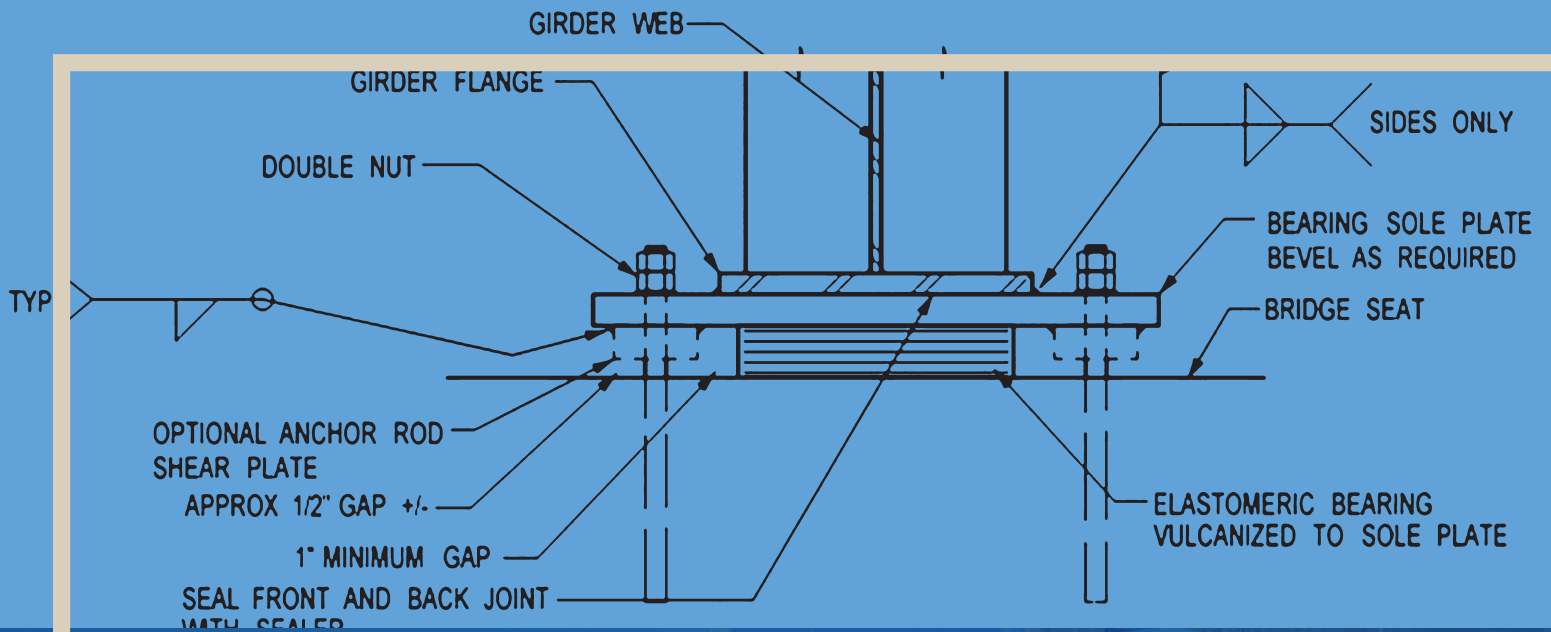




Steel Bridge Bearing Guidelines

G9.1—2022



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.

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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

C1.1

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.

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

C1.1.1

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.

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.

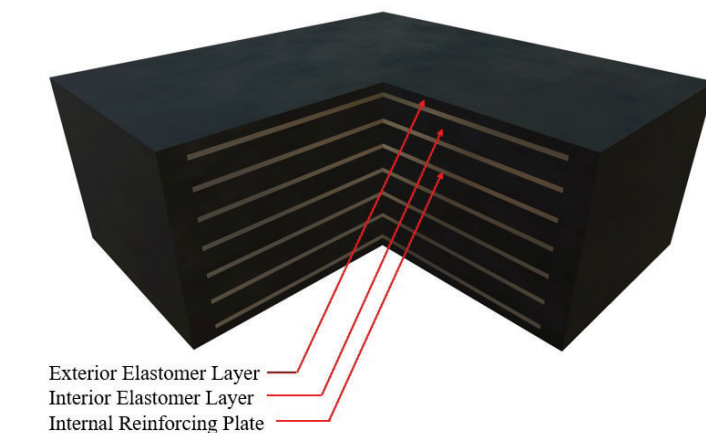


Figure 1.1.1-1. Cut-Away View of a Reinforced Elastomeric Bearing

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.

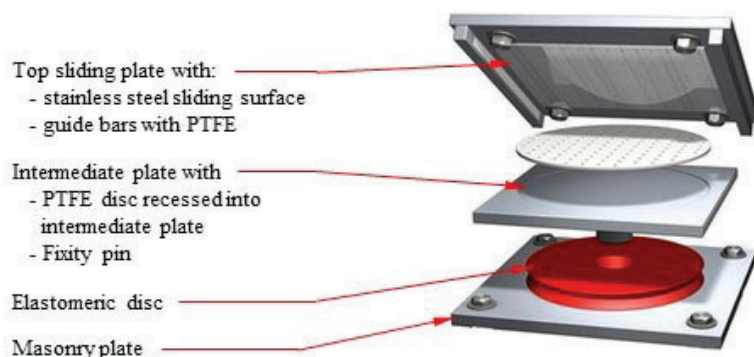


Figure 1.1.2-1. Exploded View of a High Load Multi-Rotational Bearing (Disc Bearing Shown)

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.

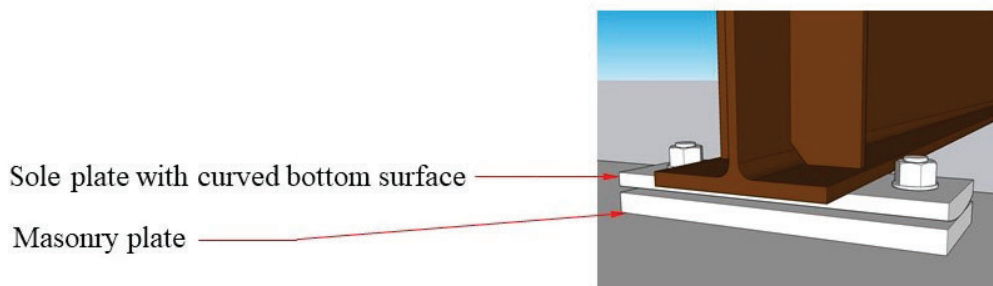


Figure 1.1.3-1. Simple Steel Bearing (Fixed Bearing Shown)

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.

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.

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

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.

C1.2.1

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

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	Maintenance
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**C1.3**

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.

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.

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.

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

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.

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.

C1.4.2

A higher level of corrosion protection may be desirable for bearings that may become exposed to severe corrosive environments. Deck expansion

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.

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.

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.

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.

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.

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.

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

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

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.

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

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.

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.

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

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.

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

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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.

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.

C2.1

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*.

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.

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.

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.

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*.

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.

C2.3.1.2

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.

The bearings should be designed for 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.

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 $\frac{1}{8}$ 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.

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.

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.

2.3.2.1—Bearings without Anchor Rods

Sole plates may be shop-welded, field-welded, or bolted for 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

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.

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.

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 through 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.

2.3.2.4—Connections 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.

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.

C2.3.2.3

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.

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.

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.

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.

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.

2.3.4—Bearing-to-Girder Connection

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

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

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

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.

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.

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.

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.

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.

Overhead welds should be avoided due to limited clearance.

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 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.