EXAMPLE 2 - TYPE I BEARING (REINFORCED) (METHOD A)   *1*
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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 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

Bearing Width	$W =$	**25.00**	in	AASHTO 14.7.5.1
Bearing Length	$L =$	**12.00**	in	AASHTO 14.7.5.1

Bearing Pad Layers

Exterior Elastomeric Thickness	$h_{re} =$	**0.125**	in	**OK**	< 70% h_{ri} AASHTO 14.7.6.1
Interior Elastomeric Thickness	$h_{ri} =$	**0.500**	in		
Steel Plate Thickness	$h_s =$	**0.125**	in		
No. of Steel Shim Plates	$n_{shims} =$	**6**			
No. of Interior Elastomer Layers	$n =$	**5**			AASHTO 14.7.6.1
Total Elastomer Thickness	$h_{rt} =$	**2.750**	in		
Total Bearing Height	$t =$	**3.50**	in	**OK**	2" minimum height per BDM 14.5.8

Bearing Material Properties

Shore A Durometer Hardness

	Duro =	**50**	(min)	AASHTO 14.7.6.2

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°.

	$G_{max}=$	**0.130**	ksi	AASHTO T14.7.6.2-1
	$G_{min}=$	**0.095**	ksi	
	Check =	0.08 ksi < G < 0.175 ksi	**OK**	AASHTO 14.7.6.2

Steel Shim Properties

Yield Strength of Steel	$F_y =$	**36.00**	ksi	AASHTO T6.4.1-1
Allowable Fatigue Threshold	$\Delta F_{TH} =$	**24.00**	ksi	AASHTO T6.6.1.2.3-1

FIGURE 1 - BEARING DETAIL

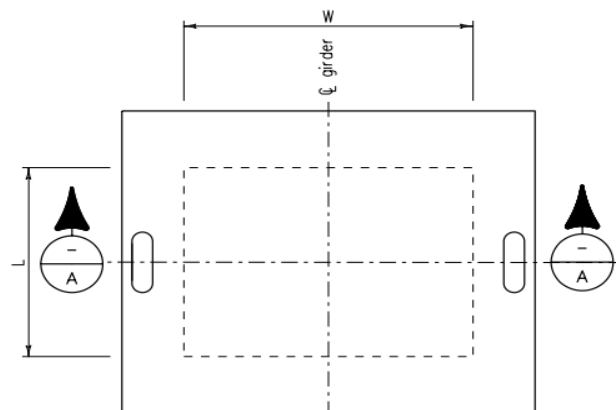===
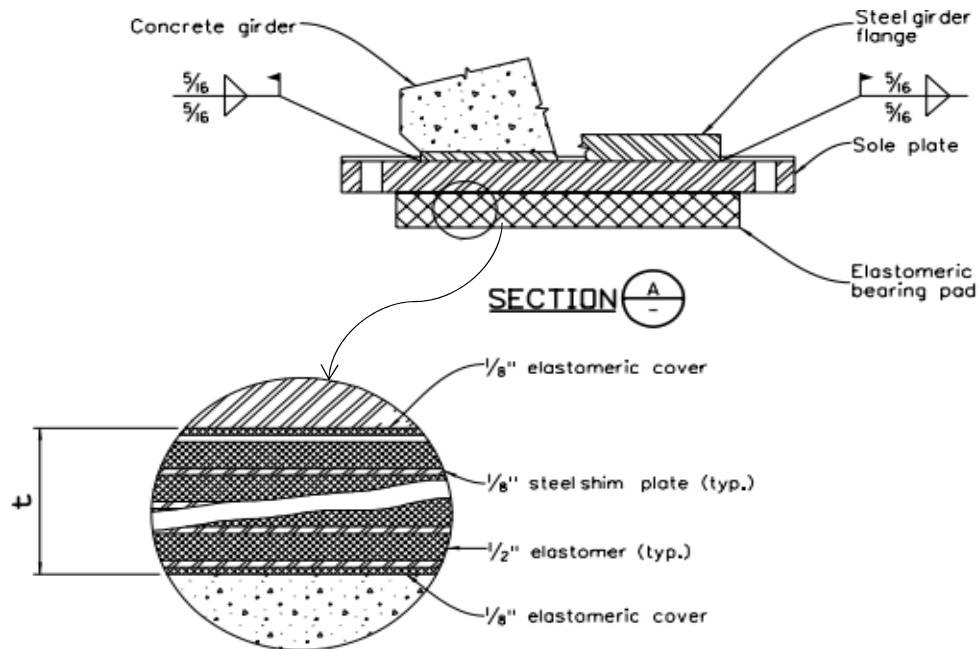
FIGURE 2 - TYPE I - STEEL REINFORCED BEARING DETAIL - SECTION

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**	kip
LL=	**43.00**	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	$T_{max} =$	**100**	°F		AASHTO F3.12.2.2-1
Minimum temperature	$T_{min} =$	**-20**	°F		AASHTO F3.12.2.2-2
Coeff. of thermal expansion	$\alpha =$	**6.0E-06**	in/in/ °F		AASHTO 5.4.2.2
Expansion length	$L =$	**75.00**	ft =	900.00 in	
Service I Load Factor, TU	$\gamma_{TU} =$	**1.20**			AASHTO T3.4.1-1
AASHTO Reduction Factor	$\alpha_{AASHTO} =$	**1.00**			BDM 14.5.3

$$\Delta_T = \alpha L (T_{max} - T_{min}) = \qquad 6.0E\text{-}6*900.00*[100\text{-}(\text{-}20)] = \qquad 0.65 \text{ in} \qquad \text{AASHTO 3.12.2.3-1}$$

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

Creep movement	$\Delta_{CR} =$	**0.21**	in
Shrinkage movement	$\Delta_{SH} =$	**0.07**	in
Elastic shortening	$\Delta_{EL} =$	**0.00**	in
Live load movement	$\Delta_{LL} =$	**0.01**	in
Miscellaneous movement	$\Delta_{MISC} =$	**0.00**	in

$\Delta_o =$ Maximum horizontal displacement of the superstructure

$\Delta_s =$ Maximum shear deformation of the bearing modified to account for substructure stiffness

Assuming the substructure is stiff enough to prevent movement:

<div align="right">AASHTO 14.7.5.3.2 & BDM 14.5.3</div>

$$\Delta_o = \Delta_s = \sum \alpha_{AASHTO}\gamma_{TU}\Delta_T + \Delta_{CR} + \Delta_{SH} + \Delta_{EL} + \Delta_{LL} + \Delta_{MISC} =$$

1.00*1.20*0.65+0.21+0.07+0.00+0.01+0.00 =   1.07 in

SOLUTION
Shape Factor

Rectangular, steel reinforced bearing shape factor without holes:

<div align="right">AASHTO 14.7.5.1-1</div>

$$S_i = \frac{LW}{2h_{ri}(L + W)} =$$ (12.00*25.00) / [2*0.50*(12.00+25.00)] =   8.11

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

Check $\dfrac{S_i^2}{n} < 22$ = (8.11^2) / 5 =   13.15   <   22   **OK**   AASHTO 14.7.6.1

Compressive Stress
<div align="right">AASHTO 14.7.6.3.2</div>

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).

$\sigma_s =$ average compressive stress due to total load from applicable service load combinations

$\sigma_s \leq 1.25 G_{min}S_i =$ 1.25*0.095*8.11 =   0.96 ksi   AASHTO 14.7.6.3.2-7

and

$\sigma_s \leq 1.25\ ksi$ AASHTO 14.7.6.3.2-8

$\sigma_s = \dfrac{DL + LL}{LW} =$ (102.00+43.00) / (12.00*25.00) =   0.48 ksi

Check $\sigma_s \leq 1.25 G_{min}S_i$ 0.48 ksi   <   0.96 ksi   **OK**

Check $\sigma_s \leq 1.25\ ksi$ 0.48 ksi   <   1.25 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.

$\delta_L \leq 0.125"$ AASHTO C14.7.5.3.6

$\delta_L = \sum \varepsilon_{Li} h_{ri} = \varepsilon_L h_{rt}$ compressive deflection due to live load   AASHTO 14.7.5.3.6-1

$\varepsilon_{Li} =$ instantaneous live load compressive strain in elastomeric pad determined from Figure C14.7.6.3.3-1

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$\sigma_L =$ average compressive stress due to live load at the service limit state

$$\sigma_L = \frac{LL}{LW} = \qquad 43.00 / (12.00*25.00) = \qquad 0.14 \text{ ksi}$$

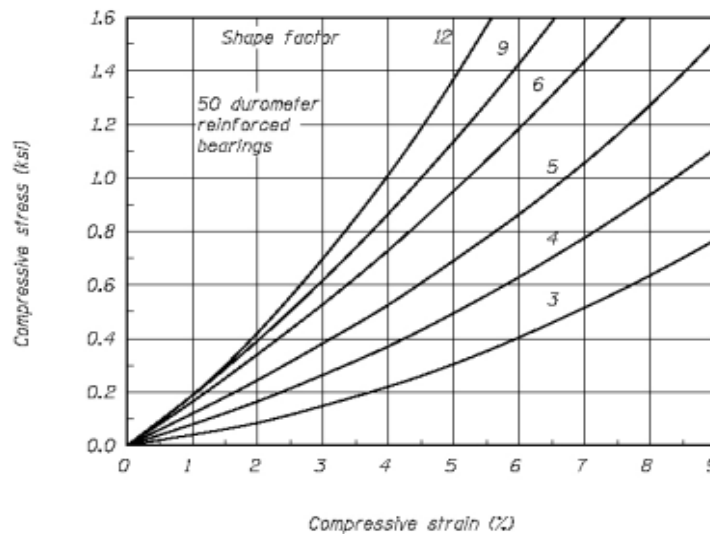**FIGURE 3 - AASHTO FIGURE C14.7.6.3.3-1**

$\varepsilon_{Li} =$ 0.005   AASHTO C14.7.6.3.3-1

$\delta_L = \varepsilon_{Li}h_{rt} =$ 0.005*2.75 =   0.0138 in

Check $\delta_L \leq 0.125"$ 0.0138 in   <   0.125 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.

<u>Initial dead load deflection:</u>

$\delta_d = \sum \varepsilon_{di}h_{ri} =$ AASHTO 14.7.5.3.6-2

$\varepsilon_{di} =$ initial dead load compressive strain in elastomeric pad determined from Figure C14.7.6.3.3-1

$\sigma_d =$ average compressive stress due to dead load at the service limit state

$$\sigma_d = \frac{DL}{LW} = \qquad 102.00 / (12.00*25.00) = \qquad 0.34 \text{ ksi}$$

$\varepsilon_{di} =$ 0.0175   AASHTO C14.7.6.3.3-1

$\delta_d = \varepsilon_{di}h_{rt} =$ 0.0175*2.75 =   0.0481 in

<u>Long term dead load deflection:</u>

$\delta_{lt} = \delta_d + \alpha_{cr}\delta_d$ AASHTO 14.7.5.3.6-3
$\alpha_{cr} =$ 0.25   AASHTO T14.7.6.2-1

$\delta_{lt} = \delta_d + \alpha_{cr}\delta_d =$ 0.0481+0.25*0.0481 =   0.060 in.

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Combined Live Load and Dead Load Compressive Deflection

$\delta_s \leq .09 h_{ri}$	= 0.09*0.50 =	0.045 in.	AASHTO 14.7.6.3.3

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

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

$\sigma_s =$ average compressive stress due to total load from applicable service load combinations

$$\sigma_s = \frac{DL + LL}{LW} = \qquad 0.48 \text{ ksi}$$

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

$\delta_s = \varepsilon_{si} h_{ri} =$ 0.026*0.50 =   0.0130 in

Check $\delta_s \leq .09 h_{ri}$ 0.0130 in   <   0.045 in   **OK**

Shear Deformation
Total elastomer thickness = h_{rt}

$h_{rt} \geq 2\Delta_s=$ 2*1.07 =   2.14 in   AASHTO 14.7.6.3.4

Check $h_{rt} =$ 2.75 in   >   2.14 in   **OK**

Stability   AASHTO 14.7.6.3.6

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

$\dfrac{L}{3} =$ 12.00 / 3 =   4.00 in

and

$\dfrac{W}{3} =$ 25.00 / 3 =   8.33 in

Check   t =   3.50 in   <   4.00 in   **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:

$h_s \geq .0625 in$

and

(Service Limit State)

$h_s \geq \dfrac{3 h_{ri} \sigma_s}{F_y} = \qquad \dfrac{3*0.500*0.48}{36} \qquad = 0.020 \text{ in}$ AASHTO 14.7.5.3.5-1

and

(Fatigue Limit State)

$h_s \geq \dfrac{2 h_{ri} \sigma_L}{\Delta F_{TH}} = \qquad \dfrac{2*0.500*0.14}{24.00} \qquad = 0.006 \text{ in}$ AASHTO 14.7.5.3.5-2

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Check

$$h_s =$$ 0.125 in   >   0.0625 in   **OK**

0.125 in   >   0.020 in   **OK**

0.125 in   >   0.006 in   **OK**

Anchorage (Bearing Pad Slip)   AASHTO 14.8.3

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_{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.

$$H_b = \mu P_{min}$$ AASHTO 14.6.3.1-1

and
$$H_b = G_{max}A \frac{\Delta_s}{h_{rt}}$$ AASHTO 14.6.3.1-2

Combining equations:
$$\Delta_{s,allow} = \frac{\mu P_{min} h_{rt}}{G_{max}A} =$$ (0.20*102.00*2.75) / (0.13*300.00) =   1.438 in.

where

$$\mu =$$ 0.20   Coefficient of friction AASHTO C14.8.3.1
$$P_{min} = DL =$$ 102.00   kip
$$A = LW =$$ 300.00   in^2
$$h_{rt} =$$ 2.75   in

Check

$$\Delta_{s,allow} =$$ 1.438 in   > $$\Delta_s =$$ 1.068 in **OK**

In cases where Δ_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.

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