LUC-23 - ELASTOMERIC BEARING - METHOD A - ABUTMENT BEARINGS

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Checker: VDK **Date:** 3/14/2023

This sheet is used to design a rectangular elastomeric bearing using AASHTO LRFD Method A. The preferred design of elastomeric bearings is Method A (ODOT BDM S14.7.5).

This sheet is in accordance with AASHTO's LRFD Design Bridge Design Specification.

User inputs are highlighted in - Yellow

Sheet assumption are highlighted in - Blue
User may change if necessary

Sheet checks are highlighted in - Green

Inputs from other files are highlighted in purple - Purple

General Structure Data

Super_Material := Steel (selected) / Concrete

Select superstructure material

Bearing_Constraint := Fixed / Expansion (selected)

Select whether the bearing is constrained or not.

$Bridge\_Length := 281.5ft$

$Skew := 3.175deg$

$Span\_Length_{span1} := 52 \cdot ft + 0 \cdot in = 52.0\,ft$

$Span\_Length_{span4} := 52 \cdot ft + 0 \cdot in = 52.0\,ft$

$Span_{max} := \max(Span\_Length_{span1}, Span\_Length_{span4}) = 52.000\,ft$

$No\_Spans := 4$

$No\_substructure\_units := No\_Spans + 1 = 5$

$Deck_{width} := 90ft + 10in = 90.833\,ft$

$Multi\_Path_{width} := 14 \cdot ft + 0 \cdot in$

$Barrier_{left} := 1ft + 2in$

$Barrier_{right} := 1ft + 8in$

$Barrier_{sidewalk} := 2ft$

$Roadway_{width} := Deck_{width} - Multi\_Path_{width} - Barrier_{left} - Barrier_{right} - Barrier_{sidewalk} = 72.000\,ft$

$No\_Lane := \text{floor}\left[Roadway_{width} \div (12 \cdot ft)\right] = 6.0$ *AASHTO 3.6.1.1.1*

$Beam_{wt\_ext} := 170 \cdot plf$ *W36x170*

$Beam_{wt\_int} := 170 \cdot plf$ *W36x170*

$Barrier_{ht} := 3ft + 6in$

$Beam_{d.prop} := 36.2 \cdot in$ *W36x170*

$Beam_{d.exist} := 36.2 \cdot in$ *W36x170*

$Beam_{d\_max} := \max(Beam_{d.prop}, Beam_{d.exist}) = 3.017\,ft$

$b_{f\_ext} := 12 \cdot in$

$b_{f\_int} := 12 \cdot in$

$A_{ext} := 50 \cdot in^2$

$A_{int} := 50 \cdot in^2$

$t_{f\_ext} := 1.10 \cdot in$

$t_{f\_int} := 1.10 \cdot in$

$t_f := \max(t_{f\_ext}, t_{f\_int}) = 1.100 \cdot in$

$Deck_{thick} := 8.5 \cdot in$ $Deck_{thick\_overhang} := 10.5in$ Minimum deck overhang thickness as mentioned in ODOT BDM

$Asphalt_{thick} := 1 \cdot in$ $Haunch_{thick} := 2 \cdot in$ *From Plans*

$Deck\_Overhang\_1 := 2 \cdot ft + 4 \cdot in$

$Deck\_Overhang\_2 := 2 \cdot ft + 6 \cdot in$

$Beam\_Space_{ext} := 6ft$ *Controlling Space* $Beam\_Space_{int} := 6ft$ *Controlling Space*

$No_{beams} := 14$

$No_{beams\_phase1} := 7$ $No_{beams\_phase2} := 7$

$Clear\_Slab_{top} := 2.5 \cdot in$ $Clear\_Slab_{bot} := 1.5 \cdot in$ *ODOT BDM 304.4.9*

$$Tributary_{width\_ext\_1} := Deck\_Overhang\_1 + \frac{1}{2} \cdot Beam\_Space_{ext} = 5.333\,ft$$

$$Tributary_{width\_ext\_2} := Deck\_Overhang\_2 + \frac{1}{2} \cdot Beam\_Space_{ext} = 5.500\,ft$$

$$Tributary_{width\_int} := Beam\_Space_{int} = 6.000\,ft$$

Distance from average beam seat to average top of footing

$H_{col1} := 23.3ft$

$H_{col2} := 23.3ft$

$H_{col3} := 23.3ft = 23.300\,ft$

$$H_{height} := \frac{\left(H_{col1} + H_{col2} + H_{col3}\right)}{3} = 23.3\,ft$$

H for abutments is equal to the average height of the column supporting bridge deck from abutment to next expansion joint
H for columns and/or piers, is equal to the column, or pier height - AASHTO 4.7.4.4

$Barrier_{height} := 3ft + 6in$

$Superstructure\_Height := Barrier_{height} + Deck_{thick} + Haunch_{thick} + Beam_{d\_max} = 7.4\,ft$

AASHTO - 3.8.1.2.1 -Average height of the top of the superstructure above surrounding ground or water surface

Merlin Dash Output

$\gamma_{conc} := 150 \cdot pcf$

$\gamma_{steel} := 490 \cdot pcf$

Total Dead Load for Bearing Calculations

$DL_{ext} := 15.34 \cdot kip$

$DL_{int} := 15.47 \cdot kip$

$DL_{Dash} := \max\left(DL_{ext}, DL_{int}\right) = 15.470 \cdot kip$

Live Load

From Merlin Dash Output TABLE 1.2.7.1=LIVE LOAD REACTIONS (UNFACTORED)
Reactions are not multiplied by Load Modifiers (ductility, redundancy and operational importance).

$LL_{ext} := 34.55 \cdot kip$

Maximum load - no impact as that is not needed for elastomeric bearings

$LL_{int} := 49.66 \cdot kip$

$LL\_no\_IM := \max\left(LL_{ext}, LL_{int}\right) = 49.660 \cdot kip$

Service I is normal operational use
Service II is for slip-control, and Service III and Service IV are for prestressed concrete

Semi Integral - Abutment - Composite Load

$Pedestal_{width} := 3 \cdot ft + 9 \cdot in$

$Load\_Plate_{ht} := 1.5 \cdot in$

$Inegral\_Abut_{ht} := Beam_{d\_max} + 9in + Load\_Plate_{ht} + Deck_{thick} = 4.600\,ft$

$$Abut\_Diaph_{length} := \left(\frac{Beam\_Space_{ext}}{2} + \frac{Beam\_Space_{int}}{2}\right) \div (\cos(Skew)) = 6.009\,ft$$

$$Semi\_Int\_Conc_{wt} := \left[\left(Pedestal_{width} \cdot Inegral\_Abut_{ht}\right) \cdot \left(Abut\_Diaph_{length}\right) \cdot \gamma_{conc} \cdots + -\left(A_{ext}\right) \cdot (1 \cdot ft + 9in) \cdot \left(\gamma_{conc}\right)\right] = 15.458 \cdot kip$$

Approach Slab - Composite DC

$App\_Slab_{thick} := 15 \cdot in$

$App\_Slab_{length} := 25 \cdot ft$

$App\_Slab_{width} := Deck_{width} \div \cos(Skew) = 90.973\,ft$

$$App\_Slab_{wt} := \frac{1}{3} \cdot \left(App\_Slab_{thick} \cdot App\_Slab_{width} \cdot App\_Slab_{length}\right) \cdot \gamma_{conc} \div No_{beams} = 10.153 \cdot kip$$

Assume 1/3 of the app slab weight goes to the bearings

Combined DL

$DL := DL_{Dash} + Semi\_Int\_Conc_{wt} + App\_Slab_{wt} = 41.081 \cdot kip$

Horizontal Forces

Braking

The greater of 25% of the axle weights of the design truck or design tandem or 5% of the design truck or tandem plus lane load. Multiple presence factors shall apply.

Design truck controls over design tandem, use design truck loads for braking force.

$HL\_Truck\_Axle_{wt} := 8 \cdot kip + 32 \cdot kip + 32 \cdot kip = 72.0 \cdot kip$ *AASHTO LRFD - 3.6.1.2.2*

$Lane_{width} := 12 \cdot ft$ $No_{lanes} := floor(Roadway_{width} \div Lane_{width}) = 6.000$

$$m_{lane} := \begin{cases} 1.2 & \text{if } No_{lanes} < 2 \\ 1.0 & \text{if } 2 \le No_{lanes} < 3 \\ 0.85 & \text{if } 3 \le No_{lanes} < 4 \\ 0.65 & \text{otherwise} \end{cases} = 0.650$$

LL Reduction factors from - AASHTO LRFD - Table 3.6.1.1.2-1

$Lane_{Load} := 0.64 \cdot klf$ *AASHTO LRFD - 3.6.1.2.4*

$R_{Lane} := Bridge\_Length \cdot Lane_{Load} = 180.16 \cdot kip$

Use whole bridge length for reaction
Even doing this BR_1 will still control

$BR_1 := 0.25 \cdot HL\_Truck\_Axle_{wt} = 18.0 \cdot kip$

$BR_2 := 0.05 \cdot (HL\_Truck\_Axle_{wt} + R_{Lane}) = 12.61 \cdot kip$

$BR_{max} := m_{lane} \cdot No_{lanes} \cdot max(BR_1, BR_2) = 70.2 \cdot kip$ *BR_1 Controls*

$BR := BR_{max} \div (No_{beams}) = 5.014 \cdot kip$ *There are 14 total bearings*

Centrifugal Forces (No centrifugal forces on this bridge)

$f := \frac{4}{3}$ *For load combinations other than fatigue.*

$v := 0mph = 0.000$ *Highway design speed*

$g := 1 \frac{ft}{s^2}$ *Gravitation acceleration*

$R_{curve} := 1ft$ *Radius of curvature of traffic lane*

$C_{factor} := f \cdot \frac{v^2}{g \cdot R_{curve}} = 0.000$ *AASHTO LRFD - 3.6.3-1*

$CE_{total} := m_{lane} \cdot C_{factor} \cdot HL\_Truck\_Axle_{wt} = 0.000 \cdot kip$

$CE := CE_{total} \div (No_{beams}) = 0.000 \cdot kip$ *There are 14 total bearings*

Horizontal Wind on Live Loads

For usual girder and slab bridges having a span length of not more 150 ft and a maximum height 30.0 ft above low ground or ground level, the following wind loading, both applied simultaneously, may be used

$WL_{long\_line} := 0.00254 \cdot klf$ *AASHTO LRFD - 3.8.1.3*

$WL_{long} := WL_{long\_line} \cdot (Bridge\_Length) \div (No_{beams}) \div No\_substructure\_units = 0.010 \cdot kip$

$WL_{trans\_line} := 0.09746 \cdot klf$ *AASHTO LRFD - 3.8.1.3*

$WL_{trans} := WL_{trans\_line} \cdot [(Bridge\_Length) \div (No_{beams}) \div No\_substructure\_units] \div (No_{beams}) = 0.028 \cdot kip$

Horizontal Wind on Superstructures

AASHTO LRFD - 3.8.1.2.3a - For usual girder and slab bridges having a span length of not more 125 ft and a maximum height 30.0 ft above low ground or ground level, the following wind loading, both applied simultaneously, may be used
Transverse - 100% of wind load calculated based on wind direction perpedicular to the longitudinal axis of the bridge

$V_{Ser\_I} := 70 \cdot mph$ *AASHTO Table 3.8.1.1.2-1*

$G_{gust} := 1.0$ *AASHTO Table 3.8.1.2.1-1 - for non-sound barriers*

$C_D := 1.3$ *AASHTO Table 3.8.1.2.1-2 - Winward on I-beam superstructures*

$Z := \max(\text{Superstructure\_Height}, 33.0 \cdot ft) = 33.0\,ft$ *AASHTO 3.8.1.2.1*

$\text{Ground\_Surface\_Roughness} :=$
Category B
Category C
Category D

AASHTO 3.8.1.1.4 - Urban and Suburban areas, wooded area, or other terrainwith numberous closely spaced obstructions having the size of single -family dwelling or larger

$K_{z\_Ser\_I} := 1.0$ *AASHTO 3.8.1.2.1*

$$P_{z\_Ser\_I} := 2.56 \cdot 10^{-6} \cdot \left[\left(V_{Ser\_I} \div mph\right)^2\right] \cdot K_{z\_Ser\_I} \cdot G_{gust} \cdot C_D \cdot ksf = 0.016 \cdot ksf$$

$\text{Exposed\_Height\_Barrier} := 3ft + 6 \cdot in = 3.500\,ft$ *Single slope concrete bridge railing - SBR-1-20*

$$\text{Exposed\_height}_{super} := \text{Beam}_{d\_max} + \text{Haunch}_{thick} + \text{Deck}_{thick} + \text{Exposed\_Height\_Barrier} = 7.392\,ft$$

$$\text{WS\_Ser\_I}_{trans} := P_{z\_Ser\_I} \cdot \text{Exposed\_height}_{super} \cdot (\text{Bridge\_Length}) \div \left(\text{No}_{beams}\right) \div \text{No\_substructure\_units} = 0.485 \cdot kip$$

$\text{WS\_Ser\_I}_{long} := (25 \cdot \%) \cdot \text{WS\_Ser\_I}_{trans} = 0.121 \cdot kip$ *AASHTO 3.8.1.2.3a simplied procedure*

Temperature Strain

Used for checking the shear - AASHTO 14.7.6.3.4

$\text{Temp}_{base} := 60 \cdot deg$ *ODOT BDM S14.7.5.3.4*

$\text{Temp}_{max\_steel} := 120 \cdot deg$ $\text{Temp}_{min\_steel} := -30 \cdot deg$

$\text{Temp}_{max\_conc} := 95 \cdot deg$ $\text{Temp}_{min\_conc} := 15 \cdot deg$ *ODOT BDM S3.12.2*

$$\Delta_{temp} := \begin{cases} \max\left(\text{Temp}_{base} - \text{Temp}_{min\_steel}, \text{Temp}_{max\_steel} - \text{Temp}_{base}\right) & \text{if Super\_Material} = \text{"Stl"} \\ \max\left(\text{Temp}_{base} - \text{Temp}_{min\_conc}, \text{Temp}_{max\_conc} - \text{Temp}_{base}\right) & \text{if Super\_Material} = \text{"Conc"} \end{cases} = 90.0 \cdot deg$$

$$\alpha := \begin{cases} 6.5 \cdot 10^{-6} \dfrac{1}{deg} & \text{if Super\_Material} = \text{"Stl"} \\ 6.0 \cdot 10^{-6} \dfrac{1}{deg} & \text{if Super\_Material} = \text{"Conc"} \end{cases} = 0.0000065 \cdot \frac{1}{deg}$$

Steel - AASHTO 6.4.1

Conc - AASHTO 5.4.2.2

$\varepsilon_{temp\_girder} := \Delta_{temp} \cdot \alpha = 0.000585$ *in. / in.*

Temperature Force to be determined later when bearing parameters are established.

Bearing Material Properties

AASHTO 14.7.6.2

Durometer := [50 / **60** / 70]

Select the Shore A Durometer Hardness of the bearing

ODOT BDM 306.4.2.1 - Elastomeric Bearings should be designed based on a durometer of either 50 or 60

AASHTO Table 14.7.6.2-1

Lower Limit of Range of Shear Modulus:

$$G_{low} := \begin{cases} 0.095 \cdot ksi & \text{if } Durometer = 50 \\ 0.130 \cdot ksi & \text{if } Durometer = 60 \\ 0.200 \cdot ksi & \text{if } Durometer = 70 \end{cases} = 0.130 \cdot ksi$$

Upper Limit of Range of Shear Modulus:

$$G_{up} := \begin{cases} 0.130 \cdot ksi & \text{if } Durometer = 50 \\ 0.200 \cdot ksi & \text{if } Durometer = 60 \\ 0.300 \cdot ksi & \text{if } Durometer = 70 \end{cases} = 0.200 \cdot ksi$$

General Design - Determine Bearing Dimensions

AASHTO 14.7.6.1

$Bearing_{length} := 13 \cdot in$ *Perpendicular to axis of rotation. Generally parallel to global long axis*

$Bearing_{width} := 20 \cdot in$ *Parallel to axis of rotation Generally parallel to global transverse axis*

$$Bearing_{area} := Bearing_{length} \cdot Bearing_{width} = 260.0 \cdot in^2$$

$h_{r\_int} := 0.4 \cdot in$ *h_{ri} is the thickness of internal layer. All internal layers are same thickness (AASHTO 14.7.6.1) So the i-th internal layer, h_{ri}, is the same as the other layers. So call this h_{r_int}*

$h_{r\_ext} := 0.25 \cdot in$ *Thickness of external layer AASHTO 14.7.6.1 - Cover Layers shall be no more than 70% of thickness of internal layers*

$n_{int} := 5$ *Number of internal layers*

$n_{ext} := 1$ *Number of external layers There is only 1 exterior layer as there is a top cover plate.*

$$n_s := (n_{int} + n_{ext}) - 1 = 5.000$$

$h_s := 0.1046 \cdot in$ *Thickness of laminate 12 Gage Steel Plate*

$h_{s\_limit} := \frac{1}{16} \cdot in$ *The thickness of steel laminates are limited to 1/16"*

$$Steel\_thickness_{check} := if(h_s \geq h_{s\_limit}, \text{"Okay"}, \text{"No Good"}) = \text{"Okay"}$$

$F_y := 36 \cdot ksi$ *Yield stress of the laminates*

$\Delta F_{TH} := 24 \cdot ksi$ *Constant Amplitude Fatigue Threshold for Category A: AASHTO Table 6.6.1.2.5-3*

$$S_i := \frac{(Bearing_{length} \cdot Bearing_{width})}{2 \cdot h_{r\_int} \cdot (Bearing_{length} + Bearing_{width})} = 9.848$$

AASHTO Eq. 14.7.5.1-1 All internal layers are similar. So the i-th internal layer is the same as the others

$$Bearing_{geometry} := \begin{cases} \dfrac{S_i^2}{n_{int}} & \text{if } h_{r\_ext} < 0.5 \cdot h_{r\_int} \\ \dfrac{S_i^2}{n_{int} + n_{ext} \cdot 0.5} & \text{otherwise} \end{cases} = 17.635$$

When h_{r_ext} is ≥ 0.5 x h_{r_int}, the parameter n (number of interior layers), may be increased by one-half for each such exterior layer. -AASHTO - 14.7.6

AASHTO 14.7.6.1 - For steel-reinforced elastomeric bearings in which the primary rotation is about the axis parallel to the transverse axis of the bridge, $S_i^2 / n < 22$ ($n = n_{int}$)

AASHTO Commentary 14.7.6.1 - For rectangular bearing pads, the specified limit of 22 for S_i^2 / n is appropriate except that a limiting value of 20 for S_i^2 / n should be considered when the value of n is greater than or equal to 3. ($n = n_{int}$)

$$Bearing\_Geometry_{check} := \text{if}\left(Bearing_{geometry} < \text{if}\left(n_{int} \geq 3, 20, 22\right), \text{"Okay"}, \text{"No Good"}\right) = \text{"Okay"}$$

Check that the total height of the bearing excluding internal laminates is between 1" and 5" ODOT BDM 306.4.2.1

$$h_{rt} := \left(h_{r\_int} \cdot n_{int}\right) + \left(h_{r\_ext} \cdot n_{ext}\right) = 2.250 \cdot in$$

$$Total\_Bearing\_Height_{check} := \text{if}\left(1 \cdot in \leq h_{rt} \leq 5 \cdot in, \text{"Okay"}, \text{"No Good"}\right) = \text{"Okay"}$$

Design Requirements *AASHTO 14.7.6.3*

Compressive Stress Requirements *AASHTO 14.7.6.3.2*

$$\sigma_{DL} := \frac{DL}{Bearing_{area}} = 0.158 \cdot ksi$$

Compressive stress due to Dead Load conservatively include DW

$$\sigma_{L\_no\_IM} := \frac{LL\_no\_IM}{Bearing_{area}} = 0.191 \cdot ksi$$

Compressive stress due to Live Load without Impact

$$\sigma_s := \frac{DL + LL\_no\_IM}{Bearing_{area}} = 0.349 \cdot ksi$$

Compressive stress for applicable service load combinations.

Service I is normal operational use
Service II is for slip-control, and Service III and Service IV are for prestressed concrete

Therefore use only Service I which has a load factor of 1.0 for DC, DW, and LL.

ODOT S14.7.5.3.2 - The effect of impact shall be ignored.

For steel reinforced elastomeric bearings designed in accordance with the provisions of AASHTO 14.7.6.3.2, the average compressive stress shall satisfy the following requirements. The stress limits may be increased by ten percent where shear deformation is prevented.

*$\sigma_s < 1.375\ G * S_i$ (1.10*1.25) for bearings fixed against shear deformation and $\sigma_s < 1.25\ G * S_i i$ for expansion bearings*

$$\sigma_{s\_allow\_1} := \text{if}\left(Bearing\_Constraint = \text{"Fix"}, 1.375 \cdot G_{low} \cdot S_i, 1.25 \cdot G_{low} \cdot S_i\right) = 1.600 \cdot ksi$$

Use G_{low} as it is conservative.

$$\sigma_s = 0.349 \cdot ksi$$

$$\sigma_{s\_check\_1} := \text{if}\left(\sigma_s \leq \sigma_{s\_allow\_1}, \text{"Okay"}, \text{"No Good"}\right) = \text{"Okay"}$$

AASHTO Eq 14.7.6.3.2-7

*$\sigma_s < 1.375$ ksi (1.10*1.25) for bearings fixed against shear deformation and $\sigma_s < 1.25$ ksi for expansion bearings*

$$\sigma_{s\_allow\_2} := \text{if}\left(Bearing\_Constraint = \text{"Fix"}, 1.375 \cdot ksi, 1.25 \cdot ksi\right) = 1.250 \cdot ksi$$

There may be a small amount of shrinkage force. However, it will most likely get resolved into the girders and not affect the bearings.

$$\sigma_s = 0.349 \cdot ksi$$

$$\sigma_{s\_check\_2} := \text{if}\left(\sigma_s \leq \sigma_{s\_allow\_2}, \text{"Okay"}, \text{"No Good"}\right) = \text{"Okay"}$$

AASHTO Eq 14.7.6.3.2-8

Compressive Deflection *AASHTO 14.7.6.3.3*

In addition to the provisions of AASHTO 14.7.6.3.3, the provisions of AASHTO 14.7.5.3.6

$E_c := 4.8 \cdot G_{low} \cdot S_i^{\,2} = 60.523 \cdot ksi$

AASHTO Eq. C14.6.3.2-1 - The load deflection curve of elastomeric is nonlinear, this is an acceptable approximation for the effective modulus
Use G_{low} as it is conservative.

$\varepsilon_L = \delta / (4.8 * G * S^2)$ *AASHTO Eq. C14.7.5.3.6-1*

Therefore: $\varepsilon_L = \delta / (E_c)$

Instantaneous Live Load Deflection

$\varepsilon_{Li} := \dfrac{\sigma_{L\_no\_IM}}{E_c} = 0.0032$

AASHTO Eq. C14.7.5.3.6-1
ε_{Li} = instantaneous live load compressive strain in the ith elastomer layer

$\delta_L := \varepsilon_{Li} \cdot h_{r\_int} = 0.001 \cdot in$ *AASHTO Eq. 14.7.5.3.6-1*

$\delta_{L\_max} := 0.125 \cdot in$

AASHTO Commentary C14.7.5.3.6
recommends a maximum value of 0.125"

$\delta_{L\_initial\_check} := \text{if}\left(\delta_L < \delta_{L\_max}, \text{"Okay"}, \text{"No Good"}\right) = \text{"Okay"}$

Initial Dead Load Deflection

$\varepsilon_{di} := \dfrac{\sigma_{DL}}{E_c} = 0.0026$

AASHTO Eq. C14.7.5.3.6-1
ε_{di} = initial dead load compressive strain in the ith elastomer layer

$\delta_d := \varepsilon_{di} \cdot h_{r\_int} = 0.001 \cdot in$ *AASHTO Eq. 14.7.5.3.6-2*

$\delta_{d\_max} := 0.125 \cdot in$

ODOT BDM 306.4.2.1- vertical deformations of the bearings greater than 1/8" are to be compensated for in the elevations of the bridge bearing seats.

$\delta_{d\_initial\_check} := \text{if}\left(\delta_d < \delta_{d\_max}, \text{"Okay"}, \text{"No Good"}\right) = \text{"Okay"}$

$Compressive\_Deflection\_Check := \text{if}\left(\delta_L + \delta_d < 0.9 \cdot h_{r\_int}, \text{"Okay"}, \text{"No Good"}\right) = \text{"Okay"}$ *AASHTO Eq. 14.7.6.3.3*

Long-term dead load deflection, including the effects of creep

Long-term dead load deflections should be considered where joints and seals between sections of the bridge rest on bearings of different design and when estimating redistribution of forces in continuous bridges caused by settlement.

Creep deflection divided by initial dead load (Table may be used) *AASHTO Table 14.7.6.2-1*

$$a_{cr} := \begin{cases} 0.25 & \text{if } Durometer = 50 \\ 0.35 & \text{if } Durometer = 60 \\ 0.45 & \text{if } Durometer = 70 \end{cases} = 0.350$$

$\delta_{lt} := \delta_d + a_{cr} \cdot \delta_d = 0.001 \cdot in$ *AASHTO Eq 14.7.5.3.6-3*

$\delta_{d\_max} = 0.125 \cdot in$

$\delta_{d\_long\_term\_check} := \text{if}\left(\delta_{lt} < \delta_{d\_max}, \text{"Okay"}, \text{"No Good"}\right) = \text{"Okay"}$

Check Total Load (excluding impact) deflection at internal layer *AASHTO 14.7.6.3.3*

$$\varepsilon_{d\_L\_no\_IM} := \frac{(\sigma_{DL} + \sigma_{L\_no\_IM})}{E_c} = 0.0058$$

AASHTO Eq. C14.7.5.3.6-1
$\varepsilon t_{\alpha t\_no\_IM}$ = initial combined DL and LL no IM compressive strain in the ith elastomer layer

$$\delta_{d\_L\_no\_IM} := \varepsilon_{d\_L\_no\_IM} \cdot h_{r\_int} = 0.0023 \cdot in$$

Similar to AASHTO Eq. 14.7.5.3.6-1 through 14.7.5.3.6-3

$$\delta_{d\_L\_no\_IM\_max} := 0.09 \cdot h_{r\_int} = 0.036 \cdot in$$

AASHTO 14.7.6.3.3

$$\delta_{d\_L\_no\_IM\_check} := if(\delta_{d\_L\_no\_IM} < \delta_{d\_L\_no\_IM\_max}, \text{"Okay"}, \text{"No Good"}) = \text{"Okay"}$$

Rotation *AASHTO 14.7.6.3.5*

AASHTO Commentary C14.7.6.3.5a - For steel-reinforced elastomeric bearings, rotation is not checked. The check is implicit on the geometric and stress limits.

Stability *AASHTO 14.7.6.3.6*

Total thickness of the pad shall not exceed L/3 or W/3.
L - Generally parallel to the global longitudinal axis
W - Generally parallel to the global transverse direction

$$Thickness_{allowable} := min\left(\frac{Bearing_{length}}{3}, \frac{Bearing_{width}}{3}\right) = 4.333 \cdot in$$

$$h_{total} := h_{rt} + n_s \cdot h_s = 2.773 \cdot in$$

$$Stability_{check} := if(h_{total} \le Thickness_{allowable}, \text{"Okay"}, \text{"No Good"}) = \text{"Okay"}$$

Reinforcement *AASHTO 14.7.6.3.7*

Reinforcement for steel-reinforced elastomeric bearings shall be designed according to AASHTO 14.7.5.3.5

$$h_{s\_service\_limit} := 3 \cdot \frac{h_{r\_int} \cdot \sigma_s}{F_y} = 0.0116 \cdot in$$

AASHTO Eq. 14.7.5.3.5-1

$h_s = 0.1046 \cdot in$

$$Reinforcement\_Service_{check} := if(h_s \ge h_{s\_service\_limit}, \text{"Okay"}, \text{"No Good"}) = \text{"Okay"}$$

$$h_{s\_fatigue\_limit} := 2 \cdot \frac{h_{r\_int} \cdot \sigma_{L\_no\_IM}}{\Delta F_{TH}} = 0.0064 \cdot in$$

AASHTO Eq. 14.7.5.3.5-2

$h_s = 0.1046 \cdot in$

$$Reinforcement\_Fatigue_{check} := if(h_s \ge h_{s\_fatigue\_limit}, \text{"Okay"}, \text{"No Good"}) = \text{"Okay"}$$

Shear Deformation

AASHTO 14.7.6.3.4

The provisions of 14.7.5.3.2 shall apply except that

h_{rt} => 2Δs For steel reinforced elastomeric bearings

For the design of the shear deformation, determine the total shear force due to temperature based on the expansion length, and then divide the deformation evenly amongst all the bearing lines over that length.

$$Span\_Expansion\_Length := \frac{2}{3} \cdot Bridge\_Length = 187.667\ ft$$

L = length of bridge deck to end of bridge deck
ODOT BDM 306.2.2.6. assume expansion length is 2/3 of the total length of the structure

$$L_{expand\_max} := Span\_Expansion\_Length = 187.667\ ft$$

For highly skewed and wide bridges, take expanding length on a diagonal between slab corners to obtain most unfavorable expansion length. Since the skew is moderate, do not adjust the factors.

$$L_{expand\_min} := \frac{1}{3} \cdot Bridge\_Length = 93.833\ ft$$

$$\Delta_{T\_total\_max} := L_{expand\_max} \cdot \Delta_{temp} \cdot \alpha = 1.317 \cdot in$$

AASHTO 3.12.2.3
May override Δ_T if bridge has unusual geometry that requires 3-d analysis.

$$\Delta_{T\_total\_min} := L_{expand\_min} \cdot \Delta_{temp} \cdot \alpha = 0.659 \cdot in$$

$$\Delta_{T\_max} := \Delta_{T\_total\_max} \div 2 = 0.659 \cdot in$$

Distribute the force for max expansion over 2 bearing lines

$$\Delta_{T\_min} := \Delta_{T\_total\_min} \div 2 = 0.329 \cdot in$$

Distribute the force for min expansion over 2 bearing lines

$$\Delta_T := \max\left(\Delta_{T\_max}, \Delta_{T\_min}\right) = 0.659 \cdot in$$

Movements from post tensioning not applicable

$$\Delta_0 := 0.65 \cdot \left(\Delta_T\right) = 0.428 \cdot in$$

AASHTO 14.7.5.3.2 - The maximum horizontal displacement of the bridge superstructure shall be taken as 65% of Δ_T

$$\Delta_s := \Delta_0 = 0.428 \cdot in$$

The maximum shear deformation at service limit state Δ_s shall be Δ_O - AASHTO 14.7.5.3.2

$h_{rt} = 2.250 \cdot in$ $2 \cdot \Delta_s = 0.856 \cdot in$

$$Shear_{check} := if\left(h_{rt} \geq 2 \cdot \Delta_s, \text{"Okay"}, \text{"No Good"}\right) = \text{"Okay"}$$

AASHTO 14.7.5.3.2

Horizontal Force and Movement *AASHTO 14.6.3.1*

According to BDM Section 1000, S14.6.3.2, no moment transferred from superstructure to substructure for elastomeric bearings without anchor bolts or only 2 anchor bolts centered at centerline of the bearing.

Determine Factored Horizontal Loads

The temperature and shrinkage forces acting on the bearings were not previously calculated as the force due to these load cases are based off of properties of the bearing by utilizing equation which a equates horizontal force based on the deformation of the bearing. AASHTO Eq. 14.6.3.1-2:

$$H_{bu\_temp} := G_{up} \cdot Bearing_{area} \cdot \frac{\Delta_T}{h_{rt}} = 15.224 \cdot kip$$

AASHTO Eq. 14.6.3.1-2
Use the maximum shear limit deformation

AASHTO 3.4.1- Service I is load case is related to normal operational use, Service II, III, and IV are not applicable

$\gamma\_BR := 1.0$ $\gamma\_WS := 1.0$ $\gamma\_WL := 1.0$ $\gamma\_TU := 1.2$ *AASHTO 3.4.1- Table 3.4.1-1*

$$H_{bu\_long} := \gamma\_BR \cdot BR + \gamma\_WS \cdot WS\_Ser\_I_{long} + \gamma\_WL \cdot WL_{long} + \gamma\_TU \cdot H_{bu\_temp} = 23.414 \cdot kip$$

Check maximum shear deformation. Use AASHTO Eq. 14.6.3.1-2 and solve for the allowable horizontal movement H_{bu_allow} with maximum deformation of 1/2 h_{rt}.

$$\Delta_{allow} := \frac{h_{rt}}{2} = 1.125 \cdot in$$ *AASHTO Eq. 14.7.5.3.2-1*

$$H_{bu\_allow} := G_{up} \cdot Bearing_{area} \cdot \frac{\Delta_{allow}}{h_{rt}} = 26.000 \cdot kip$$ *AASHTO Eq. 14.6.3.1-2*

$$Deform\_CL_{check} := if\left(H_{bu\_allow} \ge H_{bu\_long}, \text{"Okay"}, \text{"No Good"}\right) = \text{"Okay"}$$

S14.6.3.1 HORIZONTAL FORCE AND MOVEMENT
Bearings without directional seismic restraint are not required to accommodate seismic movements in the unrestrained direction. Irreparable damage due to seismic movement in accordance with BDM Section 301.4.4.1.c is permitted.

301.4.4.1.c REQUIREMENTS FOR BEARINGS
Unrestrained bearings that sustain irreparable damage during a seismic event are permissible provided loss of span is prevented by the design for the Horizontal Connection Force in BDM Section 301.4.4.1.b.

Seismic and Other Extreme Event Provisions

AASHTO 14.7.6.3.8 & ODOT BDM 301.4.4.1a

Expansion bearings designed according to Article 14.7.6 shall be provided with adequate seismic and other extreme event resistant anchorage to resist the horizontal forces in excess of those accommodated by shear in the pad unless the bearing is intended to act as a fuse or irreparable damage is permitted. The provisions of Article 14.7.5.3.7 shall also apply as applicable.

According to AASHTO 14.6.3.1 Adequate support length shall be provided for all bearings in accordance with Article 4.7.4.4.

$L_{deck\_length} := L_{expand\_max} = 187.667\,ft$

L = length of bridge deck to the adjacent expansion joint or end of bridge deck. Typically equal to the expansion length calculated for the shear deformation

$H_{height} = 23.3\,ft$

H for abutments is equal to the average height of the column supporting bridge deck from abutment to next expansion joint - AASHTO 4.7.4.4

N = minimum support length measured normal to the centerline of bearing - AASHTO - 4.7.4.4-1

$$N_{min} := \left(8 + 0.02\cdot L_{deck\_length}\cdot\frac{1}{ft} + 0.08\cdot H_{height}\cdot\frac{1}{ft}\right)\cdot\left[1 + 0.000125\cdot\left[\frac{(Skew)}{deg}\right]^2\right]\cdot in = 13.634\cdot in$$

$N_{abut} := (1ft + 9in)\cdot\cos(Skew) = 20.968\cdot in$

Figure C4.7.4.4-1 Shows that the the support length is to the end of the beam. The N value states the distance is normal to the centerline of the supports.

$Brg\_Length_{check} := if\left(N_{abut} \ge N_{min}, \text{"Okay"}, \text{"No Good"}\right) = \text{"Okay"}$

Check Summary

$Bearing\_Geometry_{check}$ = "Okay"

$Total\_Bearing\_Height_{check}$ = "Okay"

$\sigma_{s\_check\_1}$ = "Okay"

$\sigma_{s\_check\_2}$ = "Okay"

$\delta_{L\_initial\_check}$ = "Okay"

$\delta_{d\_initial\_check}$ = "Okay"

$\delta_{d\_long\_term\_check}$ = "Okay"

$\delta_{d\_L\_no\_IM\_check}$ = "Okay"

$Shear_{check}$ = "Okay"

$Stability_{check}$ = "Okay"

$Reinforcement\_Service_{check}$ = "Okay"

$Reinforcement\_Fatigue_{check}$ = "Okay"

$Deform\_CL_{check}$ = "Okay"

Brg_Length_{check} = "Okay"

Bearing Data Design Summary

Shore A Hardness:

Durometer = 60

Size:

$Bearing_{length} = 13.000 \cdot in$ *(Longitudinal Dimension)*

$Bearing_{width} = 20.000 \cdot in$ *(Transverse Dimension)*

Total Thickness, "Dim T":

$h_{total} = 2.773 \cdot in$

Internal Laminates:

Thickness:	$h_{r\_int} = 0.4000 \cdot in$
Number of Internal Laminates:	$n_{int} = 5$

External Laminates:

Thickness:	$h_{r\_ext} = 0.2500 \cdot in$
Number of External Laminates:	$n_{ext} = 1$

Steel Laminates:

Thickness:	$h_s = 0.1046 \cdot in$
Number of Steel Laminates:	$n_s = 5$

Loading Information

Dead Load:	DL = 41.1·kip	/pad
Live Load (w/out Impact):	LL_no_IM = 49.7·kip	/pad
Design Load:	DL + LL_no_IM = 90.7·kip	/pad