DESIGN COMPUTATIONS FOR

BR 52 12' x 7' Box Culvert with Anchor Wingwalls
Winhall, VT

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DESIGN CALCULATIONS
12'-0" x 7'-0" Open Top Box Culvert
With Precast Anchor Wingwalls

Prepared For:
Renaud Brothers
283 Fort Bridgeman Rd #2
Vernon, VT 05354

Project Information:
VAOT STP Culv (31)
Bridge #52 Route 30
Winhall, VT

Michie Project No: 5778

Delta 2015.059.013 CHK: RJA

CALCULATIONS FOR 12 X 7 OPEN TOP BOX CULVERT - BR #52

References

1. AASHTO LRFD Bridge Design Specifications, 5th Edition.
2. Contract Plans, "Proposed Improvement Bridge Project, Town of Winhall, VT Route 30, Bridge Numbers 47 and 52 VTRANS #STP CULV(31)" by Stantec of South Burlington VT, dated 10/9/14.

Material Information

Concrete:

$f_c := 5000 \frac{lbf}{in^2}$ $\quad Aggregate_{diam} := .75in$ $\quad w_c := 0.145$ $\quad \gamma_c := 150 \frac{lbf}{ft^3}$ $\quad K_1 := 1$

$E_c := 33000 \cdot K_1 \cdot w_c^{1.5} \cdot \sqrt{\frac{f_c}{1000psi}} \cdot ksi = 4074 \cdot ksi$ AASHTO 5.4.2.4-1

Steel:

$f_y := 60000 \frac{lbf}{in^2}$ $\quad E_s := 29000ksi$

Culvert Geometry

$S := 12ft$	Inside Span of Culvert
$H := 7ft$	Inside Rise of Culvert
$t_{leg} := 8in$	Thickness of Leg
$t_{deck} := 10in$	Thickness of Deck
$t_{btm} := 10in$	Thickness of Bottom Slab
$haunch := 9in$	Length of haunch
$cover_{out} := 2.0in$	Cover to top Mat in Deck
$notch := 0in$	Thickness of notch in btm of top slab
$cover_{insidedeck} := 2in + notch = 2 \cdot in$	Cover to inside mat in deck
$cover := 2in$	Cover everywhere else
$b_w := 12in$	Design Section Width

Assumptions

The structure will be analyzed for load combinations at two stages:
1. Construction Loading - After backfilling of the lower half of the structure and with live load surcharge applied to the walls. No top slab.
2. In-service condition - After installation of the top slab and backfilling to finished grade.

Weepholes will be installed in the box culvert, which will prevent hydrostatic pressure from developing behind the culvert walls.

Structure will be analyzed as a 1'-0" wide strip.The structure will be modeled as a centerline model. The soil loads will be calculated according to actual outside dimensions. The top slab will be assumed hinged at the top of the legs. The haunch will be ignored at the top slab for modeling purposes, but will be used to determine the critical section in the top slab.

The base slab is continuously supported by the foundation soil beneath it. This will be modeled by soils springs. Sping constant, in kips/in, is dependent on the spacing of the springs. Reference for calculation based on Modulus of Subgrade Reaction k = 200psi per in, "Pavement Analysis and Design" Figure 7.36, Huang, YH, 1993.

One end of the base will also be fixed wrt translation in the x and z directions and rotation about the x and y directions.

The structure will have the following locations analyzed:
1M. Outside Leg Moment (at or below the haunch) for negative moments at the knee.
2M. Inside Leg (if applicable) for positive moments in the leg.
3S. Leg for Shear
4M. Outside Bottom Deck Moment (at or inside the haunch) for negative moments at the knee.
5M. Inside Bottom Deck Moment (usually near midspan) for positive moments in the deck.
6S. Bottom Deck for Shear (at or inside the haunch).
7M. Inside Top Deck Moment (usually near midspan) for positive moments in the deck.
8S. Top Deck for Shear (at or near the inside face of the leg).

Per 12.5.2 and 12.5.3, this structure shall be investigated at Service Load Combination I and Strength Load Combinations I & II.

Due to curbwall and assumed distance from curb to wheel load, traffic cannot come within 24" of the end of the culvert, therefore an Edge Beam is not required per 12.11.2.1. The area of the deck supporting the curbwall will not have an independent check because after the curbwall is attached the design section becomes significantly deeper (including the depth of curbwall).

The contract plans show a culvert with 6ft of earth cover. AASHTO 12.11.2.1 states that for culverts with 2ft or more of fill, wheel loads shall be distributed as specified in section 3.6.1.2.6.

Live Load shall be AASHTO HL-93 load with appropriate Multiple Presence Factors (m) & Dynamic Allowance (IM). Per 3.6.1.3.3, only the design truck and design tandem portion of the HL-93 live load shall be applied. That is, the lane load portion of the HL-93 live load shall be ignored.

Soil backfill material assumptions as follows:

Dry unit weight of soil = 140 pcf. Soil Friction angle = 34-degrees. Concrete unit weight: 150 pcf

Design Parameters:

$\eta_D := 1.00$

Ductility Load Modifier (AASHTO 1.3.3)
Conventional. Design complying with LRFD Specifications

$\eta_R := 1.0$

$\eta_{R.earth} := 1.05$

Redundancy Load Modifiers (AASHTO 1.3.4)
Conventional levels of Redundancy.
Note: per 12.5.4, Buried structures will be considered nonredundant under earth loads. Therefore, basic load cases applying earth loads will be multiplied by 1.05.

$\eta_I := 1.00$

Importance Load Modifier (AASHTO 1.3.5) typical bridge

$\eta_i := \eta_D \cdot \eta_R \cdot \eta_I = 1$

$\eta_{i.earth} := \eta_D \cdot \eta_{R.earth} \cdot \eta_I = 1.05$

Load Modifiers (AASHTO 1.3.2.1)
(it will be applied to the BLCs below)

$\phi_{moment} := 0.90$

$\phi_{shear} := 0.90$

$\phi_{axial} := 0.90$

Per AASHTO 5.5.4.2.1

β_1 = Stress Block Factor specified in Article 5.7.2.2

$$\beta_1 := \max\left[.65, \left[\begin{array}{ll} .85 & \text{if } f_c < 4000\text{psi} \\ .85 - \frac{.05}{\text{psi}} \cdot \left(\frac{f_c - 4000\text{psi}}{1000}\right) & \text{otherwise} \end{array}\right]\right] \qquad \beta_1 = 0.8$$

$\gamma_w := 62.4 \frac{lb}{ft^3}$ $\qquad k_w := 1$

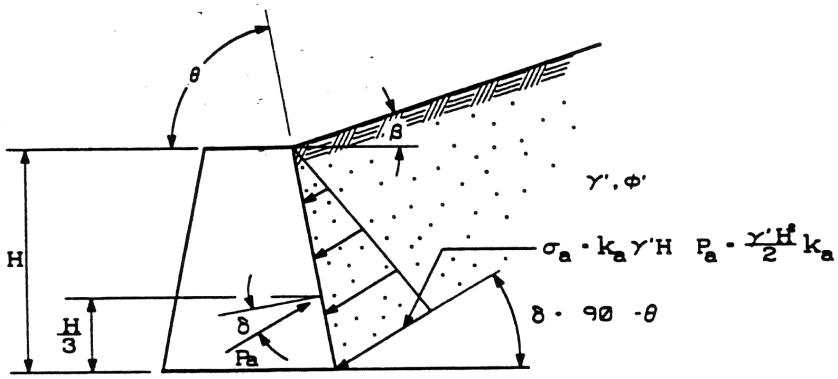
Site Conditions

$H_{overburden} := 6ft$

Depth of Soil over the Top of Deck

Backfill

$\gamma_{soil} := 140 \frac{lb}{ft^3}$



$$k_a = \frac{\sin^2(\theta - \phi')}{\sin^2\theta \, \sin(\theta - \delta)\left[1 + \sqrt{\frac{\sin(\phi' - \delta)\,\sin(\phi' - \beta)}{\sin(\theta - \delta)\,\sin(\theta - \beta)}}\right]^2}$$

γ' = EFFECTIVE UNIT WEIGHT
ϕ' = EFFECTIVE ANGLE OF INTERNAL FRICTION
δ = ANGLE OF WALL FRICTION (SEE TABLE 5.5.2B)
β = SLOPE ANGLE
θ = WALL FACE BATTER
ALL ANGLES ARE POSITIVE (+) AS SHOWN

FIGURE 5.5.2A Computational Procedures for Active Earth Pressures (Coulomb Analysis)

$\phi := 34deg$ $\beta := 0deg$ $\delta := \frac{2}{3} \cdot \phi$ $\delta = 22.667 \cdot deg$ $\theta := 90deg$

$k_a := 1 - \sin(\phi) = 0.441$ Conservatively use at rest earth pressure condition

Basic Load Cases for Risa-3D

BLC #1 - Dead Load of Structure (DC)
BLC #2 - Earth Pressure against Left Leg (EH)
BLC #3 - Earth Pressure against Right Leg (EH)
BLC #4 - Overburden Soil Pressure on Both Legs. This is the pressure exerted on the legs from the overburden soil when backfilling is complete to proposed finished grade. (ES)
BLC #5 - Overburden Soil Pressure on the Bridge Deck. (EV)
BLC #6 - Live Load Surcharge on the Left Leg. (LS)
BLC #7 - Live Load Surcharge on the Right Leg. (LS)

Moving Load Cases for Risa-3D

ML#1 - AASHTO Design Truck as distributed through the soil. (LL)
ML#2 - AASHTO Design Tandem as distributed through the soil. (LL)

Determine load for each BLC

BLC #2 & BLC #3:

These load cases apply earth pressure to the culvert legs from the submerged soil that is backfilled just to the top of the legs. The value of the distributed pressure at the bottom of the leg is:

$$\sigma_{legbackfill} := \eta_{i.earth} \cdot k_a \cdot \gamma_{soil} \cdot (H + t_{btm}) \qquad \sigma_{legbackfill} = 507.589 \frac{lb}{ft^2}$$

BLC #4:

This load case applies earth pressure to the frame legs from the soil that is backfilled over the the box culvert. The value of the distributed pressure along the entire leg is:

$$\sigma_{legoverburden} := \eta_{i.earth} \cdot k_a \cdot \gamma_{soil} \cdot (H_{overburden} + t_{deck}) \qquad \sigma_{legoverburden} = 442.791 \frac{lb}{ft^2}$$

BLC #5:

This load case applies earth pressure to the deck from the soil that is backfilled over the the box culvert. The value of the distributed pressure along the entire deck is:

$$\sigma_{deckoverburden} := \eta_{i.earth} \cdot \gamma_{soil} \cdot H_{overburden} \qquad \sigma_{deckoverburden} = 882 \frac{lb}{ft^2}$$

BLC #6 & BLC#7:

These load cases apply LL surcharge earth pressure to the legs. The equivalent height of soil is given by AASHTO Table 3.11.6.4-1:

$$H_{LS}(n) := \begin{cases} 4ft & \text{if } n \le 5ft \\ 4ft - \dfrac{n - 5ft}{5} & \text{if } 5ft < n \le 10ft \\ 3ft - \dfrac{n - 10ft}{10} & \text{if } 10ft < n \le 20ft \\ 2ft & \text{otherwise} \end{cases}$$

Height of Soil for Vehicular Loading on Abutments Perpendicular to Traffic. Table 3.11.6.4-1

$$H_{LS}\left(H + t_{btm} + t_{deck} + H_{overburden}\right) = 2.533\,ft$$

The value of the distributed pressure along the entire leg is:

$$\sigma_{legLL} := k_a \cdot \gamma_{soil} \cdot H_{LS}\left(H + t_{btm} + t_{deck} + H_{overburden}\right)$$

$$\sigma_{legLL} = 156.34\,\frac{lb}{ft^2}$$

MLC#1 and MLC#2

This load case is the Truck and tandem portions of the HL-93 Live Load as it is distributed through the overburden soil. Per AASHTO 12.11.2.1 the distribution of live load to the deck shall be as prescribed by 3.6.1.2.6.:

3.6.1.2.6

In lieu of a more precise analysis, or the use of other acceptable approximate methods of load distribution permitted in Section 12, where the depth of fill is 2.0 ft or greater, wheel loads may be considered to be uniformly distributed over a rectangular area with sides equal to the dimension of the tire contact area, as specified in Article 3.6.1.2.5, and increased by either 1.15 times the depth of the fill in select granular backfill, or the depth of fill in all other cases.

Where such areas from several wheels overlap, the total load shall be uniformly distributed over the area.

For single-span culverts, the effects of live load may be neglected where the depth of fill is more than 8.0 ft. and exceeds the span length.....

Check four cases. Truck with 1 lane loaded, Truck with 2 lanes loaded, Tandem with 1 lane loaded, and tandem with 2 lanes loaded. Note that for a single span structure, the maximum shear and moment will be caused by using the truck with a rear axle spacing = 14'. Therefore axle spacings greater than this need not be checked. Also due to size of this bridge the front axle will not be on the bridge when both rear axles are. Therefore front axle is ignored.

RISA does not allow for the application of moving distributed loads, only point loads. Therefore, the total distributed load is divided evenly into a series of equally spaced point loads. If the distributed loads overlap, there will be 50 equally spaced point loads (the maximum allowed in RISA). If there is a gap between the distributed loads, there will be two sets of 25 equally spaced point loads.

In the truck distributed load calculation:

If $H_{overburden} > 11.45ft$ then there is overlap of the front and rear axles.And the load will be applied as a single uniform load across the entire length of the design strip.

If $H_{overburden} \leq 11.45ft$ then there will be two uniform loads applied.
There will be a gap between these uniform loads. (see sketch)

In the tandem load distribution:

If $H_{overburden} > 2.75ft$ then there is overlap of the front and rear axles.And the load will be applied as a single uniform load with a length appropriate to the depth of soil.

If $H_{overburden} \leq 2.75ft$ then there will be two uniform loads applied.
There will be a gap between these uniform loads. (see sketch)

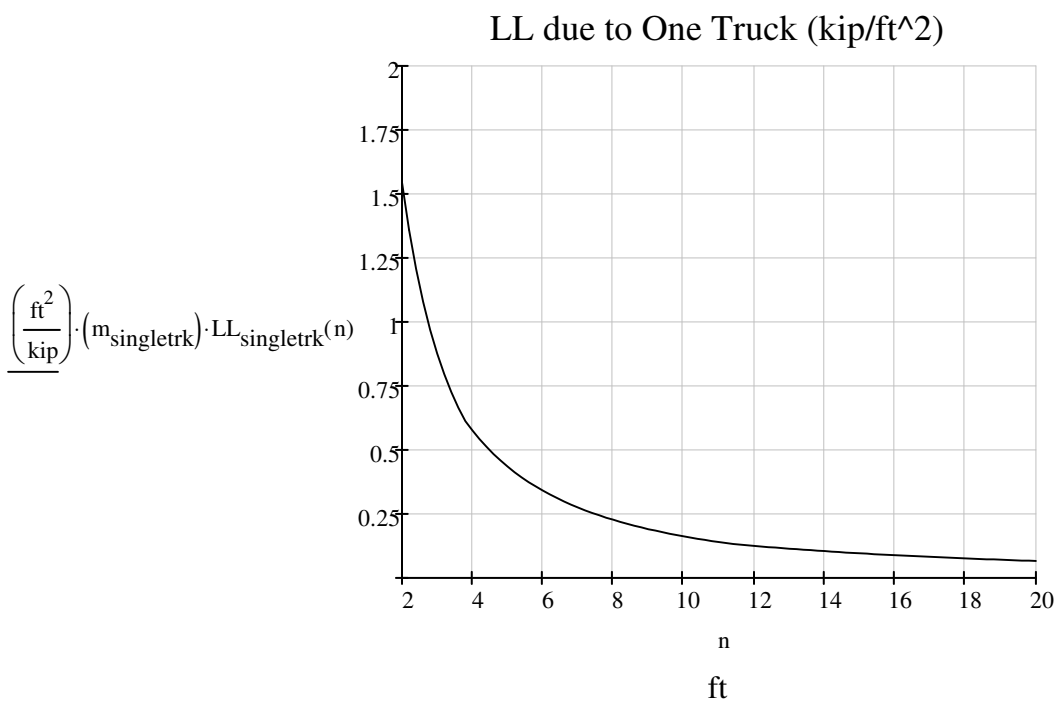
One Truck:

$H_{overburden} = 6\,ft$ Depth of overburden soil above deck. From above.

$m_{singletrk} := 1.2$ Multiple Presence Factor for One Truck AASHTO 3.6.1.1.2-1

$$LL_{singletrk}(n) := \begin{cases} \dfrac{16kip}{(20in + n\cdot 1.15)\cdot(10in + n\cdot 1.15)} & \text{if } 2.00ft \le n < 3.77ft \\ \dfrac{2\cdot 16kip}{(6ft + 20in + n\cdot 1.15)\cdot(10in + n\cdot 1.15)} & \text{if } 3.77ft \le n < 11.45ft \\ \dfrac{4\cdot 16kip}{(6ft + 20in + n\cdot 1.15)\cdot(14ft + 10in + n\cdot 1.15)} & \text{otherwise} \end{cases}$$

$n := 2ft, 2.2ft .. 20ft$



$m_{singletrk}\cdot LL_{singletrk}(H_{overburden}) = 0.341\cdot\frac{kip}{ft^2}$

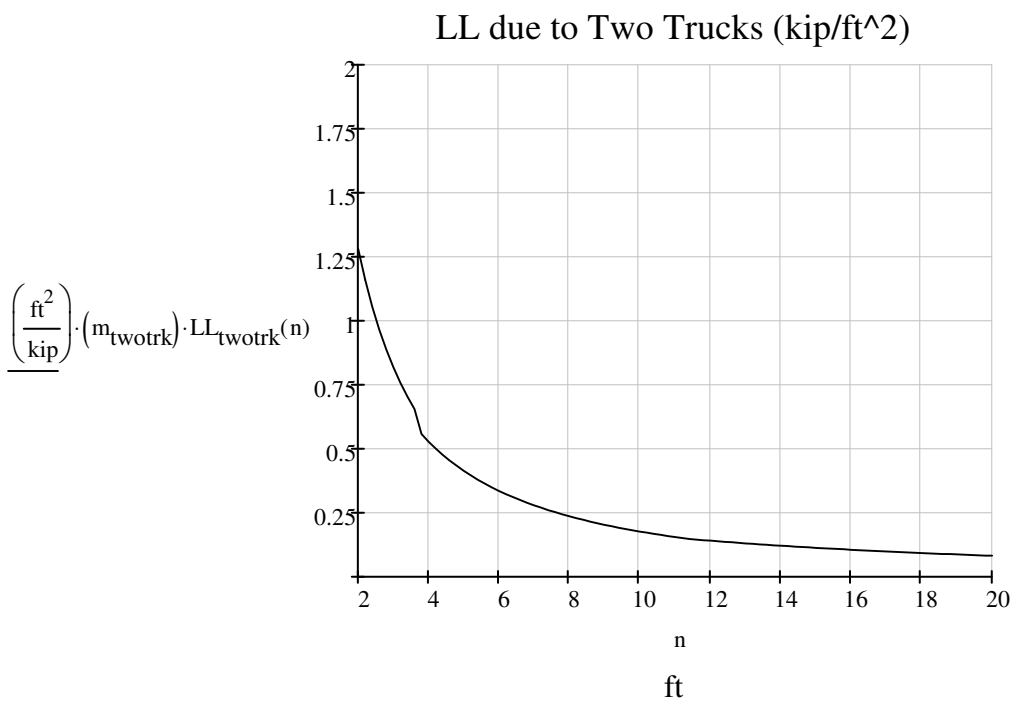
Two Trucks:

$H_{overburden} = 6\,ft$ Depth of overburden soil above deck. From above.

$m_{twotrk} := 1.0$ Multiple Presence Factor for Two Trucks AASHTO 3.6.1.1.2-1

$$LL_{twotrk}(n) := \begin{cases} \dfrac{2 \cdot 16kip}{(n \cdot 1.15 + 10in + 4ft + 10in) \cdot (10in + n \cdot 1.15)} & \text{if } 2.00ft \le n < 3.77ft \\ \dfrac{4 \cdot 16kip}{(n \cdot 1.15 + 10in + 6ft + 4ft + 6ft + 10in) \cdot (10in + n \cdot 1.15)} & \text{if } 3.77ft \le n < 11.45ft \\ \dfrac{8 \cdot 16kip}{(n \cdot 1.15 + 10in + 6ft + 4ft + 6ft + 10in) \cdot (n \cdot 1.15 + 5in + 14ft + 5in)} & \text{otherwise} \end{cases}$$

$n := 2ft, 2.2ft .. 20ft$



$m_{twotrk} \cdot LL_{twotrk}(H_{overburden}) = 0.337 \cdot \frac{kip}{ft^2}$

$LL_{trk} := \max(m_{singletrk} \cdot LL_{singletrk}(H_{overburden}), m_{twotrk} \cdot LL_{twotrk}(H_{overburden})) = 0.341 \cdot ksf$

Length of Distributed Truck Load:

$$LoadLength_{trk} := \begin{cases} H_{overburden} \cdot 1.15 + 10in & \text{if } H_{overburden} < 11.45ft \\ H_{overburden} \cdot 1.15 + 10in + 14ft & \text{otherwise} \end{cases} = 7.733\,ft$$

Length of Gap between Distributed Truck Loads:

$$Gap_{trk} := \begin{cases} 14ft - 10in - H_{overburden} \cdot 1.15 & \text{if } H_{overburden} < 11.45ft \\ 0ft & \text{otherwise} \end{cases} = 75.2 \cdot in$$

Value of each Point Load:

$$PointLoad_{trk} := b_w \cdot \begin{cases} LL_{trk} \cdot LoadLength_{trk} \cdot \frac{1}{50} & \text{if } Gap_{trk} = 0ft \\ LL_{trk} \cdot LoadLength_{trk} \cdot \frac{1}{25} & \text{otherwise} \end{cases} = 105.446 \cdot lbf$$

Spacing between each Point Load:

$$PointLoadSpacing_{trk} := \begin{cases} \frac{1}{50 - 1} \cdot LoadLength_{trk} & \text{if } Gap_{trk} = 0ft \\ \frac{1}{25 - 1} \cdot LoadLength_{trk} & \text{otherwise} \end{cases} = 3.867 \cdot in$$

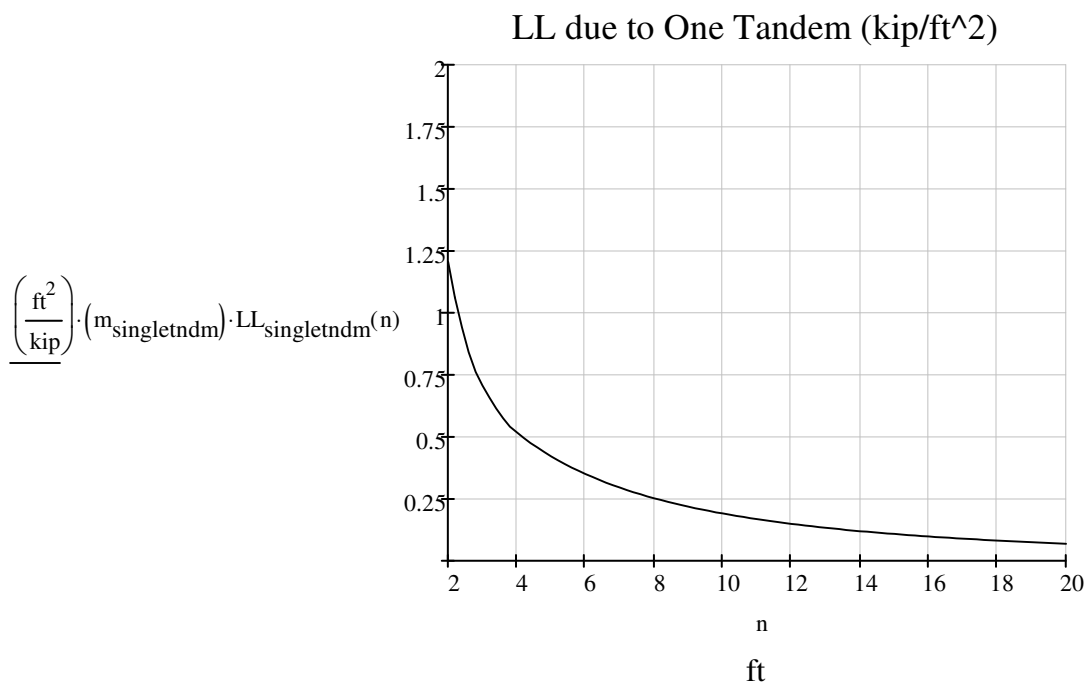
One Tandem:

$H_{overburden} = 6\,ft$ Depth of overburden soil above deck. From above.

$m_{singletndm} := 1.2$ Multiple Presence Factor for One Truck AASHTO 3.6.1.1.2-1

$$LL_{singletndm}(n) := \begin{cases} \dfrac{12.5kip}{(20in + n\cdot 1.15)\cdot(10in + n\cdot 1.15)} & \text{if } 2.00ft \le n < 2.75ft \\ \dfrac{2\cdot 12.5kip}{(20in + n\cdot 1.15)\cdot(4ft + 10in + n\cdot 1.15)} & \text{if } 2.75ft \le n < 3.77ft \\ \dfrac{4\cdot 12.5kip}{(6ft + 20in + n\cdot 1.15)\cdot(4ft + 10in + n\cdot 1.15)} & \text{otherwise} \end{cases}$$

$n := 2ft, 2.2ft .. 20ft$



$$m_{singletndm}\cdot LL_{singletndm}(H_{overburden}) = 0.351\cdot\frac{kip}{ft^2}$$

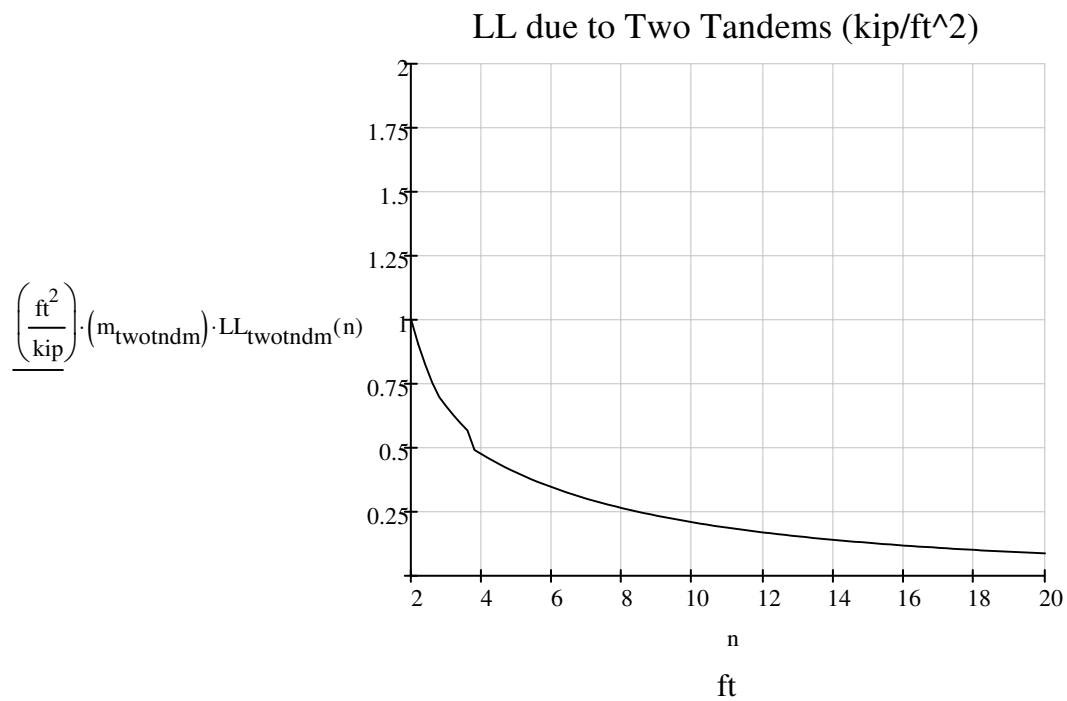
Two Tandems:

$H_{overburden} = 6\,ft$ Depth of overburden soil above deck. From above.

$m_{twotndm} := 1.0$ Multiple Presence Factor for Two Trucks AASHTO 3.6.1.1.2-1

$$LL_{twotndm}(n) := \begin{cases} \dfrac{2 \cdot 12.5kip}{(n \cdot 1.15 + 10in + 4ft + 10in) \cdot (10in + n \cdot 1.15)} & \text{if } 2.00ft \le n < 2.75ft \\ \dfrac{4 \cdot 12.5kip}{(n \cdot 1.15 + 10in + 4ft + 10in) \cdot (4ft + 10in + n \cdot 1.15)} & \text{if } 2.75ft \le n < 3.77ft \\ \dfrac{8 \cdot 12.5kip}{(n \cdot 1.15 + 10in + 6ft + 4ft + 6ft + 10in) \cdot (4ft + 10in + n \cdot 1.15)} & \text{otherwise} \end{cases}$$

$n := 2ft, 2.2ft .. 20ft$



$$m_{twotndm} \cdot LL_{twotndm}(H_{overburden}) = 0.347 \cdot \frac{kip}{ft^2}$$

$$LL_{tndm} := \max(m_{singletndm} \cdot LL_{singletndm}(H_{overburden}), m_{twotndm} \cdot LL_{twotndm}(H_{overburden}))$$

$$LL_{tndm} = 0.351 \cdot \frac{kip}{ft^2}$$

Length of Distributed Tandem Load:

$$LoadLength_{tndm} := \begin{cases} H_{overburden} \cdot 1.15 + 10in & \text{if } H_{overburden} < 2.75ft \\ H_{overburden} \cdot 1.15 + 10in + 4ft & \text{otherwise} \end{cases} = 11.733\,ft$$

Length of Gap between Distributed Tandem Loads:

$$Gap_{tndm} := \begin{cases} 4ft - 10in - H_{overburden} \cdot 1.15 & \text{if } H_{overburden} < 2.75ft \\ 0ft & \text{otherwise} \end{cases} = 0 \cdot in$$

Value of each Point Load:

$$PointLoad_{tndm} := b_w \cdot \begin{cases} LL_{tndm} \cdot LoadLength_{tndm} \cdot \frac{1}{50} & \text{if } Gap_{tndm} = 0ft \\ LL_{tndm} \cdot LoadLength_{tndm} \cdot \frac{1}{25} & \text{otherwise} \end{cases} = 0.082 \cdot kip$$

Spacing between each Point Load:

$$PointLoadSpacing_{tndm} := \begin{cases} \frac{1}{50-1} \cdot LoadLength_{tndm} & \text{if } Gap_{tndm} = 0ft \\ \frac{1}{25-1} \cdot LoadLength_{tndm} & \text{otherwise} \end{cases} = 2.873 \cdot in$$

The values calculated above are the unfactored service loads adjusted for the multiple presence factor. These loads still need to be adjusted in RISA to include the Live Load Factor and the Dynamic Load Allowance (IM). No distribution is required since the load is being applied as a distributed load to a one foot wide strip. Since we have not included the Load Modifier to the Live Load yet, we will include it in the LLF

This load factor will be as follows:

$LLF = \eta_i \cdot IM \cdot \beta_{LL}$ where,

β_{LL} = The Live Load Factor from Table 3.4.1-1 for each Limit State

IM = The Dynamic Load Allowance as determined in 3.6.2.2

η_i = Load Modifier

$\beta_{LLstrengthI} := 1.75$ $\beta_{LLstrengthII} := 1.35$ $\beta_{LLserviceI} := 1.00$

$$IM := 1 + \max\left[.33\cdot\left(1 - \frac{0.125}{ft}\cdot H_{overburden}\right), 0\right] \qquad IM = 1.083$$

$$LLF_{strengthI} := \eta_i \cdot IM \cdot \beta_{LLstrengthI} \qquad \boxed{LLF_{strengthI} = 1.894}$$

$$LLF_{strengthII} := \eta_i \cdot IM \cdot \beta_{LLstrengthII} \qquad \boxed{LLF_{strengthII} = 1.461}$$

$$LLF_{serviceI} := \eta_i \cdot IM \cdot \beta_{LLserviceI} \qquad \boxed{LLF_{serviceI} = 1.083}$$

Load Combinations for Risa-3D

Strength I Load Factors (AASHTO Table 3.4.1-1 and 3.4.1-2)

LC#1 = 1.25(BLC#1)
LC#2 = 1.25(BLC#1) + 1.5(BLC#2)
To check structure for backfill behind one leg only.
LC#3 = 1.25(BLC#1) + 1.5(BLC#2 + BLC#3) + 1.75(BLC#6 + BLC#7))
To check structure when it is backfilled to top of legs and a construction live load is present for placing stone fill in the culvert. Use maximum load factors for EH and LS to increase the effect on negative moments in the knees.
LC#4 = 1.25(BLC#1) + 0.9(BLC#2+BLC#3) + 0.75(BLC#4) + 1.3(BLC#5)
To check structure when it is backfilled to final grade. Minimum load factors on horizontal loads to maximize positive moment in the deck.
LC#5 = 1.25(BLC#1) + 1.5(BLC#2 + BLC#3) + 1.5(BLC#4) + 1.3(BLC#5)
To check structure when it is backfilled to final grade. Maximum load factors on horizontal loads to increase the negative moments in the knees.
LC#6 = 1.25(BLC#1) + 1.5(BLC#2 + BLC#3) + 1.5(BLC#4) + 1.3(BLC#5) + 1.75(BLC#6)
Applying LL surcharge behind the left leg only. Maximum load factors on horizontal loads to increase the negative moment in the knees.
LC#7 = 1.25(BLC#1) + 1.5(BLC#2 + BLC#3) + 1.5(BLC#4) + 1.3(BLC#5) + 1.75(BLC#6+BLC#7)
Applying LL surcharge behind both legs. Maximum load factors on horizontal loads to increase the negative moment in the knees.
LC#8 = 1.25(BLC#1) + 0.9(BLC#2 + BLC#3) + 0.75(BLC#4) + 1.3(BLC#5) + LLF*ML#1
Applying LL to deck only. Minimum load factors on horizontal loads to maximize positive moment in the deck.
LC#9 = 1.25(BLC#1) + 0.9(BLC#2 + BLC#3) + 0.75(BLC#4) + 1.3(BLC#5) + LLF*ML#2
Applying LL to deck only. Minimum load factors on horizontal loads to maximize positive moment in the deck.
LC#10 = 1.25(BLC#1) + 1.5(BLC#2 + BLC#3) + 1.5(BLC#4) + 1.3(BLC#5) + 1.75(BLC#6) + LLF*ML#1
Applying LL surcharge behind the left leg and deck. Maximum load factors on horizontal loads to increase the negative moment in the knees.
LC#11 = 1.25(BLC#1) + 1.5(BLC#2 + BLC#3) + 1.5(BLC#4) + 1.3(BLC#5) + 1.75(BLC#6) + LLF*ML#2
Applying LL surcharge behind the left leg and deck. Maximum load factors on horizontal loads to increase the negative moment in the knees.
LC#12 = 1.25(BLC#1) + 1.5(BLC#2 + BLC#3) + 1.5(BLC#4) + 1.3(BLC#5) + 1.75(BLC#6 + BLC#7) + LLF*ML#1
Applying LL surcharge behind both legs and deck. Maximum load factors on horizontal loads to increase the negative moment in the knees.
LC#13 = 1.25(BLC#1) + 1.5(BLC#2 + BLC#3) + 1.5(BLC#4) + 1.3(BLC#5) + 1.75(BLC#6 + BLC#7) + LLF*ML#2
Applying LL surcharge behind both legs and deck. Maximum load factors on horizontal loads to increase the negative moment in the knees.

Note: LC #9, #11, & #13 are the same as their respective preceeding LC, except with ML#2.

Strength II Load Factors (AASHTO Table 3.4.1-1 and 3.4.1-2)

Note: Only the LS and LL load factors have changed from Strength I to Strength II.

LC#15 = 1.25(BLC#1) + 1.5(BLC#2 + BLC#3) + 1.5(BLC#4) + 1.3(BLC#5) + 1.35(BLC#6)
Applying LL surcharge behind the left leg only. Maximum load factors on horizontal loads to increase the negative moment in the knees.

LC#16 = 1.25(BLC#1) + 1.5(BLC#2 + BLC#3) + 1.5(BLC#4) + 1.3(BLC#5) + 1.35(BLC#6+BLC#7)
Applying LL surcharge behind both legs. Maximum load factors on horizontal loads to increase the negative moment in the knees.

LC#17 = 1.25(BLC#1) + 0.9(BLC#2 + BLC#3) + 0.75(BLC#4) + 1.3(BLC#5) + LLF*ML#1
Applying LL to deck only. Minimum load factors on horizontal loads to maximize positive moment in the deck.

LC#18 = 1.25(BLC#1) + 0.9(BLC#2 + BLC#3) + 0.75(BLC#4) + 1.3(BLC#5) + LLF*ML#2
Applying LL to deck only. Minimum load factors on horizontal loads to maximize positive moment in the deck.

LC#19 = 1.25(BLC#1) + 1.5(BLC#2 + BLC#3) + 1.5(BLC#4) + 1.3(BLC#5) + 1.35(BLC#6) + LLF*ML#1
Applying LL surcharge behind the left leg and deck. Maximum load factors on horizontal loads to increase the negative moment in the knees.

LC#20 = 1.25(BLC#1) + 1.5(BLC#2 + BLC#3) + 1.5(BLC#4) + 1.3(BLC#5) + 1.35(BLC#6) + LLF*ML#2
Applying LL surcharge behind the left leg and deck. Maximum load factors on horizontal loads to increase the negative moment in the knees.

LC#21 = 1.25(BLC#1) + 1.5(BLC#2 + BLC#3) + 1.5(BLC#4) + 1.3(BLC#5) + 1.35(BLC#6 + BLC#7) + LLF*ML#1
Applying LL surcharge behind both legs and deck. Maximum load factors on horizontal loads to increase the negative moment in the knees.

LC#22 = 1.25(BLC#1) + 1.5(BLC#2 + BLC#3) + 1.5(BLC#4) + 1.3(BLC#5) + 1.35(BLC#6 + BLC#7) + LLF*ML#2
Applying LL surcharge behind both legs and deck. Maximum load factors on horizontal loads to increase the negative moment in the knees.

Note: LC #18, #20, & #22 are the same as their respective preceeding LC, except with ML#2.

Service I Load Factors (AASHTO Table 3.4.1-1 and 3.4.1-2)

Note: A separate model is run for the service load cases

LC#1 = 1.00(BLC#1)
LC#2 = 1.00(BLC#1) + 1.00(BLC#2)
To check structure for backfill behind one leg only.
LC#3 = 1.00(BLC#1) + 1.00(BLC#2 + BLC#3) + 1.00(BLC#6 + BLC#7))
To check structure when it is backfilled to top of legs and a construction live load is present for placing stone fill in the culvert. Use maximum load factors for EH and LS to increase the effect on negative moments in the knees.
LC#4 = 1.00(BLC#1) + 1.00(BLC#2+BLC#3) + 1.00(BLC#4) + 1.00(BLC#5)
To check structure when it is backfilled to final grade. Minimum load factors on horizontal loads to maximize positive moment in the deck.
LC#5 = 1.00(BLC#1) + 1.00(BLC#2 + BLC#3) + 1.00(BLC#4) + 1.00(BLC#5)
To check structure when it is backfilled to final grade. Maximum load factors on horizontal loads to increase the negative moments in the knees.
LC#6 = 1.00(BLC#1) + 1.00(BLC#2 + BLC#3) + 1.00(BLC#4) + 1.00(BLC#5) + 1.00(BLC#6)
Applying LL surcharge behind the left leg only. Maximum load factors on horizontal loads to increase the negative moment in the knees.
LC#7 = 1.00(BLC#1) + 1.00(BLC#2 + BLC#3) + 1.00(BLC#4) + 1.00(BLC#5) + 1.00(BLC#6+BLC#7)
Applying LL surcharge behind both legs. Maximum load factors on horizontal loads to increase the negative moment in the knees.
LC#8 = 1.00(BLC#1) + 1.00(BLC#2 + BLC#3) + 1.00(BLC#4) + 1.00(BLC#5) + LLF*ML#1
Applying LL to deck only. Minimum load factors on horizontal loads to maximize positive moment in the deck.
LC#9 = 1.00(BLC#1) + 1.00(BLC#2 + BLC#3) + 1.00(BLC#4) + 1.00(BLC#5) + LLF*ML#2
Applying LL to deck only. Minimum load factors on horizontal loads to maximize positive moment in the deck.
LC#10 = 1.00(BLC#1) + 1.00(BLC#2 + BLC#3) + 1.00(BLC#4) + 1.00(BLC#5) + 1.00(BLC#6) + LLF*ML#1
Applying LL surcharge behind the left leg and deck. Maximum load factors on horizontal loads to increase the negative moment in the knees.
LC#11 = 1.00(BLC#1) + 1.00(BLC#2 + BLC#3) + 1.00(BLC#4) + 1.00(BLC#5) + 1.00(BLC#6) + LLF*ML#2
Applying LL surcharge behind the left leg and deck. Maximum load factors on horizontal loads to increase the negative moment in the knees.
LC#12 = 1.00(BLC#1) + 1.00(BLC#2 + BLC#3) + 1.00(BLC#4) + 1.00(BLC#5) + 1.00(BLC#6 + BLC#7) + LLF*ML#1
Applying LL surcharge behind both legs and deck. Maximum load factors on horizontal loads to increase the negative moment in the knees.
LC#13 = 1.00(BLC#1) + 1.00(BLC#2 + BLC#3) + 1.00(BLC#4) + 1.00(BLC#5) + 1.00(BLC#6 + BLC#7) + LLF*ML#2
Applying LL surcharge behind both legs and deck. Maximum load factors on horizontal loads to increase the negative moment in the knees.

Note: LC #9, #11, & #13 are the same as their respective preceeding LC, except with ML#2.

Determine Number of RISA Design Sections

Need to choose number of sections such that RISA reports forces close to critical locations in the structure.

Number of Design Sections in RISA. $n_{sections} := 13$

Length of Leg in Model

$$H + \frac{1}{2}\cdot\left(t_{deck} + t_{btm}\right) = 94\cdot in$$

Closest Design Section in Leg

$sec_{leg} := 11$

Each Leg Section is:

$$\frac{H + \frac{1}{2}\cdot\left(t_{deck} + t_{btm}\right)}{n_{sections} - 1} = 7.833\cdot in$$

Location of Leg Design Section:

$$\frac{H + t_{deck}}{n_{sections} - 1}\cdot\left(sec_{leg} - 1\right) = 78.333\cdot in$$

Critical Section of Leg is at:

$$H + \frac{1}{2}\cdot t_{deck} - haunch = 80\cdot in$$

Length of Deck in Model

$$S + t_{leg} = 152\cdot in$$

Closest Design Section in Deck

$sec_{deck} := 2$

Each Deck Section is:

$$\frac{S + t_{leg}}{n_{sections} - 1} = 12.667\cdot in$$

Location of Deck Design Section:

$$\frac{S + t_{leg}}{n_{sections} - 1}\cdot\left(sec_{deck} - 1\right) = 12.667\cdot in$$

Critical Section of Deck is at:

$$\frac{1}{2}\cdot t_{leg} + haunch = 13\cdot in$$

Length of Btm in Model

$$S + t_{leg} = 152\cdot in$$

Closest Design Section in Btm

$sec_{btm} := 2$

Each Btm Section is:

$$\frac{S + t_{leg}}{n_{sections} - 1} = 12.667\cdot in$$

Location of Btm Design Section:

$$\frac{S + t_{leg}}{n_{sections} - 1}\cdot\left(sec_{btm} - 1\right) = 12.667\cdot in$$

Critical Section of Btm is at:

$$\frac{1}{2}\cdot t_{leg} + haunch = 13\cdot in$$

Calculate Sping Constant and Spring Spacing

$k_m := 0.200 \frac{ksi}{in}$ — Modulus of Subgrade Reaction per Figure 7.36 Pavement Analysis and Design, Huang 1993 Based on Assumed bearing value of 3000psf = 20psi

$n_{spring} := 13$ — Number of Soil Springs

$s_{spring} := \frac{S + t_{leg}}{n_{spring} - 1} = 1.056\,ft$ — Soil Spring Spacing

$k_{spring} := k_m \cdot s_{spring} \cdot b_w = 30.4 \cdot \frac{kip}{in}$ — Spring Constant

Check Outside Leg Moment (Design Section 1M):

Service Limit State

Check Crack Control in Section 5.7.3.4

$Ms_{outsideleg} := 6.33kip \cdot ft$ — Load Case #3

$Ns_{outsideleg} := -0.631kip$ — Min value at same section as Ms

Bar Layout: $bar_{outsideleg} := 6$ $s_{outsideleg} := 9in$

$diam_{outsideleg} := \frac{bar_{outsideleg}}{8} in$ $diam_{outsideleg} = 0.75 \cdot in$

$As_{outsideleg} := \frac{\pi \cdot diam_{outsideleg}^2}{4} \cdot 12 \frac{in}{s_{outsideleg}}$ $As_{outsideleg} = 0.59 \cdot in^2$

$d_{outsideleg} := t_{leg} - cover_{out} - \frac{diam_{outsideleg}}{2}$ $d_{outsideleg} = 5.625 \cdot in$

Stress in reinforcement calculated per MacGregor
"Reinforced Concrete Mechanics and Design" 4th Ed, Section 9-2

$\eta := \frac{E_s}{E_c} = 7.118$

$\rho_{outsideleg} := \frac{As_{outsideleg}}{b_w \cdot d_{outsideleg}} = 0.009$

$$k := \sqrt{2\rho_{outsideleg} + \left(\rho_{outsideleg} \cdot \eta\right)^2} - \rho_{outsideleg} \cdot \eta$$

$$j_{outsideleg} := 1 - \frac{k}{3} = 0.972$$

$$fss_{outsideleg} := \frac{Ms_{outsideleg} + Ns_{outsideleg} \cdot \left(d_{outsideleg} - \frac{t_{leg}}{2}\right)}{As_{outsideleg} \cdot j_{outsideleg} \cdot d_{outsideleg}} = 23.266 \cdot ksi$$

Stress in Reinforcement at Service Limit State

$$d_{c\_outsideleg} := t_{leg} - d_{outsideleg} \qquad d_{c\_outsideleg} = 2.375 \cdot in$$

$$\beta_s := 1 + \frac{d_{c\_outsideleg}}{0.7 \cdot \left(t_{leg} - d_{c\_outsideleg}\right)} \qquad \beta_s = 1.603$$

$$\gamma_e := 1.00$$ exposure factor

$$s_{max1} := \frac{700 \frac{kip}{in} \cdot \gamma_e}{\beta_s \cdot fss_{outsideleg}} - 2 \cdot d_{c\_outsideleg} \qquad \boxed{s_{max1} = 14.017 \cdot in}$$

Check Minimum Bar Spacing in Section 5.10.3.1.2:

$$s_{min} := \max\left(diam_{outsideleg}, 1.33 Aggregate_{diam}, 1in\right) \qquad \boxed{s_{min} = 1 \cdot in}$$

Check Maximum Bar Spacing in Section 5.10.3.2:

$$s_{max2} := \min\left(1.5 \cdot t_{leg}, 18in\right) \qquad \boxed{s_{max2} = 12 \cdot in}$$

$$\boxed{s_{outsideleg} = 9 \cdot in}$$

$$CheckSpacing_{Outsideleg} := \begin{cases} \text{"OK"} & \text{if } s_{min} \le s_{outsideleg} \le \min\left(s_{max1}, s_{max2}\right) \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Deflection Control (AASHTO 2.5.2.6.2):

Not Applicable to Legs

Strength Limit State

Flexural Resistance in Section 5.7.3.2

$Mu_{outsideleg} := 10.326kip \cdot ft$ Load Case #3

$Nu_{outsideleg} := -0.789kip$ Min value at the same section & LC as $Mu_{outsideleg}$
+ if tensile, - if compressive

$Vu_{outsideleg} := 3.855kip$ Max value at the same section & LC as $Mu_{outsideleg}$

Verify that f_y can be substituted for f_s in the equations of 5.7.3.2. This is allowed when $\frac{c}{d_s} \le 0.60$.

$c := \frac{As_{outsideleg} \cdot f_y}{0.85 \cdot f_c \cdot \beta_1 \cdot b_w}$ $c = 0.866 \cdot in$ Simplified equation 5.7.3.1.2-4

$\frac{c}{d_{outsideleg}} = 0.154$ **This is less than 0.60 therefore f_y can be substituted for f_s**

$a_{outsideleg} := \beta_1 \cdot c$ $a_{outsideleg} = 0.693 \cdot in$

$Mn_{outsideleg} := As_{outsideleg} \cdot f_y \cdot \left(d_{outsideleg} - \frac{a_{outsideleg}}{2} \right)$

$Mr_{outsideleg} := \phi_{moment} \cdot Mn_{outsideleg}$

$Mr_{outsideleg} = 13.992 \cdot kip \cdot ft$

$Mu_{outsideleg} = 10.326 \cdot kip \cdot ft$

$$CheckMoment_{OutsideLeg} := \begin{cases} \text{"OK"} & \text{if } Mu_{outsideleg} < Mr_{outsideleg} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Minimum Reinforcement in Section 5.7.3.3.2

$f_r := 0.24 \cdot \sqrt{f_c \cdot ksi}$ $\quad f_r = 0.537 \cdot ksi$ 5.4.2.6

$I_{g\_leg} := \frac{b_w \cdot t_{leg}^3}{12}$ $\quad I_{g\_leg} = 512 \cdot in^4$

$y_{t\_leg} := \frac{t_{leg}}{2}$ $\quad y_{t\_leg} = 4 \cdot in$

$S_{c\_leg} := \frac{I_{g\_leg}}{y_{t\_leg}} = 128 \cdot in^3$

$\gamma_1 := 1.2$ For precast members

$\gamma_3 := 0.67$ 0.67 for deformed bar

$M_{cr\_leg} := \gamma_3 \cdot \gamma_1 \cdot f_r \cdot S_{c\_leg}$ $\quad \boxed{M_{cr\_leg} = 4.602 \cdot kip \cdot ft}$ 5.7.3.3.2

$\boxed{1.33 \cdot Mu_{outsideleg} = 13.734 \cdot kip \cdot ft}$

The factored resistance shall be at least equal to the lesser of the above two values.

$$CheckMinRein_{Outsideleg1} := \begin{cases} \text{"OK"} & \text{if } Mr_{outsideleg} \geq \min(M_{cr\_leg}, 1.33 \cdot Mu_{outsideleg}) \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Minimum Reinforcement in Section 12.11.4.3.2

$\rho_{outsideleg} := \frac{As_{outsideleg}}{t_{leg} \cdot b_w}$ $\quad \boxed{\rho_{outsideleg} = 0.006}$

$\boxed{\rho_{min} := .002}$

$$CheckMinReinf_{Outsideleg2} := \begin{cases} \text{"OK"} & \text{if } \rho_{outsideleg} \geq \rho_{min} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Inside Frame Leg Moment (Design Section 2M):

Service Limit State

Check Crack Control in Section 5.7.3.4

$Ms_{insideleg} := 2.856kip \cdot ft$

Load Case #7

$Ns_{insideleg} := -6.604kip$

Min value at same section as Ms

Rebar Layout

$bar_{insideleg} := 4$

$s_{insideleg} := 12in$

$diam_{insideleg} := \frac{bar_{insideleg}}{8} in$

$diam_{insideleg} = 0.5 \cdot in$

$As_{insideleg} := \frac{\pi \cdot diam_{insideleg}^2}{4} \cdot 12 \frac{in}{s_{insideleg}}$

$As_{insideleg} = 0.2 \cdot in^2$

$d_{insideleg} := t_{leg} - cover - \frac{diam_{insideleg}}{2}$

$d_{insideleg} = 5.75 \cdot in$

Stress in reinforcement calculated per MacGregor
"Reinforced Concrete Mechanics and Design" 4th Ed, Section 9-2

$\eta := \frac{E_s}{E_c} = 7.118$

$\rho_{insideleg} := \frac{As_{insideleg}}{b_w \cdot d_{insideleg}} = 0.003$

$k := \sqrt{2\rho_{insideleg} + (\rho_{insideleg} \cdot \eta)^2} - \rho_{insideleg} \cdot \eta$

$j_{insideleg} := 1 - \frac{k}{3} = 0.981$

$fss_{insideleg} := \frac{Ms_{insideleg} + Ns_{insideleg} \cdot \left(d_{insideleg} - \frac{t_{leg}}{2}\right)}{As_{insideleg} \cdot j_{insideleg} \cdot d_{insideleg}} = 20.515 \cdot ksi$

Stress in Reinforcement at Service Limit State

$d_{c\_insideleg} := t_{leg} - d_{insideleg}$

$d_{c\_insideleg} = 2.25 \cdot in$

$\beta_s := 1 + \frac{d_{c\_insideleg}}{0.7 \cdot (t_{leg} - d_{c\_insideleg})}$

$\beta_s = 1.559$

$\gamma_e := 1.00$ exposure factor

$$s_{max1} := \frac{700\frac{kip}{in}\cdot\gamma_e}{\beta_s\cdot fss_{insideleg}} - 2\cdot d_{c\_insideleg}$$ $s_{max1} = 17.387\cdot in$

Check Minimum Bar Spacing in Section 5.10.3.1.2:

$s_{min} := \max(diam_{insideleg}, 1.33Aggregate_{diam}, 1in)$ $s_{min} = 1\cdot in$

Check Maximum Bar Spacing in Section 5.10.3.2:

$s_{max2} := \min(1.5\cdot t_{leg}, 18in)$ $s_{max2} = 12\cdot in$

$s_{insideleg} = 12\cdot in$

$$CheckSpacing_{insideleg} := \begin{cases} \text{"OK"} & \text{if } s_{min} \le s_{insideleg} \le \min(s_{max1}, s_{max2}) \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Deflection Control (AASHTO 2.5.2.6.2):

Not Applicable to Legs

Strength Limit State

Flexural Resistance in Section 5.7.3.2

$Mu_{insideleg} := 4.886kip\cdot ft$ Load Case #7

$Nu_{insideleg} := -8.613kip$ Min value at the same section & LC as $Mu_{insideleg}$
+ if tensile, - if compressive

$Vu_{insideleg} := 0.378kip$ Max value at the same section & LC as $Mu_{insideleg}$

Verify that f_y can be substituted for f_s in the equations of 5.7.3.2. This is allowed when

$\frac{c}{d_s} \le 0.60$.

$c := \frac{As_{insideleg} \cdot f_y}{0.85 \cdot f_c \cdot \beta_1 \cdot b_w}$ $\quad c = 0.289 \cdot in$ Simplified equation 5.7.3.1.2-4

$\frac{c}{d_{insideleg}} = 0.05$ **This is less than 0.60 therefore f_y can be substituted for f_s**

$a_{insideleg} := \beta_1 \cdot c$ $\quad a_{insideleg} = 0.231 \cdot in$

$Mn_{insideleg} := As_{insideleg} \cdot f_y \cdot \left(d_{insideleg} - \frac{a_{insideleg}}{2} \right)$

$Mr_{insideleg} := \phi_{moment} \cdot Mn_{insideleg}$

$\boxed{Mr_{insideleg} = 4.978 \cdot kip \cdot ft}$

$Mu_{insideleg} = 4.886 \cdot kip \cdot ft$

$$CheckMoment_{InsideLeg} := \begin{cases} \text{"OK"} & \text{if } Mu_{insideleg} < Mr_{insideleg} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Minimum Reinforcement in Section 5.7.3.3.2

$f_r := 0.24 \cdot \sqrt{f_c \cdot ksi}$ $\quad f_r = 0.537 \cdot ksi$ 5.4.2.6

$I_{g\_leg} := \frac{b_w \cdot t_{leg}^3}{12}$ $\quad I_{g\_leg} = 512 \cdot in^4$

$y_{t\_leg} := \frac{t_{leg}}{2}$ $\quad y_{t\_leg} = 4 \cdot in$

$S_{c\_leg} := \frac{I_{g\_leg}}{y_{t\_leg}} = 128 \cdot in^3$

$\gamma_1 := 1.2$ For precast members

$\gamma_3 := 0.67$ 0.67 for deformed bar

$M_{cr\_leg} := \gamma_3 \cdot \gamma_1 \cdot f_r \cdot S_{c\_leg}$ $\quad \boxed{M_{cr\_leg} = 4.602 \cdot kip \cdot ft}$ 5.7.3.3.2

$$1.33 \cdot Mu_{insideleg} = 6.498 \cdot kip \cdot ft$$

The factored resistance shall be at least equal to the lesser of the above two values.

$$CheckMinRein_{Insideleg1} := \begin{cases} \text{"OK"} & \text{if } Mr_{insideleg} \geq \min\left(M_{cr\_leg}, 1.33 \cdot Mu_{insideleg}\right) \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Minimum Reinforcement in Section 12.11.4.3.2

$$\rho_{insideleg} := \frac{As_{insideleg}}{t_{leg} \cdot b_w}$$

$$\rho_{insideleg} = 0.002$$

$$\rho_{min} := .002$$

$$CheckMinRein_{Insideleg2} := \begin{cases} \text{"OK"} & \text{if } \rho_{insideleg} \geq \rho_{min} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Leg Shear (Design Section 3S): Strength Limit State

$$d_{v\_leg} := \min\left(\frac{Mn_{insideleg}}{As_{insideleg} \cdot f_y}, \frac{Mn_{outsideleg}}{As_{outsideleg} \cdot f_y}\right)$$ C5.8.2.9-1

$$d_{v\_leg} = 5.279 \cdot in$$ Conservatively taking the smallest value for the leg.

$$Vu_{leg} := 5.834kip$$ Load Case #11

$$Mu_{leg\_RISA} := 9.086kip \cdot ft$$ Max value at the same section & LC as Vu_{leg}

$$Nu_{leg} := -9.007kip$$ Min value at the same section & LC as Vu_{leg}
+ if tensile, - if compressive

Note: This is a conservative approach, since we are taking the worse values for each of

shear, moment, and axial.

Determine Shear Resistance Section 5.8.3.4.2

The section contains less than the minimum transverse reinforcement specified in 5.8.2.5, therefore use equation 5.8.3.4.2-2 to determine the longitudinal strain (ξ_x) at the location of maximum shear.

$Mu_{leg} := \max(Mu_{leg\_RISA}, Vu_{leg} \cdot d_{v\_leg})$ $\qquad Mu_{leg} = 9.086 \cdot kip \cdot ft$

In the eqtn below Mu shall not be less than $Vu \cdot d_v$

$$\xi_{sleg} := \frac{\frac{|Mu_{leg}|}{d_{v\_leg}} + 0.5Nu_{leg} + |Vu_{leg}|}{E_s \cdot As_{outsideleg}} \qquad (5.8.3.4.2\text{-}4) \qquad 1000 \cdot \xi_{sleg} = 1.29$$

$s_{x\_leg} := d_{v\_leg}$

$$s_{xe\_leg} := s_{x\_leg} \cdot \frac{1.38in}{Aggregate_{diam} + 0.63in} = 5.279 \cdot in \qquad (5.8.3.4.2\text{-}5)$$

$$\beta_{leg} := \left(\frac{4.8}{1 + 750 \cdot \xi_{sleg}}\right) \cdot \left(\frac{51}{39 + \frac{s_{xe\_leg}}{1in}}\right) = 2.813 \qquad (5.8.3.4.2\text{-}2)$$

$$\Theta_{leg} := 29deg + 3500deg \cdot \xi_{sleg} = 33.505 \cdot deg \qquad (5.8.3.4.2\text{-}3)$$

$$Vn_{leg} := \min\left(0.25 \cdot f_c \cdot b_w \cdot d_{v\_leg}, 0.0316 \cdot \beta_{leg} \cdot \sqrt{f_c \cdot ksi} \cdot b_w \cdot d_{v\_leg}\right) = 12.591 \cdot kip$$

$Vr_{leg} := \phi_{shear} \cdot Vn_{leg} = 11.332 \cdot kip$

$Vu_{leg} = 5.834 \cdot kip$

$$Check_{Vr} := \begin{cases} \text{"OK"} & \text{if } Vr_{leg} \geq Vu_{leg} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Note: Per 5.8.2.4, Slabs, Footings, and Culverts are exempt from requiring transverse steel when $Vu > 0.5\phi Vc$.

Check Longitudinal Reinforcement per Section 5.8.3.5

Need to check each section investigated. Section 1M, 2M, & 3S.

Section 1M:

$Mu_{outsideleg} = 10.326 \cdot kip \cdot ft$ Restated from above

$Nu_{outsideleg} = -0.789 \cdot kip$ Restated from above

$Vu_{outsideleg} = 3.855 \cdot kip$ Restated from above

$As_{outsideleg} \cdot f_y = 35.343 \cdot kip$

Equation 5.8.3.5-1

$$long_{1M} := \frac{\left|Mu_{outsideleg}\right|}{d_{v\_leg} \cdot \phi_{moment}} + 0.5 \cdot \frac{Nu_{outsideleg}}{\phi_{axial}} + \left|\frac{Vu_{outsideleg}}{\phi_{shear}}\right| \cdot \cot\left(\Theta_{leg}\right) = 32.115 \cdot kip$$

$$Check_{long1M} := \begin{cases} \text{"OK"} & \text{if } As_{outsideleg} \cdot f_y \geq long_{1M} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Section 2M:

$Mu_{insideleg} = 4.886 \cdot kip \cdot ft$ Restated from above

$Nu_{insideleg} = -8.613 \cdot kip$ Restated from above

$Vu_{insideleg} = 0.378 \cdot kip$ Restated from above

$As_{insideleg} \cdot f_y = 11.781 \cdot kip$

Equation 5.8.3.5-1

$$long_{2M} := \frac{\left|Mu_{insideleg}\right|}{d_{v\_leg} \cdot \phi_{moment}} + 0.5 \cdot \frac{Nu_{insideleg}}{\phi_{axial}} + \left|\frac{Vu_{insideleg}}{\phi_{shear}}\right| \cdot \cot\left(\Theta_{leg}\right) = 8.191 \cdot kip$$

$$Check_{long2M} := \begin{cases} \text{"OK"} & \text{if } As_{insideleg} \cdot f_y \geq long_{2M} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Section 3S:

$Mu_{leg} = 9.086 \cdot kip \cdot ft$ Restated from above

$Nu_{leg} = -9.007 \cdot kip$ Restated from above

$Vu_{leg} = 5.834 \cdot kip$ Restated from Above

This design section is in the negative moment area near the knee so use outside leg reinforcing information.

$As_{outsideleg} \cdot f_y = 35.343 \cdot kip$

Equation 5.8.3.5-1

$$long_{3S} := \frac{|Mu_{leg}|}{d_{v\_leg} \cdot \phi_{moment}} + 0.5 \cdot \frac{Nu_{leg}}{\phi_{axial}} + \left| \frac{Vu_{leg}}{\phi_{shear}} \right| \cdot \cot(\Theta_{leg}) = 27.739 \cdot kip$$

$$Check_{long3S} := \begin{cases} \text{"OK"} & \text{if } As_{outsideleg} \cdot f_y \geq long_{3S} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Outside Frame Btm Slab Moment (Design Section 4M): Service Limit State

Check Crack Control in Section 5.7.3.4

$Ms_{outsidebtm} := 9.115 kip \cdot ft$ Load Case #3

$Ns_{outsidebtm} := -3.212 kip$ Min value at same section as Ms

Rebar Layout: $bar_{outsidebtm} := 6$ $s_{outsidebtm} := s_{outsideleg} = 9 \cdot in$

$$diam_{outsidebtm} := \frac{bar_{outsidebtm}}{8} in \qquad diam_{outsidebtm} = 0.75 \cdot in$$

$$As_{outsidebtm} := \frac{\pi \cdot diam_{outsidebtm}^2}{4} \cdot 12 \frac{in}{s_{outsidebtm}} \qquad As_{outsidebtm} = 0.59 \cdot in^2$$

$$d_{outsidebtm} := t_{btm} - cover - \frac{diam_{outsidebtm}}{2} \qquad d_{outsidebtm} = 7.625 \cdot in$$

Stress in reinforcement calculated per MacGregor
"Reinforced Concrete Mechanics and Design" 4th Ed, Section 9-2

$$\eta := \frac{E_s}{E_c} = 7.118$$

$$\rho_{outsidebtm} := \frac{As_{outsidebtm}}{b_w \cdot d_{outsidebtm}} = 0.006$$

$$k := \sqrt{2\rho_{outsidebtm} + \left(\rho_{outsidebtm} \cdot \eta\right)^2} - \rho_{outsidebtm} \cdot \eta$$

$$j_{outsidebtm} := 1 - \frac{k}{3} = 0.974$$

$$fss_{outsidebtm} := \frac{Ms_{outsidebtm} + Ns_{outsidebtm} \cdot \left(d_{outsidebtm} - \frac{t_{btm}}{2}\right)}{As_{outsidebtm} \cdot j_{outsidebtm} \cdot d_{outsidebtm}} = 23.064 \cdot ksi$$

Stress in Reinforcement at Service Limit State

$$d_{c\_outsidebtm} := t_{btm} - d_{outsidebtm} \qquad d_{c\_outsidebtm} = 2.375 \cdot in$$

$$\beta_s := 1 + \frac{d_{c\_outsidebtm}}{0.7 \cdot \left(t_{btm} - d_{c\_outsidebtm}\right)} \qquad \beta_s = 1.445$$

$$\gamma_e := 1.00$$ exposure factor

$$s_{max1} := \frac{700 \frac{kip}{in} \cdot \gamma_e}{\beta_s \cdot fss_{outsidebtm}} - 2 \cdot d_{c\_outsidebtm} \qquad \boxed{s_{max1} = 16.254 \cdot in}$$

Check Minimum Bar Spacing in Section 5.10.3.1.2:

$$s_{min} := \max\left(diam_{outsidebtm}, 1.33 Aggregate_{diam}, 1in\right) \qquad \boxed{s_{min} = 1 \cdot in}$$

Check Minimum Bar Spacing in Section 5.10.3.2:

$$s_{max2} := \min\left(1.5 \cdot t_{btm}, 18in\right) \qquad \boxed{s_{max2} = 15 \cdot in}$$

$$CheckSpacing_{Outsidebtm} := \begin{cases} \text{"OK"} & \text{if } s_{min} \le s_{outsidebtm} \le \min(s_{max1}, s_{max2}) \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Deflection Control (AASHTO 2.5.2.6.2):

Not Applicable to this Design Section

Strength Limit State

Flexural Resistance in Section 5.7.3.2

$Mu_{outsidebtm} := 15.085 kip \cdot ft$ Load Case #3

$Nu_{outsidebtm} := -5.123 kip$ Min value at the same section & LC as $Mu_{outsidebtm}$
+ if tensile, - if compressive

$Vu_{outsidebtm} := 1.106 kip$ Max value at the same section & LC as $Mu_{outsidebtm}$

Verify that f_y can e substituted for f_s in the equations of 5.7.3.2. This is allowed when $\frac{c}{d_s} \le 0.60$.

$$c := \frac{As_{outsidebtm} \cdot f_y}{0.85 \cdot f_c \cdot \beta_1 \cdot b_w} \qquad c = 0.866 \cdot in$$

Simplified equation 5.7.3.1.2-4

$$\frac{c}{d_{outsidebtm}} = 0.114$$

This is less than 0.60 therefore f_y can be substituted for f_s

$$a_{outsidebtm} := \beta_1 \cdot c \qquad a_{outsidebtm} = 0.693 \cdot in$$

$$Mn_{outsidebtm} := As_{outsidebtm} \cdot f_y \cdot \left(d_{outsidebtm} - \frac{a_{outsidebtm}}{2} \right)$$

$$Mr_{outsidebtm} := \phi_{moment} \cdot Mn_{outsidebtm}$$

$$Mr_{outsidebtm} = 19.293 \cdot kip \cdot ft$$

$Mu_{outsidebtm} = 15.085 \cdot kip \cdot ft$

$$CheckMoment_{Outsidebtm} := \begin{cases} \text{"OK"} & \text{if } Mu_{outsidebtm} < Mr_{outsidebtm} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Minimum Reinforcement in Section 5.7.3.3.2

$f_r := 0.24 \cdot \sqrt{f_c \cdot ksi}$ $\quad f_r = 0.537 \cdot ksi$ 5.4.2.6

$I_{g\_btm} := \frac{b_w \cdot t_{btm}^3}{12}$ $\quad I_{g\_btm} = 1000 \cdot in^4$

$y_{t\_btm} := \frac{t_{btm}}{2}$ $\quad y_{t\_btm} = 5 \cdot in$

$S_{c\_btm} := \frac{I_{g\_btm}}{y_{t\_btm}} = 200 \cdot in^3$

$\gamma_1 := 1.2$ For precast members

$\gamma_3 := 0.67$ 0.67 for deformed bar

$M_{cr\_btm} := \gamma_3 \cdot \gamma_1 \cdot f_r \cdot S_{c\_btm}$ $\quad \boxed{M_{cr\_btm} = 7.191 \cdot kip \cdot ft}$ 5.7.3.3.2

$\boxed{1.33 \cdot Mu_{outsidebtm} = 20.063 \cdot kip \cdot ft}$

The factored resistance shall be at least equal to the lesser of the above two values.

$$CheckMin_{Outbtm1} := \begin{cases} \text{"OK"} & \text{if } Mr_{outsidebtm} \geq \min(M_{cr\_btm}, 1.33 \cdot Mu_{outsidebtm}) \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Minimum Reinforcement in Section 12.11.4.3.2

$\rho_{outsidebtm} := \frac{As_{outsidebtm}}{t_{btm} \cdot b_w}$ $\quad \boxed{\rho_{outsidebtm} = 0.005}$

$\boxed{\rho_{min} := .002}$

$$CheckMinRein_{Outsidebtm2} := \begin{cases} \text{"OK"} & \text{if } \rho_{outsidebtm} \geq \rho_{min} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Inside Btm Slab Moment (Design Section 5M):
Service Limit State

Check Crack Control in Section 5.7.3.4

$Ms_{insidebtm} := 5.271kip \cdot ft$ Load Case #9

$Ns_{insidebtm} := -2.363kip$ Min value at same section as Ms

Rebar Layout: $bar_{insidebtm} := 5$ $s_{insidebtm} := 12in$

$$diam_{insidebtm} := \frac{bar_{insidebtm}}{8} in \qquad diam_{insidebtm} = 0.625 \cdot in$$

$$As_{insidebtm} := \frac{\pi \cdot diam_{insidebtm}^2}{4} \cdot 12 \frac{in}{s_{insidebtm}} \qquad As_{insidebtm} = 0.31 \cdot in^2$$

$$d_{insidebtm} := t_{btm} - cover - \frac{diam_{insidebtm}}{2} \qquad d_{insidebtm} = 7.688 \cdot in$$

Stress in reinforcement calculated per MacGregor
"Reinforced Concrete Mechanics and Design" 4th Ed, Section 9-2

$$\eta := \frac{E_s}{E_c} = 7.118$$

$$\rho_{insidebtm} := \frac{As_{insidebtm}}{b_w \cdot d_{insidebtm}} = 0.003$$

$$k := \sqrt{2\rho_{insidebtm} + (\rho_{insidebtm} \cdot \eta)^2} - \rho_{insidebtm} \cdot \eta$$

$$j_{insidebtm} := 1 - \frac{k}{3} = 0.98$$

$$fss_{insidebtm} := \frac{Ms_{insidebtm} + Ns_{insidebtm} \cdot \left(d_{insidebtm} - \frac{t_{btm}}{2}\right)}{As_{insidebtm} \cdot j_{insidebtm} \cdot d_{insidebtm}} = 24.629 \cdot ksi$$

Stress in Reinforcement at Service Limit State

$d_{c\_insidebtm} := t_{btm} - d_{insidebtm} = 2.313 \cdot in$

$\beta_s := 1 + \frac{d_{c\_insidebtm}}{0.7 \cdot (t_{btm} - d_{c\_insidebtm})}$ $\beta_s = 1.43$

$\gamma_e := 1.00$ exposure factor

$s_{max1} := \frac{700 \frac{kip}{in} \cdot \gamma_e}{\beta_s \cdot fss_{insidebtm}} - 2 \cdot d_{c\_insidebtm}$ $s_{max1} = 15.254 \cdot in$

Check Minimum Bar Spacing in Section 5.10.3.1.2:

$s_{min} := \max(diam_{insidebtm}, 1.33 Aggregate_{diam}, 1in)$ $s_{min} = 1 \cdot in$

Check Minimum Bar Spacing in Section 5.10.3.2:

$s_{max2} := \min(1.5 \cdot t_{btm}, 18in)$ $s_{max2} = 15 \cdot in$

$$CheckSpacing_{Insidebtm} := \begin{cases} \text{"OK"} & \text{if } s_{min} \le s_{insidebtm} \le \min(s_{max1}, s_{max2}) \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Deflection Control (AASHTO 2.5.2.6.2):

Not Applicable to this Design Section

Strength Limit State

Flexural Resistance in Section 5.7.3.2

$Mu_{insidebtm} := 7.628 kip \cdot ft$ Load Case #11

$Nu_{insidebtm} := -5.471 kip$ Min value at the same section & LC as $Mu_{insidebtm}$
+ if tensile, - if compressive

$Vu_{insidebtm} := 1.001kip$ Max value at the same section & LC as $Mu_{insidebtm}$

Verify that f_y can be substituted for f_s in the equations of 5.7.3.2. This is allowed when $\frac{c}{d_s} \le 0.60$.

$c := \frac{As_{insidebtm} \cdot f_y}{0.85 \cdot f_c \cdot \beta_1 \cdot b_w}$ $c = 0.451 \cdot in$ Simplified equation 5.7.3.1.2-4

$\frac{c}{d_{insidebtm}} = 0.059$ **This is less than 0.60 therefore f_y can be substituted for f_s**

$a_{insidebtm} := \beta_1 \cdot c$ $a_{insidebtm} = 0.361 \cdot in$

$Mn_{insidebtm} := As_{insidebtm} \cdot f_y \cdot \left(d_{insidebtm} - \frac{a_{insidebtm}}{2} \right)$

$Mr_{insidebtm} := \phi_{moment} \cdot Mn_{insidebtm}$

$Mr_{insidebtm} = 10.364 \cdot kip \cdot ft$

$Mu_{insidebtm} = 7.628 \cdot kip \cdot ft$

$$CheckMoment_{Insidebtm} := \begin{cases} "OK" & \text{if } Mu_{insidebtm} < Mr_{insidebtm} \\ "NG" & \text{otherwise} \end{cases} = "OK"$$

Minimum Reinforcement in Section 5.7.3.3.2

$f_r := 0.24 \cdot \sqrt{f_c \cdot ksi}$ $f_r = 0.537 \cdot ksi$ 5.4.2.6

$I_{g\_btm} := \frac{b_w \cdot t_{btm}^3}{12}$ $I_{g\_btm} = 1000 \cdot in^4$

$y_{t\_btm} := \frac{t_{btm}}{2}$ $y_{t\_btm} = 5 \cdot in$

$S_{c\_btm} := \frac{I_{g\_btm}}{y_{t\_btm}} = 200 \cdot in^3$

$\gamma_1 := 1.2$ For precast members

$\gamma_3 := 0.67$ 0.67 for deformed bar

$M_{cr\_leg} := \gamma_3 \cdot \gamma_1 \cdot f_r \cdot S_{c\_leg}$ $M_{cr\_btm} = 7.191 \cdot kip \cdot ft$ 5.7.3.3.2

$1.33 \cdot Mu_{insidebtm} = 10.145 \cdot kip \cdot ft$

The factored resistance shall be at least equal to the lesser of the above two values.

$$CheckMin_{Insidebtm1} := \begin{cases} \text{"OK"} & \text{if } Mr_{insidebtm} \geq \min(M_{cr\_btm}, 1.33 \cdot Mu_{insidebtm}) \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Minimum Reinforcement in Section 12.11.4.3.2

$$\rho_{insidebtm} := \frac{As_{insidebtm}}{t_{btm} \cdot b_w}$$ $\rho_{insidebtm} = 0.003$

$\rho_{min} := .002$

$$CheckMinRein_{Insidebtm2} := \begin{cases} \text{"OK"} & \text{if } \rho_{insidebtm} \geq \rho_{min} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Btm Slab Shear (Design Section 6S): Strength Limit State

$$d_{v\_btm} := \min\left(\frac{Mn_{insidebtm}}{As_{insidebtm} \cdot f_y}, \frac{Mn_{outsidebtm}}{As_{outsidebtm} \cdot f_y}\right)$$ C5.8.2.9-1

$d_{v\_btm} = 7.279 \cdot in$ Conservatively taking the smallest value for the btm.

$Vu_{btm} := 9.684kip$ Load Case #11

$Mu_{btm\_RISA} := 8.537kip \cdot ft$ Max value at the same section & LC as Vu_{btm}

$Nu_{btm} := -5.471kip$ Min value at the same section & LC as Vu_{btm}
+ if tensile, - if compressive

Note: This is a conservative approach, since we are taking the worse values for each of

shear, moment, and axial.

Determine Shear Resistance Section 5.8.3.4.2

The section contains less than the minimum transverse reinforcement specified in 5.8.2.5, therefore use equation 5.8.3.4.2-2 to determine the longitudinal strain (ξ_x) at the location of maximum shear.

$Mu_{btm} := \max(Mu_{btm\_RISA}, Vu_{btm} \cdot d_{v\_btm})$ $\qquad Mu_{btm} = 8.537 \cdot kip \cdot ft$

In the eqtn below Mu shall not be less than $Vu \cdot d_v$

$$\xi_{sbtm} := \frac{\frac{|Mu_{btm}|}{d_{v\_btm}} + 0.5Nu_{btm} + |Vu_{btm}|}{E_s \cdot As_{outsidebtm}} \qquad (5.8.3.4.2\text{-}4) \qquad 1000 \cdot \xi_{sbtm} = 1.23$$

$s_{x\_btm} := d_{v\_btm}$

$$s_{xe\_btm} := s_{x\_btm} \cdot \frac{1.38in}{Aggregate_{diam} + 0.63in} = 7.279 \cdot in \qquad (5.8.3.4.2\text{-}5)$$

$$\beta_{btm} := \left(\frac{4.8}{1 + 750 \cdot \xi_{sbtm}}\right) \cdot \left(\frac{51}{39 + \frac{s_{xe\_btm}}{1in}}\right) = 2.751 \qquad (5.8.3.4.2\text{-}2)$$

$$\Theta_{btm} := 29deg + 3500deg \cdot \xi_{sbtm} = 33.307 \cdot deg \qquad (5.8.3.4.2\text{-}3)$$

$$Vn_{btm} := \min\left(0.25 \cdot f_c \cdot b_w \cdot d_{v\_btm}, 0.0316 \cdot \beta_{btm} \cdot \sqrt{f_c \cdot ksi} \cdot b_w \cdot d_{v\_btm}\right) = 16.976 \cdot kip$$

$$\boxed{Vr_{btm} := \phi_{shear} \cdot Vn_{btm} = 15.279 \cdot kip}$$

$Vu_{btm} = 9.684 \cdot kip$

$$Check_{Vr} := \begin{cases} \text{"OK"} & \text{if } Vr_{btm} \geq Vu_{btm} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Note: Per 5.8.2.4 Slabs, Footings, and Culverts are exempt from requiring transverse steel when $Vu > 0.5\phi Vc$.

Check Longitudinal Reinforcement per Section 5.8.3.5

Need to check each section investigated. Section 4M, 5M, & 6S.

Section 4M:

$Mu_{outsidebtm} = 15.085 \cdot kip \cdot ft$ Restated from above

$Nu_{outsidebtm} = -5.123 \cdot kip$ Restated from above

$Vu_{outsidebtm} = 1.106 \cdot kip$ Restated from above

$As_{outsidebtm} \cdot f_y = 35.343 \cdot kip$ Equation 5.8.3.5-1

$$long_{4M} := \frac{\left|Mu_{outsidebtm}\right|}{d_{v\_btm} \cdot \phi_{moment}} + 0.5 \cdot \frac{Nu_{outsidebtm}}{\phi_{axial}} + \left|\frac{Vu_{outsidebtm}}{\phi_{shear}}\right| \cdot \cot\left(\Theta_{btm}\right) = 26.658 \cdot kip$$

$$Check_{long4M} := \begin{cases} \text{"OK"} & \text{if } As_{outsidebtm} \cdot f_y \geq long_{4M} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Section 5M:

$Mu_{insidebtm} = 7.628 \cdot kip \cdot ft$ Restated from above

$Nu_{insidebtm} = -5.471 \times 10^3\ lbf$ Restated from above

$Vu_{insidebtm} = 1.001 \cdot kip$ Restated from above

$As_{insidebtm} \cdot f_y = 18.408 \cdot kip$

Equation 5.8.3.5-1

$$long_{5M} := \frac{\left|Mu_{insidebtm}\right|}{d_{v\_btm} \cdot \phi_{moment}} + 0.5 \cdot \frac{Nu_{insidebtm}}{\phi_{axial}} + \left|\frac{Vu_{insidebtm}}{\phi_{shear}}\right| \cdot \cot\left(\Theta_{btm}\right) = 12.627 \cdot kip$$

$$Check_{long5M} := \begin{cases} \text{"OK"} & \text{if } As_{insidebtm} \cdot f_y \geq long_{5M} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Section 6S:

$Mu_{btm} = 8.537 \cdot kip \cdot ft$ Restated from above

$Nu_{btm} = -5.471 \cdot kip$ Restated from above

$Vu_{btm} = 9.684 \cdot kip$ Restated from Above

This design section is in the negative moment area near the knee so use outside btm reinforcing information.

$As_{outsidebtm} \cdot f_y = 35.343 \cdot kip$

Equation 5.8.3.5-1

$$long_{6S} := \frac{|Mu_{btm}|}{d_{v\_btm} \cdot \phi_{moment}} + 0.5 \cdot \frac{Nu_{btm}}{\phi_{axial}} + \left| \frac{Vu_{btm}}{\phi_{shear}} \right| \cdot \cot(\Theta_{btm}) = 28.975 \cdot kip$$

$$Check_{long6S} := \begin{cases} \text{"OK"} & \text{if } As_{outsidebtm} \cdot f_y \geq long_{6S} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Inside Deck Moment (Design Section 7M):

Service Limit State

Check Crack Control in Section 5.7.3.4

$Ms_{insidedeck} := 27.534 kip \cdot ft$ Load Case #9

$Ns_{insidedeck} := -0.161 kip$ Min value at same section as Ms

Rebar Layout: $bar_{insidedeck} := 8$ $s_{insidedeck} := 7in$

$$diam_{insidedeck} := \frac{bar_{insidedeck}}{8} in$$

$diam_{insidedeck} = 1 \cdot in$

$$As_{insidedeck} := \frac{\pi \cdot diam_{insidedeck}^2}{4} \cdot 12 \frac{in}{s_{insidedeck}} \qquad As_{insidedeck} = 1.35 \cdot in^2$$

$$d_{insidedeck} := t_{deck} - cover_{insidedeck} - \frac{diam_{insidedeck}}{2} \qquad d_{insidedeck} = 7.5 \cdot in$$

Stress in reinforcement calculated per MacGregor
"Reinforced Concrete Mechanics and Design" 4th Ed, Section 9-2

$$\eta := \frac{E_s}{E_c} = 7.118$$

$$\rho_{insidedeck} := \frac{As_{insidedeck}}{b_w \cdot d_{insidedeck}} = 0.015$$

$$k := \sqrt{2\rho_{insidedeck} + \left(\rho_{insidedeck} \cdot \eta\right)^2} - \rho_{insidedeck} \cdot \eta$$

$$j_{insidedeck} := 1 - \frac{k}{3} = 0.968$$

$$fss_{insidedeck} := \frac{Ms_{insidedeck} + Ns_{insidedeck} \cdot \left(d_{insidedeck} - \frac{t_{deck}}{2}\right)}{As_{insidedeck} \cdot j_{insidedeck} \cdot d_{insidedeck}} = 33.768 \cdot ksi$$

Stress in Reinforcement at Service Limit State

$$d_{c\_insidedeck} := t_{deck} - d_{insidedeck} \qquad d_{c\_insidedeck} = 2.5 \cdot in$$

$$\beta_s := 1 + \frac{d_{c\_insidedeck}}{0.7 \cdot \left(t_{deck} - d_{c\_insidedeck}\right)} \qquad \beta_s = 1.476$$

$$\gamma_e := 1.00$$ exposure factor

$$s_{max1} := \frac{700 \frac{kip}{in} \cdot \gamma_e}{\beta_s \cdot fss_{insidedeck}} - 2 \cdot d_{c\_insidedeck} \qquad \boxed{s_{max1} = 9.043 \cdot in}$$

Check Minimum Bar Spacing in Section 5.10.3.1.2:

$s_{min} := \max(diam_{insidedeck}, 1.33Aggregate_{diam}, 1in)$ $\boxed{s_{min} = 1 \cdot in}$

Check Minimum Bar Spacing in Section 5.10.3.2:

$s_{max2} := \min(1.5 \cdot t_{deck}, 18in)$ $\boxed{s_{max2} = 15 \cdot in}$

$$CheckSpacing_{InsideDeck} := \begin{cases} \text{"OK"} & \text{if } s_{min} \le s_{insidedeck} \le \min(s_{max1}, s_{max2}) \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Deflection Control (AASHTO 2.5.2.6.2):

See Below

Strength Limit State

Flexural Resistance in Section 5.7.3.2

$\boxed{Mu_{insidedeck} := 39.005kip \cdot ft}$ Load Case #9

$\boxed{Nu_{insidedeck} := -0.411kip}$ Min value at the same section & LC as $Mu_{insidedeck}$
+ if tensile, - if compressive

$\boxed{Vu_{insidedeck} := 0.969kip}$ Max value at the same section & LC as $Mu_{insidedeck}$

Verify that f_y can be substituted for f_s in the equations of 5.7.3.2. This is allowed when $\frac{c}{d_s} \le 0.60$.

$c := \frac{As_{insidedeck} \cdot f_y}{0.85 \cdot f_c \cdot \beta_1 \cdot b_w}$ $c = 1.98 \cdot in$ Simplified equation 5.7.3.1.2-4

$\frac{c}{d_{insidedeck}} = 0.264$ **This is less than 0.60 therefore f_y can be substituted for f_s**

$a_{insidedeck} := \beta_1 \cdot c$ $a_{insidedeck} = 1.584 \cdot in$

$$Mn_{insidedeck} := As_{insidedeck} \cdot f_y \cdot \left(d_{insidedeck} - \frac{a_{insidedeck}}{2} \right)$$

$$Mr_{insidedeck} := \phi_{moment} \cdot Mn_{insidedeck}$$

$$\boxed{Mr_{insidedeck} = 40.642 \cdot kip \cdot ft}$$

$$Mu_{insidedeck} = 39.005 \cdot kip \cdot ft$$

$$CheckMoment_{Insidedeck} := \begin{cases} \text{"OK"} & \text{if } Mu_{insidedeck} < Mr_{insidedeck} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Minimum Reinforcement in Section 5.7.3.3.2

$f_r := 0.24 \cdot \sqrt{f_c \cdot ksi}$ $\qquad f_r = 0.537 \cdot ksi$ $\qquad$ 5.4.2.6

$$I_{g\_deck} := \frac{b_w \cdot t_{deck}^3}{12} \qquad I_{g\_deck} = 1000 \cdot in^4$$

$$y_{t\_deck} := \frac{t_{deck}}{2} \qquad y_{t\_deck} = 5 \cdot in$$

$$S_{c\_deck} := \frac{I_{g\_deck}}{y_{t\_deck}} = 200 \cdot in^3$$

$\gamma_1 := 1.2$ $\qquad$ For precast members

$\gamma_3 := 0.67$ $\qquad$ 0.67 for deformed bar

$M_{cr\_deck} := \gamma_3 \cdot \gamma_1 \cdot f_r \cdot S_{c\_deck}$ $\qquad \boxed{M_{cr\_deck} = 7.191 \cdot kip \cdot ft}$ $\qquad$ 5.7.3.3.2

$$\boxed{1.33 \cdot Mu_{insidedeck} = 51.877 \cdot kip \cdot ft}$$

The factored resistance shall be at least equal to the lesser of the above two values.

$$CheckMin_{Insidedeck1} := \begin{cases} \text{"OK"} & \text{if } Mr_{insidedeck} \geq \min\left(M_{cr\_deck}, 1.33 \cdot Mu_{insidedeck}\right) \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Minimum Reinforcement in Section 12.11.4.3.2

$\rho_{insidedeck} := \frac{As_{insidedeck}}{t_{deck} \cdot b_w}$ $\rho_{insidedeck} = 0.011$

$\rho_{min} := .002$

$CheckMinRein_{Insidedeck2} := \begin{cases} "OK" & \text{if } \rho_{insidedeck} \geq \rho_{min} \\ "NG" & \text{otherwise} \end{cases} = "OK"$

Check Deck Shear (Design Section 8S):

Strength Limit State

$d_{v\_deck} := \frac{Mn_{insidedeck}}{As_{insidedeck} \cdot f_y} = 6.708 \cdot in$ C5.8.2.9-1

$Vu_{deck} := 10.312kip$ Load Case #9

$Mu_{deck\_RISA} := 11.922kip \cdot ft$ Max value at the same section & LC as Vu_{deck}

$Nu_{deck} := -0.411kip$ Min value at the same section & LC as Vu_{deck}

+ if tensile, - if compressive

Note: This is a conservative approach, since we are taking the worse values for each of shear, moment, and axial.

Determine Shear Resistance Section 5.8.3.4.2

The section contains less than the minimum transverse reinforcement specified in 5.8.2.5, therefore use equation 5.8.3.4.2-2 to determine the longitudinal strain (ξ_x) at the location of maximum shear.

$Mu_{deck} := \max(Mu_{deck\_RISA}, Vu_{deck} \cdot d_{v\_deck})$ $Mu_{deck} = 11.922 \cdot kip \cdot ft$

In the eqtn below Mu shall not be less than $Vu \cdot d_v$

$$\xi_{sdeck} := \frac{\frac{|Mu_{deck}|}{d_{v\_deck}} + 0.5Nu_{deck} + |Vu_{deck}|}{E_s \cdot As_{insidedeck}}$$ (5.8.3.4.2-4) $1000 \cdot \xi_{sdeck} = 0.81$

$s_{x\_deck} := d_{v\_deck} = 6.708 \cdot in$

$$s_{xe\_deck} := s_{x\_deck} \cdot \frac{1.38in}{Aggregate_{diam} + 0.63in} = 6.708 \cdot in$$ (5.8.3.4.2-5)

$$\beta_{deck} := \left(\frac{4.8}{1 + 750 \cdot \xi_{sdeck}}\right) \cdot \left(\frac{51}{39 + \frac{s_{xe\_deck}}{1in}}\right) = 3.339$$ (5.8.3.4.2-2)

$$\Theta_{deck} := 29deg + 3500deg \cdot \xi_{sdeck} = 31.818 \cdot deg$$ (5.8.3.4.2-3)

$$Vn_{deck} := \min\left(0.25 \cdot f_c \cdot b_w \cdot d_{v\_deck}, 0.0316 \cdot \beta_{deck} \cdot \sqrt{f_c \cdot ksi} \cdot b_w \cdot d_{v\_deck}\right) = 18.994 \cdot kip$$

$$\boxed{Vr_{deck} := \phi_{shear} \cdot Vn_{deck} = 17.095 \cdot kip}$$

$Vu_{deck} = 10.312 \cdot kip$

$$Check_{Vr} := \begin{cases} \text{"OK"} & \text{if } Vr_{deck} \geq Vu_{deck} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Note: Per 5.8.2.4 Slabs, Footings, and Culverts are exempt from requiring transverse steel when $Vu > 0.5\phi Vc$.

Check Longitudinal Reinforcement per Section 5.8.3.5

Need to check each section investigated. Section 7M & 8S.

Section 7M:

$Mu_{insidedeck} = 39.005 \cdot kip \cdot ft$ Restated from above

$Nu_{insidedeck} = -411\ lbf$ Restated from above

$Vu_{insidedeck} = 0.969 \cdot kip$ Restated from above

$As_{insidedeck} \cdot f_y = 80.784 \cdot kip$

Equation 5.8.3.5-1

$$long_{7M} := \frac{\left|Mu_{insidedeck}\right|}{d_{v\_deck} \cdot \phi_{moment}} + 0.5 \cdot \frac{Nu_{insidedeck}}{\phi_{axial}} + \left|\frac{Vu_{insidedeck}}{\phi_{shear}}\right| \cdot \cot\left(\Theta_{deck}\right) = 79.036 \cdot kip$$

$$Check_{long7M} := \begin{cases} \text{"OK"} & \text{if } As_{insidedeck} \cdot f_y \geq long_{7M} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Section 8S:

$Mu_{deck} = 11.922 \cdot kip \cdot ft$ Restated from above

$Nu_{deck} = -0.411 \cdot kip$ Restated from above

$Vu_{deck} = 10.312 \cdot kip$ Restated from Above

$0.20ksi \cdot f_y = 8.006 \times 10^9 \frac{lb}{ft^3 \cdot s^2} \cdot kip$

Equation 5.8.3.5-1

$$long_{8S} := \frac{\left|Mu_{deck}\right|}{d_{v\_deck} \cdot \phi_{moment}} + 0.5 \cdot \frac{Nu_{deck}}{\phi_{axial}} + \left|\frac{Vu_{deck}}{\phi_{shear}}\right| \cdot \cot\left(\Theta_{deck}\right) = 41.936 \cdot kip$$

$$Check_{long8S} := \begin{cases} \text{"OK"} & \text{if } As_{insidedeck} \cdot f_y \geq long_{8S} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Distribution Reinforcement (AASHTO 9.7.3.2):

Not applicable for soil depths greater than 2ft

Check Deflection Control (AASHTO 2.5.2.6.2, & 5.7.3.6.2):

AASHTO does not specify deflection control as a requirement, but top slab deflection will still be checked in accordance with section 2.5.2.6.2
Section 2.5.2.6.2 gives a deflection limit of Span/800 for Vehicle Loads & Span/1000 for Vehicle & Pedestrian Loads. Section 5.7.3.6.2 states that deflections may be determined as follows:

$M_{cr\_deck} = 7.191 \cdot kip \cdot ft$ Restated from above

$M_{DL\_midspan} := 20.112 kip \cdot ft$ Midspan Moment, Load Case #4 (Service I)

$M_{DL\_knee} := 0 kip \cdot ft$ No End Moment in separate top slab

$Ms_{insidedeck} = 27.534 \cdot kip \cdot ft$ Restated from above

Since Service Dead Load Moment at Midspan (where we are calculating the deflection) is greater than the cracking moment need to use effective moment of inertia.

Conservatively neglect Top mat of steel in calculating cracked moment of inertia.

$\rho_{insidedeck} = 0.011$

$n := \frac{E_s}{E_c}$ $n = 7.118$

$k := \sqrt{2 \cdot \rho_{insidedeck} \cdot n + \left(\rho_{insidedeck} \cdot n\right)^2} - \rho_{insidedeck} \cdot n$ MacGregor - 2nd Ed. Reinforced Concrete Design (9-3)

$k = 0.328$

$y_n := k \cdot d_{insidedeck}$ $y_n = 2.458 \cdot in$ Depth from compression fiber to bottom of compression block.

$area_{comp\_block} := b_w \cdot y_n$ $area_{comp\_block} = 29.492 \cdot in^2$

$I_{comp\_block} := \frac{b_w \cdot y_n^3}{12}$ $\quad I_{comp\_block} = 14.845 \cdot in^4$

$area_{steel} := As_{insidedeck} \cdot n$ $\quad area_{steel} = 9.583 \cdot in^2$

$$I_{cr\_insidedeck} := I_{comp\_block} + area_{comp\_block} \cdot \left(\frac{y_n}{2}\right)^2 + area_{steel} \cdot \left(d_{insidedeck} - y_n\right)^2$$

$I_{cr\_insidedeck} = 303.037 \cdot in^4$

$$I_{e\_DL} := \min\left[\left[\left(\frac{M_{cr\_deck}}{M_{DL\_midspan}}\right)^3 \cdot I_{g\_deck} + \left[1 - \left(\frac{M_{cr\_deck}}{M_{DL\_midspan}}\right)^3\right] \cdot I_{cr\_insidedeck}\right], I_{g\_deck}\right]$$

$I_{e\_DL} = 334.897 \cdot in^4$ AASHTO Eqtn:5.7.3.6.2-1

$$\Delta_{DL} := \frac{5}{48} \cdot \frac{S^2}{E_c \cdot I_{e\_DL}} \cdot \left(M_{DL\_midspan} + 0.2 \cdot M_{DL\_knee}\right)$$

$\Delta_{DL} = 0.382 \cdot in$

$M_{DL\_LL\_mid} := Ms_{insidedeck} = 27.534 \cdot kip \cdot ft$

$M_{DL\_LL\_knee} := 0 kip \cdot ft$ No End Moment in separate top slab

Since Total Service Load Moment at Midspan (where we are calculating the deflection) is greater than the cracking moment need to use effective moment of inertia to calculate deflections.

Conservatively neglect Top mat of steel in calculating cracked moment of inertia.

$\rho_{insidedeck} = 0.011$

$n := \frac{E_s}{E_c}$ $\quad n = 7.118$

$k := \sqrt{2 \cdot \rho_{insidedeck} \cdot n + \left(\rho_{insidedeck} \cdot n\right)^2} - \rho_{insidedeck} \cdot n$

MacGregor - 2nd Ed.
Reinforced Concrete Design (9-3)

$k = 0.328$

$y_n := k \cdot d_{insidedeck}$ $\quad y_n = 2.458 \cdot in$

Depth from compression fiber to bottom of compression block.

$area_{comp\_block} := b_w \cdot y_n$ $\quad area_{comp\_block} = 29.492 \cdot in^2$

$I_{comp\_block} := \frac{b_w \cdot y_n^3}{12}$ $\quad I_{comp\_block} = 14.845 \cdot in^4$

$area_{steel} := As_{insidedeck} \cdot n$ $\quad area_{steel} = 9.583 \cdot in^2$

$I_{cr\_insidedeck} := I_{comp\_block} + area_{comp\_block} \cdot \left(\frac{y_n}{2}\right)^2 + area_{steel} \cdot \left(d_{insidedeck} - y_n\right)^2$

$I_{cr\_insidedeck} = 303.037 \cdot in^4$

$$I_{e\_DL\_LL} := \min\left[\left[\left(\frac{M_{cr\_deck}}{M_{DL\_LL\_mid}}\right)^3 \cdot I_{g\_deck} + \left[1 - \left(\frac{M_{cr\_deck}}{M_{DL\_LL\_mid}}\right)^3\right] \cdot I_{cr\_insidedeck}\right], I_{g\_deck}\right]$$

$I_{e\_DL\_LL} = 315.454 \cdot in^4$

$$\Delta_{DL\_LL} := \frac{5}{48} \cdot \frac{S^2}{E_c \cdot I_{e\_DL\_LL}} \cdot \left(M_{DL\_LL\_mid} + 0.2 \cdot M_{DL\_LL\_knee}\right)$$

$\Delta_{DL\_LL} = 0.555 \cdot in$

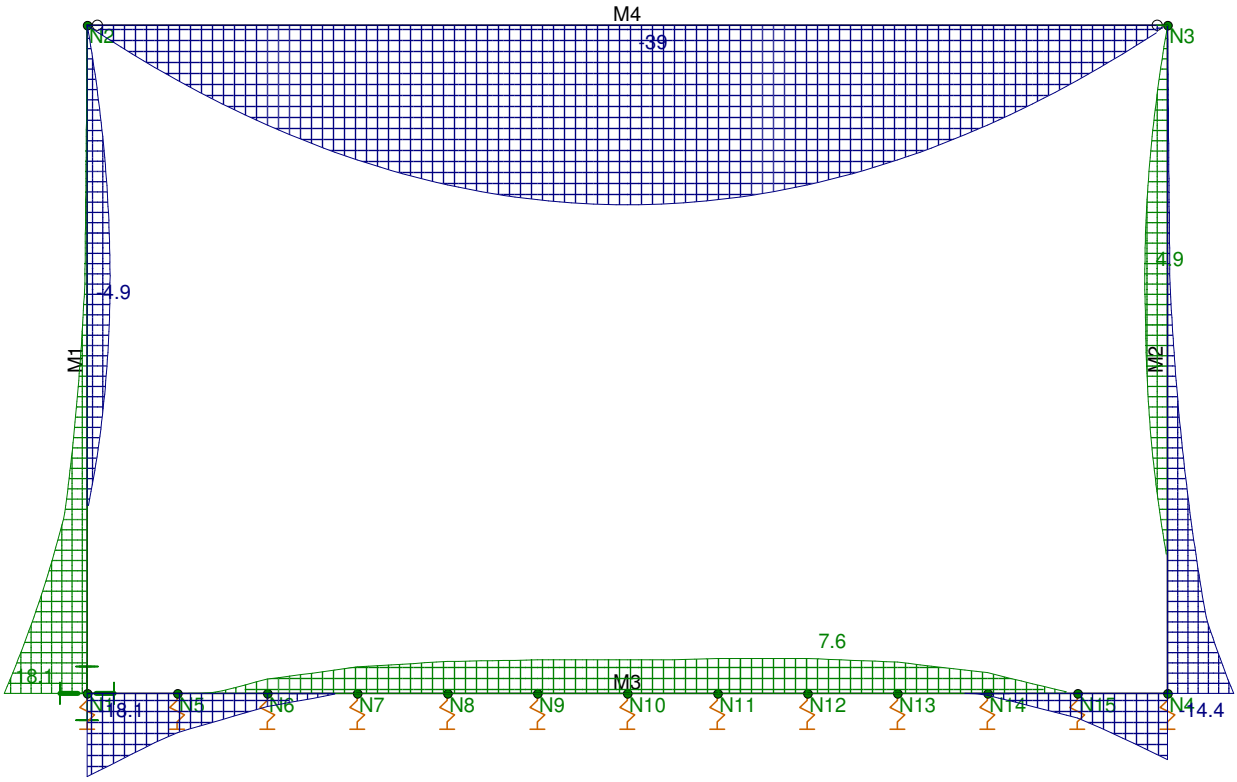
$\Delta_{LL} := \Delta_{DL\_LL} - \Delta_{DL}$ $\Delta_{LL} = 0.173 \cdot in$

$\Delta_{LL\_Ratio} := \frac{S}{\Delta_{LL}}$ $\Delta_{LL\_Ratio} = 831$

$\Delta_{LL\_allow} := 800$

800 for vehicle. 1000 for vehicle and pedestrian

$$Check_{deflection} := \begin{cases} \text{"OK"} & \text{if } \Delta_{LL\_Ratio} \geq \Delta_{LL\_allow} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$



Solution: Envelope
Member z Bending Moments (k-ft)

Renaud		SK - 1
P Lefebvre	12x7 BCwTS - BR52 - In Service Phase - Factored Loa...	Feb 23, 2015 at 5:28 PM
5778	Moment Envelope	12x7 box top_LRFD BR 52 Renau...

Delta 2015.059.013 CHK: RJA

Concrete Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (\1E...	Density[k/ft...	f'c[ksi]	Lambda	Flex Steel[...	Shear Stee...
1	Conc3000NW	3156	1372	.15	.6	.145	3	1	60	60
2	Conc3500NW	3409	1482	.15	.6	.145	3.5	1	60	60
3	Conc4000NW	3644	1584	.15	.6	.145	4	1	60	60
4	Conc5000NW	4074		.15	.6	.145	5	1	60	60
5	Conc3000LW	2085	907	.15	.6	.11	3	.75	60	60
6	Conc3500LW	2252	979	.15	.6	.11	3.5	.75	60	60
7	Conc4000LW	2408	1047	.15	.6	.11	4	.75	60	60

Concrete Section Sets

	Label	Shape	Type	Design List	Material	Design Rules	A [in2]	Iyy [in4]	Izz [in4]	J [in4]
1	LEG	CRECT8X12	Column	Rectangular...	Conc5000NW	Typical	96	1152	512	1187.84
2	DECK	CRECT10X12	Beam	Rectangular...	Conc5000NW	Typical	120	1440	1000	1900
3	BOTTOM	CRECT10X12	Beam	Rectangular...	Conc5000NW	Typical	120	1440	1000	1900

Joint Coordinates and Temperatures

	Label	X [in]	Y [in]	Z [in]	Temp [F]	Detach From Diap...
1	N1	0	0	0	0	
2	N2	0	94	0	0	
3	N3	152	94	0	0	
4	N4	152	0	0	0	
5	N5	12.666667	0	0	0	
6	N6	25.333333	0	0	0	
7	N7	38	0	0	0	
8	N8	50.666667	0	0	0	
9	N9	63.333333	0	0	0	
10	N10	76	0	0	0	
11	N11	88.666667	0	0	0	
12	N12	101.333333	0	0	0	
13	N13	114	0	0	0	
14	N14	126.666667	0	0	0	
15	N15	139.333333	0	0	0	

Joint Boundary Conditions

	Joint Label	X [k/in]	Y [k/in]	Z [k/in]	X Rot.[k-ft/rad]	Y Rot.[k-ft/rad]	Z Rot.[k-ft/rad]	Footing
1	N1	Reaction	CS30.4	Reaction	Reaction	Reaction		
2	N2							
3	N3							
4	N4		CS30.4					
5	N5		CS30.4					
6	N6		CS30.4					
7	N7		CS30.4					
8	N8		CS30.4					
9	N9		CS30.4					
10	N10		CS30.4					
11	N11		CS30.4					
12	N12		CS30.4					
13	N13		CS30.4					
14	N14		CS30.4					
15	N15		CS30.4					

Member Primary Data

	Label	I Joint	J Joint	K Joint	Rotate(d...	Section/Sha...	Type	Design List	Material	Design Ru...
1	M1	N2	N1			LEG	Column	Rectangular_MM	Conc500...	Typical
2	M2	N3	N4			LEG	Column	Rectangular_MM	Conc500...	Typical
3	M3	N1	N4			BOTTOM	Beam	Rectangular_MM	Conc500...	Typical
4	M4	N2	N3			DECK	Beam	Rectangular_MM	Conc500...	Typical

Member Advanced Data

	Label	I Release	J Release	I Offset[in]	J Offset[in]	T/C Only	Physical	TOM	Inactive	Seismic Design...
1	M1						Yes			None
2	M2						Yes			None
3	M3						Yes			None
4	M4	BenPIN	BenPIN				Yes			None

Basic Load Cases

	BLC Description	Category	X Gra...	Y Gra...	Z Gra...	Joint	Point	Distri...	Area(Member)	Surface(Plate/...
1	DEAD LOAD	DL		-1						
2	EP LEFT LEG	EPL						1		
3	EP RIGHT LEG	EPL						1		
4	OVERBURDEN SOIL LEG	EPL						2		
5	OVERBURDEN SOIL DECK	LL						1		
6	SUR LEFT LEG	LL						1		
7	SUR RIGHT LEG	LL						1		

Member Distributed Loads (BLC 2 : EP LEFT LEG)

	Member Label	Direction	Start Magnitude[k/ft,F]	End Magnitude[k/ft...	Start Location[in,%]	End Location[in,%]
1	M1	X	0	.508	0	0

Member Distributed Loads (BLC 3 : EP RIGHT LEG)

	Member Label	Direction	Start Magnitude[k/ft,F]	End Magnitude[k/ft...	Start Location[in,%]	End Location[in,%]
1	M2	X	0	-.508	0	0

Member Distributed Loads (BLC 4 : OVERBURDEN SOIL LEG)

	Member Label	Direction	Start Magnitude[k/ft,F]	End Magnitude[k/ft...	Start Location[in,%]	End Location[in,%]
1	M1	X	.443	.443	0	0
2	M2	X	-.443	-.443	0	0

Member Distributed Loads (BLC 5 : OVERBURDEN SOIL DECK)

	Member Label	Direction	Start Magnitude[k/ft,F]	End Magnitude[k/ft...	Start Location[in,%]	End Location[in,%]
1	M4	Y	-.882	-.882	0	0

Member Distributed Loads (BLC 6 : SUR LEFT LEG)

	Member Label	Direction	Start Magnitude[k/ft,F]	End Magnitude[k/ft...	Start Location[in,%]	End Location[in,%]
1	M1	X	.156	.156	0	0

Member Distributed Loads (BLC 7 : SUR RIGHT LEG)

	Member Label	Direction	Start Magnitude[k/ft,F]	End Magnitude[k/ft...	Start Location[in,%]	End Location[in,%]
1	M2	X	-.156	-.156	0	0

Moving Loads

	Tag	Pattern	Increment[in]	Bot...	1st J...	2nd J...	3rd J...	4th J...	5th J...	6th J...	7th J...	8th J...	9th J...	10th ...
1	M1	6FT_DISTRIB_TRUCK	6	Yes	N2	N3								
2	M2	6FT_DISTRIB_TANDEM	6	Yes	N2	N3								

Moving Load Patterns

Pattern Label	Load (k)	Direction	Distance (in)

¢7

Pattern Label	Load (k)	Direction	Distance (in)
6FT_DISTRIB_TRUCK	-.105	V	0
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	75.204
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864
	-.105	V	3.864

₵7

Pattern Label	Load (k)	Direction	Distance (in)
6FT_DISTRIB_TANDEM	-.082	V	0
	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868
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	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868
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	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868
	-.082	V	2.868

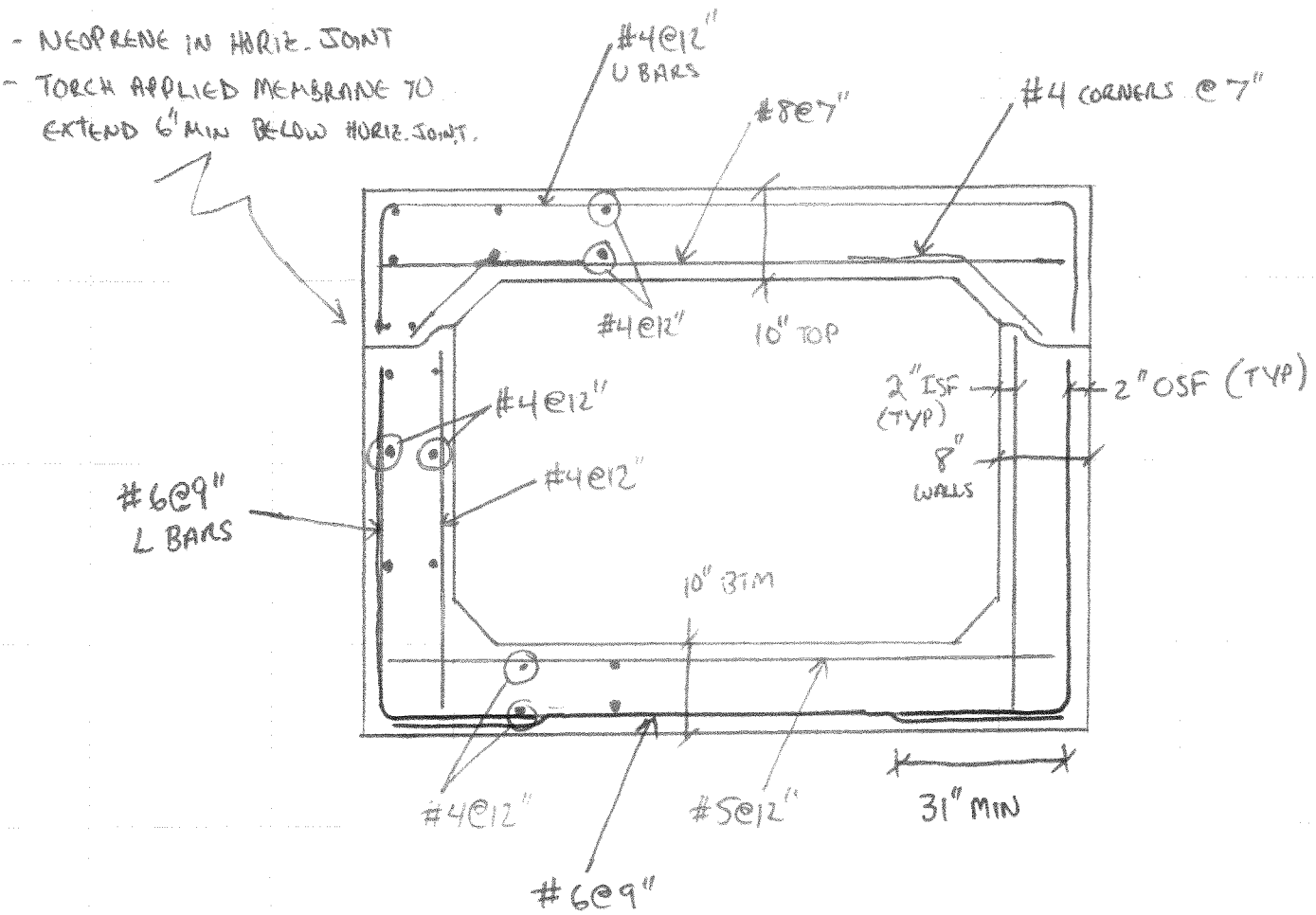
MICHIE CORPORATION
173 BUXTON INDUSTRIAL DRIVE; PO BOX 870
HENNIKER, NH 03242
PHONE: 603-428-3218
FAX: 603-428-7426

Re.: REINFORCING SUMMARY

Customer:	RENAUD
Project:	WINNALL VAOT STP CULVERT
Location:	BR 52
Project #:	5778
Description:	12x7 BCWTS
Proj. Contact:	

Date: 2/23/15	Designed by: PJL	Checked by:	Date Checked:

Page 1 of 1



MICHIE CORPORATION
173 BUXTON INDUSTRIAL DRIVE; PO BOX 870
HENNIKER, NH 03242
PHONE: 603-428-3218
FAX: 603-428-7426

Re.:

DESIGN FORCES SUMMARY

(FORCES ARE KIP & KIP-FT)

Customer: RENAUD
Project: WINHALL VT - VAULT SUP CLUB(S)
Location: -BR52-
Project #: 5778
Description: 12X7 BCWTS
Proj. Contact:

Date:	Designed by:	Checked by:	Date Checked:

Page ____ of ____

	LEG OSF (SEC 1-11)	LEG ISF (1-11)	FLOOR OSF (2-12)	FLOOR ISF (2-12)	DECK ISF (2-12)	DEFLECTION
M_S	6.33 (LC3)	2.856 (LC7)	9.115 (LC3)	5.271 (LC9)	27.534 (LC9)	M_{S_DL} = 20.112 (LC4)
N_S	-0.631	-6.604	-3.212	-2.363	-0.161	
M_U	10.326 (LC3)	4.886 (LC7)	15.085 (LC3)	7.628 (LC11)	39.005 (LC9)	
N_U	-0.789	-8.613	-5.123	-5.471	-0.411	
V_U	3.855	0.378	1.106	1.001	0.969	
V_U		5.834 (LC11)		9.684 (LC11)	10.312 (LC9)	
M_{U_RISA}		9.086		8.537	11.922	
N_U		-9.007		-5.471	-0.411	

Delta 2015.059.013 CHK: RJA

Load Combinations

	Description	Solve	PDelta	SRSS	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...
1	DL	Yes			1	1														
2	Backfill one leg	Yes			1	1	2	1												
3	Backfill two legs + Surcharge two ...	Yes			1	1	2	1	3	1	6	1	7	1						
4	Backfill to FG (Deck Moment)				1	1	2	.5	3	.5	4	.5	5	1						
5	Backfill to FG (Knee Moment)				1	1	2	1	3	1	4	1	5	1						
6	Backfill to FG + LS left leg only				1	1	2	1	3	1	4	1	5	1	6	1				
7	Backfill to FG + LS both legs				1	1	2	1	3	1	4	1	5	1	6	1	7	1		
8	LC#4 + Truck				1	1	2	.5	3	.5	4	.5	5	1	M1	1.0...				
9	LC#4 + Tandem				1	1	2	.5	3	.5	4	.5	5	1	M2	1.0...				
10	LC#6 + Truck				1	1	2	1	3	1	4	1	5	1	6	1	M1	1.0...		
11	LC#6 + Tandem				1	1	2	1	3	1	4	1	5	1	6	1	M2	1.0...		
12	LC#7 + Truck				1	1	2	1	3	1	4	1	5	1	6	1	7	1	M1	1.0...
13	LC#7 + Tandem				1	1	2	1	3	1	4	1	5	1	6	1	7	1	M2	1.0...

Envelope Member Section Forces

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
1	M1	1	max	0	1	0	1	0	1	0	1	0	1	0	1
2			min	0	1	0	1	0	1	0	1	0	1	0	1
3		2	max	.063	3	0	1	0	1	0	1	0	1	.036	3
4			min	.063	2	-.116	3	0	1	0	1	0	1	0	1
5		3	max	.126	3	0	1	0	1	0	1	0	1	.157	3
6			min	.126	2	-.259	3	0	1	0	1	0	1	0	1
7		4	max	.189	3	0	1	0	1	0	1	0	1	.38	3
8			min	.189	2	-.43	3	0	1	0	1	0	1	0	1
9		5	max	.252	3	0	1	0	1	0	1	0	1	.724	3
10			min	.252	2	-.628	3	0	1	0	1	0	1	0	1
11		6	max	.316	3	0	1	0	1	0	1	0	1	1.207	3
12			min	.316	2	-.855	3	0	1	0	1	0	1	0	1
13		7	max	.379	3	0	1	0	1	0	1	0	1	1.846	3
14			min	.379	2	-1.108	3	0	1	0	1	0	1	0	1
15		8	max	.442	3	0	1	0	1	0	1	0	1	2.66	3
16			min	.442	2	-1.39	3	0	1	0	1	0	1	0	1
17		9	max	.505	3	0	1	0	1	0	1	0	1	3.667	3
18			min	.505	2	-1.699	3	0	1	0	1	0	1	0	1
19		10	max	.568	3	0	1	0	1	0	1	0	1	4.884	3
20			min	.568	2	-2.036	3	0	1	0	1	0	1	0	1
21		11	max	.631	3	0	1	0	1	0	1	0	1	6.33	3
22			min	.631	2	-2.4	3	0	1	0	1	0	1	0	1
23		12	max	.694	3	0	1	0	1	0	1	0	1	8.023	3
24			min	.694	2	-2.792	3	0	1	0	1	0	1	0	1
25		13	max	.757	3	0	1	0	1	0	1	0	1	9.981	3
26			min	.757	2	-3.212	3	0	1	0	1	0	1	0	1
27	M2	1	max	0	1	0	1	0	1	0	1	0	1	0	1
28			min	0	1	0	1	0	1	0	1	0	1	0	1
29		2	max	.063	1	.116	3	0	1	0	1	0	1	0	1
30			min	.063	3	0	1	0	1	0	1	0	1	-.036	3
31		3	max	.126	1	.259	3	0	1	0	1	0	1	0	1
32			min	.126	3	0	1	0	1	0	1	0	1	-.157	3
33		4	max	.189	1	.43	3	0	1	0	1	0	1	0	1
34			min	.189	3	0	1	0	1	0	1	0	1	-.38	3
35		5	max	.252	1	.628	3	0	1	0	1	0	1	0	1
36			min	.252	3	0	1	0	1	0	1	0	1	-.724	3
37		6	max	.316	1	.855	3	0	1	0	1	0	1	0	1
38			min	.316	3	0	1	0	1	0	1	0	1	-1.207	3
39		7	max	.379	1	1.108	3	0	1	0	1	0	1	0	1

M_s

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
40			min	.379	3	0	1	0	1	0	1	0	1	-1.846	3
41		8	max	.442	1	1.39	3	0	1	0	1	0	1	0	1
42			min	.442	3	0	1	0	1	0	1	0	1	-2.66	3
43		9	max	.505	1	1.699	3	0	1	0	1	0	1	0	1
44			min	.505	3	0	1	0	1	0	1	0	1	-3.667	3
45		10	max	.568	1	2.036	3	0	1	0	1	0	1	0	1
46			min	.568	3	0	1	0	1	0	1	0	1	-4.884	3
47		11	max	.631	1	2.4	3	0	1	0	1	0	1	0	1
48			min	.631	3	0	1	0	1	0	1	0	1	-6.33	3
49		12	max	.694	1	2.792	3	0	1	0	1	0	1	0	1
50			min	.694	3	0	1	0	1	0	1	0	1	-8.023	3
51		13	max	.757	1	3.212	3	0	1	0	1	0	1	0	1
52			min	.757	3	0	1	0	1	0	1	0	1	-9.981	3
53	M3	1	max	3.212	3	-.302	1	0	1	0	1	0	1	0	1
54			min	0	1	-.757	2	0	1	0	1	0	1	-9.981	3
55		2	max	3.212	3	-.43	1	0	1	0	1	0	1	.386	1
56			min	0	1	-.885	2	0	1	0	1	0	1	-9.115	3
57		3	max	3.212	3	-.21	1	0	1	0	1	0	1	.541	1
58			min	0	1	-1.012	2	0	1	0	1	0	1	-8.114	3
59		4	max	3.212	3	.099	1	0	1	0	1	0	1	.561	1
60			min	0	1	-1.14	3	0	1	0	1	0	1	-6.978	3
61		5	max	3.212	3	.104	1	0	1	0	1	0	1	.524	1
62			min	0	1	-1.267	3	0	1	0	1	0	1	-5.707	3
63		6	max	3.212	3	.08	1	0	1	0	1	0	1	.481	1
64			min	0	1	-.978	3	0	1	0	1	0	1	-4.742	3
65		7	max	3.212	3	-.047	1	0	1	0	1	0	1	.463	1
66			min	0	1	-.582	2	0	1	0	1	0	1	-4.388	3
67		8	max	3.212	3	.978	3	0	1	0	1	0	1	.481	1
68			min	0	1	-.421	2	0	1	0	1	0	1	-4.742	3
69		9	max	3.212	3	1.267	3	0	1	0	1	0	1	.542	2
70			min	0	1	-.286	2	0	1	0	1	0	1	-5.707	3
71		10	max	3.212	3	1.14	3	0	1	0	1	0	1	.65	2
72			min	0	1	-.166	2	0	1	0	1	0	1	-6.978	3
73		11	max	3.212	3	1.012	3	0	1	0	1	0	1	.622	2
74			min	0	1	.21	1	0	1	0	1	0	1	-8.114	3
75		12	max	3.212	3	.885	3	0	1	0	1	0	1	.426	2
76			min	0	1	.43	1	0	1	0	1	0	1	-9.115	3
77		13	max	3.212	3	.757	3	0	1	0	1	0	1	0	1
78			min	0	1	.302	1	0	1	0	1	0	1	-9.981	3

M_s

Envelope Joint Reactions

	Joint		X [k]	LC	Y [k]	LC	Z [k]	LC	MX [k-ft]	LC	MY [k-ft]	LC	MZ [k-ft]	LC
1	N1	max	0	3	.455	1	0	1	0	1	0	1	0	1
2		min	-1.99	2	0	2	0	1	0	1	0	1	0	1
3	N4	max	0	1	.455	1	0	1	0	1	0	1	0	1
4		min	0	1	0	3	0	1	0	1	0	1	0	1
5	N5	max	0	1	.347	1	0	1	0	1	0	1	0	1
6		min	0	1	0	2	0	1	0	1	0	1	0	1
7	N6	max	0	1	.254	1	0	1	0	1	0	1	0	1
8		min	0	1	0	3	0	1	0	1	0	1	0	1
9	N7	max	0	1	.242	2	0	1	0	1	0	1	0	1
10		min	0	1	0	3	0	1	0	1	0	1	0	1
11	N8	max	0	1	.417	3	0	1	0	1	0	1	0	1
12		min	0	1	.133	1	0	1	0	1	0	1	0	1
13	N9	max	0	1	.707	3	0	1	0	1	0	1	0	1
14		min	0	1	.104	1	0	1	0	1	0	1	0	1

Envelope Joint Reactions (Continued)

	Joint		X [k]	LC	Y [k]	LC	Z [k]	LC	MX [k-ft]	LC	MY [k-ft]	LC	MZ [k-ft]	LC
15	N10	max	0	1	.799	3	0	1	0	1	0	1	0	1
16		min	0	1	.094	1	0	1	0	1	0	1	0	1
17	N11	max	0	1	.707	3	0	1	0	1	0	1	0	1
18		min	0	1	.104	1	0	1	0	1	0	1	0	1
19	N12	max	0	1	.417	3	0	1	0	1	0	1	0	1
20		min	0	1	.133	1	0	1	0	1	0	1	0	1
21	N13	max	0	1	.255	2	0	1	0	1	0	1	0	1
22		min	0	1	0	3	0	1	0	1	0	1	0	1
23	N14	max	0	1	.288	2	0	1	0	1	0	1	0	1
24		min	0	1	0	3	0	1	0	1	0	1	0	1
25	N15	max	0	1	.347	1	0	1	0	1	0	1	0	1
26		min	0	1	0	3	0	1	0	1	0	1	0	1
27	Totals:	max	0	3	3.045	1	0	1						
28		min	-1.99	2	3.045	3	0	1						

Member Section Forces

	LC	Member Label	Sec	Axial[k]	y Shear[k]	z Shear[k]	Torque[k-ft]	y-y Mo...	z-z Mo...
1	3	M1	1	0	0	0	0	0	0
2			2	.063	-.116	0	0	0	.036
3			3	.126	-.259	0	0	0	.157
4			4	.189	-.43	0	0	0	.38
5			5	.252	-.628	0	0	0	.724
6			6	.316	-.855	0	0	0	1.207
7			7	.379	-1.108	0	0	0	1.846
8			8	.442	-1.39	0	0	0	2.66
9			9	.505	-1.699	0	0	0	3.667
10			10	.568	-2.036	0	0	0	4.884
11			11	.631 Ns	-2.4	0	0	0	6.33
12			12	.694	-2.792	0	0	0	8.023
13			13	.757	-3.212	0	0	0	9.981
14	3	M2	1	0	0	0	0	0	0
15			2	.063	.116	0	0	0	-.036
16			3	.126	.259	0	0	0	-.157
17			4	.189	.43	0	0	0	-.38
18			5	.252	.628	0	0	0	-.724
19			6	.316	.855	0	0	0	-1.207
20			7	.379	1.108	0	0	0	-1.846
21			8	.442	1.39	0	0	0	-2.66
22			9	.505	1.699	0	0	0	-3.667
23			10	.568	2.036	0	0	0	-4.884
24			11	.631	2.4	0	0	0	-6.33
25			12	.694	2.792	0	0	0	-8.023
26			13	.757	3.212	0	0	0	-9.981
27	3	M3	1	3.212	-.757	0	0	0	-9.981
28			2	3.212 Ns	-.885	0	0	0	-9.115
29			3	3.212	-1.012	0	0	0	-8.114
30			4	3.212	-1.14	0	0	0	-6.978
31			5	3.212	-1.267	0	0	0	-5.707
32			6	3.212	-.978	0	0	0	-4.742
33			7	3.212	-.399	0	0	0	-4.388
34			8	3.212	.978	0	0	0	-4.742
35			9	3.212	1.267	0	0	0	-5.707
36			10	3.212	1.14	0	0	0	-6.978
37			11	3.212	1.012	0	0	0	-8.114
38			12	3.212	.885	0	0	0	-9.115
39			13	3.212	.757	0	0	0	-9.981

Load Combinations

	Description	Solve	PDelta	SRSS	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...
1	DL	Yes			1	1														
2	Backfill one leg				1	1	2	1												
3	Backfill two legs + Surcharge two ...				1	1	2	1	3	1	6	1	7	1						
4	Backfill to FG (Deck Moment)	Yes			1	1	2	.5	3	.5	4	.5	5	1						
5	Backfill to FG (Knee Moment)	Yes			1	1	2	1	3	1	4	1	5	1						
6	Backfill to FG + LS left leg only	Yes			1	1	2	1	3	1	4	1	5	1	6	1				
7	Backfill to FG + LS both legs	Yes			1	1	2	1	3	1	4	1	5	1	6	1	7	1		
8	LC#4 + Truck	Yes			1	1	2	.5	3	.5	4	.5	5	1	M1	1.0...				
9	LC#4 + Tandem	Yes			1	1	2	.5	3	.5	4	.5	5	1	M2	1.0...				
10	LC#6 + Truck	Yes			1	1	2	1	3	1	4	1	5	1	6	1	M1	1.0...		
11	LC#6 + Tandem	Yes			1	1	2	1	3	1	4	1	5	1	6	1	M2	1.0...		
12	LC#7 + Truck	Yes			1	1	2	1	3	1	4	1	5	1	6	1	7	1	M1	1.0...
13	LC#7 + Tandem	Yes			1	1	2	1	3	1	4	1	5	1	6	1	7	1	M2	1.0...

Envelope Member Section Forces

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
1	M1	1	max	8.723	9	1.95	7	0	1	0	1	0	1	0	1
2			min	.765	1	-.137	1	0	1	0	1	0	1	0	1
3		2	max	8.786	9	1.545	7	0	1	0	1	0	1	.09	1
4			min	.828	1	-.137	1	0	1	0	1	0	1	-1.142	7
5		3	max	8.849	9	1.112	7	0	1	0	1	0	1	.179	1
6			min	.891	1	-.155	9	0	1	0	1	0	1	-2.011	7
7		4	max	8.912	9	.652	7	0	1	0	1	0	1	.269	1
8			min	.955	1	-.335	9	0	1	0	1	0	1	-2.588	7
9		5	max	8.975	9	.165	7	0	1	0	1	0	1	.43	9
10			min	1.018	1	-.528	9	0	1	0	1	0	1	-2.856	7
11		6	max	9.038	9	-.137	1	0	1	0	1	0	1	.841	9
12			min	1.081	1	-.831	11	0	1	0	1	0	1	-2.797	7
13		7	max	9.101	9	-.137	1	0	1	0	1	0	1	1.392	9
14			min	1.144	1	-1.374	11	0	1	0	1	0	1	-2.392	7
15		8	max	9.164	9	-.137	1	0	1	0	1	0	1	2.091	9
16			min	1.207	1	-1.945	11	0	1	0	1	0	1	-1.624	7
17		9	max	9.227	9	-.137	1	0	1	0	1	0	1	2.947	9
18			min	1.27	1	-2.543	11	0	1	0	1	0	1	-.474	7
19		10	max	9.291	9	-.137	1	0	1	0	1	0	1	3.971	9
20			min	1.333	1	-3.169	11	0	1	0	1	0	1	.807	1
21		11	max	9.354	9	-.137	1	0	1	0	1	0	1	6.179	11
22			min	1.396	1	-3.823	11	0	1	0	1	0	1	.896	1
23		12	max	9.417	9	-.137	1	0	1	0	1	0	1	8.896	11
24			min	1.459	1	-4.504	11	0	1	0	1	0	1	.986	1
25		13	max	9.48	9	-.137	1	0	1	0	1	0	1	12.066	11
26			min	1.523	1	-5.213	11	0	1	0	1	0	1	1.076	1
27	M2	1	max	8.723	9	.137	1	0	1	0	1	0	1	0	1
28			min	.765	1	-1.95	7	0	1	0	1	0	1	0	1
29		2	max	8.786	9	.137	1	0	1	0	1	0	1	1.142	7
30			min	.828	1	-1.545	7	0	1	0	1	0	1	-.09	1
31		3	max	8.849	9	.155	9	0	1	0	1	0	1	2.011	7
32			min	.891	1	-1.112	7	0	1	0	1	0	1	-.179	1
33		4	max	8.912	9	.335	9	0	1	0	1	0	1	2.588	7
34			min	.955	1	-.687	6	0	1	0	1	0	1	-.269	1
35		5	max	8.975	9	.528	9	0	1	0	1	0	1	2.856	7
36			min	1.018	1	-.301	6	0	1	0	1	0	1	-.43	9
37		6	max	9.038	9	.734	9	0	1	0	1	0	1	2.797	7
38			min	1.081	1	.112	6	0	1	0	1	0	1	-.841	9
39		7	max	9.101	9	1.104	13	0	1	0	1	0	1	2.53	6

M_5

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
40			min	1.144	1	.137	1	0	1	0	1	0	1	-1.392	9
41		8	max	9.164	9	1.675	13	0	1	0	1	0	1	2.017	6
42			min	1.207	1	.137	1	0	1	0	1	0	1	-2.091	9
43		9	max	9.227	9	2.273	13	0	1	0	1	0	1	1.189	6
44			min	1.27	1	.137	1	0	1	0	1	0	1	-2.947	9
45		10	max	9.291	9	2.899	13	0	1	0	1	0	1	.028	6
46			min	1.333	1	.137	1	0	1	0	1	0	1	-3.971	9
47		11	max	9.354	9	3.552	13	0	1	0	1	0	1	-.896	1
48			min	1.396	1	.137	1	0	1	0	1	0	1	-5.169	9
49		12	max	9.417	9	4.234	13	0	1	0	1	0	1	-.986	1
50			min	1.459	1	.137	1	0	1	0	1	0	1	-6.954	13
51		13	max	9.48	9	4.942	13	0	1	0	1	0	1	-1.076	1
52			min	1.522	1	.137	1	0	1	0	1	0	1	-9.947	13
53	M3	1	max	4.942	13	-.867	1	0	1	0	1	0	1	-1.076	1
54			min	.137	1	-6.661	11	0	1	0	1	0	1	-12.066	11
55		2	max	4.942	13	-.994	1	0	1	0	1	0	1	-.094	1
56			min	.137	1	-6.789	11	0	1	0	1	0	1	-5.308	11
57		3	max	4.942	13	-.591	1	0	1	0	1	0	1	2.313	9
58			min	.137	1	-4.448	11	0	1	0	1	0	1	-1.284	11
59		4	max	4.942	13	-.318	1	0	1	0	1	0	1	4.2	9
60			min	.137	1	-2.691	11	0	1	0	1	0	1	.731	1
61		5	max	4.942	13	-.16	1	0	1	0	1	0	1	5.005	9
62			min	.137	1	-1.569	11	0	1	0	1	0	1	.832	1
63		6	max	4.942	13	-.087	1	0	1	0	1	0	1	5.244	9
64			min	.137	1	-.961	11	0	1	0	1	0	1	.856	1
65		7	max	4.942	13	.34	13	0	1	0	1	0	1	5.271	9
66			min	.137	1	-.639	11	0	1	0	1	0	1	.858	1
67		8	max	4.942	13	.646	13	0	1	0	1	0	1	5.362	11
68			min	.137	1	-.425	11	0	1	0	1	0	1	.856	1
69		9	max	4.942	13	1.213	13	0	1	0	1	0	1	5.32	11
70			min	.137	1	.16	1	0	1	0	1	0	1	.832	1
71		10	max	4.942	13	2.298	13	0	1	0	1	0	1	4.676	11
72			min	.137	1	.318	1	0	1	0	1	0	1	.731	1
73		11	max	4.942	13	4.06	13	0	1	0	1	0	1	2.934	11
74			min	.137	1	.591	1	0	1	0	1	0	1	.127	13
75		12	max	4.942	13	6.507	13	0	1	0	1	0	1	-.094	1
76			min	.137	1	.994	1	0	1	0	1	0	1	-3.487	13
77		13	max	4.942	13	6.379	13	0	1	0	1	0	1	-1.076	1
78			min	.137	1	.867	1	0	1	0	1	0	1	-9.947	13
79	M4	1	max	1.95	7	8.723	9	0	1	0	1	0	1	0	1
80			min	-.137	1	.765	1	0	1	0	1	0	1	0	1
81		2	max	1.95	7	7.273	9	0	1	0	1	0	1	-.74	1
82			min	-.137	1	.638	1	0	1	0	1	0	1	-8.416	9
83		3	max	1.95	7	5.888	9	0	1	0	1	0	1	-1.346	1
84			min	-.137	1	.51	1	0	1	0	1	0	1	-15.301	9
85		4	max	1.95	7	4.499	9	0	1	0	1	0	1	-1.818	1
86			min	-.137	1	.383	1	0	1	0	1	0	1	-20.658	9
87		5	max	1.95	7	3.176	9	0	1	0	1	0	1	-2.154	1
88			min	-.137	1	.255	1	0	1	0	1	0	1	-24.48	9
89		6	max	1.95	7	1.883	9	0	1	0	1	0	1	-2.356	1
90			min	-.137	1	.128	1	0	1	0	1	0	1	-26.774	9
91		7	max	1.95	7	.554	9	0	1	0	1	0	1	-2.423	1
92			min	-.137	1	-.554	9	0	1	0	1	0	1	-27.534	9
93		8	max	1.95	7	-.128	1	0	1	0	1	0	1	-2.356	1
94			min	-.137	1	-1.883	9	0	1	0	1	0	1	-26.774	9
95		9	max	1.95	7	-.255	1	0	1	0	1	0	1	-2.154	1
96			min	-.137	1	-3.176	9	0	1	0	1	0	1	-24.48	9

M_s

M_s

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
97		10	max	1.95	7	-.383	1	0	1	0	1	0	1	-1.818	1
98			min	-.137	1	-4.499	9	0	1	0	1	0	1	-20.658	9
99		11	max	1.95	7	-.51	1	0	1	0	1	0	1	-1.346	1
100			min	-.137	1	-5.888	9	0	1	0	1	0	1	-15.301	9
101		12	max	1.95	7	-.638	1	0	1	0	1	0	1	-.74	1
102			min	-.137	1	-7.273	9	0	1	0	1	0	1	-8.416	9
103		13	max	1.95	7	-.765	1	0	1	0	1	0	1	0	1
104			min	-.137	1	-8.723	9	0	1	0	1	0	1	0	1

Envelope Joint Reactions

	Joint		X [k]	LC	Y [k]	LC	Z [k]	LC	MX [k-ft]	LC	MY [k-ft]	LC	MZ [k-ft]	LC
1	N1	max	0	12	3.38	9	0	1	0	1	0	1	0	1
2		min	-1.222	10	.656	1	0	1	0	1	0	1	0	1
3	N4	max	0	1	3.47	11	0	1	0	1	0	1	0	1
4		min	0	1	.656	1	0	1	0	1	0	1	0	1
5	N5	max	0	1	2.678	9	0	1	0	1	0	1	0	1
6		min	0	1	.531	1	0	1	0	1	0	1	0	1
7	N6	max	0	1	1.909	13	0	1	0	1	0	1	0	1
8		min	0	1	.4	1	0	1	0	1	0	1	0	1
9	N7	max	0	1	1.317	11	0	1	0	1	0	1	0	1
10		min	0	1	.286	1	0	1	0	1	0	1	0	1
11	N8	max	0	1	.824	11	0	1	0	1	0	1	0	1
12		min	0	1	.201	1	0	1	0	1	0	1	0	1
13	N9	max	0	1	.489	11	0	1	0	1	0	1	0	1
14		min	0	1	.149	1	0	1	0	1	0	1	0	1
15	N10	max	0	1	.362	13	0	1	0	1	0	1	0	1
16		min	0	1	.131	1	0	1	0	1	0	1	0	1
17	N11	max	0	1	.473	13	0	1	0	1	0	1	0	1
18		min	0	1	.149	1	0	1	0	1	0	1	0	1
19	N12	max	0	1	.784	13	0	1	0	1	0	1	0	1
20		min	0	1	.201	1	0	1	0	1	0	1	0	1
21	N13	max	0	1	1.279	13	0	1	0	1	0	1	0	1
22		min	0	1	.286	1	0	1	0	1	0	1	0	1
23	N14	max	0	1	1.911	11	0	1	0	1	0	1	0	1
24		min	0	1	.4	1	0	1	0	1	0	1	0	1
25	N15	max	0	1	2.714	11	0	1	0	1	0	1	0	1
26		min	0	1	.531	1	0	1	0	1	0	1	0	1
27	Totals:	max	0	12	20.188	9	0	1						
28		min	-1.222	10	4.576	1	0	1						

Member Section Forces

	LC	Member Label	Sec	Axial[k]	y Shear[k]	z Shear[k]	Torque[k-ft]	y-y Mo...	z-z Mo...
1	7	M1	1	6.351	1.95	0	0	0	0
2			2	6.414	1.545	0	0	0	-1.142
3			3	6.477	1.112	0	0	0	-2.011
4			4	6.541	.652	0	0	0	-2.588
5			5	6.604 N_s	.165	0	0	0	-2.856
6			6	6.667	-.351	0	0	0	-2.797
7			7	6.73	-.894	0	0	0	-2.392
8			8	6.793	-1.464	0	0	0	-1.624
9			9	6.856	-2.063	0	0	0	-.474
10			10	6.919	-2.689	0	0	0	1.075
11			11	6.982	-3.342	0	0	0	3.042
12			12	7.045	-4.023	0	0	0	5.444
13			13	7.108	-4.732	0	0	0	8.301
14	7	M2	1	6.351	-1.95	0	0	0	0
15			2	6.414	-1.545	0	0	0	1.142
16			3	6.477	-1.112	0	0	0	2.011
17			4	6.541	-.652	0	0	0	2.588
18			5	6.604	-.165	0	0	0	2.856
19			6	6.667	.351	0	0	0	2.797
20			7	6.73	.894	0	0	0	2.392
21			8	6.793	1.464	0	0	0	1.624
22			9	6.856	2.063	0	0	0	.474
23			10	6.919	2.689	0	0	0	-1.075
24			11	6.982	3.342	0	0	0	-3.042
25			12	7.045	4.023	0	0	0	-5.444
26			13	7.108	4.732	0	0	0	-8.301
27	7	M3	1	4.732	-4.891	0	0	0	-8.301
28			2	4.732	-5.018	0	0	0	-3.071
29			3	4.732	-3.24	0	0	0	.282
30			4	4.732	-1.908	0	0	0	2.228
31			5	4.732	-1.019	0	0	0	3.236
32			6	4.732	-.485	0	0	0	3.682
33			7	4.732	-.179	0	0	0	3.803
34			8	4.732	.485	0	0	0	3.682
35			9	4.732	1.019	0	0	0	3.236
36			10	4.732	1.908	0	0	0	2.228
37			11	4.732	3.24	0	0	0	.282
38			12	4.732	5.018	0	0	0	-3.071
39			13	4.732	4.891	0	0	0	-8.301
40	7	M4	1	1.95	6.351	0	0	0	0
41			2	1.95	5.293	0	0	0	-6.145
42			3	1.95	4.234	0	0	0	-11.174
43			4	1.95	3.176	0	0	0	-15.084
44			5	1.95	2.117	0	0	0	-17.878
45			6	1.95	1.059	0	0	0	-19.554
46			7	1.95	0	0	0	0	-20.112
47			8	1.95	-1.059	0	0	0	-19.554
48			9	1.95	-2.117	0	0	0	-17.878
49			10	1.95	-3.176	0	0	0	-15.084
50			11	1.95	-4.234	0	0	0	-11.174
51			12	1.95	-5.293	0	0	0	-6.145
52			13	1.95	-6.351	0	0	0	0

Envelope Member Section Forces

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
1	M1	1	max	8.723	9	.367	9	0	9	0	9	0	9	0	9
2			min	6.351	9	.161	9	0	9	0	9	0	9	0	9
3		2	max	8.786	9	.216	9	0	9	0	9	0	9	-.057	9
4			min	6.414	9	.01	9	0	9	0	9	0	9	-.191	9
5		3	max	8.849	9	.051	9	0	9	0	9	0	9	-.01	9
6			min	6.477	9	-.155	9	0	9	0	9	0	9	-.279	9
7		4	max	8.912	9	-.129	9	0	9	0	9	0	9	.149	9
8			min	6.541	9	-.335	9	0	9	0	9	0	9	-.254	9
9		5	max	8.975	9	-.322	9	0	9	0	9	0	9	.43	9
10			min	6.604	9	-.528	9	0	9	0	9	0	9	-.108	9
11		6	max	9.038	9	-.528	9	0	9	0	9	0	9	.841	9
12			min	6.667	9	-.734	9	0	9	0	9	0	9	.169	9
13		7	max	9.101	9	-.749	9	0	9	0	9	0	9	1.392	9
14			min	6.73	9	-.955	9	0	9	0	9	0	9	.585	9
15		8	max	9.164	9	-.983	9	0	9	0	9	0	9	2.091	9
16			min	6.793	9	-1.189	9	0	9	0	9	0	9	1.15	9
17		9	max	9.227	9	-1.232	9	0	9	0	9	0	9	2.947	9
18			min	6.856	9	-1.438	9	0	9	0	9	0	9	1.872	9
19		10	max	9.291	9	-1.494	9	0	9	0	9	0	9	3.971	9
20			min	6.919	9	-1.7	9	0	9	0	9	0	9	2.76	9
21		11	max	9.354	9	-1.769	9	0	9	0	9	0	9	5.169	9
22			min	6.982	9	-1.975	9	0	9	0	9	0	9	3.825	9
23		12	max	9.417	9	-2.059	9	0	9	0	9	0	9	6.553	9
24			min	7.045	9	-2.265	9	0	9	0	9	0	9	5.074	9
25		13	max	9.48	9	-2.363	9	0	9	0	9	0	9	8.13	9
26			min	7.108	9	-2.569	9	0	9	0	9	0	9	6.516	9
27	M2	1	max	8.723	9	-.161	9	0	9	0	9	0	9	0	9
28			min	6.351	9	-.367	9	0	9	0	9	0	9	0	9
29		2	max	8.786	9	-.01	9	0	9	0	9	0	9	.191	9
30			min	6.414	9	-.216	9	0	9	0	9	0	9	.057	9
31		3	max	8.849	9	.155	9	0	9	0	9	0	9	.279	9
32			min	6.477	9	-.051	9	0	9	0	9	0	9	.01	9
33		4	max	8.912	9	.335	9	0	9	0	9	0	9	.254	9
34			min	6.541	9	.129	9	0	9	0	9	0	9	-.149	9
35		5	max	8.975	9	.528	9	0	9	0	9	0	9	.108	9
36			min	6.604	9	.322	9	0	9	0	9	0	9	-.43	9
37		6	max	9.038	9	.734	9	0	9	0	9	0	9	-.169	9
38			min	6.667	9	.528	9	0	9	0	9	0	9	-.841	9
39		7	max	9.101	9	.955	9	0	9	0	9	0	9	-.585	9
40			min	6.73	9	.749	9	0	9	0	9	0	9	-1.392	9
41		8	max	9.164	9	1.189	9	0	9	0	9	0	9	-1.15	9
42			min	6.793	9	.983	9	0	9	0	9	0	9	-2.091	9
43		9	max	9.227	9	1.438	9	0	9	0	9	0	9	-1.872	9
44			min	6.856	9	1.232	9	0	9	0	9	0	9	-2.947	9
45		10	max	9.291	9	1.7	9	0	9	0	9	0	9	-2.76	9
46			min	6.919	9	1.494	9	0	9	0	9	0	9	-3.971	9
47		11	max	9.354	9	1.975	9	0	9	0	9	0	9	-3.825	9
48			min	6.982	9	1.769	9	0	9	0	9	0	9	-5.169	9
49		12	max	9.417	9	2.265	9	0	9	0	9	0	9	-5.074	9
50			min	7.045	9	2.059	9	0	9	0	9	0	9	-6.553	9
51		13	max	9.48	9	2.569	9	0	9	0	9	0	9	-6.516	9
52			min	7.108	9	2.363	9	0	9	0	9	0	9	-8.13	9
53	M3	1	max	2.569	9	-4.622	9	0	9	0	9	0	9	-6.516	9
54			min	2.363	9	-6.105	9	0	9	0	9	0	9	-8.13	9
55		2	max	2.569	9	-4.75	9	0	9	0	9	0	9	-1.284	9
56			min	2.363	9	-6.233	9	0	9	0	9	0	9	-1.959	9

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
57		3	max	2.569	9	-2.873	9	0	9	0	9	0	9	2.313	9
58			min	2.363	9	-3.685	9	0	9	0	9	0	9	1.26	9
59		4	max	2.569	9	-1.549	9	0	9	0	9	0	9	4.2	9
60			min	2.363	9	-1.932	9	0	9	0	9	0	9	2.937	9
61		5	max	2.569	9	-.689	9	0	9	0	9	0	9	5.005	9
62			min	2.363	9	-.922	9	0	9	0	9	0	9	3.677	9
63		6	max	2.569	9	-.175	9	0	9	0	9	0	9	5.244	9
64			min	2.363	9	-.462	9	0	9	0	9	0	9	3.939	9
65		7	max	2.569	9	.277	9	0	9	0	9	0	9	5.271	9
66			min	2.363	9	-.277	9	0	9	0	9	0	9	4.007	9
67		8	max	2.569	9	.462	9	0	9	0	9	0	9	5.244	9
68			min	2.363	9	.175	9	0	9	0	9	0	9	3.939	9
69		9	max	2.569	9	.922	9	0	9	0	9	0	9	5.005	9
70			min	2.363	9	.689	9	0	9	0	9	0	9	3.677	9
71		10	max	2.569	9	1.932	9	0	9	0	9	0	9	4.2	9
72			min	2.363	9	1.549	9	0	9	0	9	0	9	2.937	9
73		11	max	2.569	9	3.685	9	0	9	0	9	0	9	2.313	9
74			min	2.363	9	2.873	9	0	9	0	9	0	9	1.26	9
75		12	max	2.569	9	6.233	9	0	9	0	9	0	9	-1.284	9
76			min	2.363	9	4.75	9	0	9	0	9	0	9	-1.959	9
77		13	max	2.569	9	6.105	9	0	9	0	9	0	9	-6.516	9
78			min	2.363	9	4.622	9	0	9	0	9	0	9	-8.13	9
79	M4	1	max	.367	9	8.723	9	0	9	0	9	0	9	0	9
80			min	.161	9	6.351	9	0	9	0	9	0	9	0	9
81		2	max	.367	9	7.273	9	0	9	0	9	0	9	-6.145	9
82			min	.161	9	5.274	9	0	9	0	9	0	9	-8.416	9
83		3	max	.367	9	5.888	9	0	9	0	9	0	9	-11.174	9
84			min	.161	9	4.168	9	0	9	0	9	0	9	-15.301	9
85		4	max	.367	9	4.499	9	0	9	0	9	0	9	-15.084	9
86			min	.161	9	3.033	9	0	9	0	9	0	9	-20.658	9
87		5	max	.367	9	3.176	9	0	9	0	9	0	9	-17.878	9
88			min	.161	9	1.868	9	0	9	0	9	0	9	-24.48	9
89		6	max	.367	9	1.883	9	0	9	0	9	0	9	-19.554	9
90			min	.161	9	.674	9	0	9	0	9	0	9	-26.774	9
91		7	max	.367	9	.554	9	0	9	0	9	0	9	-20.112	9
92			min	.161	9	-.554	9	0	9	0	9	0	9	-27.534	9
93		8	max	.367	9	-.674	9	0	9	0	9	0	9	-19.554	9
94			min	.161	9	-1.883	9	0	9	0	9	0	9	-26.774	9
95		9	max	.367	9	-1.868	9	0	9	0	9	0	9	-17.878	9
96			min	.161	9	-3.176	9	0	9	0	9	0	9	-24.48	9
97		10	max	.367	9	-3.033	9	0	9	0	9	0	9	-15.084	9
98			min	.161	9	-4.499	9	0	9	0	9	0	9	-20.658	9
99		11	max	.367	9	-4.168	9	0	9	0	9	0	9	-11.174	9
100			min	.161	9	-5.888	9	0	9	0	9	0	9	-15.301	9
101		12	max	.367	9	-5.274	9	0	9	0	9	0	9	-6.145	9
102			min	.161	9	-7.273	9	0	9	0	9	0	9	-8.416	9
103		13	max	.367	9	-6.351	9	0	9	0	9	0	9	0	9
104			min	.161	9	-8.723	9	0	9	0	9	0	9	0	9

Member Section Forces

	LC	Member Label	Sec	Axial[k]	y Shear[k]	z Shear[k]	Torque[k-ft]	y-y Mo...	z-z Mo...
1	4	M1	1	6.351	.372	0	0	0	0
2			2	6.414	.22	0	0	0	-.194
3			3	6.477	.055	0	0	0	-.284
4			4	6.541	-.124	0	0	0	-.262
5			5	6.604	-.317	0	0	0	-.119
6			6	6.667	-.524	0	0	0	.155
7			7	6.73	-.745	0	0	0	.568
8			8	6.793	-.979	0	0	0	1.13
9			9	6.856	-1.227	0	0	0	1.85
10			10	6.919	-1.489	0	0	0	2.736
11			11	6.982	-1.765	0	0	0	3.797
12			12	7.045	-2.055	0	0	0	5.043
13			13	7.108	-2.358	0	0	0	6.483
14	4	M2	1	6.351	-.372	0	0	0	0
15			2	6.414	-.22	0	0	0	.194
16			3	6.477	-.055	0	0	0	.284
17			4	6.541	.124	0	0	0	.262
18			5	6.604	.317	0	0	0	.119
19			6	6.667	.524	0	0	0	-.155
20			7	6.73	.745	0	0	0	-.568
21			8	6.793	.979	0	0	0	-1.13
22			9	6.856	1.227	0	0	0	-1.85
23			10	6.919	1.489	0	0	0	-2.736
24			11	6.982	1.765	0	0	0	-3.797
25			12	7.045	2.055	0	0	0	-5.043
26			13	7.108	2.358	0	0	0	-6.483
27	4	M3	1	2.358	-4.617	0	0	0	-6.483
28			2	2.358	-4.744	0	0	0	-1.542
29			3	2.358	-2.865	0	0	0	1.414
30			4	2.358	-1.543	0	0	0	2.975
31			5	2.358	-.727	0	0	0	3.675
32			6	2.358	-.301	0	0	0	3.926
33			7	2.358	-.116	0	0	0	3.981
34			8	2.358	.301	0	0	0	3.926
35			9	2.358	.727	0	0	0	3.675
36			10	2.358	1.543	0	0	0	2.975
37			11	2.358	2.865	0	0	0	1.414
38			12	2.358	4.744	0	0	0	-1.542
39			13	2.358	4.617	0	0	0	-6.483
40	4	M4	1	.372	6.351	0	0	0	0
41			2	.372	5.293	0	0	0	-6.145
42			3	.372	4.234	0	0	0	-11.174
43			4	.372	3.176	0	0	0	-15.084
44			5	.372	2.117	0	0	0	-17.878
45			6	.372	1.059	0	0	0	-19.554
46			7	.372	0	0	0	0	-20.112
47			8	.372	-1.059	0	0	0	-19.554
48			9	.372	-2.117	0	0	0	-17.878
49			10	.372	-3.176	0	0	0	-15.084
50			11	.372	-4.234	0	0	0	-11.174
51			12	.372	-5.293	0	0	0	-6.145
52			13	.372	-6.351	0	0	0	0

M_{S_DL}

Load Combinations

	Description	Solve	PDelta	SRSS	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...
1	DL	Yes			1	1.25														
2	Backfill one leg	Yes			1	1.25	2	1.5												
3	Backfill two legs + Surcharge two ...	Yes			1	1.25	2	1.5	3	1.5	6	1.75	7	1.75						
4	Backfill to FG (Deck Moment)				1	1.25	2	.9	3	.9	4	.75	5	1.3						
5	Backfill to FG (Knee Moment)				1	1.25	2	1.5	3	1.5	4	1.5	5	1.3						
6	Backfill to FG + LS left leg only				1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.75				
7	Backfill to FG + LS both legs				1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.75	7	1.75		
8	LC#4 + Truck				1	1.25	2	.9	3	.9	4	.75	5	1.3	M1	1.8...				
9	LC#4 + Tandem				1	1.25	2	.9	3	.9	4	.75	5	1.3	M2	1.8...				
10	LC#6 + Truck				1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.75	M1	1.8...		
11	LC#6 + Tandem				1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.75	M2	1.8...		
12	LC#7 + Truck				1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.75	7	1.75	M1	1.8...
13	LC#7 + Tandem				1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.75	7	1.75	M2	1.8...
14	Strength II																			
15	Backfill to FG + LS left leg only				1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.35				
16	Backfill to FG + LS both legs				1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.35	7	1.35		
17	LC#4 + Truck				1	1.25	2	.9	3	.9	4	.75	5	1.3	M1	1.4...				
18	LC#4 + Tandem				1	1.25	2	.9	3	.9	4	.75	5	1.3	M2	1.4...				
19	LC#15 + Truck				1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.35	M1	1.4...		
20	LC#15 + Tandem				1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.35	M2	1.4...		
21	LC#16 + Truck				1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.35	7	1.35	M1	1.4...
22	LC#16 + Tandem				1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.35	7	1.35	M2	1.4...

Envelope Member Section Forces

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
1	M1	1	max	0	1	0	1	0	1	0	1	0	1	0	1
2			min	0	1	0	1	0	1	0	1	0	1	0	1
3		2	max	.079	3	0	1	0	1	0	1	0	1	.063	3
4			min	.079	1	-.199	3	0	1	0	1	0	1	0	1
5		3	max	.158	3	0	1	0	1	0	1	0	1	.269	3
6			min	.158	1	-.439	3	0	1	0	1	0	1	0	1
7		4	max	.237	3	0	1	0	1	0	1	0	1	.645	3
8			min	.237	1	-.721	3	0	1	0	1	0	1	0	1
9		5	max	.316	3	0	1	0	1	0	1	0	1	1.219	3
10			min	.316	1	-1.044	3	0	1	0	1	0	1	0	1
11		6	max	.394	3	0	1	0	1	0	1	0	1	2.018	3
12			min	.394	1	-1.409	3	0	1	0	1	0	1	0	1
13		7	max	.473	3	0	1	0	1	0	1	0	1	3.068	3
14			min	.473	1	-1.815	3	0	1	0	1	0	1	0	1
15		8	max	.552	3	0	1	0	1	0	1	0	1	4.397	3
16			min	.552	1	-2.263	3	0	1	0	1	0	1	0	1
17		9	max	.631	3	0	1	0	1	0	1	0	1	6.032	3
18			min	.631	1	-2.752	3	0	1	0	1	0	1	0	1
19		10	max	.71	3	0	1	0	1	0	1	0	1	7.999	3
20			min	.71	1	-3.283	3	0	1	0	1	0	1	0	1
21		11	max	.789	3	0	1	0	1	0	1	0	1	10.326	3
22			min	.789	1	-3.855	3	0	1	0	1	0	1	0	1
23		12	max	.868	3	0	1	0	1	0	1	0	1	13.04	3
24			min	.868	1	-4.468	3	0	1	0	1	0	1	0	1
25		13	max	.947	3	0	1	0	1	0	1	0	1	16.169	3
26			min	.947	1	-5.123	3	0	1	0	1	0	1	0	1
27	M2	1	max	0	1	0	1	0	1	0	1	0	1	0	1
28			min	0	1	0	1	0	1	0	1	0	1	0	1
29		2	max	.079	3	.199	3	0	1	0	1	0	1	0	1
30			min	.079	1	0	1	0	1	0	1	0	1	-.063	3

Mu

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
31		3	max	.158	3	.439	3	0	1	0	1	0	1	0	1
32			min	.158	1	0	1	0	1	0	1	0	1	-.269	3
33		4	max	.237	3	.721	3	0	1	0	1	0	1	0	1
34			min	.237	1	0	1	0	1	0	1	0	1	-.645	3
35		5	max	.316	3	1.044	3	0	1	0	1	0	1	0	1
36			min	.316	1	0	1	0	1	0	1	0	1	-1.219	3
37		6	max	.394	3	1.409	3	0	1	0	1	0	1	0	1
38			min	.394	1	0	1	0	1	0	1	0	1	-2.018	3
39		7	max	.473	3	1.815	3	0	1	0	1	0	1	0	1
40			min	.473	1	0	1	0	1	0	1	0	1	-3.068	3
41		8	max	.552	3	2.263	3	0	1	0	1	0	1	0	1
42			min	.552	1	0	1	0	1	0	1	0	1	-4.397	3
43		9	max	.631	3	2.752	3	0	1	0	1	0	1	0	1
44			min	.631	1	0	1	0	1	0	1	0	1	-6.032	3
45		10	max	.71	3	3.283	3	0	1	0	1	0	1	0	1
46			min	.71	1	0	1	0	1	0	1	0	1	-7.999	3
47		11	max	.789	3	3.855	3	0	1	0	1	0	1	0	1
48			min	.789	1	0	1	0	1	0	1	0	1	-10.326	3
49		12	max	.868	3	4.468	3	0	1	0	1	0	1	0	1
50			min	.868	1	0	1	0	1	0	1	0	1	-13.04	3
51		13	max	.947	3	5.123	3	0	1	0	1	0	1	0	1
52			min	.947	1	0	1	0	1	0	1	0	1	-16.169	3
53	M3	1	max	5.123	3	-.378	1	0	1	0	1	0	1	0	1
54			min	0	1	-.947	2	0	1	0	1	0	1	-16.169	3
55		2	max	5.123	3	-.537	1	0	1	0	1	0	1	.483	1
56			min	0	1	-1.106	2	0	1	0	1	0	1	-15.085	3
57		3	max	5.123	3	-.262	1	0	1	0	1	0	1	.676	1
58			min	0	1	-1.265	2	0	1	0	1	0	1	-13.834	3
59		4	max	5.123	3	.124	1	0	1	0	1	0	1	.701	1
60			min	0	1	-1.425	2	0	1	0	1	0	1	-12.414	3
61		5	max	5.123	3	.13	1	0	1	0	1	0	1	.654	1
62			min	0	1	-1.584	3	0	1	0	1	0	1	-10.826	3
63		6	max	5.123	3	.1	1	0	1	0	1	0	1	.601	1
64			min	0	1	-1.367	3	0	1	0	1	0	1	-9.467	3
65		7	max	5.123	3	-.059	1	0	1	0	1	0	1	.579	1
66			min	0	1	-.954	2	0	1	0	1	0	1	-8.948	3
67		8	max	5.123	3	1.367	3	0	1	0	1	0	1	.601	1
68			min	0	1	-.705	2	0	1	0	1	0	1	-9.467	3
69		9	max	5.123	3	1.584	3	0	1	0	1	0	1	.654	1
70			min	0	1	-.482	2	0	1	0	1	0	1	-10.826	3
71		10	max	5.123	3	1.425	3	0	1	0	1	0	1	.764	2
72			min	0	1	-.281	2	0	1	0	1	0	1	-12.414	3
73		11	max	5.123	3	1.265	3	0	1	0	1	0	1	.768	2
74			min	0	1	.262	1	0	1	0	1	0	1	-13.834	3
75		12	max	5.123	3	1.106	3	0	1	0	1	0	1	.534	2
76			min	0	1	.537	1	0	1	0	1	0	1	-15.085	3
77		13	max	5.123	3	.947	3	0	1	0	1	0	1	0	1
78			min	0	1	.378	1	0	1	0	1	0	1	-16.169	3

M_u

Envelope Joint Reactions

	Joint		X [k]	LC	Y [k]	LC	Z [k]	LC	MX [k-ft]	LC	MY [k-ft]	LC	MZ [k-ft]	LC
1	N1	max	0	3	.569	1	0	1	0	1	0	1	0	1
2		min	-2.985	2	0	2	0	1	0	1	0	1	0	1
3	N4	max	0	1	.569	1	0	1	0	1	0	1	0	1
4		min	0	1	0	3	0	1	0	1	0	1	0	1
5	N5	max	0	1	.434	1	0	1	0	1	0	1	0	1

Envelope Joint Reactions (Continued)

	Joint		X [k]	LC	Y [k]	LC	Z [k]	LC	MX [k-ft]	LC	MY [k-ft]	LC	MZ [k-ft]	LC
6		min	0	1	0	2	0	1	0	1	0	1	0	1
7	N6	max	0	1	.318	1	0	1	0	1	0	1	0	1
8		min	0	1	0	2	0	1	0	1	0	1	0	1
9	N7	max	0	1	.228	1	0	1	0	1	0	1	0	1
10		min	0	1	0	3	0	1	0	1	0	1	0	1
11	N8	max	0	1	.376	3	0	1	0	1	0	1	0	1
12		min	0	1	.166	1	0	1	0	1	0	1	0	1
13	N9	max	0	1	.956	3	0	1	0	1	0	1	0	1
14		min	0	1	.13	1	0	1	0	1	0	1	0	1
15	N10	max	0	1	1.142	3	0	1	0	1	0	1	0	1
16		min	0	1	.118	1	0	1	0	1	0	1	0	1
17	N11	max	0	1	.956	3	0	1	0	1	0	1	0	1
18		min	0	1	.13	1	0	1	0	1	0	1	0	1
19	N12	max	0	1	.376	3	0	1	0	1	0	1	0	1
20		min	0	1	.166	1	0	1	0	1	0	1	0	1
21	N13	max	0	1	.357	2	0	1	0	1	0	1	0	1
22		min	0	1	0	3	0	1	0	1	0	1	0	1
23	N14	max	0	1	.385	2	0	1	0	1	0	1	0	1
24		min	0	1	0	3	0	1	0	1	0	1	0	1
25	N15	max	0	1	.443	2	0	1	0	1	0	1	0	1
26		min	0	1	0	3	0	1	0	1	0	1	0	1
27	Totals:	max	0	3	3.806	1	0	1						
28		min	-2.985	2	3.806	3	0	1						

Member Section Forces

	LC	Member Label	Sec	Axial[k]	y Shear[k]	z Shear[k]	Torque[k-ft]	y-y Mo...	z-z Mo...
1	3	M1	1	0	0	0	0	0	0
2			2	.079	-.199	0	0	0	.063
3			3	.158	-.439	0	0	0	.269
4			4	.237	-.721	0	0	0	.645
5			5	.316	-1.044	0	0	0	1.219
6			6	.394	-1.409	0	0	0	2.018
7			7	.473	-1.815	0	0	0	3.068
8			8	.552	-2.263	0	0	0	4.397
9			9	.631	-2.752	0	0	0	6.032
10			10	.71	-3.283	0	0	0	7.999
11			11	.789 N_u	-3.855 V_u	0	0	0	10.326
12			12	.868	-4.468	0	0	0	13.04
13			13	.947	-5.123	0	0	0	16.169
14	3	M2	1	0	0	0	0	0	0
15			2	.079	.199	0	0	0	-.063
16			3	.158	.439	0	0	0	-.269
17			4	.237	.721	0	0	0	-.645
18			5	.316	1.044	0	0	0	-1.219
19			6	.394	1.409	0	0	0	-2.018
20			7	.473	1.815	0	0	0	-3.068
21			8	.552	2.263	0	0	0	-4.397
22			9	.631	2.752	0	0	0	-6.032
23			10	.71	3.283	0	0	0	-7.999
24			11	.789	3.855	0	0	0	-10.326
25			12	.868	4.468	0	0	0	-13.04
26			13	.947	5.123	0	0	0	-16.169
27	3	M3	1	5.123	-.947	0	0	0	-16.169
28			2	5.123 N_u	-1.106 V_u	0	0	0	-15.085
29			3	5.123	-1.265	0	0	0	-13.834
30			4	5.123	-1.425	0	0	0	-12.414
31			5	5.123	-1.584	0	0	0	-10.826
32			6	5.123	-1.367	0	0	0	-9.467
33			7	5.123	-.571	0	0	0	-8.948
34			8	5.123	1.367	0	0	0	-9.467
35			9	5.123	1.584	0	0	0	-10.826
36			10	5.123	1.425	0	0	0	-12.414
37			11	5.123	1.265	0	0	0	-13.834
38			12	5.123	1.106	0	0	0	-15.085
39			13	5.123	.947	0	0	0	-16.169

Load Combinations

	Description	Solve	PDelta	SRSS	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...
1	DL	Yes			1	1.25														
2	Backfill one leg				1	1.25	2	1.5												
3	Backfill two legs + Surcharge two ...				1	1.25	2	1.5	3	1.5	6	1.75	7	1.75						
4	Backfill to FG (Deck Moment)	Yes			1	1.25	2	.9	3	.9	4	.75	5	1.3						
5	Backfill to FG (Knee Moment)	Yes			1	1.25	2	1.5	3	1.5	4	1.5	5	1.3						
6	Backfill to FG + LS left leg only	Yes			1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.75				
7	Backfill to FG + LS both legs	Yes			1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.75	7	1.75		
8	LC#4 + Truck	Yes			1	1.25	2	.9	3	.9	4	.75	5	1.3	M1	1.8...				
9	LC#4 + Tandem	Yes			1	1.25	2	.9	3	.9	4	.75	5	1.3	M2	1.8...				
10	LC#6 + Truck	Yes			1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.75	M1	1.8...		
11	LC#6 + Tandem	Yes			1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.75	M2	1.8...		
12	LC#7 + Truck	Yes			1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.75	7	1.75	M1	1.8...
13	LC#7 + Tandem	Yes			1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.75	7	1.75	M2	1.8...
14	Strength II																			
15	Backfill to FG + LS left leg only	Yes			1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.35				
16	Backfill to FG + LS both legs	Yes			1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.35	7	1.35		
17	LC#4 + Truck	Yes			1	1.25	2	.9	3	.9	4	.75	5	1.3	M1	1.4...				
18	LC#4 + Tandem	Yes			1	1.25	2	.9	3	.9	4	.75	5	1.3	M2	1.4...				
19	LC#15 + Truck	Yes			1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.35	M1	1.4...		
20	LC#15 + Tandem	Yes			1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.35	M2	1.4...		
21	LC#16 + Truck	Yes			1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.35	7	1.35	M1	1.4...
22	LC#16 + Tandem	Yes			1	1.25	2	1.5	3	1.5	4	1.5	5	1.3	6	1.35	7	1.35	M2	1.4...

Envelope Member Section Forces

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
1	M1	1	max	12.365	11	3.2	7	0	1	0	1	0	1	0	1
2			min	.957	1	-.172	1	0	1	0	1	0	1	0	1
3		2	max	12.444	11	2.567	7	0	1	0	1	0	1	.112	1
4			min	1.035	1	-.172	1	0	1	0	1	0	1	-1.884	7
5		3	max	12.523	11	1.893	7	0	1	0	1	0	1	.224	1
6			min	1.114	1	-.172	1	0	1	0	1	0	1	-3.342	7
7		4	max	12.602	11	1.177	7	0	1	0	1	0	1	.336	1
8			min	1.193	1	-.352	9	0	1	0	1	0	1	-4.347	7
9		5	max	12.681	11	.42	7	0	1	0	1	0	1	.448	1
10			min	1.272	1	-.656	9	0	1	0	1	0	1	-4.87	7
11		6	max	12.76	11	-.172	1	0	1	0	1	0	1	.767	9
12			min	1.351	1	-1.219	11	0	1	0	1	0	1	-4.886	7 Mu
13		7	max	12.839	11	-.172	1	0	1	0	1	0	1	1.523	9
14			min	1.43	1	-2.059	11	0	1	0	1	0	1	-4.367	7
15		8	max	12.918	11	-.172	1	0	1	0	1	0	1	2.519	9
16			min	1.509	1	-2.941	11	0	1	0	1	0	1	-3.286	7
17		9	max	12.997	11	-.172	1	0	1	0	1	0	1	3.77	9
18			min	1.588	1	-3.863	11	0	1	0	1	0	1	-1.617	7
19		10	max	13.075	11	-.172	1	0	1	0	1	0	1	5.609	11
20			min	1.666	1	-4.828	11	0	1	0	1	0	1	.669	7
21		11	max	13.154	11	-.172	1	Vu 0	1	0	1	0	1	9.086	11
22			min	1.745	1	-5.834	11	0	1	0	1	0	1	1.121	1
23		12	max	13.233	11	-.172	1	0	1	0	1	0	1	13.234	11
24			min	1.824	1	-6.881	11	0	1	0	1	0	1	1.233	1
25		13	max	13.312	11	-.172	1	0	1	0	1	0	1	18.078	11
26			min	1.903	1	-7.969	11	0	1	0	1	0	1	1.345	1
27	M2	1	max	12.365	9	.172	1	0	1	0	1	0	1	0	1
28			min	.957	1	-3.2	7	0	1	0	1	0	1	0	1
29		2	max	12.444	9	.172	1	0	1	0	1	0	1	1.884	7
30			min	1.035	1	-2.567	7	0	1	0	1	0	1	-.112	1

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
31		3	max	12.523	9	.172	1	0	1	0	1	0	1	3.342	7
32			min	1.114	1	-1.893	7	0	1	0	1	0	1	-.224	1
33		4	max	12.602	9	.352	9	0	1	0	1	0	1	4.347	7
34			min	1.193	1	-1.239	6	0	1	0	1	0	1	-.336	1
35		5	max	12.681	9	.656	9	0	1	0	1	0	1	4.87	7
36			min	1.272	1	-.66	6	0	1	0	1	0	1	-.448	1
37		6	max	12.76	9	.984	9	0	1	0	1	0	1	4.886	7
38			min	1.351	1	-.039	6	0	1	0	1	0	1	-.767	9
39		7	max	12.839	9	1.586	13	0	1	0	1	0	1	4.608	6
40			min	1.43	1	.172	1	0	1	0	1	0	1	-1.523	9
41		8	max	12.918	9	2.467	13	0	1	0	1	0	1	3.974	6
42			min	1.509	1	.172	1	0	1	0	1	0	1	-2.519	9
43		9	max	12.997	9	3.39	13	0	1	0	1	0	1	2.868	6
44			min	1.588	1	.172	1	0	1	0	1	0	1	-3.77	9
45		10	max	13.075	9	4.355	13	0	1	0	1	0	1	1.262	6
46			min	1.666	1	.172	1	0	1	0	1	0	1	-5.292	9
47		11	max	13.154	9	5.36	13	0	1	0	1	0	1	-.87	6
48			min	1.745	1	.172	1	0	1	0	1	0	1	-7.102	9
49		12	max	13.233	9	6.407	13	0	1	0	1	0	1	-1.233	1
50			min	1.824	1	.172	1	0	1	0	1	0	1	-9.835	13
51		13	max	13.312	9	7.496	13	0	1	0	1	0	1	-1.345	1
52			min	1.903	1	.172	1	0	1	0	1	0	1	-14.371	13
53	M3	1	max	7.496	13	-1.083	1	0	1	0	1	0	1	-1.345	1
54			min	.172	1	-9.525	11	0	1	0	1	0	1	-18.078	11
55		2	max	7.496	13	-1.243	1	0	1	0	1	0	1	-.117	1
56			min	.172	1	-9.684	11	0	1	0	1	0	1	-8.537	11
57		3	max	7.496	13	-.738	1	0	1	0	1	0	1	3.14	9
58			min	.172	1	-6.451	11	0	1	0	1	0	1	-2.867	11
59		4	max	7.496	13	-.398	1	0	1	0	1	0	1	5.811	9
60			min	.172	1	-3.986	11	0	1	0	1	0	1	.74	11
61		5	max	7.496	13	-.2	1	0	1	0	1	0	1	6.966	9
62			min	.172	1	-2.399	11	0	1	0	1	0	1	1.04	1
63		6	max	7.496	13	.276	9	0	1	0	1	0	1	7.312	9
64			min	.172	1	-1.536	11	0	1	0	1	0	1	1.071	1
65		7	max	7.496	13	.537	13	0	1	0	1	0	1	7.35	9
66			min	.172	1	-1.06	11	0	1	0	1	0	1	1.073	1
67		8	max	7.496	13	.985	13	0	1	0	1	0	1	7.581	11
68			min	.172	1	-.738	11	0	1	0	1	0	1	1.071	1
69		9	max	7.496	13	1.777	13	0	1	0	1	0	1	7.628	11
70			min	.172	1	.2	1	0	1	0	1	0	1	1.04	1
71		10	max	7.496	13	3.298	13	0	1	0	1	0	1	6.832	11
72			min	.172	1	.398	1	0	1	0	1	0	1	.914	1
73		11	max	7.496	13	5.772	13	0	1	0	1	0	1	4.514	11
74			min	.172	1	.738	1	0	1	0	1	0	1	-.397	13
75		12	max	7.496	13	9.191	13	0	1	0	1	0	1	-.117	1
76			min	.172	1	1.243	1	0	1	0	1	0	1	-5.35	13
77		13	max	7.496	13	9.032	13	0	1	0	1	0	1	-1.345	1
78			min	.172	1	1.083	1	0	1	0	1	0	1	-14.371	13
79	M4	1	max	3.2	7	12.365	9	0	1	0	1	0	1	0	1
80			min	-.172	1	.957	1	0	1	0	1	0	1	0	1
81		2	max	3.2	7	10.312	9	0	1	0	1	0	1	-.926	1
82			min	-.172	1	.797	1	0	1	0	1	0	1	-11.922	9
83		3	max	3.2	7	8.371	9	0	1	0	1	0	1	-1.683	1
84			min	-.172	1	.638	1	0	1	0	1	0	1	-21.676	9
85		4	max	3.2	7	6.423	9	0	1	0	1	0	1	-2.272	1
86			min	-.172	1	.478	1	0	1	0	1	0	1	-29.266	9
87		5	max	3.2	7	4.591	9	0	1	0	1	0	1	-2.693	1

V_u V_u M_u

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
88			min	-.172	1	.319	1	0	1	0	1	0	1	-34.679	9
89		6	max	3.2	7	2.811	9	0	1	0	1	0	1	-2.945	1
90			min	-.172	1	.159	1	0	1	0	1	0	1	-37.929	9
91		7	max	3.2	7	.969	9	0	1	0	1	0	1	-3.029	1
92			min	-.172	1	-.969	9	0	1	0	1	0	1	-39.005	9 M_u
93		8	max	3.2	7	-.159	1	0	1	0	1	0	1	-2.945	1
94			min	-.172	1	-2.811	9	0	1	0	1	0	1	-37.929	9
95		9	max	3.2	7	-.319	1	0	1	0	1	0	1	-2.693	1
96			min	-.172	1	-4.591	9	0	1	0	1	0	1	-34.679	9
97		10	max	3.2	7	-.478	1	0	1	0	1	0	1	-2.272	1
98			min	-.172	1	-6.423	9	0	1	0	1	0	1	-29.266	9
99		11	max	3.2	7	-.638	1	0	1	0	1	0	1	-1.683	1
100			min	-.172	1	-8.371	9	0	1	0	1	0	1	-21.676	9
101		12	max	3.2	7	-.797	1	0	1	0	1	0	1	-.926	1
102			min	-.172	1	-10.312	9	0	1	0	1	0	1	-11.922	9
103		13	max	3.2	7	-.957	1	0	1	0	1	0	1	0	1
104			min	-.172	1	-12.365	9	0	1	0	1	0	1	0	1

Envelope Joint Reactions

	Joint		X [k]	LC	Y [k]	LC	Z [k]	LC	MX [k-ft]	LC	MY [k-ft]	LC	MZ [k-ft]	LC
1	N1	max	0	12	4.699	9	0	1	0	1	0	1	0	1
2		min	-2.138	10	.82	1	0	1	0	1	0	1	0	1
3	N4	max	0	1	4.927	11	0	1	0	1	0	1	0	1
4		min	0	1	.82	1	0	1	0	1	0	1	0	1
5	N5	max	0	1	3.733	9	0	1	0	1	0	1	0	1
6		min	0	1	.664	1	0	1	0	1	0	1	0	1
7	N6	max	0	1	2.668	13	0	1	0	1	0	1	0	1
8		min	0	1	.5	1	0	1	0	1	0	1	0	1
9	N7	max	0	1	1.863	11	0	1	0	1	0	1	0	1
10		min	0	1	.357	1	0	1	0	1	0	1	0	1
11	N8	max	0	1	1.179	11	0	1	0	1	0	1	0	1
12		min	0	1	.251	1	0	1	0	1	0	1	0	1
13	N9	max	0	1	.704	11	0	1	0	1	0	1	0	1
14		min	0	1	.186	1	0	1	0	1	0	1	0	1
15	N10	max	0	1	.519	13	0	1	0	1	0	1	0	1
16		min	0	1	.164	1	0	1	0	1	0	1	0	1
17	N11	max	0	1	.675	13	0	1	0	1	0	1	0	1
18		min	0	1	.186	1	0	1	0	1	0	1	0	1
19	N12	max	0	1	1.108	13	0	1	0	1	0	1	0	1
20		min	0	1	.251	1	0	1	0	1	0	1	0	1
21	N13	max	0	1	1.796	13	0	1	0	1	0	1	0	1
22		min	0	1	.357	1	0	1	0	1	0	1	0	1
23	N14	max	0	1	2.672	11	0	1	0	1	0	1	0	1
24		min	0	1	.5	1	0	1	0	1	0	1	0	1
25	N15	max	0	1	3.822	11	0	1	0	1	0	1	0	1
26		min	0	1	.664	1	0	1	0	1	0	1	0	1
27	Totals:	max	0	12	28.008	9	0	1						
28		min	-2.138	10	5.719	1	0	1						

Member Section Forces

	LC	Member Label	Sec	Axial[k]	y Shear[k]	z Shear[k]	Torque[k-ft]	y-y Mo...	z-z Mo...
1	7	M1	1	8.218	3.2	0	0	0	0
2			2	8.297	2.567	0	0	0	-1.884
3			3	8.376	1.893	0	0	0	-3.342
4			4	8.455	1.177	0	0	0	-4.347
5			5	8.534	.42	0	0	0	-4.87
6			6	8.613 N_u	-.378 V_u	0	0	0	-4.886
7			7	8.692	-1.218	0	0	0	-4.367
8			8	8.771	-2.1	0	0	0	-3.286
9			9	8.849	-3.023	0	0	0	-1.617
10			10	8.928	-3.987	0	0	0	.669
11			11	9.007	-4.993	0	0	0	3.597
12			12	9.086	-6.04	0	0	0	7.196
13			13	9.165	-7.129	0	0	0	11.492
14	7	M2	1	8.218	-3.2	0	0	0	0
15			2	8.297	-2.567	0	0	0	1.884
16			3	8.376	-1.893	0	0	0	3.342
17			4	8.455	-1.177	0	0	0	4.347
18			5	8.534	-.42	0	0	0	4.87
19			6	8.613	.378	0	0	0	4.886
20			7	8.692	1.218	0	0	0	4.367
21			8	8.771	2.1	0	0	0	3.286
22			9	8.849	3.023	0	0	0	1.617
23			10	8.928	3.987	0	0	0	-.669
24			11	9.007	4.993	0	0	0	-3.597
25			12	9.086	6.04	0	0	0	-7.196
26			13	9.165	7.129	0	0	0	-11.492
27	7	M3	1	7.129	-6.429	0	0	0	-11.492
28			2	7.129	-6.588	0	0	0	-4.622
29			3	7.129	-4.338	0	0	0	-.127
30			4	7.129	-2.616	0	0	0	2.55
31			5	7.129	-1.437	0	0	0	3.984
32			6	7.129	-.703	0	0	0	4.642
33			7	7.129	-.255	0	0	0	4.827
34			8	7.129	.703	0	0	0	4.642
35			9	7.129	1.437	0	0	0	3.984
36			10	7.129	2.616	0	0	0	2.55
37			11	7.129	4.338	0	0	0	-.127
38			12	7.129	6.588	0	0	0	-4.622
39			13	7.129	6.429	0	0	0	-11.492
40	7	M4	1	3.2	8.218	0	0	0	0
41			2	3.2	6.849	0	0	0	-7.952
42			3	3.2	5.479	0	0	0	-14.458
43			4	3.2	4.109	0	0	0	-19.519
44			5	3.2	2.739	0	0	0	-23.133
45			6	3.2	1.37	0	0	0	-25.302
46			7	3.2	0	0	0	0	-26.025
47			8	3.2	-1.37	0	0	0	-25.302
48			9	3.2	-2.739	0	0	0	-23.133
49			10	3.2	-4.109	0	0	0	-19.519
50			11	3.2	-5.479	0	0	0	-14.458
51			12	3.2	-6.849	0	0	0	-7.952
52			13	3.2	-8.218	0	0	0	0

Envelope Member Section Forces

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
1	M1	1	max	12.365	9	.771	9	0	9	0	9	0	9	0	9
2			min	8.218	9	.411	9	0	9	0	9	0	9	0	9
3		2	max	12.444	9	.542	9	0	9	0	9	0	9	-.195	9
4			min	8.297	9	.182	9	0	9	0	9	0	9	-.43	9
5		3	max	12.523	9	.288	9	0	9	0	9	0	9	-.232	9
6			min	8.376	9	-.073	9	0	9	0	9	0	9	-.702	9
7		4	max	12.602	9	.009	9	0	9	0	9	0	9	-.095	9
8			min	8.455	9	-.352	9	0	9	0	9	0	9	-.8	9
9		5	max	12.681	9	-.295	9	0	9	0	9	0	9	.233	9
10			min	8.534	9	-.656	9	0	9	0	9	0	9	-.708	9
11		6	max	12.76	9	-.624	9	0	9	0	9	0	9	.767	9
12			min	8.613	9	-.984	9	0	9	0	9	0	9	-.409	9
13		7	max	12.839	9	-.978	9	0	9	0	9	0	9	1.523	9
14			min	8.692	9	-1.338	9	0	9	0	9	0	9	.112	9
15		8	max	12.918	9	-1.356	9	0	9	0	9	0	9	2.519	9
16			min	8.771	9	-1.717	9	0	9	0	9	0	9	.873	9
17		9	max	12.997	9	-1.76	9	0	9	0	9	0	9	3.77	9
18			min	8.849	9	-2.12	9	0	9	0	9	0	9	1.889	9
19		10	max	13.075	9	-2.188	9	0	9	0	9	0	9	5.292	9
20			min	8.928	9	-2.548	9	0	9	0	9	0	9	3.176	9
21		11	max	13.154	9	-2.641	9	0	9	0	9	0	9	7.102	9
22			min	9.007	9	-3.001	9	0	9	0	9	0	9	4.751	9
23		12	max	13.233	9	-3.119	9	0	9	0	9	0	9	9.216	9
24			min	9.086	9	-3.48	9	0	9	0	9	0	9	6.63	9
25		13	max	13.312	9	-3.622	9	0	9	0	9	0	9	11.65	9
26			min	9.165	9	-3.982	9	0	9	0	9	0	9	8.829	9
27	M2	1	max	12.365	9	-.411	9	0	9	0	9	0	9	0	9
28			min	8.218	9	-.771	9	0	9	0	9	0	9	0	9
29		2	max	12.444	9	-.182	9	0	9	0	9	0	9	.43	9
30			min	8.297	9	-.542	9	0	9	0	9	0	9	.195	9
31		3	max	12.523	9	.073	9	0	9	0	9	0	9	.702	9
32			min	8.376	9	-.288	9	0	9	0	9	0	9	.232	9
33		4	max	12.602	9	.352	9	0	9	0	9	0	9	.8	9
34			min	8.455	9	-.009	9	0	9	0	9	0	9	.095	9
35		5	max	12.681	9	.656	9	0	9	0	9	0	9	.708	9
36			min	8.534	9	.295	9	0	9	0	9	0	9	-.233	9
37		6	max	12.76	9	.984	9	0	9	0	9	0	9	.409	9
38			min	8.613	9	.624	9	0	9	0	9	0	9	-.767	9
39		7	max	12.839	9	1.338	9	0	9	0	9	0	9	-.112	9
40			min	8.692	9	.978	9	0	9	0	9	0	9	-1.523	9
41		8	max	12.918	9	1.717	9	0	9	0	9	0	9	-.873	9
42			min	8.771	9	1.356	9	0	9	0	9	0	9	-2.519	9
43		9	max	12.997	9	2.12	9	0	9	0	9	0	9	-1.889	9
44			min	8.849	9	1.76	9	0	9	0	9	0	9	-3.77	9
45		10	max	13.075	9	2.548	9	0	9	0	9	0	9	-3.176	9
46			min	8.928	9	2.188	9	0	9	0	9	0	9	-5.292	9
47		11	max	13.154	9	3.001	9	0	9	0	9	0	9	-4.751	9
48			min	9.007	9	2.641	9	0	9	0	9	0	9	-7.102	9
49		12	max	13.233	9	3.48	9	0	9	0	9	0	9	-6.63	9
50			min	9.086	9	3.119	9	0	9	0	9	0	9	-9.216	9
51		13	max	13.312	9	3.982	9	0	9	0	9	0	9	-8.829	9
52			min	9.165	9	3.622	9	0	9	0	9	0	9	-11.65	9
53	M3	1	max	3.982	9	-6.027	9	0	9	0	9	0	9	-8.829	9
54			min	3.622	9	-8.622	9	0	9	0	9	0	9	-11.65	9
55		2	max	3.982	9	-6.187	9	0	9	0	9	0	9	-1.882	9
56			min	3.622	9	-8.781	9	0	9	0	9	0	9	-3.062	9

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
57		3	max	3.982	9	-3.79	9	0	9	0	9	0	9	3.14	9
58			min	3.622	9	-5.211	9	0	9	0	9	0	9	1.298	9
59		4	max	3.982	9	-2.08	9	0	9	0	9	0	9	5.811	9
60			min	3.622	9	-2.751	9	0	9	0	9	0	9	3.602	9
61		5	max	3.982	9	-.935	9	0	9	0	9	0	9	6.966	9
62			min	3.622	9	-1.341	9	0	9	0	9	0	9	4.643	9
63		6	max	3.982	9	.276	9	0	9	0	9	0	9	7.312	9
64			min	3.622	9	-.708	9	0	9	0	9	0	9	5.031	9
65		7	max	3.982	9	.443	9	0	9	0	9	0	9	7.35	9
66			min	3.622	9	-.443	9	0	9	0	9	0	9	5.138	9
67		8	max	3.982	9	.708	9	0	9	0	9	0	9	7.312	9
68			min	3.622	9	-.276	9	0	9	0	9	0	9	5.031	9
69		9	max	3.982	9	1.341	9	0	9	0	9	0	9	6.966	9
70			min	3.622	9	.935	9	0	9	0	9	0	9	4.643	9
71		10	max	3.982	9	2.751	9	0	9	0	9	0	9	5.811	9
72			min	3.622	9	2.08	9	0	9	0	9	0	9	3.602	9
73		11	max	3.982	9	5.211	9	0	9	0	9	0	9	3.14	9
74			min	3.622	9	3.79	9	0	9	0	9	0	9	1.298	9
75		12	max	3.982	9	8.781	9	0	9	0	9	0	9	-1.882	9
76			min	3.622	9	6.187	9	0	9	0	9	0	9	-3.062	9
77		13	max	3.982	9	8.622	9	0	9	0	9	0	9	-8.829	9
78			min	3.622	9	6.027	9	0	9	0	9	0	9	-11.65	9
79	M4	1	max	.771	9	12.365	9	0	9	0	9	0	9	0	9
80			min	.411	9	8.218	9	0	9	0	9	0	9	0	9
81		2	max	.771	9	10.312	9	0	9	0	9	0	9	-7.952	9
82			min	.411 M_u	9	6.817	9	0	9	0	9	0	9	-11.922	9
83		3	max	.771	9	8.371	9	0	9	0	9	0	9	-14.458	9
84			min	.411	9	5.364	9	0	9	0	9	0	9	-21.676	9
85		4	max	.771	9	6.423	9	0	9	0	9	0	9	-19.519	9
86			min	.411	9	3.86	9	0	9	0	9	0	9	-29.266	9
87		5	max	.771	9	4.591	9	0	9	0	9	0	9	-23.133	9
88			min	.411	9	2.304	9	0	9	0	9	0	9	-34.679	9
89		6	max	.771	9	2.811	9	0	9	0	9	0	9	-25.302	9
90			min	.411	9	.698	9	0	9	0	9	0	9	-37.929	9
91		7	max	.771	9	.969 V_u	9	0	9	0	9	0	9	-26.025	9
92			min	.411 M_u	9	-.969	9	0	9	0	9	0	9	-39.005	9
93		8	max	.771	9	-.698	9	0	9	0	9	0	9	-25.302	9
94			min	.411	9	-2.811	9	0	9	0	9	0	9	-37.929	9
95		9	max	.771	9	-2.304	9	0	9	0	9	0	9	-23.133	9
96			min	.411	9	-4.591	9	0	9	0	9	0	9	-34.679	9
97		10	max	.771	9	-3.86	9	0	9	0	9	0	9	-19.519	9
98			min	.411	9	-6.423	9	0	9	0	9	0	9	-29.266	9
99		11	max	.771	9	-5.364	9	0	9	0	9	0	9	-14.458	9
100			min	.411	9	-8.371	9	0	9	0	9	0	9	-21.676	9
101		12	max	.771	9	-6.817	9	0	9	0	9	0	9	-7.952	9
102			min	.411	9	-10.312	9	0	9	0	9	0	9	-11.922	9
103		13	max	.771	9	-8.218	9	0	9	0	9	0	9	0	9
104			min	.411	9	-12.365	9	0	9	0	9	0	9	0	9

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Envelope Member Section Forces

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
1	M1	1	max	12.365	11	2.719	11	0	11	0	11	0	11	0	11
2			min	8.218	11	2.359	11	0	11	0	11	0	11	0	11
3		2	max	12.444	11	2.086	11	0	11	0	11	0	11	-1.336	11
4			min	8.297	11	1.726	11	0	11	0	11	0	11	-1.571	11
5		3	max	12.523	11	1.412	11	0	11	0	11	0	11	-2.245	11
6			min	8.376	11	1.052	11	0	11	0	11	0	11	-2.715	11
7		4	max	12.602	11	.697	11	0	11	0	11	0	11	-2.7	11
8			min	8.455	11	.336	11	0	11	0	11	0	11	-3.405	11
9		5	max	12.681	11	-.06	11	0	11	0	11	0	11	-2.675	11
10			min	8.534	11	-.421	11	0	11	0	11	0	11	-3.615	11
11		6	max	12.76	11	-.859	11	0	11	0	11	0	11	-2.142	11
12			min	8.613	11	-1.219	11	0	11	0	11	0	11	-3.317	11
13		7	max	12.839	11	-1.699	11	0	11	0	11	0	11	-1.074	11
14			min	8.692	11	-2.059	11	0	11	0	11	0	11	-2.485	11
15		8	max	12.918	11	-2.58	11	0	11	0	11	0	11	.556	11
16			min	8.771	11	-2.941	11	0	11	0	11	0	11	-1.09	11
17		9	max	12.997	11	-3.503	11	0	11	0	11	0	11	2.774	11
18			min	8.849	11	-3.863	11	0	11	0	11	0	11	.893	11
19		10	max	13.075	11	-4.468	11	0	11	0	11	0	11	5.609	11
20			min	8.928	11	-4.828	11	0	11	0	11	0	11	3.492	11
21		11	max	13.154	11	-5.473	11	0	11	0	11	0	11	9.086	11
22			min	9.007	11	-5.834	11	0	11	0	11	0	11	6.735	11
23		12	max	13.233	11	-6.521	11	0	11	0	11	0	11	13.234	11
24			min	9.086	11	-6.881	11	0	11	0	11	0	11	10.647	11
25		13	max	13.312	11	-7.609	11	0	11	0	11	0	11	18.078	11
26			min	9.165	11	-7.969	11	0	11	0	11	0	11	15.257	11
27	M2	1	max	12.365	11	-2.359	11	0	11	0	11	0	11	0	11
28			min	8.218	11	-2.719	11	0	11	0	11	0	11	0	11
29		2	max	12.444	11	-1.904	11	0	11	0	11	0	11	1.629	11
30			min	8.297	11	-2.265	11	0	11	0	11	0	11	1.394	11
31		3	max	12.523	11	-1.408	11	0	11	0	11	0	11	2.947	11
32			min	8.376	11	-1.769	11	0	11	0	11	0	11	2.477	11
33		4	max	12.602	11	-.871	11	0	11	0	11	0	11	3.929	11
34			min	8.455	11	-1.231	11	0	11	0	11	0	11	3.223	11
35		5	max	12.681	11	-.292	11	0	11	0	11	0	11	4.546	11
36			min	8.534	11	-.652	11	0	11	0	11	0	11	3.605	11
37		6	max	12.76	11	.328	11	0	11	0	11	0	11	4.772	11
38			min	8.613	11	-.032	11	0	11	0	11	0	11	3.596	11
39		7	max	12.839	11	.99	11	0	11	0	11	0	11	4.579	11
40			min	8.692	11	.63	11	0	11	0	11	0	11	3.168	11
41		8	max	12.918	11	1.693	11	0	11	0	11	0	11	3.94	11
42			min	8.771	11	1.333	11	0	11	0	11	0	11	2.294	11
43		9	max	12.997	11	2.438	11	0	11	0	11	0	11	2.83	11
44			min	8.849	11	2.078	11	0	11	0	11	0	11	.948	11
45		10	max	13.075	11	3.224	11	0	11	0	11	0	11	1.219	11
46			min	8.928	11	2.864	11	0	11	0	11	0	11	-.897	11
47		11	max	13.154	11	4.051	11	0	11	0	11	0	11	-.918	11
48			min	9.007	11	3.691	11	0	11	0	11	0	11	-3.27	11
49		12	max	13.233	11	4.92	11	0	11	0	11	0	11	-3.609	11
50			min	9.086	11	4.56	11	0	11	0	11	0	11	-6.196	11
51		13	max	13.312	11	5.831	11	0	11	0	11	0	11	-6.881	11
52			min	9.165	11	5.471	11	0	11	0	11	0	11	-9.703	11
53	M3	1	max	5.831	11	-6.931	11	0	11	0	11	0	11	-15.257	11
54			min	5.471	11	-9.525	11	0	11	0	11	0	11	-18.078	11
55		2	max	5.831	11	-7.09	11	0	11	0	11	0	11	-7.357	11
56			min	5.471	11	-9.684	11	0	11	0	11	0	11	-8.537	11

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Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y She...	LC	z Shear[...	LC	Torque[k-ft]	LC	y-y Moment[k-...	LC	z-z Moment[...	LC
57		3	max	5.831	11	-5.031	11	0	11	0	11	0	11	-1.025	11
58			min	5.471	11	-6.451	11	0	11	0	11	0	11	-2.867	11
59		4	max	5.831	11	-3.315	11	0	11	0	11	0	11	2.95	11
60			min	5.471	11	-3.986	11	0	11	0	11	0	11	.74	11
61		5	max	5.831	11	-1.993	11	0	11	0	11	0	11	5.222	11
62			min	5.471	11	-2.399	11	0	11	0	11	0	11	2.899	11
63		6	max	5.831	11	-1.035	11	0	11	0	11	0	11	6.442	11
64			min	5.471	11	-1.536	11	0	11	0	11	0	11	4.16	11
65		7	max	5.831	11	-.5	11	0	11	0	11	0	11	7.13	11
66			min	5.471	11	-1.06	11	0	11	0	11	0	11	4.919	11
67		8	max	5.831	11	.335	11	0	11	0	11	0	11	7.581	11
68			min	5.471	11	-.738	11	0	11	0	11	0	11	5.299	11
69		9	max	5.831	11	1.001	11	0	11	0	11	0	11	7.628	11
70			min	5.471	11	.595	11	0	11	0	11	0	11	5.306	11
71		10	max	5.831	11	2.416	11	0	11	0	11	0	11	6.832	11
72			min	5.471	11	1.745	11	0	11	0	11	0	11	4.622	11
73		11	max	5.831	11	4.895	11	0	11	0	11	0	11	4.514	11
74			min	5.471	11	3.474	11	0	11	0	11	0	11	2.672	11
75		12	max	5.831	11	8.553	11	0	11	0	11	0	11	-.175	11
76			min	5.471	11	5.959	11	0	11	0	11	0	11	-1.355	11
77		13	max	5.831	11	8.394	11	0	11	0	11	0	11	-6.881	11
78			min	5.471	11	5.8	11	0	11	0	11	0	11	-9.703	11
79	M4	1	max	2.719	11	12.365	11	0	11	0	11	0	11	0	11
80			min	2.359	11	8.218	11	0	11	0	11	0	11	0	11
81		2	max	2.719	11	10.312	11	0	11	0	11	0	11	-7.952	11
82			min	2.359	11	6.817	11	0	11	0	11	0	11	-11.922	11
83		3	max	2.719	11	8.371	11	0	11	0	11	0	11	-14.458	11
84			min	2.359	11	5.364	11	0	11	0	11	0	11	-21.676	11
85		4	max	2.719	11	6.423	11	0	11	0	11	0	11	-19.519	11
86			min	2.359	11	3.86	11	0	11	0	11	0	11	-29.266	11
87		5	max	2.719	11	4.591	11	0	11	0	11	0	11	-23.133	11
88			min	2.359	11	2.304	11	0	11	0	11	0	11	-34.679	11
89		6	max	2.719	11	2.811	11	0	11	0	11	0	11	-25.302	11
90			min	2.359	11	.698	11	0	11	0	11	0	11	-37.929	11
91		7	max	2.719	11	.969	11	0	11	0	11	0	11	-26.025	11
92			min	2.359	11	-.969	11	0	11	0	11	0	11	-39.005	11
93		8	max	2.719	11	-.698	11	0	11	0	11	0	11	-25.302	11
94			min	2.359	11	-2.811	11	0	11	0	11	0	11	-37.929	11
95		9	max	2.719	11	-2.304	11	0	11	0	11	0	11	-23.133	11
96			min	2.359	11	-4.591	11	0	11	0	11	0	11	-34.679	11
97		10	max	2.719	11	-3.86	11	0	11	0	11	0	11	-19.519	11
98			min	2.359	11	-6.423	11	0	11	0	11	0	11	-29.266	11
99		11	max	2.719	11	-5.364	11	0	11	0	11	0	11	-14.458	11
100			min	2.359	11	-8.371	11	0	11	0	11	0	11	-21.676	11
101		12	max	2.719	11	-6.817	11	0	11	0	11	0	11	-7.952	11
102			min	2.359	11	-10.312	11	0	11	0	11	0	11	-11.922	11
103		13	max	2.719	11	-8.218	11	0	11	0	11	0	11	0	11
104			min	2.359	11	-12.365	11	0	11	0	11	0	11	0	11

Design/Analysis References:

1. AASHTO LRFD Bridge Design Specifications, 6th Edition.
2. NHDOT 2010 Standard Specifications for Road and Bridge Construction.
3. Das, Principles of Foundation Engineering, 5th Edition.
4. Holtz & Kovacs, Introduction to Geotechnical Engineering
5. AISC, Steel Construction Manual, 13th Edition
6. Highway Innovative Technology Evaluation Center (HITEC), Evaluation of the Con/Span Wingwall System, CERF Report #40580, July 2001.

Assumptions:

1. It is assumed that the failure plane of the soil to be retained by this wall will lie within the proposed backfill material.
2. Backfill and foundation material assumptions shall match that of the shop drawings.
3. The installation of the weepholes will preclude the development of hydrostatic pressures on the wall.
4. Passive earth pressure in front of the wall is ignored per AASHTO 11.6.3.5.
5. Wing Angles (w.r.t roadway). The 12x7 Box Culvert and Wingwalls comprise the crossing of VT Route 30 over an unnamed brook. WW1-3 are skewed 45 deg from the culvert. WW4 is skewed approx 68 deg. The roadway is skewed 76 degrees from the culvert (i.e. 14 degrees off of square). Therefore, WW1 is skewed 31 deg from the roadway, WW4 is skewed 8 deg from the roadway, and WW2/WW3 are skewed 59 deg from the roadway.
6. Backslope Angle. The roadway behind WW4 has a backslope of 2:1. The roadway behind WW2 is 3:1.
7. Live Load Surcharge. Vehicular Surcharge is applied when traffic can come within a distance of half the height of the wall to the back face of wall (measured perpendicular to the road). Conservatively take distance to traffic (d.traffic) at the wing-culvert connection. All wings are greater than H/2 from traffic. Use 10' for simplicity.
8. Controlling Wingwall Design(s). WW4 and WW2 are the tallest wings and have +- the same design height. Since WW4 has a 2:1 backslope behind it, WW4 will control design.
9. Design Methodology.
   - The HITEC Evaluation (page 3) explains that the Anchor Wall acts as a cantilever wall for most of its length since the weight of the soil within and above the anchors provides resistance to overturning. The wall also has attributes of a bin wall since arching and friction of soil masses between anchors provides additional resistance. Therefore, the provisions of AASHTO Sections 11.6 (Conventional Retaining Walls) and 11.11 (Modular Walls) shall be applied.
   - Per AASHTO 11.11.4.4, a maximum of 80% of the weight of the retained soil is effective in resisting overturning. The HITEC Evaluation (pages D29-D33) evaluated the accuracy of this assumption and found that using 80% of the soil weight is a conservative assumption.

General Input:

$ELV_{walltop} := 1930.25ft - 2in = 1930.08\,ft$	Elevation of the Wingwall at its tallest point
$ELV_{walltip} := 1929.25ft$	Elevation of Wingwall at its tip.
$ELV_{bot.ftg} := 1916.52ft$	Elevation of the Bottom of the Wall Footing
$t_{ftg} := 3ft$	Thickness of Wall Footing
$h_{ftg} := 3ft + 2in = 3.167\,ft$	Height of Wall Footing
$h_{short} := ELV_{walltip} - ELV_{bot.ftg} - h_{ftg} - 1in = 9.48\,ft$	Short end of wall (less 1" for shim)
$h_{tall} := ELV_{walltop} - ELV_{bot.ftg} - h_{ftg} - 1in = 10.313\,ft$	Tall end of wall (less 1" for shim)
$l_{wall} := 10ft$	Length of Wall Panel
$l_{flat} := 1ft$	Length of flat portion of wingwall before break in slope.
$t_{wall} := 10in$	Thickness of Wall Panel
$t_{stem} := 6in$	Thickness of Anchor Stem
$w_{flange} := 2ft + 6in$	Width of Anchor Flange
$\alpha_{skew} := 76deg - 68deg = 8 \cdot deg$	Angle of ww skew in plan view, measured from edge of roadway. (to measure distance to traffic for each anchor)
$\theta_{wall} := 90deg$	Wall batter angle with horizontal
$\theta_{anchor} := \theta_{wall} + 30deg$	Anchor batter angle with horizontal
$\beta := atan\left(\frac{\cos(\alpha_{skew})}{2}\right) = 26.342 \cdot deg$	Backfill slope angle with horizontal, measured perpendicular to the wall.
$d_{traffic} := 10ft$	Estimated minimum distance to traffic, measured from backfill side of wall and perpendicular to the wall.
$BreakInSlope := 2ft$	Assumed distance from face of guardrail to break-in-slope, meaured perpendicular to the wall.

Wall Material Properties

Concrete

$f_c := 5000\frac{lbf}{in^2}$ $E_c := 4074ksi$ $Aggregate_{diam} := .75in$

$\gamma_c := 150pcf$ Assumed unit weight of concrete panel.

β_1 = Stress Block Factor specified in Article 5.7.2.2

$$\beta_1 := \max\left[.65, \left[\begin{array}{ll} .85 & \text{if } f_c < 4000psi \\ .85 - \frac{.05}{psi}\cdot\left(\frac{f_c - 4000psi}{1000}\right) & \text{otherwise} \end{array}\right]\right] = 0.8$$

Steel:

$f_y := 60000\frac{lbf}{in^2}$ $E_s := 29000ksi$

Soil:

$q_R := 6ksf$ Factored Bearing Resistance (per contract) at service limit state controls. Conservatively use factored loads at strength limit state against the service level bearing resistance shown.

$\gamma_s := 140pcf$ Assumed soil unit weight for all soil

$q_{sur} := 2ft\cdot\gamma_s = 280\cdot psf$ Surcharge Soil Pressure (AASHTO Tbl 3.11.6.4-2)

$\phi_{ftg} := 35deg$ Friction Angle of Soil below Wall Footing

$\phi_{backfill} := 34deg$ Friction Angle of Backfill Soil

$\delta_{wall} := 0.75\cdot\phi_{backfill} = 25.5\cdot deg$ AASHTO C3.11.5.9-1 and HITEC p.D19

$\delta_{anchor} := 0.50\cdot\phi_{backfill} = 17\cdot deg$ AASHTO C3.11.5.9-1 and HITEC p.D19

$$k_{a.wall} := \frac{\sin(\theta_{wall} + \phi_{backfill})^2}{\sin(\theta_{wall})^2\cdot\sin(\theta_{wall} - \delta_{wall})\cdot\left(1 + \sqrt{\frac{\sin(\phi_{backfill} + \delta_{wall})\cdot\sin(\phi_{backfill} - \beta)}{\sin(\theta_{wall} - \delta_{wall})\cdot\sin(\theta_{wall} + \beta)}}\right)^2} = 0.402$$

AASHTO 3.11.5.3

$$k_{a.anchor} := \frac{\sin(\theta_{anchor} + \phi_{backfill})^2}{\sin(\theta_{anchor})^2 \cdot \sin(\theta_{anchor} - \delta_{anchor}) \cdot \left(1 + \sqrt{\frac{\sin(\phi_{backfill} + \delta_{anchor}) \cdot \sin(\phi_{backfill} - \beta)}{\sin(\theta_{anchor} - \delta_{anchor}) \cdot \sin(\theta_{anchor} + \beta)}}\right)^2} = 0.127$$

AASHTO 3.11.5.3

$$k_0 := 1 - \sin(\phi_{backfill}) = 0.441$$

AASHTO 3.11.5.2-1

Determine Load Factors (Strength I) (AASHTO 1.3 and Table 3.4.1-1)

Load Modifiers

$\eta_D := 1.00$ Ductility for a conventional design

$\eta_R := 1.00$ Redundancy for conventional design

$\eta_I := 1.00$ Importance for a conventional bridge

$\eta_i := \max(\eta_D \cdot \eta_R \cdot \eta_I, 0.95)$ $\eta_i = 1$

Load Factor	Max	Min	Service	
γ_{DC}	1.25	0.9	1.0	Component Dead Loads
γ_{EH}	1.5	0.9	1.0	Horizontal Earth Loads
γ_{EV}	1.35	1.0	1.0	Vertical Earth Loads
γ_{LL}	1.75	1.75	1.0	Live Loads

Anchor Types, Layout and Backfill Geometry

ConnectedToBridge := "No"

To account for the connection of the wing to the bridge. Choose between Yes and No.

$AnchorType_1$:= "D"

$AnchorType_2$:= "D"

Anchor Type to be tied to the back face of the wall. Chosen between Anchor Type B, C, D, and E as defined below.

$AnchorType_3 := \text{"D"}$

$dist_{anchor.1} := 2.5ft$

$dist_{anchor.2} := 5ft$

$dist_{anchor.3} := 0$

Distance to each anchor is from culvert end of wing. Anchor 1 is closest to culvert.

Note: Research in HITEC report supports spacing from 2.5 ft (anchors are touching) to 5.5 feet (HITEC Report pages D29-D33). If distance between anchors increases beyond 5.5 ft, data supporting the usable 80% soil weight assumption shall be provided due to possible affects on soil arching between the anchors. Similarly, anchor closest to the wall tip shall not exceed 3 feet without supporting data.

If only 1 anchor is used, set $dist_{anchor2} = dist_{anchor3} = 0$.

If only 2 anchors are used, set $dist_{anchor3} = 0$.

Tributary Width of Wall for each Anchor

$$trib_{plates} := \begin{cases} 0 & \text{if } ConnectedToBridge = \text{"No"} \\ \frac{1}{2} \cdot dist_{anchor.1} & \text{otherwise} \end{cases} = 0\,ft$$

$$trib_1 := \begin{cases} l_{wall} - trib_{plates} & \text{if } dist_{anchor.2} = 0 \\ \frac{1}{2} \cdot \left(dist_{anchor.1} + dist_{anchor.2}\right) - trib_{plates} & \text{otherwise} \end{cases} = 3.75\,ft$$

$$trib_2 := \begin{cases} \left[l_{wall} - \frac{1}{2}\left(dist_{anchor.1} + dist_{anchor.2}\right)\right] & \text{if } dist_{anchor.3} = 0 \\ \frac{1}{2}\left(dist_{anchor.2} + dist_{anchor.3}\right) - \frac{1}{2}\left(dist_{anchor.1} + dist_{anchor.2}\right) & \text{otherwise} \end{cases} = 6.25\,ft$$

$$trib_3 := l_{wall} - \left(trib_1 + trib_2 + trib_{plates}\right) = 0\,ft$$

Height of Wall at CL of Each Anchor

$$h(x) := \begin{cases} 0 & \text{if } x = 0 \\ h_{tall} & \text{if } 0 < x \le l_{flat} \\ \left[h_{tall} - \left(\frac{h_{tall} - h_{short}}{l_{wall} - l_{flat}}\right) \cdot \left(x - l_{flat}\right)\right] & \text{otherwise} \end{cases}$$

$h_{wall.1} := h\left(dist_{anchor.1}\right) = 10.174\,ft$ Height of wall at each anchor

$h_{wall.2} := h\left(dist_{anchor.2}\right) = 9.943\,ft$

$h_{wall.3} := h(dist_{anchor.3}) = 0\,ft$

Length of each Anchor Stem Extension

$$W(x) := \begin{cases} (0ft) & \text{if } x = \text{"B"} \\ (1ft) & \text{if } x = \text{"C"} \\ (2ft) & \text{if } x = \text{"D"} \\ (3ft) & \text{if } x = \text{"E"} \end{cases}$$

W is the additional anchor stem length beyond that of a "B" anchor. W(B) = 0

$W_1 := W(AnchorType_1) = 2\,ft$

$W_2 := W(AnchorType_2) = 2\,ft$

$W_3 := W(AnchorType_3) = 2\,ft$

Width of Soil Column above each Anchor

B_{bot} is the width of the soil column at the top of the anchor, measured from backfill side of wall to upper tip of each anchor.

$$B_{bot.1} := W_1 + (3ft + 5.375in) + \frac{7in}{\cos(30deg)} = 6.121\,ft$$

$$B_{bot.2} := W_2 + (3ft + 5.375in) + \frac{7in}{\cos(30deg)} = 6.121\,ft$$

$$B_{bot.3} := W_3 + (3ft + 5.375in) + \frac{7in}{\cos(30deg)} = 6.121\,ft$$

$B_{bot.lower}$ is the width of the soil column at the bottom of the anchor, measured from backfill side of wall to bottom tip of anchor.

$$B_{bot.lower.1} := W_1 + \left(1ft + 4in + \frac{7in}{\cos(30deg)}\right) = 4.007\,ft$$

$$B_{bot.lower.2} := W_2 + \left(1ft + 4in + \frac{7in}{\cos(30deg)}\right) = 4.007\,ft$$

$$B_{bot.lower.3} := W_3 + \left(1ft + 4in + \frac{7in}{\cos(30deg)}\right) = 4.007\,ft$$

Perpendicular Distance to Traffic at each Anchor

$$d_{traffic.1} := d_{traffic} + dist_{anchor.1} \cdot \tan(\alpha_{skew}) = 10.351\,ft$$

$$d_{traffic.2} := d_{traffic} + dist_{anchor.2} \cdot \tan(\alpha_{skew}) = 10.703\,ft$$

$d_{traffic.3} := d_{traffic} + dist_{anchor.3} \cdot \tan(\alpha_{skew}) = 10\,ft$

Height of backfill at CL of each anchor

$d_{slope.1} := \max(0, \min(B_{bot.1}, d_{traffic.1} - BreakInSlope)) = 6.121\,ft$

$d_{slope.2} := \max(0, \min(B_{bot.2}, d_{traffic.2} - BreakInSlope)) = 6.121\,ft$

$d_{slope.3} := \max(0, \min(B_{bot.3}, d_{traffic.3} - BreakInSlope)) = 6.121\,ft$

Distance to break in slope, measured perpendicular to wall from inside face of wall, limited by B.bot.

$h_{backfill.1} := \max(h_{wall.1}, h_{wall.1} + \min(B_{bot.1}, d_{slope.1}) \cdot \tan(\beta)) = 13.205\,ft$

$h_{backfill.2} := \max(h_{wall.2}, h_{wall.2} + \min(B_{bot.2}, d_{slope.2}) \cdot \tan(\beta)) = 12.974\,ft$

$h_{backfill.3} := \max(h_{wall.3}, h_{wall.3} + \min(B_{bot.3}, d_{slope.3}) \cdot \tan(\beta)) = 3.031\,ft$

The height of backfill is taken at the end of the reinforced soil mass.

External Stability Analysis at Anchor 1

Calculate Vertical Loads and Associated Lever Arms ***(All Lever Arms are from Point "O")***

$DC_{wall.1} := t_{wall} \cdot h_{wall.1} \cdot \gamma_c = 1.272 \cdot \frac{kip}{ft}$

$x_{DC.wall.1} := \frac{1}{2} t_{wall} = 0.417\,ft$

$EV1a_1 := \frac{1}{2} \gamma_s \cdot (h_{backfill.1} - h_{wall.1}) \cdot (d_{slope.1}) = 1.299 \cdot \frac{kip}{ft}$

$x_{EV1a.1} := t_{wall} + \frac{2}{3} d_{slope.1} = 4.914\,ft$

$EV1b_1 := \gamma_s \cdot (h_{backfill.1} - h_{wall.1}) \cdot (B_{bot.1} - d_{slope.1}) = 0 \cdot \frac{kip}{ft}$

$x_{EV1b.1} := t_{wall} + d_{slope.1} + \frac{1}{2}(B_{bot.1} - d_{slope.1}) = 6.955\,ft$

$EV2_1 := \gamma_s \cdot (h_{wall.1} - 3.5ft) \cdot B_{bot.1} = 5.72 \cdot \frac{kip}{ft}$

$x_{EV2.1} := t_{wall} + \frac{1}{2} B_{bot.1} = 3.894\,ft$

$EV3_1 := \gamma_s \cdot (3.5ft) \cdot \left(B_{bot.lower.1} - \frac{7in}{\cos(30deg)}\right) = 1.633 \cdot \frac{kip}{ft}$

$x_{EV3.1} := t_{wall} + \frac{1}{2}\left(B_{bot.lower.1} - \frac{7in}{\cos(30deg)}\right) = 2.5\,ft$

$$EV4_1 := \gamma_s \cdot \frac{1}{2} \cdot 3.5ft \cdot \left[\left(W_1 + 3ft + 5.375in \right) - \left(B_{bot.lower.1} - \frac{7in}{\cos(30deg)} \right) \right] = 0.518 \cdot \frac{kip}{ft}$$

$$x_{EV4.1} := t_{wall} + B_{bot.lower.1} + \frac{1}{3} \cdot \left[W_1 + 3ft + 5.375in - \left(B_{bot.lower.1} - \frac{7in}{\cos(30deg)} \right) \right] = 5.545\,ft$$

$$DC_{anchor.1} := \frac{1}{trib_1} \cdot \begin{cases} (1740lbf) & \text{if } AnchorType_1 = \text{"B"} \\ (2010lbf) & \text{if } AnchorType_1 = \text{"C"} \\ (2285lbf) & \text{if } AnchorType_1 = \text{"D"} \\ (2550lbf) & \text{if } AnchorType_1 = \text{"E"} \end{cases} = 0.609 \cdot \frac{kip}{ft}$$

(See Anchor Geometry Drawing)

$$x_{anchor.1} := t_{wall} + \begin{cases} (2ft + 2.25in) & \text{if } AnchorType_1 = \text{"B"} \\ (2ft + 8.8125in) & \text{if } AnchorType_1 = \text{"C"} \\ (3ft + 5.125in) & \text{if } AnchorType_1 = \text{"D"} \\ (4ft + 0.0625in) & \text{if } AnchorType_1 = \text{"E"} \end{cases} = 4.26 \cdot ft$$

$$LS_{vert.1} := \begin{cases} \left[q_{sur} \cdot \left[B_{bot.1} - \left(d_{traffic.1} \right) \right] \right] & \text{if } d_{traffic.1} < B_{bot.1} \\ 0 & \text{otherwise} \end{cases} = 0 \cdot \frac{kip}{ft}$$

Used in bearing calcs only

$$x_{LS.vert.1} := t_{wall} + d_{traffic.1} + \frac{1}{2} \left(B_{bot.1} - d_{traffic.1} \right) = 9.07\,ft$$

$$DC_{ftg.1} := \gamma_c \cdot t_{ftg} \cdot h_{ftg} = 1.425 \cdot \frac{kip}{ft}$$

$$x_{DC.ftg.1} := \frac{t_{ftg}}{2} = 1.5\,ft$$

Note: This moment arm is measured from the front toe of the ftg since it is only used in bearing calculations.

Calculate Lateral Loads and Associated Lever Arms

$$EH1_{1.vert} := \frac{1}{2} k_{a.wall} \cdot \gamma_s \cdot \left(h_{backfill.1} - 3.5ft \right)^2 \cdot \sin\left(\delta_{wall} \right) = 1.14 \cdot \frac{kip}{ft}$$

$$EH1_{1.hor} := \frac{1}{2} k_{a.wall} \cdot \gamma_s \cdot \left(h_{backfill.1} - 3.5ft \right)^2 \cdot \cos\left(\delta_{wall} \right) = 2.391 \cdot \frac{kip}{ft}$$

$$x_{EH1.1} := t_{wall} + B_{bot.1} = 6.955\,ft$$

$$y_{EH1.1} := 3.5ft + \frac{1}{3} \left(h_{backfill.1} - 3.5ft \right) = 6.735\,ft$$

$$EH2_{1.vert} := k_{a.anchor} \cdot \gamma_s \cdot \left(h_{backfill.1} - 3.5ft \right) \cdot (4ft) \cdot \sin\left(\delta_{anchor} - 30deg \right) = -0.155 \cdot \frac{kip}{ft}$$

$$EH2_{1.hor} := k_{a.anchor} \cdot \gamma_s \cdot \left(h_{backfill.1} - 3.5ft\right) \cdot (4ft) \cdot \cos\left(\delta_{anchor} - 30deg\right) = 0.674 \cdot \frac{kip}{ft}$$

$$x_{EH2.1} := t_{wall} + \frac{1}{2}\left(B_{bot.1} + B_{bot.lower.1}\right) = 5.898\,ft$$

$$y_{EH2.1} := 3.5ft - \frac{1}{2} \cdot 4ft = 1.5\,ft$$

$$EH3_{1.vert} := \frac{1}{2} k_{a.anchor} \cdot \gamma_s \cdot (4ft)^2 \cdot \sin\left(\delta_{anchor} - 30deg\right) = -0.032 \cdot \frac{kip}{ft}$$

$$EH3_{1.hor} := \frac{1}{2} k_{a.anchor} \cdot \gamma_s \cdot (4ft)^2 \cdot \cos\left(\delta_{anchor} - 30deg\right) = 0.139 \cdot \frac{kip}{ft}$$

$$x_{EH3.1} := t_{wall} + B_{bot.lower.1} + \left(3.5ft - \frac{2}{3} \cdot 4ft\right) \tan(30deg) = 5.321\,ft$$

$$y_{EH3.1} := 3.5ft - \frac{2}{3} \cdot 4ft = 10 \cdot in$$

$$LS_{hor.1} := \begin{cases} \left(k_{a.wall} \cdot q_{sur} \cdot h_{backfill.1}\right) & \text{if } d_{traffic.1} < \frac{h_{wall.1}}{2} \\ 0 & \text{otherwise} \end{cases} = 0 \cdot \frac{kip}{ft}$$

$$x_{LS.hor.1} := t_{wall} + \frac{1}{2}\left(B_{bot.lower.1} + B_{bot.1}\right) = 5.898\,ft$$ (Assumed for ease of calculation)

$$y_{LS.hor.1} := \frac{1}{2} h_{backfill.1} = 6.603\,ft$$

Check Sliding

Per AASHTO 11.11.4.2, Sliding shall be evaluated according to 10.6.3.4. Per 11.5.3, sliding shall be evaluated at the strength limit state. Use minimum load factors for vertical loads and maximum load factors for horizontal loads. Assume the failure plane is beneath the wall ftg, which will be grouted to the wall during construction. This is consistent with assumptions in the HITEC report (page D24).

Resisting Forces

$$\phi_\tau := 0.9$$ AASHTO Table 10.5.5.2.2-1, "Precast on Sand" or "Soil on Soil"

$$\Sigma V_1 := 0.9\left(DC_{wall.1} + DC_{anchor.1} + DC_{ftg.1}\right) + 1.0 \cdot \left(EV1a_1 + EV1b_1 + EV2_1 + EV3_1 + EV4_1\right) \ldots + \eta_i \cdot 1.50 \cdot \left(EH1_{1.vert} + EH2_{1.vert} + EH3_{1.vert}\right) = 13.575 \cdot \frac{kip}{ft}$$

$$R_{\tau.1} := 0.8 \cdot \tan\left(\phi_{ftg}\right) \cdot \Sigma V_1 = 7.604 \cdot \frac{kip}{ft}$$ AASHTO 10.6.3.4

$$\boxed{R_{r.1} := \phi_\tau \cdot R_{\tau.1} = 6.844 \cdot \frac{kip}{ft}}$$

Driving Forces

$$\Sigma H_{\tau.1} := \eta_i \cdot \left[1.50 \cdot \left(EH1_{1.hor} + EH2_{1.hor} + EH3_{1.hor}\right) + 1.75LS_{hor.1}\right] = 4.805 \cdot \frac{kip}{ft}$$

$$Check_{sliding.1} := \begin{cases} \text{"OK"} & \text{if } \frac{R_{r.1}}{\Sigma H_{\tau.1}} \geq 1 \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Overturning and Eccentricity

Per AASHTO 11.11.4.4, Overturning shall be evaluated according to 11.6.3.3. A maximum of 80% of the retained soil shall be used to resist overturning. Per 11.6.3.3, evaluate overturning and eccentricity at the strength limit state using maximum load factors for horizontal loads and minimum load factors for vertical loads. First, evaluate eccentricity at the base of the panel. Second, evaluate eccentricity at the base of the footing. The location of the resultant of the reaction forces shall be located within the middle half of the base width (panel width plus anchor projection for case 1; footing width plus anchor projection for case 2). Eccentricity is measured from the center of the base width toward the stream side of the footing. Assume that a negative eccentricity (beyond the center of the base, toward the backfill) is acceptable since this condition will engage passive earth pressures.

Resisting Forces

$$\begin{aligned} Resisting_1 := {} & 0.9\left(DC_{wall.1} \cdot x_{DC.wall.1} + DC_{anchor.1} \cdot x_{anchor.1}\right) \ldots \\ & + 1.0 \cdot 0.8 \cdot \left(EV1a_1 \cdot x_{EV1a.1} + EV1b_1 \cdot x_{EV1b.1} + EV2_1 \cdot x_{EV2.1} + EV3_1 \cdot x_{EV3.1} + EV4_1 \cdot x_{EV4.1}\right) \ldots \\ & + 1.50\left(EH1_{1.vert} \cdot x_{EH1.1} + EH2_{1.vert} \cdot x_{EH2.1} + EH3_{1.vert} \cdot x_{EH3.1}\right) \end{aligned} = 41.569 \cdot \frac{kip \cdot ft}{ft}$$

Driving Forces

$$Driving_1 := 1.50 \cdot \left(EH1_{1.hor} \cdot y_{EH1.1} + EH2_{1.hor} \cdot y_{EH2.1} + EH3_{1.hor} \cdot y_{EH3.1}\right) + 1.75LS_{hor.1} \cdot y_{LS.hor.1} = 25.843 \cdot \frac{kip \cdot ft}{ft}$$

$$Check_{OT.1} := \begin{cases} \text{"OK"} & \text{if } \frac{Resisting_1}{Driving_1} \geq 1 \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

$$\begin{aligned} \Sigma V_{e.1} := {} & 0.9\left(DC_{wall.1} + DC_{anchor.1}\right) + 1.0 \cdot 0.8 \cdot \left(EV1a_1 + EV1b_1 + EV2_1 + EV3_1 + EV4_1\right) \ldots \\ & + 1.50\left(EH1_{1.vert} + EH2_{1.vert} + EH3_{1.vert}\right) \end{aligned} = 10.458 \cdot \frac{kip}{ft}$$

Case 1: Eccentricity of Resultant without footing

$$l_{case1.1} := \frac{\left(Resisting_1 - Driving_1\right)}{\Sigma V_{e.1}} = 1.504\,ft$$ (Distance to resultant from face of wall)

$$B_{case1.1} := B_{bot.lower.1} + t_{wall} = 4.84\,ft$$

$$e_{case1.1} := \max\left(\frac{B_{case1.1}}{2} - l_{case1.1}, 0ft\right) = 0.916\,ft$$

$$e_{allow.case1.1} := \frac{B_{case1.1}}{4} = 1.21\,ft$$ (Within Middle Half per AASHTO 11.6.3.3)

$$Check_{e.case1.1} := \begin{cases} "OK" & \text{if } \frac{e_{case1.1}}{e_{allow.case1.1}} \le 1 \\ "NG" & \text{otherwise} \end{cases} = "OK"$$

Case 2: Eccentricity of Resultant with footing

$$l_1 := \frac{\left[\Sigma V_{e.1} \cdot \left[\frac{\left(Resisting_1 - Driving_1\right)}{\Sigma V_{e.1}} + \frac{1}{2}\left(t_{ftg} - t_{wall}\right)\right] + 0.9DC_{ftg.1} \cdot x_{DC.ftg.1}\right]}{\Sigma V_{e.1} + 0.9DC_{ftg.1}} = 2.468\,ft$$ (Distance to resultant from face of ftg)

$$B_1 := B_{bot.lower.1} + t_{wall} + \frac{1}{2}\left(t_{ftg} - t_{wall}\right) = 5.924\,ft$$

$$e_1 := \max\left(\frac{B_1}{2} - l_1, 0ft\right) = 0.493\,ft$$

$$e_{allow.1} := \frac{B_1}{4} = 1.481\,ft$$ (Within Middle Half of ftg per AASHTO 11.6.3.3)

$$Check_{e.1} := \begin{cases} "OK" & \text{if } \frac{e_1}{e_{allow.1}} \le 1 \\ "NG" & \text{otherwise} \end{cases} = "OK"$$

Check Bearing Pressure

Per 11.11.4.3 Evaluate bearing pressure with respect to resistance calculated in 10.6.3. Per HITEC p. D24, use the horizontal portion of the anchor at its base plus the footing width. Evaluate at the strength limit state. Use 100% of the weight of the retained soil. When Live Load Surcharge is present, Strength I with maximum load factors for vertical loads

and horizontal loads controls. Include the effects of live load surcharge. Since lever arms are calculated from the front face of the wall, must add to the eccentricity the distance between wall and toe of footing.

$$Resisting_{brg.1} := 1.25\left(DC_{wall.1}\cdot x_{DC.wall.1} + DC_{anchor.1}\cdot x_{anchor.1}\right) \ldots + 1.35\cdot\left(EV1a_1\cdot x_{EV1a.1} + EV1b_1\cdot x_{EV1b.1} + EV2_1\cdot x_{EV2.1} + EV3_1\cdot x_{EV3.1} + EV4_1\cdot x_{EV4.1}\right) \ldots + 1.35\left(EH1_{1.vert}\cdot x_{EH1.1} + EH2_{1.vert}\cdot x_{EH2.1} + EH3_{1.vert}\cdot x_{EH3.1}\right) \ldots + 1.75\cdot\left(LS_{vert.1}\cdot x_{LS.vert.1}\right) = 61.224\cdot\frac{kip\cdot ft}{ft}$$

$$Driving_{brg.1} := 1.35\left(EH1_{1.hor}\cdot y_{EH1.1} + EH2_{1.hor}\cdot y_{EH2.1} + EH3_{1.hor}\cdot y_{EH3.1}\right) + 1.75LS_{hor.1}\cdot y_{LS.hor.1} = 23.258\cdot\frac{kip\cdot ft}{ft}$$

$$\Sigma V_{brg.1} := 1.25\cdot\left(DC_{wall.1} + DC_{anchor.1}\right) + 1.35\cdot\left(EV1a_1 + EV1b_1 + EV2_1 + EV3_1 + EV4_1\right) \ldots + 1.35\cdot\left(EH1_{1.vert} + EH2_{1.vert} + EH3_{1.vert}\right) + 1.75\cdot\left(LS_{vert.1}\right) = 16.018\cdot\frac{kip}{ft}$$

$$l_{brg.1} := \frac{\left[\Sigma V_{brg.1}\cdot\left[\frac{\left(Resisting_{brg.1} - Driving_{brg.1}\right)}{\Sigma V_{brg.1}} + \frac{1}{2}\left(t_{ftg} - t_{wall}\right)\right] + 1.25DC_{ftg.1}\cdot x_{DC.ftg.1}\right]}{\Sigma V_{brg.1} + 1.25DC_{ftg.1}} = 3.258\,ft$$

(Distance to resultant from face of ftg)

$$e_{brg.1} := \max\left(\frac{B_1}{2} - l_{brg.1}, 0ft\right) = 0\,ft$$

$$\sigma_{foot.1} := \frac{\Sigma V_{brg.1}}{B_1 - 2\cdot e_{brg.1}} = 2.704\cdot ksf$$

Eq. 11.6.3.2-1, Rectangular Distibution for Foundations on soil

$$q_R = 6\cdot ksf$$

$$CheckBearing_1 := \begin{cases} \text{"OK"} & \text{if } \frac{q_R}{\sigma_{foot.1}} \geq 1 \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

External Stability Analysis at Anchor 2

<u>Calculate Vertical Loads and Associated Lever Arms</u> ***<u>(All Lever Arms are from Point "O")</u>***

$$DC_{wall.2} := t_{wall}\cdot h_{wall.2}\cdot\gamma_c = 1.243\cdot\frac{kip}{ft}$$

$$x_{DC.wall.2} := \frac{1}{2}t_{wall} = 0.417\,ft$$

$$EV1a_2 := \frac{1}{2}\gamma_s \cdot \left(h_{backfill.2} - h_{wall.2}\right)\cdot\left(d_{slope.2}\right) = 1.299\cdot\frac{kip}{ft}$$

$$x_{EV1a.2} := t_{wall} + \frac{2}{3}d_{slope.2} = 4.914\,ft$$

$$EV1b_2 := \gamma_s \cdot \left(h_{backfill.2} - h_{wall.2}\right)\cdot\left(B_{bot.2} - d_{slope.2}\right) = 0\cdot\frac{kip}{ft}$$

$$x_{EV1b.2} := t_{wall} + d_{slope.2} + \frac{1}{2}\left(B_{bot.2} - d_{slope.2}\right) = 6.955\,ft$$

$$EV2_2 := \gamma_s \cdot \left(h_{wall.2} - 3.5ft\right)\cdot B_{bot.2} = 5.522\cdot\frac{kip}{ft}$$

$$x_{EV2.2} := t_{wall} + \frac{1}{2}B_{bot.2} = 3.894\,ft$$

$$EV3_2 := \gamma_s \cdot (3.5ft)\cdot\left(B_{bot.lower.2} - \frac{7in}{\cos(30deg)}\right) = 1.633\cdot\frac{kip}{ft}$$

$$x_{EV3.2} := t_{wall} + \frac{1}{2}\left(B_{bot.lower.2} - \frac{7in}{\cos(30deg)}\right) = 2.5\,ft$$

$$EV4_2 := \gamma_s \cdot \frac{1}{2}\cdot 3.5ft\cdot\left[\left(W_2 + 3ft + 5.375in\right) - \left(B_{bot.lower.2} - \frac{7in}{\cos(30deg)}\right)\right] = 0.518\cdot\frac{kip}{ft}$$

$$x_{EV4.2} := t_{wall} + B_{bot.lower.2} + \frac{1}{3}\cdot\left[W_2 + 3ft + 5.375in - \left(B_{bot.lower.2} - \frac{7in}{\cos(30deg)}\right)\right] = 5.545\,ft$$

$$DC_{anchor.2} := \frac{1}{trib_2}\cdot \begin{cases} (1740lbf) & \text{if } AnchorType_2 = \text{"B"} \\ (2010lbf) & \text{if } AnchorType_2 = \text{"C"} \\ (2285lbf) & \text{if } AnchorType_2 = \text{"D"} \\ (2550lbf) & \text{if } AnchorType_2 = \text{"E"} \end{cases} = 0.366\cdot\frac{kip}{ft}$$

(See Anchor Geometry Drawing)

$$x_{anchor.2} := t_{wall} + \begin{cases} (2ft + 2.25in) & \text{if } AnchorType_2 = \text{"B"} \\ (2ft + 8.8125in) & \text{if } AnchorType_2 = \text{"C"} \\ (3ft + 5.125in) & \text{if } AnchorType_2 = \text{"D"} \\ (4ft + 0.0625in) & \text{if } AnchorType_2 = \text{"E"} \end{cases} = 4.26\cdot ft$$

$$LS_{vert.2} := \begin{cases} \left[q_{sur}\cdot\left[B_{bot.2} - \left(d_{traffic.2}\right)\right]\right] & \text{if } d_{traffic.2} < B_{bot.2} \\ 0 & \text{otherwise} \end{cases} = 0\cdot\frac{kip}{ft}$$

Used in bearing calcs only

$$x_{LS.vert.2} := t_{wall} + d_{traffic.2} + \frac{1}{2}\left(B_{bot.2} - d_{traffic.2}\right) = 9.245\,ft$$

$$DC_{ftg.2} := \gamma_c \cdot t_{ftg} \cdot h_{ftg} = 1.425 \cdot \frac{kip}{ft}$$

$$x_{DC.ftg.2} := \frac{t_{ftg}}{2} = 1.5\,ft$$

Note: This moment arm is measured from the front toe of the ftg since it is only used in bearing calculations.

Calculate Lateral Loads and Associated Lever Arms

$$EH1_{2.vert} := \frac{1}{2} k_{a.wall} \cdot \gamma_s \cdot \left(h_{backfill.2} - 3.5ft\right)^2 \cdot \sin\left(\delta_{wall}\right) = 1.087 \cdot \frac{kip}{ft}$$

$$EH1_{2.hor} := \frac{1}{2} k_{a.wall} \cdot \gamma_s \cdot \left(h_{backfill.2} - 3.5ft\right)^2 \cdot \cos\left(\delta_{wall}\right) = 2.278 \cdot \frac{kip}{ft}$$

$$x_{EH1.2} := t_{wall} + B_{bot.2} = 6.955\,ft$$

$$y_{EH1.2} := 3.5ft + \frac{1}{3}\left(h_{backfill.2} - 3.5ft\right) = 6.658\,ft$$

$$EH2_{2.vert} := k_{a.anchor} \cdot \gamma_s \cdot \left(h_{backfill.2} - 3.5ft\right) \cdot (4ft) \cdot \sin\left(\delta_{anchor} - 30deg\right) = -0.152 \cdot \frac{kip}{ft}$$

$$EH2_{2.hor} := k_{a.anchor} \cdot \gamma_s \cdot \left(h_{backfill.2} - 3.5ft\right) \cdot (4ft) \cdot \cos\left(\delta_{anchor} - 30deg\right) = 0.657 \cdot \frac{kip}{ft}$$

$$x_{EH2.2} := t_{wall} + \frac{1}{2}\left(B_{bot.2} + B_{bot.lower.2}\right) = 5.898\,ft$$

$$y_{EH2.2} := 3.5ft - \frac{1}{2} \cdot 4ft = 1.5\,ft$$

$$EH3_{2.vert} := \frac{1}{2} k_{a.anchor} \cdot \gamma_s \cdot (4ft)^2 \cdot \sin\left(\delta_{anchor} - 30deg\right) = -0.032 \cdot \frac{kip}{ft}$$

$$EH3_{2.hor} := \frac{1}{2} k_{a.anchor} \cdot \gamma_s \cdot (4ft)^2 \cdot \cos\left(\delta_{anchor} - 30deg\right) = 0.139 \cdot \frac{kip}{ft}$$

$$x_{EH3.2} := t_{wall} + B_{bot.lower.2} + \left(3.5ft - \frac{2}{3} \cdot 4ft\right) \tan(30deg) = 5.321\,ft$$

$$y_{EH3.2} := 3.5ft - \frac{2}{3} \cdot 4ft = 10 \cdot in$$

$$LS_{hor.2} := \begin{cases} \left(k_{a.wall} \cdot q_{sur} \cdot h_{backfill.2}\right) & \text{if } d_{traffic.2} < \frac{h_{wall.2}}{2} \\ 0 & \text{otherwise} \end{cases} = 0 \cdot \frac{kip}{ft}$$

$$x_{LS.hor.2} := t_{wall} + \frac{1}{2}\left(B_{bot.lower.2} + B_{bot.2}\right) = 5.898\,ft$$

(Assumed for ease of calculation)

$$y_{LS.hor.2} := \frac{1}{2} h_{backfill.2} = 6.487\,ft$$

Check Sliding

Per AASHTO 11.11.4.2, Sliding shall be evaluated according to 10.6.3.4. Per 11.5.3, sliding shall be evaluated at the strength limit state. Use minimum load factors for vertical loads and maximum load factors for horizontal loads. Assume the failure plane is beneath the wall ftg, which will be grouted to the wall during construction. This is consistent with assumptions in the HITEC report (page D24).

Resisting Forces

$\phi_\tau := 0.9$ AASHTO Table 10.5.5.2.2-1, "Precast on Sand" or "Soil on Soil"

$$\Sigma V_2 := 0.9\left(DC_{wall.2} + DC_{anchor.2} + DC_{ftg.2}\right) + 1.0\cdot\left(EV1a_2 + EV1b_2 + EV2_2 + EV3_2 + EV4_2\right) \ldots = 13.056\cdot\frac{kip}{ft}$$
$$+\eta_i\cdot 1.50\cdot\left(EH1_{2.vert} + EH2_{2.vert} + EH3_{2.vert}\right)$$

$$R_{\tau.2} := 0.8\cdot\tan\left(\phi_{ftg}\right)\cdot\Sigma V_2 = 7.314\cdot\frac{kip}{ft}$$ AASHTO 10.6.3.4

$$\boxed{R_{r.2} := \phi_\tau\cdot R_{\tau.2} = 6.582\cdot\frac{kip}{ft}}$$

Driving Forces

$$\Sigma H_{\tau.2} := \eta_i\cdot\left[1.50\cdot\left(EH1_{2.hor} + EH2_{2.hor} + EH3_{2.hor}\right) + 1.75LS_{hor.2}\right] = 4.612\cdot\frac{kip}{ft}$$

$$Check_{sliding.2} := \begin{cases} \text{"OK"} & \text{if } \dfrac{R_{r.2}}{\Sigma H_{\tau.2}} \geq 1 \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Overturning and Eccentricity

Per AASHTO 11.11.4.4, Overturning shall be evaluated according to 11.6.3.3. A maximum of 80% of the retained soil shall be used to resist overturning. Per 11.6.3.3, evaluate overturning and eccentricity at the strength limit state using maximum load factors for horizontal loads and minimum load factors for vertical loads. First, evaluate eccentricity at the base of the panel. Second, evaluate eccentricity at the base of the footing. The location of the resultant of the reaction forces shall be located within the middle half of the base width (panel width plus anchor projection for case 1; footing width plus anchor projection for case 2). Eccentricity is measured from the center of the base width toward the stream side of the footing. Assume that a negative eccentricity (beyond the center of the base, toward the backfill) is acceptable since this condition will engage passive earth pressures.

Resisting Forces

$$Resisting_2 := 0.9\left(DC_{wall.2}\cdot x_{DC.wall.2} + DC_{anchor.2}\cdot x_{anchor.2}\right) \ldots + 1.0\cdot 0.8\cdot\left(EV1a_2\cdot x_{EV1a.2} + EV1b_2\cdot x_{EV1b.2} + EV2_2\cdot x_{EV2.2} + EV3_2\cdot x_{EV3.2} + EV4_2\cdot x_{EV4.2}\right) \ldots + 1.50\left(EH1_{2.vert}\cdot x_{EH1.2} + EH2_{2.vert}\cdot x_{EH2.2} + EH3_{2.vert}\cdot x_{EH3.2}\right) = 39.478\cdot\frac{kip\cdot ft}{ft}$$

Driving Forces

$$Driving_2 := 1.50\cdot\left(EH1_{2.hor}\cdot y_{EH1.2} + EH2_{2.hor}\cdot y_{EH2.2} + EH3_{2.hor}\cdot y_{EH3.2}\right) + 1.75LS_{hor.2}\cdot y_{LS.hor.2} = 24.404\cdot\frac{kip\cdot ft}{ft}$$

$$Check_{OT.2} := \begin{cases} \text{"OK"} & \text{if } \frac{Resisting_2}{Driving_2} \ge 1 \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

$$\Sigma V_{e.2} := 0.9\left(DC_{wall.2} + DC_{anchor.2}\right) + 1.0\cdot 0.8\cdot\left(EV1a_2 + EV1b_2 + EV2_2 + EV3_2 + EV4_2\right) \ldots + 1.50\left(EH1_{2.vert} + EH2_{2.vert} + EH3_{2.vert}\right) = 9.979\cdot\frac{kip}{ft}$$

Case 1: Eccentricity of Resultant without footing

$$l_{case1.2} := \frac{\left(Resisting_2 - Driving_2\right)}{\Sigma V_{e.2}} = 1.51\,ft$$ (Distance to resultant from face of wall)

$$B_{case1.2} := B_{bot.lower.2} + t_{wall} = 4.84\,ft$$

$$e_{case1.2} := \max\left(\frac{B_{case1.2}}{2} - l_{case1.2}, 0ft\right) = 0.91\,ft$$

$$e_{allow.case1.2} := \frac{B_{case1.2}}{4} = 1.21\,ft$$ (Within Middle Half per AASHTO 11.6.3.3)

$$Check_{e.case1.2} := \begin{cases} \text{"OK"} & \text{if } \frac{e_{case1.2}}{e_{allow.case1.2}} \le 1 \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Case 2: Eccentricity of Resultant with footing

$$l_2 := \frac{\left[\Sigma V_{e.2}\cdot\left[\frac{\left(Resisting_2 - Driving_2\right)}{\Sigma V_{e.2}} + \frac{1}{2}\left(t_{ftg} - t_{wall}\right)\right] + 0.9DC_{ftg.2}\cdot x_{DC.ftg.2}\right]}{\Sigma V_{e.2} + 0.9DC_{ftg.2}} = 2.469\,ft$$

(Distance to resultant from face of ftg)

$$B_2 := B_{bot.lower.2} + t_{wall} + \frac{1}{2}\left(t_{ftg} - t_{wall}\right) = 5.924\,ft$$

$$e_2 := \max\left(\frac{B_2}{2} - l_2, 0ft\right) = 0.493\,ft$$

$$e_{allow.2} := \frac{B_2}{4} = 1.481\,ft$$

(Within Middle Half of ftg per AASHTO 11.6.3.3)

$$Check_{e.2} := \begin{cases} \text{"OK"} & \text{if } \frac{e_2}{e_{allow.2}} \le 1 \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Bearing Pressure

Per 11.11.4.3 Evaluate bearing pressure with respect to resistance calculated in 10.6.3. Per HITEC p. D24, use the horizontal portion of the anchor at its base plus the footing width. Evaluate at the strength limit state. Use 100% of the weight of the retained soil. When Live Load Surcharge is present, Strength I with maximum load factors for vertical loads and horizontal loads controls. Include the effects of live load surcharge. Since lever arms are calculated from the front face of the wall, must add to the eccentricity the distance between wall and toe of footing.

$$\begin{aligned} Resisting_{brg.2} := {} & 1.25\left(DC_{wall.2}\cdot x_{DC.wall.2} + DC_{anchor.2}\cdot x_{anchor.2}\right) \ldots \\ & + 1.35\cdot\left(EV1a_2\cdot x_{EV1a.2} + EV1b_2\cdot x_{EV1b.2} + EV2_2\cdot x_{EV2.2} + EV3_2\cdot x_{EV3.2} + EV4_2\cdot x_{EV4.2}\right) \ldots \\ & + 1.35\left(EH1_{2.vert}\cdot x_{EH1.2} + EH2_{2.vert}\cdot x_{EH2.2} + EH3_{2.vert}\cdot x_{EH3.2}\right) \ldots \\ & + 1.75\cdot\left(LS_{vert.2}\cdot x_{LS.vert.2}\right) \end{aligned} = 58.393\cdot\frac{kip\cdot ft}{ft}$$

$$Driving_{brg.2} := 1.35\left(EH1_{2.hor}\cdot y_{EH1.2} + EH2_{2.hor}\cdot y_{EH2.2} + EH3_{2.hor}\cdot y_{EH3.2}\right) + 1.75LS_{hor.2}\cdot y_{LS.hor.2} = 21.964\cdot\frac{kip\cdot ft}{ft}$$

$$\begin{aligned} \Sigma V_{brg.2} := {} & 1.25\cdot\left(DC_{wall.2} + DC_{anchor.2}\right) + 1.35\cdot\left(EV1a_2 + EV1b_2 + EV2_2 + EV3_2 + EV4_2\right) \ldots \\ & + 1.35\cdot\left(EH1_{2.vert} + EH2_{2.vert} + EH3_{2.vert}\right) + 1.75\cdot\left(LS_{vert.2}\right) \end{aligned} = 15.341\cdot\frac{kip}{ft}$$

$$l_{brg.2} := \frac{\left[\Sigma V_{brg.2}\cdot\left[\frac{\left(Resisting_{brg.2} - Driving_{brg.2}\right)}{\Sigma V_{brg.2}} + \frac{1}{2}\left(t_{ftg} - t_{wall}\right)\right] + 1.25DC_{ftg.2}\cdot x_{DC.ftg.2}\right]}{\Sigma V_{brg.2} + 1.25DC_{ftg.2}} = 3.254\,ft$$

(Distance to resultant from face of ftg)

$$e_{brg.2} := \max\left(\frac{B_2}{2} - l_{brg.2}, 0ft\right) = 0\,ft$$

$$\sigma_{foot.2} := \frac{\Sigma V_{brg.2}}{B_2 - 2 \cdot e_{brg.2}} = 2.59 \cdot ksf$$

Eq. 11.6.3.2-1, Rectangular Distibution for Foundations on soil

$$q_R = 6 \cdot ksf$$

$$CheckBearing_2 := \begin{cases} \text{"OK"} & \text{if } \frac{q_R}{\sigma_{foot.2}} \geq 1 \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Wall Reinforcement

Assume the wall stem is cantilevered above the anchor. Use tallest wall section above anchor. Use maximum horizontal load factors to calculate moments and shears. Use minimum load factor for axial compression.

Calculate Horizontal Loads and resp. Lever Arms at top of Anchor

$$h_{wall.internal} := h_{backfill.1} - 3.5ft = 9.705\,ft$$

$$EH_{wall} := \frac{1}{2} k_{a.wall} \cdot \gamma_s \cdot h_{wall.internal}^2 = 2.649 \cdot \frac{kip}{ft} \qquad y_{EH.wall} := \frac{1}{3} h_{wall.1} = 3.391\,ft$$

$$LS_{wall} := \begin{cases} 0 & \text{if } d_{traffic.1} \geq \frac{1}{2} \cdot h_{wall.1} \\ \left(k_{a.wall} \cdot q_{sur} \cdot h_{wall.internal}\right) & \text{otherwise} \end{cases} = 0 \cdot \frac{kip}{ft} \qquad y_{LS.wall} := \frac{1}{2} h_{wall.1} = 5.087\,ft$$

$$Mu_{wall} := \eta_i \cdot \left(1.5 \cdot EH_{wall} \cdot y_{EH.wall} + 1.75 LS_{wall} \cdot y_{LS.wall}\right) = 13.475 \cdot \frac{kip \cdot ft}{ft}$$

$$Vu_{wall} := \eta_i \cdot \left(1.5 EH_{wall} + 1.75 LS_{wall}\right) = 3.973 \cdot \frac{kip}{ft}$$

$$Nu_{wall} := -\eta_i \cdot \left(0.9 \cdot \gamma_c \cdot t_{wall} \cdot h_{wall.internal}\right) = -1.092 \cdot \frac{kip}{ft}$$

Check Moment Capacity

$bar_{wall} := 5$ $\qquad s_{wall} := 9in$ $\qquad cover_{wall} := 2in$

$b_w := 1ft$

$$diam_{wall} := \frac{bar_{wall}}{8} in = 0.625 \cdot in$$

$$As_{wall} := \frac{\pi \cdot diam_{wall}^2}{4} \cdot 12 \frac{in}{s_{wall}} = 0.409 \cdot in^2$$

$$d_{wall} := t_{wall} - cover_{wall} - \frac{diam_{wall}}{2} = 7.688 \cdot in$$

$\phi_{moment} := 0.90$ Per AASHTO 5.5.4.2.1

$\phi_{shear} := 0.90$ Per AASHTO 5.5.4.2.1

Verify that f_y can be substituted for f_s in the equations of 5.7.3.2. This is allowed when $\frac{c}{d_s} \le 0.60$.

$$c_{wall} := \frac{As_{wall} \cdot f_y}{0.85 \cdot f_c \cdot \beta_1 \cdot b_w} = 0.602 \cdot in$$

Simplified equation 5.7.3.1.2-4

$$\frac{c_{wall}}{d_{wall}} = 0.078$$

This is less than 0.60 therefore f_y can be substituted for f_s

$$a_{wall} := \beta_1 \cdot c_{wall} = 0.481 \cdot in$$

$$Mn_{wall} := As_{wall} \cdot f_y \cdot \left(d_{wall} - \frac{a_{wall}}{2} \right)$$

$$Mr_{wall} := \phi_{moment} \cdot Mn_{wall} = 13.708 \cdot kip \cdot ft$$

$$Mu_{wall} \cdot b_w = 13.475 \cdot kip \cdot ft$$

$$Check_{WallFlexure} := \begin{cases} \text{"OK"} & \text{if } \frac{Mr_{wall}}{Mu_{wall} \cdot b_w} \ge 1 \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Minimum Flexural Reinforcement (5.7.3.3.2)

$f_r := 0.24 \cdot \sqrt{f_c \cdot ksi} = 0.537 \cdot ksi$ AASHTO 5.4.2.6

$$I_{g.wall} := \frac{1}{12} \cdot b_w \cdot t_{wall}^3 = 1 \times 10^3 \cdot in^4$$

$y_{t.wall} := \frac{t_{wall}}{2} = 5 \cdot in$ Distance from centroid to extreme tension fibers. Conservatively ignore reinforcement.

$S_{c.wall} := \frac{I_{g.wall}}{y_{t.wall}} = 200 \cdot in^3$

$\gamma_3 := 0.67$ 0.67 = Factor for Grade 60 ASTM A615 rebar

$\gamma_1 := 1.2$ 1.2 = Factor for precast segmental structures

$M_{cr.wall} := \gamma_3 \cdot \gamma_1 \cdot S_{c.wall} \cdot f_r = 7.191 \cdot kip \cdot ft$ Simplified AASHTO Eq 5.7.3.3.2-1

$1.33Mu_{wall} \cdot b_w = 17.922 \cdot kip \cdot ft$

$$Check_{MinSteelWall} := \begin{cases} \text{"OK"} & \text{if } Mr_{wall} \geq \min\left(1.33Mu_{wall} \cdot b_w, M_{cr.wall}\right) \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Shear Resistance at Bottom of Wall (Section 5.8.3.4.2)

The section contains less than the minimum transverse reinforcement specified in 5.8.2.5, therefore use equation 5.8.3.4.2-2 to determine the longitudinal strain effect factor (β) at the location of maximum shear.

$Mu := \max\left(Mu_{wall}, Vu_{wall} \cdot d_{wall}\right)$ In the eqtn below Mu shall not be less than $Vu \cdot d_v$

$$\xi_{s\_wall} := \frac{\frac{|Mu|}{d_{wall}} + 0.5Nu_{wall} + |Vu_{wall}|}{E_s \cdot As_{wall}} \cdot b_w \qquad 1000 \cdot \xi_{s\_wall} = 2.06 \qquad (5.8.3.4.2\text{-}4)$$

$s_{x\_wall} := d_{wall}$

$$s_{xe\_wall} := s_{x\_wall} \cdot \frac{1.38in}{Aggregate_{diam} + 0.63in} = 7.687 \cdot in \qquad (5.8.3.4.2\text{-}5)$$

$$\beta_{wall} := \left(\frac{4.8}{1 + 750 \cdot \xi_{s\_wall}}\right) \cdot \left(\frac{51}{39 + \frac{s_{xe\_wall}}{1in}}\right) = 2.059 \qquad (5.8.3.4.2\text{-}2)$$

$$\Theta_{wall} := 29deg + 3500deg \cdot \xi_{s\_wall} = 36.217 \cdot deg \qquad (5.8.3.4.2\text{-}3)$$

$$Vn_{wall} := \min\left(0.25 \cdot f_c \cdot b_w \cdot d_{wall}, 0.0316 \cdot \beta_{wall} \cdot \sqrt{f_c \cdot ksi} \cdot b_w \cdot d_{wall}\right) = 13.421 \cdot kip \qquad (5.8.3.3)$$

$Vr_{wall} := \phi_{shear} \cdot Vn_{wall} = 12.079 \cdot kip$

$Vu_{wall} \cdot b_w = 3.973 \cdot kip$

$$Check_{WallShear} := \begin{cases} \text{"OK"} & \text{if } \dfrac{Vr_{wall}}{Vu_{wall} \cdot b_w} \geq 1 \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Crack Control in Section 5.7.3.4

Stress in reinforcement calculated per MacGregor "Reinforced Concrete Mechanics and Design" 4th Ed

$$Ms_{wall} := \eta_i \cdot \left(1.0 \cdot EH_{wall} \cdot y_{EH.wall} + 1.0 LS_{wall} \cdot y_{LS.wall}\right) = 8.984 \cdot \frac{kip \cdot ft}{ft}$$

$$Ns_{wall} := -\eta_i \cdot \left(1.0 \cdot \gamma_c \cdot t_{wall} \cdot h_{wall.internal}\right) = -1.213 \cdot \frac{kip}{ft}$$

$$\eta := \frac{E_s}{E_c} = 7.118$$

$$\rho_{wall} := \frac{As_{wall}}{b_w \cdot d_{wall}} = 0.004$$

$$k := \sqrt{2\rho_{wall} + \left(\rho_{wall} \cdot \eta\right)^2} - \rho_{wall} \cdot \eta$$

$$j_{wall} := 1 - \frac{k}{3} = 0.977$$

$$fss_{wall} := \frac{Ms_{wall} + Ns_{wall} \cdot \left(d_{wall} - \frac{t_{wall}}{2}\right)}{As_{wall} \cdot j_{wall} \cdot d_{wall}} = 34.013 \cdot \frac{ksi}{ft}$$

Stress in Reinforcement at Service Limit State

$$d_{c\_wall} := t_{wall} - d_{wall} = 2.313 \cdot in$$

$$\beta_s := 1 + \frac{d_{c\_wall}}{0.7 \cdot \left(t_{wall} - d_{c\_wall}\right)} = 1.43$$

$$\gamma_e := 1.00$$

exposure factor

$$s_{max} := \frac{700 \frac{kip}{in} \cdot \gamma_e}{\beta_s \cdot fss_{wall} \cdot b_w} - 2 \cdot d_{c\_wall} = 9.77 \cdot in$$

$$Check_{MaxSpacing} := \begin{cases} \text{"OK"} & \text{if } s_{wall} \leq s_{max} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Minimum Bar Spacing in Section 5.10.3.1.2:

$s_{min} := \max(diam_{wall}, 1.33Aggregate_{diam}, 1in) = 1 \cdot in$

$Check_{MinSpacing} := \begin{cases} "OK" & \text{if } s_{wall} \ge s_{min} \\ "NG" & \text{otherwise} \end{cases} = "OK"$

Check Maximum Bar Spacing in Section 5.10.3.2:

$s_{max} := \min(1.5 \cdot t_{wall}, 18in) = 15 \cdot in$

$Check_{MaxSpacing} := \begin{cases} "OK" & \text{if } s_{wall} \le s_{max} \\ "NG" & \text{otherwise} \end{cases} = "OK"$

Check Anchor Attachment to Wall

Check Moment Capacity of Connection Bars

Conservatively assume the entire wall is cantilevered about the footing, therefore consider only driving moments. Use total loads instead of loads per foot. Use 100% of soil weight. Must determine controlling anchor, since tributary width is variable, not necessarily the anchor at the tallest wall. Assume only top four connection bars resist tension. This assumption is consistent with HITEC p.D28.

$Mu_{anchor} := \max(Driving_{brg.1} \cdot trib_1, Driving_{brg.2} \cdot trib_2) = 137.275 \cdot kip \cdot ft$

$bar_{anchor} := 5$ size of bar

$diam_{anchor} := \frac{bar_{anchor}}{8} in = 0.625 \cdot in$

$As_{anchor} := \frac{\pi}{4} \cdot diam_{anchor}^2 = 0.307 \cdot in^2$

$n := 6$ Number of bars in tension

$b_{anchor} := t_{stem} = 6 \cdot in$ thickness of anchor stem

$h_{stem} := 3ft + 6in$ height of anchor stem

$d_{anchor} := 30.5in$ distance from centroid of tension reinforcement extreme compression fiber.

Verify that f_y can be substituted for f_s in the equations of 5.7.3.2. This is allowed when $\frac{c}{d_s} \le 0.60$.

$c_{anchor} := \frac{n \cdot As_{anchor} \cdot f_y}{0.85 \cdot f_c \cdot \beta_1 \cdot b_{anchor}} = 5.414 \cdot in$ Simplified equation 5.7.3.1.2-4

$\frac{c_{anchor}}{d_{anchor}} = 0.178$

This is less than 0.60 therefore f_y can be substituted for f_s

$a_{anchor} := \beta_1 \cdot c_{anchor} = 4.331 \cdot in$

$Mn_{anchor} := n \cdot As_{anchor} \cdot f_y \cdot \left(d_{anchor} - \frac{a_{anchor}}{2} \right)$

$Mr_{anchor} := \phi_{moment} \cdot Mn_{anchor} = 234.708 \cdot kip \cdot ft$

$Mu_{anchor} = 137.275 \cdot kip \cdot ft$

$$Check_{AnchorFlexure} := \begin{cases} \text{"OK"} & \text{if } \frac{Mr_{anchor}}{Mu_{anchor}} \geq 1 \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Minimum Flexural Reinforcement (5.7.3.3.2)

$f_r = 0.537 \cdot ksi$

AASHTO 5.4.2.6

$I_{g.anchor} := \frac{1}{12} \cdot t_{stem} \cdot h_{stem}^3 = 3.704 \times 10^4 \cdot in^4$

$y_{t.anchor} := \frac{h_{stem}}{2} = 1.75\,ft$

Distance from centroid to extreme tension fibers.
Conservatively ignore reinforcement.

$S_{c.anchor} := \frac{I_{g.anchor}}{y_{t.anchor}} = 1.764 \times 10^3 \cdot in^3$

$\gamma_3 := 0.67$

0.67 = Factor for Grade 60 ASTM A615 rebar

$\gamma_1 := 1.2$

1.2 = Factor for precast segmental structures

$M_{cr.anchor} := \gamma_3 \cdot \gamma_1 \cdot S_{c.anchor} \cdot f_r = 63.426 \cdot kip \cdot ft$

Simplified AASHTO Eq 5.7.3.3.2-1

$1.33 Mu_{anchor} \cdot b_w = 182.575\,ft \cdot kip \cdot ft$

$$Check_{MinSteelAnchor} := \begin{cases} \text{"OK"} & \text{if } Mr_{anchor} \geq \min\left(1.33 Mu_{anchor}, M_{cr.anchor}\right) \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Check Minimum Steel for Temperature and Shrinkage (11.6.1.5.1 & 5.10.8)

$$As_{min.anchor} := \max\left[0.11\frac{in^2}{ft}, \min\left[0.60\frac{in^2}{ft}, \frac{1.30 \cdot b_{anchor} \cdot h_{stem}}{2 \cdot \left(b_{anchor} + h_{stem}\right) \cdot \frac{f_y}{ksi}}\right]\right] = 0.6 \cdot \frac{in^2}{ft}$$

$$As_{min.anchor} \cdot h_{stem} = 2.1 \cdot in^2$$

$$As_{anchor} \cdot (n + 2) = 2.454 \cdot in^2$$

Account for extra two bars in compression face

Check Hook Development of Connection Steel in Wall

Per 5.10.2, A standard hook with a 180 degree bend shall have a 4*db extension, but not less than 2.5 inches. Per 5.12.3, Cover beyond free end of bar shall be 2 inches.

$$l_{hb} := \frac{38.0 diam_{anchor}}{\sqrt{\left(\frac{f_c}{ksi}\right)}} = 10.621 \cdot in$$

Basic development length for a Grade 60 bar with a standard hook (AASHTO 5.11.2.4.1)

Modification Factors to be applied to the Basic Development Length (AASHTO 5.11.2.4.2)

$M_{strength} := 1$ — Increase by fy/60 for yield strength greater than 60ksi

$M_{cover} := 0.7$ — 0.7 if side cover normal to plane of hook is at least 2.5 inches AND Cover beyond hook is at least 2.0in

$M_{stirrups} := 1.0$ — 0.8 if hook is enclose in with ties or stirrups as specified in 5.11.2.4.2

$M_{As} := 1.0$ — Conservatively assume entire area of steel provided is required.

$M_{lightweight} := 1.0$ — 1.3 if lightweight concrete is used.

$M_{epoxy} := 1.0$ — 1.2 if epoxy rebar is used.

$$M := M_{strength} \cdot M_{cover} \cdot M_{stirrups} \cdot M_{As} \cdot M_{lightweight} \cdot M_{epoxy} = 0.7$$

$$l_{dh} := \max\left(6in, 8 \cdot diam_{anchor}, M \cdot l_{hb}\right) = 7.435 \cdot in$$

$$t_{wall.min} := cover_{wall} + l_{dh} = 9.435 \cdot in$$

$$Check_{Wall.Thickness} := \begin{cases} \text{"OK"} & \text{if } t_{wall} \geq t_{wall.min} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Lifting Capacity Checks - Bridge #52, Winhall VT

Case 1 - "5 Ton Utility Anchor, 2 Pick Points"

Note: Case 1 covers cutoff walls, wingwall footings, and wingwalls.

$SWL_{case1} := 10kip$ — Safe working load of a "Oxford A750-7", i.e. 5-ton utility anchor, at 60deg sling angle, 4:1 SF

$n_{case1} := 2$ — Number of anchors used in controlling condition

$W_{case1} := 15.42kip$ — Weight of heaviest pick, WW1

$$\frac{SWL_{case1} \cdot n_{case1}}{W_{case1}} = 1.297$$

$$\begin{cases} \text{"OK"} & \text{if } \frac{SWL_{case1} \cdot n_{case1}}{W_{case1}} \geq 1 \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Case 2 - "RL-24 4T Plate Anchor, 2 Pick Points"

Note: Case 2 covers box culvert top slabs when stripping.

$SWL_{case2} := 8kip = 8 \cdot kip$ — Safe working load of a "Meadow Burke RL-24 4T x 3.5" Plate Anchor, straight pick from overhead crane, 4:1 SF

$n_{case2} := 2$ — Number of anchors used in controlling condition

$W_{case2} := 15.79kip$ — Weight of heaviest pick, box culvert top slab (typ)

$$\frac{SWL_{case2} \cdot n_{case2}}{W_{case2}} = 1.013$$

$$\begin{cases} \text{"OK"} & \text{if } \frac{SWL_{case2} \cdot n_{case2}}{W_{case2}} \geq 1 \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Case 3 - "RL-24 4T Plate Anchor, 4 Pick Points"

Note: Case 3 covers box culvert base sections when stripping, base sections when setting in field, and top slabs when setting in field.

$SWL_{case3} := 8kip \cdot \sin(60deg) = 6.928 \cdot kip$

Safe working load of a "Meadow Burke RL-24 4T x 3.5" Plate Anchor, 60 degree sling angle, 4:1 SF

$n_{case3} := 4$

Number of anchors used in controlling condition

$W_{case3} := 24.78kip$

Weight of heaviest pick, box culvert base sections with baffle (typ)

$$\frac{SWL_{case3} \cdot n_{case3}}{W_{case3}} = 1.118$$

$$\begin{cases} \text{"OK"} & \text{if } \frac{SWL_{case3} \cdot n_{case3}}{W_{case3}} \geq 1 \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

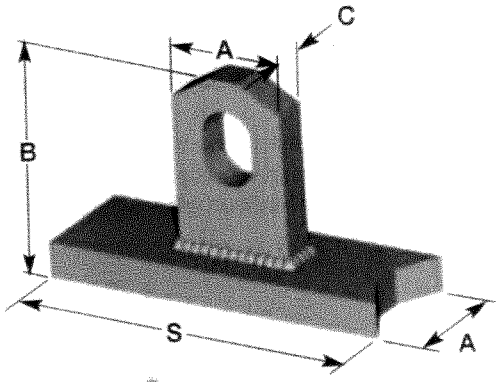
Rapid Lift System Anchors

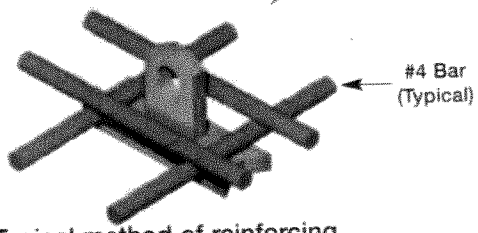
(6060) RL-24 PLATE ANCHOR
2-Ton, 4-Ton and 8-Ton

The RL-24 Plate Anchor is designed with a plate welded to the bottom to provide high pullout strength with a low profile. This design makes the anchor ideal for face and back lifts of thin-wall units and stripping, handling and erection applications. The Plate Anchor is available in the sizes shown in the table and in plain or hot dip galvanize finish.

See Ring clutches on page 46, 47, and 48, and the Recessing Members on page 49, 50 and 53.

Reinforcing Recommendation:
Crisscross the lower plate of the anchor with four (4) 18" long #4 rebar as shown in the sketch.





Typical method of reinforcing Plate Anchors

36 **NOTE:** The Plate Anchor has allowable face shear loads that are equal to or greater than the face tension loads for anchors located in a panel or concrete unit at a distance of at least 3B+A from the edges.

RL-24 RAPID LIFT PLATE ANCHOR DATA

Ring Clutch System	Clutch I.D.	Item Number	A	B	C	S	Allowable Unreinforced Tension Load 4:1 SF (lbs)	Allowable Reinforced Tension Load 4:1 SF (lbs)	Ultimate Mechanical Load Tension (lbs)	Weight Per Piece (lbs)
2T/2.5T	2.5T	79128	1 1/4"	2 1/4"	3/8"	3 3/4"	952	4,000	16,000	0.71
4T/5T	5T	45846	1 1/2"	3"	5/8"	3"	3,574	8,000	32,000	1.21
4T/5T	5T	45847	1 1/2"	3 1/2"	5/8"	3"	4,700	8,000	32,000	1.31
4T/5T	5T	79044	1 1/2"	4 3/8"	5/8"	3 7/8"	4,732	8,000	32,000	1.91
8T/10T	10T	79054	2 1/2"	6 1/4"	3/4"	5"	6,350	12,000	64,000	4.29
8T/10T	10T	79043	–	7 1/8"	Discontinued: See Plate Anchor Item 79042					
8T/10T	10T	79042	2 1/2"	7 1/8"	3/4"	5"	10,000	16,000	64,000	5.55

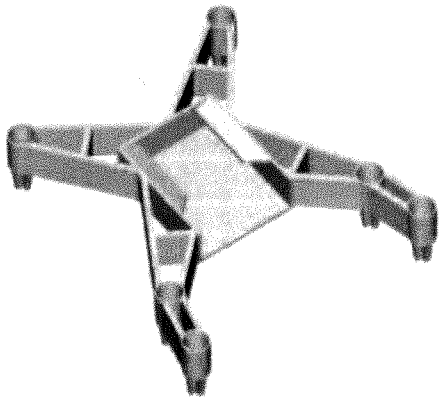
1) Table is based on dead load only, 150 PCF and a standard concrete compressive strength of 3,500 psi and a minimum edge distance of (3B+A)/2.
2) Tension values shown are based on 3,000 psi standard weight concrete, a minimum edge distance of 10" and #4 rebar cut to 18" lengths reinforcing the anchor as shown in the sketch.
3) Available with plate anchor base.

To Order, Specify: quantity, name, item number and finish.

(6190) RL-60 PLATE ANCHOR BASE
4-Ton

The RL-60 Plate Anchor Base is a plastic base designed for use with specific RL-24 Plate Anchor 4-Ton units (item numbers 45846 and 45847) to hold and position the anchors in face lift applications.

To Order, Specify: quantity, name and item number.



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Oxford Lift System®

Anchors & Accessories

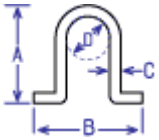
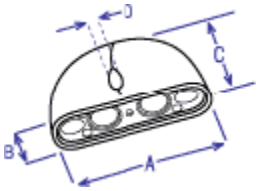
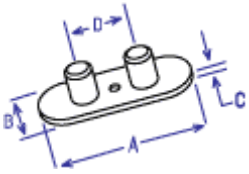
Anchor	Product Code	A	B	C	D	Unit Weight
	**A 500-3**	3.00"	6.25"	(1/2") .500"	2.00"	.625 lbs.
	A 500-4	4.00"	6.25"	(1/2") .500"	2.00"	.75 lbs.
	A 500-5	5.00"	6.25"	(1/2") .500"	2.00"	.775 lbs.
	A 750-5	4.75"	7.50"	(3/4") .750"	3.00"	1.75 lbs.
	A 750-7	6.75"	7.50"	(3/4") .750"	3.00"	2.00 lbs.
Block Out	Product Code	A	B	C	D	Unit Weight
	**B 500**	7.00"	2.00"	3.00"	(1/2") .500"	1.10 lbs.
	Void Dimensions Shown without Anchor					
	B 750	8.00"	3.00"	4.00"	(3/4") .750"	3.50 lbs.
	Void Dimensions Shown without Anchor					
Mounting Plate	Product Code	A	B	C	D	Unit Weight
	**SMP 500** (Snap-On Mounting Plate)	6.50"	1.50"	(3/8") .375"	2.25"	7.95 lbs.
	MMP 500 (Magnetic Mounting	6.50"	1.50"	(3/8") .375"	2.25"	.900 lbs.

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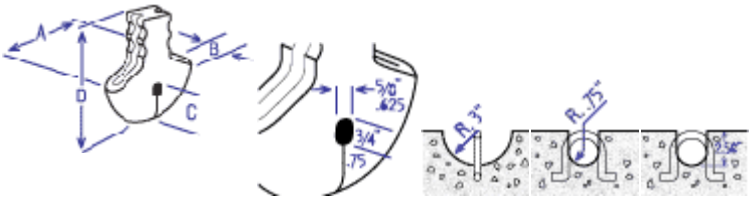
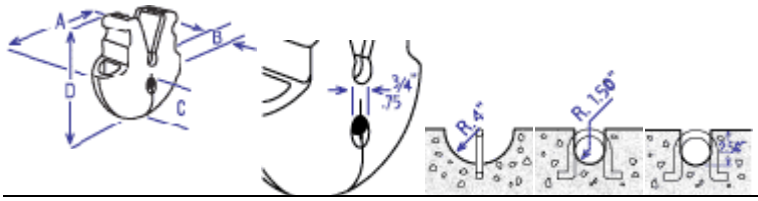
	Plate)					
	SMP 750 (Snap-On Mounting Plate)	7.25"	2.25"	(3/8") .375"	2.25"	1.75 lbs.
	MMP 750 (Magnetic Mounting Plate)	7.25"	2.25"	(3/8") .375"	2.25"	2.00 lbs.
Original Sink-It	Product Code	A	B	C	D	Unit Weight
	S 150	6.00"	1.50"	2.50"	6.75"	1.50 lbs.



S-300 Sink-It	Product Code	A	B	C	D	Unit Weight
	S 300	8.00"	3.00"	3.50"	8.00"	4.00 lbs.



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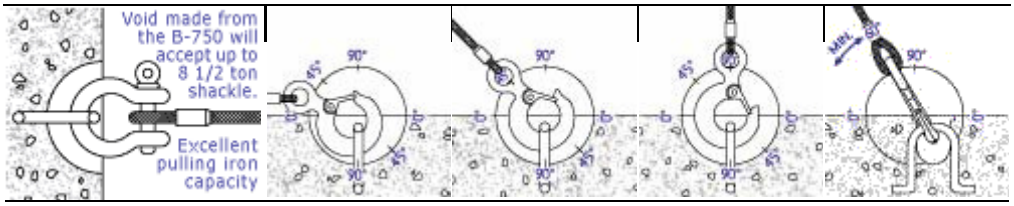

Anchor Product Code	Slab Min. Inches	Safe Working Load @ 90 degree Shear-0 degree Pull	Safe Working Load @ 90 degree Shear-45 degree Pull	Safe Working Load @ 90 degree Tension-90 degree Pull	Safe Working Load @ 90 degree Shear-60 degree Pull
A 500-3	4.00"	4,500	4,000	3,500	4,000
A 500-4	5.00"	8,000	5,500	4,000	5,000
A 500-5	6.00"	10,500	6,500	5,000	5,500
A 750-5	6.00"	12,500	8,000	7,000	7,000
A 750-7	8.00"	15,000	12,500	10,000	10,000

Note: Safe Working Load provides a factor of safety of approximately 4:1
Test Results are based on a minimum concrete compressive strength of 4,000 psi.

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