Steel Bridges: Bearing Design

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Steel Bridge Design Handbook: Bearing Design

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1.0 INTRODUCTION

This module provides practical information for efficient bearing design and detailing. The information contained in this module is drawn largely from the following two sources - NSBA's "Steel Bridge Bearing Selection and Design Guide," Highway Structures Design Guide, Volume II, Chapter 4 (HSDH Volume II, Chapter 4) (1) and AASHTO/NSBA Steel Bridge Collaboration, G9.1-2004 "Steel Bridge Bearing Design and Detailing Guidelines" (AASHTO/NSBA G9.1-2004) (2).

2.0 BEARING TYPES

Steel bridge bearings may be divided into three general types: elastomeric bearings, high-load multi-rotational bearings, and mechanical bearings. The designer must determine which bearing type is best suited to cost effectively accommodate the design requirements. Design of elastomeric bearings is typically the responsibility of the design engineer whereas the manufacturer performs the design of most high-load multi-rotational (HLMR) bearing assemblies.

2.1 Elastomeric Bearings

Plain pads, steel reinforced and cotton duck elastomeric bearings are the three predominant elastomeric bearing styles designed and supplied in the USA. 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.

2.1.1 Plain Pads

Plain elastomeric bearing pads (PEP) rely upon friction at the contact surfaces to resist bulging. Local slip resulting from friction loss leads to increased strain, thus limiting the load carrying capacity of the bearing. The permissible compressive stress is a function of the shape factor so plain pads must be relatively thin to carry the maximum compressive load, and therefore can accommodate only small horizontal translations and rotations.

2.1.2 Steel Reinforced Elastomeric Bearings

Steel reinforced elastomeric bearings rely upon both contact surface friction and restraint of the bonded steel shims to resist elastomer bulging. Thin, uniformly spaced elastomer layers allow for higher design compressive stresses and higher translation and rotation capacity than PEPs.

The shape factor, which varies with modifications to plan dimensions and layer thickness, affects compressive and rotational stiffness that controls the stress in the steel shims and elastomer strain. It does not affect the translational stiffness or the deformation capacity.

Steel reinforced elastomeric bearings can handle larger rotations and translations than other elastomeric bearings by employing multiple elastomer layers, but the design must satisfy stability requirements. Furthermore, if the horizontal shear force is greater than one-fifth of the minimum permanent dead load, the bearing is subject to slip and must be secured against horizontal movement. However, a one-time slip to bring the pad to equilibrium in the center of its thermal expansion/contraction range is acceptable, especially in cases where the slip can only occur at the pad/beam surface interface. The one-fifth limit is directly related to the design coefficient of friction that can be assumed between elastomer and clean concrete and unpolished, debris-free steel. For additional information, see the discussion on masonry plates and anchor rods later in this module.

2.1.3 Cotton Duck Bearings

Cotton duck reinforced Pads (CDP), or fabric-reinforced bearings, are fabricated by vulcanizing very thin layers of elastomer with cotton fabric weave. They have an overall Shore 'A' durometer hardness in excess of 90, which is stiff against shear and rotation and can accommodate high compressive loads. Because of their resistance to translation, they are commonly used with a PTFE sliding surface and do not require a metallic substrate between the PTFE and the CDP.

2.2 High-Load Multi-Rotational (HLMR) Bearings

Pot, disc and spherical bearings currently make up the readily available variety of HLMR bearings that sustain high loads and are able to rotate in any direction. They can be fixed or, when fabricated with sliding surfaces, they can accommodate translation for use as expansion bearings. In addition, guide bars can be used to restrict movement to one direction.

2.2.1 Pot Bearings

Pot bearings subject a confined elastomeric element (disc) to high pressures, effectively causing the disc to behave as a fluid. Refer to figures in HSDH Volume II, Chapter 4 showing components of pot bearings. The neoprene or natural rubber elastomeric disc is confined within the machined pot plate. The vertical force is transmitted to the elastomeric disc via the piston, which seats within the pot. Tight fitting brass sealing rings prevent the elastomer from escaping in the gap between the piston and the pot. Horizontal forces are resisted by contact of the piston face width against the pot wall. The vertical and horizontal loads are transmitted from the piston and pot to the sole and masonry plates through bearing and by mechanical connections.

2.2.2 Disc Bearings

Disc bearings subject an unconfined elastomeric disc to high pressures. The polyether urethane disc is stiff against compression, flexible enough to allow rotation, but is free to bulge. Horizontal forces are transmitted from an upper load plate to either a shear pin at the center of the disc, or to a restricting ring. The latter is similar in detail to the pot bearing, except that the disc is unconfined with no requirement for sealing rings. If a restricting ring configuration is used, a positive locator device is supplied. The shear pin serves this purpose when it is used to resist the horizontal loads. The vertical and horizontal loads are transmitted from the upper load plate and shear pin to the sole and masonry plates through bearing and by mechanical connections.

2.2.3 Spherical Bearings

Spherical bearings transmit all loads, both vertical and horizontal, through the spherical coupling of a convex and concave plate. This interface is typically a mating of low coefficient of friction PTFE and stainless steel. All vertical loads are assumed to be transmitted radially through the interface and all horizontal loads are resisted by the spherical geometry of the plates.

2.3 Mechanical Bearings

Mechanical bearings (incorporation of bronze plates is included) or steel bearings distribute forces, both vertical and horizontal, through metal-to-metal contact. Most fixed bearings rely upon a pin or knuckle to allow rotation while restricting translational movement. Rockers, rollers, and sliding types are common expansion styles historically used and under certain circumstances can still be used today.

The metal-to-metal contact typically results in corrosion and eventual “freezing” of the bearing components. Lubricants have been used to mitigate corrosion, but trap debris, which in turn holds moisture and promotes corrosion. Mechanical bearings should not be specified for new designs unless special circumstances exist. For example, this bearing type might be used in bridge widening projects where existing bearing styles must be matched.

3.0 BEARING DESIGN REQUIREMENTS

3.1 Loads, Rotation and Translation

Compressive loads include structure dead loads and traffic live loads. Impact does not need to be considered for many bearing types. Elastomeric bearings are designed for unfactored service loads, regardless of the design code being followed: the *AASHTO Standard Specifications for Highway Bridges, 17th Edition 2002* (referred to herein as the Standard Specifications) (3), or the *AASHTO LRFD Bridge Design Specifications, 7th Edition (2014)* (referred to herein as AASHTO LRFD 7th Edition (2014)) (4). HLMR bearings designed in accordance with the Standard Specifications require unfactored load combinations from Section 3, and those designed in accordance with the AASHTO LRFD 7th Edition (2014) require factored service vertical loads in addition to applicable strength and extreme horizontal forces. Steel bearings should be designed for the same loads as HLMR bearings, but the vertical loads should also include impact.

Horizontal loads to the bearing resulting from translation restraint or Extreme Event I (Seismic) come from the analysis of the structure. In the case of HLMR and mechanical bearings, horizontal loads must be taken as not less than 10% of the maximum vertical design load. For elastomeric bearings, if the horizontal loads exceed the shear resistance of the bearing then consideration should be given to a method (internal or external to the bearing) that will resist the additional force.

HSDH Volume II, Chapter 4, Part II, Section 1 (1) provides general guidance for the movements (rotations and translations) to be considered. Sources include bridge skew, curvature effects, initial camber, construction loads, misalignment, construction tolerances, support settlement, thermal effects, and live loads.

Whether or not the bearing is intended to resist movement, the bearing, connections and substructure units should be designed to transfer the forces imparted by the bearings' resistance to movement. Elastomeric bearings resist movement by shear stiffness. Additionally, the frictional forces of steel bearings and bearings utilizing PTFE/stainless steel sliding surfaces should be considered. The design coefficients of friction should be examined at all compressive load levels and the expected low temperature. See HSDH Volume II, Chapter 4 (1) for further discussion.

3.2 Design Requirements

This section discusses the application of the AASHTO LRFD 7th Edition (2014) and recommends considerations for design. Additional reference is made to HSDH Volume II, Chapter 4, Part I, Section 2 (1).

3.2.1 Elastomeric Bearings

Steel reinforced elastomeric bearings can be designed by either the AASHTO LRFD 7th Edition (2014) Method 'A' (Article 14.7.6) or Method 'B' (Article 14.7.5). The stress limits associated with Method A usually result in a bearing with a lower capacity than a bearing designed using

Method B. This increased capacity resulting from the use of Method B requires additional testing and quality control (Article C14.7.5.1). Designers need to specify which method is used in the bearing design to ensure fabrication and quality control complies with the appropriate requirements.

Other elastomeric bearings [plain elastomeric pads (PEP), fiberglass-reinforced pads (FGP), and cotton duck fabric pads (CDP)] must be designed in accordance with the AASHTO LRFD 7th Edition (2014) Method ‘A’.

Shear modulus (G) is a critically important material property in the design and performance of elastomeric bearings. The designer should use the minimum and maximum values of G for various durometer hardness as shown in the AASHTO LRFD 7th Edition (2014). Fabricators have compounds for different durometer hardness, which in turn have average shear moduli. Although it is possible to specify the elastomer by a shear modulus, check with fabricators to obtain their shear modulus limits. If the elastomer is specified by its shear modulus, the AASHTO LRFD 7th Edition (2014) allows the fabricator to provide a measured shear modulus within 15% of the value specified. Instead, elastomers are typically specified by durometer hardness only. Therefore, no reference to a required shear modulus should be stated if specifying durometer hardness, and vice versa.

Elastomeric bearings cannot be set with an initial offset to account for varying temperatures at the time of installation. When an initial offset is necessary, the designer should make provisions by multiplying the design translation by a minimum factor of safety of 1.5 or ensure that the contractor is required to reset the bearing. For bearings that must be reset, the contract documents should include a note similar to that found in the Ohio Department of Transportation Bridge Design Manual (6), typical plan notes for repositioning of elastomeric bearings for steel beam and girder bridges. “If the steel is erected at an ambient temperature higher than 80 °F [26.7 °C] or lower than 40 °F [4.4 °C] and the bearing shear deflection exceeds one-sixth of the bearing height at 60 °F ± 10 °F [15.6 °C ± 5.6 °C], the beams or girders shall be raised to allow the bearings to return to their undeformed shape at 60 °F ± 10 °F [15.6 °C ± 5.6 °C].” If the elastomeric bearing includes a sliding surface, the designer should indicate, in the contract plans, the initial offset from centerline to use during erection/installation depending on temperature.

Some states require elastomeric bearings to be designed for one-way translation equal to the movement expected through the entire high-low temperature range. This is very conservative, but allows the bearing to be set at any temperature without requiring it to be reset at a given mid-range temperature.

The AASHTO LRFD 7th Edition (2014) C14.4.2 requires the design rotation for elastomeric bearings to be the sum of the rotations due to all unfactored loads and an allowance for uncertainties, taken as 0.005 radians (unless an approved quality control plan justifies the use of a smaller value). The AASHTO LRFD 7th Edition (2014) also requires that sole plates be beveled to produce a level-bearing surface at the top of the elastomeric bearing when the underside of the girder, under the full dead load and at the mean annual temperature, is out of level by more than 0.01 radians (1%). This implies that beveled sole plates are not required if the out of plane rotation is less than 1%. If the designer elects not to use beveled sole plates (see discussion on sole plates later in this module) at slopes less than or equal to 1.0%, then the additional permanent rotation induced by the out of plane condition must be added into the required design rotation sum, including the 0.005 radian allowance for uncertainties.

Elastomeric bearings have also been used in the design of seismic isolation systems. Refer to AASHTO Guide Specifications for Seismic Isolation Design (7) for design, fabrication and quality control tests supplementary to the Standard Specifications.

3.2.2 HLMR Bearings

The AASHTO LRFD 7th Edition (2014) Article 14.7.4 has detailed design requirements for pot bearings. The code also allows for the design of internal pot components following accepted engineering principles. These include but are not limited to using failure theories (Von Mises Theory, Mohr's Theory, etc.) for the calculation of pot wall thickness for square pots.

Flat brass sealing rings used with pot bearings are available in 0.125 in. [3.2 mm] increment widths but the available thickness is less diversified; therefore the fabricator may use more than the minimum required number of rings to achieve the required overall thickness. Round brass sealing rings are not available in Federal Specification QQB-626, Composition 2, which is referenced in many older documents. The specification has been replaced by ASTM B16 Alloy CDA360, Half-Hard.

Less guidance is provided in the AASHTO LRFD 7th Edition (2014) for the design of spherical bearings. For a complete description of PTFE/Spherical bearing design theory and a design example, the reader is directed to the California Department of Transportation (Caltrans) "Memo to Designers 7-1" (8). This Caltrans document cautions that the maximum radius of the mating convex and concave plates should not exceed 36 inches [914.4 mm] due to manufacturing limitations. However, some manufacturers are able to achieve radii in excess of this limitation.

The memo also states that for horizontally restrained bearings, the ratio of the maximum horizontal force to the minimum vertical force should not exceed 0.40 to avoid overstressing the PTFE fabric at the spherical interface. If this criterion cannot be met, alternate means to transfer the horizontal forces should be employed. As the spherical cap of the concave plate approaches hemispherical, it becomes increasingly difficult to fabricate and bond the woven fabric PTFE from a single piece. If the ratio of the arc length of the cap to the base diameter of the cap exceeds 1.15, it may be necessary to fabricate the woven fabric PTFE from multiple pieces.

FHWA Structural Committee for Economical Fabrication (SCEF) Standard 106, High Load Multi-Rotational Bearings (9), offers assistance to bridge design engineers specifying multi-rotational bearings. The AASHTO LRFD 7th Edition (2014) suggests that disc bearings are less likely to experience metal-to-metal contact than other HLMR bearings, and therefore the total required design rotation (actual plus allowance for fabrication/setting tolerances and uncertainties) is less than that of other HLMR bearings. SCEF requires that the shear restriction mechanism be designed to withstand the design horizontal forces without exceeding the shear, bending, and bearing capacities, excluding the shear resistance of the disc. AASHTO LRFD 7th Edition (2014) requires that the shear resisting mechanism transmit horizontal forces between the upper and lower steel plates. Therefore, it is important to be cautious and ensure that designs avoid metal-to-metal contact.

Disc bearings with a sliding surface have also been used in the design of seismic isolation systems. Refer to AASHTO Guide Specifications for Seismic Isolation Design (7) for design, fabrication, and quality control tests supplementary to the Standard Specifications.

3.2.3 Mechanical Bearings

Limited design information is also provided in AASHTO LRFD 7th Edition (2014) for mechanical (steel) bearing design (Article 14.7.1). Mechanical bearings such as metal bolsters, metal rockers, and roller bearing assemblies are viewed by many as an outdated system with high initial costs and costly long term maintenance requirements.

4.0 BEARING STYLE SELECTION GUIDELINES

In this section, requirements and appropriateness of bearing styles are discussed with respect to design and fabrication.

4.1 Design Limitations

Each bearing style has practical limitations that make it more or less suitable for a particular design situation than another style. The following bearing style limitations are summarized from HSDH Volume II, Chapter 4 selection tables and graphs. The practical limitations discussed below are not absolute and the designer must verify compliance with the AASHTO LRFD 7th Edition (2014) as the limitations are often adjusted with updates and revisions to the Specifications.

Plain elastomeric pads are limited to 800 psi [5.5 MPa] compressive stress in accordance with the AASHTO LRFD 7th Edition (2014) Article 14.7.6.3.2. Compressive forces will generally be limited to approximately 100 - 200 kips [444.8 – 889.6 kN]. Practical limitations for rotation and translation are very small, on the order of 0.01 radians and 0.5" [12.7 mm] respectively.

For cotton duck pads, in accordance with Article 14.7.6.3.2 of the AASHTO LRFD 7th Edition (2014), the compressive stress due to applicable service load combinations shall be less than 3,000 psi, and the average compressive stress at the service limit state (load factor of 1.0) due to live load is limited to 2,000 psi. Design compressive forces should generally be limited to approximately 700 – 1,400 kips [3,113.7 – 6,227.5 kN]. Reasonably, rotation is limited to approximately 0.003 radians, and movement without PTFE bonded to the upper surface, is limited to approximately 0.25" [6.4 mm]. Currently, the use of CDP is limited by the low rotational capacity due to relatively large compressive strains at the service limit stress.

Steel reinforced elastomeric bearings designed in accordance with the AASHTO LRFD 7th Edition (2014) Method ‘A’ are limited to 800 psi [6.9 MPa] compressive stress, as they are treated as plain elastomeric pads under Method ‘A’. Steel reinforced elastomeric bearings designed using Method ‘B’ often result in bearings with a higher capacity than those designed with Method ‘A’. In past specifications, the bearings designed in accordance with Method ‘B’ were limited to 1,600 psi [11.0 MPa] or 1,750 psi [12.0 MPa] when subjected to shear deformations or fixed conditions, respectively. A compressive force limit of approximately 750 – 1,500 kips [3,336.2 – 6,672.3 kN] should be considered. A practical limitation for translation, based on stability and economics, is in the order of 4 inches [101.6 mm] without the addition of a sliding element, and rotation is generally limited to 0.02 radians.

Typically, steel reinforced elastomeric bearings are designed for conditions in which the direction of movement and live load rotation is along the same axis and therefore, rectangular shapes are suitable. For horizontally curved structures and short span highly skewed structures, these directions may not coincide, or their directions may not be easily defined. In these instances, circular bearings may be considered since they easily accommodate translation and rotation in any direction although rectangular pads work fine.

For any style of elastomeric bearing, if a sliding element is required, the bearing must be designed to accommodate the expected bearing translation as the result of frictional forces that build up prior to sliding. Friction is greatest at low temperatures and low compressive stresses. Therefore, the shear deformation resistance of the bearing must be greater than the translation expected from the frictional forces generated at the coldest expected temperature and the minimum vertical load condition.

HLMR bearings designed for expansion with a PTFE/stainless steel sliding surface can nearly accommodate horizontal movements to whatever the requirement may be (see additional discussion later in this module). Pot bearings can safely be designed for rotations in the range of 0.04-0.05 radians, and disc and spherical bearings can be designed for a rotation in excess of 0.05 radians. If the anticipated minimum vertical load is 20% or less than the vertical design capacity of the bearing, pot and spherical bearings should not be used, in accordance with the AASHTO LRFD 7th Edition (2014) Article 14.6.1.

The pot elastomeric disc and PTFE elements of all HLMR bearing styles are designed to an average permissible compressive stress of 3,500 psi [24.1 MPa], while most polyether urethane elements of disc bearings are generally designed for an average compressive stress of 5,000 psi [34.5 MPa]. (A less often specified, softer urethane compound, limits the maximum average compressive stress to 3,700 psi [25.5 MPa].)

Given the higher bearing pressures passing through the HLMR bearing components, it is necessary to check the imposed concrete bearing pressures. AASHTO LRFD 7th Edition (2014) permits the concrete bearing stress capacity to be increased by $(A_2/A_1)^{1/2}$, but not more than 2.0 (see Article 5.7.5).

HSDH Volume II, Chapter 4 suggests a maximum compressive force of 2,250 kips [10,000 kN] for HLMR bearings, although there are many HLMR bearings in service today that exceed this boundary without known serviceability issues.

4.2 Fabrication and Testing Limitations

Perhaps the single most limiting factor to contribute to a bearing style selection is the feasibility of the bearing to be fabricated and tested.

The largest domestic press available for testing, at the time of this publication, is capable of compressive forces on the order of 12,000 kips [53,380 kN] maximum. Consideration should be given to the design compressive force and the testing force required.

Steel reinforced elastomeric bearings are molded in the presence of heat and pressure. The pressure required during the molding process is on the same order as that to which the bearing is designed. The AASHTO LRFD 7th Edition (2014) requires load testing to 150% of the maximum design stress, and often times, the same press that was used to mold the bearing can be used to test it. The compressive stress controls the press that is required for testing, so if a press other than the one used to mold the bearing is required, free height available must be considered. Total bearing height must include vulcanized plates if required. Equipment available to mold and test bearings varies among fabricators. Designs that approach the recommended maximum compressive forces and translation limits should be verified with fabricators at an early stage in design.

HLMR bearings can often be stripped of upper and lower load plates to test the rotational elements and therefore, for testing purposes, are not necessarily subjected to the same bearing height issues as elastomeric bearings.

Very large bearings typically require large or thick plates, which can be machined to specified tolerances by a limited number of facilities. Plate availability varies depending on the thickness required. In general, plate material less than six inches in thickness is usually available. Required plate thicknesses in excess of six inches may require a special order, which adds significantly to the manufacturing time. ASTM A709, Grade 50 [A709M, Grade 345] is available only up to a purchase thickness of four inches. If greater than four-inch purchase thickness is required at the same strength, then ASTM A588/A588M should be specified or permitted. (In accordance with Specification ASTM A709/A709M, Grade 50W [345W] is also included in Specification ASTM A588/A588M)

The convex plate of a spherical bearing is typically machined from a piece of solid stainless steel. A stainless steel surface may also be obtained by welding a specified thickness stainless steel overlay to a carbon steel plate. The surface is then machined to the desired finish. The typical and recommended specification for solid stainless steel is ASTM A240, Type 304. Solid stainless steel plate in excess of six inches may be difficult to procure in ASTM A240, Type 304 material. If it is required that the plate be solid stainless steel, other material specifications or the option of purchasing non-domestic material should be written into the specifications. Due to unavailability of solid stainless steel or long lead times to purchase foreign or alternate stainless steel material, allowing a stainless steel welded overlay should be considered as an option. Fabricators should be consulted to determine the manufacturing feasibility of large or unusual bearings.

5.0 COST EFFECTIVE DETAILING RECOMMENDATIONS

This section draws attention to commentary and details provided in AASHTO/NSBA G9.1-2004 (2) and HSDH Volume II, Chapter 4 (1) that should be considered during the design phase. All bearings should be considered replaceable. Provisions should be made during the design stage to ensure that the superstructure and substructure can structurally and physically accommodate jacking and removal of each bearing element. Likewise, for HLMR bearings, the entire bearing, or internal elements of the bearing assembly (i.e. – pot, disc, concave and convex plates, etc), should be designed for removal and replacement.

5.1 Anchorage to Structure

5.1.1 Sole Plates

Sole plates (a plate attached to the bottom flange of a beam that distributes the reaction of the bearing to the beam) are not always required with the design of elastomeric bearings. When they are, beveled sole plates should be used to produce a level bearing surface at the top of the elastomeric bearing when the underside of the girder, under the full dead load and at the mean annual temperature, is out of level by more than 0.01 radians (1%). In addition, if the required difference in the sole plate thickness due to the bevel exceeds 0.125 in. [3.2 mm], the sole plate should be beveled. Fabricators have the resources to machine nearly any bevel requirement. If the difference in plate thickness due to the bevel is as little as 0.125 in. [3.2 mm], it may be difficult for the contractor to differentiate the proper orientation of the plate. For these cases, the fabricator shall be required to mark the plate in some way to delineate the thick and thin ends. It is suggested that the designer include the bevel information in the contract documents.

Refer to AASHTO/NSBA G9.1-2004, Sections 1.4.3 and 1.4.4 for sole plate thickness requirements (2). Beveled sole plate thickness should not be less than 0.75 in. [19.1 mm] and should be designed for bending if the width of the elastomeric bearing extends beyond the edges of the girder flange.

Sole plates are to be connected to the girders by welding or bolting. Welding is preferred because it allows for greater adjustment during installation or erection and is more economical. If bolted, it is desirable to use standard or oversized holes with a bolt and nut combination (as shown on AASHTO/NSBA G9.1-2004, Drawing Number E1.2, Option ‘A’ (2)) or tap through holes in the sole plate. If the sole plate is drilled and tapped for bolts within the imprint of the bearing components (as shown on Drawing Number E1.2, Option ‘B’), the sole plate thickness should be designed to allow for a minimum of one bolt diameter length of thread engagement per the recommendations of the Industrial Fasteners Institute (IFI) Technical Reference Guide (IFI Divisions IV/V). Standard bolt lengths are in 0.25 in. [6.4 mm] increments. When the required bolt lengths vary, threaded studs with double nuts are another option (as shown on the right side of Option ‘B’ in the AASHTO/NSBA document). Additional plate thickness is required to account for the bottom portion of the hole unable to be tapped (generally 0.313 in. to 0.438 in. [7.9 mm to 11.1 mm] depending on the diameter) and the plate thickness to remain intact (usually 0.25 in. to 0.375 in. [6.4 mm to 9.5 mm]).

Vulcanize bonding the sole plate to the elastomeric bearing is recommended when the design requires "connection" on the bearing to prevent it from "walking".

Refer to AASHTO/NSBA G9.1-2004, Sections 2.4.3 and 2.4.4 for additional HLMR bearing sole plate connection requirements and details (2). For welded connections between the girder and sole plate, weld current shall not be permitted to pass between the sole plate and masonry plate to prevent fusion of metal-to-metal contact surfaces. Expansion bearings utilize a low-coefficient of friction material sliding surface to accommodate longitudinal and transverse translations. To ensure the bearing sole plate is either centered or offset at the proper location during installation/erection, the fabricator should mark the transverse (and longitudinal if required) centerlines of the upper and lower bearing assembly components.

5.1.2 Masonry Plates and Anchor Rods

Refer to AASHTO/NSBA G9.1-2004, Sections 1.4.5 and 2.4.6 for recommended design and detailing considerations (2). In all cases, bearings are shown without a masonry plate. Should the horizontal force of the structure exceed one-fifth the minimum vertical load due to permanent loads, the bearing needs to be secured against slippage. Specifying that the bearing be shop vulcanize bonded to a masonry plate, which in turn is then anchored to the substructure, achieves this. Although field epoxy bonding the bearing to the concrete surface would satisfy this requirement, bearings should never be epoxy bonded or adhesively bonded to the concrete bearing surface unless the elastomeric bearing has been vulcanize bonded to a sole plate. If not vulcanize bonded to a sole plate, when the epoxy bond breaks, an extremely low friction surface results, which is conducive to the bearing "walking" out.

AASHTO/NSBA G9.1-2004, Detail Sheets E1.1-E4.2 and H1.4-H1.9 provide anchor rod details and connections between the bearing and the substructure (2). Anchor rods for HLMR bearings should generally be located beyond the imprint of the sole plate to facilitate installation and avoid interference with bearing components during movement and rotation. For HLMR bearings whose components are welded (as opposed to tightly fit within a machined recess) to the sole and masonry plates to allow for future bearing removal, the use of a headed "anchor" bolt, coupler and anchor rod is suggested. If the anchor assemblies are under the sole plate or other bearing component plates, clearance to install and remove the bolt must be considered. An example of this removable detail is presented in Figure 1. Heavy hex coupler nuts (DH or 2H) are compatible with ASTM A563 or A194 nuts of the same grade and are used to develop the full tensile capacity of the heavy hex bolt. If the headed "anchor" bolt expects tension, the designer must verify the entire anchor assembly and substructure are also designed for this tension.

Due to the large cost difference between heavy hex and standard grade coupler nuts, the contract documents must clearly state that the heavy hex grade is required. Otherwise, it is customary for fabricators to purchase the standard grade when the bearing resists only horizontal shear forces.

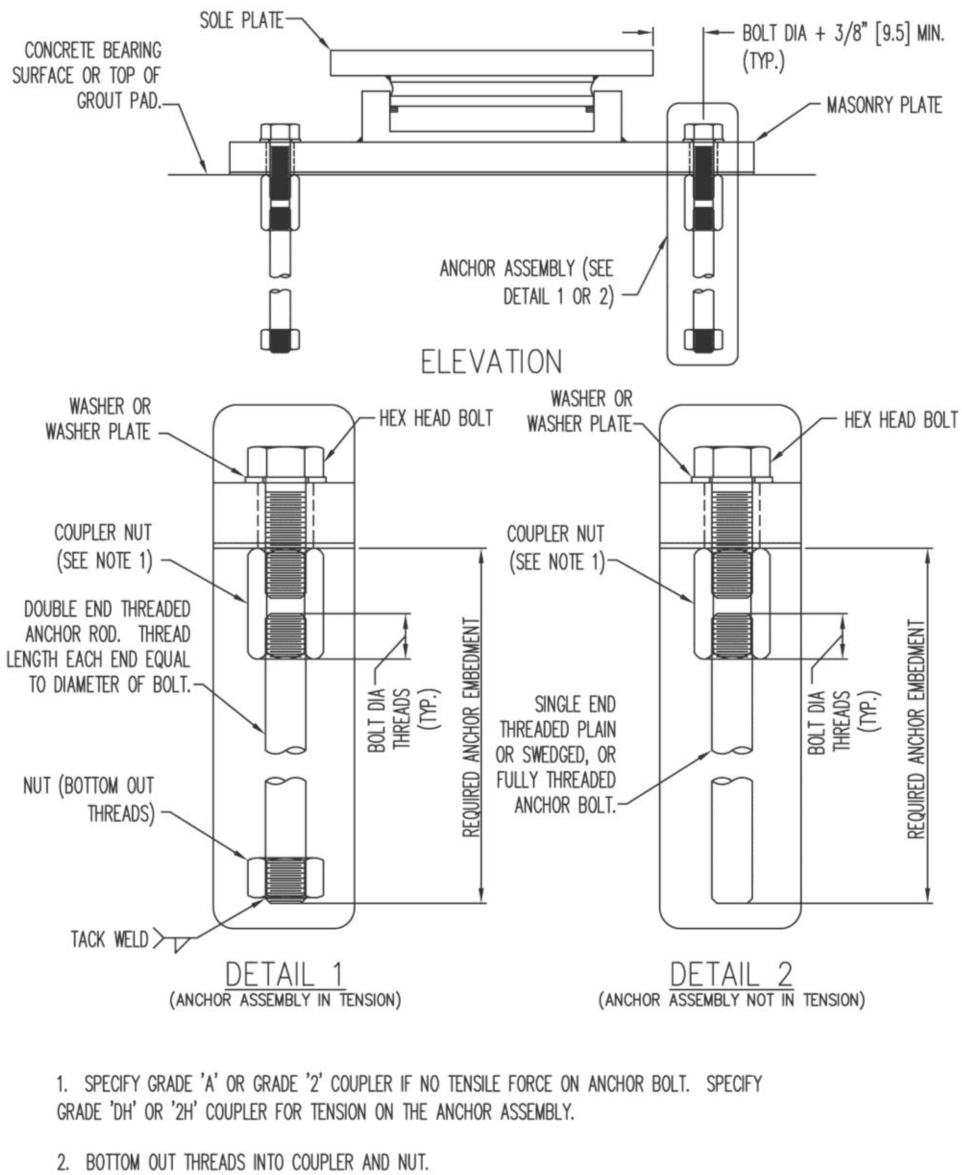


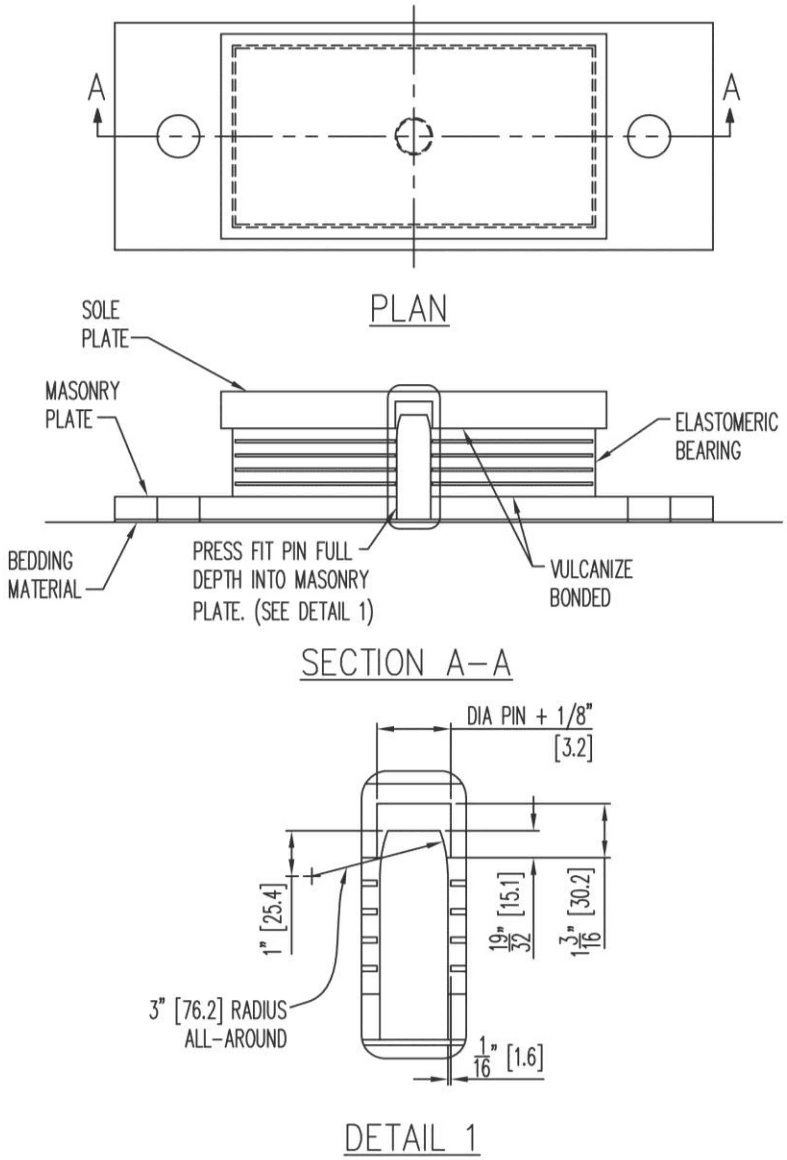
Figure 1 Sketch of a removable bearing detail.

5.2 Lateral Restraint

AASHTO/NSBA G9.1-2004, Detail Sheets (2) and HSDH Volume II, Chapter 4 (1) provide examples of approaches for laterally restraining elastomeric bearings. For expansion elastomeric bearings, if the restraint system is external to the bearing and stainless steel is required on the guiding system, there should be a corresponding low coefficient of friction material for it to mate. The stainless steel should completely cover the material in all movement extremes, and consideration must be given to vertical displacement due to construction and application of the dead loads.

Some states have incorporated a pin, internal to the bearing, to provide restraint in the horizontal direction. The anchor pin diameter is designed to resist the applied horizontal force, as should all other elements in the load path. The shear resistance of the elastomer can be included if the bearing is vulcanize bonded to the upper and lower plates. Generally, a 1.5 in. [38.1 mm] minimum anchor pin diameter is specified. As shown in Figure 2 (based on New York State Department of Transportation, Bridge Detail Sheet BD-BG2 R1) (11), the pin should be tapered at the top and should be received by an opening in the underside of the sole plate.

Longitudinally guided expansion bearings on structures with a horizontally curved alignment and structures with non-parallel girders should be guided in the same direction with respect to the centerline of the substructure where the line of bearings is installed. Guiding at differing directions will cause the bearings to bind. This effect is magnified by increased amounts of required movement. It is generally accepted for design purposes that the direction of movement for structures on a horizontally curved alignment is along the chord from the fixed point to the expansion point. In rare occasions, the structure can be forced to move in any direction the designer chooses; however, the resulting forces must be accounted for in the design of the bearing and substructure.



1. THE DIAMETER OF THE PIN SHALL BE CHECKED FOR SHEAR DUE TO HORIZONTAL LOADS. THE MINIMUM PIN DIAMETER SHALL BE 1.5" [38.1 mm].

2. TOTAL RESISTANCE = ELASTOMER RESISTANCE + ANCHOR PIN RESISTANCE.

Figure 2 Sketch of a lateral restraint detail.

5.3 Uplift Restraint

Uplift due to service loads should be avoided with strategic placement of additional dead load. If uplift due to service loads cannot be averted, special bearings, not addressed in the AASHTO LRFD 7th Edition (2014) or this module, are required. Uplift forces due to construction loads should be offset either by revising the deck pouring sequence, or restrained by means other than the bearing. The uplift restraint system for elastomeric bearings should be external to the bearing. This can be accomplished through the use of tie-down anchor rods from the superstructure to the substructure. HSDH Volume II, Chapter 4 provides uplift restraint details for elastomeric bearings (1). Relatively low uplift forces due to construction loads or seismic events can economically and feasibly be built into an HLMR bearing. For HLMR bearings, methods similar to those used with elastomeric bearings can be applied, or the bearing can be designed with attachments.

5.4 Miscellaneous

If a PTFE sliding element is required for an elastomeric bearing and the PTFE is the same plan dimensions as the elastomeric bearing, theoretically, a load plate between the PTFE and the elastomeric bearing is not required. The code requires that a load plate be used when the hardness of the elastomer is less than 90 durometer. If the design load plate for this situation is thin (0.375 in. [9.5 mm] or less), it becomes impractical to apply a protective coating to the plate edges and depending on the size of the plate, using the galvanization process could significantly warp the plate. Consideration should be given to using stainless steel or uncoated weathering steel for this plate.

Because of the importance of keeping sliding surfaces free of debris and damage, and the complexity of HLMR bearings with sliding surfaces, it is recommended that the protective coating system be applied in its entirety in the shop prior to field installation. Minimal field protective coating application is required and generally limited to faying surfaces that were shop primed only or bare.

The AASHTO LRFD Bridge Construction Specifications, 3rd Edition, (2010) Article 18.2.6, prohibits welding on exterior plates of elastomeric bearings unless 1.5 in. [38.1 mm] of steel exists between the elastomer and the weld, and also restricts the temperature of the steel adjacent to the elastomer to 400 °F [204.4 °C] while welding on the exterior plates. During the molding process, the core temperature of the elastomer reaches approximately 240 °F [115.6 °C] and is held there for roughly 60 minutes. Therefore, for practical purposes the temperature of the steel adjacent to the elastomer should never exceed 200 °F [93.3 °C] rather than the 400 °F [204.4 °C] limitation set by the AASHTO LRFD Bridge Construction Specifications. The temperature of the steel adjacent to the elastomer should be monitored by the use of pyrometric sticks or other suitable means.

AASHTO LRFD 7th Edition (2014) requires that woven PTFE be attached to the metallic substrate by mechanical interlocking. The term “mechanical interlocking” refers to woven PTFE fabric without a reinforced interwoven backing being bonded to the metallic substrate, which has been machined to a grid-like surface. The code offers no guidance on the pattern or depth of the grid or other machining requirements. The purpose of the “mechanical interlocking” is to control creep in the same manner that recessing sheet PTFE controls creep and cold flow. Recessing woven PTFE serves no purpose. Woven PTFE is more commonly fabricated with strands of fiber reinforcing agents (e.g. Kevlar) interlocked into the strands of the PTFE to control creep. The fiber reinforcing serves as a means to mechanically interlock the PTFE to the metallic substrate. The strands should not come to the surface, nor should the epoxy adhesive used to bond the fabric to the steel.

When HLMR bearings are designed to accommodate translation with a sliding surface, the bearing manufacturer must assume that the girder has been stiffened sufficiently to resist bending and local buckling as the girder transitions through the full range of movement.

6.0 INSPECTION AND MAINTENANCE

Elastomeric bearings and HLMR bearings are relatively maintenance free. However, all bearings 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.

Elastomeric bearings should be checked for over-translation. 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, the bearing should be considered 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 off of the substructure support, lateral translation of up to half the thickness of the pad should not be a reason for concern.

Elastomeric bearings should be checked for evidence that the bearing has "walked out" from under the beam or girder. Laminated elastomeric bearings should be checked for any splitting or tearing. 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 reinforcing becomes subjected to an excessively corrosive environment. Check the area where the pad is bonded to the sole and masonry plates, if applicable. 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 is near semicircular which may lead to splitting) and/or rolling of the bearing on the bridge seat or beam.

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 the PTFE surface. The stainless steel should be examined for scratching, weld spatter, grout, paint, and any other type of debris, which 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.

Pot bearings should be checked for any "leakage" of elastomer from within the pot.
The elastomeric element of disc bearings should be checked for splitting, cracking, and excessive bulging.

Other elements (fasteners, anchors, bearing support, welds, etc.) of elastomeric and HLMR bearings should be examined as outlined in the governing bridge inspection manual.

7.0 REFERENCES

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