FRICTION, KEEPER ANGLES, OR KEEPER BLOCKS.*
5. *DASHED FIELD WELDING SYMBOL REFERS TO OPTIONAL FIELD/SHOP WELD. THE WELDING DETAILS OF BEARINGS VARY FROM STATE TO STATE. REFER TO STATE STANDARDS.*
6. *ONE OF THESE WELDS SHOULD BE FIELD-WELDED TO ALLOW FOR ADJUSTMENT DURING INSTALLATION. THE CONTRACTOR SHOULD BE ALLOWED THE OPTION.*

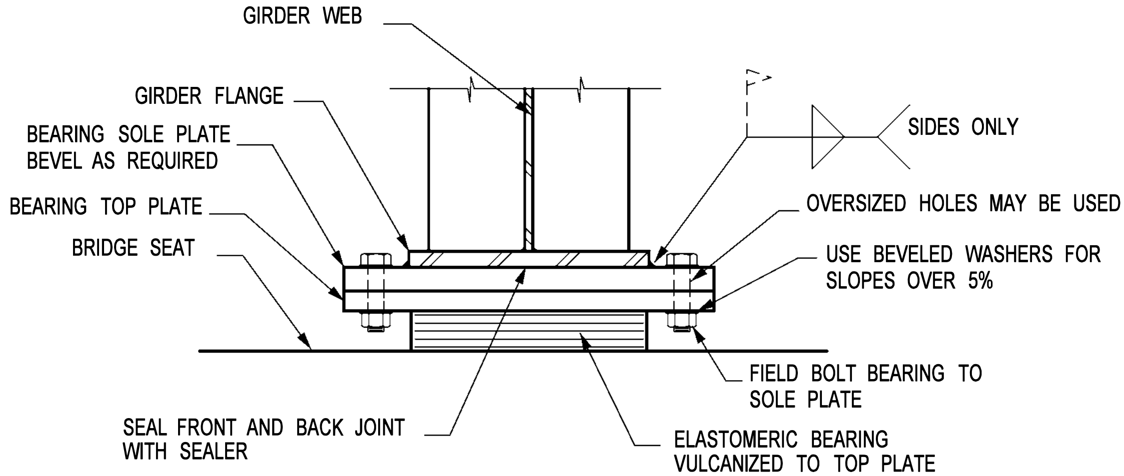


OPTION B - BEVELED BEARING TOP PLATE

COMMENTARY:

1. *GOOD FOR LOCATIONS WHERE A LOW BEARING PROFILE IS REQUIRED, SUCH AS REHABILITATION PROJECTS.*
2. *CARE MUST BE EXERCISED WITH THE FIELD WELDING. THE TEMPERATURE OF THE STEEL ADJACENT TO THE BEARING MUST BE KEPT TO BELOW 225 DEGREES F. TEMPERATURE CRAYONS SHOULD BE USED TO MONITOR THE STEEL TEMPERATURE DURING WELDING.*
3. *THIS DESIGN IS PREFERRED WHEN MANY OF THE BEARINGS ON THE BRIDGE HAVE THE SAME SLOPE ON THE BEVELED SOLE PLATE. THIS REDUCES FABRICATION COSTS.*
4. *LATERAL RESTRAINT BY FRICTION, KEEPER ANGLES, OR KEEPER BLOCKS.*

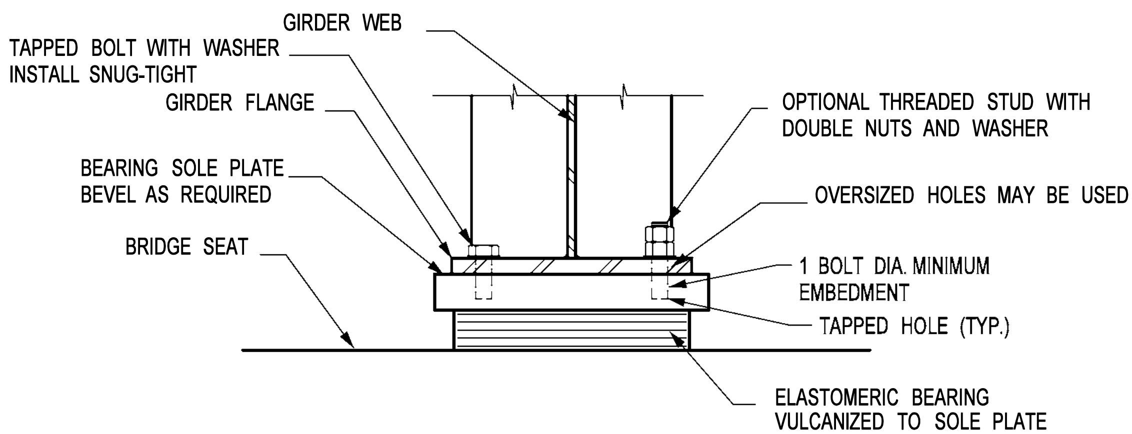
AASHTO/NSBA STEEL BRIDGE COLLABORATION	ELASTOMERIC BEARINGS	LATEST REVISION DATE 12-15-22
	EXPANSION BEARINGS WITH FIELD-WELDED CONNECTIONS	DRAWING NUMBER E 1.1



OPTION A - SEPARATE BEVELED SOLE PLATE

COMMENTARY:

1. *THIS DESIGN IS PREFERRED FOR BRIDGES WITH MANY DIFFERENT SOLE PLATES, SINCE THE SLOPE OF THE SOLE PLATE DOES NOT AFFECT THE MANUFACTURE OF THE BEARING.*
2. *GIRDER FABRICATOR AND BEARING MANUFACTURER MUST COORDINATE BOLT HOLE LOCATIONS. THE DESIGNER SHOULD TRY TO MINIMIZE THE NUMBER OF BOLT HOLE PATTERNS ON EACH PROJECT.*
3. *LATERAL RESTRAINT BY FRICTION, KEEPER ANGLES OR KEEPER BLOCKS.*
4. *DASHED FIELD WELDING SYMBOL REFERS TO OPTIONAL FIELD/SHOP WELD. THE WELDING DETAILS OF BEARINGS VARY FROM STATE TO STATE. REFER TO STATE STANDARDS.*

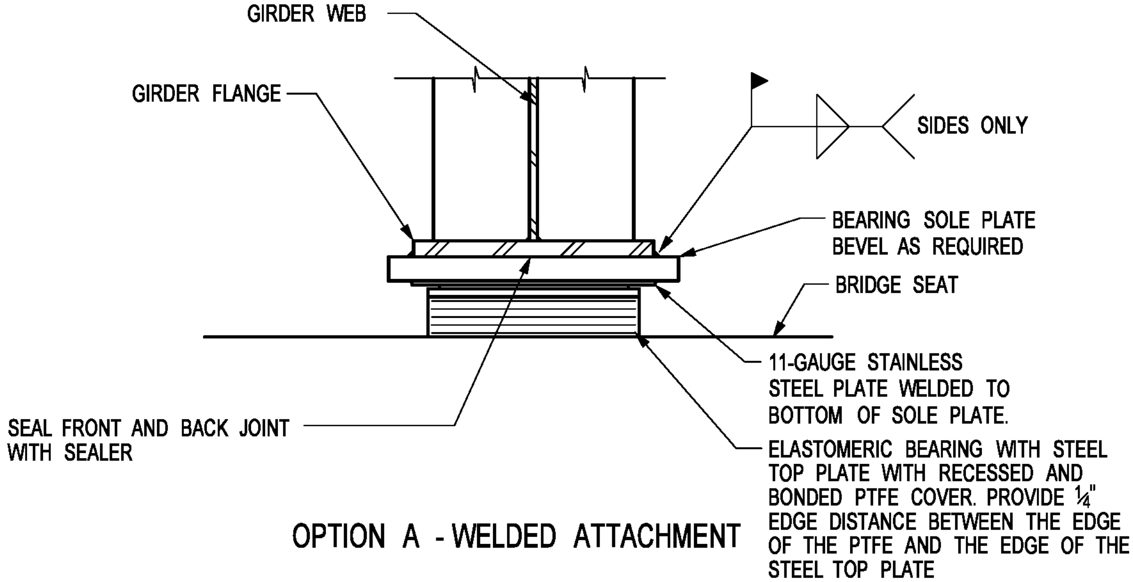


OPTION B - BEVELED BEARING TOP PLATE

COMMENTARY:

1. *THIS DESIGN IS PREFERRED ON BRIDGES THAT HAVE MANY BEARINGS WITH THE SAME SLOPE ON THE BEVELED SOLE PLATE. THIS REDUCES FABRICATION COSTS.*
2. *GIRDER FABRICATOR AND BEARING MANUFACTURER MUST COORDINATE BOLT HOLE LOCATIONS. THE DESIGNER SHOULD TRY TO MINIMIZE THE NUMBER OF BOLT HOLE PATTERNS ON EACH PROJECT.*
3. *LATERAL RESTRAINT BY FRICTION, KEEPER ANGLES, OR KEEPER BLOCKS.*

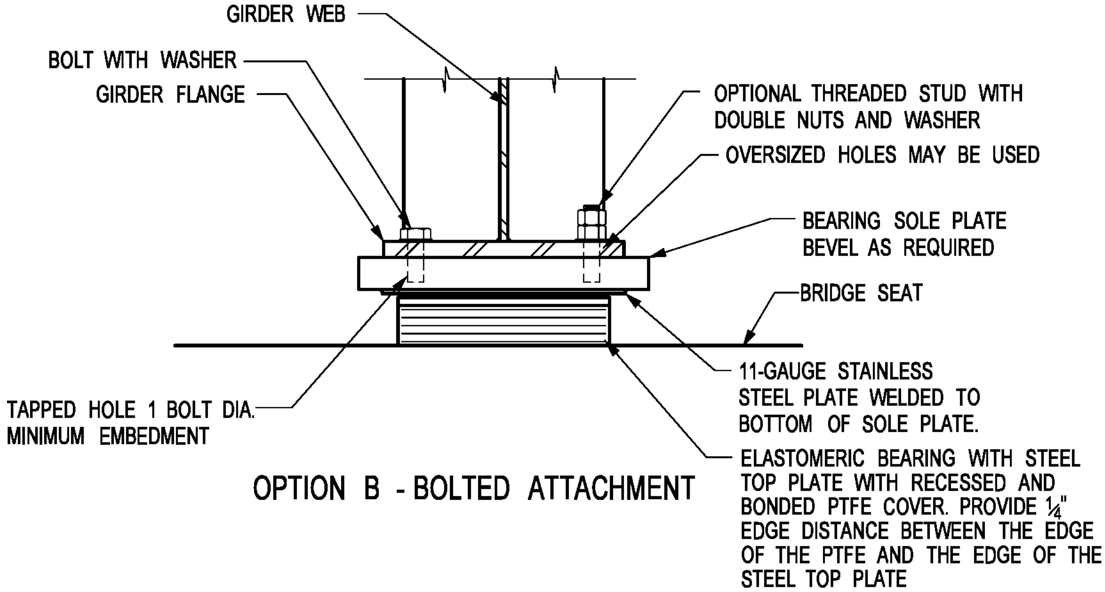
AASHTO/NSBA STEEL BRIDGE COLLABORATION	ELASTOMERIC BEARINGS	LATEST REVISION DATE 12-15-22
	EXPANSION BEARINGS WITH BOLTED CONNECTIONS	DRAWING NUMBER E 1.2



OPTION A - WELDED ATTACHMENT

COMMENTARY:

1. *FIELD-WELDED CONNECTION RECOMMENDED TO PREVENT DAMAGE TO STAINLESS STEEL PLATE DURING SHIPPING.*
2. *LATERAL LOADS TO BE RESISTED BY KEEPER ANGLES OR CONCRETE KEEPER BLOCKS. SEE DETAILS ON DRAWINGS E 4.1 AND E 4.2.*
3. *SEVERAL STATES SPECIFY RESTRAINT FOR ELASTOMERIC BEARINGS. FOR THESE CASES, A BONDED MASONRY PLATE WITH ANCHOR RODS MAY BE ADDED TO THIS DETAIL TO RESTRAIN THE BEARING FROM MOVEMENT.*

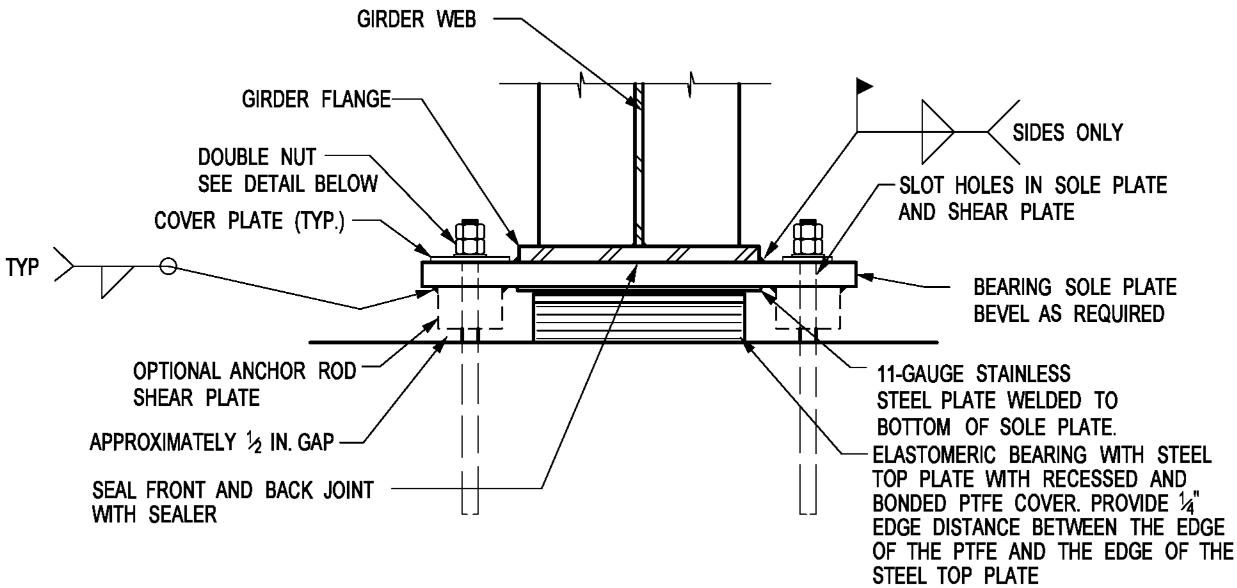


OPTION B - BOLTED ATTACHMENT

COMMENTARY:

1. *OVERSIZED HOLES FOR THE BOLTED CONNECTION ALLOWS FOR MINOR ADJUSTMENT OF THE BEARING TO BEAM CONNECTION.*
2. *LATERAL LOADS TO BE RESISTED BY KEEPER ANGLES OR KEEPER BLOCKS. SEE DETAILS ON DRAWINGS E 4.1 AND E 4.2.*
3. *GIRDER FABRICATOR AND BEARING MANUFACTURER MUST COORDINATE BOLT HOLE LOCATIONS. THE DESIGNER SHOULD TRY TO MINIMIZE THE NUMBER OF BOLT HOLE PATTERNS ON EACH PROJECT.*
4. *SEVERAL STATES SPECIFY RESTRAINT FOR ELASTOMERIC BEARINGS. FOR THESE CASES, A BONDED MASONRY PLATE WITH ANCHOR RODS MAY BE ADDED TO THIS DETAIL TO RESTRAIN THE BEARING FROM MOVEMENT.*

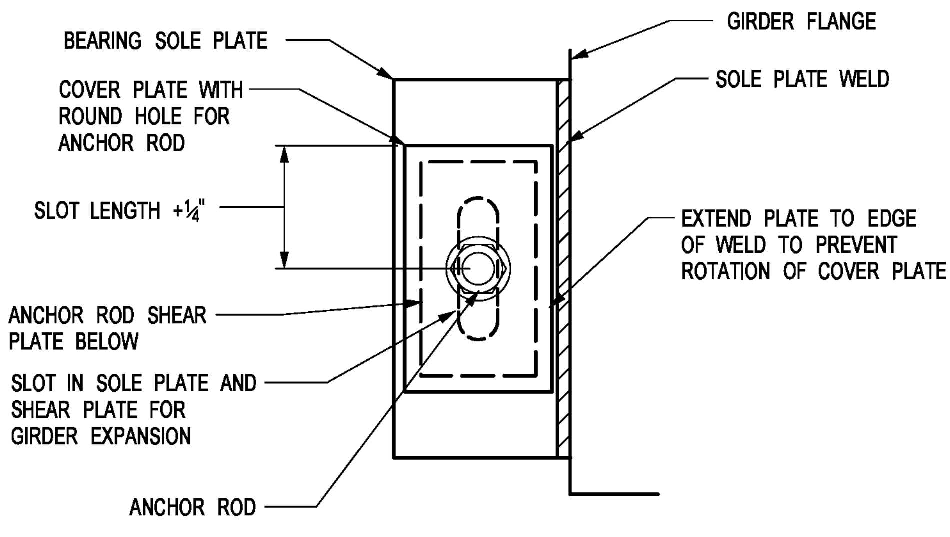
AASHTO/NSBA STEEL BRIDGE COLLABORATION	ELASTOMERIC BEARINGS	LATEST REVISION DATE 12-15-22
	LARGE MOVEMENT NON-GUIDED EXPANSION BEARINGS	DRAWING NUMBER E 2.1



OPTION A - WELDED ATTACHMENT

COMMENTARY:

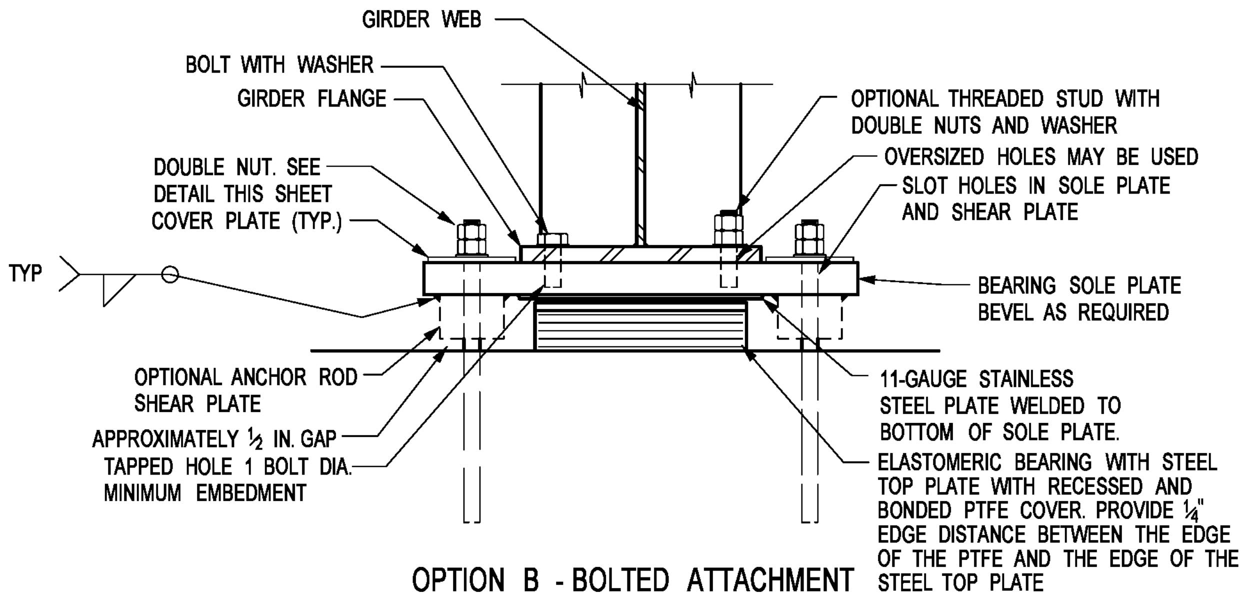
1. *WELDED CONNECTION ALLOWS FOR MINOR ADJUSTMENT OF THE BEARING TO BEAM CONNECTION.*
2. *ANCHOR ROD SHEAR PLATE USED TO MINIMIZE BENDING IN ANCHOR RODS UNDER LATERAL LOAD.*
3. *SHEAR PLATE MAY BE OMITTED FOR BEARINGS WITH SMALL LATERAL LOADS AND/OR LOW-PROFILE BEARINGS.*
4. *INSTALL LOWER NUT IN CONTACT WITH TOP PLATE AND THEN BACK OFF ½ TURN. INSTALL UPPER NUT SNUG TIGHT TO PREVENT LOWER NUTS FROM LOOSENING. LARGER GAPS MAY BE REQUIRED FOR BEARINGS WITH MORE THAN TWO RODS DUE TO VERTICAL MOVEMENT AT THE RODS DURING GIRDER ROTATION.*
5. *THE RELATIVE TRANSVERSE LOCATION OF ANCHOR RODS NEEDS TO MATCH THE SOLE PLATE.*



ANCHOR ROD SLOT DETAIL

PLAN

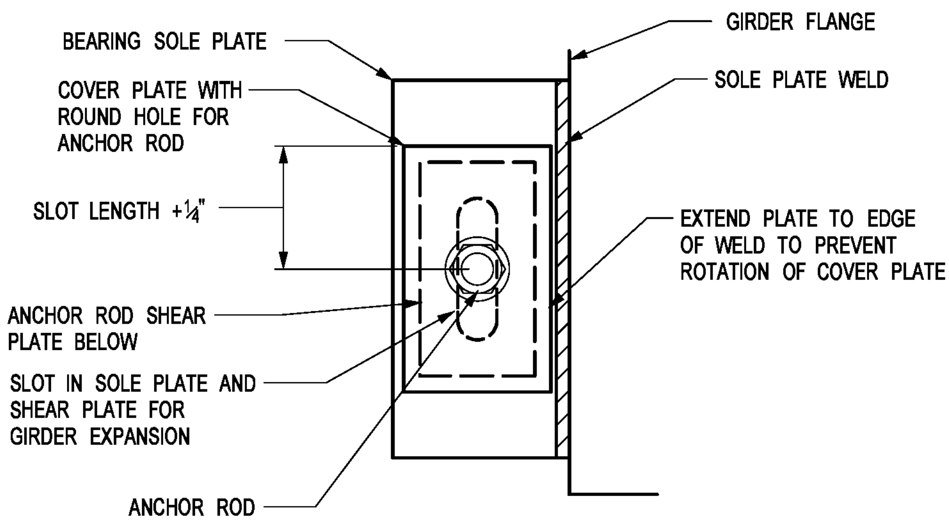
AASHTO/NSBA STEEL BRIDGE COLLABORATION	ELASTOMERIC BEARINGS	LATEST REVISION DATE 12-15-22
	LARGE MOVEMENT EXPANSION BEARINGS WITH WELDED ATTACHMENT WITH BEARING ANCHOR RODS	DRAWING NUMBER E 2.2



OPTION B - BOLTED ATTACHMENT

COMMENTARY:

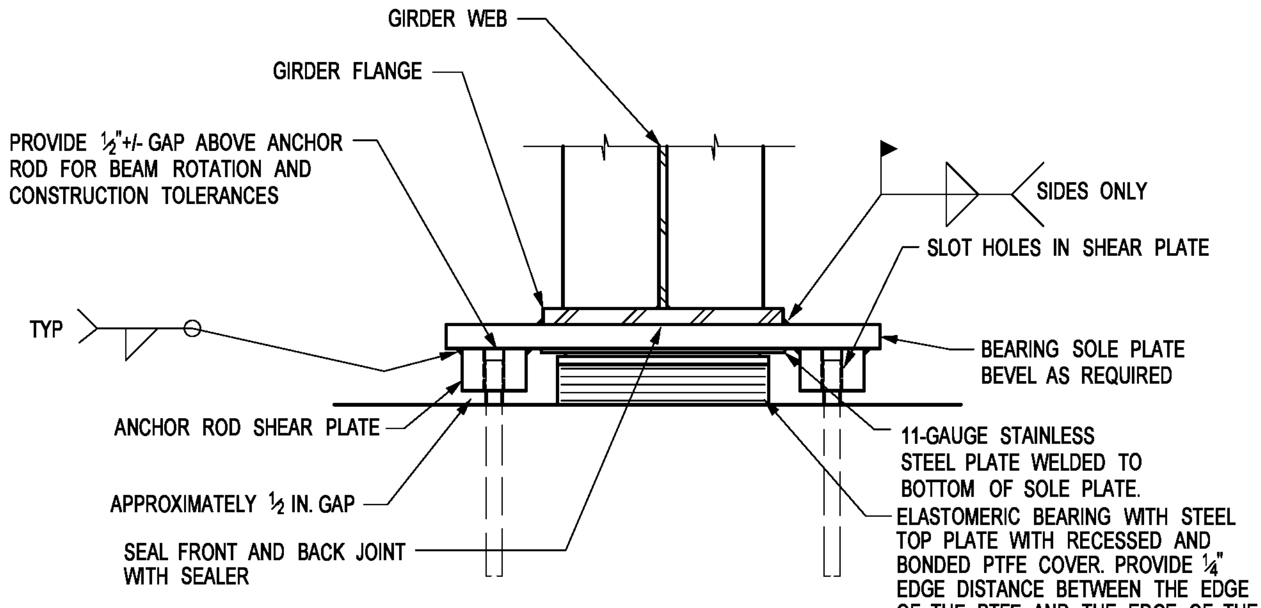
1. *OVERSIZED HOLES FOR THE BOLTED CONNECTION ALLOW FOR MINOR ADJUSTMENT OF THE BEARING TO BEAM CONNECTION.*
2. *ANCHOR ROD SHEAR PLATE USED TO MINIMIZE BENDING IN ANCHOR RODS UNDER LATERAL LOAD.*
3. *SHEAR PLATE MAY BE OMITTED FOR BEARINGS WITH SMALL LATERAL LOADS AND/OR LOW-PROFILE BEARINGS.*
4. *GIRDER FABRICATOR AND BEARING MANUFACTURER MUST COORDINATE BOLT HOLE LOCATIONS. THE DESIGNER SHOULD TRY TO MINIMIZE THE NUMBER OF BOLT HOLE PATTERNS ON EACH PROJECT.*
5. *THE RELATIVE TRANSVERSE LOCATION OF ANCHOR RODS NEEDS TO MATCH THE SOLE PLATE.*
6. *INSTALL LOWER NUT IN CONTACT WITH TOP PLATE AND THEN BACK OFF ½ TURN. INSTALL UPPER NUT SNUG TIGHT TO PREVENT LOWER NUTS FROM LOOSENING. LARGER GAPS MAY BE REQUIRED FOR BEARINGS WITH MORE THAN TWO RODS DUE TO VERTICAL MOVEMENT AT THE RODS DURING GIRDER ROTATION.*



ANCHOR ROD SLOT DETAIL

PLAN

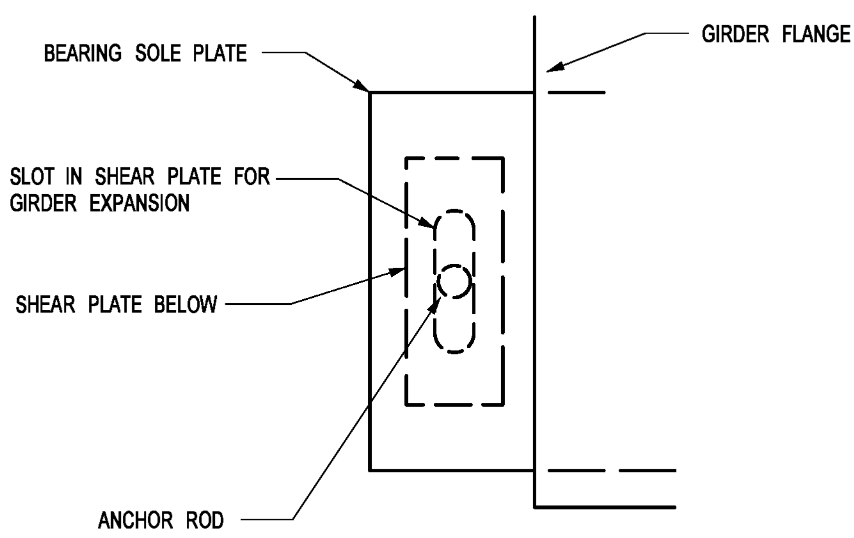
AASHTO/NSBA STEEL BRIDGE COLLABORATION	ELASTOMERIC BEARINGS	LATEST REVISION DATE 12-15-22
	LARGE MOVEMENT EXPANSION BEARINGS WITH BOLTED ATTACHMENT WITH BEARING ANCHOR RODS	DRAWING NUMBER E 2.3



OPTION A - WELDED ATTACHMENT

COMMENTARY:

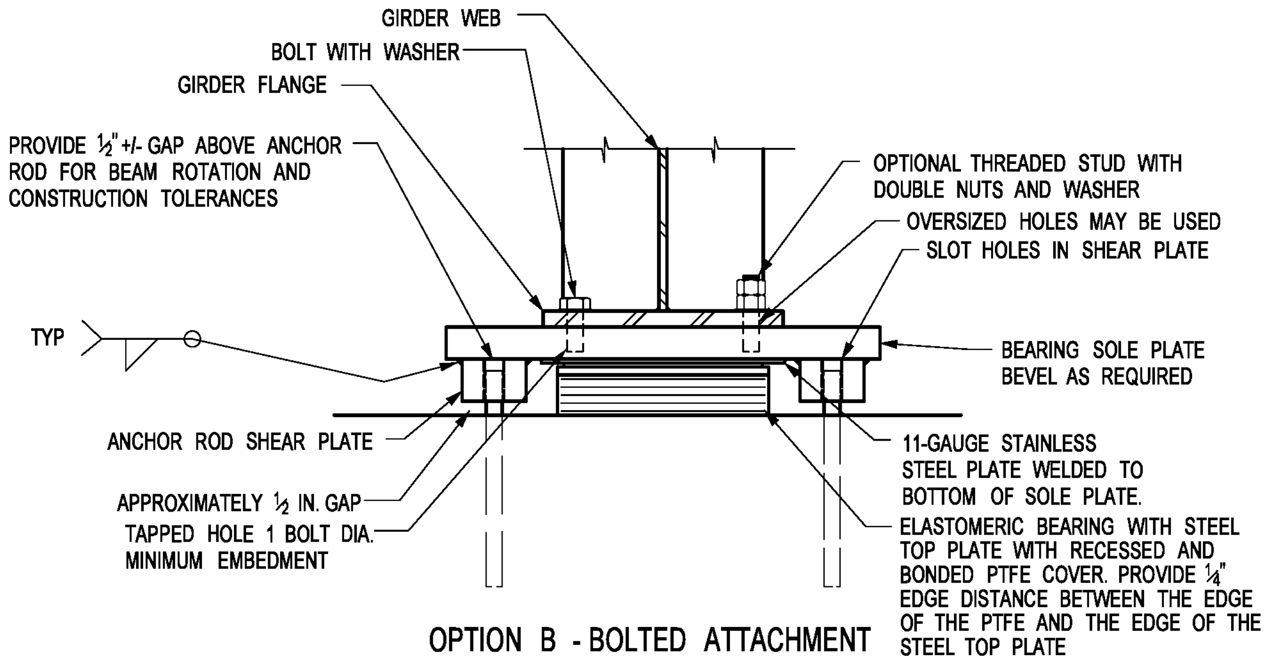
1. *WELDED CONNECTIONS ALLOW FOR MINOR ADJUSTMENT OF THE BEARING TO BEAM CONNECTION.*
2. *ANCHOR ROD SHEAR PLATE USED TO MINIMIZE BENDING IN ANCHOR RODS UNDER LATERAL LOAD.*
3. *OVERSIZED HOLES ONLY ALLOW FOR MINOR ADJUSTMENT IN THE FIELD, THEREFORE CORRECT ANCHOR ROD LOCATIONS ARE CRITICAL.*
4. *THIS BEARING MAY BE USED IN SITUATIONS WHERE UPLIFT RESTRAINT IS NOT REQUIRED.*



ANCHOR ROD SLOT DETAIL

PLAN

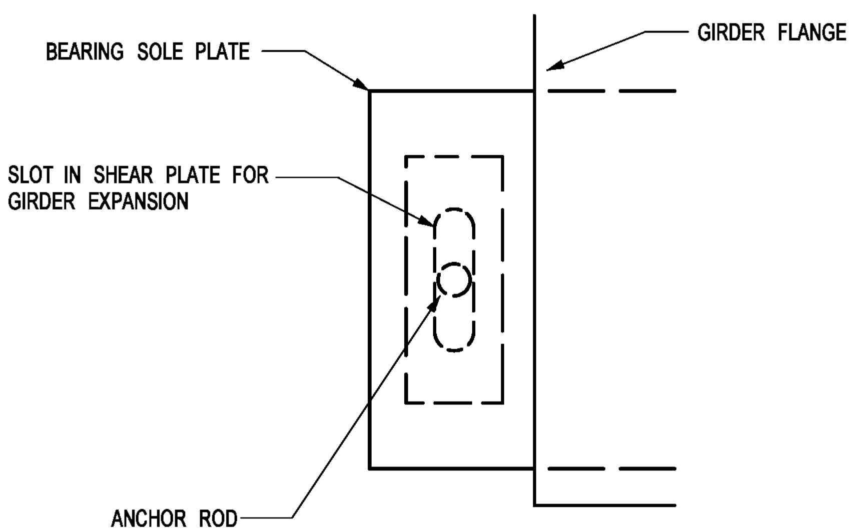
AASHTO/NSBA STEEL BRIDGE COLLABORATION	ELASTOMERIC BEARINGS	LATEST REVISION DATE 12-15-22
	LARGE MOVEMENT EXPANSION BEARINGS WITH WELDED ATTACHMENT WITH BEARING ANCHOR STUDS	DRAWING NUMBER E 2.4



OPTION B - BOLTED ATTACHMENT

COMMENTARY:

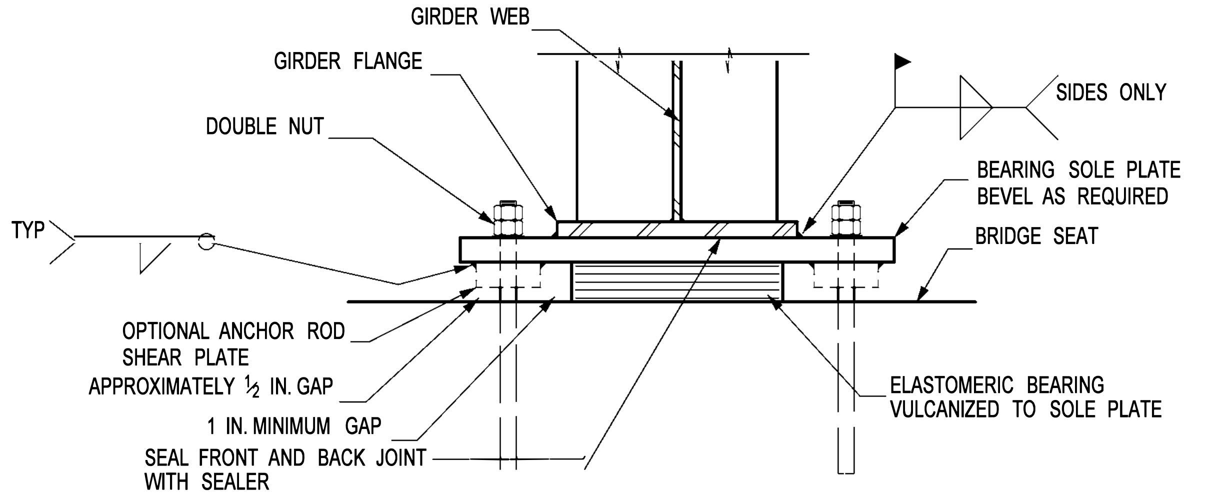
1. *OVERSIZED HOLES FOR THE BOLTED CONNECTION ALLOW FOR MINOR ADJUSTMENT OF THE BEARING TO BEAM CONNECTION.*
2. *ANCHOR ROD SHEAR PLATE USED TO MINIMIZE BENDING IN ANCHOR RODS UNDER LATERAL LOAD.*
3. *GIRDER FABRICATOR AND BEARING MANUFACTURER MUST COORDINATE BOLT HOLE LOCATIONS. THE DESIGNER SHOULD TRY TO MINIMIZE THE NUMBER OF BOLT HOLE PATTERNS ON EACH PROJECT.*
4. *OVERSIZED HOLES ONLY ALLOW FOR MINOR ADJUSTMENT IN THE FIELD, THEREFORE CORRECT ANCHOR ROD LOCATIONS ARE CRITICAL.*



ANCHOR ROD SLOT DETAIL

PLAN

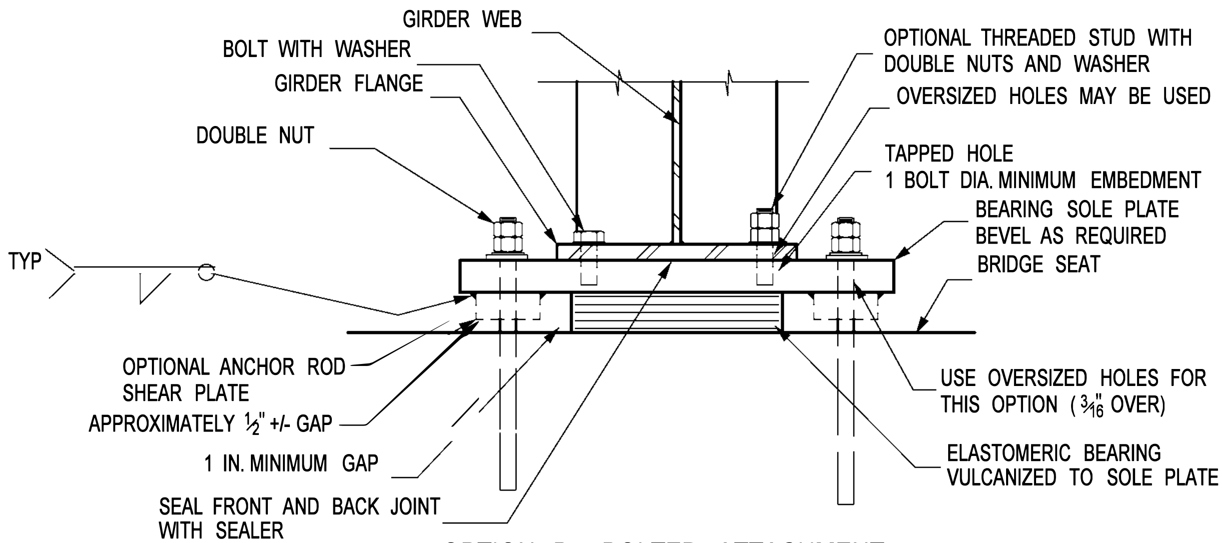
AASHTO/NSBA STEEL BRIDGE COLLABORATION	ELASTOMERIC BEARINGS	LATEST REVISION DATE 12-15-22
	LARGE MOVEMENT EXPANSION BEARINGS WITH BOLTED ATTACHMENT WITH BEARING ANCHOR STUDS	DRAWING NUMBER E 2.5



OPTION A - WELDED ATTACHMENT

COMMENTARY:

1. *WELDED CONNECTIONS ALLOW FOR MINOR ADJUSTMENT OF THE BEARING TO BEAM CONNECTION.*
2. *ANCHOR ROD SHEAR PLATE USED TO MINIMIZE BENDING IN ANCHOR RODS UNDER LATERAL LOAD. SHEAR PLATE MAY BE OMITTED FOR BEARINGS WITH SMALL LATERAL LOADS.*
3. *ADDITIONAL LATERAL RESTRAINT MAY BE PROVIDED BY KEEPER ANGLES, OR KEEPER BLOCKS BETWEEN BEAMS.*
4. *INSTALL LOWER NUT IN CONTACT WITH TOP PLATE AND THEN BACK OFF ½ TURN. INSTALL UPPER NUT SNUG TIGHT TO PREVENT LOWER NUTS FROM LOOSENING. LARGER GAPS MAY BE REQUIRED FOR BEARINGS WITH MORE THAN TWO RODS DUE TO VERTICAL MOVEMENT AT THE RODS DURING GIRDER ROTATION.*
5. *OVERSIZED HOLES ONLY ALLOW FOR MINOR ADJUSTMENT IN THE FIELD, THEREFORE CORRECT ANCHOR ROD LOCATIONS ARE CRITICAL.*

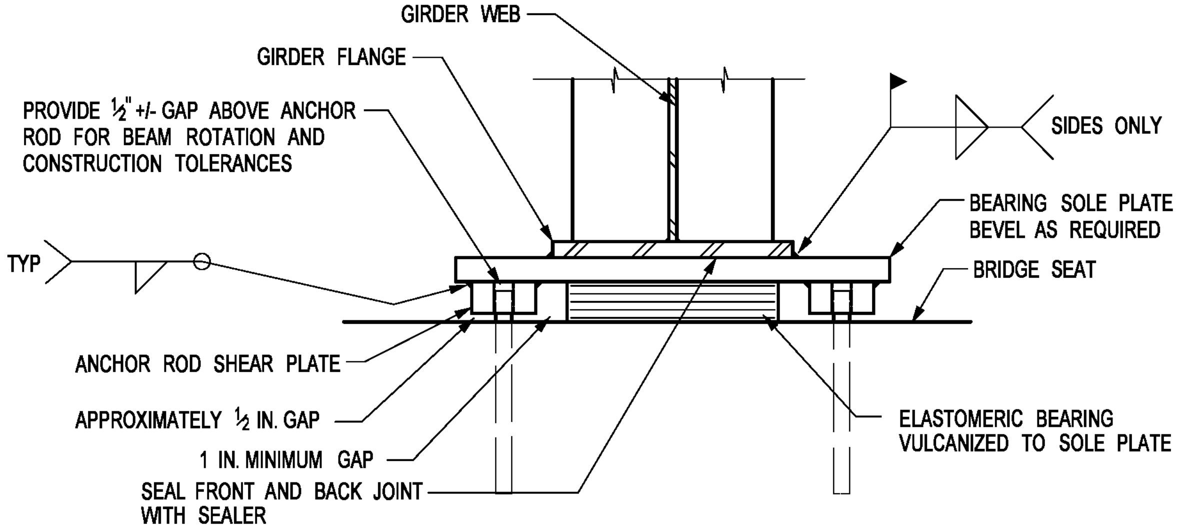


OPTION B - BOLTED ATTACHMENT

COMMENTARY:

1. *SIMILAR COMMENTARY TO OPTION A.*
2. *OVERSIZED HOLES ONLY ALLOW FOR MINOR ADJUSTMENT IN THE FIELD, THEREFORE CORRECT ANCHOR ROD LOCATIONS ARE CRITICAL.*
3. *GIRDER FABRICATOR AND BEARING MANUFACTURER MUST COORDINATE BOLT HOLE LOCATIONS. THE DESIGNER SHOULD TRY TO MINIMIZE THE NUMBER OF BOLT HOLE PATTERNS ON EACH PROJECT.*

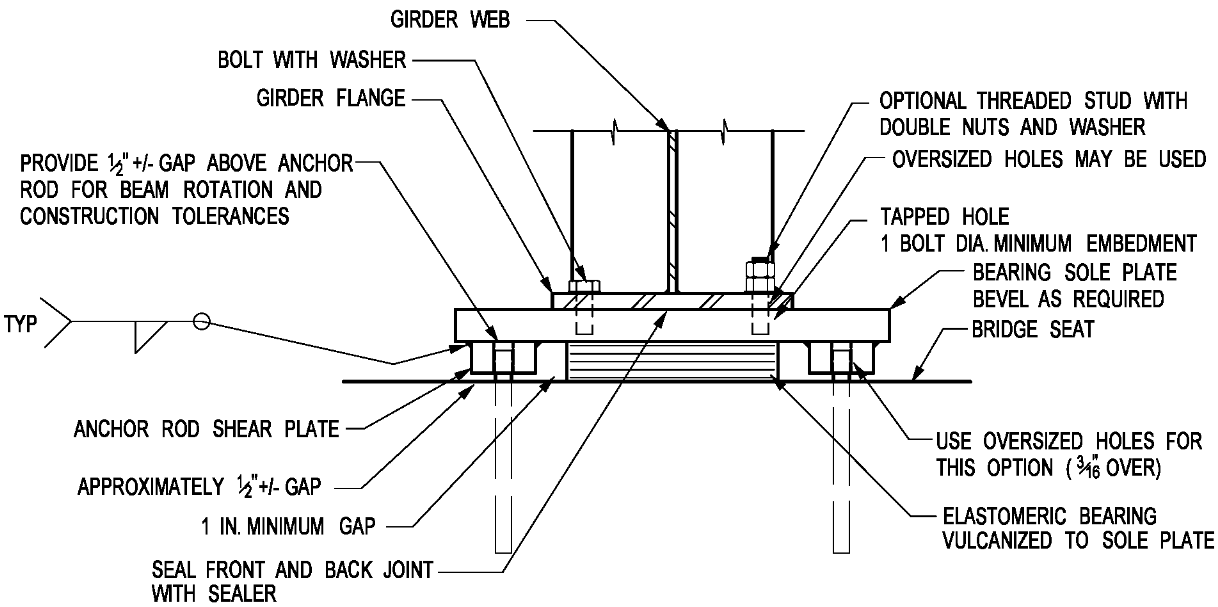
AASHTO/NSBA STEEL BRIDGE COLLABORATION	ELASTOMERIC BEARINGS	LATEST REVISION DATE 12-15-22
	FIXED ELASTOMERIC BEARINGS WITH ANCHOR RODS	DRAWING NUMBER E 3.1



OPTION A - WELDED ATTACHMENT

COMMENTARY:

1. *WELDED CONNECTION ALLOWS FOR MINOR ADJUSTMENT OF THE BEARING/BEAM CONNECTION.*
2. *ANCHOR ROD SHEAR PLATE USED TO MINIMIZE BENDING IN ANCHOR RODS UNDER LATERAL LOAD.*

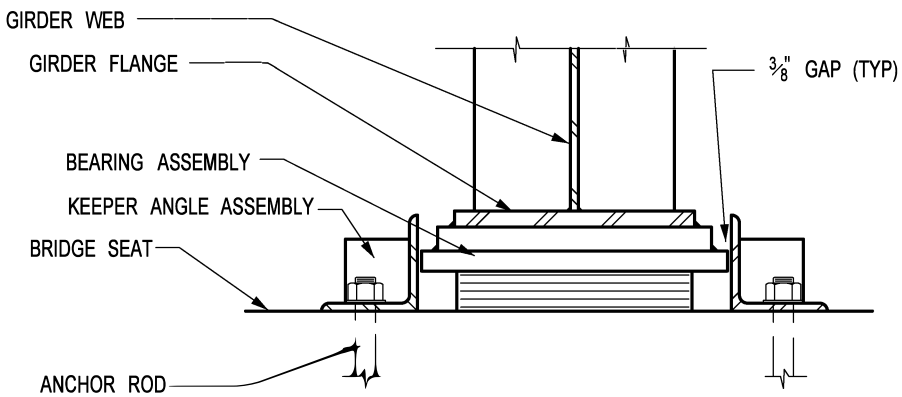


OPTION B - BOLTED ATTACHMENT

COMMENTARY:

1. *SIMILAR COMMENTARY TO OPTION A.*
2. *OVERSIZED HOLES ONLY ALLOW FOR MINOR ADJUSTMENT IN THE FIELD, THEREFORE CORRECT ANCHOR ROD LOCATIONS ARE CRITICAL.*
3. *GIRDER FABRICATOR AND BEARING MANUFACTURER MUST COORDINATE BOLT HOLE LOCATIONS. THE DESIGNER SHOULD TRY TO MINIMIZE THE NUMBER OF BOLT HOLE PATTERNS ON EACH PROJECT.*

AASHTO/NSBA STEEL BRIDGE COLLABORATION	ELASTOMERIC BEARINGS	LATEST REVISION DATE 12-15-22
	FIXED ELASTOMERIC BEARINGS WITH ANCHOR STUDS	DRAWING NUMBER E 3.2

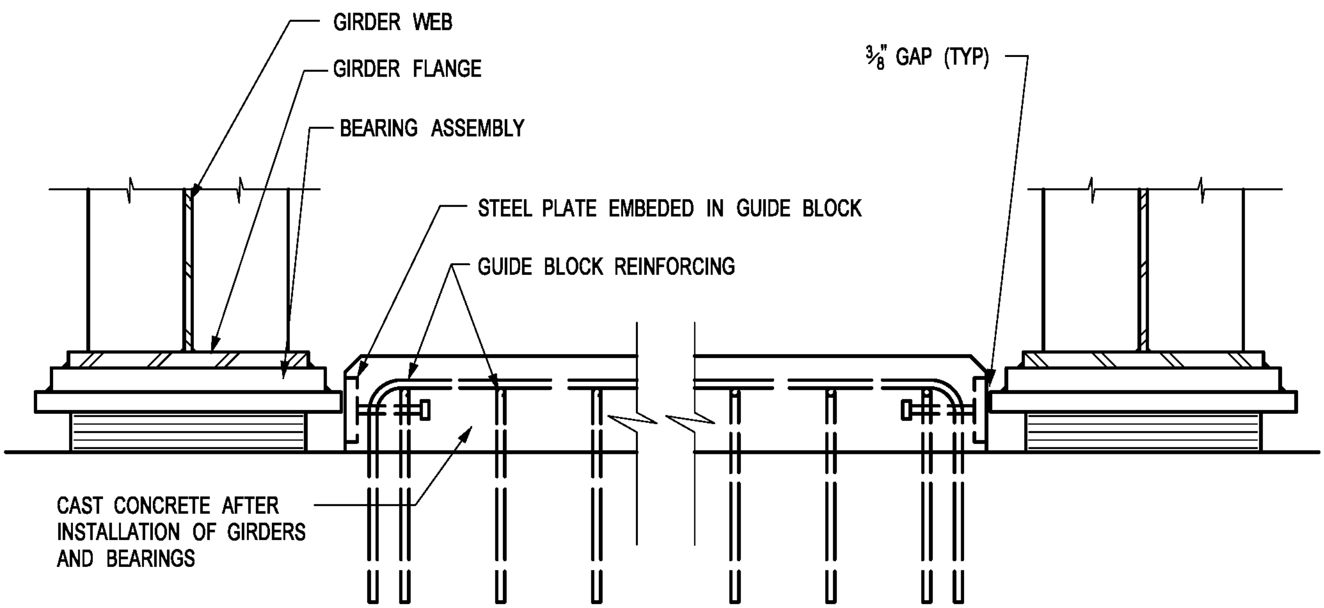


STEEL KEEPER ANGLES

COMMENTARY

1. *WELDED BEARING ASSEMBLY SHOWN. DETAILS SIMILAR FOR OTHER BEARING DESIGNS.*
2. *KEEPER ANGLES DO NOT NEED TO BE INSTALLED ON EVERY BEARING. ON WIDE BRIDGES WITH SIGNIFICANT LATERAL THERMAL MOVEMENT, THE KEEPERS SHOULD BE USED ON THE INTERIOR GIRDERS ONLY IN ORDER TO PREVENT BINDING OF THE BEARING ASSEMBLY DUE TO LATERAL THERMAL MOVEMENT OF THE BRIDGE.*
3. *ON BRIDGES WITH A SKEW GREATER THAN 30 DEGREES, CONSIDERATION SHOULD BE GIVEN TO SKEWING THE KEEPER ASSEMBLY ALONG THE LINE OF THERMAL MOVEMENT OF THE BRIDGE DECK. SEE SECTION 2.3.5.1 AND APPENDIX B.*
4. *CARE SHALL BE TAKEN IN THE LAYOUT OF THE ANCHOR RODS ON BRIDGES WITH HEAVILY REINFORCED PIER BENT CAPS IN ORDER TO AVOID CONFLICTS WITH PIER REINFORCING. THIS PROBLEM IS MORE PRONOUNCED ON SKEWED BRIDGES AND REHABILITATION PROJECTS. THE DESIGNER SHOULD SHOW THE BEARING KEEPER ASSEMBLY IN PLAN WITH THE PIER REINFORCING TO DOCUMENT THE LAYOUT.*
5. *ALL STEEL IN KEEPER ASSEMBLIES SHALL BE GALVANIZED ACCORDING TO ASTM A123.*
6. *THE GAP BETWEEN THE KEEPERS MAY BE ADJUSTED AS PER STATE STANDARDS AND UNUSUAL THERMAL MOVEMENT CONDITIONS.*

AASHTO/NSBA STEEL BRIDGE COLLABORATION	ELASTOMERIC BEARINGS	LATEST REVISION DATE 12-15-22
	LATERAL RESTRAINT DEVICES STEEL KEEPER ANGLES	DRAWING NUMBER E 4.1



KEEPER BLOCK

COMMENTARY

1. *WELDED BEARING ASSEMBLY SHOWN. DETAILS SIMILAR FOR OTHER BEARING DESIGNS.*
2. *THIS DESIGN IS GOOD FOR HEAVILY REINFORCED PIER CAPS, SKEWED BRIDGES, AND REHABILITATION PROJECTS WHERE THE EXACT LOCATION OF THE SUBSTRUCTURE REINFORCING MAY NOT BE KNOWN. FOR THIS CASE, THE LOCATION OF THE REINFORCING BARS MAY BE ADJUSTED IN THE FIELD TO MISS THE UNDERLYING STEEL.*
3. *KEEPER BLOCKS DO NOT NEED TO BE INSTALLED ON EVERY BEARING. ON WIDE BRIDGES WITH SIGNIFICANT LATERAL THERMAL MOVEMENT, THE KEEPER BLOCKS SHOULD BE USED BETWEEN THE INTERIOR GIRDERS ONLY IN ORDER TO PREVENT BINDING OF THE BEARING ASSEMBLY DUE TO LATERAL THERMAL MOVEMENT OF THE BRIDGE.*
4. *ON BRIDGES WITH A SKEW GREATER THAN 30 DEGREES, CONSIDERATION SHOULD BE GIVEN TO SKEWING THE KEEPER BLOCK ALONG THE LINE OF THERMAL MOVEMENT OF THE BRIDGE DECK. SEE SECTION 2.3.5.1 AND APPENDIX B.*
5. *ALL STEEL ASSEMBLIES SHALL BE GALVANIZED ACCORDING TO ASTM A123.*
6. *THE GAP BETWEEN THE KEEPERS MAY BE ADJUSTED AS PER STATE STANDARDS AND UNUSUAL THERMAL MOVEMENT CONDITIONS.*

AASHTO/NSBA STEEL BRIDGE COLLABORATION	ELASTOMERIC BEARINGS	LATEST REVISION DATE 12-15-22
	LATERAL RESTRAINT DEVICES CONCRETE KEEPER BLOCK	DRAWING NUMBER E 4.2

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Section 3: High Load Multi-Rotational Bearings

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Section 3:

HIGH LOAD MULTI-ROTATIONAL BEARINGS

3.1—GENERAL

This Section is intended to assist in the design and detailing of high load multi-rotational bearing (HLMR) assemblies. The information included is intended to permit efficient fabrication, installation, and maintenance of these bearings

C3.1

High load multi-rotational bearings are frequently used on modern steel bridges where the number of girders is minimized and the span lengths are maximized. There are three basic HLMR bearing types currently used: elastomeric pot bearings, polyurethane disc bearings, and spherical bearings.

Article 14.7 of the *AASHTO LRFD Bridge Design Specifications* give significant detail in the design requirements of HLMR bearings. However, there are numerous ways of achieving the requirements set forth in the *AASHTO LRFD Bridge Design Specifications*. Each bearing manufacturer has a unique way to fabricate bearings in an economical fashion based on the equipment that they possess and the personnel that they employ. In order to allow the individual manufacturer to achieve the greatest economy in bearing construction, it is recommended that the engineer specify the loads and geometric requirements for the bearing but leave the actual design and detailing of the bearing to the manufacturer. A table has been provided on Drawing H 1.7 in Article 3.11 depicting required information from the designer.

Because their design may incorporate sliding steel plates, HLMR bearings require long-term maintenance. The following Articles include recommendations on design and detailing practices that will reduce initial costs and allow for future maintenance. The intent of these recommendations is to allow for future removal with minimal vertical jacking of the bridge superstructure. This allows the removal of individual bearings without interrupting the traffic on the bridge, and without causing damage to bridge deck expansion joint systems and utilities carried by the superstructure.

3.2—BASIC ASSUMPTIONS

3.2.1—Approach

Contract plans for bridges with HLMR bearings should not include specific details for the bearings. Only schematic bearing details combined with specified loads, movements, and rotations need to be shown. The bearing is designed by the manufacturer, taking advantage of the cost-effective fabrication procedures that are available in the shop.

C3.2.1

The detailing of HLMR bearings varies from manufacturer to manufacturer. This complicates the design process since a designer would need to detail multiple bearings from multiple manufacturers in order to make bidding competitive. This is even further complicated when multiple bearing types are feasible.

The bridge owner may elect to require specific preferred details to facilitate future maintenance.

3.2.2—Recommended Bearing Types

There are three common HLMR bearing types that function in essentially the same manner:

- disc bearings,
- pot bearings, and
- spherical bearings.

C3.2.2

All three types of HLMR bearings can be allowed on most projects. Spherical bearings are useful for bridges with magnitudes of rotation at beam ends.

3.3—DESIGN AND DETAILING

3.3.1—Design

The design of HLMR bearings should be the responsibility of the bearing manufacturer in accordance with the *AASHTO LRFD Bridge Design Specifications* based on the parameters outlined below. The design of accessory pieces of the bearing, such as the sole plate, masonry plate, and anchor rods, are the responsibility of the bridge designer.

It is recommended that only one bearing per box girder be detailed at each support.

C3.3.1

Sole plate, masonry plate, and anchor rod design are best handled by the bridge designer since the bearing manufacturer may not be aware of important dimensional limitations.

The bridge designer should include notes on the plans allowing the bearing manufacturer to make minor adjustments to the dimensions of the sole plate, masonry plate, and anchor rods. The bridge designer should also identify dimensions that are not to be changed due to design or geometric constraints. For instance, the reinforcing steel in the concrete substructure often limits anchor rod locations. The bearing designer must coordinate any changes with both the contractor and the bridge design engineer.

Dual bearings at a box girder support can result in lack of contact due to construction tolerances, and uplift for bridges with skewed supports.

3.3.1.1—Design Rotation and Movement

HLMR bearing assemblies with beveled sole plates should typically be designed for live load rotations, rotations due to profile grade, and additional rotations for uncertainties (0.005 radians) and construction tolerances (0.005 radians for pot and spherical bearings only) as specified in Article 14.4.2.2 of the *AASHTO LRFD Bridge Design Specifications.*

If beveled sole plates are not specified, then the bearing design should also include dead load rotation and rotation due to the profile grade slope.

C3.3.1.1

The beveled sole plate is used to provide parallel surfaces between the bottom of the sole plate and the top of the masonry plate in the completed bridge. See Appendix A for information on the effect of beveled sole plates on bearing design rotations.

Bearing assemblies consist of the bearing element, connection plates (if required), and a flat or beveled sole plate (if required). See Article 3.11 for details of typical bearing assemblies. Please refer to Appendix A for information on calculating rotations.

If an approximate (average) sole plate slope is specified, the bearing should be designed for a rotation equal to the difference between the theoretical sole plate slope and the specified sole plate slope. See Article 3.3.4 for more information on this approach to detailing sole plates.

The design rotations for uncertainties and construction tolerances are specified in Article 14.4.2.2 of the *AASHTO LRFD Bridge Design Specifications*. The specified design rotation for uncertainties and construction tolerances should be sufficient for virtually all situations. The value of 0.005 radians is a significant rotation. It is equivalent to a slope of $^1/_8$ in. in 24 in. This tolerance level has proven to be attainable in the field. Specifying a larger rotation can increase the bearing cost unnecessarily.

If the beam is cambered for dead loads, the dead load design rotation acting on the elastomer can be neglected. The bearing designer should check the bearing for this temporary condition to ensure that no damage occurs and that there is no metal-to-metal contact.

See Appendix A for information on the effect of beam cambering on bearing design rotations.

The bearings should be designed for longitudinal and lateral movements.

Longitudinal movement due to dead load girder rotation may need to be accounted for on beams with large rotations or for deep girders. This movement should be added to the design longitudinal thermal movement. Refer to Appendix B for guidance on horizontal movements.

The designer should include a temperature setting table on the plans for expansion bearings. This table should indicate the position of the top plates of the bearing relative to the base plates for different installation temperatures.

Owners have different requirements for this issue. A recommended temperature range is the average ambient temperature range for the bridge location plus or minus 10 degrees F. Larger values can be specified provided that the bearing is designed for the additional movement.

For example, the Massachusetts DOT *LRFD Bridge Manual* includes the following text:

DT for structural steel members:

- 70 degrees F temperature rise (from an assumed ambient temperature of 50 degrees F)
- 100 degrees F temperature fall (from an assumed ambient temperature of 70 degrees F)

The variable ambient temperature assumption in the design accounts for an assumed temperature at installation of between 50 degrees F and 70 degrees F.

3.3.1.2—Bearing Sizes

Approximate sizes of typical HLMR bearings are included in Article 3.11, which can be used for design and detailing.

C3.3.1.2

The design of the masonry plate is the responsibility of the designer. The masonry plate should be sized for the required force distribution and to accommodate the bearing base with room for adjustment during installation and anchor rods.

The details can include provisions for adjustment of the beam seat elevation after the final design of the bearing is completed.

The design of the sole plate is also the responsibility of the designer and should be sized to accommodate the bearing top plate with adequate room for adjustment and bolts (if used).

The details should allow for reasonable adjustment. The plans or specifications should indicate that the beam seats should not be constructed prior to approval of the final bearing designs.

3.3.1.3—Transverse Eccentricity

Transverse eccentricities within specified tolerance (perpendicular to the longitudinal axis of the girder) of the installed bearing can be neglected in the design of the bearing.

C3.3.1.3

A transverse eccentricity due to the transverse offset is a superstructure/girder issue and will not affect the performance of the bearing if the core portion of the bearing is within the area defined by the bearing stiffeners. The bearing does not resist any significant moments since the stiffness of the bearing is significantly less than the stiffness of the girder and bearing stiffeners. If the bottom flange remains level, the bearing will not experience any eccentric forces.

3.3.2—Specifications

The approach for HLMR bearing specifications should be similar to a design–build format. The specifications should outline the parameters that will be allowed for the design and the *AASHTO LRFD Bridge Design Specifications* will be referenced for most criteria.

3.3.3—Sole Plate Connections

The preferred connection of the sole plate to I-girders can be either shop-welded, field-welded, or bolted depending on the circumstances of the bearing details. This Article and Articles 3.3.4 through 3.3.6 describe the recommended connections for common bearing details. Field-welded connections should be made after the deck has been placed.

Bolting with oversized holes may be used provided that there is another mechanism to make field adjustments, such as an additional auxiliary plate (see Article 3.11 for details).

C3.3.3

Welding allows for greater adjustment during installation and is more economical. The damage due to removal of the weld for future removal and maintenance can be reasonably repaired. Article 3.7 of the *AASHTO/AWS D1.5/D1.5M Bridge Welding Code* has information on weld removal and repair.

Also, stainless steel sliding surfaces that are integral with the sole plate can be damaged during shipping if attached to the girder in the shop. The connection of the sole plate should be made after the deck has been placed.

Bolted connections with oversized holes allow for minor field adjustments of the bearing during installation. Another option to achieve adjustability is to use oversized pockets for anchor rods that can be filled with grout after the beams are erected and the exact location of the bearing is known.

Connection to box girders should be bolted with oversized holes. If the bolts are installed in drilled and tapped holes in the sole plate, the bolts and the hole should be made perpendicular to the plane of the bottom flange, which is also the plane of the top of the sole plate.

Box girder bearings should be attached with bolts since a welded sole plate requires an overhead weld that is often difficult to perform due to limited access.

3.3.4—Sole Plate Details

Sole plates attached by welding should extend transversely beyond the edge of the bottom flange of I-girders at least 1 in. on each side.

Welds for sole plate connections for I-girders should only be longitudinal to the girder axis. Transverse joints should be sealed with an approved caulking material.

The minimum thickness of the sole plate should be ¾ in.

The designer should strive for a design with a limited number of different sole plate bevels. The bearing designs can account for minor variations between different beam ends. The designer should indicate the theoretical sole plate slope and the specified sole plate slope on the plans and note that the bearing needs to be designed for the difference between the two values.

For bearings requiring sole plates with minor bevels (<0.01 radians), the designer may alternatively choose to use flat sole plates and design the bearing to account for the theoretical sole plate bevel.

If an average sole plate bevel or a flat sole plate is specified, the final slope of the bottom of the sole plate for each bearing should be shown on the plans.

C3.3.4

The sole plate extension is to facilitate the field-welding process by allowing for ½ in. of adjustment in the field (see “H” Drawings in Article 3.11). This is only for I-girders. Sole plates need not extend beyond flanges on box beams, and they should be field-bolted in order to avoid overhead welds that are difficult to perform due to limited clearance.

The longitudinal welds are made in the horizontal position, which is the position most likely to result in a quality fillet weld. Transverse welds require overhead welds and are very difficult to complete due to limited clearance. The silicone caulking of the underside transverse joint is intended to prevent corrosion between the sole plate and the bottom flange. Caulking must be installed after welding. Most owners use a silicone-based caulk; however, other materials may be used.

The minimum thickness of ¾ in. is to control plate distortion due to welding.

The use of a limited number of sole plate bevels is applicable to bridges with multiple spans that have similar beam end rotations. A common sole plate can be detailed with a bevel slope equal to the average theoretical slope for all bearings in a similar group. Each bearing can then be designed to accommodate the difference between the theoretical slope and the specified sole plate slope.

The use of flat sole plates can result in a significant cost savings as the impact on the bearing design may be minor, which can be offset by the savings in machining of the sole plate. It can also result in a time savings in the bearing/beam fabrication process.

The recommendation to show sole plate slopes on the drawings is for use by construction inspectors and future bridge inspectors that may be assuming that the bottom of the sole plate should be level. Having a value shown on the plans (along with notes) should address this potential issue.

Sole plates should be designed with adequate length and width to accommodate the movements in each direction from the bearing's setting position, including consideration of an allowable range or tolerance on the setting temperature and beam end rotation. Designers are encouraged to be generous in setting sole plate length and width to allow for uncertainties in construction and future performance of the bridge.

Slightly oversizing the sole plates to accommodate uncertainties is encouraged. Doing so adds little or no initial cost to the bridge; conversely, under-sizing a sole plate could lead to significant performance problems that necessitate costly repairs and retrofits over the life of the bridge.

For bearings subject to particularly large movements, it may be necessary to detail auxiliary bearing stiffeners if the range of movement results in the bearing stiffener moving to positions where it cannot effectively carry the bearing reaction.

There is no known authoritative guidance on how large of an offset between the bearing stiffeners and the centroid of the bearing is acceptable. Designers should consider the type of bearing, its ability to tolerate eccentric loading, and other related issues when deciding whether to provide auxiliary bearing stiffeners. If auxiliary bearing stiffeners are provided, they should be detailed with ease of fabrication in mind, considering welding access between adjacent stiffeners, distortion of the girder flanges during welding, etc. The *FHWA Bridge Welding Reference Manual* includes some helpful guidance on this subject.

3.3.5—Detailing for Future Maintenance

HLMR bearings should be designed for future removal with a maximum vertical jacking height of ¼ in. after the load is removed.

The minimum distance between the bottom of masonry plate to top of sole plate should be 4 in.

C3.3.5

Designing the bridge for jacking allows for future removal of the main bearing elements for maintenance. By limiting the jacking, the work can be done under live load and without damage to bridge joints, utilities, etc. The jacking height is measured after all compressive deflection due to load and rotation is removed.

Some owners require a recess in the masonry plate to restrain the bearing and allow for future removal without removal of a weld.

The minimum distance under the top flange is set in order to facilitate weld removal, bolting, and jacking operations.

3.3.6—Masonry Plates and Anchor Rods

The masonry plate should bear directly on a ⅛-in.-thick preformed pad that rests directly on the substructure.

C3.3.6

This method of using a preformed pad to take up bearing surface irregularities is preferred to grouting under a masonry plate supported by leveling nuts. The grouting option results in point loads at the anchor rods due to the high stiffness of the rods when compared to the grout material, which can lead to masonry plate warping. For this reason, grouting should be limited to special cases only. No design of the bearing pad is required since it is assumed that the pad will yield and deform to fill the uneven surfaces of the concrete bearing seat. The preformed pad may be either an elastomeric or fabric bearing with a maximum durometer of 70. The least expensive option is a plain elastomeric pad.

The location of anchor rods should allow room for future bearing removal.

Details without anchor rod nuts are preferred in order to facilitate installation and future maintenance. Article 3.11 includes several details for this approach.

3.3.6.1—Anchor Rods

Material for anchor rods should conform to ASTM F1554, and should be either threaded (with nuts) or swedged on the embedded portion of the rod. The design yield strength of this material may be specified as 36 ksi, 55 ksi, or 105 ksi, depending on the design. The yield strength should be given in the specifications or on the plans.

C3.3.6.1

The term "anchor bolts" should not be used because "bolt" implies that the rod has a hex head. This material is specifically designed for anchor rod applications. Other materials have been used, but do not offer the economies of ASTM F1554. The designer should offer options of swedging or threading the anchor as different suppliers supply one or both of these options.

Swedging is a process of indenting a rod through the use of a press force. Figure C2.3.5.3-1 shows swedged anchor rods.

3.4—MANUFACTURING

The manufacturing of HLMR bearings should be in accordance with the project special provisions, the *AASHTO LRFD Bridge Construction Specifications*, or both.

The HLMR bearing fabricator should be certified for the AISC "Components" category at a minimum.

All machined surface finish tolerances should be verified by the use of calibrated profilometers. Overall bearing height should be not more than 0.25 in. greater than, nor 0.06 in. less than, the detailed dimension shown on the shop drawings.

Welding should conform to the requirements of *AASHTO/AWS D1.5/D1.5M Bridge Welding Code* and should comply with the *AASHTO LRFD Bridge Design Specifications* and *LRFD Bridge Construction Specifications* requirements.

Thermal cutting of plates and anchor rod holes is recommended.

C3.4

Distortion and deformation from the heat input during welding should be anticipated and measures should be taken to minimize it.

Some owners require these large-diameter anchor rod holes to be drilled. Modern flame-cutting equipment is able to produce a reasonably smooth edge.

The allowable surface roughness of the cut edges should be free of abrupt irregularities and have an ANSI surface roughness not exceeding 1,000 µin.

Plate edges and hole perimeters may be produced by drilling, sawing, or thermal cutting; however, thermal cutting is the most cost-effective.

3.5—INSPECTION AND TESTING

Shop inspection should be performed to ensure that the bearings are manufactured and tested in accordance with the project specifications. The inspector shall verify that critical dimensions for installation and clearances exist for all in-service and test conditions.

Testing should include but not necessarily be limited to vertical load verification, rotation, friction, horizontal load verification, and uplift testing if applicable.

Long-term deterioration (LTD) testing should be used for product pre-qualification. It is not necessary for individual projects. Figure 3.5-1 shows a typical LTD test set-up.

Figure 3.5-1. Long-Term Deterioration Test (Cyclic Rotation Test Frame)

C3.5

Vertical load and rotation testing can be combined by loading the bearing in the test frame with a beveled sole plate corresponding to the design rotation. Horizontal load testing is not always required but can be done if required by the owner.

The LTD cyclic rotation testing of the bearing should be performed on an approved test frame. The number of cycles varies from 5,000–15,000 and a typical speed is 0.50 cycles per minute but is dependent on the amount of rotation required. This test is very time-consuming, which is why it should be considered for pre-qualification purposes only.

For bearings with larger load requirements, prototype testing can also be acceptable given equipment limitations.

Another phase of LTD testing is friction/sliding surface testing. Typically, 1,000 cycles of sliding are conducted and the surfaces are then inspected for unusual wear. This again should be part of a material/manufacturer qualification test procedure and not necessarily run as part of a project production bearing testing plan.

3.6—MARKING

The designer should add the following notes to the plans:

"All bearings shall be marked prior to shipping. The marks shall include the bearing location on the bridge, and a direction arrow that points up-station. All marks shall be permanent and be visible after the bearing is installed. The marks shall be on the top plate of the bearing."

C3.6

Problems have occurred in the field with the installation of bearings with beveled sole plates. It is not always obvious which orientation a bearing must take on a beam before the dead load rotation has been applied. This is especially true for bearings with minor bevels.

3.7—INSTALLATION PRACTICE

HLMR bearings should be installed in accordance with the requirements in Article 18.1.7 of the AASHTO *LRFD Bridge Construction Specifications*.

C3.7

A qualified manufacturer's representative should be on site during the initial phases of the installation process and should remain on site until it is determined by the owner's representative that the contractor is fully qualified to install the bearings properly.

The contractor should take special care to protect the stainless steel and PTFE sliding surfaces from damage or contamination during the installation of bearings and anchorage.

For bearings that are stored on site prior to installation, care should be taken so that they are stored in a protected area and are not stacked on top of each other.

The contractor should adjust the pedestal elevations to accommodate the final bearing heights. The designer should add a note to the plans indicating that the beam seats should not be poured until final approval of the bearing working drawings.

The bearings should be set level and also to the girder orientation angle as shown on the contract plans. Care should be taken to ensure that all bolt holes shall be aligned to permit insertion of the bolts without damage to the threads.

For expansion bearings it is imperative that the upper sliding/sole plates be installed so that they are in synchronization with the bridge's movement cycle. Match marks and temperature settings should be clearly marked on the bearing plates.

For bearings to be field-welded, this should be done in accordance with the contract plans. Care should be taken so that the plates in contact with the PTFE and rubber elements do not generate too much heat that might damage these components.

The maximum allowable temperature for these plates is 225 degrees F. A protective cover should be used on the bearing device during field welding to protect the critical bearing components from sparks and flash. Figure C3.7-1 shows a completed field weld and protection of the bearing core.

Figure C3.7-1. Field Welding of Disc Bearing

Magnetic particle testing should be specified for field welds.

Ultrasonic testing is not appropriate for fillet welds.

All bearings shall be clearly marked with the name of the manufacturer, the project number, the bearing number, the location of the bearing on the bridge, and the date of manufacture.

Figure C3.7-2 shows a common bearing marking scheme.

Figure C3.7-2. Typical Bearing Marking

3.8—FIELD INSPECTION

HLMR bearings have a proven track record of durability. There are several key features that should be checked during routine inspection:

1. Signs of wear of the PTFE sliding surfaces
2. Leaking of elastomer on pot bearings
3. Signs of wear of the elastomeric discs (disc bearings)

C3.8

Flaking and PTFE debris would be an indication of potential wear problems with the sliding material. Leaking (extruding) of woven PTFE material would indicate overloading and failure of the PTFE.

There have been documented cases of elastomer leaking out of the pot caused by a failure of the sealing rings. Inspectors should look for evidence of elastomer extruding from around the piston.

Signs of elastomeric disc wear would be characterized as elastomer debris found adjacent to the disc at the top and bottom plate.

3.9—FUTURE MAINTENANCE

HLMR bearings with sliding surfaces may require maintenance in the future. The following are potential maintenance items:

1. Replacement of PTFE materials in sliding surfaces

C3.9

The intervals of maintenance and design service life are not well-known or defined in the *AASHTO LRFD Bridge Design Specifications*. History has shown that HLMR bearings are very durable. Anecdotal evidence states that the minimum interval for maintenance may be in excess of 25 years.

2. Replacement of elastomer discs in disc bearings
3. Replacement of elastomer and sealing rings in pot bearings
4. Maintenance of corrosion protection systems

3.10—REFERENCES

AASHTO. *AASHTO LRFD Bridge Design Specifications*, 9th Ed. LRFDBDS-9. American Association of State Highway and Transportation Officials, Washington, DC, 2020.

AASHTO. *LRFD Bridge Construction Specifications*, 4th Ed., with 2020 and 2022 Interim Revisions. LRFDCONS-4. American Association of State Highway and Transportation Officials, Washington, DC, 2017.

AASHTO. M 270M/M 270, Standard Specification for Structural Steel for Bridges. American Association of State Highway and Transportation Officials, Washington, DC.

ASTM. F1554, Portland Bolt. ASTM International, West Conshohocken, PA.

AWS/AASHTO. *AWS/AASHTO D1.5/D1.5M Bridge Welding Code*, 8th Ed. American Welding Society, Doral, FL, 2020.

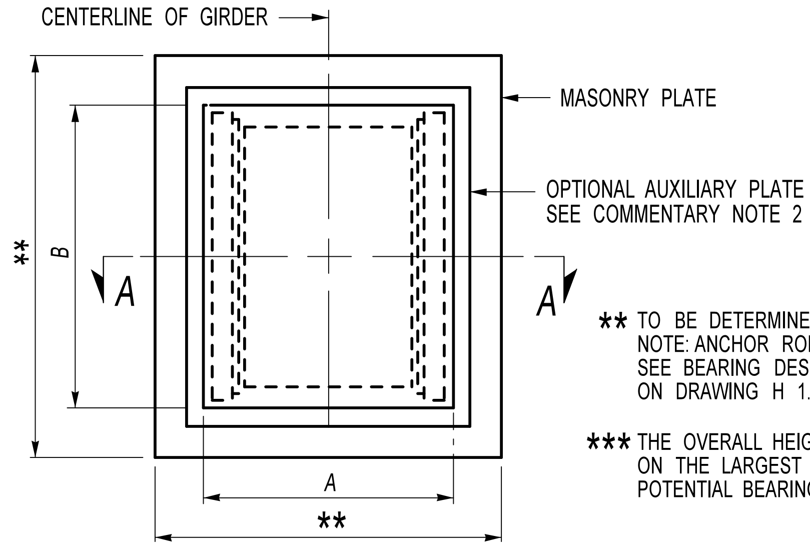
FHWA. *Bridge Welding Reference Manual*, Publication No. FHWA-HIF-19-088, Federal Highway Administration, McLean, VA, 2019.

MassDOT. *LRFD Bridge Manual*. Massachusetts Department of Transportation, Boston, MA, 2013. Available at https://www.mass.gov/manual/lrfd-bridge-manual-2013-edition.

SCEF. Standard 106, High Load Multi-Rotational Bearings. Mid-Atlantic States Structural Committee for Economical Fabrication. n.p.

3.11—RECOMMENDED DRAWING DETAILS

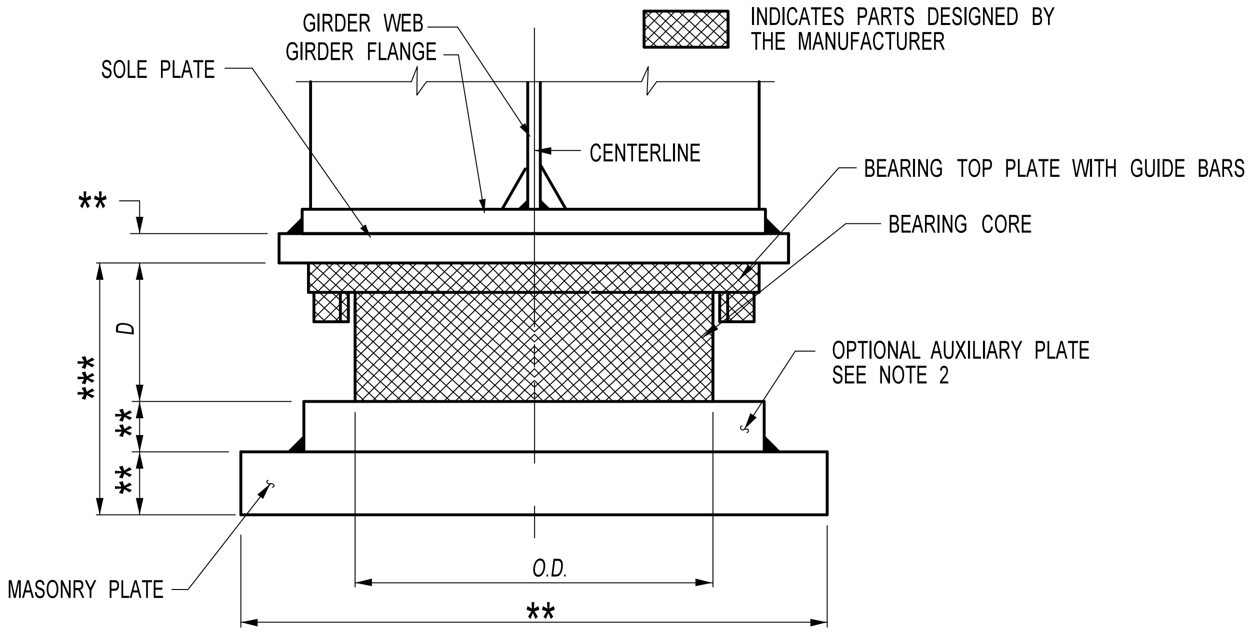
The following pages contain drawings that include recommended design and detailing guidance for high load multi-rotational bearings. These drawings are not intended to supersede any standards established by the bridge owner. The designer should obtain permission to use any detail that is in conflict with the owner's standards.



** TO BE DETERMINED BY DESIGNER
NOTE: ANCHOR RODS ARE NOT SHOWN. SEE BEARING DESIGNER NOTES 3 AND 4 ON DRAWING H 1.4

*** THE OVERALL HEIGHT SHOULD BE BASED ON THE LARGEST "*D*" VALUES FROM ALL POTENTIAL BEARING MANUFACTURERS

GUIDED EXPANSION BEARING



SECTION A-A

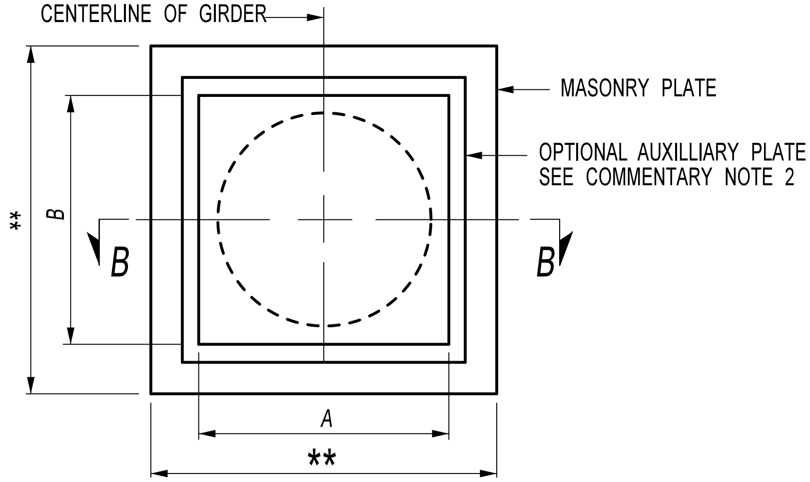
COMMENTARY:

1. *THE DETAILS DO NOT DEPICT ANY PARTICULAR BEARING. DETAILS VARY BY MANUFACTURER.*
2. *THE AUXILIARY PLATE IS USED TO:*
   A. INCREASE THE DISTANCE FROM THE FIELD WELD TO THE ELASTOMER AND/OR PTFE SURFACES
   B. PROVIDE ROOM FOR THE FIELD-WELDING PROCESS
   C. PROVIDE MORE ADJUSTABILITY DURING INSTALLATION
   THIS PLATE CAN BE ELIMINATED IN SOME SITUATIONS.
3. *THE BEARING MANUFACTURER MAY INCORPORATE THE BEVELED SOLE PLATE INTO THE DESIGN OF THE BEARING TOP PLATE, THEREBY ELIMINATING THE SOLE PLATE.*
4. *SOME STATES REQUIRE BOLTED ATTACHMENT OF THE BEARING TOP PLATE TO THE GIRDER. SEE DRAWING E 1.2 FOR DETAILS OF BOLTED BEARING ATTACHMENTS.*
5. *SEE DRAWING H 1.3 FOR RECOMMENDED DIMENSIONS NOTED IN THE DETAIL. SEE DRAWING H 1.5 AND H 1.6 FOR CONNECTION DETAILS.*

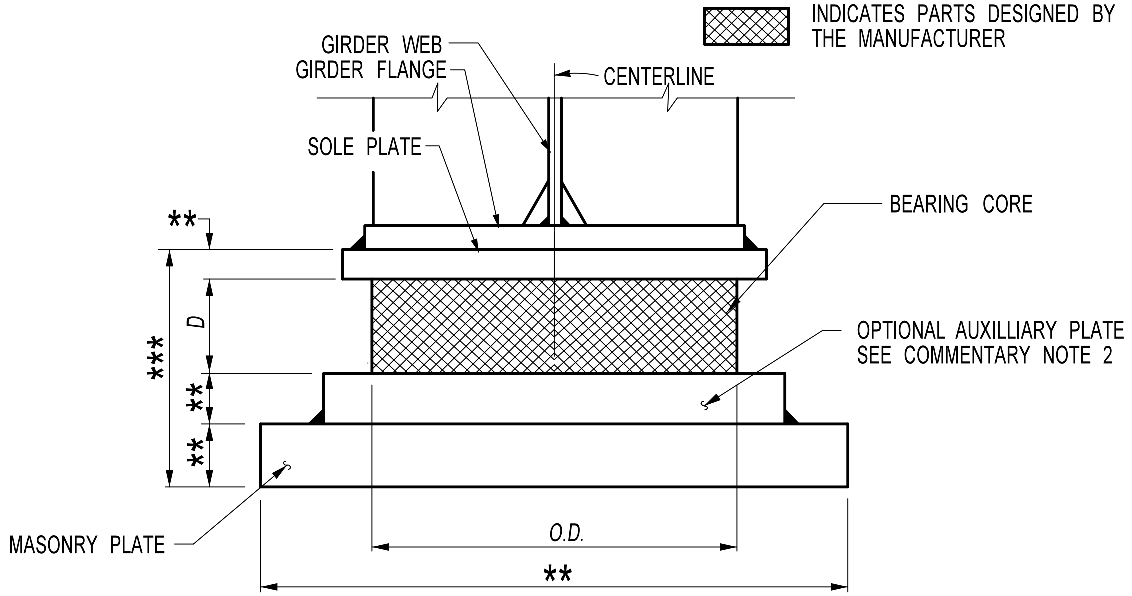
AASHTO/NSBA STEEL BRIDGE COLLABORATION	HIGH LOAD MULTI-ROTATIONAL BEARINGS	LATEST REVISION DATE 12-15-22
	GUIDED EXPANSION BEARING	DRAWING NUMBER H 1.1

** TO BE DETERMINED BY DESIGNER
NOTE: ANCHOR RODS ARE NOT SHOWN. SEE BEARING DESIGNER NOTES 3 AND 4 ON DRAWING H 1.4

*** THE OVERALL HEIGHT SHOULD BE BASED ON THE LARGEST " " VALUES FROM ALL POTENTIAL BEARING MANUFACTURERS



NON-GUIDED BEARING



SECTION B-B

COMMENTARY:

1. *THE DETAILS DO NOT DEPICT ANY PARTICULAR BEARING. DETAILS VARY BY MANUFACTURER.*
2. *THE AUXILIARY PLATE IS USED TO:*
   - *A. INCREASE THE DISTANCE FROM THE FIELD WELD TO THE ELASTOMER AND/OR PTFE SURFACES*
   - *B. PROVIDE ROOM FOR THE FIELD-WELDING PROCESS*
   - *C. PROVIDE MORE ADJUSTABILITY DURING INSTALLATION*

   THIS PLATE CAN BE ELIMINATED IN SOME SITUATIONS.
3. *THE BEARING MANUFACTURER MAY INCORPORATE THE BEVELED SOLE PLATE INTO THE DESIGN OF THE BEARING TOP PLATE, THEREBY ELIMINATING THE SOLE PLATE.*
4. *SOME STATES REQUIRE BOLTED ATTACHMENT OF THE BEARING TOP PLATE TO THE GIRDER. SEE DRAWING E 1.2 FOR DETAILS OF BOLTED BEARING ATTACHMENTS.*
5. *SEE DRAWING H 1.3 FOR RECOMMENDED DIMENSIONS NOTED IN THE DETAIL. SEE DRAWINGS H 1.5 AND H 1.6 FOR CONNECTION DETAILS.*

AASHTO/NSBA STEEL BRIDGE COLLABORATION	HIGH LOAD MULTI-ROTATIONAL BEARINGS	LATEST REVISION DATE 12-15-22
	NON-GUIDED BEARING	DRAWING NUMBER H 1.2

DESIGNER NOTES

1. *THE VALUES SHOWN ARE APPROXIMATE AND SHOULD BE USED AS A REFERENCE TO ASSIST THE DESIGNER IN SIZING THE SOLE PLATE AND THE MASONRY PLATE.*

2. *THE DESIGNER SHOULD CONTACT MANUFACTURERS WITH SPECIFIC REQUIREMENTS FOR THIER PRODUCTS TO GET MORE DETAILED INFORMATION ON BEARING DIMENSIONS.*

APPROXIMATE DIMENSIONS FOR GUIDED EXPANSION BEARING

TOTAL VERTICAL LOAD kips	TOTAL HORIZ. LOAD kips	*A* INCHES	*B* INCHES	*O.D.* INCHES	*D* INCHES
250	50.0	17.750	16.000	12.875	5.000
500	100.0	23.750	22.750	19.375	7.000
750	150.0	28.250	27.250	24.125	8.500
1,000	200.0	32.250	31.750	27.500	9.750
1,500	300.0	33.500	29.000	33.500	11.500
2,000	400.0	33.750	35.125	38.125	12.500
2,500	500.0	37.125	42.000	42.625	13.375
3,000	600.0	40.500	45.000	46.250	14.375
3,500	700.0	43.750	47.750	49.375	15.625

APPROXIMATE DIMENSIONS FOR FIXED BEARING

TOTAL VERTICAL LOAD kips	TOTAL HORIZ. LOAD kips	A INCHES	B INCHES	O.D. INCHES	D INCHES
250	50	11.750	11.750	12.875	3.625
500	100	15.750	15.750	19.375	4.250
750	150	18.750	18.750	24.125	4.875
1,000	200	21.500	21.500	27.500	5.375
1,500	300	25.750	25.750	33.500	6.125
2,000	400	29.250	29.250	38.125	6.875
2,500	500	32.500	32.500	42.625	7.625
3,000	600	35.250	35.250	46.625	7.875
3,500	700	38.000	38.000	49.375	8.625

NOTES:
1. VALUES USED IN THESE TABLES ARE BASED ON UNFACTORED LOADS
2. DIMENSION *A* REFERS TO BEARING TOP PLATE WIDTH
3. DIMENSION *B* REFERS TO BEARING TOP PLATE LENGTH
4. DIMENSION *O.D.* REFERS TO OUTER DIMENSION
5. DIMENSION *D* REFERS TO BEARING HEIGHT

AASHTO/NSBA STEEL BRIDGE COLLABORATION	HIGH LOAD MULTI-ROTATIONAL BEARINGS	LATEST REVISION DATE 12-15-22
	BEARING DIMENSIONS FOR PRELIMINARY DESIGN	DRAWING NUMBER H 1.3

THE FOLLOWING NOTES SHOULD BE ADDED TO THE PLANS OR SPECIFICATIONS.

BEARING DESIGNER NOTES:

1. THE "*B*" DIMENSION GIVEN IN THE TABLES ON DRAWING H 1.3 INCLUDES 1 IN. FOR MOVEMENT AND 1 IN. FOR CONSTRUCTION TOLERANCE EACH WAY. IF THE MAXIMUM ONE-WAY DESIGN MOVEMENT EXCEEDS 1 IN., THE "*B*" DIMENSION MUST BE INCREASED BY TWICE THE DIFFERENCE. FOR EXAMPLE: DESIGN MOVEMENT = 1½ , "*B*" DIMENSION SHOULD BE INCREASED BY 1 IN. THE CENTERLINE OF ALL BEARING COMPONENTS SHALL BE IN LINE AT 70 DEGREES F UNDER FULL DEAD LOAD.

2. THE DESIGNER SHALL DESIGN AND DETAIL THE SOLE PLATE, MASONRY PLATE AND ANCHOR ROD SPACING BASED ON THE BEARING SELECTED FROM THE APPROPRIATE TABLES ON DRAWING H 1.3.

3. THE DESIGNER SHALL SET THE LOCATION OF ANCHOR RODS. THEY MAY BE SET OUTSIDE OF THE SOLE PLATE OR UNDER THE SOLE PLATE. A MINIMUM OF FOUR ANCHOR RODS, 1 IN. DIAMETER, SHALL BE USED FOR ALL HLMR BEARINGS. IF THE ANCHOR RODS ARE LOCATED UNDER THE SOLE PLATE, A MINIMUM CLEARANCE EQUAL TO TWO TIMES THE THICKNESS OF THE ANCHOR NUT PLUS 1 IN. SHALL BE PROVIDED BETWEEN THE TOP OF THE MASONRY PLATE AND THE BOTTOM OF THE SOLE PLATE. THE PROJECTION OF THE ANCHOR ROD ABOVE THE TOP OF THE ANCHOR NUT SHALL BE NO MORE THAN ½ IN.

4. THE WIDTH OF THE MASONRY PLATE WILL BE DEPENDENT ON THE ANCHOR ROD LOCATION. THE LENGTH OF THE MASONRY PLATE SHALL BE AT LEAST 4 IN. GREATER THAN THE AUXILIARY PLATE. THE THICKNESS OF MASONRY PLATE SHALL BE DETERMINED BY THE DESIGNER.

5. AT LOCATIONS WHERE LARGE MOVEMENTS ARE EXPECTED OR WHEN VERY LARGE SOLE PLATES ARE REQUIRED. THE DESIGNER SHALL GIVE CONSIDERATION TO PROVIDING FOUR BEARING STIFFENERS TO BETTER DISTRIBUTE THE LOAD TO THE BEARING, RATHER THAN USING TWO BEARING STIFFENERS LOCATED AT THE CENTERLINE OF BEARING. IF FOUR STIFFENERS ARE USED THEY SHALL BE SPREAD APART AT LEAST THE WIDTH OF THE STIFFENER TO FACILITATE WELDING THE STIFFENERS TO THE WEB.

6. THE MINIMUM GAP BETWEEN THE GUIDE BARS AND THE BEARING ON EXPANSION BEARINGS SHALL BE ⅛ IN. (1⁄16 IN. ON EACH GUIDE BAR). ON STRUCTURES WIDER THAN 40 FT. OR CURVED STRUCTURES WHERE LATERAL MOVEMENTS ARE EXPECTED, THE DESIGNER SHALL SPECIFY THE REQUIRED GUIDE CLEARANCE.

7. TOP AND BOTTOM BEARING PLATES SHALL BE WELDED TO THE SOLE PLATE AND MASONRY PLATE RESPECTIVELY. THE SIZE OF THE WELD SHALL NOT BE LESS THAN 5⁄16 IN. THE PLATES SHALL BE PREHEATED IN ACCORDANCE WITH *AASHTO/AWS D1.5/D1.5M BRIDGE WELDING CODE.*

8. WITH MULTI-ROTATIONAL EXPANSION BEARINGS, THE COEFFICIENT OF FRICTION USED FOR COMPUTING THE DESIGN HORIZONTAL FORCES ACTING ON THE SUPPORTING SUBSTRUCTURE SHALL BE 5 PERCENT, WHEREAS THE MAXIMUM COEFFICIENT OF FRICTION VALUE SPECIFIED FOR THE MANUFACTURER IS 3 PERCENT.

9. THE MINIMUM VERTICAL LOAD ON HLMR BEARINGS SHALL NOT BE LESS THAN 20 PERCENT OF THE LOAD CAPACITY OF THE BEARING.

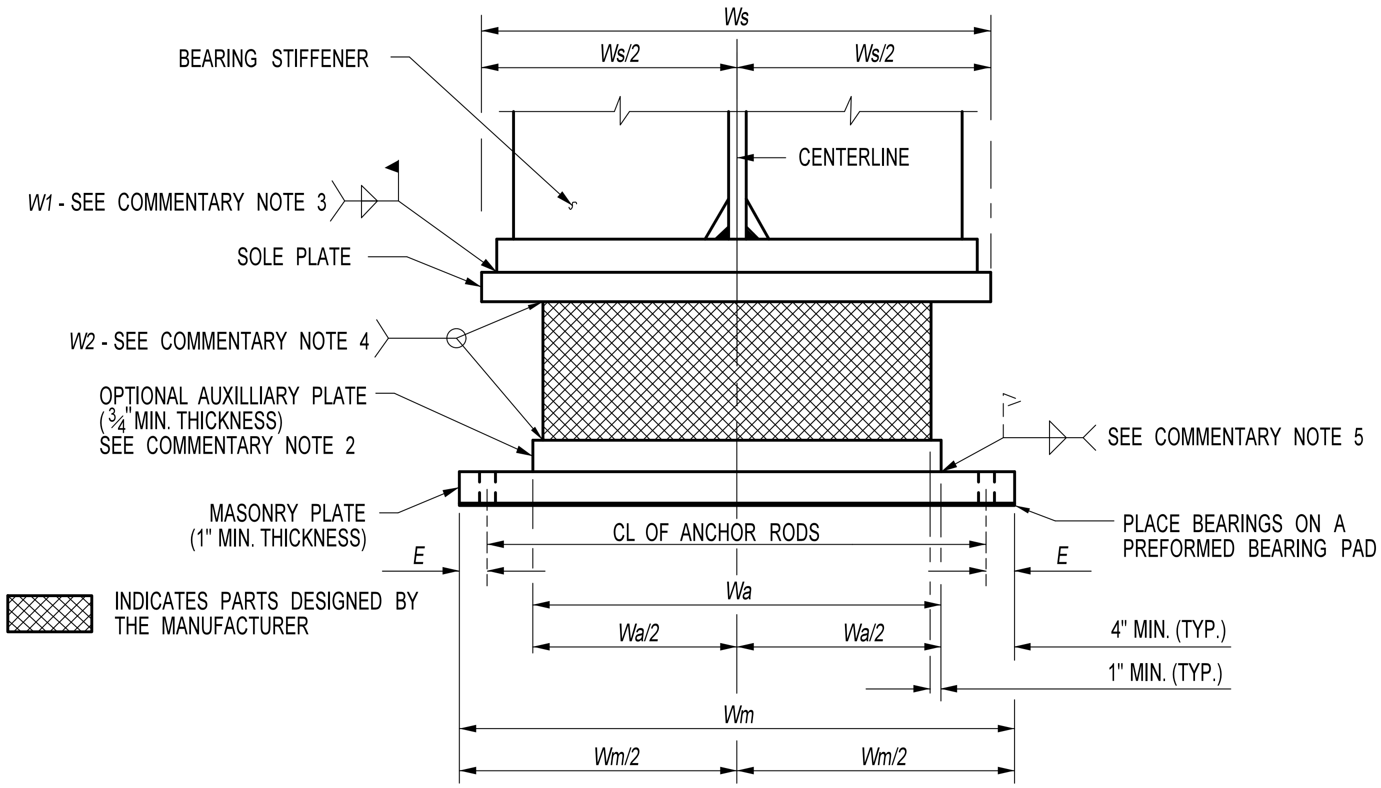
10. A TAPERED SOLE PLATE MAY BE REQUIRED WHEN THE BOTTOM OF THE BEAM/GIRDER AND THE TOP OF THE BEARINGS ARE NOT PARALLEL TO EACH OTHER. THE SOLE PLATE SHALL BE TAPERED IF EITHER OF THE FOLLOWING CONDITIONS EXIST:
    1) LONGITUDINAL GRADE OF THE BOTTOM FLANGE IS ONE PERCENT OR MORE.
    2) THE REQUIRED TAPER IS ⅛ IN. OR MORE.

    FOR CASES WHERE THE SOLE PLATE IS NOT TAPERED, THE BEARING MUST BE DESIGNED FOR A ROTATION EQUAL TO THE THEORETICAL GRADE OF THE SOLE PLATE.

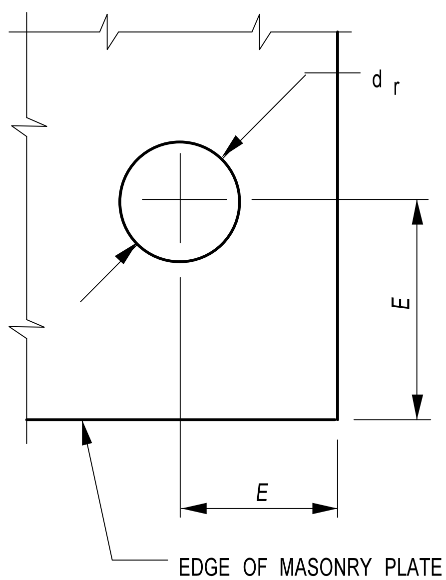
11. THE DESIGNER SHALL ASTERISK (*) THE PEDESTAL ELEVATIONS ON THE SUBSTRUCTURE SHEETS AND PLACE THE FOLLOWING NOTE ON THE RESPECTIVE SHEETS:

    *THESE ELEVATIONS MAY HAVE TO BE ADJUSTED TO ACCOMMODATE THE ACTUAL BEARINGS FURNISHED. IT IS THE RESPONSIBILITY OF THE CONTRACTOR TO COORDINATE ANY CHANGES IN THE BEARINGS WHICH MAY AFFECT THE PEDESTAL ELEVATIONS.

AASHTO/NSBA STEEL BRIDGE COLLABORATION	HIGH LOAD MULTI-ROTATIONAL BEARINGS	LATEST REVISION DATE 12-15-22
	BEARING DESIGNER NOTES	DRAWING NUMBER H 1.4



FRONT VIEW



ANCHOR ROD DETAIL

COMMENTARY:

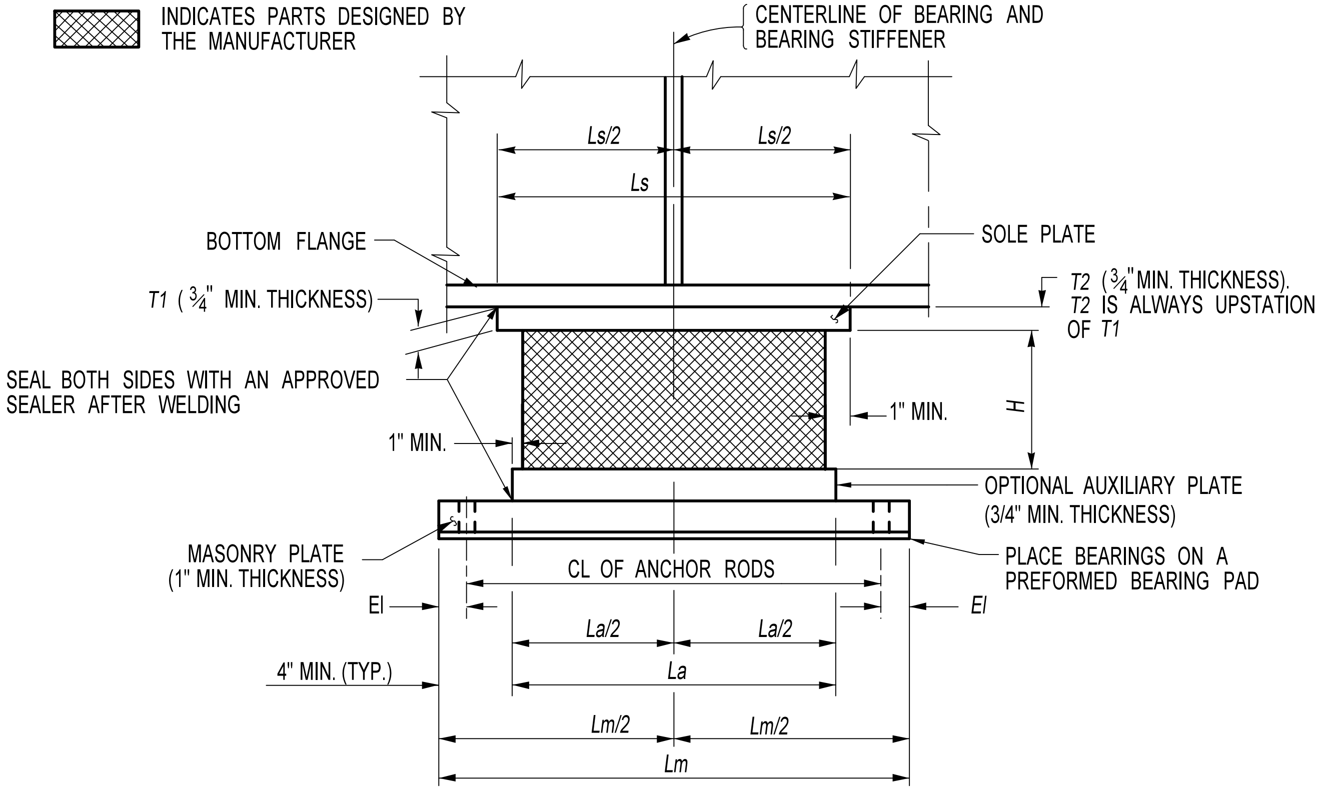
1. *THE DETAILS DO NOT DEPICT ANY PARTICULAR BEARING. DETAILS VARY BY MANUFACTURER.*
2. *THE AUXILIARY PLATE IS USED TO:*
   - *A. INCREASE THE DISTANCE FROM THE FIELD WELD TO THE ELASTOMER AND/OR PTFE SURFACES*
   - *B. PROVIDE ROOM FOR THE FIELD-WELDING PROCESS*
   - *C. PROVIDE MORE ADJUSTABILITY DURING INSTALLATION*

   THE PLATE CAN BE ELIMINATED IN SOME SITUATIONS.
3. *THE BEARING DESIGNER SHALL DETERMINE THE SIZE OF WELD "W1". THE USE OF CAP SCREWS OR BOLTS IS ALLOWED AS AN ALTERNATE.*
4. *THE BEARING DESIGNER SHALL DETERMINE THE SIZE OF WELD "W2" ($\frac{5}{16}$" IN. MINIMUM). THE BEARING DESIGNER SHALL DETERMINE THE SIZE OF ALL COMPONENTS AND MAKE APPROPRIATE ENTRIES IN THE CHART SHOWN ON DRAWING H 1.7. THE DESIGNER MAY WISH TO INCLUDE A SCHEMATIC BEARING LOCATION PLAN VIEW SHOWING BEARING TYPES AND THEIR LOCATIONS.*
5. *FOR BEARINGS WITHOUT AUXILIARY PLATE THE WELD OF THE BEARING TO THE MASONRY PLATE MAY BE EITHER A SHOP WELD OR A FIELD WELD.*
6. *SOME STATES REQUIRE BOLTED ATTACHMENT OF THE BEARING TOP PLATE TO THE GIRDER. SEE DETAIL DRAWING E 1.2 FOR DETAILS OF BOLTED BEARING ATTACHMENTS.*
7. *MINIMUM DISTANCES FOR DESIGN:*

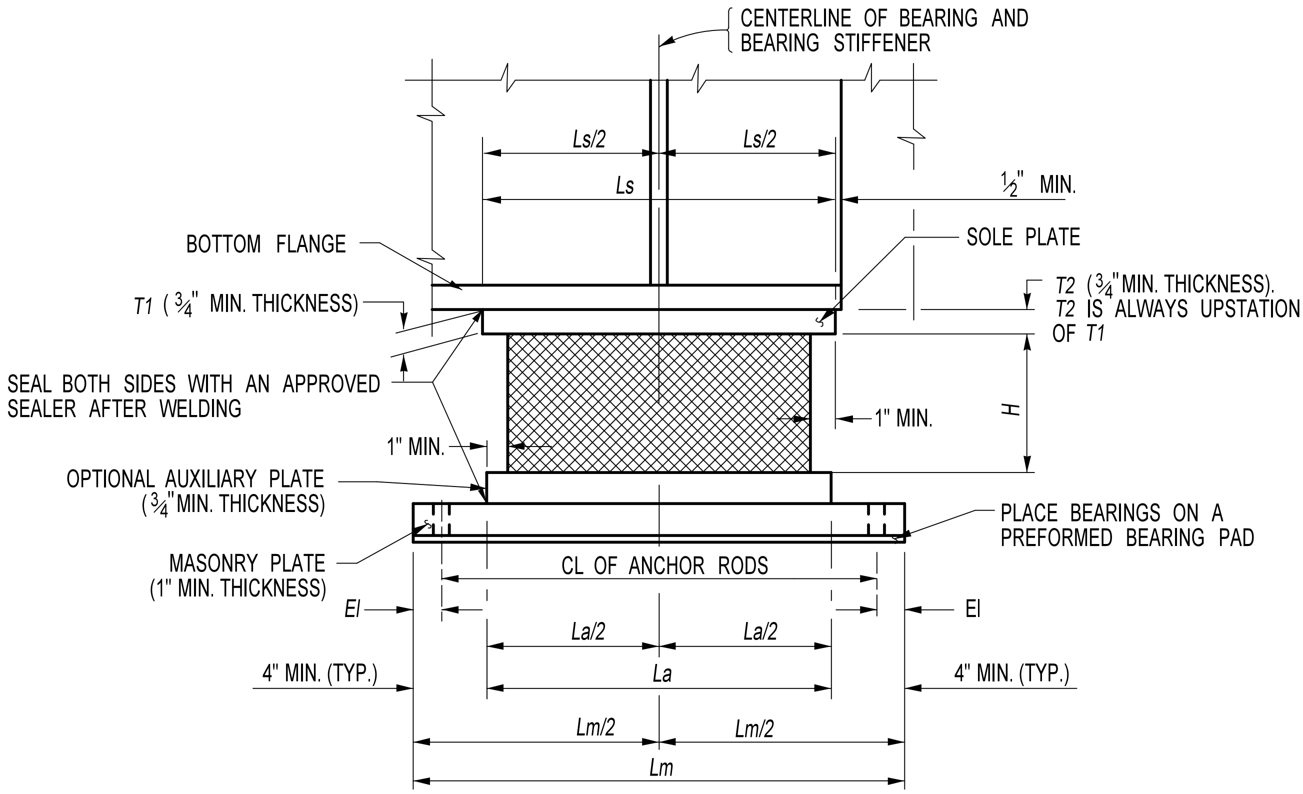
   d_r = *ROD DIA.* + $\frac{5}{16}$ *IN.*

   E = *1.75 X ROD DIA.* + $\frac{5}{16}$ *IN.*

AASHTO/NSBA STEEL BRIDGE COLLABORATION	HIGH LOAD MULTI-ROTATIONAL BEARINGS	LATEST REVISION DATE 12-15-22
	BEARING CONNECTION DETAILS	DRAWING NUMBER H 1.5



SIDE VIEW AT AN INTERIOR SUPPORT



SIDE VIEW AT END OF GIRDER

AASHTO/NSBA STEEL BRIDGE COLLABORATION	HIGH LOAD MULTI-ROTATIONAL BEARINGS	LATEST REVISION DATE 12-15-22
	SIDE VIEW DETAILS	DRAWING NUMBER H 1.6

RECOMMENDED NOTES TO BE INCLUDED ON THE PLANS

NOTES:

THE CONTRACTOR SHALL SUPPLY MULTI-ROTATIONAL STRUCTURAL BRIDGE BEARINGS CONFORMING TO THE REQUIREMENTS OF THE SPECIFICATION AND SUBJECT TO THE FOLLOWING CONDITIONS:

1. THE BEARING DEVICES SUPPLIED SHALL BE CAPABLE OF TRANSMITTING THE LOADS AND MOVEMENT SHOWN ON THESE PLANS.
2. THE DIMENSION "*H*" IN THE BEARING TABLE REPRESENTS THE ASSUMED TOTAL HEIGHT OF BEARING MECHANISM BETWEEN THE SOLE PLATE AND MASONRY PLATE USED BY THE DESIGNER TO ESTABLISH THE PEDESTAL ELEVATIONS. THE MINIMUM PEDESTAL HEIGHT SHALL NOT BE CHANGED WITHOUT WRITTEN APPROVAL.
3. THE BEARING DEVICE, MASONRY PLATE, SOLE PLATE, ANCHOR RODS, NUTS, WASHER PLATES AND BEARING PAD SHALL BE INCLUDED IN THE UNIT PRICE BID FOR THE BEARING ITEMS.
4. ALL EXPANSION BEARINGS SHALL HAVE A MAXIMUM FRICTION COEFFICIENT OF 5 PERCENT.
5. ALL STEEL SHALL CONFORM TO AASHTO M 270 GRADE 50 (M 270M GRADE 345).
6. ALL EXPOSED METAL COMPONENTS OF THE BEARING SYSTEM SHALL EITHER BE PAINTED OR METALIZED OR GALVANIZED.
7. THE BEARING DESIGN SHALL CONFORM TO THE PROVISIONS OF THE LATEST EDITION OF THE AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS.

WHENEVER JACKING OF THE SUPERSTRUCTURE IS NEEDED TO RESET THE BEARINGS, THE CONTRACTOR SHALL SUBMIT A JACKING SEQUENCE FOR APPROVAL.

RECOMMENDED TABLE TO BE INCLUDED ON THE PLANS

BEARING APPURTANENCES SCHEDULE

BEARING ID	FIXITY		*ONE-WAY LONGIT. MOVEMENT	(*G*) GUIDE CLEARANCE	MASONRY PLATE					AUXILLIARY PL			SOLE PLATE				BRG. *H*	d_b	ANCHOR RODS		WELD SIZE	
	LONG.	TRANS.			*Lm*	*Wm*	*Tm*	*Et*	*El*	*La*	*Wa*	*Ta*	*Ls*	*Ws*	*T1*	*T2*			*d*	RODS/BRG.	*W1*	*W2*

T2 IS UPSTATION OF *T1*.

THE DESIGNER SHALL ALSO INCLUDE DESIGN LOAD AND MOVEMENT REQUIREMENTS AS SHOWN IN AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS TYPICAL BRIDGE BEARING SCHEDULE

**ONE-WAY LONGITUDINAL MOVEMENT IS THE MAXIMUM ONE-WAY MOVEMENT (EXPANSION OR CONTRACTION) OF THE SUPERSTRUCTURE WHEN BEARINGS ARE SET AT 70 DEGREES F PLUS 1 IN. TOLERANCE.*

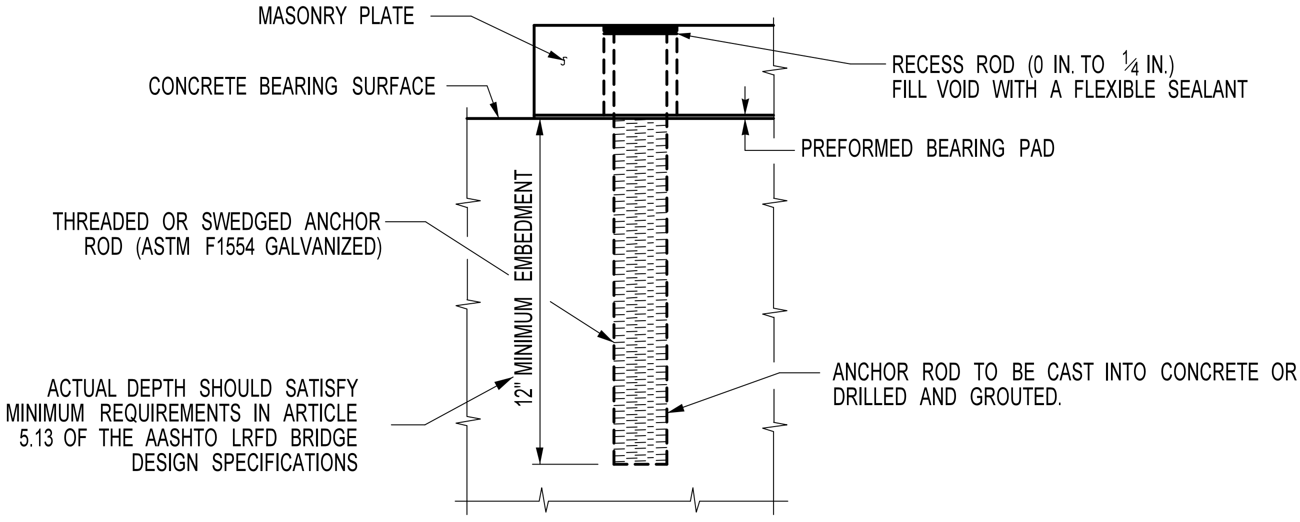
AASHTO/NSBA STEEL BRIDGE COLLABORATION

HIGH LOAD MULTI-ROTATIONAL BEARINGS

INFORMATION AND NOTES TO BE INCLUDED ON CONSTRUCTION PLANS

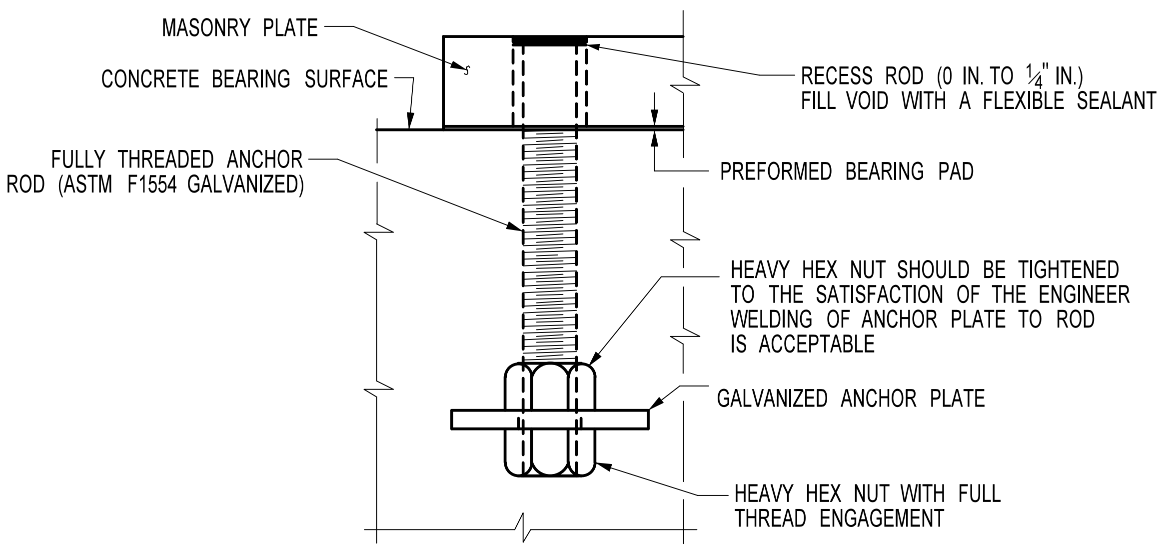
LATEST REVISION DATE 12-15-22

DRAWING NUMBER H 1.7



ANCHOR ROD DETAIL

ANCHOR RODS, WASHERS, WASHER PLATES, ANCHOR PLATES AND NUTS SHOULD BE GALVANIZED OR METALLIZED.



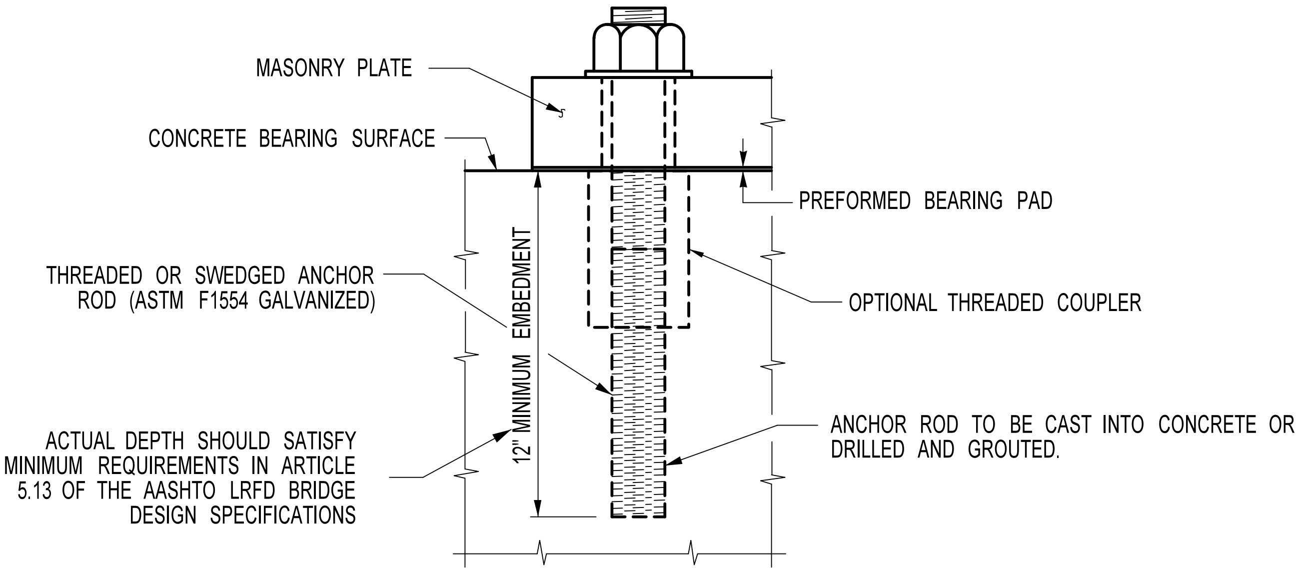
OPTIONAL ANCHOR ROD DETAIL WITH ANCHOR PLATE ON PEDESTALS

ANCHOR RODS, WASHERS, WASHER PLATES, ANCHOR PLATES AND NUTS SHOULD BE GALVANIZED OR METALLIZED.

COMMENTARY:

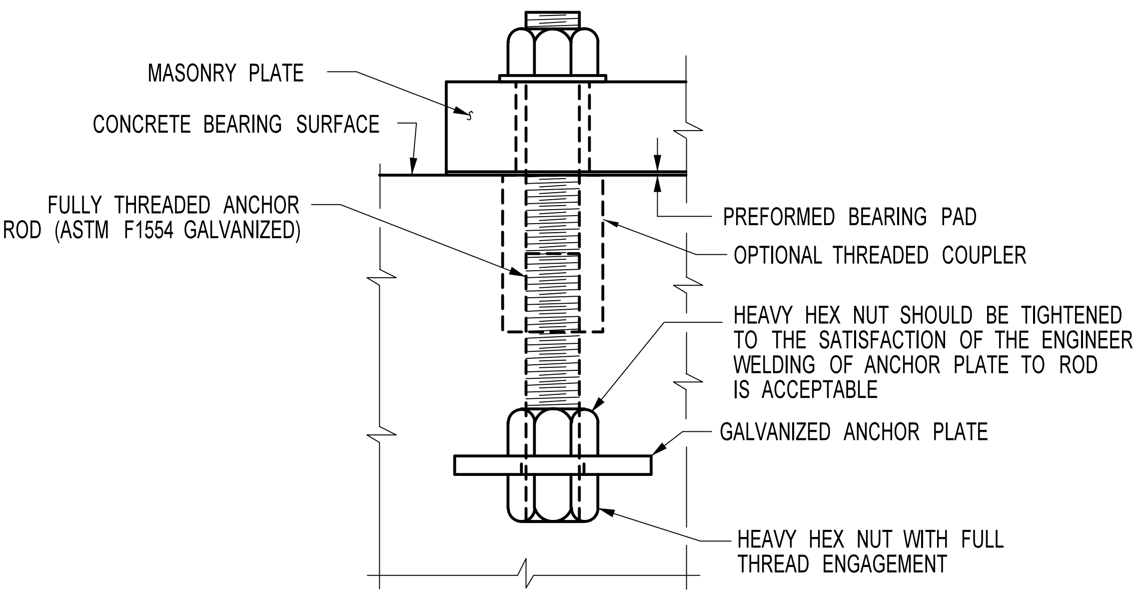
1. *BOTH OPTIONS SHOWN HAVE PROVEN TO BE ACCEPTABLE. THE BRIDGE DESIGNER SHOULD CHOOSE ONE OR BOTH OPTIONS AND DETAIL THE PLANS ACCORDINGLY.*
2. *IF THE BEARINGS MUST RESIST CALCULATED UPLIFT, SPECIAL DETAILS MUST BE DESIGNED AND DETAILED.*

AASHTO/NSBA STEEL BRIDGE COLLABORATION	HIGH LOAD MULTI-ROTATIONAL BEARINGS	LATEST REVISION DATE 12-15-22
	ANCHOR ROD DETAILS WITHOUT ANCHOR ROD NUTS	DRAWING NUMBER H 1.8



ANCHOR ROD DETAIL

ANCHOR RODS, WASHERS, WASHER PLATES, ANCHOR PLATES AND NUTS SHOULD BE GALVANIZED OR METALLIZED.



OPTIONAL ANCHOR ROD DETAIL WITH ANCHOR PLATE

ANCHOR RODS, WASHERS, WASHER PLATES, ANCHOR PLATES AND NUTS SHOULD BE GALVANIZED OR METALLIZED.

COMMENTARY:

1. *BOTH OPTIONS SHOWN HAVE PROVEN TO BE ACCEPTABLE. THE BRIDGE DESIGNER SHOULD CHOOSE ONE OR BOTH OPTIONS AND DETAIL THE PLANS ACCORDINGLY.*
2. *LOCATE ANCHOR RODS AWAY FROM THE BEARING UNIT TO FACILITATE INSTALLATION AND ALLOW FOR FUTURE MAINTENANCE AND REMOVAL. NOTE: THIS MAY REQUIRE A LARGER MASONRY PLATE.*
3. *THE HEX COUPLER CAN BE USED TO FACILITATE FUTURE REMOVAL OF THE BEARING. IF USED, THE TOP PORTION OF THE ANCHOR ROD CAN BE REPLACED WITH A HIGH-STRENGTH BOLT.*

AASHTO/NSBA STEEL BRIDGE COLLABORATION	HIGH LOAD MULTI-ROTATIONAL BEARINGS	LATEST REVISION DATE 12-15-22
	ANCHOR ROD DETAILS WITH ANCHOR ROD NUTS	DRAWING NUMBER H 1.9

Section 4: Steel Bearings

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SECTION 4: STEEL BEARINGS

4.1—GENERAL

This Article is intended to assist civil engineers in the design and detailing of steel bearings. The information included is intended to permit efficient fabrication, installation, and maintenance of these types of bearings.

C4.1

Where practical, steel bearings should only be considered for fixed bearing types.

Many owners have experienced long-term problems with steel expansion bearings. The most important issues have been high cost, the need for expensive sliding surfaces (bronze), corrosion and binding of parts, and poor performance.

Steel roller and rocker expansion bearings should not be used below bridge deck mechanical expansion joints. The design of these types of bearings relies on the rotation between steel elements. Debris and corrosion between steel plates due to deck joint failure will result in poor performance of the bearing.

4.2—BASIC ASSUMPTIONS

4.2.1—Approach

These Guidelines make the following design and detailing assumptions for steel bearings:

1. Steel bearings are limited to fixed bearing designs that do not need sliding or rolling surfaces.
2. The bearings are attached to the girder by field welding or bolting.
3. Lateral forces are restrained by means of keeper angles, concrete keeper blocks (keys), or anchor rods.

C4.2.1

If an owner desires to use steel sliding surface expansion bearing, refer to Section 3 (High Load Multi-Rotational Bearings) for design guidelines.

Some owners prefer welding and others prefer bolting. Welded attachment allows for minor adjustment during installation and is often the most economical design. Bolting provides limited damage to coating systems and allows for easier removal in the future.

See Drawings E 4.1 and E 4.2 in Article 2.10 for examples of keeper angles and keeper blocks.

4.3—DESIGN AND DETAILING RECOMMENDATIONS

4.3.1—Design

The design of steel bearings is the responsibility of the design engineer. The design should follow the provisions of the *AASHTO LRFD Bridge Design Specifications*.

Sole plate, masonry plate, and anchor rod design are best handled by the bridge designer since the bearing manufacturer may not be aware of important dimensional limitations.

The bridge designer should include notes on the plans allowing the bearing manufacturer to make minor adjustments to the dimensions of the sole plate, masonry plate, and anchor rods. The bridge designer should also identify dimensions that are not to be changed due to design or geometric constraints. For instance, the reinforcing steel in the concrete substructure often limits anchor rod locations. The bearing designer must coordinate any changes with both the contractor and the bridge design engineer.

4.3.1.1—Design Rotation

In general, steel bearing assemblies should be designed for unfactored dead load and live load rotations and additional rotations for uncertainties and construction tolerances.

The bearing should also be designed for dead load and live load rotations, rotations due to profile grade, and additional rotations for uncertainties (0.005 radians) and construction tolerances (0.005 radians).

Sole plates should be detailed as flat plates. If beveled sole plates are used, the design rotation for the bearing due to profile grade should be neglected.

If the beam is cambered for dead loads, the dead load design rotation of the bearing should be neglected.

C4.3.1.1

Bearing assemblies consist of the bearing element, connection plates, and a sole plate (beveled or flat). See Article 4.6 for details of a typical bearing assembly. Please refer to Appendix A for information on calculating rotations.

It is relatively easy to design a steel bearing for significant rotation, therefore the rotation due to grade of beams can normally be accommodated in the bearing.

Refer to Appendix A for information on the effect of beam cambering on bearing design rotations.

4.3.2—Sole Plate Connections

The connection of the sole plate to girders should be field-welded.

C4.3.2

Welding of the sole plate provided flexibility in accommodating erection tolerances, as the location of most steel bearings is fixed by the anchor rods. Welding allows for minor adjustment in the location of the sole plate relative to the beam.

The damage due to removal of the weld for future removal and maintenance can be reasonably repaired. The *AASHTO/AWS D1.5/D1.5M Bridge Welding Code* has information on weld removal and repair.

4.3.3—Sole Plate Details

The sole plate should extend transversely beyond the edge of the bottom flange of the girder at least 1 in. on each side.

C4.3.3

The recommendation to extend the sole plate is to facilitate the welding process and to allow sufficient room for welding. Fabricators will not overturn a girder in the shop to make a small weld; therefore, it is assumed that the girder will be upright when this weld is made in the shop or in the field.

The minimum thickness of the sole plate should be ¾ in.

The minimum thickness specified in the *AASHTO LRFD Bridge Design Specifications* to control plate distortion due to welding is ¾ in. This requirement is specified in those specifications' Article 14.7.4.6, however industry experience has shown that this minimum thickness is considered good practice for all bearing types.

4.3.4—Bearing to Girder Connection

The bearing may be connected to the girder by field welding or bolting.

If welding is used, the welds should be in the horizontal position.

The welds for the sole plate connection should only be along the longitudinal girder axis. Transverse joints should be sealed with an acceptable caulking material.

C4.3.4

Welding and bolting are both acceptable. If bolting is selected, oversized holes are recommended to facilitate field fit-up. Refer to each owner's standard details.

Overhead welds are difficult to perform due to limited access.

The longitudinal welds are made in the horizontal position, which is the position most likely to result in a quality fillet weld. Transverse welds require overhead welds and are very difficult to complete due to limited access. The caulking of the underside transverse joint is intended to prevent corrosion between the sole plate and the bottom flange. Most owners use a silicone-based caulk; however, other materials may be used.

4.3.5—Masonry Plates and Anchor Rods

The masonry plate should bear directly on a $^1/_8$-in.-thick preformed pad that rests directly on the substructure. The preformed pad may be an elastomeric, elastomeric cotton duck, or random fiber elastomeric material.

C4.3.5

This method of using a preformed pad to take up bearing surface irregularities is preferred to grouting under a masonry plate supported by leveling nuts. The grouting option results in point loads at the anchor rods due to the high stiffness of the rods when compared to the grout material, which can lead to masonry plate warping. For this reason, grouting should be limited to special cases only. No design of the bearing pad is required since it is assumed that the pad will yield and deform to fill the uneven surfaces of the concrete bearing seat.

4.3.5.1—Anchor Rods

Material for anchor rods should conform to ASTM F1554, and should be either threaded (with nuts) or swedged on the embedded portion of the rod. The design yield strength of this material may be specified as 36 ksi, 55 ksi, or 105 ksi, depending

C4.3.5.1

The term "anchor bolts" should not be used because "bolt" implies that the rod has a hex head. This material is specifically designed for anchor rod applications. Other materials have been used, but do not offer the economies of ASTM F1554.

on the design. The yield strength should be given in the specifications or on the plans.

The designer should offer options of swedging or threading the anchor as different suppliers supply one or both of these options.

Swedging is a process of indenting a rod through the use of a press force. Figure C2.3.5.3-1 shows swedged anchor rods.

4.4—MARKING

The designer should add the following notes to the plans:

> *"All bearings shall be marked prior to shipping. The marks shall include the bearing location on the bridge, and a direction arrow that points up-station. All marks shall be permanent and be visible after the bearing is installed. The marks shall be on the top plate of the bearing."*

C4.4

Problems have occurred in the field with the installation of bearings with beveled sole plates. It is not always obvious which orientation a bearing must take on a beam before the dead load rotation has been applied. This is especially true for bearings with minor bevels.

4.5—REFERENCES

AASHTO. *AASHTO LRFD Bridge Design Specifications*, 9th Ed. LRFDBDS-9. American Association of State Highway and Transportation Officials, Washington, DC, 2020.

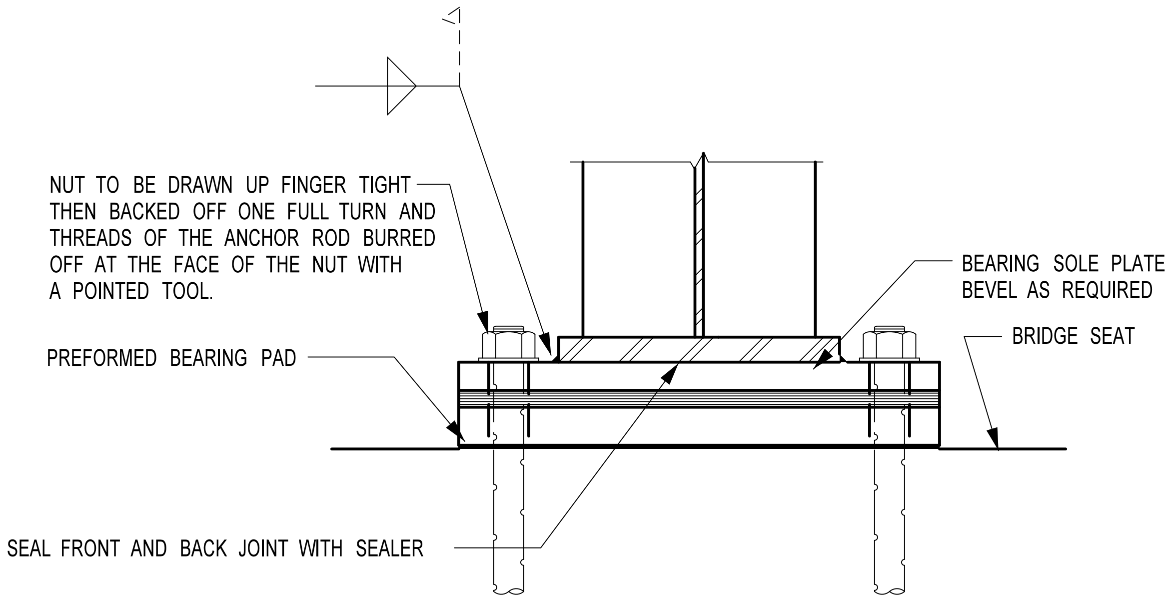
AASHTO. *LRFD Bridge Construction Specifications*, 4th Ed., with 2020 and 2022 Interim Revisions. LRFDCONS-4. American Association of State Highway and Transportation Officials, Washington, DC, 2017.

ASTM. F1554, Portland Bolt. ASTM International, West Conshohocken, PA.

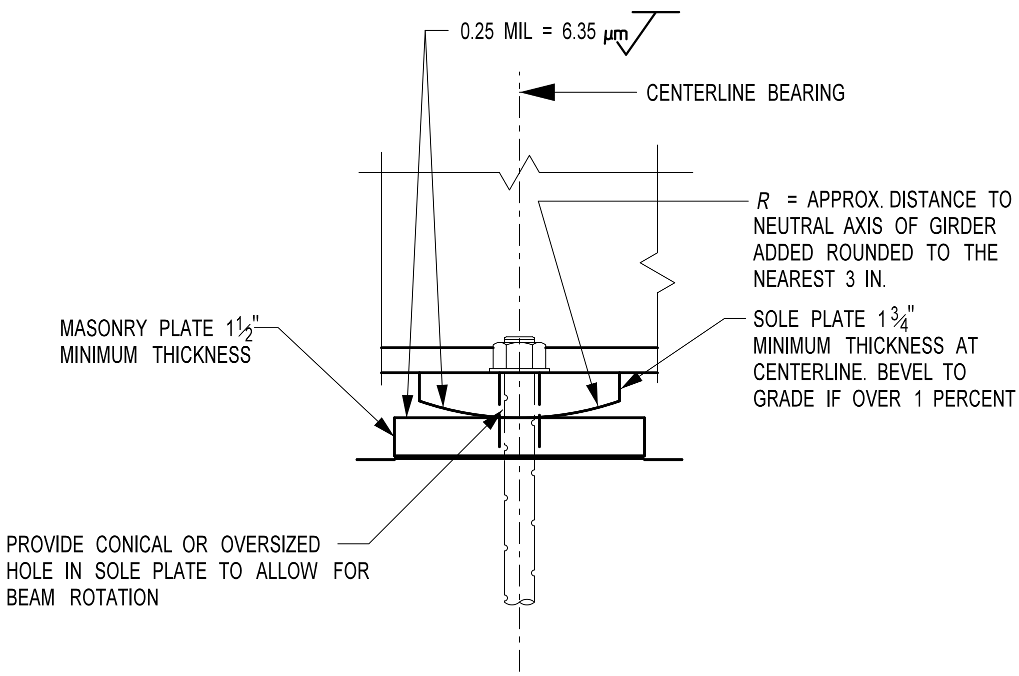
AWS/AASHTO. *AWS/AASHTO D1.5/D1.5M Bridge Welding Code*, 8th Ed. American Welding Society, Doral, FL, 2020.

4.6—RECOMMENDED DRAWING DETAILS

The following page contains a drawing that include recommended design and detailing guidance for steel bearings. This drawing is not intended to supersede any standards established by the bridge owner. The designer should obtain permission to use any detail that is in conflict with the owner's standards.



END VIEW



SIDE VIEW

NOTE A: CHECK DESIGN FOR CONTACT BEARING STRESSES.

NOTE B: PINTELS MAY BE USED TO CONNECT THE BOTTOM PLATE TO THE TOP PLATE. IN THIS CASE, THE SOLE PLATE SHOULD BE MADE NARROWER THAN THE MASONRY PLATE AND THE ANCHOR RODS RUN THROUGH THE MASONRY PLATE ONLY.

AASHTO/NSBA STEEL BRIDGE COLLABORATION	STEEL BEARINGS	LATEST REVISION DATE 12-15-22
	STEEL FIXED BEARING	DRAWING NUMBER S 1.1

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Section 5: Seismic Isolation Bearings

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Section 5:
SEISMIC ISOLATION BEARINGS

5.1—GENERAL

Seismic isolation bearings should be considered for the design of bridges in high seismic areas. The bearings can be used to improve the seismic resistance of the structure and reduce the costs of the substructures and foundations.

C5.1

One of the methods to make steel bridges even more cost-effective is the use of seismic isolation bearings. Hundreds of steel bridges have employed the use of seismic isolation bearings in North America, with hundreds more in other parts of the world. Seismically isolated structures have performed well in recent earthquakes and records from these structures show good correlation between predicted and actual results.

The use of seismic isolation bearings is not limited to the U.S. West Coast, as many steel bridges have been seismically isolated in the Northeastern, Southeastern, and Midwestern states as well. An isolated bridge is usually less expensive than a conventionally-designed structure due to the savings in the foundation costs.

5.2—APPROACH TO DESIGNING AND DETAILING

The approach to the design and detailing of seismic isolation bearings is similar to high load multi-rotational bearings. See Section 3 for more information.

5.3—TYPES OF SEISMIC ISOLATION BEARINGS

There are several different types of seismic isolation bearings on the market. The following Articles include a general description of each bearing type.

C5.3

Each of the types of bearings listed below has their own advantages and disadvantages depending on the site conditions and type of structure.

For design examples and technical information, it is recommended that the bridge designer contact a manufacturer of isolation bearings.

5.3.1—Flat Sliding Isolator (FSI) Disc Bearings

Sliding disc bearing can be used for seismic isolation. Figure 5.3.1-1 shows an FSI disc bearing.

C5.3.1

Disc bearings can be designed and fabricated with external restoration force springs to limit displacements and to re-center the bridge after the seismic event.

The nature of sliding bearings leads to an isolation system. The sliding of the bearing lengthens the period of the structure.

Energy dissipation is achieved via external springs that will limit the amount of displacement during the seismic event.

Figure 5.3.1-1. FSI Disc Bearing. Note: Photo shows bearing prior to installation in the inverted position without the base plate.

5.3.2—Lead Rubber Bearing (LRB)

Elastomeric bearings with lead cores can be used for seismic isolation. Figure 5.3.2-1 shows a lead rubber bearing.

C5.3.2

The internal lead core is used for energy dissipation.

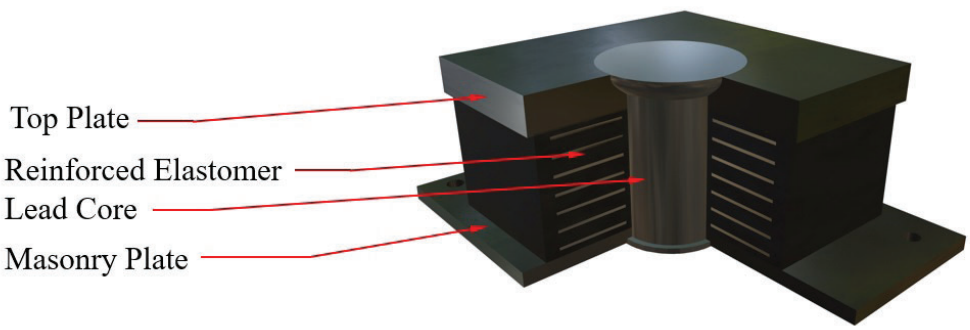

Figure 5.3.2-1. Lead Rubber Bearing (Cut-Away View)

5.3.3—Friction Pendulum Spherical Bearing (FPB)

Friction pendulum spherical bearings can be used for seismic isolation.

C5.3.3

Energy dissipation is achieved via a convex spherical sliding surface traveling along the spherical surface causing the bridge to rise slightly in a pendulum fashion.

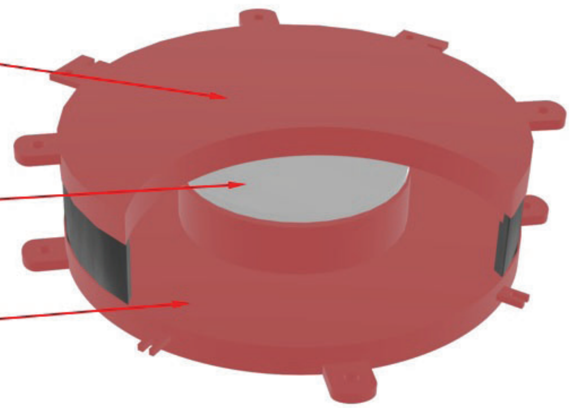

Figure 5.3.3-1. Friction Pendulum Spherical Bearing (Cut-Away View). Note: Different Manufacturers have varying details based on the same principle.

5.4—DESIGN AND DETAILING

5.4.1—Design for Non-Seismic Loads and Movements

In addition to seismic isolation design (see Article 5.4.2), the bearings need to be designed to accommodate all non-seismic loads and accommodate all anticipated movements in accordance with the *AASHTO LRFD Bridge Design Specifications*.

C5.4.1

The seismic isolation bearing must be able to provide rigidity to accommodate service forces such as live load, dead load, wind, braking forces, etc.

5.4.2—Seismic Isolation Design

The design of bearings for seismic isolation should be in accordance with the following specifications:

- *AASHTO LRFD Bridge Design Specifications* (force-based method)
- *AASHTO Guide Specifications for LRFD Seismic Bridge Design* (displacement-based method)
- AASHTO's *Guide Specifications for Seismic Isolation Design*

C5.4.2

The principles of seismic isolation apply to both methods of design. The AASHTO *Guide Specifications for Seismic Isolation Design* supplements the two cited design specifications. The AASHTO *Guide Specifications for Seismic Isolation Design* were written by a working group consisting of academics, consultants, designers, and industry. They represent an objective compilation of information on seismic isolation. There are a number of design examples in the appendix of AASHTO's *Guide Specifications for Seismic Isolation Design*.

5.4.2.1—Concepts of Seismic Isolation Design

The basic principle of seismic isolation is to increase the vibrational period of the structure in order to reduce the seismic forces acting on resistance elements such as the substructures and foundations.

Seismic isolation should also include elements of energy dissipation to limit displacements during seismic events.

C5.4.2.1

The basic idea of isolation bearings is to create some flexibility between the superstructure and substructure that in effect lengthens the fundamental period of vibration during strong ground motions, which typically results in force reductions imparted to the foundation. Force reductions of three to five times are typical depending on the type of isolator and the characteristics of the ground acceleration.

The trade-off to an increased period of vibration is increased displacement; therefore, it is imperative that the device have some form of energy dissipation to limit this displacement to a manageable level.

5.4.3—Detailing Requirements

The detailing of seismic isolation bearings is similar to detailing for high load multi-rotational bearings. The designer should indicate the non-seismic loads, rotations, and movements on the plans.

The designer should indicate the required seismic properties for the bearings on the plans.

C5.4.3

See Section 3 for specifics regarding high load multi-rotational bearing detailing requirements.

AASHTO's *Guide Specifications for Seismic Isolation Design* include information on how to design and specify the isolator design parameters.

5.5—REFERENCES

AASHTO. *AASHTO LRFD Bridge Design Specifications*, 9th Ed. LRFDBDS-9. American Association of State Highway and Transportation Officials, Washington, DC, 2020.

AASHTO. *LRFD Bridge Construction Specifications*, 4th Ed., with 2020 and 2022 Interim Revisions. LRFDCONS-4. American Association of State Highway and Transportation Officials, Washington, DC, 2017.

AASHTO. *AASHTO Guide Specifications for LRFD Seismic Bridge Design*, 2nd Ed., with 2012, 2014, 2020 and 2022 Interim Revisions. LRFDSEIS-2 American Association of State Highway and Transportation Officials, Washington, DC, 2011.

AASHTO. *Guide Specifications for Seismic Isolation Design*, 4th Ed. GSID-4. American Association of State Highway and Transportation Officials, Washington, DC, 2014.

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Appendix A:

RECOMMENDATIONS FOR BEAM ROTATION CALCULATIONS

A1—DEAD LOAD ROTATIONS

In general, bearings should not be designed for dead load rotations if proper camber is provided in the girders. The bearing design is based on a girder that provides a level surface for the bearing to support. Some owners design bridges with minor grades without beveled sole plates. For these cases, the bearing must be designed for rotation due to profile as well (see Article A3.2 for detailed discussion on these issues).

A1.1—Non-Composite Dead Load Rotation

- Rotation for non-composite dead load should be calculated with steel section properties only.
- If deck pour sequences are incorporated into the design, these sequences and the appropriate stiffness changes that take place during deck casting may be accounted for in the rotation calculations.

A1.2—Composite Dead Load Calculations

- All composite dead loads should be distributed to each girder equally. The rotations should be calculated using section properties based on long term dead loads (concrete modular ratio of $3 \times n$).

A2—LIVE LOAD ROTATIONS

There is great variation in the methods used for calculation of live load rotations. The following guide has been developed based on methods used by several owners. Experience has shown that actual rotations measured in the field are significantly lower than those typically calculated.

In an effort to provide more cost-effective bridges, the AASHTO/NSBA Steel Bridge Collaboration recommends that a realistic approach be taken in the calculation of live load rotations. Many of these recommendations are now part of the *AASHTO LRFD Bridge Design Specifications*. The *AASHTO LRFD Bridge Design Specifications* require that bearings be designed for uncertainties. Therefore, there is no need for excessive conservatism in the design for beam rotation.

A2.1—Live Load Distribution

The live load condition is to have all lanes loaded on the bridge. This represents the maximum credible load condition that the bridge will experience. Therefore, the live load should be applied to all travel lanes and distributed to each beam equally.

$$\text{wheel load distribution factor} = (\text{number of lanes} \times 2 \text{ wheels/lane})/\text{number of beams}$$

A2.2—Simple-Span Bridges

The maximum rotation of the beam end can be calculated using normal stiffness methods. However, many beam design computer programs do not calculate the beam end rotation. An approximate beam end rotation can be determined based on maximum mid-span deflection as follows (note that this is an exact solution only in the case when the beam is prismatic, and the beam deflection is parabolic):

1. Calculate the maximum deflection due to live load (LL) = Δ
2. Approximate end rotation = $4 \times \Delta$/(beam span length)

A2.3—Continuous-Span Bridges

Composite section properties should be used for all segments of all girders. This includes the negative moment regions, where the transformed concrete slab should be used in place of the cracked section (beam and slab reinforcement). A crack in a slab may cause localized stress increases that warrant a cracked section analysis for design; however, the overall behavior of the beam has been demonstrated in field studies to be as if the slab is uncracked.

A3—EFFECT OF BEVELED SOLE PLATES AND GIRDER CAMBER ON BEARING DESIGN

The use of beveled sole plates and cambering of beams have an impact on the design rotations for bearings on steel bridges. The designer should account for these in the design of the bearings.

A3.1—Girder Camber

Girder camber is used to provide a beam that has a web that follows the final roadway profile after the application of total dead load. This means that the dead load rotation of the beam at each support is built into the girder via an opposite rotation. When the beam is placed, the bottom of the beam will be out of parallel by a factor that is equal to the dead load rotation. This will induce a rotation into the bearing as the beam is set; however, this rotation decreases to zero as the beam is loaded with total dead load. Ideally, the dead load rotation that the bearing experiences is zero in the finished structure. Many designers do not evaluate elastomeric bearings under this temporary condition when the beam is set, since the situation is temporary, and the loads and rotations are much lower than the full design load and rotation of the bearing. HLMR bearings are normally checked for this temporary condition to ensure that no damage occurs and that there is no metal-to-metal contact.

A3.2—Beveled Sole Plates

Properly-beveled sole plates provide a level surface under the sole plate after the application of full dead load. As stated in Article A3.1, the beam camber normally accounts for the dead load rotation. If a beam is not cambered, then the sole plate can also be used to account for the dead load rotation. The sole plate normally only accounts for the profile of the beam. If the beam is cambered, then the sole plate only needs to account for the beam profile.

Table A3.2-1 demonstrates the effects of beam cambering and a beveled sole plate on the rotation analysis of elastomeric bearings on a simple steel bridge. The numbers shown are not specific to any bridge; however, they demonstrate the effects of cambering and beveled sole plates.

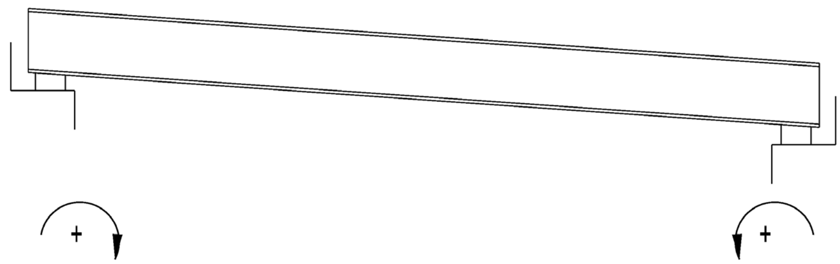
The first table is for a beam without camber and beveled plates. The addition of a rotation due to profile grade and the dead load rotation tend to increase the design rotation of the bearing.

The second table is for a beam with cambering but without beveled sole plates. Many designers use this scenario for beams with flat profiles (typically less than 0.01 radians). In this case, the cambering eliminates the dead load rotation from the design rotation of the bearing.

The third table is for a beam with both cambering and beveled sole plates. In this case, the beveled sole plate eliminates the rotation induced by profile grade.

Table A3.2-1. Sample Tabulation of Bearing Rotations for Elastomeric Bearings

SAMPLE TABULATION OF BEARING ROTATIONS FOR ELASTOMERIC BEARINGS



Bearing Rotations **without** Beveled Sole Plates and **without** Girder Camber (radians)		
Rotation Component	Left End	Right End
Profile Grade	+0.005	-0.005
Dead Load	+0.014	+0.014
Live Load	+0.011	+0.011
Uncertainties and Tolerances	+0.005	+0.005
Design Rotation	+0.035	+0.025

Bearing Rotations **without** Beveled Sole Plates and **with** Girder Camber (radians)		
Rotation Component	Left End	Right End
Profile Grade	+0.005	-0.005
Dead Load	+0.000	+0.000
Live Load	+0.011	+0.011
Uncertainties and Tolerances	+0.005	+0.005
Design Rotation	+0.021	+0.011

Bearing Rotations **with** Beveled Sole Plates and **with** Girder Camber (radians)		
Rotation Component	Left End	Right End
Profile Grade	+0.000	-0.000
Dead Load	+0.000	+0.000
Live Load	+0.011	+0.011
Uncertainties and Tolerances	+0.005	+0.005
Design Rotation	+0.016	+0.016

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Appendix B:

RECOMMENDATIONS FOR THERMAL MOVEMENT CALCULATIONS

The AASHTO specifications outline requirements for calculation of thermal movement. The following are general guidelines based on the experience of the NSBA Collaboration members that are intended to supplement Article 14.1 of the *AASHTO LRFD Bridge Design Specifications*. The designer should establish an installation temperature range and design and specify the bearings accordingly.

B1—STANDARD BRIDGES

In this context, a standard bridge is defined as a steel stringer bridge that has the following geometric conditions:

- Straight beams.
- Zero to moderate skew (approximately 30 degrees).
- Span length-to-width ratio greater than 2.
- Fewer than three travel lanes.

The major contributor to thermal movements is the bridge deck. This portion of the bridge structure is exposed to the highest temperature extremes and is a continuous flat plate. A flat plate will expand and contract in two directions, and will not be significantly affected by the steel framing below. For bridges that meet the general criteria listed above, the calculations for thermal movement can be based on the assumption that the bridge expands along its major axis, which is along the span length.

B2—NON-STANDARD BRIDGES

The treatment of non-standard bridges requires careful design and planning. A refined analysis may be required for non-standard bridges to determine the thermal movements, beam rotations (transverse and longitudinal), and structural behavior of the system. The stiffness of substructure elements may also influence the thermal movement at bearings. The following are general basic guidelines outlining the thermal movement behavior for non-standard bridges.

B2.1—Curved Girder Bridges

It has been well-documented that curved girder bridges do not expand and contract along the girder lines. The most often used approach is to design bearing devices to expand along a chord that runs from the point of zero movement (usually a fixed substructure element) to the bearing element under consideration (see Figure B2.1-1).

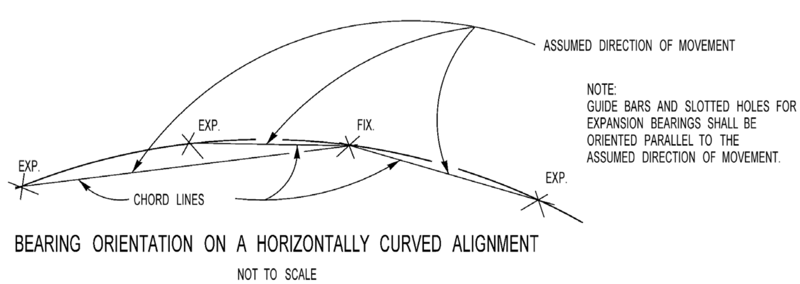

Figure B2.1-1. Bearing Orientation on a Horizontally-Curved Alignment (Not to Scale)

B2.2—Large Skew Bridges

The major axis of thermal movement on a highly skewed bridge is along the diagonal from the acute corners, due to the thermal movement of the bridge deck. The alignment of bearings and keeper assemblies should be parallel to this axis. The design of the bearings should also be based on thermal movement along this line (see Figure B2.2-1).

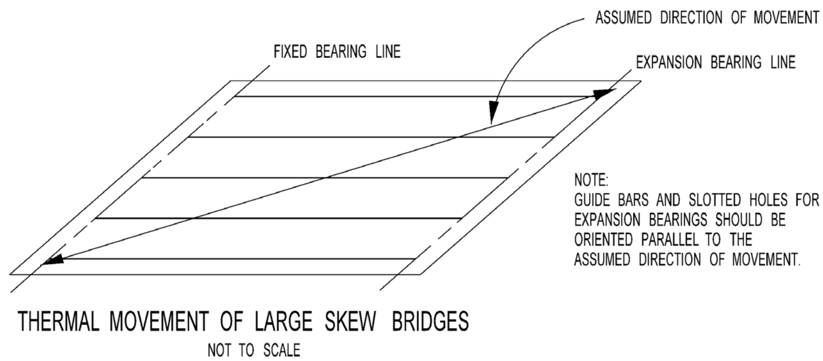

Figure B2.2-1. Thermal Movement of Large Skew Bridges (Not to Scale)

B2.3—Bridges with Small Span-to-Width Ratios

Bridges with widths that approach and sometimes exceed their lengths are subject to unusual thermal movements. A square bridge will expand equally in both directions, and bridges that are wider than they are long will expand more in the transverse direction than in the longitudinal direction. The design of bearing devices and keeper assemblies should take this movement into account.

B2.4—Wide Bridges

Bridges that are wider than three lanes will experience transverse thermal movements that can become excessive. Care should be taken along bearing lines not to guide or fix all bearings along the line. Guides and keeper assemblies should be limited to the interior portions of the bridge that do not experience large transverse movements.