Section Twelve
Bridge Bearings

12.1 Bearings Types

Bridge bearings transfer superstructure loads to the substructure while also providing for the thermal movement and rotation of the superstructure. Although many different types of bridge bearings have been used by the NYSDOT, elastomeric and multi-rotational bearings are the only general types of bridge bearings currently being used on new bridges of short to moderate length. Major-span bridges require special bearings to handle their extreme loads, movements, and rotations. These special bearings will not be covered in this section.

12.1.1 Steel Rocker Bearings (Type S.R.)

A steel rocker bearing consists of a pinned joint to accommodate rotation and a rocker to accommodate longitudinal movement at the expansion end of the structure. At the fixed end, there is no rocker, as the bearing is rigidly attached to a masonry plate. Steel rocker bearings do not allow for transverse movement. These bearings were widely used in New York through the 1970s. Steel rocker bearings have fallen out of favor due to concern regarding their performance in extreme site conditions (e.g., steep grade) or during a seismic event. The relatively tall bearings could tip over and cause the superstructure to drop a considerable distance or, in the worst-case scenario, to fall off of the bridge seat. Steel rocker bearings also require periodic maintenance to ensure their performance. This bearing type is no longer used on new bridges.

12.1.2 Steel Sliding Bearings (Type S.S.)

Steel sliding bearings consist of a pinned joint to accommodate rotation and a sliding element to accommodate longitudinal movement. The sliding element is usually some form of lubricated bronze plate. Steel sliding bearings do not allow for transverse movements. These bearings were widely used in NYS through the 1970s. Steel sliding bearings also require periodic maintenance to ensure their performance. This bearing type is no longer used on new bridges.

12.1.3 Elastomeric Bearings

The main component of all elastomeric bearings is a neoprene pad that distributes the loads from the superstructure to the substructure and uses its material flexibility to accommodate the rotation and longitudinal movement of the superstructure. Elastomeric bearings may use thin steel laminate reinforcement between the elastomer layers to provide for greater strength, a steel sole plate to allow attachment to steel superstructures, and may use a steel masonry plate. Elastomeric bearings perform well during seismic events because of their relatively large plan dimensions and low height, and the natural dampening effect of the elastomer material.
Elastomeric bearings require very little maintenance to ensure their performance. This bearing type is currently being used on new bridges.

12.1.3.1 Plain Elastomeric Bearings (Type E.P.)

The plain elastomeric bearing is the least expensive bearing system. Due to its relatively low compressive strength, the plain elastomeric pad is only used under shorter prestressed concrete box beams and slab units. Since its longitudinal expansion capacity is limited, the main function of this bearing is to take up any misalignment of the beams with the surface of the bridge seat. The expansion bearing is provided with a hole through which a 25-mm diameter anchor dowel is inserted and compressible material is injected. The fixed bearing is also provided with a hole, through which a 25-mm diameter anchor dowel is inserted and an approved noncompressible epoxy or grout is placed. In both cases, the anchor dowel is intended to prevent “walking” of the bearing.

12.1.3.2 Steel Laminated Elastomeric Bearings (Type E.L.)

Longer prestressed concrete box beam bridges require that the bearings accommodate higher loads and greater thermal expansions. In order to increase the longitudinal movement and rotational capacity of elastomeric bearings while increasing their compressive strength, thin steel laminate reinforcement is placed between the elastomeric pads. The greater height of total elastomer allows for more movement, while the steel load plates prevent excessive bulging of the elastomer. The expansion bearing is provided with a hole through which a 25-mm diameter anchor dowel is inserted and compressible material injected. The fixed bearing is also provided with a hole through which a 25-mm diameter anchor dowel is inserted and an approved noncompressible epoxy or grout is placed. In both cases, the anchor dowel is intended to prevent “walking” of the bearing.

12.1.3.3 Steel Laminated Elastomeric Bearings With Sole Plate (Type E.B.)

This bearing is to be used with steel girder and prestressed NEBT and I-beam superstructures. It is identical to the Type E.L. bearing except there is a 40-mm minimum thickness steel sole plate vulcanized to the top of the bearing. The steel sole plate is welded or fastened to the beams. This sole plate may be beveled to take up any grade differences in order to achieve a level top elastomer surface if the longitudinal grade of the bottom flange is one percent or more or the required taper is 3 mm or more.

Type E.B. bearings are vulcanized to a steel masonry plate that is bolted to the substructure. For fixed Type E.B. bearings, a minimum 38-mm diameter pin is press fit through the masonry plate to prevent the bearing from translating longitudinally or transversely.

12.1.4 Multi-Rotational Bearings (Type M.R.)

Multi-rotational bearings are generally used in high load situations, or where the thermal movements are excessive for elastomeric bearings. Multi-rotational bearings consist of a
confined elastomeric element (Pot design) or an unconfined polyether urethane disc (Disc design) to accommodate rotation, and a sliding element to accommodate movement. The expansion bearings of this type may be guided, allowing movement in one direction, or nonguided, allowing movement in any direction.

At locations where large movements are expected or where large sole plates are required, consideration shall be given to using four bearing stiffeners to better distribute the load rather than two located at the centerline of bearing. If four stiffeners are used, they shall be spaced apart at least the width of the stiffener. When using guided expansion bearings on very wide structures or curved structures, it may be necessary to increase the standard clearance between the guide bars and the bearing body to accommodate the transverse movement due to thermal expansion.

The coefficient of friction used for the design of the bearings shall be 5%, whereas the maximum coefficient of friction specified to the manufacturer is 3%. Multi-rotational bearings require more regular maintenance to ensure their performance than elastomeric bearings. This bearing type is currently being used on new bridges.

For multi-rotational bearings with a capacity greater than 2250 kN, 5-mm shim plates are used in lieu of the normal 3 mm plates.

12.2 General Design Considerations

12.2.1 Design Method

The provisions of the NYSDOT LRFD Bridge Design Specification shall be used for the design of bridge bearings. Elastomeric bearings shall be designed using Method A. Multi-rotational bearings shall be designed by the fabricator. Design examples of various bearings types can be found in Appendices 12A – 12F of this manual.

12.2.2 Live Load on Bearings

Impact shall not be included in the live load when designing elastomeric bearings. Impact shall be included in the live load when designing multi-rotational bearings.

12.2.3 Minimum Loads on Bearings

Elastomeric bearings used with steel superstructures have a minimum pressure requirement due to dead load plus superimposed dead load of 1.38 MPa to ensure the rubber element does not “walk” out of position. Elastomeric bearings used with prestressed box beams or slab units do not have a minimum load requirement due to the presence of the anchor dowel. The minimum load on multi-rotational bearings due to dead load plus superimposed dead load is 20% of the capacity of the bearing to ensure proper operation of the bearing.
12.2.4 Uplift

Bridges with severe skews, curved girders, or unbalanced continuous spans may experience uplift of one or more of the beams. The preferred method of resisting uplift is to design a concrete counterweight over the bearings to weigh down the beam end and provide the minimum load for the bearing. If it is not possible to design a counterweight heavy enough to hold the beam end down, other possible solutions include changing the continuous spans to simple spans, making the uplift end of the beam the fixed end and providing uplift restraints that allow rotation in any direction, or changing the span or skew arrangement to eliminate the conditions creating the uplift. Care must be taken in designing uplift restraints that allow longitudinal movement. Anchor rods embedded in the pedestal passing through slotted holes in the girder usually do not work well due to a tendency for the anchor rods to bind. For specific design requirements for uplift, see the NYSDOT LRFD Bridge Design Specification.

12.2.5 Bearings for Curved Girders

When setting bearings for curved girders, the assumed direction of expansion between points of support is a straight line chord between the fixed bearing and each expansion bearing along the continuous curved girder. However, the actual direction of expansion is in two planes. Bearings need to be designed to accommodate these movements.

Multi-rotational bearings are recommended for curved girders on skewed supports because they are better able to resist tensional forces in the superstructure.

12.3 Bearing Selection Criteria

Elastomeric bearings are preferred for most structures. Multi-rotational bearings are used when large loads and movements cannot be efficiently accommodated by elastomeric bearings. Only one type and size of bearing shall be used for each line of bearings.

When required design load or movement exceed the limits of the standard elastomeric bearings given below, the elastomeric bearings shall be specially designed or multi-rotational bearings shall be used.

Round elastomeric bearings should be considered for situations where there are sizable vertical loads or large skews where the use of rectangular bearings would necessitate a very wide bridge seat or pier cap.

12.4 Painting of Bearings

The steel parts of all bearings, including weathering steel, shall be painted due to concern for the bearing steel being in contact with water for long periods of time and the resulting durability concerns with uncoated weathering steel. Painting of the bearing steel is covered under the NYSDOT Standard Specifications for Construction and Materials and the cost is included in the bearing items.
12.5 Standard Bearing Designs

Standard bearing design tables assume a total induced rotation of 0.007 radians (dead load rotation of 0.000 radians, live load rotation of 0.005 radians, and a rotation of 0.002 radians to account for installation uncertainties). The designer is responsible for determining specific required rotations and sizing the bearings accordingly.

The following are descriptions for the titles in the elastomeric bearing design tables. Bearings sizes in *bold italic* are preferred sizes, and should be used whenever possible.

<table>
<thead>
<tr>
<th>Length</th>
<th>Measured along the girder centerline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>Measured perpendicular to the girder centerline</td>
</tr>
<tr>
<td>Max. Load</td>
<td>Maximum allowable compressive load</td>
</tr>
<tr>
<td>Min. Load</td>
<td>Minimum load to ensure adequate bearing performance</td>
</tr>
<tr>
<td>n</td>
<td>Number of elastomer layers</td>
</tr>
<tr>
<td>n_i</td>
<td>Number of internal elastomer layers</td>
</tr>
<tr>
<td>Max. Move.</td>
<td>Maximum Movement: Maximum allowable bearing movement</td>
</tr>
<tr>
<td>h_{rt}</td>
<td>Total elastomer height (n x height of 1 layer)</td>
</tr>
<tr>
<td>Shape Factor</td>
<td>As defined by NYSDOT LRFD Section 14.7.5.1</td>
</tr>
<tr>
<td>Comp. Area*</td>
<td>Compressive Area: Plan area of the steel laminate reinforcement</td>
</tr>
<tr>
<td>Shear Area*</td>
<td>Plan area of the elastomer layer</td>
</tr>
</tbody>
</table>

* Included reduction for 50-mm diameter hole
### STANDARD TYPE E.L. ELASTOMERIC BEARINGS

<table>
<thead>
<tr>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Max. Load (kN)</th>
<th>$n_i$</th>
<th>$h_{rl}$</th>
<th>Max. Move. (mm)</th>
<th>Shape Factor</th>
<th>Comp. Area* (sq. mm)</th>
<th>Shear Area* (sq. mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>850</td>
<td>400</td>
<td>1</td>
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<td>125540</td>
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<tr>
<td>200</td>
<td>850</td>
<td>675</td>
<td>2</td>
<td>36</td>
<td>18</td>
<td>6.20</td>
<td>161770</td>
<td>168040</td>
</tr>
<tr>
<td>250</td>
<td>850</td>
<td>1000</td>
<td>3</td>
<td>48</td>
<td>24</td>
<td>7.44</td>
<td>203970</td>
<td>210540</td>
</tr>
</tbody>
</table>

**Table 12-1**
Bearing Design – Standard Type E.L Elastomeric

### STANDARD TYPE E.B. ELASTOMERIC BEARINGS

<table>
<thead>
<tr>
<th>Len. (mm)</th>
<th>Wid. (mm)</th>
<th>Max Load (kN)</th>
<th>Min Load (kN)</th>
<th>N</th>
<th>$h_{rl}$</th>
<th>Max Mov (mm)</th>
<th>S Fact (Exp)</th>
<th>S Fact (Fix)**</th>
<th>Comp Area (sq mm) (Exp)</th>
<th>Comp Area (sq mm) (Fix)**</th>
<th>Shear Area (sq mm) (Exp)</th>
<th>Shear Area (sq mm) (Fix)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>450</td>
<td>500</td>
<td>155</td>
<td>3</td>
<td>36</td>
<td>18</td>
<td>6.70</td>
<td>6.70</td>
<td>108335</td>
<td>106950</td>
<td>112500</td>
<td>111365</td>
</tr>
<tr>
<td>250</td>
<td>450</td>
<td>500</td>
<td>155</td>
<td>4</td>
<td>48</td>
<td>24</td>
<td>6.70</td>
<td>6.70</td>
<td>108335</td>
<td>106950</td>
<td>112500</td>
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<td>500</td>
<td>155</td>
<td>5</td>
<td>60</td>
<td>30</td>
<td>6.70</td>
<td>6.70</td>
<td>108335</td>
<td>106950</td>
<td>112500</td>
<td>111365</td>
</tr>
<tr>
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<td>450</td>
<td>850</td>
<td>215</td>
<td>5</td>
<td>60</td>
<td>30</td>
<td>8.20</td>
<td>8.20</td>
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<td>151350</td>
<td>157500</td>
<td>156365</td>
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<td>450</td>
<td>850</td>
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<td>72</td>
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<td>156365</td>
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<td>850</td>
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<td>96</td>
<td>48</td>
<td>8.20</td>
<td>8.20</td>
<td>152735</td>
<td>151350</td>
<td>157500</td>
<td>156365</td>
</tr>
<tr>
<td>450</td>
<td>450</td>
<td>1250</td>
<td>275</td>
<td>7</td>
<td>84</td>
<td>36</td>
<td>9.38</td>
<td>9.38</td>
<td>197135</td>
<td>195750</td>
<td>202500</td>
<td>201365</td>
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<tr>
<td>450</td>
<td>450</td>
<td>1250</td>
<td>275</td>
<td>8</td>
<td>96</td>
<td>42</td>
<td>9.38</td>
<td>9.38</td>
<td>197135</td>
<td>195750</td>
<td>202500</td>
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<tr>
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<td>1250</td>
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<td>9</td>
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<td>197135</td>
<td>195750</td>
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<tr>
<td>450</td>
<td>450</td>
<td>1250</td>
<td>275</td>
<td>10</td>
<td>120</td>
<td>54</td>
<td>9.38</td>
<td>9.38</td>
<td>197135</td>
<td>195750</td>
<td>202500</td>
<td>201365</td>
</tr>
</tbody>
</table>

** A 38 mm diameter pin is assumed. The pin hole is not subtracted from the Shape Factor calculation because it is tightly fit. It is accounted for in the compression and shear areas.

**Table 12-2**
Bearing Design – Standard Type E.B. Elastomeric
Design Example; Plain Elastomeric Bearing (Type EP)

Note: Highlighted values on the following pages require user input. This bearing design assumes straight, single span concrete beams and skews below 30 degrees. Modification to accommodate alternate bearing designs is at the user's discretion. Enclosed information based on the 2007 AASHTO LRFD Bridge Design Specifications. The designer is responsible for the final design.

Enter known data:

(A ** indicates typical conditions and may not require changing.)

Superstructure Properties:

- $L_{span} := 9.997\text{m}$  
- $\Delta_{LL} := 12.7\text{mm}$
- $L_{h/3} := 127.664\text{kN}$
- $D_{C1} := 68.503\text{kN}$
- $D_{C2} := 5.338\text{kN}$
- $D_{W} := 8.896\text{kN}$
- $D := 380\text{mm}$
- $\Delta_{initial} := 15.748\text{mm}$
- $\Delta_{final} := 12.7\text{mm}$
- $P := 3869.953\text{kN}$
- $E := 34474\text{MPa}$
- $A := 359999\text{mm}^2$
- Seismic := 0\text{kN}
- $\Delta_{ES} := 13.93\text{mm}$
- $\Delta_{CS} := 30\text{MPa}$
- $\Delta_{creep} := 50\text{MPa}$
- $\Delta_{elastic\_shortening} := 99.73\text{MPa}$

Vertical Curve Data:

- $G_1 := 1\%$
- $G_2 := 1.0\%$
- $L_{vc} := 0\text{m}$
- STA_{PVI} := 0\text{m}

Bearing Data:

- $L_{brg} := 250\text{mm}$  
- $W_{brg} := 850\text{mm}$
- $STA_{brg} := 120002.4\text{mm}$
- Location := 0
- $n := 1$
- $h_i := 24\text{mm}$
- $D_{ia} := 50\text{mm}$

(Expansion/Span Length)  
(LL Deflection, w/ Impact)  
(Unfactored LL, w/o Impact)  
(Unfactored DL)  
(Unfactored DL Load on Composite Section)  
(Unfactored FWS Load on Composite Section)  
(Depth of Girder)  
(Initial Camber)  
(Final Camber)  
(Total Prestress Force)  
(Beam Concrete Modulus of Elasticity)  
(Cross-Sectional Beam Area)  
(Maximum horizontal Seismic Load)  
(Final Concrete Shrinkage Losses, taken from CONSPAN)  
(Final Concrete Creep Losses, taken from CONSPAN)  
(Initial Total Prestress Losses, taken from CONSPAN)  
(Location of bearing on span, 0 for begin or 1 for end)  
(Plain Pads have one layer)  
(Elastomer layer thickness)  
(Hole diameter for anchor rod)
Thermal Conditions:
(AASHTO 'Cold Climate' Zone 'C', LRFD Table 3.12.2.1-1 - Regions 10 and 11 are in 'Moderate Climate' zone)
For concrete girder bridges with concrete decks.

\[
\begin{align*}
T_{\text{high}} &= 27 \degree C \\
T_{\text{low}} &= -18 \degree C \\
\alpha &= 10.8 \times 10^{-6} \frac{1}{\degree C}
\end{align*}
\]

Temperature range \quad LRFD 3.12.2.1-1
Concrete coefficient of thermal expansion \quad LRFD 5.4.2.2

Total Loading:
\[
\begin{align*}
\text{LL} &= L_{hl93} \\
\text{TL} &= DC1 + DC2 + DW + LL \\
\text{SDL} &= DC2 + DW \\
\text{P}_{\text{strength,1}} &= 1.25(DC1 + DC2) + 1.50DW + 1.75L_{hl93} \\
\text{P}_{\text{strength}} &= \text{P}_{\text{strength,1}}
\end{align*}
\]

Max. live load \quad LL = 127.664kN
Service I limit state no impact \quad TL = 210.401kN
Unfactored Dead Load on composite section \quad SDL = 14.234kN
Strength I limit state (no impact) \quad P_{\text{strength,1}} = 329.057kN
\quad P_{\text{strength}} = 329.057kN

\[
\begin{align*}
\text{PLAN} \\
\text{PLAIN ELASTOMERIC BEARING (TYPE E.P.)}
\end{align*}
\]

\[
\begin{align*}
\text{SECTION C-C}
\end{align*}
\]
LRFD 14.7.5.1 Shape Factor

\[ S := \frac{L_{brg} W_{brg} - \pi \cdot \text{Dia}^2}{h_i \left( 2L_{brg} + 2W_{brg} + \pi \cdot \text{Dia} \right)} \]

LRFD 14.7.5.1-1

\[ S = 3.72 \]

LRFD 3.12.2.1 Movements

Temperature Range to Determine Design Movement

Expansion:

\[ \Delta_{Texp} := \alpha \cdot L_{span} \left( T_{high} - 20C \right) \]

\[ \Delta_{Texp} = 0.756\text{mm} \]

Contraction:

\[ \Delta_{Tcont} := \alpha \cdot L_{span} \left( 20C - T_{low} \right) \]

\[ \Delta_{Tcont} = 4.103\text{mm} \]

Movement Due to Camber Release, \( \Delta_{CR} \)

Change in Camber = \( C := \Delta_{\text{initial}} - \Delta_{\text{final}} \)

\[ \Delta_{CR} := \frac{4 \cdot C \cdot D}{L_{\text{span}}} \] (expansion)

\[ \Delta_{CR} = 0.463\text{mm} \]

Movement Due to Concrete Shrinkage, and Creep:

Assume \% of Shrinkage, and Creep
at Installation = \%_{\text{shrinkageAndCreep}} := 50\%

\[ \Delta_{CSAndCREEP} := \frac{(\Delta_{CS} + \Delta_{creep}) \cdot \%_{\text{shrinkageAndCreep}} \cdot \Delta_{ES}}{\Delta_{\text{elastic_shortening}}} \]

\[ \Delta_{CSAndCREEP} = 5.587\text{mm} \]

In order to approximate bearing movements due to concrete shrinkage and creep combined, it is first assumed that half of these losses have occurred prior to beam erection. Then, a ratio is calculated based on the known movements caused by initial losses (elastic shortening) and multiplied by half the predicted final shrinkage and creep losses to determine the approximated movement caused by shrinkage and creep after the beam has been erected.

Total Movement

\[ \Delta_{S_{\text{expansion}}} := \Delta_{Texp} + \Delta_{CR} - \Delta_{CSAndCREEP} \]

\[ \Delta_{S_{\text{expansion}}} = -4.368\text{mm} \]

\[ \Delta_{S_{\text{contraction}}} := \Delta_{Tcont} - \Delta_{CR} + \Delta_{CSAndCREEP} \]

\[ \Delta_{S_{\text{contraction}}} = 9.227\text{mm} \]

LRFD 14.7.6.3.4 Shear Deformation check

The shear deformation is checked to ensure that the bearing is capable of allowing the anticipated horizontal bridge movement.

\[ h_n \geq 2 \cdot \Delta_{\text{service}} \]

\[ \gamma_{tu} := 1.2 \] For service limit state

LRFD Table 3.4.1-1

\[ \Delta_{\text{service}} = \gamma_{tu} \cdot \Delta_{S_{\text{expansion or contraction}}} \]

\[ t_{req} := \left( \gamma_{tu} \cdot 2 \cdot \max \left( \left| \Delta_{S_{\text{expansion}}} \right|, \left| \Delta_{S_{\text{contraction}}} \right| \right) \right) \]

\[ t_{req} = 22.144\text{mm} \]

\[ h_n := h_i \]

\[ h_n = 24\text{mm} \]

Check\(_1 := \text{if}(t_{req} \leq h_n, "OKAY", "Increase number of layers") \]

Check\(_1 = "OKAY" \)
LRFD 14.7.6.2 Material Properties

All Elastomer shall be 50 Durometer hardness on the Shore A scale (BD-BG-R1)

G := 0.66MPa
C_max := 0.9MPa

Base Value of Shear Modulus of Elastomer
Assuming a Hardness of "50" ==========> LRFD Table 14.7.5.2-1

LRFD 14.7.6.3.2 Compressive Stress

Compare allowable to applied compressive stress:

σ_TL := \frac{TL}{L_{brg} \cdot W_{brg} \cdot \frac{\pi}{4} \cdot Dia^2} \leq \sigma_{allow}

σ_{allow} := 5.5MPa

Check_2 := if(σ_TL ≤ σ_{allow}, "OKAY", "FAILS")

Check_2 = "OKAY"

LRFD 14.7.6.3.3 Compressive Deflection

Find Compressive Strain From AASHTO Fig. 14.6.5.3.3-1

Must comply with section 14.7.5.3.3:

Δ = \sum ε_i h_{ri} considered for both total and live loads, and
Δ < or = 0.07 h_{ri} for any layer

Refer to Figure3- C1 of Section C14.7.5.3.3 to obtain values of ε_i & input below:

The compressive deflection of PEP should be taken as 3 times the deflection estimated for steel reinforced bearing of the same shape factor. LRFD 14.7.6.3.3

σ_{TL} := \frac{TL}{L_{brg} \cdot W_{brg} \cdot \frac{\pi}{4} \cdot Dia^2} \Rightarrow σ_{TL} = 0.999MPa \Rightarrow ε_{TL} := 3ε(σ_{TL},S) \Rightarrow ε_{TL} = 0.063

σ_{DC1} := \frac{DC1}{L_{brg} \cdot W_{brg} \cdot \frac{\pi}{4} \cdot Dia^2} \Rightarrow σ_{DC1} = 0.325MPa \Rightarrow ε_{DC1} := 3ε(σ_{DC1},S) \Rightarrow ε_{DC1} = 0.022

σ_{LL} := \frac{LL}{L_{brg} \cdot W_{brg}} \Rightarrow σ_{LL} = 0.601MPa \Rightarrow ε_{LLandSDL} := ε_{TL} - ε_{DC1} \Rightarrow ε_{LLandSDL} = 0.041
Compressive Deflection of the bearing due to total loading:

\[ \Delta_{TL} := e_{TL} \cdot h_{rt} \]

Limiting instantaneous deflection is important to ensure that deck joints and seals are not damaged. Furthermore, bearings that are too flexible in compression could cause a small step in the road surface at deck joint when traffic passes from one girder to the other, giving rise to impact loading. A maximum relative deflection across a joint of 3 mm is suggested LRFD C14.7.5.3.3

\[ \Delta_{LLandSDL} := e_{LLandSDL} \cdot h_{rt} \]

Check3 := if\((\Delta_{LLandSDL} \leq 3\,\text{mm})\), "OKAY", "Excessive deflection"

The initial compressive deflection of PEP or in any layer of steel-reinforced Elastomeric bearing at the service limit without impact shall not exceed 0.07 \( h_i \) LRFD 14.7.6.3

\[ \Delta_{TL,i} := e_{TL} \cdot h_i \]

Check4 := if\((\Delta_{TL,i} > 0.07 \cdot h_i)\), "Excessive deflection", "OKAY"

**LRFD 14.8.2 Determine if Grade at Center Line of Bearings**

Rate of change of grade =

\[ r := \frac{G_2 - G_1}{L_{vc}} \]

\[ STAPVC := STAPVI - \frac{L_{vc}}{2} \]

Grade at C.L. of brgs. =

\[ G_{CL} := G_i + \left(STABrg - STAPVC\right) \cdot r \]

**LRFD 14.7.6.3.5b Rotation**

The bearing must be capable of resisting the induced rotation due to Final Camber (\( \theta_{DL} \)), Live Load (\( \theta_{LL} \)) and construction inaccuracies to prevent an area of zero stress underneath the bearing. The first step is to determine the maximum rotation that the bearing will experience.

where:

- \( \theta_{DC1} \) = Induced rotation due to highway grade and beam camber
- \( \theta_{LL} \) = Induced live load rotation
- \( \theta_C \) = Estimated rotation due to construction inaccuracies

\[ \theta_{Grade} := \begin{cases} -G_{CL} & \text{if Location = 0} \\ G_{CL} & \text{if Location = 1} \\ 0 & \text{otherwise} \end{cases} \]

\[ \theta_{Camber} := \begin{cases} \frac{2 \cdot \Delta_{final}}{0.5 \cdot L_{span}} & \text{if Location = 0} \\ \frac{2 \cdot \Delta_{final}}{0.5 \cdot L_{span}} & \text{otherwise} \end{cases} \]

\[ \theta_{DC1} := \theta_{Grade} + \theta_{Camber} \]

\[ \theta_{LL} := \frac{2 \cdot \Delta_{LL}}{0.5 \cdot L_{span}} \]
\[ \theta_C := 0.00 \]  
(assumed value based on strict NYSDOT testing and quality control procedures)

\[ \theta_m := |\theta_{DC1} + \theta_{LL}| + \theta_C \]

\[ \theta_m = 0.002 \]

**14.7.6.3.5b Rotation of PEP**

- Rectangular pads shall satisfy:

\[ \sigma \geq 0.5 G S \left( \frac{L}{h_{rt}} \right)^2 \theta_{z,z} \quad \text{and} \quad (14.7.6.3.5b-1) \]

\[ \sigma \geq 0.5 G S \left( \frac{W}{h_{rt}} \right)^2 \theta_{z,z} \quad (14.7.6.3.5b-2) \]

Next, the induced rotation is converted into a stress and compared to the maximum compressive stress.

PEP and steel reinforced Elastomeric bearings are quite flexible in compressive loading, and as a consequence very large strains are tolerated. PEP and steel reinforced Elastomeric bearings are checked for uplift only. LRFD C14.7.6.3.5b

\[ \sigma_{TL_{rot}} := 0.5 G_{max} S \left( \frac{L_{brg}}{h_{rt}} \right)^2 \theta_m \]

LRFD 14.7.6.3.5b

\[ \sigma_{TL_{rot}} = 0.393 \text{MPa} \]

As long as the compressive stress is more than the induced rotational stress, there will not be an area of zero pressure under the bearing.

\[ \text{Check}_5 := \text{if} (\sigma_{TL} \geq \sigma_{TL_{rot}}, "OKAY", "Thicker elastomer needed") \]

**Check for Excessive Strain**

\[ C_d := 0.25 \]  
(Creep deflection)

LRFD Table 14.7.6.2-1

\[ \Delta h_{rt} := \theta_m \frac{L_{brg}}{2} \]

\[ \Delta h_{rt} = 0.27 \text{mm} \]

\[ \varepsilon_{due\_to\_rotation} := \frac{\Delta h_{rt}}{h_{rt}} \]

\[ \varepsilon_{due\_to\_rotation} = 0.011 \]

\[ \varepsilon_{total} := \varepsilon_{due\_to\_rotation} + \left( 1 + C_d \right) \varepsilon_{DC1} + \varepsilon_{LL\_and\_SDL} \]

\[ \varepsilon_{total} = 7.976\% \]

\[ \text{Check}_6 := \text{if} (\varepsilon_{total} \leq 10\%, "OKAY", "Excessive Strain") \]

\[ \text{Check}_6 = "OKAY" \]
Bearing Design Example (Type EP)

**LRFD 14.7.6.3.6 Stability**

To ensure stability, the total thickness of the Elastomer pads and steel laminates is:

\[ T_t := h_n \]

shall not exceed the least of \( \frac{L_{brg}}{3} \) or \( \frac{W_{brg}}{3} \):

\[
\text{Check}_7 := \text{if} \left( T_t \leq \min \left( \frac{L_{brg}}{3}, \frac{W_{brg}}{3} \right) \right) \text{"OKAY"}, \text{"FAILS Stability"}
\]

**Connection of Beam to Substructure**

Reinforcing bar used to connect the beam to the substructure in shear:

\[ \phi_{Anchor\_rod} := 25\text{mm} \]

(25mm Minimum Diameter)

\[ A_{Anchor\_rod} := \pi \frac{\phi_{Anchor\_rod}^2}{4} \]

\[ F_{u\_Anchor\_rod} := 620\text{MPa} \]

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When Threads are excluded in the shear plane,

\[ R_n := 0.6A_{Anchor\_rod}F_{u\_Anchor\_rod} \]

LRFD 6.13.2.7

\[ R_n = 182.605\text{kN} \]

Resistance Factor for reinforcing rod in shear may be conservatively estimated as,

\[ \phi_s := 0.6 \]

LRFD 6.5.4.2

\[ \text{Check}_8 := \text{if} \left( \max \left( 10\% P_{strength, Seismic} \right) \leq \phi_s R_n, \text{"OKAY"}, \text{"Anchor Rod Too Small"} \right) \]

**Compressive Stress on the Concrete Pedestal**

The maximum allowable stress of an Elastomeric pad is less than the maximum allowed stress for concrete. Therefore, it is never necessary to check for overstress of the pedestal in compression under the pad or masonry plate.
Output Required for "Bearing Table"

**Loading**

\[
\text{DC1 + DC2 + DW = 82.7kN} \quad \text{LL = 127.7kN} \quad \text{TL = 210.40 kN} \quad \text{S = 3.722}
\]

**Elastomer Layers**

\[
h_i = 24\text{mm} \quad n = 1 \quad L_{\text{brg}} = 250\text{mm} \quad W_{\text{brg}} = 850\text{mm} \quad h_{rt} = 24\text{mm}
\]

**Areas**

\[
\text{Compressive}_\text{Area} := (L_{\text{brg}})(W_{\text{brg}}) \quad \Rightarrow \quad \text{Compressive}_\text{Area} = 212500\text{mm}^2
\]

\[
\text{Shear}_\text{Area} := W_{\text{brg}}L_{\text{brg}} \quad \Rightarrow \quad \text{Shear}_\text{Area} = 212500.00\text{mm}^2
\]

**Anchor Dowel Diameter**

\[
\phi_{\text{Anchorrod}} = 25\text{mm}
\]

**CODE CHECKS**

\[
\begin{align*}
\text{Check} &= \left( \text{"LRFD S14.7.6.3.4 Shear Deformation Check" OKAY}" \right) \\
&\quad \text{"LRFD S14.7.6.3.2 Compressive Stress Check" OKAY}" \\
&\quad \text{"LRFD C14.7.5.3.3 Joint System Deflection Check" OKAY}" \\
&\quad \text{"LRFD S14.7.6.3.3 Initial Compressive Deflection" OKAY}" \\
&\quad \text{"LRFD S14.7.6.3.5 Rotational Stress Check" OKAY}" \\
&\quad \text{"Total Excessive Strain Check" OKAY}" \\
&\quad \text{"LRFD S14.7.6.3.6 Stability Check" OKAY}" \\
&\quad \text{"Capacity of Connection of Beam to Substructure Check" OKAY}" 
\end{align*}
\]
Appendix 12B
Design Example; Steel Laminated Elastomeric Bearing (Type EL)

Note: Highlighted values on the following pages require user input. This bearing design assumes straight, single span concrete beams and skews below 30 degrees. Modification to accommodate alternate bearing designs is at the user's discretion. Enclosed information based on the 2007 AASHTO LRFD Bridge Design Specifications. The designer is responsible for the final design.

Enter known data:
(A "***" indicates typical conditions and may not require changing.)

<table>
<thead>
<tr>
<th>Superstructure Properties:</th>
<th>Bearing Data:</th>
</tr>
</thead>
<tbody>
<tr>
<td>L&lt;sub&gt;span&lt;/sub&gt; := 21 m</td>
<td>L&lt;sub&gt;brg&lt;/sub&gt; := 200 mm (Parallel to Girder)</td>
</tr>
<tr>
<td>Δ&lt;sub&gt;LL&lt;/sub&gt; := 20 mm</td>
<td>W&lt;sub&gt;brg&lt;/sub&gt; := 850 mm (Perpendicular to Girder)</td>
</tr>
<tr>
<td>LL&lt;sub&gt;hl93&lt;/sub&gt; := 143.233kN</td>
<td>T&lt;sub&gt;STABrg&lt;/sub&gt; := 24018.11r (Center line of bearing)</td>
</tr>
<tr>
<td>DC1 := 186.825kN</td>
<td>Location := 1 (Location of bearing on span, 0 for begin or 1 for end)</td>
</tr>
<tr>
<td>DC2 := 16.458kN</td>
<td>n := 3 (Number of internal layers, do not include exterior layers)</td>
</tr>
<tr>
<td>DW := 13.345kN</td>
<td>h&lt;sub&gt;i&lt;/sub&gt; := 12 mm (Elastomer layer thickness)</td>
</tr>
<tr>
<td>D := 840 mm</td>
<td>Dia := 50mm (Hole diameter for anchor rod)</td>
</tr>
<tr>
<td>Δ&lt;sub&gt;initial&lt;/sub&gt; := 28mm</td>
<td>(Initial Camber)</td>
</tr>
<tr>
<td>Δ&lt;sub&gt;final&lt;/sub&gt; := 18 mm</td>
<td>(Final Camber)</td>
</tr>
<tr>
<td>P := 7300kN</td>
<td>(Total Prestress Force)</td>
</tr>
<tr>
<td>E := 34474MPa</td>
<td>(Beam Concrete Modulus of Elasticity)</td>
</tr>
<tr>
<td>A := 485160mm&lt;sup&gt;2&lt;/sup&gt;</td>
<td>(Cross-Sectional Beam Area)</td>
</tr>
<tr>
<td>Seismic := 0 kN</td>
<td>(Maximum horizontal Seismic Load)</td>
</tr>
<tr>
<td>Δ&lt;sub&gt;ES&lt;/sub&gt; := 13.93 mm</td>
<td>(Beam Shortening, taken from CONSPAN)</td>
</tr>
<tr>
<td>Δ&lt;sub&gt;CS&lt;/sub&gt; := 48.48MPa</td>
<td>(Final Concrete Shrinkage Losses, taken from CONSPAN)</td>
</tr>
<tr>
<td>Δ&lt;sub&gt;creep&lt;/sub&gt; := 91.71 MPa</td>
<td>(Final Concrete Creep Losses, taken from CONSPAN)</td>
</tr>
<tr>
<td>Δ&lt;sub&gt;elastic_shortening&lt;/sub&gt; := 99.73MPa</td>
<td>(Initial Total Prestress Losses, taken from CONSPAN)</td>
</tr>
</tbody>
</table>

Vertical Curve Data:
(if no VC exist then enter "0" for L<sub>vc</sub> AND STAPVI) (if VC, verify that bearing falls within limits otherwise "no VC")

| G<sub>1</sub> := 3.0% | (Start Grade) |
| G<sub>2</sub> := 3.0% | (End Grade) |
| L<sub>vc</sub> := 30.4 m | (VC length) |
| STAPVI := 24018.2m | (PVI Station) |

January 2008
Thermal Conditions:
(AASHTO 'Cold Climate' Zone 'C', LRFD Table 3.12.2.1-1 - Regions 10 and 11 are in 'Moderate Climate' zone)

For concrete girder bridges with concrete decks.

\[ T_{\text{high}} := 27 \degree C \]
\[ T_{\text{low}} := -18 \degree C \]
\[ \alpha := 10.8 \times 10^{-6} \frac{1}{\degree C} \]

Temperature range
Concrete coefficient of thermal expansion

Total Loading:

\[ LL := L_{\text{hl}93} \]
\[ TL := DC1 + DC2 + DW + LL \]
\[ SDL := DC2 + DW \]
\[ P_{\text{strength},1} := 1.25(\text{DC1} + \text{DC2}) + 1.50\text{DW} + 1.75L_{\text{hl}93} \]
\[ P_{\text{strength}} := P_{\text{strength},1} \]

Max. live load
Service I limit state no impact
Unfactored Dead Load on composite section
Strength I limit state (no impact)

\[ LL = 143.233kN \]
\[ TL = 359.861kN \]
\[ SDL = 29.803kN \]
\[ P_{\text{strength},1} = 524.779kN \]
\[ P_{\text{strength}} = 524.779kN \]

**LRFD 14.7.5.1 Shape Factor**

\[ S := \frac{L_{\text{brg}} W_{\text{brg}} - \frac{\pi}{4} \cdot \text{Dia}^2}{h_1 \left( 2L_{\text{brg}} + 2W_{\text{brg}} + \pi \cdot \text{Dia} \right)} \]

\[ S = 6.20 \]
**LRFD 3.12.2.1 Movements**

**Temperature Range to Determine Design Movement**

Expansion: \( \Delta_{\text{Exp}} := \alpha \cdot L_{\text{span}} (T_{\text{high}} - 20^\circ\text{C}) \)  
Contraction: \( \Delta_{\text{Cont}} := \alpha \cdot L_{\text{span}} (20^\circ\text{C} - T_{\text{low}}) \)  

\( \Delta_{\text{Exp}} = 1.588\text{mm} \)  
\( \Delta_{\text{Cont}} = 8.618\text{mm} \)

**Movement Due to Camber Release, \( \Delta_{\text{CR}} \)**

Change in Camber = \( C := \Delta_{\text{initial}} - \Delta_{\text{final}} \)  
\( C = 10\text{mm} \)

**Deflect := "One end is free to deflect"**

\( \Delta_{\text{CR}} := \begin{cases} 4 \cdot C \cdot D \cdot L_{\text{span}} & \text{if Deflect = "One end is free to deflect"} \\ 2 \cdot C \cdot D \cdot L_{\text{span}} & \text{if Deflect = "Both ends are free to deflect"} \end{cases} \)  

**Movement Due to Concrete Shrinkage, and Creep:**

Assume \( \% \text{ of Shrinkage, and Creep at Installation} = \%_{\text{shrinkageAndCreep}} := 50\% \)

\( \Delta_{\text{CSandCREEP}} := \left( \frac{\Delta_{S} + \Delta_{\text{creep}}}{\Delta_{\text{elastic_shortening}}} \right) \cdot \Delta_{E} \)  
\( \Delta_{\text{CSandCREEP}} = 9.791\text{mm} \)

In order to approximate bearing movements due to concrete shrinkage and creep combined, it is first assumed that half of these losses have occurred prior to beam erection. Then, a ratio is calculated based on the known movements caused by initial losses (elastic shortening) and multiplied by half the predicted final shrinkage and creep losses to determine the approximated movement caused by shrinkage and creep after the beam has been erected.

**Total Movement**

\( \Delta_{\text{S\_expansion}} := \Delta_{\text{Exp}} + \Delta_{\text{CR}} - \Delta_{\text{CSandCREEP}} \)  
\( \Delta_{\text{S\_contraction}} := \Delta_{\text{Cont}} - \Delta_{\text{CR}} + \Delta_{\text{CSandCREEP}} \)  

\( \Delta_{\text{S\_expansion}} = -6.604\text{mm} \)  
\( \Delta_{\text{S\_contraction}} = 16.81\text{mm} \)

**LRFD 14.7.5.3.4 Shear Deformation**

\( h_{\text{f}} \geq 2 \cdot \Delta_{\text{service}} \)

\( \gamma_{\text{tu}} := 1.2 \)  
For service limit state

\( \Delta_{\text{service}} = \gamma_{\text{tu}} \Delta_{\text{S\_expansion or contraction}} \)

\( t_{\text{req}} := \left( \gamma_{\text{tu}} \cdot 2 \cdot \max(\left| \Delta_{\text{S\_expansion}} \right|, \left| \Delta_{\text{S\_contraction}} \right|) \right) \)

\( h_{\text{f}} := (n + 1) \cdot h_{i} \)

Check \( t_{\text{req}} \) := if \( t_{\text{req}} \leq h_{\text{f}}, \text{"OKAY"}, \text{"Increase number of layers"} \)
**NYSDOT Bridge Manual**

**LRFD 14.7.6.2 Material Properties**

All Elastomer shall be 50 Durometer hardness on the Shore A scale (BD-BG-R1)

Base Value of Shear Modulus of Elastomer

Assuming a Hardness of "50"

\[ G := 0.66 \text{MPa} \]

\[ G_{\text{max}} := 0.9 \text{MPa} \]

**LRFD 14.7.6.3.2 Compressive Stress**

Compare allowable to applied compressive stress:

\[ \sigma_{\text{TL}} := \frac{\sigma_{\text{TL}}}{L_{\text{brg}} W_{\text{brg}} \cdot \frac{\pi}{4} \cdot \text{Dia}^2} \]

\[ \sigma_{\text{TL}} = 2.142 \text{MPa} \]

Check2 := "OKAY" if \( \sigma_{\text{TL}} \leq 7 \text{MPa} \) \( \wedge \) \( \sigma_{\text{TL}} \leq 1.0 \cdot G \)

Check2 = "OKAY"

**LRFD 14.7.6.3.3 Compressive Deflection**

Find Compressive Strain From AASHTO Fig. 14.6.5.3.3-1

Must comply with section 14.7.5.3.3:

\[ \Delta = \Sigma \varepsilon \cdot h_{\text{lf}} \text{ considered for both total and live loads, and} \]

\[ \Delta < or = 0.07 h_{\text{lf}} \text{ for any layer} \]

Refer to Figure 3- C1 of Section C14.7.5.3.3 to obtain values of \( \varepsilon \) & input below:

\[ \sigma_{\text{TL}} := \frac{\sigma_{\text{TL}}}{L_{\text{brg}} W_{\text{brg}} \cdot \frac{\pi}{4} \cdot \text{Dia}^2} \]

\[ \sigma_{\text{TL}} = 2.142 \text{MPa} \]

\[ \varepsilon_{\text{TL}} := \varepsilon(\sigma_{\text{TL}}, S) = 0.018 \]

\[ \sigma_{\text{DC1}} := \frac{\sigma_{\text{DC1}}}{L_{\text{brg}} W_{\text{brg}} \cdot \frac{\pi}{4} \cdot \text{Dia}^2} \]

\[ \sigma_{\text{DC1}} = 1.112 \text{MPa} \]

\[ \varepsilon_{\text{DC1}} := \varepsilon(\sigma_{\text{DC1}}, S) = 9.199 \times 10^{-3} \]

\[ \sigma_{\text{LL}} := \frac{\sigma_{\text{LL}}}{L_{\text{brg}} W_{\text{brg}}} \]

\[ \sigma_{\text{LL}} = 0.843 \text{MPa} \]

\[ \varepsilon_{\text{LLandSDL}} := \varepsilon_{\text{TL}} - \varepsilon_{\text{DC1}} \]

\[ \varepsilon_{\text{LLandSDL}} = 8.863 \times 10^{-3} \]

Compressive Deflection of the bearing due to total loading:

\[ \Delta_{\text{TL}} := \varepsilon_{\text{TL}} \cdot h_{\text{lf}} \]

\[ \Delta_{\text{TL}} = 0.87 \text{mm} \]

Limiting instantaneous deflection is important to ensure that deck joints and seals are not damaged. Furthermore, bearings that are too flexible in compression could cause a small step in the road surface at deck joint when traffic passes from one girder to the other, giving rise to impact loading. A maximum relative deflection across a joint of 3 mm is suggested.  

LRFD C14.7.5.3.3
Bearing Design Example (Type EL)

\[ \Delta_{LLandSDL} := \varepsilon_{LLandSDL} \cdot h_i \]

\[ \text{Check}_3 := \text{if} \left( \Delta_{LLandSDL} \leq 3 \text{mm} \right) \text{"OKAY"}, \text{"Excessive deflection"} \]

The initial compressive deflection of PEP or in any layer of steel-reinforced Elastomeric bearing at the service limit without impact shall not exceed 0.07 \( h_i \) \cite{LRFD 14.7.6.3.3}.

\[ \Delta_{TL,i} := \varepsilon_{TL} \cdot h_i \]

\[ \text{Check}_4 := \text{if} \left( \Delta_{TL,i} > 0.07 \cdot h_i \right) \text{"Excessive deflection"}, \text{"OKAY"} \]

LRFD 14.8.2 Tapered Plates (Determine if Internal Plate Must be Beveled) (function of grade and final camber)

\[ r := \frac{G_2 - G_1}{L_{vc}} \]

\[ r = 0 \text{ mm} \]

\[ \text{STA}_{PVC} = 24003 \text{m} \]

\[ \text{G}_{CL} = 3.0\% \]

January, 2008
Req'd thickness change due to grade = \( t_{\%} = \left| \frac{G_{CL} \cdot L_{brg}}{m} \right| \)

\( \theta_{Camber} := \begin{cases} 0, & \text{Location } = 0, \\ \frac{2 \cdot A_{final}}{0.5 \cdot L_{span}}, & \frac{2 \cdot A_{final}}{0.5 \cdot L_{span}} \end{cases} \)

Req'd thickness change due to camber = \( S_{camber} := \theta_{Camber} \cdot L_{brg} \)

The top internal steel shim must be beveled if the grade at the bearing is greater than 1.0% from horizontal, or the total thickness change is greater than or equal to 3 mm. Due to machining limitations, the minimum beveled laminate thickness = 6 mm. \( S_2 \) below accounts for additional thickness required, if any, for vertical curve and beam camber.

\[ S_1 := \begin{cases} 1 \cdot \% + S_{camber} \geq 3 \text{mm}, 6\text{mm}, 3\text{mm} \end{cases} \]

\[ S_2 := \begin{cases} 1 \cdot \% + S_{camber} \geq 3 \text{mm}, S_{camber} + t_{\%} + S_1, S_1 \end{cases} \]

\( S_1 = 6 \text{mm} \)

\( S_2 = 11.314 \text{mm} \)

**LRFD 14.7.6.3.5d Rotation**
Bearing Design Example (Type EL)

The bearing must be capable of resisting the induced rotation due to Final Camber ($\theta_{DL}$), Live Load ($\theta_{LL}$), and construction inaccuracies to prevent an area of zero stress underneath the bearing. The first step is to determine the maximum rotation that the bearing will experience. The Final Camber rotation is zero if the bearing has a beveled top internal laminate. Otherwise, the rotations due to Final Camber must be included.

where:  
- $\theta_{DC1}$ = Induced rotation not accounted for by beveled internal laminate  
  (if beveled internal shim is used, $\theta_{DC1} = 0$)  
- $\theta_{LL}$ = Induced live load rotation  
- $\theta_{C}$ = Estimated rotation due to construction inaccuracies

$$
\theta_{DC1} := \begin{cases} 
\theta_{Camber} & \text{if Location} = 0 \text{ if } S_1 = S_2 \\
-G_{CL} & \text{if Location} = 1 \\
0 & \text{otherwise}
\end{cases}
$$

$$
\theta_{DC1} = 0.000
$$

$$
\theta_{LL} := \frac{2\cdot\Delta_{LL}}{0.5\cdot L_{span}}
$$

$$
\theta_{LL} = 0.004
$$

$$
\theta_{C} := 0.002 \quad \text{(assumed value based on strict NYSDOT testing and quality control procedures)}
$$

$$
\theta_m := |\theta_{DC1} + \theta_{LL}| + \theta_{C} = 0.006
$$

Next, the induced rotation is converted into a stress and compared to the maximum compressive stress.

$$
\sigma_{TL,\text{rot}} := \frac{0.5 \cdot G_{\text{max}} \cdot S \cdot \left( \frac{L_{\text{brg}}}{h_{i}} \right)^2 \cdot \theta_{m}}{n + 1} \quad LRFD 14.7.6.3.5d \quad \sigma_{TL,\text{rot}} = 1.126 \text{MPa}
$$

As long as the compressive stress is more that the induced rotational stress, there will not be an area of zero pressure under the bearing.

$$
\text{Check}_5 := \text{if} \left( \sigma_{TL} \geq \sigma_{TL,\text{rot}} \right. \text{, "OKAY", "More elastomer layers needed" } \right) \quad \text{Check}_5 = "\text{OKAY}" \quad LRFD 14.7.6.2-1
$$

Check for Excessive Strain

$$
C_d := 0.25 \quad \text{(Creep deflection)}
$$

$$
\Delta h_{rt} := \theta_m \cdot \frac{L_{\text{brg}}}{2}
$$

$$
\varepsilon_{\text{due to rotation}} := \frac{\Delta h_{rt}}{h_{rt}}
$$

$$
\varepsilon_{\text{total}} := \varepsilon_{\text{due to rotation}} + \left( 1 + C_d \right) \cdot \varepsilon_{DC1} + \varepsilon_{LL\text{andSDL}}
$$

$$
\text{Check}_6 := \text{if} \left( \varepsilon_{\text{total}} \leq 10\% \text{, "OKAY", "Excessive Strain" } \right) \quad \text{Check}_6 = "\text{OKAY}" \quad LRFD 14.7.6.3.6 Stability
$$

To ensure stability, the total thickness of the elastomer pads and steel laminates is:

$$
T_t := (n + 1) \cdot h_{i} + \left[ S_1 \leq S_2, 3\text{mm}(n + 1), 3\text{mm}h_{i} + \frac{S_1 + S_2}{2} \right] \quad T_t = 65.657\text{mm}
$$
Shall not exceed the least of $L_{brg}/3$ or $W_{brg}/3$:

\[
\text{Check}_7 := \text{if} \left( T_1 \leq \min \left( \frac{L_{brg}}{3}, \frac{W_{brg}}{3} \right) \right) \quad \text{OKAY}, \\text{"FAILS Stability"}
\]

**LRFD 14.7.6.3.7 Reinforcement**

\[ h_{\text{max}} := h_i \]

For Service Limit State:

\[ h_{\text{steel req str}} := \frac{3h_{\text{max}} \cdot \sigma_{TL}}{F_{y_{\text{internal}}}} \]

\[ \text{Check}_8 := \text{if} \left( h_{\text{steel req str}} \leq 3\text{mm, "OKAY", "Steel Reinforcement Too Thin"} \right) \quad \text{OKAY} \]

For Fatigue Limit State:

\[ \Delta F_{TH} := 165\text{MPa} \]

\[ h_{\text{steel req ftg}} := \frac{2h_{\text{max}} \cdot \sigma_{LL}}{\Delta F_{TH}} \]

\[ \text{Check}_9 := \text{if} \left( h_{\text{steel req ftg}} \leq 3\text{mm, "OKAY", "Steel Reinforcement Too Thin"} \right) \quad \text{OKAY} \]

**LRFD 14.8.3.1 Anchorage and Anchor Bolts - Masonry Plate Anchor Bolts**

Reinforcing bar used to connect the beam to the substructure in shear:

\[ \phi_{\text{Anchor rod}} := 30\text{mm} \quad \text{(24mm Minimum Diameter)} \]

\[ A_{\text{Anchor rod}} := \frac{\phi_{\text{Anchor rod}}^2}{4} \]

\[ F_{u_{\text{Anchor rod}}} := 620\text{MPa} \quad \text{ASTM A615 GRADE 420} \]

When Threads are excluded in the shear plane,

\[ R_n := 0.6A_{\text{Anchor rod}} F_{u_{\text{Anchor rod}}} \quad \text{LRFD 6.13.2.7} \]

\[ R_n = 59.114\text{kip} \]

Resistance Factor for reinforcing rod in shear may be conservatively estimated as,

\[ \phi_s := 0.6 \]

\[ \text{Check}_{10} := \text{if} \left( \max \left( 10\%P_{\text{strength, Seismic}} \right) \leq \phi_s R_n, "OKAY", "Anchor Rod Too Small" \right) \quad \text{OKAY} \]

**Compressive Stress on the Concrete Pedestal**

The maximum allowable stress of an elastomeric pad is less than the maximum allowed stress for concrete. Therefore, it is never necessary to check for overstress of the pedestal in compression under the pad or masonry plate.
**Output Required for "Bearing Table"**

**Loading**

\[ \text{DC1} + \text{DC2} + \text{DW} = 216.6\text{kN} \quad \text{LL} = 143.2\text{kN} \quad \text{TL} = 359.861\text{kN} \quad S = 6.204 \]

**Elastomer Layers**

\[ h_1 = 12\text{mm} \quad n = 3 \quad L_{\text{brg}} = 200\text{mm} \quad W_{\text{brg}} = 850\text{mm} \quad h_{\text{rt}} = 48\text{mm} \]

**Areas**

\[ \text{Compressive\_Area} := (L_{\text{brg}} - 6\text{mm}) \cdot (W_{\text{brg}} - 6\text{mm}) \quad \Rightarrow \quad \text{Compressive\_Area} = 163736\text{mm}^2 \]

\[ \text{Shear\_Area} := W_{\text{brg}} \cdot L_{\text{brg}} \quad \Rightarrow \quad \text{Shear\_Area} = 170000.00\text{mm}^2 \]

**Beveled Steel Shim**

\[ S_1 = 6\text{mm} \quad S_2 = 11\text{mm} \]

**Anchor Dowel Diameter**

\[ \phi_{\text{Anchor\_rod}} = 30\text{mm} \]

**CODE CHECKS**

\[ \text{Check} = \left\{ \begin{array}{ll} "\text{Shear Deformation Check}" & "\text{OKAY}" \\ "\text{Compressive Stress Check}" & "\text{OKAY}" \\ "\text{Joint System Deflection Check}" & "\text{OKAY}" \\ "\text{Initial Compressive Deflection}" & "\text{OKAY}" \\ "\text{Rotational Stress Check}" & "\text{OKAY}" \\ "\text{Total Excessive Strain Check}" & "\text{OKAY}" \\ "\text{Stability Check}" & "\text{OKAY}" \\ "\text{Reinforcement for Strength limit State Check}" & "\text{OKAY}" \\ "\text{Reinforcement for Fatigue limit State Check}" & "\text{OKAY}" \\ "\text{Capacity of Connection of Beam to Substructure Check}" & "\text{OKAY}" \end{array} \right. \]
Appendix 12C
Design Example; Steel Laminated Elastomeric Bearing with Sole Plate - Fixed (Type EB)

Note: Highlighted values on the following pages require user input. This bearing design assumes straight, single span steel beams and skews below 30 degrees. Modification to accommodate alternate bearing designs is at the user's discretion. Enclosed information based on the 2007 AASHTO LRFD Bridge Design Specifications. The designer is responsible for the final design. Elastomeric bearings shall be designed using Method A. B.M 12.2.1

Enter known data:
(A *** indicates typical conditions and may not require changing.)

Superstructure Properties:

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{\text{span}}$</td>
<td>25.900 m</td>
</tr>
<tr>
<td>$\Delta_{\text{LL}}$</td>
<td>25.4 mm</td>
</tr>
<tr>
<td>$L_{\text{hl93}}$</td>
<td>333.617 kN</td>
</tr>
<tr>
<td>$D_{\text{C1}}$</td>
<td>280.238 kN</td>
</tr>
<tr>
<td>$D_{\text{C2}}$</td>
<td>35.586 kN</td>
</tr>
<tr>
<td>$D_{\text{W}}$</td>
<td>35.586 kN</td>
</tr>
<tr>
<td>$w_{\text{bf}}$</td>
<td>305 mm</td>
</tr>
<tr>
<td>$F_{u_{\text{girder}}}$</td>
<td>450 MPa</td>
</tr>
<tr>
<td>Seismic</td>
<td>0 kN</td>
</tr>
</tbody>
</table>

Bearing Data:

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{\text{brg}}$</td>
<td>350 mm</td>
</tr>
<tr>
<td>$W_{\text{brg}}$</td>
<td>450 mm</td>
</tr>
<tr>
<td>$n$</td>
<td>5</td>
</tr>
<tr>
<td>Location</td>
<td>0</td>
</tr>
<tr>
<td>$h_{s}$</td>
<td>3 mm</td>
</tr>
<tr>
<td>$F_{Y}$</td>
<td>345 MPa</td>
</tr>
<tr>
<td>$STAB_{\text{brg}}$</td>
<td>63916.189 m</td>
</tr>
<tr>
<td>$h_{i}$</td>
<td>12 mm</td>
</tr>
</tbody>
</table>

Vertical Curve Data:

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$G_{1}$</td>
<td>1.3%</td>
</tr>
<tr>
<td>$G_{2}$</td>
<td>1.3%</td>
</tr>
<tr>
<td>$L_{\text{VC}}$</td>
<td>0 m</td>
</tr>
<tr>
<td>$STA_{\text{PVI}}$</td>
<td>63916.189 m</td>
</tr>
</tbody>
</table>

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Total Loading:

\[
\text{LL} := \text{LL}_{hl93} \\
\text{TL} := \text{DC1} + \text{DC2} + \text{DW} + \text{LL} \\
\text{SDL} := \text{DC2} + \text{DW} \\
\text{P}_{\text{strength,1}} := 1.25(\text{DC1} + \text{DC2}) + 1.5(\text{DW}) + 1.75\text{LL}_{hl93} \\
\text{P}_{\text{strength}} := \text{P}_{\text{strength,1}}
\]

Max. live load
Service I limit state no impact
Unfactored Dead Load on composite section
Strength I limit state no impact

\[
\text{LL} = 333.617\text{kN} \\
\text{TL} = 685.027\text{kN} \\
\text{SDL} = 71.172\text{kN} \\
\text{P}_{\text{strength,1}} = 1032\text{kN} \\
\text{P}_{\text{strength}} = 1032\text{kN}
\]

LRFD 14.7.5.1 Shape Factor

\[
S := \frac{L_{\text{brg}}W_{\text{brg}}}{2h_i(L_{\text{brg}} + W_{\text{brg}})}
\]

\[
S = 8.20
\]

Note: The above method calculates the Shape Factor for elastomeric bearings without holes. Fixed laminated elastomeric bearings with external load plates have a vertical steel pin tightly pressed into a hole to prevent translation. The effect of the pin hole on the Shape Factor may be ignored since the area of the pin is a small percentage of the pad area, and the elastomer cannot bulge in the hole due to the tight fit pin.

LRFD 3.12.2.1 Movements

The amount of movement of the bearing due to camber release of the beams shall be ignored. The specification requires that the Contractor reset the bearings to the neutral position prior to attaching the bearings to the beams.
LRFD 14.7.6.2 Material Properties

All Elastomer shall be 50 durometer hardness on the Shore A scale  BD-BG-R1

Base Value of Shear Modulus of Elastomer

Assuming a Hardness of "50" ======> LRFD Table 14.7.5.2-1

\[ G := 0.66 \text{ MPa} \]

\[ G_{\text{max}} := 0.90 \text{ MPa} \]

LRFD 14.7.6.3.2 Compressive Stress

Compare allowable to applied compressive stress:

\[ \sigma_{\text{TL}} := \frac{\text{TL}}{L_{\text{brg}} \cdot W_{\text{brg}}} \]

\[ \sigma_{\text{TL}} = 4.349 \text{ MPa} \]

\[ \text{Check}_1 := \begin{cases} \text{"OKAY"} & \text{if } \sigma_{\text{TL}} \leq 7 \text{ MPa} \land \sigma_{\text{TL}} \leq 1.1 \cdot G \\ \text{"FAILS"} & \text{otherwise} \end{cases} \]

\[ \text{Check}_1 = \text{"OKAY"} \]

Since this is a Type E.B. bearing, it is necessary to check the minimum compressive stress due to dead load and superimposed dead loads only:

\[ \sigma_{\text{min}} := \frac{\text{DC1} + \text{SDL}}{L_{\text{brg}} \cdot W_{\text{brg}}} \]

\[ \sigma_{\text{min}} = 2.231 \text{ MPa} \]

\[ \text{Check}_2 := \begin{cases} \text{"OKAY"} & \text{if } \sigma_{\text{min}} \geq 1.4 \text{ MPa} \\ \text{"Minimum compression not met"} & \text{otherwise} \end{cases} \]

\[ \text{Check}_2 = \text{"OKAY"} \]

LRFD 14.7.6.3.3 Compressive Deflection

Find Compressive Strain From LRFD Fig. C14.7.5.3.3-1

Must comply with section 14.7.5.3.3:

\[ \Delta = \sum \varepsilon_i h_{ri} \text{ considered for both total and live loads, and} \]

\[ \Delta < \text{or} = 0.07 h_{ri} \text{ for any layer} \]

Refer to Figure3- C1 of Section C14.7.5.3.3 to obtain values of \( \varepsilon_i \) & input below:

\[ \sigma_{\text{TL}} := \frac{\text{TL}}{L_{\text{brg}} \cdot W_{\text{brg}}} \quad \Rightarrow \quad \sigma_{\text{TL}} = 4.349 \text{ MPa} \quad \Rightarrow \quad \varepsilon_{\text{TL}} := \varepsilon(\sigma_{\text{TL}}, S) = \varepsilon_{\text{TL}} = 0.032 \]

\[ \sigma_{\text{DC1}} := \frac{\text{DC1}}{L_{\text{brg}} \cdot W_{\text{brg}}} \quad \Rightarrow \quad \sigma_{\text{DC1}} = 1.779 \text{ MPa} \quad \Rightarrow \quad \varepsilon_{\text{DC1}} := \varepsilon(\sigma_{\text{DC1}}, S) = \varepsilon_{\text{DC1}} = 0.013 \]

\[ \sigma_{\text{LL}} := \frac{\text{LL}}{L_{\text{brg}} \cdot W_{\text{brg}}} \quad \Rightarrow \quad \sigma_{\text{LL}} = 2.118 \text{ MPa} \quad \varepsilon_{\text{LL and SDL}} := \varepsilon_{\text{TL}} - \varepsilon_{\text{DC1}} \quad \varepsilon_{\text{LL and SDL}} = 0.018 \]
Deflection of the bearing due to total loading:

\[ \Delta_{TL} := \varepsilon_{TL} \cdot h_{rt} \]

Limiting instantaneous deflection is important to ensure that deck joints and seals are not damaged. Furthermore, bearings that are too flexible in compression could cause a small step in the road surface at deck joint when traffic passes from one girder to the other, giving rise to impact loading. A maximum relative deflection across a joint of 3 mm is suggested. LRFD C14.7.5.3.3

\[ \Delta_{LL\text{andSDL}} := \varepsilon_{LL\text{andSDL}} \cdot h_{rt} \]

Check 3 := if \( \left( \Delta_{LL\text{andSDL}} \leq 3\text{mm} \right) \), "OKAY", "Excessive deflection"

The initial compressive deflection of PEP or in any layer of steel-reinforced elastomeric bearing at the service limit without impact shall not exceed 0.07 \( h_i \). LRFD 14.7.6.3.3

\[ \Delta_{TL_i} := \varepsilon_{TL_i} \cdot h_i \]

Check 4 := if \( \left( \Delta_{TL_i} > 0.07 \cdot h_i \right) \), "Excessive deflection", "OKAY"

Determine Sole Plate Dimensions
Bearing Design Example (Type EB - Fixed)

Length => \( L_s := \text{Ceil}\left(\left( L_{brg} + 26\text{mm}\right), 5\text{mm}\right) \)

\( L_s = 380\text{mm} \)

Width => \( W_s := \text{Ceil}\left(\left( \max(W_{brg}, W_{bf}) + 26\text{mm}\right), 5\text{mm}\right) \)

\( W_s = 480\text{mm} \)

Minimum Thickness of Sole Plate

Assume the plate between the beam and the bearing is fully supported (i.e., no distortion allowed). The only length free to bend is the length that is being loaded by the bearing and not supported by the beam.

\[
\phi_b := 0.9
\]

\[
OH := \frac{|W_{bf} - W_{brg}|}{2}
\]

\[
t_{\text{min}} := OH \sqrt{\frac{2 \cdot P_{\text{strength}}}{\phi_b \cdot F_y \cdot L_{brg} \cdot W_{brg}}}
\]

\[
T_1 := \text{if} \left( t_{\text{min}} < 40\text{mm} \right) \right \} \left( 40\text{mm}, t_{\text{min}} \right)\]

**Resistance Factor for Bending**

**AISC FACTOR**

\( OH = 72.5\text{mm} \)

\( t_{\text{min}} = 14.9\text{mm} \)

\( T_1 = 40\text{mm} \)

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LRFD 14.8.2 Tapered Plates (Determine if Sole Plate Must be Beveled)

Rate of change of grade = \( r := \frac{G_2 - G_1}{L_{vc}} \)

\[
STAPVC := STAPVI - \frac{L_{vc}}{2}
\]

Grade at C.L. of brgs. = \( G_{CL} := G_i + \left( STABrg - STAPVC \right) r \)

Req'd thickness change = \( t\% := |G_{CL} L_s| \)

The sole plate must be beveled if the rate of change at the bearing is greater than 1%, or the total thickness change is greater than or equal to 3mm. \( T_2 \), below is the indicated bevel treatment:

\[
T_2 := \text{if} \left( |G_{CL}| \geq 1\% \lor t\% \geq 3\text{mm}, T_1 + t\%, T_1 \right)
\]

\[
T_1 = 40\text{mm} \quad T_2 = 45\text{mm}
\]

LRFD 14.7.6.3.5d Rotation

The bearing must be capable of resisting the induced rotation due to live load and construction inaccuracies to prevent an area of zero stress underneath the bearing. The first step is to determine the maximum rotation that the bearing will experience.

where: \( \theta_{DC1} = \) Induced dead load rotation not accounted for by beveled sole plate

\( \theta_{LL} = \) Induced live load rotation

\( \theta_C = \) Estimated rotation due to construction inaccuracies

Induced dead load rotation not accounted for by a beveled sole plate will reduce or increase rotation towards the midspan depending on the bearing location and grade.

\[
\theta_{DC1} := \begin{cases} 
T_1 = T_2 & \theta_{DC1} = 0.000 \\
- G_{CL} & \text{if Location } = 0 \land G_{CL} < 0 \\
G_{CL} & \text{if Location } = 1 \land G_{CL} > 0 \\
- G_{CL} & \text{if Location } = 0 \land G_{CL} > 0 \\
G_{CL} & \text{if Location } = 1 \land G_{CL} < 0 \\
0 & \text{otherwise} \\
0 & \text{otherwise}
\end{cases}
\]

\[
\theta_{LL} := \frac{2 \Delta_{LL}}{0.5 L_{span}} \quad \theta_{LL} = 0.004
\]

\[
\theta_C := 0.00; \quad \text{(assumed value based on strict NYSDOT testing and quality control procedures)}
\]

\[
\theta_m := |\theta_{DC1} + \theta_{LL}| + \theta_C \quad \theta_m = 0.006
\]
Next, the induced rotation is converted into a stress and compared to the maximum compressive stress.

\[
\sigma_{\text{TL}_{\text{rot.transverse}}} := \frac{0.5 \cdot G_{\text{max}} \cdot S}{n} \left( \frac{L_{\text{brg}}}{h_i} \right)^2 \cdot \theta_m
\]

\[
\sigma_{\text{TL}_{\text{rot.transverse}}} = 3.72 \text{MPa}
\]

The service rotation due to the total load about longitudinal axis is negligible compared to the service rotation about the transverse axis. Therefore, the check about the longitudinal axis will be assumed to be negligible and is not computed in this bearing design example.

As long as the compressive stress is more that the induced rotational stress, there will not be an area of zero pressure under the bearing.

\[
\text{Check}_5 := \text{if} \left( \sigma_{\text{TL}} \geq \sigma_{\text{TL}_{\text{rot.transverse}}} \right. \left. \text{"OKAY"}, \text{"More elastomer layers needed"} \right)
\]

\[
\text{Check}_5 = \text{"OKAY"}
\]

**Check for Excessive Strain**

\[
\Delta h_{rt} := \frac{\theta_m \cdot L_{\text{brg}}}{2}
\]

\[
\Delta h_{rt} = 1.036 \text{mm}
\]

\[
\varepsilon_{\text{due.to.rotation}} := \frac{\Delta h_{rt}}{h_{rt}}
\]

\[
\varepsilon_{\text{due.to.rotation}} = 0.017
\]

\[
\varepsilon_{\text{total}} := \varepsilon_{\text{due.to.rotation}} + (1 + 0.25) \cdot \varepsilon_{\text{DC1}} + \varepsilon_{\text{LLandSDL}}
\]

\[
\varepsilon_{\text{total}} = 5.226\%
\]

\[
\text{Check}_6 := \text{if} \left( \varepsilon_{\text{total}} \leq 10 \% \right. \left. \text{"OKAY"}, \text{"Excessive Strain"} \right)
\]

\[
\text{Check}_6 = \text{"OKAY"}
\]

**AASHTO 14.7.6.3.6 Stability**

To ensure stability, the total thickness of the elastomer pads and steel laminates is

\[
T_t := n \cdot h_i + (n - 1) \cdot h_s
\]

\[
T_t = 72 \text{mm}
\]

Shall not exceed the least of \( \frac{L_{\text{brg}}}{3} \) or \( \frac{W_{\text{brg}}}{3} \):

\[
\text{Check}_7 := \text{if} \left( T_t \leq \min \left( \frac{L_{\text{brg}}}{3}, \frac{W_{\text{brg}}}{3} \right) \right. \left. \text{"OKAY"}, \text{"FAILS Stability"} \right)
\]

\[
\text{Check}_7 = \text{"OKAY"}
\]
AASHTO 14.7.6.3.7 Reinforcement

\[ h_{\text{max}} := h_i \]

For Service Limit State:

\[ h_{\text{steel req str}} := \frac{3 \cdot h_{\text{max}} \cdot \sigma_{\text{TL}}}{F_y} \]

Check\(_8 := \text{if}(h_{\text{steel req str}} \leq h_s, "OKAY", "Steel Reinforcement Too Thin") \]

For Fatigue Limit State:

\[ \Delta F_{\text{TH}} := 165 \text{MPa} \]

\[ h_{\text{steel req ftg}} := \frac{2 \cdot h_{\text{max}} \cdot \sigma_{\text{LL}}}{\Delta F_{\text{TH}}} \]

Check\(_9 := \text{if}(h_{\text{steel req ftg}} \leq h_s, "OKAY", "Steel Reinforcement Too Thin") \]

LRFD 6.13.3.2.4 Fillet Welded Connection of Beam to Sole Plate

\[ \phi_2 := 0.8 \]

AWS E7018 weld type AWS A5.1

\[ F_{\text{exx}} := 480 \text{MPa} \]

\[ \text{Weld} := \max \left[ 8 \text{mm}, \frac{\max \left( 10 \% P_{\text{strength}, \text{Seismic}} \right)}{(2 \cdot L_s \cdot 0.707 \cdot 0.6 \cdot \phi_2 F_{\text{exx}})} \right] \]

\[ \text{Weld} = 8 \text{mm} \]

High Strength Bolts

\[ \text{Dia}_{\text{bolt sole}} := 20 \text{mm} \]

\[ A_{\text{bolt sole}} := \pi \cdot \left( \frac{\text{Dia}_{\text{bolt sole}}}{2} \right)^2 = 314.2 \text{mm}^2 \]

\[ F_{\text{u bolt sole}} := \text{if}\left(\left(\text{Dia}_{\text{bolt sole}} \leq 24 \text{mm} \right), 825 \text{MPa}, 725 \text{MPa}\right) \]

\[ F_{\text{u bolt sole}} = 825 \text{MPa} \]

When Threads are included in the shear plane,

\[ R_n := 0.38 A_{\text{bolt sole}} \cdot F_{\text{u bolt sole}} \]

\[ \phi_s := 0.8 \]

Resistance Factor for A325 bolts in shear, LRFD 6.5.4.2

\[ \text{Bolts} := \max \left( \frac{\max \left( 10 \% P_{\text{strength}, \text{Seismic}} \right)}{\phi_s R_n} \cdot 4 \right) \]

\[ \text{Bolts} = 4.0 \]
Optional Cap Screws (ASTM F835M)

\[
\text{Dia}_{\text{screw\_sole}} := 16\text{mm}
\]

\[
A_{\text{screw\_sole}} := \pi \cdot \left(\frac{\text{Dia}_{\text{screw\_sole}}}{2}\right)^2
\]

\[
F_u_{\text{screw\_sole}} := 1172\text{MPa}
\]

When Threads are included in the shear plane,

\[
R_n := 0.38A_{\text{screw\_sole}}F_{u_{\text{screw\_sole}}}
\]

Resistance Factor for screws in shear,

\[
\phi_s := 0.8
\]

\[
\text{Cap\_Screws} := \max\left(\frac{\text{max}(10\%-P_{\text{strength\_Seismic}})}{\phi_s \cdot R_n}, 4\right)
\]

LRFD 5.7.5 Bearing (Check Bearing Stress on Concrete Pedestal)

The maximum allowable stress of an elastomeric pad is less than the maximum allowed stress for concrete. Therefore, it is never necessary to check for overstress of the pedestal in compression under the pad or masonry plate.

AASHTO 14.8.3.1 Anchorage and Anchor Bolts - Masonry Plate Anchor Bolts

Masonry Anchor Bolts:

\[
\phi_{\text{AnchBlt}} := 24\text{mm} \quad (24\text{mm. Minimum Diameter})
\]

\[
\text{bolts} := 2 \quad (2\text{ Bolt Minimum, Typical})
\]

\[
A_{\text{AnchBlt}} := \pi \cdot \left(\frac{\phi_{\text{AnchBlt}}}{2}\right)^2
\]

\[
F_{u_{\text{AnchBlt}}} := \text{if} \left(\phi_{\text{AnchBlt}} \leq 24\text{mm, 825MPa, 725MPa}\right)
\]

When Threads are included in the shear plane,

\[
R_n := 0.38A_{\text{AnchBlt}}F_{u_{\text{AnchBlt}}}
\]

Resistance Factor for A325 bolts in shear,

\[
\phi_s := 0.8
\]

\[
\text{AnchBlt\_req} := \frac{\text{max}(10\%-P_{\text{strength\_Seismic}})}{\phi_s \cdot R_n}
\]

\[
\text{Anchor\_bolt} := \text{if}\left(\text{bolts} \geq \text{AnchBlt\_req} , \text{bolts} , "\text{Anchor bolts FAIL}" \right)
\]

\[
\phi_m := \phi_{\text{AnchBlt}} + 10\text{mm}
\]
Masonry Plate Dimensions referred to BM section 12

Longitudinal min. bolt cover = \( E_l := 1.75 \phi_{AnchBlt} + 40\text{mm} \)

Length - \( L_m := \text{Ceil}\left[\left(L_{brg} + 50\text{mm}\right), 5\text{mm}\right] \)

\( L_m = 400\text{mm} \)

Width - Based on the sum of the sole plate width and the anchor bolt location.

\( E_l := 1.75 \phi_{AnchBlt} + 5\text{mm} \)

\( E_l = 47\text{mm} \)

\( E_L := \begin{cases} E_l & \text{if bolts } > 2 \\ \frac{L_m}{2} & \text{if bolts } = 2 \\ E_l & \text{if bolts } < 2 \end{cases} \)

\( E_L = 200\text{mm} \)

\( E_z := \phi_{AnchBlt} + 10\text{mm} \)

\( E_z = 34\text{mm} \)

-For Anchor Bolts Located Outside of Sole Plate:

\( W_{mout} := \text{Ceil}\left[W_s + 2\left(E_z + E_l\right), 5\text{mm}\right] \)

\( W_{mout} = 645\text{mm} \)

-For Anchor Bolts Located Inside of Sole Plate:

\( W_{mln} := \text{Ceil}\left[W_{brg} + 2\left(E_z + E_l\right), 5\text{mm}\right] \)

\( W_{mln} = 615\text{mm} \)

The masonry plate width will be controlled by whether or not enough room is provided to fasten the bolt (Note that 0.7 is a conservative ratio of anchor nut thickness to anchor bolt diameter.):

\( W_m := \text{Ceil}\left[\text{if}\left[W_{mln} > W_{mout}, W_{mln}, \text{if}\left[T_t > \left(2 \cdot 0.7 \cdot \phi_{AnchBlt} + 25\text{mm}\right), W_{mln}, W_{mout}\right], 5\text{mm}\right] \right] \)

\( W_m = 615\text{mm} \)

Thickness - Masonry Plate is standard at \( T_m := 25\text{mm} \)
Design Anchor Pin for Fix Bearing

For the controlling girder

\[ P_{\text{strength}} = 1032 \text{kN} \]

The maximum transverse horizontal earthquake load per bearing is then:

\[ H_{EO} := 0.1 P_{\text{strength}} \]

The factored shear resistance of the anchor pin per bearing is then

Assume \( \phi_{\text{anchor pin}} := 38 \text{mm} \) diameter Anchor pin with min tensile strength

A588 Minimum tensile strength of 480MPa

\[ F_{ub} := 480 \text{MPa} \]

\[ N_s := 1 \]

\[ \phi_{\text{anchor pin}} := 38 \text{mm} \]

\[ A_{\text{anchor pin}} := \pi \cdot \frac{\phi_{\text{anchor pin}}^2}{4} \]

\[ R_n_{\text{Anchor pin}} := 0.6 A_{\text{anchor pin}} F_{ub} N_s \]

\[ \phi_s := 0.65 \]

\[ R_{t,\text{Anchor pin}} := \phi_s R_{n,\text{Anchor pin}} \]

The Check10 := if \( R_{total} \geq \max(H_{EO}, \text{Seismic}, \"OKAY\", \"Anchor Pin Too Small\") \)

Final determination of total bearing height: 

\[ H_{\text{bearing}} := n h_{ri} + (n - 1) h_a + T_m + \frac{T_1 + T_2}{2} \]

\[ H_{\text{bearing}} := 139 \text{mm} \]
Output Required for "Bearing Table"

Loading
DC1 + SDL = 351.4kN  LL = 333.6kN  TL = 685.0kN  S = 8.203

Elastomer Layers
h₁ = 12mm  n = 5  Lₗₜₜ = 350mm  Wₗₜₜ = 450mm  hᵣᵣ = 60mm

Areas
Compressive_Area := (Lₗₜₜ - 6mm)(Wₗₜₜ - 6mm) - π·(φanchor_pin/4)²
Shear_Area := Wₗₜₜ·Lₗₜₜ - π·(φanchor_pin/4)²

Masonry Plate
Tₙₙ = 25mm  Wₙₙ = 615mm  Lₙₙ = 400mm  Eᵣ = 47mm  Eₖ = 200mm  E₂ = 34mm  φₙₙ = 34mm

Anchor Bolts
φAnchBlt = 24mm  bolts = 2

Connection of Beam to Substructure
Wₙₙ = 8mm
Number of cap screws necessary with D.C.E.S. approval = Cap_Screws = 4

Sole Plate (it is the designer's responsibility to verify if T₂ is upstation of T₁)
Wₜₜ = 480mm  Lₜₜ = 380mm  T₁ = 40mm  T₂ = 45mm

Fixed Anchor Pin  Bearing Height
φanchor_pin = 38mm  H_bearing = 139mm

CODE CHECKS
Check = {
  "Compressive Stress Check" : "OKAY",
  "Minimum Compression Check" : "OKAY",
  "Joint System Deflection Check" : "OKAY",
  "Initial Compressive Deflection" : "OKAY",
  "Rotational Stress Check" : "OKAY",
  "Total Excessive Strain Check" : "OKAY",
  "Stability Check" : "OKAY",
  "Service Limite State Check" : "OKAY",
  "Fatigue Limite State Check" : "OKAY",
  "Anchor Pin Resistance Check" : "OKAY"
}
Appendix 12D
Design Example; Steel Laminated Elastomeric Bearing with Sole Plate - Expansion (Type EB)

Note: Highlighted values on the following pages require user input. This bearing design assumes straight, single span steel beams and skews below 30 degrees. Modification to accommodate alternate bearing designs is at the user's discretion. Enclosed information based on the 2007 AASHTO LRFD Bridge Design Specifications. The designer is responsible for the final design. Elastomeric bearings shall be designed using Method A. B. M 12.2.1

Enter known data:
(A *** indicates typical conditions and may not require changing.)

Superstructure Properties:

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(L_{\text{span}}) (Expansion Length)</td>
<td>25.900 m</td>
</tr>
<tr>
<td>(\Delta_{LL}) (Unfactored LL Deflection)</td>
<td>25.4 mm</td>
</tr>
<tr>
<td>(L_{\text{hl93}}) (Unfactored LL (no impact))</td>
<td>333.617 kN</td>
</tr>
<tr>
<td>(D_{C1}) (Unfactored DL)</td>
<td>280.238 kN</td>
</tr>
<tr>
<td>(D_{C2}) (Unfactored DL Load on Composite Section)</td>
<td>35.86 kN</td>
</tr>
<tr>
<td>(D_{W}) (Unfactored FWS Load on Composite Section)</td>
<td>35.86 kN</td>
</tr>
<tr>
<td>(w_{bf}) (Bottom Flange Width at CL Bearing)</td>
<td>305 mm</td>
</tr>
<tr>
<td>(F_{u_\text{girder}}) (Girder Ultimate Tensile Strength, Steel Only)</td>
<td>450 MPa</td>
</tr>
<tr>
<td>(\text{Seismic}) (Maximum Horizontal Load from Seismic Analysis - LRFD 14.8.3.2)</td>
<td>0 kN</td>
</tr>
</tbody>
</table>

Bearing Data:

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(L_{\text{brg}}) (Parallel to Girder)</td>
<td>350 mm</td>
</tr>
<tr>
<td>(W_{\text{brg}}) (Perpendicular to Girder)</td>
<td>450 kN</td>
</tr>
<tr>
<td>(n) (number of elastomeric layers)</td>
<td>5</td>
</tr>
<tr>
<td>(\text{Location}) (Location of bearing on span, 0 for begin or 1 for end)</td>
<td>0</td>
</tr>
<tr>
<td>(h_{s}) (Steel Laminate Thickness)</td>
<td>3 mm</td>
</tr>
<tr>
<td>(h_{l}) (Individual elastomer layer thickness)</td>
<td>12 mm</td>
</tr>
</tbody>
</table>

Vertical Curve Data:

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(G_{1}) (Start Grade)</td>
<td>1.3%</td>
</tr>
<tr>
<td>(G_{2}) (End Grade)</td>
<td>1.3%</td>
</tr>
<tr>
<td>(L_{\text{vc}}) (VC length)</td>
<td>0 m</td>
</tr>
<tr>
<td>(\text{STA}_{\text{PVI}})</td>
<td>63916.189 m</td>
</tr>
</tbody>
</table>

Thermal Conditions:

(AASHTO 'Cold Climate' Zone 'C', LRFD Table 3.12.2.1-1 - Regions 10 and 11 are in 'Moderate Climate' zone)

For steel girder bridges with concrete decks.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(T_{\text{high}}) Temperature range</td>
<td>50 °C</td>
</tr>
<tr>
<td>(T_{\text{low}})</td>
<td>-35 °C</td>
</tr>
<tr>
<td>(\alpha) (steel coefficient of thermal expansion)</td>
<td>(11.7 \cdot 10^{-6} \frac{1}{\text{C}})</td>
</tr>
</tbody>
</table>

January 2008
Total Loading:

\[
\begin{align*}
LL & := LL_{hl93} & \text{Max. live load} & \quad LL = 333.617kN \\
TL & := DC1 + DC2 + DW + LL & \text{Service I limit state no impact} & \quad TL = 685.027kN \\
SDL & := DC2 + DW & \text{Unfactored Dead Load on composite section} & \quad SDL = 71.172kN \\
P_{\text{strength,1}} & := 1.25(DC1 + DC2) + 1.50DW + 1.75LL_{hl93} & \text{Strength I limit state no impact} & \quad P_{\text{strength,1}} = 1032kN \\
P_{\text{strength}} & := P_{\text{strength,1}} & & \quad P_{\text{strength}} = 1032kN
\end{align*}
\]

LRFD 14.7.5.1 Shape Factor

For rectangular bearing without holes, the shape factor for \( i \)th layer is:

\[
S := \frac{L_{\text{beg}} \cdot W_{\text{beg}}}{2 \cdot h_i \cdot (L_{\text{beg}} + W_{\text{beg}})}
\]

LRFD 3.12.2.1 Movements

Temperature Range to Determine Design Movement

Expansion: \( \Delta_{\text{Exp}} := T_{\text{high}} - 20^\circ C \)

Contraction: \( \Delta_{\text{Cont}} := 20^\circ C - T_{\text{low}} \)

\[
\Delta_s := \text{if}(\Delta_{\text{Cont}} > \Delta_{\text{Exp}}, \alpha \cdot \Delta_{\text{Cont}} \cdot L_{\text{span}}, \alpha \cdot \Delta_{\text{Exp}} \cdot L_{\text{span}})
\]

\[
\Delta_{\text{Exp}} = 30^\circ C \quad \Delta_{\text{Cont}} = 55^\circ C 
\]

The amount of movement of the bearing due to camber release of the beams shall be ignored. The specification requires that the Contractor reset the bearings to the neutral position prior to attaching the bearings to the beams.
LRFD 14.7.6.3.4 Shear Deformation check

The shear deformation is checked to ensure that the bearing is capable of allowing the anticipated horizontal bridge movement. Also, the shear deformation is limited in order to avoid rollover at the edges and delamination due to fatigue caused by cyclic expansion and contraction deformations.

\[ h_{rt} \geq 2 \cdot \Delta_{\text{service}} \]

For service limit state

\[ \gamma_{tu} := 1.2 \]

\[ \Delta_{\text{service}} := \gamma_{tu} \cdot \Delta_s \]

\[ t_{\text{req}} := 2 \cdot \Delta_{\text{service}} \]

LRFD 3.4.1-1

\[ t_{\text{req}} = 40 \text{min} \]

\[ h_{rt} := n \cdot h_i \]

LRFD 14.7.6.2 Material Properties

All Elastomer shall be 50 durometer hardness on the shore a scale BD-BG-R1

Base Value of Shear Modulus of Elastomer
Assuming a Hardness of "50" \( \Rightarrow \) LRFD Table 14.7.5.2-1

\[ G := 0.66 \text{MPa} \]

\[ G_{\text{max}} := 0.90 \text{MPa} \]

LRFD 14.7.6.3.2 Compressive Stress

Compare allowable to applied compressive stress:

\[ \sigma_{TL} := \frac{TL}{L_{\text{brg}} W_{\text{brg}}} \]

\[ \sigma_{\text{TL}} = 4.349 \text{MPa} \]

LRFD 3.4.1-1

\[ \sigma_{\text{TL}} \leq 7 \text{MPa} \land \sigma_{\text{TL}} \leq 1.0 \cdot G \]

Check 1.1 := "OKAY" if \( \sigma_{\text{TL}} \leq 1.4 \text{MPa} \)

"FAILS" otherwise

Check 1.1 := "OKAY"

Since this is a Type E.B. bearing, it is necessary to check the minimum compressive stress due to dead load and superimposed dead loads only:

\[ \sigma_{\text{min}} := \frac{DC1 + SDL}{L_{\text{brg}} W_{\text{brg}}} \]

LRFD 3.4.1-1

\[ \sigma_{\text{min}} = 2.231 \text{MPa} \]

Check 2 := if \( \sigma_{\text{min}} \geq 1.4 \text{MPa} \), "OKAY", "Minimum compression not met"

Check 2 = "OKAY"
LRFD 14.7.6.3.3 Compressive Deflection

Find Compressive Strain From LRFD Fig. C14.7.5.3.3-1

Must comply with section 14.7.5.3.3:

\[ \Delta = \Sigma \varepsilon_i h_i \]

considered for both total and live loads, and

\[ \Delta < or = 0.07 h_i \]

for any layer

Refer to Figure 3- C1 of Section C14.7.5.3.3 to obtain values of \( \varepsilon_i \) & input below:

\[
\sigma_{TL} := \frac{TL}{L_{brg} \cdot W_{brg}} \quad \Rightarrow \quad \sigma_{TL} = 4.349 \text{MPa} \quad \Rightarrow \quad \varepsilon_{TL} := \varepsilon(\sigma_{TL}, S) = \varepsilon_{TL} = 0.032
\]

\[
\sigma_{DC1} := \frac{DC1}{L_{brg} \cdot W_{brg}} \quad \Rightarrow \quad \sigma_{DC1} = 1.779 \text{MPa} \quad \Rightarrow \quad \varepsilon_{DC1} := \varepsilon(\sigma_{DC1}, S) = \varepsilon_{DC1} = 0.013
\]

\[
\sigma_{LL} := \frac{LL}{L_{brg} \cdot W_{brg}} \quad \Rightarrow \quad \sigma_{LL} = 2.118 \text{MPa} \quad \Rightarrow \quad \varepsilon_{LL} := \varepsilon_{TL} - \varepsilon_{DC1} = \varepsilon_{LL and SDL} = 0.018
\]

Deflection of the bearing due to total loading:

\[ \Delta_{TL} := \varepsilon_{TL} \cdot h_i \]

\[ \Delta_{TL} = 1.90 \text{mm} \]

Limiting instantaneous deflection is important to ensure that deck joints and seals are not damaged. Furthermore, bearings that are too flexible in compression could cause a small step in the road surface at deck joint when traffic passes from one girder to the other, giving rise to impact loading. A maximum relative deflection across a joint of 3 mm. is suggested LRFD C14.7.5.3.3

\[ \Delta_{LL and SDL} := \varepsilon_{LL and SDL} \cdot h_i \]

\[ \Delta_{LL and SDL} = 1.087 \text{mm} \]

Check3 := if\( \left( \Delta_{LL and SDL} \leq 3 \text{mm} \right) \), "OKAY", "Excessive deflection"

Check3 = "OKAY"

The initial compressive deflection of PEP or in any layer of steel-reinforced elastomeric bearing at the service limit without impact shall not exceed \( 0.07 h_i \) LRFD 14.7.6.3.3

\[ \Delta_{TL,i} := \varepsilon_{TL} \cdot h_i \]

\[ \Delta_{TL,i} = 0.38 \text{mm} \]

Check3.1 := if\( \left( \Delta_{TL,i} > 0.07 h_i \right) \), "Excessive initial compressive deflection", "OKAY"

Check3.1 = "OKAY"
Determine Sole Plate Dimensions

**Length**

\[ L_s := \text{Ceil} \left( \frac{L_{brg} + 26\text{mm}}{5\text{mm}} \right) \]

**Width**

\[ W_s := \text{Ceil} \left( \frac{\max(W_{brg}, W_{bd}) + 26\text{mm}}{5\text{mm}} \right) \]

**Minimum Thickness of Sole Plate**

Assume the plate between the beam and the bearing is fully supported (i.e., no distortion allowed). The only length free to bend is the length that is being loaded by the bearing and not supported by the beam.

January, 2008 12D-5
\[ \phi_b := 0.9 \]

Resistance Factor for Bending

\[ \text{OH} := \frac{w_{bf} - W_{brg}}{2} \]

\[ t_{\text{min}} := \text{OH} \sqrt{\frac{2 \cdot P_{\text{strength}}}{\phi_b \cdot F_y \cdot L_{\text{brg}} \cdot W_{brg}}} \]

AISC LRFD Equation

\[ T_1 := \text{if} \left( t_{\text{min}} < 40 \text{mm}, 40 \text{mm}, t_{\text{min}} \right) \]

LRFD 14.8.2 Tapered Plates (Determine if Sole Plate Must Be Beveled)

Rate of change of grade =

\[ r := \frac{G_2 - G_1}{L_{vc}} \]

\[ \text{STAPVC} := \text{STAPV1} - \frac{L_{vc}}{2} \]

Grade at C. L. of brgs. =

\[ G_{CL} := G_1 + (\text{STABrg} - \text{STAPVC}) \cdot r \]

Req'd thickness change =

\[ t_{\%} := \left| G_{CL} \cdot L_s \right| \]

The sole plate must be beveled if the grade at the bearing is greater than 1.0% from horizontal, or the total thickness change is greater than or equal 3 mm. \( T_2 \), below is the indicated bevel treatment: BD-BG3-R1

\[ T_2 := \text{if} \left( G_{CL} \geq 1.0\% \lor t_{\%} \geq 3 \text{mm}, T_1 + t_{\%}, T_1 \right) \]

LRFD 14.7.6.3.5d Rotation

The bearing must be capable of resisting the induced rotation due to live load and construction inaccuracies to prevent an area of zero stress underneath the bearing. The first step is to determine the maximum rotation that the bearing will experience.

where:

- \( \theta_{DC1} \) = Induced dead load rotation not accounted for by beveled sole plate
- \( \theta_{LL} \) = Induced live load rotation
- \( \theta_C \) = Estimated rotation due to construction inaccuracies

Induced dead load rotation not accounted for by a beveled sole plate will reduce or increase rotation towards the midspan depending on the bearing location and grade.

\[ \theta_{DC1} := \begin{cases} T_2 & \text{if } T_1 = T_2 \\ -G_{CL} & \text{if Location} = 0 \\ G_{CL} & \text{if Location} = 1 \\ 0 & \text{otherwise} \\ 0 & \text{otherwise} \end{cases} \]

\( \theta_{DC1} = 0.000 \)
\[ \theta_{LL} := \frac{2 \cdot \Delta_{LL}}{0.5 \cdot L_{span}} \]

\[ \theta_{C} := 0.002 \quad \text{(Assumed value based on strict NYSDOT testing and quality control procedures)} \]

\[ \theta_m := |\theta_{DC1} + \theta_{LL}| + \theta_{C} \]

Next, the induced rotation is converted into a stress and compared to the maximum compressive stress.

\[ \sigma_{TL\text{-}rot\text{-}transverse} := \frac{0.5 \cdot G_{\max} \cdot S}{n} \left( \frac{L_{brg}}{h_i} \right)^2 \cdot \theta_m \]

\[ \sigma_{TL\text{-}rot\text{-}transverse} = 3.72 \text{MPa} \]

The service rotation due to the total load about longitudinal axis is negligible compared to the service rotation about the transverse axis. Therefore, the check about the longitudinal axis will be assumed to be negligible and is not computed in this bearing design example.

As long as the compressive stress is more that the induced rotational stress, there will not be an area of zero pressure under the bearing.

Check4 := if(\[\sigma_{TL} \geq \sigma_{TL\text{-}rot\text{-}transverse}\), "OKAY", "More elastomer layers needed")

Check4 = "OKAY"

Check for Excessive Strain

\[ \Delta h_{rt} := \frac{\theta_m \cdot L_{brg}}{2} \]

\[ \varepsilon_{\text{due\_to\_rotation}} := \frac{\Delta h_{rt}}{h_{rt}} \]

\[ \varepsilon_{\text{total}} := \varepsilon_{\text{due\_to\_rotation}} + (1 + 0.25) \cdot \varepsilon_{DC1} + \varepsilon_{LL\text{and}SDL} \]

Check5 := if(\[\varepsilon_{\text{total}} \leq 10\%\), "OKAY", "Excessive Strain")

Check5 = "OKAY"

LRFD 14.7.6.3.6 Stability

To ensure stability, the total thickness of the elastomer pads and steel laminates is:

\[ T_t := n \cdot h_i + (n - 1) \cdot h_s \]

\[ T_t = 72 \text{mm} \]

shall not exceed the least of Lbrg/3 or Wbrg/3:

Check6 := if(\[T_t \leq \text{min}\left( \frac{L_{brg}}{3}, \frac{W_{brg}}{3} \right)\), "OKAY", "FAILS Stability")

Check6 = "OKAY"
LRFD 14.7.6.3.7 Reinforcement

\[
h_{\text{max}} := h_i \\
F_{y, \text{internal}} := 345 \text{MPa}
\]

For Service Limit State:

\[
h_{\text{steel req str}} := \frac{3h_{\text{max}} \sigma_{\text{TL}}}{F_{y, \text{internal}}}
\]

\[
\text{Check}_7 := \begin{cases} 
\text{"OKAY"}, & \text{if } h_{\text{steel req str}} \leq h_s, \\
\text{"Steel Reinforcement Too Thin"}, & \text{otherwise}
\end{cases}
\]

For Fatigue Limit State:

\[
\Delta F_{\text{TH}} := 165 \text{MPa}
\]

\[
h_{\text{steel req ftg}} := \frac{2h_{\text{max}} \sigma_{\text{LL}}}{\Delta F_{\text{TH}}}
\]

\[
\text{Check}_8 := \begin{cases} 
\text{"OKAY"}, & \text{if } h_{\text{steel req ftg}} \leq h_s, \\
\text{"Steel Reinforcement Too Thin"}, & \text{otherwise}
\end{cases}
\]

LRFD 6.13.3.2.4 Fillet Welded Connection of Beam to Sole Plate

\[
\phi_2 := 0.8 \\
F_{\text{exx}} := 480 \text{MPa}
\]

\[
\text{Weld} := \max \left[ 8 \text{mm}, \frac{\max \left( 10 \% P_{\text{strength}}, \text{Seismic} \right)}{\left( 2L_s \right) \cdot 0.707 \left( 0.6 \phi_2 F_{\text{exx}} \right)} \right]
\]

\[
\text{Weld} = 8 \text{mm}
\]

High Strength Bolts

\[
\phi_3 := 0.8 \\
A_{\text{b Bolt sole}} := 314.2 \text{mm}^2
\]

\[
F_{\text{u Bolt sole}} := \begin{cases} 
825 \text{MPa}, & \text{if } \text{Diabolt sole} \leq 24 \text{mm}, \\
725 \text{MPa}, & \text{otherwise}
\end{cases}
\]

When Threads are included in the shear plane,

\[
R_n := 0.38A_{\text{b Bolt sole}} F_{\text{u Bolt sole}}
\]

\[
\text{Bolts} := \max \left( \frac{\max \left( 10 \% P_{\text{strength}}, \text{Seismic} \right)}{\phi_3 R_n}, 4 \right)
\]

\[
\text{Bolts} = 4.0
\]
Optional Cap Screws (ASTM F835M)

\[
\text{Diascrew}_\text{sole} := 16\text{mm} \\
\text{A}_{\text{screw}_\text{sole}} := \pi \cdot \frac{\text{Diascrew}_\text{sole}^2}{4} \\
\text{F}_{u\text{,screw}_\text{sole}} := 1172\text{MPa}
\]

When Threads are included in the shear plane, 
\[
\phi_s := 0.8 \\
R_n := 0.38\text{A}_{\text{screw}_\text{sole}}\text{F}_{u\text{,screw}_\text{sole}} \\
\text{LRFD 6.13.2.7}
\]

\[
\text{Cap\_Screws} := \max \left( \frac{\max(10\%P_{\text{strength},\text{Seismic}})}{\phi_c R_n}, 4 \right)
\]

\[
\text{LRFD 5.7.5 Bearing (Check Bearing Stress on Concrete Pedestal)}
\]

The maximum allowable stress of an elastomeric pad is less than the maximum allowed stress for concrete. Therefore, it is never necessary to check for overstress of the pedestal in compression under the pad or masonry plate.

\[
\text{LRFD 14.8.3.1 Anchorage and Anchor Bolts - Masonry Plate Anchor Bolts}
\]

Masonry Anchor Bolts:

\[
\phi_{\text{AnchBlt}} := 24\text{mm} \\
\text{bolts} := 2
\]

\[
\text{LRFD 6.5.4.2}
\]

\[
\phi_s := 0.8 \\
\phi_c := \text{max} (10\% P_{\text{strength},\text{Seismic}}, 4)
\]

\[
\text{AnchBlt\_req} := \frac{\max(10\%P_{\text{strength},\text{Seismic}})}{\phi_c R_n} \\
\text{AnchBlt\_req} = 0.91
\]

\[
\text{Anchor\_bolt} := \text{if}(\text{bolts} \geq \text{AnchBlt\_req}, \text{bolts}, "\text{Anchor bolts FAIL}"
\]

\[
\text{Anchor\_bolt} = 2
\]
Washer Plate Details (refer to BD-BG5 for typical slotted hole detail.):

where

\[
\begin{align*}
A_m &= \phi_{AB} + 40\text{mm} \\
B_m &= \phi_{AB} + 10\text{mm} \\
A_{wp} &= A_m + 26\text{mm} \\
B_{wp} &= B_m + 26\text{mm}
\end{align*}
\]

Determine "Slotted Hole" details for masonry plate:

\[
\begin{align*}
A_m &= \phi_{AnchBlt} + 40\text{mm} \\
A_{wp} &= A_m + 26\text{mm} \\
B_m &= \phi_{AnchBlt} + 10\text{mm} \\
B_{wp} &= B_m + 26\text{mm}
\end{align*}
\]

Masonry Plate Dimensions referred to BM section 12

**Length** -

\[
L_m := \text{Ceil}\left( L_{brg} + 50\text{mm} \right) + 5\text{mm}
\]

\[L_m = 400\text{mm}\]

**Width** - Based on the sum of the sole plate width and the anchor bolt location.

\[
E_t := 1.75 \phi_{AnchBlt} + 5\text{mm}
\]

\[
E_L := \begin{cases} 
E_t & \text{if bolts > 2} \\
\frac{L_m}{2} & \text{if bolts = 2} \\
E_t & \text{if bolts < 2}
\end{cases}
\]

\[E_t = 47\text{mm}\]

\[E_L = 200\text{mm}\]

Longitudinal min. bolt cover =

\[
E_{L_{min}} := 1.75 \phi_{AnchBlt} + 40\text{mm}
\]

\[E_t = 34\text{mm}\]

- For Anchor Bolts Located Outside of Sole Plate:

\[
W_{mout} := \text{Ceil}\left( W_s + 2\left( E_z + E_t \right) \right) + 5\text{mm}
\]

\[W_{mout} = 645\text{mm}\]

- For Anchor Bolts Located Inside of Sole Plate:

\[
W_{min} := \text{Ceil}\left( W_{brg} + 2\left( E_z + E_t \right) \right) + 5\text{mm}
\]

\[W_{min} = 615\text{mm}\]
The masonry plate width will be controlled by whether or not enough room is provided to fasten the bolt (Note: Assume the anchor nut thickness is equal to the anchor bolt diameter):
Output Required for "Bearing Table"

Loading
DC1 + DC2 + DW = 351.4kN  LL = 333.6kN  TL = 685.027kN  S = 8.203

Elastomer Layers
h_i = 12mm  n = 5  L_brg = 350mm  W_brg = 450mm  h_r = 60mm

Areas
Compressive_Area := (L_brg - 6mm)(W_brg - 6mm)  =====> Compressive_Area = 152736mm^2
Shear_Area := W_brg*L_brg  =====> Shear_Area = 157500mm^2

Masonry Plate
T_m = 25mm  W_m = 645mm  L_m = 400mm  E_t = 47mm  E_L = 200mm  E_z = 34mm

Anchor Bolts
ϕ_ArchBl = 24mm  bolts = 2

Connection of Beam to Substructure
Weld Size = Weld = 8mm
Number bolts necessary for bolt option = Bolts = 4
Number of cap screws necessary with D.C.E.S. approval = Cap_Screws = 4

Washer Plate
A_wp = 90mm  B_wp = 60mm

Sole Plate (it is the designer's responsibility to verify if T_2 is up station of T_1)
W_s = 480mm  L_s = 380mm  T_1 = 40mm  T_2 = 45mm

Bearing Height
H_bearing = 139mm

CODE CHECKS
Check = ("Shear Deformation Check" "OKAY")
"Compressive Stress Check" "OKAY"
"Minimum Compression Check" "OKAY"
"Joint System Deflection Check" "OKAY"
"Initial Compressive Deflection" "OKAY"
"Rotational Stress Check" "OKAY"
"Total Excessive Strain Check" "OKAY"
"Stability Check" "OKAY"
"Service Limit State Check" "OKAY"
"Fatigue Limit State Check" "OKAY"
Appendix 12E
Design Example; Multi-Rotational Bearing – Fixed (Type MR)

Note: Highlighted values on the following pages require user input. This bearing design assumes straight, single span steel beams and skews below 30 degrees. Modification to accommodate alternate bearing designs is at the user’s discretion. Enclosed information based on the 2007 AASHTO LRFD Bridge Design Specification. The designer is responsible for the final design.

Enter known data:
(A *** indicates typical conditions and may not require changing.)

Superstructure Properties:

<table>
<thead>
<tr>
<th>Superstructure Properties</th>
<th>Bearing Data (See BD-BG5, R1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L_{span} := 129.54,m</td>
<td>Vertical Load := 1779,kN</td>
</tr>
<tr>
<td>A_{LL} := 50,mm</td>
<td>Horizontal Load := 338,kN</td>
</tr>
<tr>
<td>LL_{hl93} := 578.269,kN</td>
<td>A := 560,mm</td>
</tr>
<tr>
<td>LL_{min.hl93} := 0,kN</td>
<td>B := 480,mm</td>
</tr>
<tr>
<td>DC1 := 971.047,kN</td>
<td>OD := 435,mm</td>
</tr>
<tr>
<td>DC2 := 46.706,kN</td>
<td>D := 175,mm</td>
</tr>
<tr>
<td>DW := 44.482,kN</td>
<td>STABrg := 1520,\pi</td>
</tr>
<tr>
<td>\text{wbf} := 600,mm</td>
<td>Masonry:</td>
</tr>
<tr>
<td>\text{FU, gird} := 450,MPa</td>
<td>\text{f''c} := 21,MPa</td>
</tr>
<tr>
<td>\text{Wout} := 9559,mm</td>
<td>(Pedestal Concrete 28 Day Strength)</td>
</tr>
<tr>
<td>\text{Seismic} := 0,kN</td>
<td></td>
</tr>
<tr>
<td>\text{F}_y := 345,MPa</td>
<td></td>
</tr>
</tbody>
</table>

Vertical Curve Data:
(if no VC exist then enter "0" for L_{VC} AND STAPVI; if VC, verify that bearing falls within limits otherwise "no VC")

<table>
<thead>
<tr>
<th>Vertical Curve Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>G_1 := 5.9%</td>
</tr>
<tr>
<td>G_2 := -0.199%</td>
</tr>
<tr>
<td>L_{VC} := 886,\pi</td>
</tr>
<tr>
<td>STAPVI := 1469,\pi</td>
</tr>
</tbody>
</table>

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**Total Loading:**

\[
\begin{align*}
L_{L_{\text{min}}} & := L_{\text{min}, hl_{93}} \\
LL & := L_{hl_{93}} \\
TL & := DC1 + DC2 + DW + LI \\
SDL & := DC2 + DW \\
P_{\text{strength}, 1} & := 1.25 \cdot (DC1 + DC2) + 1.50 \cdot DW + 1.75 \cdot L_{hl_{93}} \\
P_{\text{strength}} & := P_{\text{strength}, 1}
\end{align*}
\]

- **Max. live load**
  - \( L_{\text{min}} = 0 \)
  - \( LL = 578.269 \text{kN} \)
- **Service I limit state no impact**
  - \( TL = 1.641 \times 10^3 \text{kN} \)
  - \( SDL = 91.188 \text{kN} \)
- **Unfactored Dead Load on composite section**
  - \( P_{\text{strength}, 1} = 2.351 \times 10^3 \text{kN} \)
  - \( P_{\text{strength}} = 2.351 \times 10^3 \text{kN} \)

---

**LRFD 3.12.2.2.1 Temperature Range for Procedure A**

The amount of movement of the bearing due to camber release of the beams shall be ignored. The specification requires that the Contractor reset the bearings to the neutral position prior to attaching the bearings to the beams.

**Top Plate Length**

The (B) dimension in the bearing tables includes 25 mm for design movement and an additional 25 mm for construction tolerance each way. The following calculation is only used for expansion bearings where the calculated movement exceeds 25 mm of built in design movement. NYSDOT BD-BG4-R1
Determine Sole Plate Dimensions

**Length** => \( L_s := \text{Ceil}(2 \cdot (0.5 \cdot B + 25\text{mm})), 5\text{mm} \)

**Width** => \( W_s := \text{Ceil}(\text{if}(w_{bf} > A, w_{bf} + 50\text{mm}, A + 50\text{mm})), 5\text{mm} \)

**Minimum Thickness of Sole Plate**

Assume the plate between the beam and the bearing is fully supported (i.e., no distortion allowed). The only length free to bend is the length that is being loaded by the bearing and not supported by the beam.

**Resistance Factor for Bending**

\( \phi_b := 0.9 \)

**AISC FACTOR**

\( t_{\min} := 20\text{mm} \)

Minimum thickness of Sole Plate 20 mm.  NYSDOT BD-BG5-R1

\[ \text{OH} := \frac{w_{bf} - A}{2} \]

\( \text{OH} = 20\text{mm} \)

\[ t_{\text{min}} := \text{OH} \sqrt{\frac{2 \cdot P_{\text{strength}}}{\phi_b \cdot F_y \cdot L_s \cdot W_s}} \]

AISC LRFD Equation

\( t_{\text{min}} = 4.193\text{mm} \)

\[ T_1 := \text{if}(t_{\text{min}} < t_{\min}), t_{\min}, t_{\text{min}} \]

\( T_1 = 20\text{mm} \)
LRFD 14.8.2 Tapered Plates (Determine if Sole Plate Must be Beveled)

Rate of change of grade = 
\[ r := \frac{G_2 - G_1}{L_{vc}} \]

\[ r = -6.884 \times 10^{-8} \text{ mm} \]

\[ STAPVC := STAPVI - \frac{L_{vc}}{2} \]

\[ STA_{PVC} = 1026000 \text{ mm} \]

Grade at C.L. of brgs. = 
\[ G_{CL} := G_i + (STABrgs - STAPVC) \cdot r \]

\[ G_{CL} = 2.499\% \]

Req'd thickness change = 
\[ t\% := |G_{CL} \cdot L_s| \]

\[ t\% = 13.247 \text{ mm} \]

The sole plate must be beveled if the grade at the bearing is greater than 1.0% from horizontal, or the total thickness change is greater than or equal to 3 mm. \( T_2 \), below is the indicated bevel treatment:

\[ T_2 := \text{if} \left( |G_{CL}| \geq 1.0\% \lor t\% \geq 3\text{mm}, t\% + T_1, T_1 \right) \]

\[ T_2 = 33.247 \text{ mm} \]

LRFD 6.13.3.2.4 Fillet Welded Connection of Beam to Sole Plate

NYSDOT BD-BG4-R1

Top and bottom bearing plates shall be welded to the sole plate and masonry plate, respectively. The size of weld shall not be less than 8 mm

**Note**: NYSDOT Bridge Manual §8.6.3 specifies 8 mm as the minimum fillet weld size for a base material thickness greater than 40 mm. However, an 8 mm fillet weld is the largest that can be deposited in a single pass by manual process. Thus, in cases that an 8 mm fillet weld provides sufficient strength and the proper preheat procedures are utilized (a requirement for all field welds) and 8 mm weld is to be used.

\[ \phi_{e2} := 0.8 \]

\[ F_{exx} := 480\text{MPa} \]

\[ W_1 := \max \left[ 8\text{mm}, \max \left\{ 10\% P_{strength, Seismic}, \left( \frac{2 \cdot L_s}{(2 - B)} \cdot 0.707 \cdot 0.6 \cdot \phi_{e2} F_{exx} \right) \right\} \right] \]

\[ W_1 = 8\text{mm} \]

\[ W_2 := \max \left[ 8\text{mm}, \max \left\{ 10\% P_{strength, Seismic}, \left( \frac{2 \cdot B}{(2 - B)} \cdot 0.707 \cdot 0.27 \cdot 420\text{MPa} \right) \right\} \right] \]

\[ W_2 = 8\text{mm} \]

**High Strength Bolts**

\[ \text{diameter}_{bolt, sole} := 20\text{mm} \]

\[ A_{bolt, sole} := \pi \cdot \left( \frac{\text{diameter}_{bolt, sole}}{2} \right)^2 \]

\[ A_{bolt, sole} = 314.159\text{mm}^2 \]

\[ F_{u, bolt, sole} := \text{if} \left( \text{diameter}_{bolt, sole} \leq 24\text{mm}, 825\text{MPa}, 725\text{MPa} \right) \]

\[ F_{u, bolt, sole} = 825\text{MPa} \]
Bearing Design Example (Type EP)

When Threads are included in the shear plane,

\[ R_n := 0.38 \phi_{b_s} F_{u,bolt_sole} \quad \text{LRFD 6.13.2.7} \]

\[ \phi_s := 0.8 \quad \text{Resistance Factor for A325 bolts in shear, LRFD 6.5.4.2} \]

\[ \text{Bolts} := \max \left( \frac{\max\left(10\% P_{\text{strength, Seismic}}\right)}{\phi_s R_n}, 4 \right) \]

Optional Cap Screws (ASTM F835M):

\[ \text{Diascrew_sole} := 16\text{mm} \]

\[ A_{\text{screw_sole}} := \pi \left( \frac{\text{Diascrew_sole}}{2} \right)^2 \]

\[ F_{u,\text{screw_sole}} := 1172\text{MPa} \]

\[ R_n := 0.38 A_{\text{screw_sole}} F_{u,\text{screw_sole}} \quad \text{When Threads are included in the shear plane, LRFD 6.13.2.7} \]

\[ \phi_s := 0.8 \quad \text{Resistance Factor for screws in shear, LRFD 6.5.4.2} \]

\[ \text{Cap_Screws} := \max \left( \frac{\max\left(10\% P_{\text{strength, Seismic}}\right)}{\phi_s R_n}, 4 \right) \]

LRFD 14.8.3.1 Anchorage and Anchor Bolts - Masonry Plate Anchor Bolts

Masonry Anchor Bolts:

\[ \phi_{\text{AnchBlt}} := 24\text{mm} \quad (24\text{ mm Minimum Diameter}) \]

\[ \text{bolts} := 4 \quad (4\text{ Bolt Minimum, Typical}) \]

\[ A_{\text{AnchBlt}} := \pi \left( \frac{\phi_{\text{AnchBlt}}}{2} \right)^2 \]

\[ F_{u,\text{AnchBlt}} := \text{if}\left( \phi_{\text{AnchBlt}} \leq 24\text{mm, 825MPa}, 725\text{MPa} \right) \]

\[ R_n := 0.38 A_{\text{AnchBlt}} F_{u,\text{AnchBlt}} \quad \text{When Threads are included in the shear plane, LRFD 6.13.2.7} \]

\[ \phi_s := 0.8 \quad \text{Resistance Factor for A325 bolts in shear, LRFD 6.5.4.2} \]

\[ \text{AnchBlt req} := \frac{\max\left(10\% P_{\text{strength, Seismic}}\right)}{\phi_s R_n} \]

\[ \text{Anchor_bolt} := \text{if}\left( \text{bolts} \geq \text{AnchBlt req, bolts, "Anchor bolts FAIL" } \right) \]

\[ \phi_m := \phi_{\text{AnchBlt}} + 10\text{mm} \]

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Determine "Slotted Hole" details for masonry plate:

\[
\begin{align*}
A_m &= \phi_{\text{AnchBlt}} + 40\text{mm} \\
A_{wp} &= A_m + 26\text{mm} \\
B_m &= \phi_{\text{AnchBlt}} + 10\text{mm} \\
B_{wp} &= B_m + 26\text{mm}
\end{align*}
\]

\[
\begin{align*}
A_m &= 64\text{mm} \\
A_{wp} &= 90\text{mm} \\
B_m &= 34\text{mm} \\
B_{wp} &= 60\text{mm}
\end{align*}
\]

**Masonry Plate Dimensions**

- **Longitudinal min. bolt cover** = 
  \[E_i := 1.75 \phi_{\text{AnchBlt}} + 40\text{mm} \]
  \[E_i = 82.00\text{mm}\]

- **Width** - Based on the sum of the sole plate width and the anchor bolt location.
  \[E_i := 1.75 \phi_{\text{AnchBlt}} + 5\text{mm} \]
  \[E_i = 47\text{mm}\]
  \[E_z := \phi_{\text{AnchBlt}} + 10\text{mm} \]
  \[E_z = 34\text{mm}\]

- For Anchor Bolts Located *Outside* of Sole Plate:
  \[W_{\text{mout}} := \text{Ceil}[W_s + 2(E_z + E_i)], 5\text{mm}] \]
  \[W_{\text{mout}} = 815\text{mm}\]

- For Anchor Bolts Located *Inside* of Sole Plate:
  \[W_{\text{min}} := \text{Ceil}[OD + 2(E_z + E_i)], 5\text{mm}] \]
  \[W_{\text{min}} = 600\text{mm}\]

The masonry plate width will be controlled by whether or not enough room is provided to fasten the bolt (Note: Assume the anchor nut thickness is equal to the anchor bolt diameter.):

\[
W_m := \text{Ceil}[\text{if}W_{\text{mIn}} > W_{\text{mout}}, W_{\text{mIn}}, \text{if}D > (2\phi_{\text{AnchBlt}} + 25\text{mm}), W_{\text{mIn}}, W_{\text{mout}}], 5\text{mm}]
\]

\[W_m = 600\text{mm}\]

- **Length** - Based on the greater of either the anchor bolt placement or 2in. plus the base plate (O.D.).
  \[L_m := \text{Ceil}[\text{max}[OD + 50\text{mm}, (bolts + 1)E_i], 5\text{mm}] \]
  \[L_m = 485\text{mm}\]
**Thickness** - Masonry Plate is standard at $T_{m} := 20\text{mm}$ NYSDOT BD-BG5-R1

$$T_{\text{min.mp}} := 20\text{mm}$$

$$OH_{m} := \frac{W_{m} - \text{OD}}{2}$$

$$OH_{m} = 82.5\text{mm}$$

$$T_{\text{min.masonryplate}} := \begin{cases} \frac{2 \cdot P_{\text{strength}}}{\phi_{b} \cdot F_{y} \cdot W_{m} \cdot L_{m}} < T_{\text{min.mp}}, & \text{T}_{\text{min.masonryplate}} \end{cases}$$

$$T_{\text{min.masonryplate}} = 20\text{mm}$$

**LRFD 5.7.5 Bearing (Check Bearing Stress on Concrete Pedestal)**

Assume 75 mm of cover on the front and back edges of the masonry plate to the edge of pedestal and 200 mm from the anchor bolts.

$$A_{\text{pedestal}} := \left( W_{m} - 2 \cdot E_{t} + 2 \cdot 200\text{mm}\right) \cdot \left( L_{m} + 2 \cdot 75\text{mm}\right)$$

$$A_{\text{pedestal}} = 5.75 \times 10^5 \text{ mm}^2$$

$$A_{\text{masonry}} := L_{m} \cdot W_{m}$$

$$A_{\text{masonry}} = 291000\text{mm}^2$$

Check resistance of concrete pedestal, $P_{n}$

$$P_{n} := 0.85 \cdot f'_{c} \cdot A_{\text{masonry}} \cdot \min \left( 2, \sqrt{\frac{A_{\text{pedestal}}}{A_{\text{masonry}}}} \right)$$

$$\phi_{c} := 0.70$$

$$\text{Check}_{1} := \text{if} \left( TL \leq \phi_{c} \cdot P_{n}, "\text{OKAY}" \right)$$

$$\text{Check}_{1} = "\text{OKAY}"$$

The minimum vertical loading is 20% of SDL and DL (LRFD 14.6.1) plus any LL uplift.

$$\sigma_{\text{min}} := 20\%-\text{Vertical Load}$$

$$\sigma_{\text{TDC}} := \text{SDL} + \text{DC1} \cdot \text{if} \left( L_{L_{\text{min}}} < 0 \cdot \text{kN}, L_{L_{\text{min}}}, 0 \right)$$

$$\text{Check}_{2} := \text{if} \left( \sigma_{\text{min}} \leq \sigma_{\text{TDC}}, "\text{OKAY}" \right)$$

$$\text{Check}_{2} = "\text{OKAY}"$$
Output Required for "Bearing Table"

**Capacity**

Vertical Load = 1779 kN

Horizontal Load = 338 kN

**Masonry Plate**

$L_m = 485 \text{ mm}$  \quad $W_m = 600 \text{ mm}$  \quad $T_m = 20 \text{ mm}$  \quad $E_t = 47 \text{ mm}$  \quad $E_l = 82 \text{ mm}$  \quad (minimum)

$A_m = 64 \text{ mm}$  \quad $B_m = 34 \text{ mm}$

*The designer shall determine the masonry plate thickness.

**Washer Plate**

$A_{wp} = 90 \text{ mm}$  \quad $B_{wp} = 60 \text{ mm}$

**Sole Plate** (it is the designer's responsibility to verify if $T_2$ is upstation of $T_1$)

$W_s = 650 \text{ mm}$  \quad $L_s = 530 \text{ mm}$  \quad $T_1 = 20 \text{ mm}$  \quad $T_2 = 33 \text{ mm}$

**Bearing Height**

$D = 175 \text{ mm}$

**Anchor Bolts**

$\phi_{AnchBlt} = 24 \text{ mm}$  \quad bolts = 4

**Connection of Beam to Substructure**

Weld Sizes: $W_1 = 8 \text{ mm}$  \quad $W_2 = 8 \text{ mm}$

Number bolts necessary for bolt option = Bolts = 4.0

Number of cap screws necessary with D.C.E.S. approval = Cap_Screws = 4

**Additional Information**

Check$_1$ = "OKAY"  \quad Check$_2$ = "OKAY"

$E_z = 34 \text{ mm}$
Appendix 12F
Design Example; Multi-Rotational Bearing – Expansion (Type MR)

Note: Highlighted values on the following pages require user input. This bearing design assumes straight, single span Steel beams and skews below 30 degrees. Modification to accommodate alternate bearing designs is at the user's discretion. Enclosed information based on the 2007 AASHTO LRFD Bridge Design Specifications. The designer is responsible for the final design.

Enter known data:
(A *** indicates typical conditions and may not require changing.)

Superstructure Properties:
- **Lspan**: 129.54 m (Expansion Length)
- **A_LL**: 50 mm (LL Deflection)
- **LL_h93**: 578.269 kN (HL93 Unfactored LL w/ impact)
- **LL_min_h93**: 0 kN (HL93 Minimum LL w/impact, including uplift)
- **DC1**: 971.047 kN (Unfactored DL)
- **DC2**: 46.706 kN (Unfactored DL Load on Composite Section)
- **DW**: 44.482 kN (Unfactored FWS Load on Composite Section)
- **w_kf**: 600 mm (Bottom Flange Width at CL Bearing)
- **F_u_girder**: 45 (MPa) (Girder Ultimate Tensile Strength, Steel Only)
- **W_out**: 9559 mm (Distance Between Fascia Beams)
- **Seismic**: 0 kN (Maximum Horizontal Load from Seismic Analysis - RC 14.8.3.2)
- **F_y**: 345 MPa

Bearing Data (See BD-BG5, R1)
- **Vertical_Load**: 1779 kN
- **Horizontal_Load**: 338 kN
- **A**: 560 mm
- **B**: 480 mm
- **OD**: 435 mm
- **STA**: 1520 mm

Masonry:
- **f’c**: 21 MPa (Pedestal Concrete 28 Day Strength)

Vertical Curve Data:
- **G1**: 5.9% (Start Grade)
- **G2**: -0.199% (End Grade)
- **L_vc**: 886 m (VC length)
- **STAPVI**: 1469 m

Thermal Conditions:
(AASHTO 'Cold Climate' Zone 'C', LRFD Table 3.12.2.1-1 - Regions 10 and 11 are in 'Moderate Climate' zone)
For steel girder bridges with concrete decks.
- **T_high**: 50°C
- **T_low**: -35°C
- **\( \alpha \)**: 11.7 \times 10^{-6} / °C (Steel coefficient of thermal expansion)

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**Total Loading:**

\[ \text{LL}_{\text{min}} := \text{LL}_{\text{min},h93} \]

\[ \text{LL} := \text{LL}_{h93} \]

\[ \text{TL} := \text{DC1} + \text{DC2} + \text{DW} + \text{LL} \]

\[ \text{SDL} := \text{DC2} + \text{DW} \]

\[ \text{P}_{\text{strength},1} := 1.25(\text{DC1} + \text{DC2}) + 1.50\text{DW} + 1.75\text{LL}_{h93} \]

\[ \text{P}_{\text{strength}} := \text{P}_{\text{strength},1} \]

---

**LRFD 3.12.2.2.1 Temperature Range for Procedure A**

Temperature Range to Determine Design Movement

Expansion:

\[ \Delta_{\text{Texp}} := T_{\text{high}} - 20C \]

Contraction:

\[ \Delta_{\text{Tcont}} := 20C - T_{\text{low}} \]

\[ \Delta_s := \text{if} (\Delta_{\text{Tcont}} > \Delta_{\text{Texp}}, \alpha \cdot \Delta_{\text{Tcont}} \cdot L_{\text{span}}, \alpha \cdot \Delta_{\text{Texp}} \cdot L_{\text{span}}) \]

\[ \Delta_{\text{Texp}} = 30C \]

\[ \Delta_{\text{Tcont}} = 55C \]

\[ \Delta_s = 83.4\text{mm} \]

The amount of movement of the bearing due to camber release of the beams shall be ignored. The specification requires that the Contractor reset the bearings to the neutral position prior to attaching the bearings to the beams.

**Top Plate Length**

The (B) dimension in the bearing tables includes 25 mm for design movement and an additional 25 mm for construction tolerance each way. The following calculation is only used for expansion bearings where the calculated movement exceeds 25 mm of built in design movement.  

\[ B := \text{Ceil} \left[ \text{if} (\Delta_s > 25mm, B + 2(\Delta_s - 25mm), B) \right], 5mm \]

\[ B = 600.0\text{mm} \]
Bearing Design Example (Type MR - Fixed)

Determine Sole Plate Dimensions (rounds up to nearest 6 mm in interval)

Length => \( L_s := \text{Ceil}(2 \cdot (0.5 \cdot B + 25\text{mm}), 5\text{mm}) \)  
\( L_s = 650\text{mm} \)

Width => \( W_s := \text{Ceil}\left(\text{if}(w_{bf} > A, w_{bf} + 50\text{mm}, A + 50\text{mm})\right), 5\text{mm}\)  
\( W_s = 650\text{mm} \)

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Minimum Thickness of Sole Plate

Assume the plate between the beam and the bearing is fully supported (i.e., no distortion allowed). The only length free to bend is the length that is being loaded by the bearing and not supported by the beam.

\[ \phi_b := 0.9 \]  

Resistance Factor for Bending  

\[ t_{\text{min}} := 20\text{mm} \]  

Minimum thickness of Sole Plate 20 mm NYSDOT BD-BG5-R1  

\[ \text{OH} := \frac{|w_{bf} - A|}{2} \]  

AISC FACTOR  

\[ t_{\text{min}} := \text{OH} \sqrt{\frac{2 \cdot P_{\text{strength}}}{\phi_b \cdot F_y \cdot L_s \cdot W_s}} \]  

AISC LRFD Equation  

\[ T_1 := \text{if } (t_{\text{min}} < t_{\text{min}}), t_{\text{min}}, t_{\text{min}} \]  

LRFD 14.8.2 Tapered Plates (Determine if Sole Plate Must Be Beveled)

Rate of change of grade =  

\[ r := \frac{G_2 - G_1}{L_{vc}} \]  

\[ r = -6.884 \times 10^{-8} \frac{1}{\text{mm}} \]  

\[ \text{STA}_{\text{PVC}} := \text{STA}_{\text{PVI}} - \frac{L_{vc}}{2} \]  

\[ \text{STA}_{\text{PVC}} = 102600\text{mm} \]  

Grade at C.L. of brgs. =  

\[ G_{CL} := G_1 + (\text{STA}_{\text{Brg}} - \text{STA}_{\text{PVC}}) \cdot r \]  

\[ G_{CL} = 2.499\% \]  

Req'd thickness change =  

\[ t_{\%} := \left| G_{CL} \cdot L_s \right| \]  

\[ t_{\%} = 16.246\text{mm} \]  

The sole plate must be beveled if the grade at the bearing is greater than 1.0% from horizontal, or the total thickness change is greater than or equal to 3 mm. \( T_2 \) below is the indicated bevel treatment:

\[ T_2 := \text{if } (|G_{CL}| \geq 1\% \lor t_{\%} \geq 3\text{mm}, t_{\%} + T_1, T_1) \]  

\[ T_2 = 36.246\text{mm} \]  

"Guide Clearance" Check and Design (See note 7 on BD-BG4, R1)

Coefficient of Expansion for Concrete =  

\[ \alpha_c := 10.8 \times 10^{-6} \frac{1}{C} \]  

Guide_Clearance := \text{if } (W_{out} > 12\text{m}, "Non-Standard", "Standard")  

\[ \text{Guide}_\text{Clearance} = "Standard" \]  

\[ G_{\text{min.gap}} := \text{if } (W_{out} > 12\text{m}, \alpha_c \cdot \max(\Delta_{\text{exp}}, \Delta_{\text{cont}}) \frac{W_{out}}{2}, 3\text{mm}) \]  

\[ G_{\text{min.gap}} = 3\text{mm} \]
Bearing Design Example (Type MR - Fixed)

LRFD 6.13.3.2.4 Fillet Welded Connection of Beam to Sole Plate

NYSDOT BD-BG4-R1

Top and bottom bearing plates shall be welded to the sole plate and masonry plate, respectively. The size of weld shall not be less than 8 mm

Note: NYSDOT Bridge Manual S8.6.3 specifies 8 mm as the minimum fillet weld size for a base material thickness greater than 40 mm. However, an 8 mm fillet weld is the largest that can be deposited in a single pass by manual process. Thus, in cases that an 8 mm fillet weld provides sufficient strength and the proper preheat procedures are utilized (a requirement for all field welds) and 8 mm weld is to be used.

\[ \phi_{e2} := 0.8 \]

\[ F_{exx} := 480 \text{MPa} \]  
AWS E7018 weld type
AWS A5.1

\[ W_1 := \max \left[ 8 \text{mm}, \frac{\max \{10\%P_{\text{strength},\text{Seismic}}\}}{(2 \cdot L_s) \cdot 0.707 \cdot 0.6 \cdot \phi_{e2} \cdot F_{exx}} \right] \]

\[ W_1 = 8 \text{mm} \]

\[ W_2 := \max \left[ 8 \text{mm}, \frac{\max \{10\%P_{\text{strength},\text{Seismic}}\}}{(2 \cdot B) \cdot 0.707 \cdot (0.27 \cdot 420 \text{MPa})} \right] \]

\[ W_2 = 8 \text{mm} \]

High Strength Bolts

\[ \text{Diabolt}_\text{sole} := 20 \text{mm} \]

\[ A_{\text{bolt}_\text{sole}} := \pi \cdot \frac{\text{Diabolt}_\text{sole}}{4}^2 \]

\[ A_{\text{bolt}_\text{sole}} = 314.159 \text{mm}^2 \]

\[ F_{u_{\text{bolt}_\text{sole}}} := \text{if}(\text{Diabolt}_\text{sole} \leq 24 \text{mm}, 825 \text{MPa}, 725 \text{MPa}) \]

\[ F_{u_{\text{bolt}_\text{sole}}} = 825 \text{MPa} \]

\[ R_n := 0.38 A_{\text{bolt}_\text{sole}} \cdot F_{u_{\text{bolt}_\text{sole}}} \]

When Threads are included in the shear plane, LRFD 6.13.2.7

\[ R_n = 98.489 \text{kN} \]

\[ \phi_s := 0.8 \]

Resistance Factor for A325 bolts in shear, LRFD 6.5.4.2

\[ \text{Bolts} := \max \left( \frac{\max \{10\%P_{\text{strength},\text{Seismic}}\}}{\phi_s \cdot R_n}, 4 \right) \]

\[ \text{Bolts} = 4.0 \]

Optional Cap Screws (ASTM F835M):

\[ \text{DiascREW}_\text{sole} := 16 \text{mm} \]

\[ A_{\text{scREW}_\text{sole}} := \pi \cdot \frac{\text{DiascREW}_\text{sole}}{4}^2 \]

\[ A_{\text{scREW}_\text{sole}} = 201.062 \text{mm}^2 \]

\[ F_{u_{\text{scREW}_\text{sole}}} := 1172 \text{MPa} \]

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\[ R_n := 0.38A_{\text{screw, sole}}F_{u, \text{screw, sole}} \quad \text{When Threads are included in the shear plane} \]

\[ \phi_s := 0.8f \quad \text{Resistance Factor for screws in shear,} \]

\[ \text{Cap}_s_{\text{screws}} := \max \left( \frac{\max(10 \cdot P_{\text{strength, Seismic}})}{\phi_s R_n}, 4 \right) \]

**LRFD 14.8.3.1 Anchorage and Anchor Bolts - Masonry Plate Anchor Bolts**

**Masonry Anchor Bolts:**

\[ \phi_{\text{AnchBlt}} := 24\text{mm} \quad \text{(24 mm Minimum Diameter)} \]

\[ \text{bolts} := 4 \quad \text{(4 Bolt Minimum, Typical)} \]

\[ A_{\text{AnchBlt}} := \pi \phi_{\text{AnchBlt}}^2 / 4 \]

\[ F_{u, \text{AnchBlt}} := \text{if} \left( \phi_{\text{AnchBlt}} \leq 24\text{mm}, 825\text{MPa}, 725\text{MPa} \right) \]

\[ R_n := 0.38A_{\text{AnchBlt}}F_{u, \text{AnchBlt}} \quad \text{When Threads are included in the shear plane,} \]

\[ \phi_s := 0.8 \quad \text{Resistance Factor for A325 bolts in shear,} \]

\[ \text{AnchBlt}_{\text{req}} := \max \left( \frac{10 \cdot P_{\text{strength, Seismic}}}{\phi_s R_n}, 4 \right) \]

\[ \text{Anchor bolt} := \text{if}(\text{bolts} \geq \text{AnchBlt}_{\text{req}}, \text{bolts}, "\text{Anchor bolts FAIL}"") \]

**Washer Plate Details (refer to BD- BD5-R1):**

where

| \[ A_m = \phi_{\text{AB}} + 40\text{mm} \] |
| \[ B_m = \phi_{\text{AB}} + 10\text{mm} \] |
| \[ A_{wp} = A_m + 26\text{mm} \] |
| \[ B_{wp} = B_m + 26\text{mm} \] |

Determine "Slotted Hole" details for masonry plate: NYSDOT BD-BG5-BR1

\[ A_m := \phi_{\text{AnchBlt}} + 40\text{mm} \quad A_m = 64\text{mm} \]

\[ A_{wp} := A_m + 26\text{mm} \quad A_{wp} = 90\text{mm} \]

\[ B_m := \phi_{\text{AnchBlt}} + 10\text{mm} \quad B_m = 34\text{mm} \]

\[ B_{wp} := B_m + 26\text{mm} \quad B_{wp} = 60\text{mm} \]
Masonry Plate Dimensions

Longitudinal min. bolt cover =  

\[ E_1 := 1.75 \phi_{\text{AnchBlt}} + 40 \text{mm} \]  

\[ E_1 = 82 \text{mm} \]

Width - Based on the sum of the sole plate width and the anchor bolt location.

\[ E_1 := 1.75 \phi_{\text{AnchBlt}} + 5 \text{mm} \]  

\[ E_1 = 47 \text{mm} \]

\[ E_2 := \phi_{\text{AnchBlt}} + 10 \text{mm} \]  

\[ E_2 = 34 \text{mm} \]

-For Anchor Bolts Located Outside of Sole Plate:

\[ W_{\text{mout}} := \text{Ceil}[W_s + 2 (E_z + E_1)], 5 \text{mm}] \]  

\[ W_{\text{mout}} = 815 \text{mm} \]

-For Anchor Bolts Located Inside of Sole Plate:

\[ W_{\text{mln}} := \text{Ceil}[\text{OD} + 2 (E_z + E_1)], 5 \text{mm}] \]  

\[ W_{\text{mln}} = 600 \text{mm} \]

The masonry plate width will be controlled by whether or not enough room is provided to fasten the bolt (Note: Assume the anchor nut thickness is equal to the anchor bolt diameter.).

\[ W_m := \text{Ceil}[\text{if } W_{\text{mln}} > W_{\text{mout}}, W_{\text{mln}}, \text{if } D > (2 \cdot \phi_{\text{AnchBlt}} + 25 \text{mm}), W_{\text{mln}}, W_{\text{mout}}], 5 \text{mm}] \]  

\[ W_m = 600 \text{mm} \]

Length - Based on the greater of either the anchor bolt placement or 50 mm. plus the base plate (O.D.).

\[ L_m := \max[\text{OD} + 50 \text{mm}, (\text{bolts } + 1) \cdot E_1] \]  

\[ L_m = 485 \text{mm} \]

Thickness of Masonry Plate

Thickness - Masonry Plate is standard at \( T_{\text{mp}} := 20 \text{mm} \) NYSDOT SBD-BG5-R1

\[ T_{\text{min.mp}} := 20 \text{mm} \]

\[ \text{OH}_{\text{m}} := \frac{W_m - \text{OD}}{2} \]  

\[ \text{OH}_{\text{m}} = 82.5 \text{mm} \]

\[ T_{\text{min.masonryplate}} := \begin{cases} \text{OH}_{\text{m}} \sqrt{\frac{2 \cdot P_{\text{strength}}}{\phi_y \cdot F_y \cdot W_m \cdot T_{\text{mp}}}} < T_{\text{min.mp}}, T_{\text{min.mp}}, \text{OH}_{\text{m}} \sqrt{\frac{2 \cdot P_{\text{strength}}}{\phi_y \cdot F_y \cdot W_m \cdot T_{\text{mp}}}} \end{cases} \]  

\[ T_{\text{min.masonryplate}} = 20 \text{mm} \]
LRFD 5.7.5 Bearing (Check Bearing Stress on Concrete Pedestal)

Assume 75 mm of cover on the front and back edges of the masonry plate to the edge of pedestal and 200 mm from the anchor bolts.

\[
A_{\text{pedestal}} := (W_m - 2 \cdot E_t + 2 \cdot 200 \text{mm}) \left( L_m + 2 \cdot 75 \text{mm} \right)
\]

\[
A_{\text{masonry}} := L_m \cdot W_m
\]

Check resistance of concrete pedestal, \( P_n \)

\[
P_n := 0.85 f'_c \cdot A_{\text{masonry}} \cdot \min \left( 2, \sqrt{\frac{A_{\text{pedestal}}}{A_{\text{masonry}}}} \right)
\]

\[
\phi_c := 0.7
\]

Check\(_1\) := if\( TL \leq \phi_c \cdot P_n, "OKAY", "Pedestal Overstressed" \)

The minimum vertical loading is 20% of SDL and DC1 (LRFD 14.6.1) plus any LL uplift.

\[
\sigma_{\text{min}} := 20\% \cdot \text{Vertical\_Load}
\]

\[
\sigma_{\text{TDC}} := \sigma_{\text{DC1}} + \text{if}(\text{LL}_{\text{min}} < 0 \text{kN}, \text{LL}_{\text{min}}, 0)
\]

Check\(_2\) := if\( \sigma_{\text{min}} \leq \sigma_{\text{TDC}}, "OKAY", "FAILS" \)
Output Required for "Bearing Table"

**Capacity**

Vertical Load = 1779kN

Horizontal Load = 338kN

One Way Longitudinal Movement = $\Delta_s + 25\text{mm} = 108.359\text{mm}$

Guide Clearance = "Standard" at a value of $G_{\text{min,gap}} = 3\text{mm}$

**Masonry Plate**

$L_m = 485\text{mm}$  
$W_m = 600\text{mm}$  
$A_m = 64\text{mm}$  
$B_m = 34\text{mm}$

*The designer shall determine the masonry plate thickness.*

**Washer Plate**

$A_{wp} = 90\text{mm}$  
$B_{wp} = 60\text{mm}$

**Sole Plate** (it is the designer's responsibility to verify if $T_2$ is upstation of $T_1$)

$W_s = 650\text{mm}$  
$L_s = 650\text{mm}$  
$T_1 = 20\text{mm}$  
$T_2 = 36\text{mm}$

**Bearing Height**

$D = 175\text{mm}$

**Anchor Bolts**

$\phi_{\text{AnchBlt}} = 24\text{mm}$

bolts = 4

**Connection of Beam to Substructure**

Weld Sizes =  
$W_1 = 8\text{mm}$  
$W_2 = 8\text{mm}$

Number bolts necessary for bolt option =  
Bolts = 4.0

Number of cap screws necessary with D.C.E.S. approval =  
Cap_Screws = 4

**Additional Information**

Check$_1$ = "OKAY"  
Check$_2$ = "OKAY"

$E_z = 34\text{mm}$