19. Expansion Joints and Bearings

19.1.   Expansion Joints
19.2.   Bearings

19.1. Expansion Joints

Reference: LRFD Articles 14.4 and 14.5.

19.1.1. General

Expansion joints accommodate the expansion and contraction of bridges due to temperature variations. The following general criteria apply to all expansion joints in bridges:

Minimize Number

When conditions permit, the bridge engineer should eliminate expansion joints and tie the approach slab into the superstructure. Where expansion joints are required to accommodate movement, minimize the number of joints.

Service Requirements

Failed joints contribute to many of the maintenance problems on bridges. Where joints are required, consider the long-term performance and maintenance requirements of the expansion joints.

Consistency of Joint Details

Where possible, use the same type of joint and joint construction details throughout the bridge.

Temperature Range

Use Procedure A of LRFD Article 3.12.1 as modified by replacing LRFD Table 3.12.2.1-1 with the temperature ranges in Table 19-1 specific to Alaska unless more detailed, site-specific information is available.

Construction at extreme temperatures (i.e., at or near the minimum or maximum temperatures of the assumed range) results in thermal movements in a single direction.

Recess Detail

Recess embedded steel elements, such as approach slab protection angles and strip seal expansion joint restrainers, 0.25 inch from finished grade. This recess provides protection from snowplow blades and accommodates milling of the concrete adjacent to the joints.

Effects of Skew

The thermal movements of skewed bridges are such that asymmetrical movements ("racking") can occur along the length of the expansion joints. The movement is not solely in the longitudinal direction. The acute corners of a bridge with parallel skewed supports tend to expand and contract more than the obtuse corners, causing the joint to rack.

Racking should be limited to 20 percent of the rated movement of the joint. For bridges with expansion joints, avoid skews between 25 degrees and 35 degrees due to plow snagging.

Other Geometric Considerations

Horizontally curved bridges and bridges with other special geometric elements, such as splayed girders, do not necessarily expand and contract in the longitudinal direction of the girders.

A refined analysis of the entire bridge may be necessary to characterize the thermal movement of complex bridges. The effect of thermal movements on the joints of complex bridges could be more pronounced compared to bridges with simple geometrics.

The bridge engineer should use a refined analysis of horizontally curved, steel-girder bridges to estimate thermal effects, because even slight curvature may develop significant movements in the radial direction.

Table 19-1
Alaska Temperature Ranges

DOT&PF Region	Temperature Range (˚F)
Southcoast (maritime)	120
Central (intermediate)	140
Northern (interior/continental)	160

Blockouts

Provide details on the plans for blockouts in decks and approach slabs at expansion joints to allow for placement of the joint. During construction, contractors will install the expansion joint assembly and place the blockout concrete after profile grinding has been completed.

Cover Plates Over Expansion Joints

Use cover plates over expansion joints at sidewalks. Consider using cover plates in the shoulder area where bicycles are anticipated in the roadway. Use cover plates when strip seals are used. Overlap the cover plate consistent with the traffic direction to prevent snowplow snagging.

19.1.2. Expansion Joint Selection and Design

Reference: LRFD Article 14.5.3.2.

Table 19-2 presents the types of expansion joints used by DOT&PF and their maximum joint movement.

Select the type of expansion joint and its required movement rating based on the expansion and racking demands, skew, gap widths, and whether the joint is new or a retrofit.

Gap width is the perpendicular distance between the faces of the joint at the road surface. Use a minimum gap of not less than 1 inch for steel bridges. The gap for concrete bridges may be less than 1 inch where creep and shrinkage must be considered. Use a maximum gap width of 4 inches for strip seals and 3 inches for individual components of modular joints.

Silicone Joint Sealant

Reference: LRFD Article 14.5.6.5.

DOT&PF practice is to use this system where anticipated movements are small and where the strip seal joint is impractical.

The joint width at the time of installation dictates the movement capacity of this type of joint, which is a function of the installation width plus or minus some percent of original gap size.

The silicone joint sealant is easily maintained because local joint failures can be easily repaired.

This system can be bonded to concrete or steel, although bonding to steel is more effective in repairs and rehabilitation because the steel bonding surface is more easily cleaned.

Closed-Cell Compression Seal

Low-density, closed-cell foam products consist of pre-formed shapes compressed into the joint. For the size of the material and movement capacity, follow the manufacturer's recommendations.

Larger joints may also require a cover plate for protection of the compression seal. Closed-cell compression seals are used typically for rehabilitation.

Strip Seal

Reference: LRFD Article 14.5.6.7.

A strip seal consists of a gland rigidly attached to a steel restrainer on both sides of the joint. The material is pre-molded into a "V" shape that opens as the joint width increases and closes as the joint width decreases. Strip seal joints are usually protected by a steel cover plate. Strip seals are typically used for new construction.

Strip seal joints are watertight when properly installed. Under typical conditions, the life of a strip seal tends to be longer than that of other joint seals. However, these seals can be difficult to replace and splices in the gland should be avoided. Snowplows can damage the joint, especially if the skew is 20 degrees or greater.

Table 19-2
Expansion Joint Selection

Joint Type	Total Joint Movement
Silicone Joint Sealant	$\leq$ 3 inches
Closed-Cell Compression Seal	$\leq$ 4 inches
Strip Seal	$\leq$ 4 inches
Modular Expansion	> 4 inches

Where practical and where additional protection for bearing assemblies and hinges is warranted, provide a secondary sealing system below the expansion joint assembly.

DOT&PF prefers strip seal glands made of natural rubber (virgin natural polyisoprene); however, as natural rubber becomes less available, the bridge engineer must consider using synthetic rubber (i.e., neoprene).

Strip seals and closed-cell compression foam have replaced preformed elastomeric joint seals on DOT&PF bridge designs. Elastomeric compression seals were difficult to compress and install in warm weather, and they frequently exceeded their tensile capacity in extremely cold weather. They are also not available in natural rubber.

Modular Expansion
Reference: LRFD Article 14.5.6.9

Due to their expense and maintenance requirements, use modular joints only where necessary to accommodate movements greater than 4 inches.

In the selection of modular joint systems, use only those that have been designed to facilitate the repair and replacement of components and that have been verified by long-term in-service performance.

Include a detailed description of the requirements for the modular joint system in the contract documents.

The following apply to the design of modular-type expansion joints:

1. **Joint Support**. The blockouts and supports needed for modular joint systems are large and require special attention when detailing. For modular joints supported from the top of the girder, provide a detail of the supporting device in the contract documents.

2. **Splices**. Where practical, modular joints should be full length with no field splices across the roadway width. If a field splice is required for staged construction of a cast-in-place bridge deck, space the support girders at a maximum of 2 feet from the splice location, which should be outside of the wheel path.

3. **Synthetic-Rubber Seal**. The synthetic-rubber seal, which is a strip seal gland in a modular joint, is one piece across the roadway width, regardless of stage construction considerations.

19.2. Bearings

19.2.1. General

Reference: LRFD Articles 14.4, 14.6, and 14.8.

Movements

Bridge bearings accommodate superstructure movements and transmit the loads to the substructure.

The consideration of movement is important for bearing design, which includes both translations and rotations. The sources of movement include initial camber or curvature, construction loads, misalignment, construction tolerances, settlement of supports, thermal effects, creep, shrinkage, seismic, and traffic loading.

Effect of Camber and Construction Procedures

The initial camber of bridge girders induces bearing rotation. Initial camber may cause a larger initial rotation on the bearing, but this rotation may decrease as the construction of the bridge progresses. Rotation due to camber and the initial construction tolerances are sometimes the largest component of the total bearing rotation.

Evaluate both the initial rotation and its short duration. At intermediate stages of construction, add deflections and rotations due to the progressive weight of the bridge elements and construction equipment to the effects of live load and temperature.

Also, consider the direction of loads, movements, and rotations, because it is inappropriate to simply add the absolute maximum magnitudes of these design requirements. Do not consider combinations of absolute maximums that cannot realistically occur.

In special 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 to minimize the adverse effect of these temporary initial conditions.

Seismic Requirements

Reference: LRFD Articles 14.6.5 and 14.8.3.2.

Bearing selection and design must be consistent with the intended seismic response of the entire bridge system.

Steel-reinforced elastomeric bearing pads should provide adequate seismic performance for most bridges; however, they cannot be counted on to transmit seismic forces to the substructure.

Superstructure seismic forces will typically be transferred to the substructure using shear keys or dowels. In unique situations, restrainers, shock transmission units, or dampers may be considered.

Do not apply these provisions to seismic isolation bearings or structural fuse bearings.

Anchor Bolts

Although the *LRFD Specifications* require anchor bolts in various circumstances, design needs should dictate anchor bolt use. Do not rely on anchor bolts to transfer lateral seismic loads.

19.2.2. Bearing Types

Steel-reinforced elastomeric bearings are typically the first option for all new bridges. Bridges with large movements resulting in excessive bearing pad heights may require sliding surfaces.

In general, the bridge engineer should restrain vertical displacements, allow rotations to occur as freely as possible, and either accommodate or restrain horizontal displacements. Distribute the loads among the bearings in accordance with the superstructure analysis.

The bridge engineer may use sole plates for steel girders to distribute the load uniformly.

Steel-Reinforced Elastomeric Bearings

These bearings are usually the preferred low-cost option and require minimal maintenance.

Limit the height of steel-reinforced elastomeric bearings to 6 inches. Provide elastomeric fixed bearings with a horizontal restraint (typically, a row of dowels connecting the diaphragm to the cap beam) adequate for the full horizontal load.

Polytetrafluoroethylene (PTFE) Sliding Surfaces

Reference: LRFD Article 14.7.2.

Where horizontal movements result in steel-reinforced elastomeric bearing pads exceeding the 6-inch height limit, use a combination bearing. These bearings use a steel-reinforced elastomeric pad to accommodate rotation and a stainless steel plate/PTFE sliding surface to provide translational capability. See Appendix 19.A for a design procedure and example.

Seismic Isolation Bearings

There are various types of seismic isolation bearings, most of which are proprietary. See the AASHTO *Guide Specifications for Seismic Isolation Design* and

the FHWA *Seismic Retrofitting Manual for Highway Structures: Part 1 – Bridges* for detailed information. Isolation bearings increase the fundamental period of vibration of the bridge resulting in lower seismic forces. Although this period shift lowers the seismic forces, it increases the seismic displacements.

Isolation bearings also provide improved damping characteristics to limit the seismic displacement demands.

Consider cold climate behavior when selecting seismic isolation bearings; the preference is to use friction pendulum bearings. Friction pendulum bearings are proprietary and require sole-source procurement.

Chapter 23 discusses the use of seismic isolation bearings on bridge rehabilitation projects.

19.2.3. Design of Steel-Reinforced Elastomeric Bearings

Reference: LRFD Articles 14.7.5.

Steel-reinforced elastomeric bearings may become excessively large if they are designed for loads greater than approximately 650 kips. Although no limiting maximum design load is specified, the maximum practical load capacity of a steel-reinforced elastomeric bearing pad is approximately 750 kips. If the design loads exceed 650 kips, the bridge engineer should check with manufacturers for availability.

Design Method
Use the Method B procedure in the *LFRD Specifications* for the design of steel-reinforced elastomeric bearings. Method B requires additional acceptance testing.

Use 100 percent of the total movement range previously specified in Table 19-1 for the design of bearings. This practice assumes that the bearing is installed at the maximum or minimum design temperature. DOT&PF practice increases the LRFD design value of 65 percent of the total movement as specified in LRFD Article 14.7.5.3.2.

Orientation
Orient elastomeric pads and bearings so that the long side is parallel to the principal axis of rotation.

Holes in Elastomer
Do not use holes in steel-reinforced elastomeric bearings.

Edge Distance
For elastomeric pads and bearings resting directly on a concrete bridge seat, use 3 inches as the minimum edge distance from the edge of the pad to the edge of the concrete seat.

Dimensions
The minimum elastomeric bearing length or width shall be 6 inches. Provide a minimum of 0.25 inches of cover at the edges of the steel shims.

Make the internal elastomer layers not less than approximate 0.5 inches to accommodate adequate fabrication.

Elastomer
Use Grade 5, natural rubber for steel-reinforced elastomeric bearings. Indicate the bearing loads and elastomer grade in the contract documents.

Appendix 19.A
PTFE/Elastomeric Bearings

19.A.1 General

The basic PTFE/elastomeric bearing design consists of:

- PTFE disks sliding on stainless steel surfaces to accommodate the longitudinal movements, and
- elastomeric bearing pads to accommodate the rotational movements.

PTFE/elastomeric bearings are suitable for structures with moderate to large longitudinal translations, and relatively small rotations. This non-proprietary bearing is simple to design and fabricate. Good performance can be attained with careful attention to loading, rotation, and the physical properties/limitations of the manufacturing materials.

This example does not apply to the design of steel-reinforced elastomeric bearings without PTFE.

19.A.2 PTFE/Elastomeric Bearing Components

PTFE/elastomeric bearings consist of five basic components:

- sole plate,
- PTFE disk,
- intermediate plate,
- elastomeric bearing pad, and
- masonry plate.

The function of these components and the typical manufacturing materials are (see Figure 19-1):

- **Sole Plate**. Transfers superstructure loads to the bearing and provides a stainless steel sliding surface for superstructure translation. The sole plate is fabricated from A709, Gr. 50 steel and has a stainless steel surfacing. The stainless steel surface is bonded to the sole plate with epoxy resin and stainless steel cap screws or by perimeter welding.
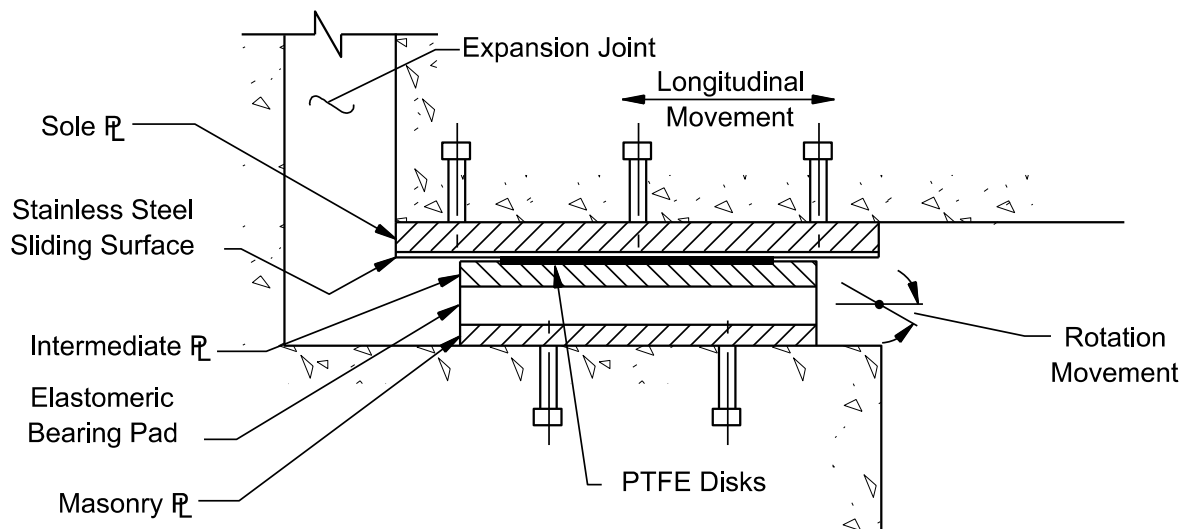
Figure 19-1
PTFE/Elastomeric Bearing

- **PTFE Disk**. Provides a low friction sliding surface for the sole plate. The PTFE disk is manufactured from 100 percent pure virgin unfilled dimpled sheet resin. The PTFE disk must be recessed one-half its thickness into the intermediate plate to control cold flow.

- **Intermediate Plate**. Transfers loads from PTFE disk to elastomeric pad. The intermediate plate is manufactured from A709, Gr. 50 steel.

- **Elastomeric Bearing Pad**. Allows rotation of the superstructure while maintaining 100 percent contact between the PTFE disk and the sole plate. The steel reinforced elastomeric bearing is fully vulcanized to the intermediate and masonry plates. Fabric reinforced pads are not allowed.

- **Masonry Plate**. The masonry plate transfers load from the elastomeric bearing pad and anchors the bearing to the seat. The masonry plate is fabricated from A709, Gr. 50 steel.

19.A.3   Design Requirements

PTFE/elastomeric bearings are designed in accordance with the *LRFD Specifications*, Sections 14 and 15. All loads are service loads. Minimum vertical loads are for dead loads and superimposed dead loads. Maximum vertical loads are for dead loads, superimposed dead loads, and live loads (no impact).

Unfilled PTFE sheet resin stresses are limited to 3,500 psi maximum. The design coefficient of friction varies from 0.08 to 0.04 at bearing pressures of 500 psi and 3,500 psi, respectively.

Steel reinforced elastomeric bearing pads with shape factors ≥ 7.5 may be loaded to a maximum stress of 1,000 psi. The shear modulus (G) used for design is 100 psi.

19.A.4   Design Guidelines

PTFE surfaces should be loaded to a minimum of 2,000 psi (DL only) for optimum performance. Use a design coefficient of friction of 0.06 for designs with bearing pressures from 2,000 psi to 3,500 psi. Actual lubricated friction values are lower; however, do not use these for design because the long-term effects of the grease are unknown. Use a minimum and maximum PTFE thickness of 3/16 inch and ¼ inch.

To reduce rotational stresses, orient rectangular bearings so that the long side is parallel to the axis about which the largest rotation occurs.

A bearing pad with a low shape factor accommodates rotation most readily, and a bearing pad with a high shape factor is best for resisting compression. Therefore, the best choice represents a compromise between the two. Use a minimum shape factor of 7.5.

19.A.5   Design Procedure

19.A.5.1   Elastomeric Bearing Pad

1. Determine the width (W) and length (L) of the elastomeric pad for the applied vertical load (DL + LL not including impact) using an allowable unit stress of 1,000 psi. The shape factor (S) ≥ 7.5:

$$\frac{DL + LL}{1,000 \text{ psi}} = W \times L$$

2. Check the compressive strain of the elastomer due to dead load and live load from the stress/strain curves for various shape factors shown in Figure 19-2. These curves, developed by Caltrans, are based on tests of pads constructed with ½ inch layers of elastomers between steel plates meeting California specifications. To account for compressive creep of the elastomer under sustained dead load, the initial deflection from dead load is increased by 25 percent. The total deflection from dead load (DL) and live load (LL) shall not exceed 0.07 times the thickness of the elastomeric bearing.
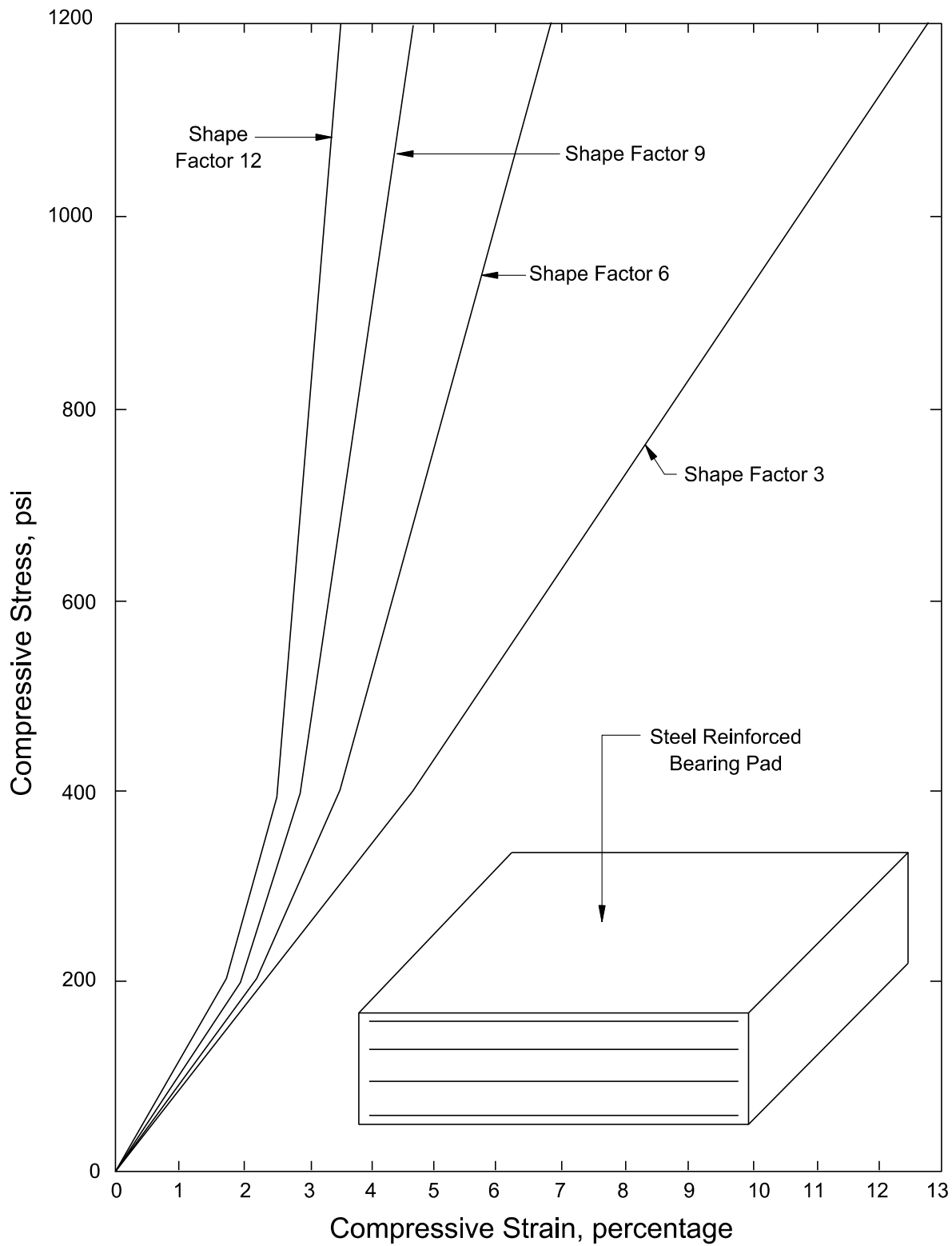
Figure 19-2
Recommended Compressive Stress vs. Strain Curves
for Steel Reinforced Bearing Pads

3. Determine the initial thickness of the elastomer required for structure rotation. The structure rotation should include rotations from DL, LL, camber changes, construction tolerances, and erection sequences.

The relative rotation between top and bottom surfaces of the bearing shall be limited by:

$$L\alpha_L + W\alpha_W \leq 2\Delta_c \qquad \text{(for rectangular bearings)}$$

$$D\sqrt{\alpha_L^2 + \alpha_W^2} \leq 2\Delta_c \qquad \text{(for circular bearings)}$$

$$\Delta_c = \sum_i \varepsilon_{ci} t_i, \quad \therefore \ \Delta_c = \varepsilon_{tot} T$$

Therefore, the elastomer thickness (T) may be determined from:

$$T \geq \frac{L\alpha_L + W\alpha_W}{2\varepsilon_{Tot}} \qquad \text{(rectangular bearings)}$$

$$T \geq \frac{D\sqrt{\alpha_L^2 + \alpha_W^2}}{2\varepsilon_{Tot}} \qquad \text{(circular bearings)}$$

Where:
- L = gross length of rectangular bearing parallel to the longitudinal axis of the bridge (inches)
- W = gross width of rectangular bearing perpendicular to longitudinal axis of the bridge (inches)
- D = gross diameter of circular bearing (inches)
- α_L, α_W = relative rotation of top and bottom surfaces of bearings about an axis perpendicular (parallel) to the longitudinal axis of the bridge (radians)
- Δ_c = instantaneous compressive deflection of bearing (inches)
- ε_{ci} = compressive strain of ith elastomer layer (change in thickness divided by unstressed thickness)
- ε_{Tot} = total compressive strain of elastomer
- t_i = thickness of ith elastomer layer (inches)
- T = total elastomer thickness of bearing (inches)
- $= \Sigma t_i$

4. Determine the maximum allowable shear force (F_s) in the elastomer:

$$F_s = G\frac{A}{T}\Delta_s$$

Where:
- Δ_s = shear deflection of bearing (inches)
- G = shear modulus of elastomer (psi) at 73°F
- A = plan area of bearing (square inches)

The maximum allowable shear force in the elastomer must be greater than the maximum lateral force required to slip the PTFE disk under dead load (see Figure 19-3).
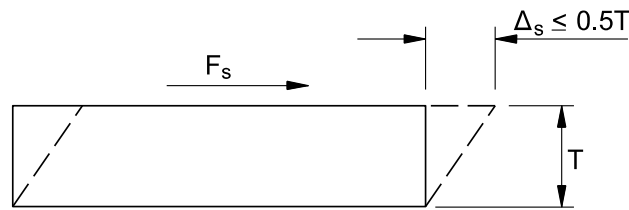
Figure 19-3
Shear Force in Elastomer

Note that the shear modulus (G) decreases with increasing temperature and increases with decreasing temperature. Values of 135 psi and 95 psi are recommended for this calculation.

The maximum shear deflection (Δ_s) in the elastomer shall be limited by:

$$T \geq 2\Delta_s$$

If the maximum allowable shear force is exceeded, the area of the elastomeric pad may be increased to provide greater shear capacity. It is evident from the above formulas that the elastomer design is sensitive to both the shear modulus and the friction force transmitted through the stainless steel sliding surface.

19.A.5.2   PTFE Disk

1. Determine the area of the PTFE disk required to support vertical loads (DL + LL, no impact), using a 3,500 psi maximum compressive stress. Note that the allowable compressive stress for the PTFE is 3.5 times the allowable stress for the elastomer. To minimize the thickness of the intermediate plate in which the PTFE is recessed, the length, width or radius of the PTFE should be such that the edge distance is held to a minimum. A 2,000 psi to 2,500 psi (DL only) design compressive stress on the PTFE should provide a reasonable intermediate top plate thickness.

    PTFE disks are used to facilitate fabrication of the recess in the steel intermediate plate.

2. Calculate the lateral force (F_f) required to slip the PTFE disk under dead load:

    F_f = μN
    μ = friction coefficient
    N   = dead load

    Use the friction values given in LRFD Article 14.7.2.5. Note that the actual coefficient of friction will probably be less because the stainless steel slider plate will be coated with silicone grease.

3. Compare the maximum allowable shear force (F_s) in the elastomer with the lateral force (F_f) required to slip the PTFE under dead load:

    $$F_s \geq F_f$$

19.A.5.3   Intermediate Plate

1. Size the intermediate plate, length, and width to match the dimensions of the elastomeric bearing pad.

2. Determine required plate thickness. Design in accordance with AISC design procedure for column base plates. As a suggestion, convert PTFE disk area to equivalent square area to design plate thickness.

19.A.5.4   Sole Plate

Size the sole plate so that it remains in full contact with the PTFE disk under all loading conditions.

The safety overhang (L_o) provides a minimum edge distance and allows for additional sliding surface beyond the calculated movement. The value reflects the certainty or uncertainty of the total movement calculation:

D_D =   diameter of PTFE disk

L_{max} = maximum longitudinal movement (including creep, shrinkage, post tensioning, thermal effects, and seismic).

T_m = maximum transverse movement

L_o = safety overhang

1. Longitudinal length (L_{sp}) and transverse width (W_{sp}) of sole plate:

    $$L_{sp} = D_D + L_{max} \text{ (total)} + L_{oL}$$

    Single disk:

    $$W_{sp} = D_D + T_m + L_{oT}$$

2. Plate thickness (T_{sp}):

    Design in accordance with AISC design procedure for column base plates when mounted on concrete. Recommended minimum thickness is 0.75 inch.

3. Anchorage may be accomplished with shear studs, bolts, or welding depending on the structure type. Studs smaller than 0.75-inch diameter are not recommended.

19.A.5.5   Masonry Plate (When Needed)

1. Size the masonry plate, length, and width to match the dimensions of the elastomeric bearing pad unless a larger plate is required for anchorage.

2. A plate thickness of 0.75 inch is recommended.

3. Anchorage may be accomplished with shear studs, sleeved anchor bolts, or welding depending on the structure type. Studs smaller than 0.75 inch in diameter are not recommended.

19.A.6   Example — PTFE/Elastomeric Bearing, CIP P/S Structure

Given: Structure Length   =   785 feet

Contributory Length: 176 feet + 255 feet (CIP P/S)   =   431 feet
DL Reaction/Girder: Service Load   =   271 kips
LL Reaction/Girder: Service Load, No Impact   =   43 kips
Moderate Temperature Zone: Rise and Fall   =   35°F
f'_c = 4 ksi
F_y = 50 ksi

19.A.6.1   Elastomeric Bearing Pad

1. Determine width (W) and length (L):

    $$\frac{DL + LL}{1,000 \text{ psi}} = W \times L \qquad \frac{271 \text{ kips} + 43 \text{ kips}}{1,000 \text{ psi}} = 314 \text{ square inches}$$

    Try 12 inch × 28 inch   Area = 336 square inches **>** 314 square inches Okay

    Note: Slender bearing pad selected to maximize rotation capacity.

    Shape factor (S) $= \dfrac{12 \times 28}{12 + 28} = 8.4 > 7.5 \quad \therefore 1,000 \text{ psi is okay}$

    Actual load on elastomer:

$$\frac{271 \text{ kips} + 43 \text{ kips}}{12 \times 28} = 934 \text{ psi (DL + LL)}$$

$$\frac{271 \text{ kips}}{12 \times 28} = 807 \text{ psi (DL)}$$

2. Check compressive strain:

    S = 8.4; obtain strain values from the curves shown on Figure 19-2.
    P_{TL} = 934 psi $\qquad$ ε_{TL} = 4.4%
    P_{DL} = 807 psi $\qquad$ ε_{DL} = 4.0%
    ε_{Total} = 4.4 + (4.0)(0.25) = 5.4% < 7.0% Okay

3. Determine initial thickness (T) for rotation:

    $$T \geq \frac{L\alpha_L + W\alpha_w}{2\varepsilon_{Tot}} \qquad \text{assume } W\alpha_w \text{ is negligible}$$

    $$\therefore T \geq \frac{L\alpha_L}{2\varepsilon_{Tot}} = \frac{(12)(0.015)}{2(0.054)} = 1.67 \text{ inches; say 2 inches (elastomer only)}$$

    Structure Rotation: $\qquad\qquad$ β_s = 0.003 radians
    Construction Rotation: $\qquad$ β_c = 0.01 radians

    LRFD Specifications require 0.015 radians (minimum)

4. Determine the maximum allowable shear force (F_s) in the elastomer:

    $$F_s = G\frac{A}{T}\Delta_s = 100 \times \frac{12 \times 28}{2} \times 1 = 16.8 \text{ kips}$$

    $$\Delta_{s\,max} = \frac{T}{2} = \frac{2}{2} = 1 \text{ inch}$$

19.A.6.2   PTFE Disk

1. Determine area of PTFE disks:

    Use two disk design: -

    $$\text{DL area required} = \frac{271 \text{ kips}}{2 \times 2,500 \text{ psi}} = \frac{\pi D_D^2}{4} \qquad \therefore D_D = 8.3 \text{ - inch diameter}$$

    Try D_D = 8.5-inch diameter

    $$\text{DL stress on PTFE} = \frac{271 \text{ kips}}{\left[2 \times \pi \times \dfrac{8.5^2}{4} \right]} = 2,388 \text{ psi} > 2,000 \text{ psi} \text{ Okay}$$

    $$\text{DL + LL on PTFE} = \frac{271 + 43}{\left[2 \times \pi \times \dfrac{8.5^2}{4} \right]} = 2,766 \text{ psi} < 3,500 \text{ psi} \text{ Okay}$$

    Use two ¼-inch × 8.5-inch diameter PTFE disks.

2. Calculate the lateral force (F_f) required to slip PTFE:

$F_f = \mu N$ $\mu = 0.06$
N = 271 kips (DL)
$F_f = 0.06 \times 271{,}000 = 16.2$ kips

3. Compare allowable shear force (F_s) required to slip force (F_F):
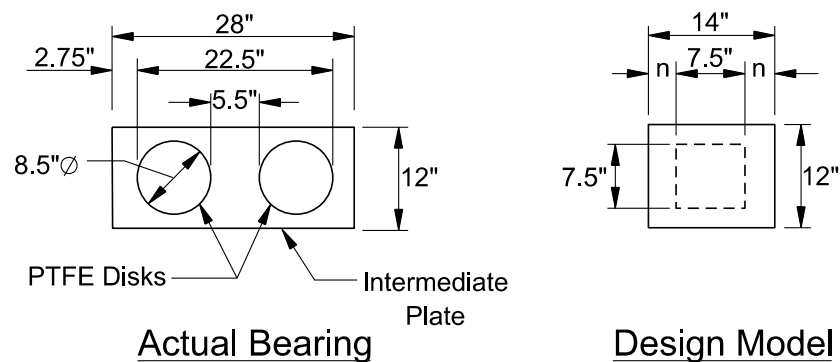
$F_s \geq F_f$ 16.8 > 16.2 kips   Okay

19.A.6.3   Intermediate Plate

1. Size intermediate plate length (L) and width (W) to match elastomeric pad dimensions:

L = 12 inches
W = 28 inches

2. Determine plate thickness (T_p):

Actual Bearing   Design Model

$$T_p = 2n\sqrt{\dfrac{f_p}{F_y}}$$

f_p = actual bearing pressure on elastomer
F_y = steel yield strength
F_b = 0.75F_y

Model – Convert disk to equivalent square to determine (n):

$$f_p = \frac{271\,k + 43\,k}{12 \times 28} = 934 \text{ psi}$$

$$n = \frac{14 - 7.5}{2} = 3.25 \text{ inches}$$

$$T_p = 2 \times 3.25 \times \sqrt{\frac{934}{50{,}000}} = 0.89$$

Total plate thickness (T_p) including 1/8-inch recess:

$T_p = $ 0.89 $+ 0.125$ inch $= 1.02$ inch; say 1.0-inch thick

19.A.6.4 Sole Plate

1. Longitudinal length (L_{sp}) and width (W_{sp}):

   Temperature movement $= (1.5)\,(2)\,(0.0000060)\,(35°F)\,(431\text{ feet})\,(12\text{ inch/foot}) = \pm3.26$ inches

   P/S shortening $= (0.70)\,(0.10\text{ feet}/100\text{ feet})\,(431\text{ feet})\,(12\text{ inch/foot}) = 3.62$ inches

   Seismic movement $= \pm3.0$ inches

   $L_{max} = 3.26 + 3.62 + 2(3.0) = 12.88$ inches
   $L_{oL} = 2(1.0)$ (edge distance) $= 2.0$ inches
   $D_D = 8.5$ inches
   $T_m = $ (seismic) $= \pm 1.0$ inch
   $L_{sp} = D_D + L_{max}$ (total) $+ L_{oL}$
   $L_{sp} = 8.5 + 12.88 + 2 = 23.28$ inches; say 24.0 inches
   $W_{sp} = D_D + T_m + L_o$
   $L_{oT} = 2(1.0)$ (edge distance) $= 2.0$ inches
   $W_{sp} = [(2)(8.5) + 5.5] + 2(1.0) + 2.0 = 26.5$ inches

   Notes:

   (1) Thermal movement was multiplied by 2 because 35°F is rise or fall temperature.
   (2) Thermal movement was multiplied by 1.5 because it is not always possible to place the sole plate at a "mean temperature."
   (3) Position sole plate to account for one directional movement of P/S shortening.

2. Plate thickness (T_{sp}):

   Design in accordance with AISC design procedure for column base plates mounted on concrete:

   $L_{sp} = 24.0$ inches $W_{sp} = 26.5$ inches
   $f_c' = 4$ ksi $F_y = 50$ ksi

   $$f_b = 0.30\,f_c'\,\sqrt{A_2/A_1} \le 0.60\,f_c'$$

   Assume for this example that $A_2/A_1 = 1.5$

   Maximum bearing pressure (f_b) on loaded area:

   $$f_b = (0.30)(4{,}000)\,\sqrt{1.5} = 1{,}470\text{ psi}$$
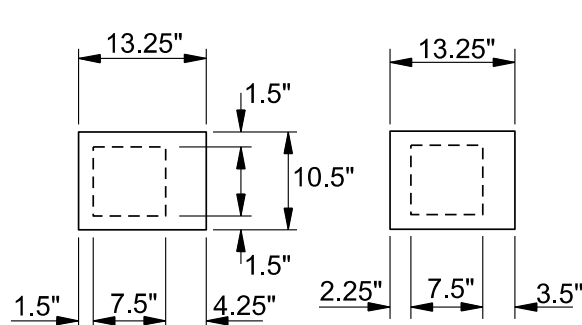
3. Determine required plate area:

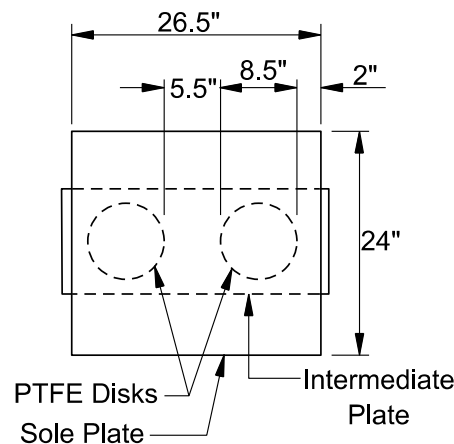 $$\frac{271 + 43}{1{,}470} = 213.6\text{ square inches}$$

   Because the length of the sole plate was determined for sliding purposes, determine the required length to distribute the load to the concrete:

   $$\frac{213.6}{26.5} = 8.1\text{ inches; use disk diameter + edge distance }(8.5 + 2) = 10.5\text{ inches}$$

   Design thickness for 26.5-inch $\times$ 10.5-inch plate

Design Model   **Actual Bearing**

Model information:

- Convert disks to equivalent square
- 1-inch transverse movement (T_m) shown

f_b = actual bearing pressure

F_y = steel yield strength (50 ksi)

F_b = 0.75 F_y

$$T_{sp} = 2n\sqrt{\frac{f_b}{F_y}}$$

$$f_b = \frac{271\,k + 43\,k}{2(10.5 \times 13.25)} = 1{,}128\ psi$$

$$T_{sp} = 2 \times 4.25 \times \sqrt{\frac{1{,}128}{50{,}000}} = 1.28\ inches$$

19.A.6.5   Masonry Plate

1. Size plate area to match elastomer area:

    Use 12-inch × 28-inch plate.

2. Plate thickness:

    A plate thickness of 0.75 inch is adequate because the masonry plate has the same area and load as the elastomeric pad:

    934 psi < 1,470 psi.

3. Anchorage:

    Because structure is cast in place, use shear studs.

19.A.6.6 Summary of Calculations

Plan Bearings:

- Elastomeric bearing pad $2'' \times 1'\text{-}0'' \times 2'\text{-}4''$
- PTFE disk (2)   ¼″ × 8½″ diameter
- Intermediate plate $1¼'' \times 1'\text{-}0'' \times 2'\text{-}4''$
- Sole plate $1½'' \times 2'\text{-}0'' \times 2'\text{-}4''$
- Masonry plate $¾'' \times 1'\text{-}0'' \times 2'\text{-}4''$

Total Bearing Height:

- Sole plate   1.50
- Stainless steel   0.060
- PTFE disk (¼-inch thick recessed ⅛ inch)   0.125
- Intermediate plate   1.25
- Elastomer (2 + (4)(0.075))   2.30
- Masonry plate   0.75
- Total   5.99 inches = 6.0 inches