**APPENDIX A**

**EXAMPLE 2 - TYPE I BEARING (STEEL REINFORCED)**

**METHOD A**

**GENERAL INFORMATION**

Per CDOT Bridge Design Manual (BDM) Section 14.5.8, reinforced bearing pads may be designed using Method A upon approval by CDOT Unit Leader in coordination with the Bearing SMEs. This example is in accordance with AASHTO LRFD 7th Edition Section 14.7.6.

This example assumes a concrete superstructure that can displace under the effects of temperature, creep, and shrinkage, and assumes a rectangular bearing similar to that shown in Figure 1. The structure is assumed to move freely in the longitudinal direction for the range of temperatures conforming to AASHTO 3.12.2.2 Procedure B. Design for rotation is implicit within Method A procedures per AASHTO C14.7.6.1 and is not investigated. The Designer, however, shall confirm that the thickness of the bearing pad is sufficient to prevent girder-to-support contact as a result of anticipated girder rotations, girder skew, and roadway vertical geometry.

**MATERIAL AND SECTION PROPERTIES**

### Bearing Dimensions

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing Width W</td>
<td>25.00 in</td>
<td>AASHTO 14.7.5.1</td>
</tr>
<tr>
<td>Bearing Length L</td>
<td>12.00 in</td>
<td>AASHTO 14.7.5.1</td>
</tr>
</tbody>
</table>

### Bearing Pad Layers

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior Elastomeric Thickness hre</td>
<td>0.125 in</td>
<td>&lt; 70% hri AASHTO 14.7.6.1</td>
</tr>
<tr>
<td>Interior Elastomeric Thickness hri</td>
<td>0.500 in</td>
<td>AASHTO 14.7.6.1</td>
</tr>
<tr>
<td>Steel Plate Thickness hs</td>
<td>0.125 in</td>
<td>AASHTO 14.7.5.1</td>
</tr>
<tr>
<td>No. of Steel Shim Plates nshims</td>
<td>6</td>
<td>AASHTO 14.7.6.1</td>
</tr>
<tr>
<td>No. of Interior Elastomer Layers n</td>
<td>5</td>
<td>AASHTO 14.7.6.1</td>
</tr>
<tr>
<td>Total Elastomer Thickness hrt</td>
<td>2.750 in</td>
<td>AASHTO 14.7.5.1</td>
</tr>
<tr>
<td>Total Bearing Height t</td>
<td>3.50 in</td>
<td>2&quot; minimum height per BDM 14.5.8</td>
</tr>
</tbody>
</table>

### Bearing Material Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shore A Durometer Hardness Duro</td>
<td>50 (min)</td>
<td>AASHTO 14.7.6.2</td>
</tr>
</tbody>
</table>

**Shear Modulus**

The least favorable value is assumed at each check since the material is specified by its hardness value (AASHTO 14.7.6.2). The shear modulus of the elastomer is based on a temperature of 73°F.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$G_{\text{max}}$</td>
<td>0.130 ksi</td>
<td>AASHTO T14.7.6.2-1</td>
</tr>
<tr>
<td>$G_{\text{min}}$</td>
<td>0.095 ksi</td>
<td>AASHTO T14.7.6.2-1</td>
</tr>
<tr>
<td>Check</td>
<td>0.08 ksi &lt; G &lt; 0.175 ksi</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AASHTO 14.7.6.2</td>
</tr>
</tbody>
</table>

### Steel Shim Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield Strength of Steel $F_y$</td>
<td>36.00 ksi</td>
<td>AASHTO T6.4.1-1</td>
</tr>
<tr>
<td>Allowable Fatigue Threshold $\Delta F_{\text{TH}}$</td>
<td>24.00 ksi</td>
<td>AASHTO T6.6.1.2.3-1</td>
</tr>
</tbody>
</table>

*FIGURE 1 - BEARING DETAIL*
APPENDIX A: EXAMPLE 2 - TYPE I BEARING (REINFORCED) (METHOD A)

BEARING LOADS

Loads acting on the bearing are dead and live load girder reactions at the service limit state. Per AASHTO 14.4.1, dynamic load allowance is excluded from the live load influence. Loads are per bearing.

*Service I Limit State Loads*

\[
DL = 102.00 \text{ kip}
\]

\[
LL = 43.00 \text{ kip}
\]

HORIZONTAL MOVEMENT

Shear deformations include movements from temperature, creep and shrinkage, prestressing effects, live loads, wind, braking, earthquake, and construction tolerances from service load combinations per AASHTO C14.4.1.

*Uniform Temperature Movement Range:*

- Maximum temperature \( T_{\text{max}} = 100 \degree \text{F} \)  
- Minimum temperature \( T_{\text{min}} = -20 \degree \text{F} \)  
- Coeff. of thermal expansion \( \alpha = 6.0 \times 10^{-6} \text{ in/} \degree \text{F} \)  
- Expansion length \( L = 75.00 \text{ ft} = 900.00 \text{ in} \)  
- Service I Load Factor, TU \( y_{\text{TU}} = 1.20 \)  
- AASHTO Reduction Factor \( \gamma_{\text{AASHTO}} = 1.00 \)

\[
\Delta_T = aL(T_{\text{max}} - T_{\text{min}}) = 6.0 \times 10^{-6} \times 900.00 \times [100 - (-20)] = 0.65 \text{ in}
\]

*Creep, Shrinkage, Elastic Shortening, Live Load, and Miscellaneous Movements:*

\[
\Delta_{\text{CR}} = 0.21 \text{ in}
\]

\[
\Delta_{\text{SH}} = 0.07 \text{ in}
\]

\[
\Delta_{\text{EL}} = 0.00 \text{ in}
\]

\[
\Delta_{\text{LL}} = 0.01 \text{ in}
\]

\[
\Delta_{\text{MISC}} = 0.00 \text{ in}
\]

\[
\Delta_o = \text{Maximum horizontal displacement of the superstructure}
\]

\[
\Delta_s = \text{Maximum shear deformation of the bearing modified to account for substructure stiffness}
\]
Assuming the substructure is stiff enough to prevent movement:

\[ \Delta_w = \Delta_s = \sum \alpha_{AASHTO} \gamma_{LT} \Delta_T + \Delta_{GR} + \Delta_{SH} + \Delta_{EL} + \Delta_{LL} + \Delta_{MISC} = 1.07 \text{ in} \]

**SOLUTION**

**Shape Factor**
Rectangular, steel reinforced bearing shape factor without holes:

\[ S_i = \frac{LW}{2h_r(L + W)} = \frac{(12.00 \times 25.00)}{[(2 \times 0.50 \times (12.00 + 25.00))] = 8.11 \text{ AASHTO 14.7.5.1-1} \]

Confirm Method A is applicable for the design of the reinforced bearing pad per AASHTO 14.7.6.1

\[ \text{Check } \frac{\sigma_i^2}{n} < 22 = \frac{(8.11^2)}{5} = 13.15 < 22 \text{ OK AASHTO 14.7.6.1} \]

**Compressive Stress**
AASHTO 14.7.6.3.2

The compressive stress of the bearing shall satisfy the criteria below for a steel reinforced elastomeric bearing pad. Since shear deformation is not prevented, a 10% increase in stress limits is not permitted (AASHTO 14.7.6.3.2).

\[ \sigma_s = \text{average compressive stress due to total load from applicable service load combinations} \]

\[ \sigma_s \leq 1.25 G_{min} S_i = 1.25 \times 0.095 \times 8.11 = 0.96 \text{ ksi AASHTO 14.7.6.3.2-7} \]

and

\[ \sigma_s \leq 1.25 \text{ ksi AASHTO 14.7.6.3.2-8} \]

\[ \sigma_s = \frac{DL + LL}{LW} = \frac{(102.00 + 43.00)}{12.00 \times 25.00} = 0.48 \text{ ksi} \]

\[ \text{Check } \sigma_s \leq 1.25 G_{min} S_i = 0.48 \text{ ksi} < 0.96 \text{ ksi OK} \]

\[ \text{Check } \sigma_s \leq 1.25 \text{ ksi} = 0.48 \text{ ksi} < 1.25 \text{ ksi OK} \]

**Compressive Deflection**

Compressive deflection under instantaneous live load and initial dead load shall meet the following criteria in AASHTO 14.7.6.3.3 (Method A) and 14.7.5.3.6 (Method B). Note the design aids presented in Figure C14.7.6.3.3-1 are used in determining the compressive strain. For cases where the steel reinforced bearing pad material is specified by its shear modulus, equation C14.7.5.3.6-1 is used in lieu of these graphs to determine the strain in the bearing pad under applicable stresses. Refer to Example 3 accordingly.

**Live Load Compressive Deflection**

Minimizing deflection from instantaneous live loads is recommended when bridge joints are present. For jointless bridges, these criteria may be omitted. Method A requirements per 14.7.6.3.3 refer to Method B deflection checks per 14.7.5.3.6.

\[ \delta_L \leq 0.125'' \text{ AASHTO 14.7.5.3.6} \]

\[ \delta_L = \sum \epsilon_{LL} h_r = \epsilon_{LL} h_r \text{ compressive deflection due to live load AASHTO 14.7.5.3.6-1} \]

\[ \epsilon_{LL} = \text{instantaneous live load compressive strain in elastomeric pad determined from Figure C14.7.6.3.3-1} \]
**APPENDIX A: EXAMPLE 2 - TYPE I BEARING (REINFORCED) (METHOD A)**

**Average Compressive Stress Due to Live Load at the Service Limit State**

\[
\sigma_L = \frac{LL}{LW} = \frac{43.00}{12.00 \times 25.00} = 0.14 \text{ ksi}
\]

**Check**

\[
0.0138 < 0.125 \text{ in}
\]

**OK**

**Dead Load Compressive Deflection**

AASHTO does not have limitations on initial or long term dead load deflections. The following calculation is for demonstration only. Engineering judgment shall be used in evaluating appropriate allowable deflections in the bearing. Method A requirements per 14.7.6.3.3 refer to Method B deflection checks per 14.7.5.3.6.

**Initial Dead Load Deflection**

\[
\delta_d = \sum \varepsilon_{di} h_{ri} = \frac{DL}{LW} = \frac{102.00}{12.00 \times 25.00} = 0.34 \text{ ksi}
\]

\[
\varepsilon_{di} = 0.0175 \text{ AASHTO C14.7.6.3.3-1}
\]

\[
\delta_d = \varepsilon_{di} h_{rt} = 0.0175 \times 2.75 = 0.0481 \text{ in}
\]

**Long Term Dead Load Deflection**

\[
\delta_{lt} = \delta_d + \alpha_c \delta_d
\]

\[
\alpha_c = 0.25 \text{ AASHTO T14.7.6.2-1}
\]

\[
\delta_{lt} = \delta_d + 0.25 \delta_d = 0.0481 + 0.25 \times 0.0481 = 0.060 \text{ in.}
\]
Combined Live Load and Dead Load Compressive Deflection

\[ \delta_c \leq 0.9h_{rt} = 0.9 \times 0.50 = 0.45 \text{ in.} \]  
AASHTO 14.7.6.3.3

\[ \delta_c = \sum \varepsilon_{si} h_{ri} \]  
compressive deflection due to live load and dead load  
AASHTO 14.7.5.3.6-1

\[ \varepsilon_{si} = \text{instantaneous live and dead load compressive strain in elastomeric pad determined from Figure C14.7.6.3.3-1} \]

\[ \sigma_s = \frac{DL + LL}{LW} = 0.48 \text{ ksi} \]

\[ \varepsilon_{si} = 0.026 \]  
AASHTO C14.7.6.3.3-1

\[ \delta_c = \varepsilon_{si} h_{rt} = 0.026 \times 0.50 = 0.0130 \text{ in} \]

Check \[ \delta_c \leq 0.9h_{rt} \]  
0.0130 in < 0.045 in \textbf{OK}

Shear Deformation

Total elastomer thickness = \( h_{rt} \)

\[ h_{rt} \geq 2\Delta_s = 2 \times 1.07 = 2.14 \text{ in} \]  
AASHTO 14.7.6.3.4

Check \[ h_{rt} = 2.75 \text{ in} > 2.14 \text{ in} \textbf{OK} \]

Stability

Total bearing thickness, \( t \), shall not exceed the lesser of the following dimensions:

\[ L = \frac{12.00}{3} = 4.00 \text{ in} \]

and

\[ W = \frac{25.00}{3} = 8.33 \text{ in} \]

Check \[ t = 3.50 \text{ in} < 4.00 \text{ in} \textbf{OK} \]

Reinforcement

AASHTO 14.7.5.3.5

Note that holes are not present in the bearing. The allowable thickness does not need to be increased per AASHTO 14.7.5.3.5

The minimum thickness of steel reinforcement shall satisfy the following:

\[ h_s \geq 0.0625 \text{ in} \]

and

(Service Limit State)

\[ h_s \geq 3\frac{h_{rt}\sigma_s}{F_y} = \frac{3 \times 0.500 \times 0.48}{36} = 0.020 \text{ in} \]  
AASHTO 14.7.5.3.5-1

and

(Fatigue Limit State)

\[ h_s \geq \frac{2h_{rt}\sigma_s}{F_{TH}} = \frac{2 \times 0.500 \times 0.14}{24.00} = 0.006 \text{ in} \]  
AASHTO 14.7.5.3.5-2
Check

\[ h_s = 0.125 \text{ in} > 0.0625 \text{ in} \quad \text{OK} \]

\[ 0.125 \text{ in} > 0.020 \text{ in} \quad \text{OK} \]

\[ 0.125 \text{ in} > 0.006 \text{ in} \quad \text{OK} \]

**Anchorage (Bearing Pad Slip)**

The bearing pad must be secured against horizontal movement if the shear force sustained by the deformed pad exceeds the minimum vertical force due to permanent loads modified for the concrete friction. \( G_{\text{max}} \) is used since the pad is stiffer at colder temperatures and will produce larger shear forces. Note the following example considers longitudinal deformations only; wind, breaking, and seismic loads shall also be considered as appropriate, in the direction of consideration.

\[
H_b = \mu P_{\text{min}} \\
H_b = G_{\text{max}} A \frac{\Delta_s}{h_{rt}}
\]

Combining equations:

\[
\Delta_{s,allow} = \frac{\mu P_{\text{min}} h_{rt}}{G_{\text{max}} A} = \frac{(0.20 \times 102.00 \times 2.75)}{(0.13 \times 300.00)} = 1.438 \text{ in.}
\]

where

\[ \mu = 0.20 \quad \text{Coefficient of friction AASHTO C14.8.3.1} \]

\[ P_{\text{min}} = DL = 102.00 \text{ kip} \]

\[ A = LW = 300.00 \text{ in}^2 \]

\[ h_{rt} = 2.75 \text{ in} \]

Check

\[ \Delta_{s,allow} = 1.438 \text{ in} > \Delta_s = 1.068 \text{ in} \quad \text{OK} \]

In cases where \( \Delta_s \) exceeds \( \Delta_{s,allow} \), anchor bolts shall be sized and designed in accordance with those Articles specified in AASHTO 14.8.3

**Geometry**

The minimum unreinforced bearing pad thickness of 2 in. is assumed sufficient to prevent girder-to-support contact under the applied girder rotations and compressive deflections. Under extreme skews, large girder loads or rotations, and/or steep profile grades, the Designer shall confirm the bearing thickness. Refer to Example 1 - Elastomeric Leveling Pad.