American
Iron and Steel
Institute

NATIONAL STEEL BRIDGE ALLIANCE

STEEL BRIDGE BEARING SELECTION AND DESIGN GUIDE

Vol. II, Chapter. 4
HIGWAY STRUCTURES
DESIGN HANDBOOK

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A = Plan area of elastomeric bearing (mm^2).

B = Length of pad if rotation is about its transverse axis, or width of pad if rotation is about its longitudinal axis (mm). Note that L or W were used for this variable in the 1994 AASHTO LRFD Specifications. The nomenclature was changed in this document to improve the clarity of its meaning.

b_{ring} = Width of brass sealing ring in pot bearing (mm).

D = Diameter of the projection of the loaded surface of a spherical bearing in the horizontal plane (mm).

= Diameter of circular elastomeric bearing (mm).

D_p = Internal pot diameter in pot bearing (mm).

d = Distance between neutral axis of girder and bearing axis (mm). Note that this definition is an addition to that used in the 1994 AASHTO LRFD Specifications.

E_s = Young's modulus for steel (MPa).

E_c = Effective modulus in compression of elastomeric bearing (MPa).

F = Friction force (kN).

F_y = Yield strength of the least strong steel at the contact surface (MPa).

G = Shear Modulus of the elastomer (MPa).

H_T = Total service lateral load on the bearing or restraint (kN).

H_u = Factored lateral load on the bearing or restraint (kN).

h_{ri} = Thickness of i^{th} elastomeric layer in elastomeric bearing (mm).

h_{rmax} = Thickness of thickest elastomeric layer in elastomeric bearing (mm).

h_{rt} = Total elastomer thickness in an elastomeric bearing (mm).

h_s = Thickness of steel laminate in steel-laminated elastomeric bearing (mm).

I = Moment of inertia (mm^4).

L = Length of a rectangular elastomeric bearing (parallel to longitudinal bridge axis) (mm).

M = Moment (kN-m).

M_{max} = Maximum service moment (kN-m).

M_u = Factored bending moment (kN-m).

M_x = Maximum moment about transverse axis (kN-m).

N = Normal force, perpendicular to surface (kN).

n = Number of elastomer layers.

P_D = Service compressive load due to dead load (kN).

P_L = Service compressive load due to live load (kN).

P_r = Factored compressive resistance (kN).

P_T = Service compressive load due to total load (kN).

P_u = Factored compressive load (kN).

R = Radius of a curved sliding surface (mm).

S = Shape factor of thickest elastomer layer of an elastomeric bearing

= $\frac{\text{Plan Area}}{\text{Area of Perimeter Free to Bulge}}$

= $\frac{LW}{2h_{rmax}\,(L+W)}$ for rectangular bearings without holes

= $\frac{D}{4h_{rmax}}$ for circular bearings without holes

t_r = Thickness of elastomeric pad in pot bearing (mm).

t_{ring} = Thickness of brass sealing ring in pot bearing (mm).

t_w = Pot wall thickness (mm).

t_{pist} = Piston thickness (pot bearing) (mm).

t_{rim} = Height of piston rim in pot bearing (mm).

W = Width of a rectangular elastomeric bearing
(perpendicular to longitudinal bridge axis) (mm).

α = Coefficient of thermal expansion.

β = Effective angle of applied load in curved sliding bearings.

= $\tan^{-1}(H_u/P_D)$

Δ_O = Maximum service horizontal displacement of the bridge deck (mm).

Δ_s = Maximum service shear translation (mm).

Δ_u = Maximum factored shear deformation of the elastomer (mm).

$(\Delta F)_{TH}$ = Fatigue limit stress from AASHTO LRFD Specifications Table 6.6.1.2.5-3 (MPa).

ΔT = Change in temperature (degrees C).

θ = Service rotation due to total load about the transverse or longitudinal axis (RAD).

θ_D = Maximum service rotation due to dead load (RAD).

θ_L = Maximum service rotation due to live load (RAD).

θ_{max} = Maximum service rotation about any axis (RAD).

θ_T = Maximum service rotation due to total load (RAD).

θ_x = Service rotation due to total load about transverse axis (RAD).

θ_z = Service rotation due to total load about longitudinal axis (RAD).

θ_u = Factored, or design, rotation (RAD).

μ = Coefficient of friction.

σ_D = Service average compressive stress due to dead load (MPa).

σ_L = Service average compressive stress due to live load (MPa).

σ_{PTFE} = Maximum permissible stress on PTFE (MPa).

σ_T = Service average compressive stress due to total load (MPa). Note that this variable is identified as σ_s in the 1994 AASHTO LRFD Specifications.

σ_U = Factored average compressive stress (MPa).

ϕ = Subtended angle for curved sliding bearings.

ϕ_t = Resistance factor for tension (=0.9).

Part I

STEEL BRIDGE BEARING SELECTION GUIDE

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SELECTION OF BEARINGS FOR STEEL BRIDGES

This Selection Guide facilitates the process of selecting cost-effective and appropriate bearing systems for steel girder bridges. Its intended use is to provide a quick reference to assist with the planning stages of construction. The selection process is divided into three steps: Definition of Design Requirements, Evaluation of Bearing Types and Bearing Selection and Design. A more detailed analysis of bearing design is provided in the *Steel Bridge Bearing Design Guide and Commentary* in Part II of this document.

Step 1. Definition of Design Requirements

Define the direction and magnitude of the applied loads, translations and rotations using the AASHTO LRFD Bridge Design Specifications. It is important at this stage to ensure that

- the bridge and bearings have been conceived as a consistent system. In general, vertical displacements are prevented, rotations are allowed to occur as freely as possible and horizontal displacements may be either accommodated or prevented.
- the loads are being distributed among the bearings in accordance with the superstructure analysis.
- and that no inconsistent demands are being made. For instance, only possible combinations of load and movement should be addressed.

Step 2. Evaluation of Bearing Types

After defining the design requirements refer to Table I-A to identify the bearing types which satisfy the load, translation and rotational requirements for the project. This table is organized in ascending order based on the initial and maintenance costs associated with each type of bearing. Read down the table to identify a bearing type which meets the design requirements at the lowest overall cost. It should be noted that the limits are not absolute, but are practical limits which approximate the most economical application of each bearing type. Ease of access for inspection, maintenance and possible replacement must be considered in this step.

Figures I-1, I-2 and I-3 are to be used for preliminary selection of the most common steel bridge bearing types or systems for the indicated design parameters. These diagrams were compiled using components that would result in the lowest initial cost and maintenance requirements for the application. Figure I-1 gives the first estimate of the system for bearings with minimal rotation (maximum rotation $\leq$ 0.005 radians). Figure I-2 gives the first estimate for bearings with moderate rotation ($\leq$ 0.015 radians), and Figure I-3 gives a first estimate for bearings with large rotations.

Consideration of two or more possible alternatives may result from this step if the given set of design requirements plot near the limits of a particular region in the figures. The relative cost ratings in Table I-A are approximate and are intended to help eliminate bearing types that are likely to be much more expensive than others.

Step 3. Bearing Selection and Design

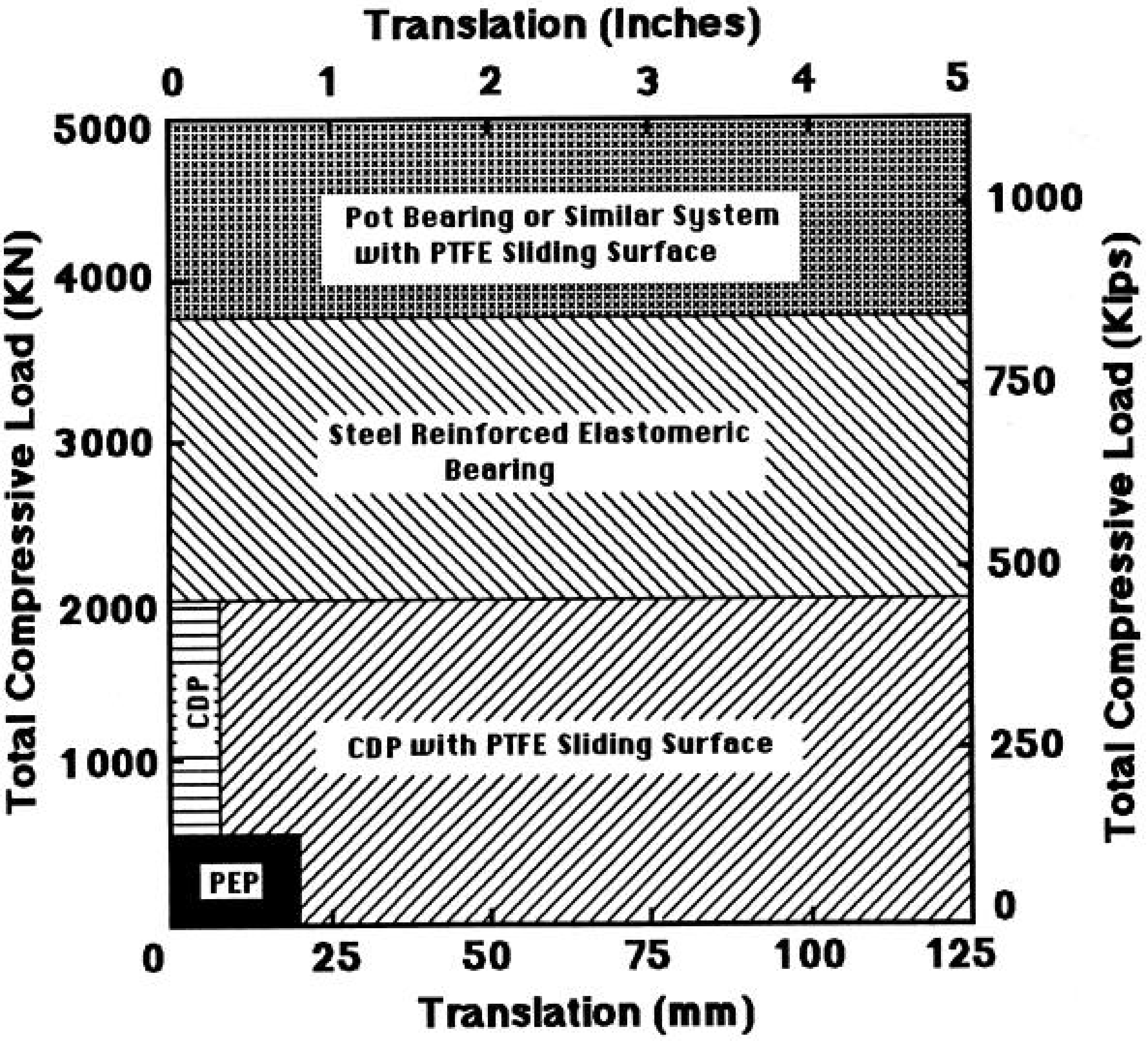
The final step in the selection process consists of completing a design of the bearing in accordance with the AASHTO LRFD Bridge Design Specifications. The resulting design will provide the geometry and other pertinent specifications for the bearing. It is likely that one or more of the preliminary selections will be eliminated in this step because of an undesirable attribute. The final selection should be the bearing system with the lowest combination of first cost and maintenance costs as indicated in Table I-A. If no bearing appears suitable, the selection process must be repeated with different constraints. The most likely cause of the elimination of all possible bearing types is that a mutually exclusive set of design criteria was established. In this case the basis of the requirements should be reviewed and, if necessary, the overall system of superstructure and bearings should be re-evaluated before repeating the bearing selection process. The *Steel Bridge Bearing Design Guide and Commentary* summarizes these design requirements and provides software to aid in the design of a steel reinforced elastomeric bearing.

Bearing Type	Load		Translation		Rotation	Costs	
	Min. (kN)	Max. (kN)	Min. (mm)	Max. (mm)	Limit (Rad.)	Initial	Maintenance
Elastomeric Pads							
Plain (PEP)	0	450	0	15	0.01	Low	Low
Cotton Duck (CDP)	0	1400	0	5	0.003	Low	Low
Fiberglass (FGP)	0	600	0	25	0.015	Low	Low
Steel Reinforced Elastomeric Bearing	225	3500	0	100	0.04	Low	Low
Flat PTFE Slider (Polytetrafluorethylene)	0	>10 000	25	>100	0	Low	Moderate
Curved Lubricated Bronze	0	7000	0	0	>0.04	Moderate	Moderate
Pot Bearing	1200	10 000	0	0	0.02	Moderate	High
Pin Bearing	1200	4500	0	0	>0.04	Moderate	High
Rocker Bearing	0	1800	0	100	>0.04	Moderate	High
Single Roller	0	450	25	>100	>0.04	Moderate	High
Curved PTFE	1200	7000	0	0	>0.04	High	Moderate
Multiple Rollers	500	10 000	100	>100	>0.04	High	High

Note: 1 kip = 4.45 kN and 1 in. = 25.4 mm

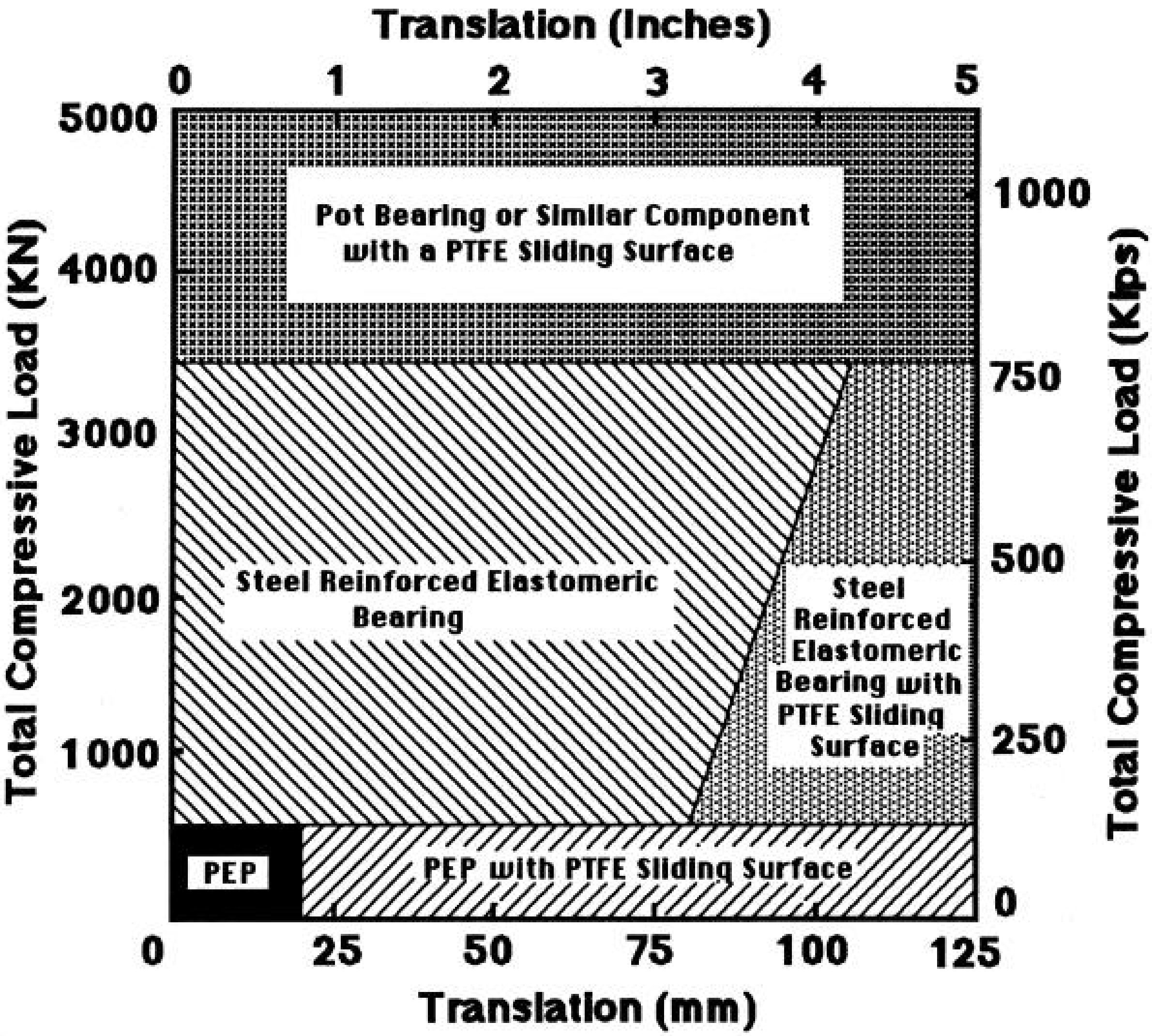
Table I-A: Summary of Bearing Capabilities

Figure I-1: Preliminary Bearing Selection Diagram for Minimal Design Rotation (Rotation ≤ 0.005 radians)



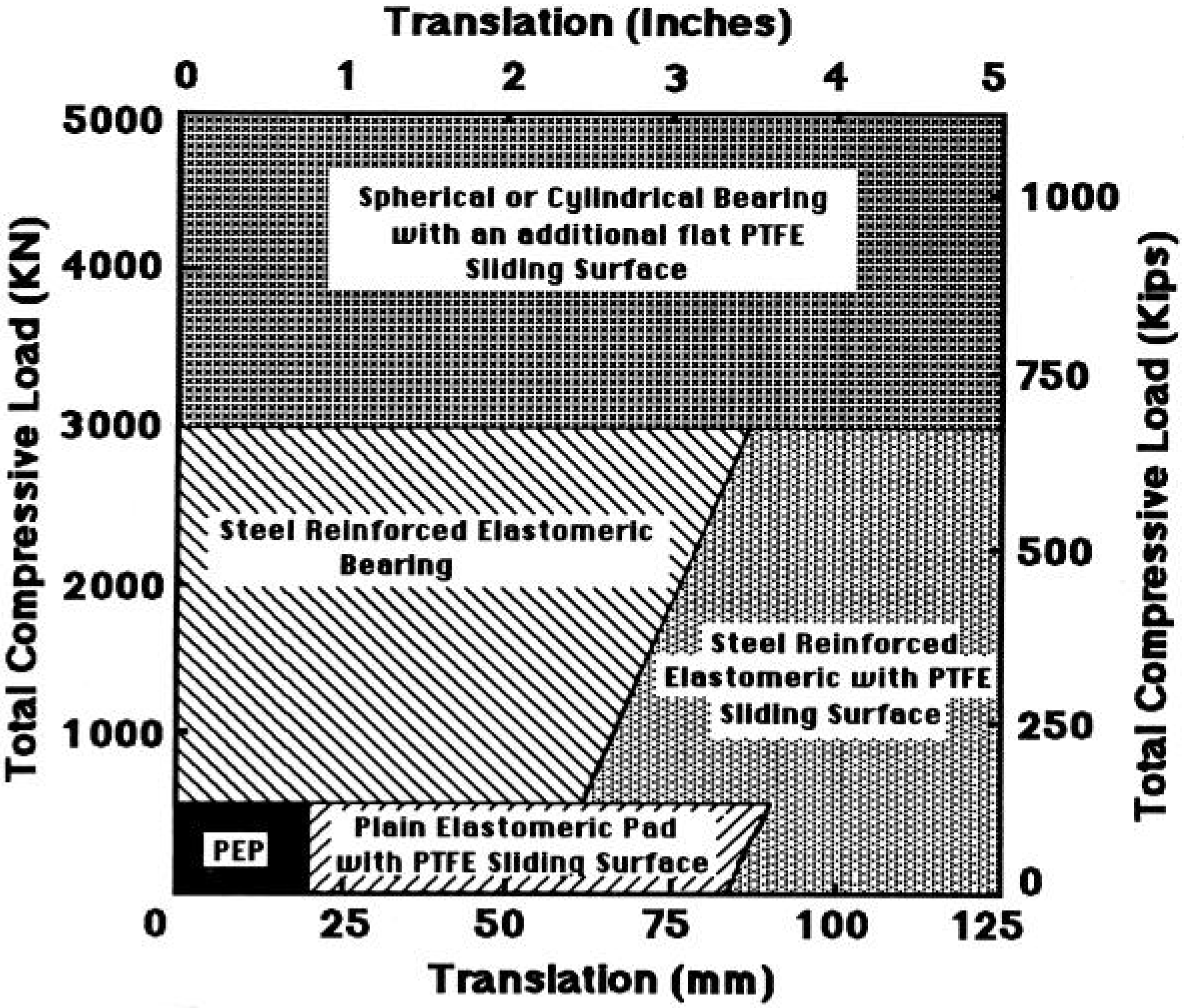
Note that the limit lines which define the regions in this diagram are only approximate. The limits could move 5% in either direction. As a result, the user should examine both options when the application falls near one of these limit lines.

Figure I-2: Preliminary Bearing Selection Diagram for Moderate Design Rotation (Rotation ≤ 0.015 radians)



Note that the limit lines which define the regions in this diagram are only approximate. The limits could move 5% in either direction. As a result, the user should examine both options when the application falls near one of these limit lines.

Figure I-3: Preliminary Bearing Selection Diagram for Large Design Rotation (Rotation > 0.015 radians)



Note that the limit lines which define the regions in this diagram are only approximate. The limits could move 5% in either direction. As a result, the user should examine both options when the application falls near one of these limit lines.

Part II

STEEL BRIDGE BEARING DESIGN GUIDE AND COMMENTARY

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Section 1
General Design Requirements

Bearings assure the functionality of a bridge by allowing translation and rotation to occur while supporting the vertical loads. However, the designer should first consider the use of integral abutments as recommended in Volume II, Chapter 5 of the *Highway Structures Design Handbook*.

MOVEMENTS

Consideration of movement is important for bearing design. Movements include both translations and rotations. The sources of movement include bridge skew and curvature effects, initial camber or curvature, construction loads, misalignment or construction tolerances, settlement of supports, thermal effects, and traffic loading.

Effect of Bridge Skew and Curvature

Skewed bridges move both longitudinally and transversely. The transverse movement becomes significant on bridges with skew angles greater than 20 degrees.

Curved bridges move both radially and tangentially. These complex movements are predominant in curved bridges with small radii and with expansion lengths that are longer than one half the radius of curvature. Further, the relative stiffnesses of the substructure and superstructure affect these movements.

Effect of Camber and Construction Procedures

Initial camber of bridge girders and out of level support surfaces induce bearing rotation. Initial camber may cause a large initial rotation on the bearing, but this rotation may grow smaller as the construction of the bridge progresses. Rotation due to camber and the initial construction tolerances is sometimes the largest component of the total bearing rotation. Both the initial rotation and its short duration should be considered. If the bearing is installed level at an intermediate stage of construction, deflections and rotations due to the weight of the deck slab and construction equipment must be added to the effects of live load and temperature. Construction loads and movements due to tolerances should be included. The direction of loads, movements and rotations must also be considered, since it is inappropriate to simply add the absolute magnitudes of these design requirements. Rational design requires that the engineer consider the worst possible combination of conditions without designing for unrealistic or impossible combinations or conditions. In many cases it may be economical to install the bearing with an initial offset, or to adjust the position of the bearing after construction has started, in order to minimize the adverse effect of these temporary initial conditions. Combinations of load and movement which are not possible should not be considered.

Thermal Effects

Thermal translations, D_O, are estimated by

$$\Delta_O = \alpha \, L \, \Delta T \qquad \text{(Eq. 1-1)}$$

where L is the expansion length, a is the coefficient of thermal expansion, and DT is the change in the average bridge temperature from the installation temperature. A change in the average bridge temperature causes a thermal translation. A change in the temperature gradient induces bending and deflections(1). The design temperature changes are specified by the AASHTO LRFD Specifications(10). Maximum and minimum bridge temperatures are defined depending upon whether the location is viewed as a cold or moderate climate. The installation temperature or an expected range of installation temperatures for the bridge girders are estimated. The change in average bridge temperature, DT, between the installation temperature and the design extreme temperatures is used to compute the positive and negative movements in Eq. 1-1. It should be further noted that a given temperature change causes thermal movement in all directions. This means that a short, wide bridge may experience greater transverse movement than longitudinal movement.

Traffic Effects

Movements caused by traffic loading are not yet a formalized part of the design of bridge bearings, but they are receiving increased recognition. Traffic causes girder rotations, and because the neutral axis is typically high in the girder these rotations lead to displacements at the bottom flange. These movements and rotations can be estimated from a dynamic analysis of the bridge under traffic loading. There is evidence(4) to suggest that these traffic-induced bearing displacements cause significant wear to polytetrafluorethylene (PTFE) sliding bearings.

LOADS AND RESTRAINT

Restraint forces occur when any part of a movement is prevented. Forces due to direct loads include the dead load of the bridge and loads due to traffic, earthquakes, water and wind. Temporary loads due to construction equipment and staging also occur. It should be noted that the majority of the direct design loads are reactions of the bridge superstructure on the bearing, and they can be estimated from the structural analysis. The applicable AASHTO load combinations must be considered. However, care must be taken in the interpretation of these combinations, since impossible load combinations are sometimes mistakenly applied in bearing design. For example, large lateral loads due to earthquake loading can occur only when the dead load is present, and therefore load combinations which include extremely large lateral loads and very small vertical loads are inappropriate. Such impossible load combinations can lead to inappropriate bearing types, and result in a costly bearing which performs poorly.

SERVICEABILITY, MAINTENANCE AND PROTECTION REQUIREMENTS

Bearings are typically located in an area which collects large amounts of dirt and moisture and promotes problems of corrosion and deterioration. As a result, bearings should be designed and installed to have the maximum possible protection against the environment and to allow easy access for inspection.

The service demands on bridge bearings are very severe and result in a service life that is typically shorter than that of other bridge elements. Therefore, allowances for bearing replacement should be part of the design process. Lifting locations should be provided to facilitate removal and re-installation of bearings without damaging the structure. In most cases, no additional hardware is needed for this purpose. The primary requirements are to allow space suitable for lifting jacks during the original design and to employ details which permit quick removal and replacement of the bearing.

Section 2
Special Design Requirements for Different Bearing Types

Once the design loads, translations and rotations are determined, the bearing type must be selected and designed. Some applications will require combinations of more than one bearing component. For example, elastomeric bearings are often combined with PTFE sliding surfaces to accommodate very large translations. These individual components are described in detail in this Section. It should be noted that the design requirements for bridge bearings are frequently performed at service limit states, since most bearing failures are serviceability failures.

An overview of the behavior, a summary of the design requirements and example designs are included for each bearing component. It should be noted that mechanical bearings and disk bearings are not included in this Section. Mechanical bearings are excluded because they are an older system with relatively high first cost and lifetime maintenance requirements. As a result, their use in steel bridges is rare. Disc bearings are excluded because they were a patented item produced by one manufacturer.

Design examples that illustrate some of the concepts discussed are included in this section. Table II-A summarizes the major design requirements used in these examples.

	Elastomeric Bearing Pads	**Steel Reinforced Elastomeric Bearing**	**Pot Bearing**	**PTFE Sliding Surface**
Live Load	110 kN	1200 kN	1110 kN	1200 kN
Dead Load	200 kN	2400 kN	2670 kN	2400 kN
Longitudinal Translation	±6 mm	±100 mm	Cannot Tolerate Translation	±200 mm
Rotation about Transverse Axis	Negligible	0.015 radians	0.02 radians	0.005 radians accommodated by elastomeric bearing
Longitudinal Force			330 kN	

Table II-A: Summary of Design Examples

ELASTOMERIC BEARING PADS AND STEEL REINFORCED ELASTOMERIC BEARINGS

Elastomers are used in both elastomeric bearing pads and steel reinforced elastomeric bearings(10). The behavior of both pads and bearings is influenced by the shape factor, *S*, where

$$S = \frac{\text{Plan Area}}{\text{Area of Perimeter Free to Bulge}} \qquad \text{(Eq. 2-1)}$$

Elastomeric bearing pads and steel reinforced elastomeric bearings have fundamentally different behaviors, and therefore they are discussed separately. It is usually desirable to orient elastomeric pads and bearings so that the long side is parallel to the axis of rotation, since this facilitates the accommodation of rotation.

Elastomeric bearing pads and steel reinforced elastomeric bearings have many desirable attributes. They are usually a low cost option, and they require minimal maintenance. Further, these components are relatively forgiving if subjected to loads, movements or rotations which are slightly larger than those considered in their design. This is not to encourage the engineer to underdesign elastomeric pads and bearings, but it simply notes that extreme events which have a low probability of occurrence will have far less serious consequences with these elastomeric components than with other bearing systems.

Elastomer

Both natural rubber and neoprene are used in the construction of bridge bearings. The differences between the two are usually not very significant. Neoprene has greater resistance than natural rubber to ozone and a wide range of chemicals, and so it is more suitable for some harsh chemical environments. However, natural rubber generally stiffens less than neoprene at low temperatures.

All elastomers are visco-elastic, nonlinear materials and therefore their properties vary with strain level, rate of loading and temperature. Bearing manufacturers evaluate the materials on the basis of Shore A Durometer hardness, but this parameter is not a good indicator of shear modulus, G. Shore A Durometer hardnesses of 60 ± 5 are common, and they lead to shear modulus values in the range of 0.55 to 1.25 MPa (80 to 180 psi). The shear stiffness of the bearing is its most important property since it affects the forces transmitted between the superstructure and substructure. The effect of this shear stiffness is explained in greater detail in the discussion for steel reinforced elastomeric bearings.

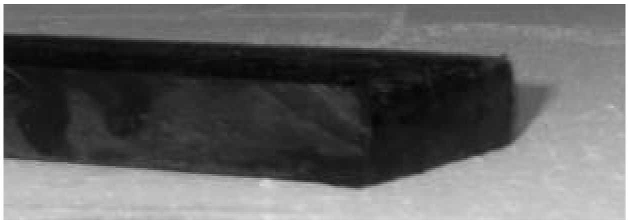
Elastomers are flexible under shear and uniaxial deformation, but they are very stiff against volume changes. This feature makes possible the design of a bearing that is stiff in compression but flexible in shear.

Elastomers stiffen at low temperatures(5,6). The low temperature stiffening effect is very sensitive to elastomer compound, and the increase in shear resistance can be controlled by selection of an elastomer compound which is appropriate for the climatic conditions.

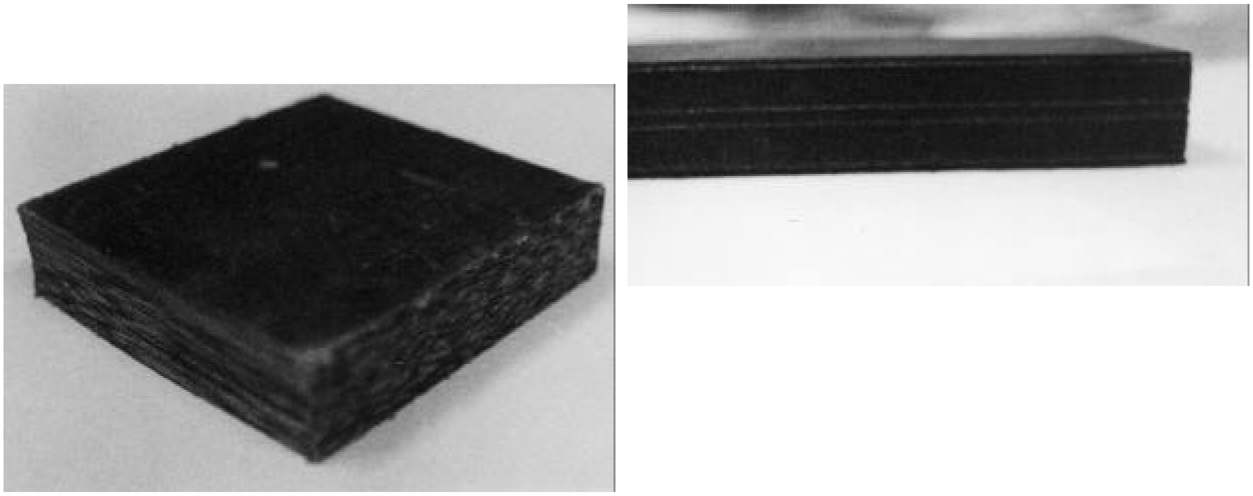
Elastomeric Bearing Pads

Elastomeric bearing pads include plain elastomeric pads (PEP) as shown in Figure II-2.1a, cotton duck reinforced pads (CDP) such as shown in Figure II-2.1b, and layered fiberglass reinforced bearing pads (FGP) as shown in Figure II-2.1c. There is considerable variation between pad types. Elastomeric bearing pads can support modest gravity loads but they can only accommodate limited rotation or translation. Hence, they are best suited for bridges with expansion lengths less than approximately 40 m (130 ft).

Plain elastomeric pads rely on friction at their top and bottom surfaces to restrain bulging due to the Poisson effect. Friction is unreliable and local slip results in a larger elastomer strain than that which occurs in reinforced elastomeric pads and bearings. The increased elastomer strain limits the load capacity of the PEP. The allowable stress depends upon the shape factor of the elastomeric bearing pad, and so PEP must be relatively thin if they are to carry the maximum allowable compressive load. Thin elastomeric bearing pads can tolerate only small translations and rotations. PEP occasionally "walk" from under their loads. This walking is partly caused by vibration and movement in the bridge, but recent research(7) has also attributed it to the reduced friction caused by migration of anti-ozonant waxes to the surface in natural rubber elastomer.



a) Plain Elastomeric Pad



b) Cotton Duck Reinforced Pad **c) Fiberglass Reinforced Pad**

Figure II-2.1: Typical Elastomeric Bearing Pads

Cotton duck reinforced pads as shown in Figure II-2.1b have very thin elastomer layers [less than 0.4 mm ($\frac{1}{60}$ in.)]. They are stiff and strong in compression so they have much larger compressive load capacities than PEP, but they have very little rotational or translational capacity. CDP are sometimes used with a PTFE slider to accommodate horizontal translation.

The behavior of elastomeric pads reinforced with discrete layers of fiberglass (FGP) as shown in Figure II-2.1c is closer to that of steel reinforced elastomeric bearings than to that of other elastomeric bearing pads. The fiberglass, however, is weaker, more flexible, and bonds less well to the elastomer than does the steel reinforcement. Sudden failure occurs if the reinforcement ruptures. These factors limit the compressive load capacity of the fiberglass reinforced bearing pad. FGP accommodate larger gravity load than a PEP of identical geometry, but their load capacity may be smaller than that achieved with CDP. FGP can accommodate modest translations and rotations.

Design Requirements

The capabilities of elastomeric bearing pads are limited and the design procedure is simple. The primary design limit is the compressive stress on the bearing pad. PEP have limited compressive load capacity because bulging is restrained only by friction at the load interface and local slip will result in larger elastomer strain. As a result, the average total compressive stress, s_T under service loading for a PEP must be limited to

$$\sigma_T \leq 0.55\, G\, S \leq 5.5 \text{ MPa (800 psi)} \qquad \text{(Eq.2-2)}$$

CDP exhibit very small elastomer strains under compressive load and s_T is limited to

$$\sigma_T \leq 10.5 \text{ MPa (1500 psi)} \qquad \text{(Eq. 2-3)}$$

In a FGP, the strains of the elastomer are considerably smaller than in a PEP with the same nominal compressive stress and shape factor. For FGP, s_T must be limited to

$$\sigma_T \leq 1.00 \text{ G S} \leq 5.5 \text{ MPa (800 psi)} \qquad \text{(Eq.2-4)}$$

Translations and rotations are also limiting factors in the design of elastomeric pads. CDP have negligible translation capacity, and therefore due to shear limitations the total elastomer thickness, h_{rt} must satisfy

$$h_{rt} \geq 10\, \Delta_s \qquad \text{(Eq. 2-5a)}$$

where D_s is the maximum translation under service conditions.

PEP and FGP accommodate modest translations the magnitudes of which are controlled by the maximum shear strain in the elastomer. Therefore, to prevent separation of the edge of the elastomeric bearing pad from the girder, maximum service translation, D_s, in PEP and FGP is limited by ensuring that h_{rt} satisfies

$$h_{rt} \geq 2\, \Delta_s \qquad \text{(Eq. 2-5b)}$$

Rotation in elastomeric pads must also be considered. The AASHTO LRFD Specifications contain requirements intended to prevent net uplift. Rectangular pads must satisfy

$$\sigma_T \;\geq\; 0.5 \text{ G S}\left(\frac{B}{h_{rt}}\right)^2 \theta \qquad \text{(Eq. 2-6a)}$$

where B is the horizontal plan dimension normal to the axis of rotation of the bearing and q is the rotation angle about that axis. This condition must be satisfied separately about the longitudinal and transverse axes of the bearing. For circular bearing pads, the limit is very similar except that

$$\sigma_T \;\geq\; 0.375 \text{ G S}\left(\frac{D}{h_{rt}}\right)^2 \theta_{\max} \qquad \text{(Eq. 2-6b)}$$

where θ_{max} is the maximum rotation about any axis calculated using the vector sum of the components and *D* is the diameter of the pad. In these calculations, *S* is taken as the shape factor for PEP and FGP. CDP have negligible rotation capacity, and therefore these equations may be used but future Interims to the AASHTO LRFD Specifications are likely to require that *S* be taken as 100, since this better reflects the high rotational stiffness of CDP.

In order to prevent buckling under compressive load, the total thickness of pad is limited by the stability requirements of the AASHTO LRFD Specifications to the smaller of *L*/3, *W*/3, or *D*/4.

Design Example

Elastomeric bearing pads are primarily suitable for relatively short span steel bridge with modest translations and design loads. A design example is presented to illustrate the application of the above design requirements.

Dead Load	200 kN (45 kips)
Live Load	110 kN (25 kips)
Longitudinal Translation	6 mm (0.25 in.)
Rotation	Negligible Rotation

There are no design translations in the transverse direction. The steel girder has a bottom flange width of 250 mm (10 in.). The bearing is to extend no closer than 25 mm (1 in.) to the edge of the flange.

Examination of Figure I-1 of the *Steel Bridge Bearing Selection Guide* contained in Part I of this report illustrates that PEP or CDP are logical alternatives. CDP do not easily accommodate translation and rotation. The design translations are relatively small, but a minimum thickness of 63 mm (2.5 in.) would be required for such a pad. This thickness is possible, but it is likely to be impractical and a CDP is regarded as less suitable for the given application than is an PEP or a FGP.

To satisfy the shear strain limitations, the design translation requires a minimum thickness of 12 mm (0.5 in.) for a PEP or FGP. A PEP is selected here. The 250 mm (10 in.) flange width imposes an upper limit of 200 mm (8 in.) on the width of the bearing, so to satisfy limit of Eq. 2-2, the length, *L*, of the bearing must be at least

$$\mathrm{L} > \frac{310\ \mathrm{kN\ x\ 1000}}{5.5\ \mathrm{MPa\ x\ 200\ mm}} = 282\ \mathrm{mm}$$

A typical elastomer with hardness in the range of 65 Shore A durometer and a shear modulus in the range of 0.83 to 1.10 MPa (120 to 160 psi) is proposed. Trial dimensions of 200 x 300 mm are selected, so the shape factor, *S*, of the unreinforced pad is

$$\mathrm{S} = \frac{\mathrm{L\ W}}{2\ \mathrm{h_{rt}}\left(\mathrm{L} + \mathrm{W}\right)} = \frac{200\ \mathrm{x}\ 300}{2\ \mathrm{x}\ 12\ \mathrm{x}\left(200 + 300\right)} = 5.00$$

This shape factor is relatively low and it severely limits the stress level on the PEP. Eq. 2-2 requires

$$\sigma_T \leq 0.55GS = 0.55\ (0.83)\ 5.0 = 2.28\ \mathrm{MPa}$$

This stress limit results in an increased length requirement. That is,

$$L > \frac{310 \text{ kN x } 1000}{2.28 \text{ MPa x } 200 \text{ mm}} = 680 \text{ mm}$$

and the increased length results in an increased shape factor. After several iterations, it is clear that a 200 x 575 x 12 mm (8 x 23 x 0.5 in.) pad will produce a shape factor of 6.18 and a bearing capacity of 324 kN (73 kips). The geometry of the pad clearly satisfies the $W/3$ stability limit, and this pad would satisfy all design requirements.

This elastomeric bearing pad is quite large and illustrates the severe limitations of PEP. A somewhat smaller bearing pad could be achieved if a FGP were used.

Summary

Elastomeric bearing pads are restricted for practical reasons to lighter bearing loads, in the order of 700 kN (160 kips) or less. CDP may support somewhat larger loads than PEP or FGP. Translations of less than 25 mm (1 in.) and rotations of a degree or less are possible with FGP. Smaller translations and rotations are possible with PEP. No significant movements are practical with CDP. Elastomeric bearing pads are a low cost method of supporting small or moderate compressive loads with little or no translation or rotation.

Steel Reinforced Elastomeric Bearings

Steel reinforced elastomeric bearings are often categorized with elastomeric bearing pads, but the steel reinforcement makes their behavior quite different(8,9). Steel reinforced elastomeric bearings have uniformly spaced layers of steel and elastomer as shown in Figure II-2.2. The bearing accommodates translation and rotation by deformation of the elastomer as illustrated in Figures II-2.3a and b. The elastomer is flexible under shear stress, but stiff against volumetric changes. Under uniaxial compression the flexible elastomer would shorten significantly and sustain large increases in its plan dimension, but the stiff steel layers restrain this lateral expansion. This restraint induces the bulging pattern shown in Figure II-2.3c, and provides a large increase in stiffness under compressive load. This permits a steel reinforced elastomeric bearing to support relatively large compressive loads while accommodating large translations and rotations.