Flood Risk Management Feasibility Study

Peckman River Basin
New Jersey

Draft Integrated Feasibility Report and Environmental Assessment

Appendix C5: Structural Analysis

US Army Corps of Engineers®
New York District

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SECTION C5 – STRUCTURAL NARRATIVE

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SECTION C5 – STRUCTURAL NARRATIVE

1.0 CODES AND STANDARDS

Design will be based on the following Codes and Standards:

- ACI 318-14 – Building Code Requirements for Structural Concrete
- EM 1110-2-2104 – Strength Design of Reinforced Concrete Hydraulic Structures
- EM 1110-2-2100 – Stability Analysis of Concrete Structures
- EM 1110-2-2502 – Retaining and Flood Walls
- USACE Engineering and Construction Bulletin (ECB) No. 2017-2
- AASHTO LRFD 8th Edition, 2017 – Bridge Design Specifications
- AASHTO LRFR 3rd Edition, 2018 – The Manual for Bridge Evaluation
- EM 1110-2-1913 Design and Constructions of Levees (Pg. 8-16)

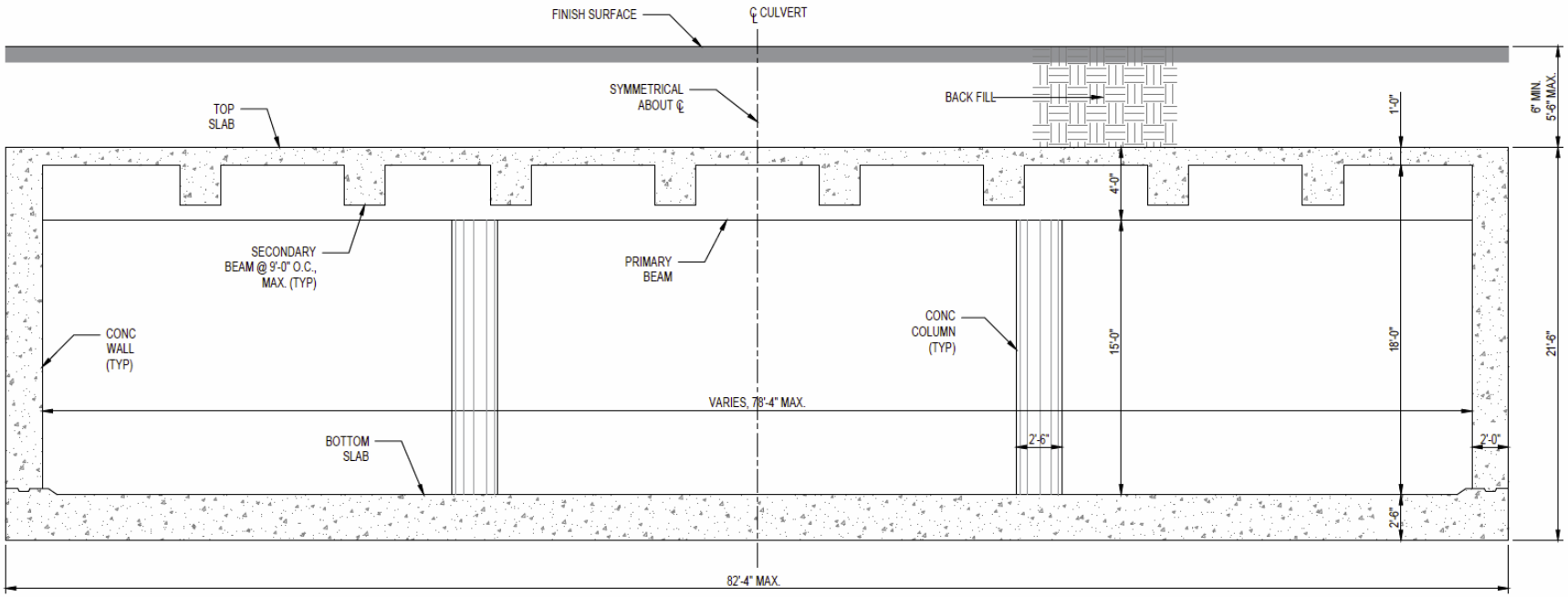
2.0 DIVERSION CULVERT AND OTHER STRUCTURAL COMPONENTS

The diversion culvert is a cast in place reinforced concrete structure consisting of two components: 78.35 to 40 feet wide Culvert Entrance and a 40 feet wide Double Box Culvert.

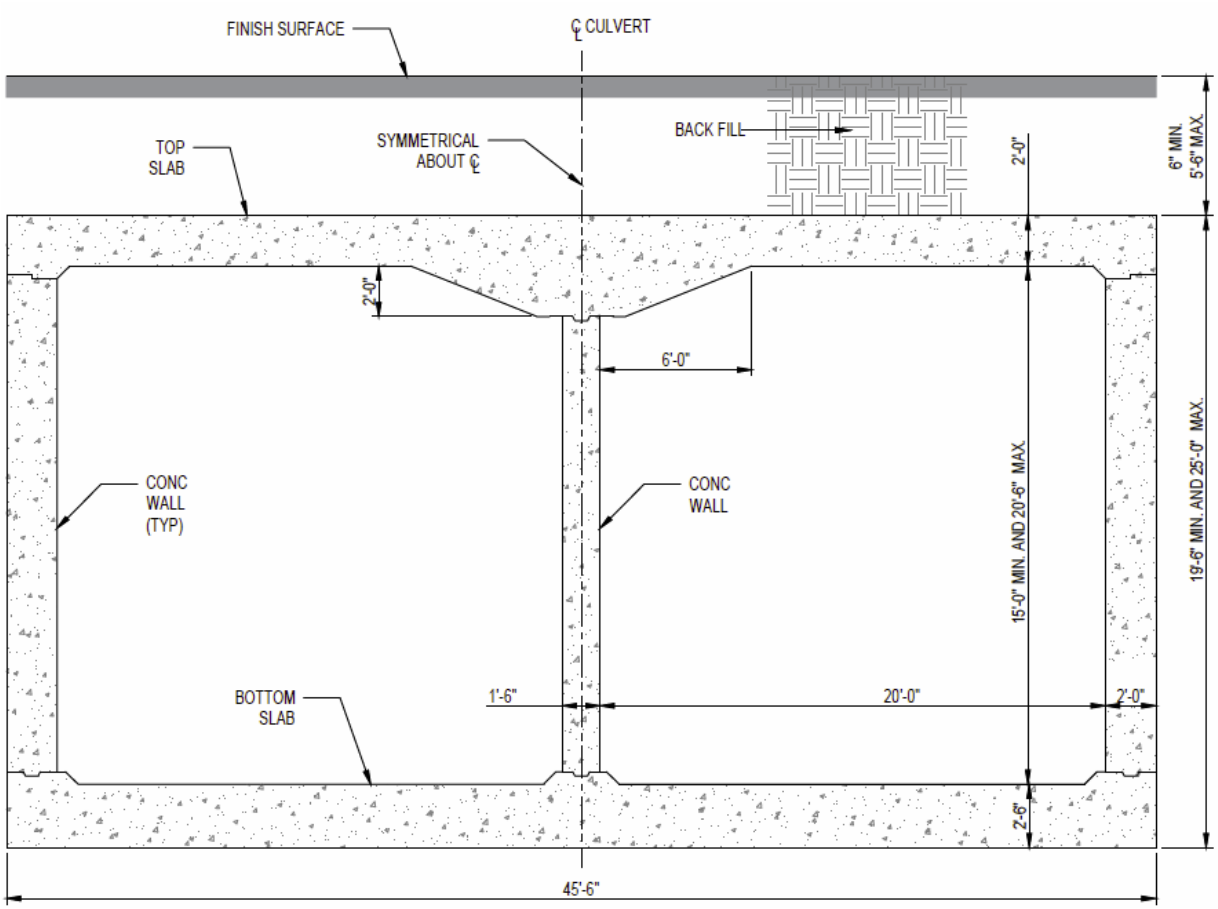
The Culvert Entrance consists of a 12” thick concrete slab, supported by 24” thick exterior concrete walls on both sides and a framing system. The framing system comprises of 36” by 48” primary beams, 27” by 44” secondary beams, and 30” by 66” columns. In addition, 24” by 48” columns are added in the exterior walls to support the primary beam ends. The exterior walls and columns are supported by a 30” thick concrete slab/foundation. Refer to **Culvert Figure 1** for the cross-section of the Culvert Entrance.

The Double Box Culvert consists of a 24” thick concrete slab at top, supported by 24” thick exterior walls on both sides and an 18” thick interior concrete wall at the center of the culvert. The 24” thick concrete slab at the top is thickened to 48”, adjacent to the interior wall where the maximum shear and negative bending moment occur, to optimize the design strength of the section. The exterior walls and interior wall of the culvert are supported by a 30” thick bottom slab/foundation. Refer to **Culvert Figure 2** for the cross-section of the Double Box Culvert.

The backfill over the top of the Culvert Entrance and Double Box Culvert was assumed to be 5 feet with soil backfill and additional 6 inches for wearing surface. The top slab of the Double Box Culvert will be raised up when the backfill depth exceeds 5 feet in height. As a result, the exterior walls will carry more lateral loads. This condition has been considered in the analysis.



Culvert Figure 1: Cross-section of the Culvert Entrance

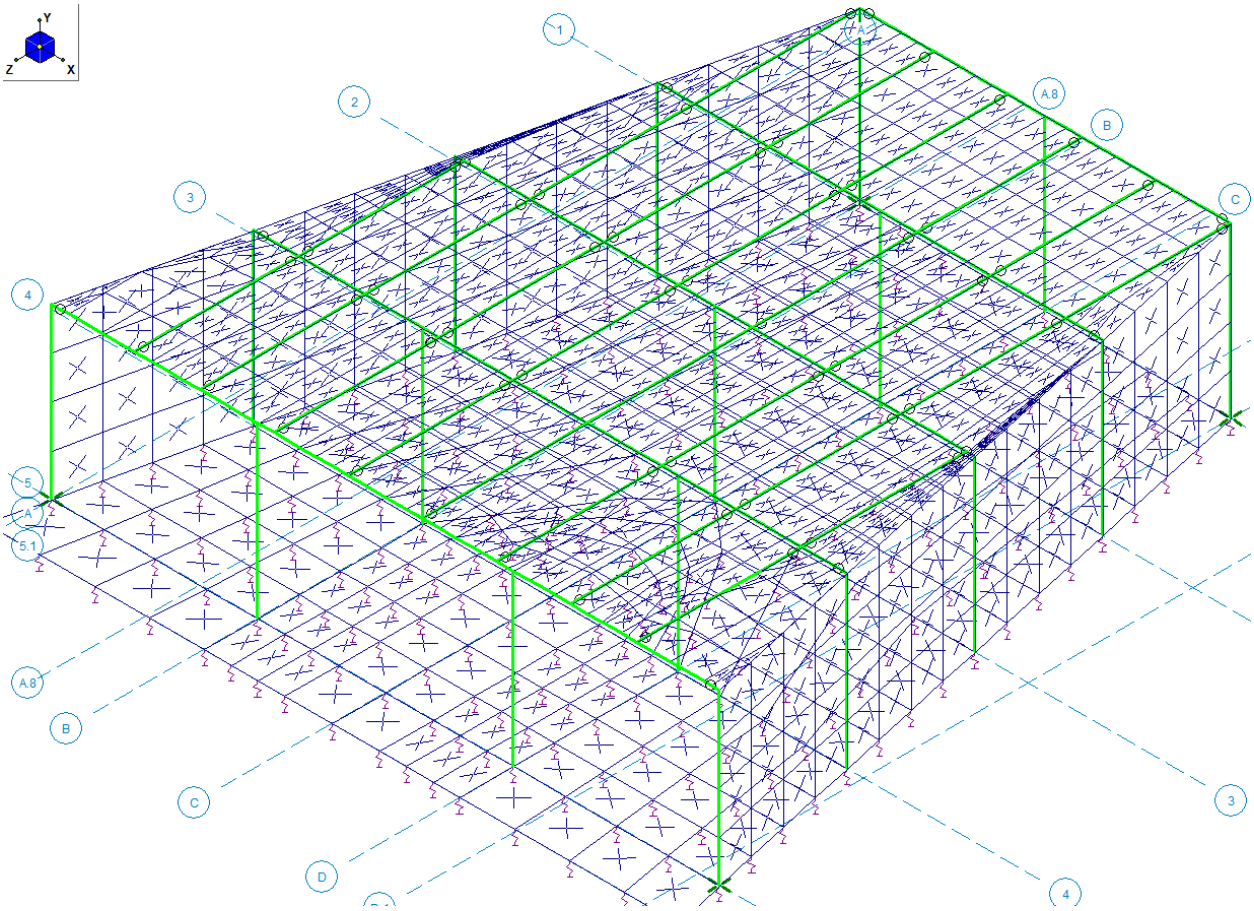


Culvert Figure 2: Cross-section of the Double Box Culvert

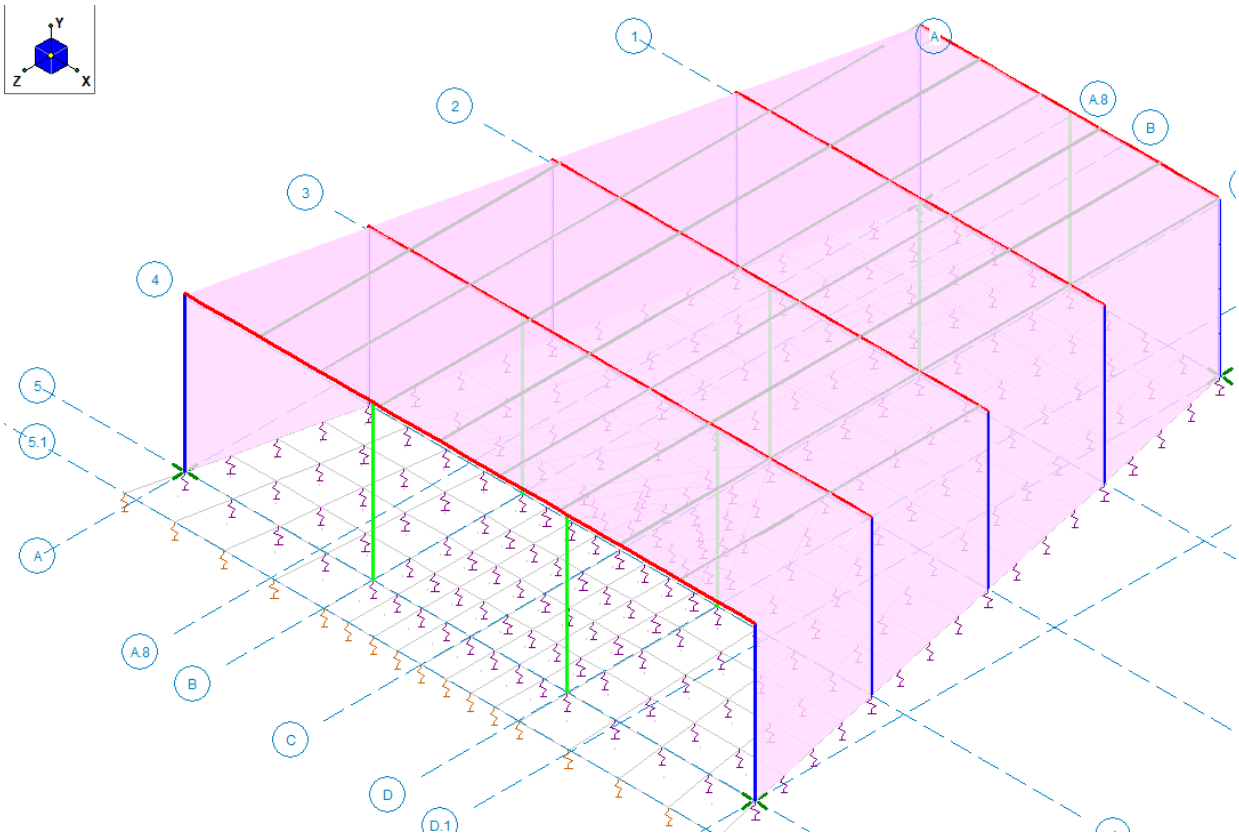
The structural elements are designed to resist various load combinations from wearing surface, vertical earth load, lateral soil and surcharge pressures in accordance with AASHTO LRFD. The top slabs and framing system were conservatively designed for HL93 live load. Concrete thickness and reinforcement cover will be in accordance with EM 1110-2-2104.

Mathcad program V15.0 was used for loading calculations, and RISA 3D V15.0 program was used to analyze the Culvert Entrance and Double Box Culvert.

A comprehensive 3D model with top and bottom slabs, exterior walls, and the framing system was created for the Culvert Entrance structure (see ***Culvert Figure 3*** and **Culvert Figure 4**). In this model, the top and bottom slabs and exterior walls were considered as "plate" elements, and the beams and columns were considered as "rectangular member" elements. The Culvert Entrance structure was designed for 1, 2, and 3-lanes loaded. The corresponding multiple presence factor per AASHTO LRFD, Table 3.6.1.1.2-1 was applied for each case.

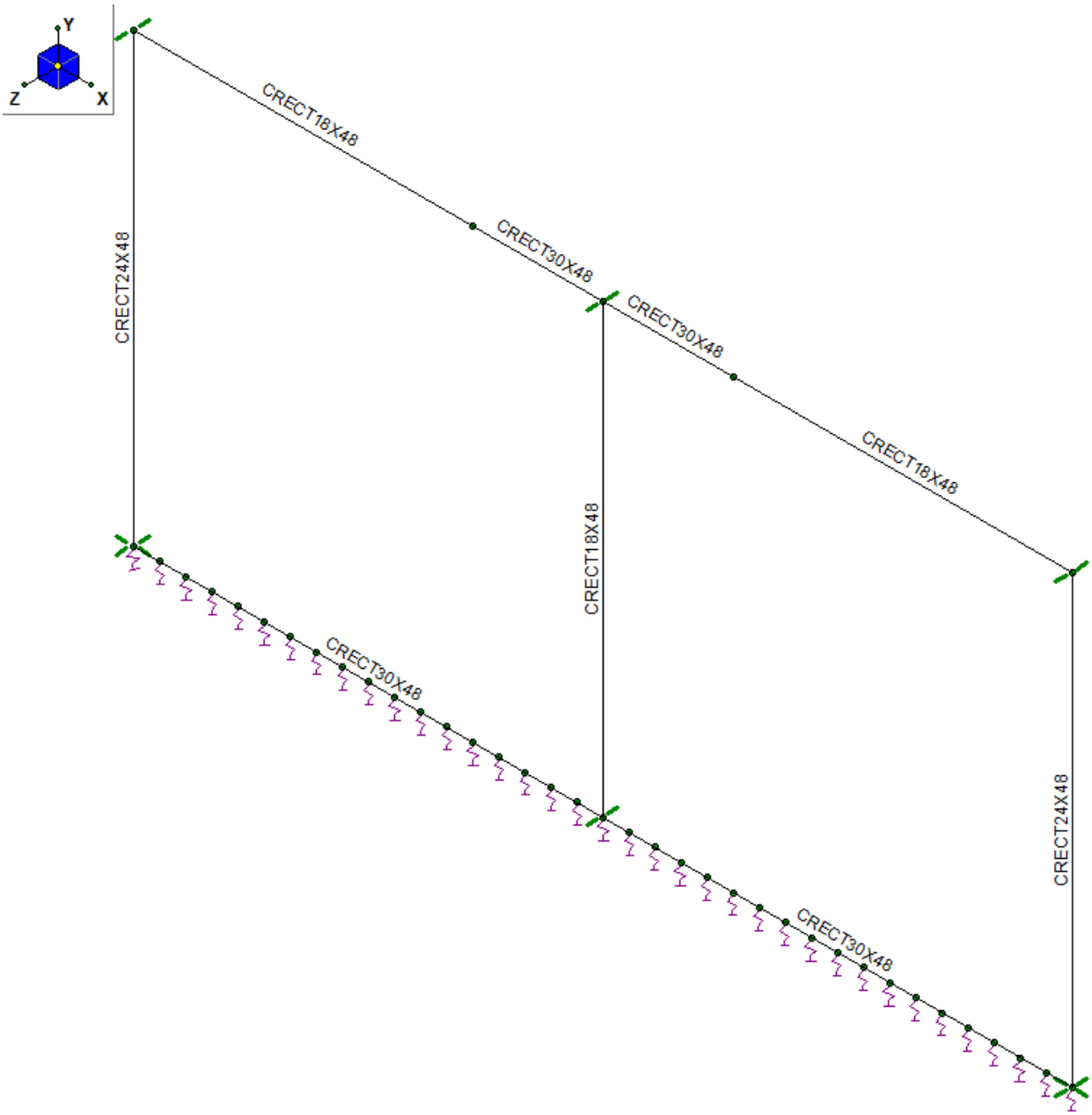


Culvert Figure 3: Culvert Entrance Entire Model in RISA with Plate Elements and Framing System



Culvert Figure 4: Rendered View of the Culvert Entrance Model
(Note: The bottom slab of the culvert was not rendered in the figure in order to highlight the springs of elastic foundation supports)

A simplified 2D model was used to analyze the Double Box Culvert. All elements in this model are rectangular members, 48 inches wide (see **Culvert Figure 5**). The 48 inches wide of rectangular members is used in RISA to optimize the reinforcement results. It should be noted that the loads were calculated in Mathcad per linear foot segments. Thus, the load factors in the load combinations in RISA model were multiplied by 4.



Culvert Figure 5: Double Box Culvert Model in RISA w/ Member Cross-section

Load factors and combinations were based on AASHTO LRFD Section 3.4. However, since this is a preliminary design for cost estimating and constructability evaluation, the minimum load factors, $\square_{min}$, were ignored. These minimum load factors shall be included in design calculations of the next phase of the project.

The culvert was also checked for floatation to determine if the gravity loads would resist the buoyant forces when the culvert is empty. Since this is a preliminary design, there are several unknown parameters, such as final grading plan, that affects the actual gravity loads to resist the

buoyant forces. The height of soil over the top of the culvert were based on the existing natural ground. As shown in the results (see structural appendix), positive uplift does not exist along the culvert. However, a portion of the culvert has demand over capacity ratio close to the allowable value. Therefore, during the next design of the project, if positive uplift exists, it is recommended to use a drain system to lower the groundwater level.

Other structural components, including the Weirs #1 and #2, and retaining walls at the culvert entrance and outlet, were analyzed for stability to study the geometry of the structures. Strength design and reinforcement shall be determined during the next phase of the project after the final grading design of the entire project is complete.

The soil properties used in the analysis are presented in **Table 1** below.

Table 1 – Soil Properties

Soil Properties	Value	Note
Moist unit weight, γ_m	130 pcf	
Saturated unit weight, γ_s	130 pcf	
Normal angle of internal friction, ϕ	32 deg	
Subgrade modulus, k	150 pci	
Bearing capacity, q	3000 psf	

3.0 FLOODWALLS

The floodwalls are cast-in-place reinforced concrete structures. The floodwall stem is one feet thick as a minimum and the footings are 12 feet wide by 2 feet thick. There will be a 3 feet deep by 1 feet thick key at the unprotected side to aid in sliding resistance.

The floodwalls are designed to resist various load combinations from soil and water pressure in addition to permanent and temporary loads as prescribed by EM 1110-2-2100, EM 1110-2-2502, and ECB No. 2017-2.

Based on EM 1110-2-2100 Table B-4, the structure will be evaluated for five (5) different load conditions. Considering the floodwalls as critical structures, ECB No. 2017-2 groups all these load conditions into three (3) categories: usual (<10 year recurrence interval), unusual (10-750 year recurrence interval), and extreme (>750 year recurrence interval). Based on the different load conditions, the structure will be checked for global stability regarding location of resultant (overturning), sliding, flotation, and allowable bearing capacity. The required factors of safety are established on EM 2100 Table 3-2 for sliding and Table 3-4 for flotation. The structure is considered critical when calculating the factor of safety for sliding. Table 3-5 establishes the requirements for the location of the resultant force acting on the structure. The factor of safety for bearing capacity is established on Table 2 of the ECB No. 2017-2.

To analyze the global stability of the structure, a spreadsheet was created in Mathcad V15.0. All the different load conditions were evaluated based on the different water levels and applied loads.

Table B-4 Inland Flood-Wall Loading-Condition Classification
Structure Type: Inland Flood Walls, EM 1110-2-2502

Load Case	Loading Description	Classification
I1	Infrequent Flood	UN
I2	MDF	UN/E
I3a	Coincident Pool + OBE	UN
I3b	Coincident Pool + MCE	E
I4	Construction	UN

Table 1 (EM 1110-2-2100, Table 3-1) Load Condition Probabilities

Load Condition Categories	Annual Probability (p)	Return Period (t_r)
Usual	Greater than or equal to 0.10	Less than or equal to 10 years
Unusual (normal structures)	Less than 0.10 but greater than or equal to 0.0033	Greater than 10 years but less than or equal to 300 years
Unusual (critical structures)	Less than 0.10 but greater than or equal to 0.00133	Greater than 10 years but less than or equal to 750 years
Extreme (normal structures)	Less than 0.0033	Greater than 300 years
Extreme (critical structures)	Less than 0.00133	Greater than 750 years

Table 3-2 Required Factors of Safety for Sliding - Critical Structures

	Load Condition Categories		
Site Information Category	**Usual**	**Unusual**	**Extreme**
Well Defined	1.7	1.3	1.1
Ordinary	2.0	1.5*	1.1*
Limited**	-	-	-

Table 3-4 Required Factors of Safety for Flotation – All Structures

	Load Condition Categories		
Site Information Category	**Usual**	**Unusual**	**Extreme**
All Categories	1.3	1.2	1.1

Table 3-5 Requirements for Location of the Resultant – All Structures

	Load Condition Categories		
Site Information Category	**Usual**	**Unusual**	**Extreme**
All Categories	100% of Base in Compression	75% of Base in Compression	Resultant Within Base

Table 2 Bearing Capacity Minimum Factors of Safety

	Load Condition Categories		
Structure Designation	**Usual**	**Unusual**	**Extreme***
Critical	3.5	3.0	2.0
Normal	3.0	2.0	>1.0

The structures will be designed using the strength design method in accordance with EM 1110-2-2104. The design will follow the established strength and serviceability requirements, applicable loads, load factors and combinations, design equations, and limits and detail of reinforcement.

Serviceability limit states are used for load cases that are likely to occur during the service life of the structure. Strength limit states are used for load cases that are possible, but unlikely to occur during the service life of a structure. EM 2104 provides three (3) general load combinations, two (2) for serviceability and one (1) for strength. The serviceability load combinations are for either usual or unusual load categories. The strength load combination is for the extreme load category. Each load category has specific load factors for each loading type. These load factors are presented in Table 3-1 of the EM.

3.3.2.2. General load combinations.

3.3.2.2.1. Serviceability:

Usual $$U = 2.2\ [\Sigma\ Lp + \Sigma\ Lt_U + Ld_U] \quad (3\text{-}2)$$

Unusual $$U = 1.6\ [\Sigma\ Lp + Lt_{Ni} \text{ or } Ld_{Ni} + \Sigma\ Lt_U + Ld_U{}^*] \quad (3\text{-}3)$$

3.3.2.2.2. Serviceability – For Members in Direct Tension:

Usual $$U = 2.8\ [\Sigma\ Lp + \Sigma\ Lt_U + Ld_U] \quad (3\text{-}4)$$

Unusual $$U = 2.0\ [\Sigma\ Lp + (Lt_{Ni} \text{ or } Ld_{Ni}) + \Sigma\ Lt_U + Ld_U{}^*] \quad (3\text{-}5)$$

3.3.2.2.3. Strength

$$U = \Sigma\ \gamma_X\ Lp + (\gamma_X\ Lt_{Xi} \text{ or } \gamma_X\ Ld_{Xi}) + \Sigma\ 1.0\ Lt_U + 1.0\ Ld_U{}^* \quad (3\text{-}6)$$

Table 3-1. Minimum Load Factors.

Limit State		Serviceability[6]		Strength
Load Category		U. Usual	N. Unusual	X. Extreme
Return Period, years - Critical		10	10-750	> 750
Return Period, years - Normal		10	10-300	> 300
Permanent Loads, Lp		γ_U	γ_N	γ_X
Dead	D	2.2[5]	1.6[5]	1.2[1], 0.9[2]
Vertical Earth	EV	2.2[5]	1.6[5]	1.35[1], 1.0[2]
Lateral Earth	EH	2.2[5]	1.6[5]	See Note 3
Hydrostatic (Companion Load)	Hs	2.2[5]	1.6[5]	1.0
Gravity (Mud/Ice)	G	2.2[5]	1.6[5]	1.6[1], 0[2]
Temporary Loads, Lt		γ_U	γ_N	γ_X
Peak Hydrostatic - Flood, Drought, Surge, Maintenance (Principal Load)	Hs	2.2[5]	1.6[5]	1.0 or 1.3[4]
Thermal Expansion of Ice	IX	NA	1.6[5]	1.0 or 1.3[4]
Soil Surcharge	ES	2.2[5]	1.6[5]	1.0 or 1.3[4]
Operating Equipment	Q	2.2[5]	1.6[5]	1.0 or 1.3[4]
Live Load (vertical)	L	2.2[5]	1.6[5]	ASCE 7[7]
Self Straining	T	2.2[5]	1.6[5]	ACI 318[7]
Vehicle Live Loads	V	2.2[5]	1.6[5]	AASHTO[7]
Dynamic Loads, Ld		γ_U	γ_N	γ_X
Hydrodynamic (except seismic)	Hd	2.2[5]	1.6[5]	1.0 or 1.3[4]
Wave	Hw	2.2[5]	1.6[5]	1.0 or 1.3[4]

Table 3-1. Minimum Load Factors (Continued).

Limit State		Serviceability[6]	Strength	
Debris/Floating Ice Impact	I	2.2[5]	1.6[5]	1.0 or 1.3[4]
Barge/Boat Impact	IM	2.2[5]	1.6[5]	1.0 or 1.3[4]
Wind	W	NA	1.6[5]	ASCE 7[7]
Earthquake	EQ	NA	Para 3.3.3	Para. 3.3.3
Hawser	B	NA	1.6[5]	NA

Table 3-1 Notes:

1. Applied when loads add to the predominant load effect.
2. Applied when loads subtract from the predominant load effect.
3. Load Factors for Lateral Earth Pressure:

   Structures using at-rest pressure for design

   Driving pressure = 1.35; Resisting pressure = 0.9.

   All other structures

   Driving (Active) pressure = 1.5; Resisting (Passive) Pressure = 0.5

   Dynamic analysis (response spectra and time history) of earthquake (at-rest pressure) = 1.0
4. Temporary and dynamic Extreme loads shall be designed with:

   Load factor =1.3

   Loads that are physically limited with return periods lower than 3,000 years for normal structures or 10,000 years for critical structures.

   Loads for which return period cannot be determined.

   Load Factor = 1.0

   Loads that are not limited, for which return period can be determined, with design with return periods greater than or equal to 3,000 years for normal structures or 10,000 years for critical structures.
5. For members in direction tension (net tension across the entire cross section): Usual load factor = 2.8, Unusual load factor = 2.0.
6. Load factors for serviceability limit states are intended to provide designs with stresses in the concrete and reinforcing steel that limit cracking under service loads. The load factors are not reliability based.
7. Where other standards are referenced, load cases and load factors from those standards will be used for design when those loads are primary loads. See load descriptions for details.

Flood Risk Management Feasibility Study

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New Jersey

Integrated Feasibility Report and Environmental Assessment

Appendix C5: Structural Analysis Attachments

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Peckman River
Flood Risk Management Study

Culvert Entrance

Preliminary Analysis

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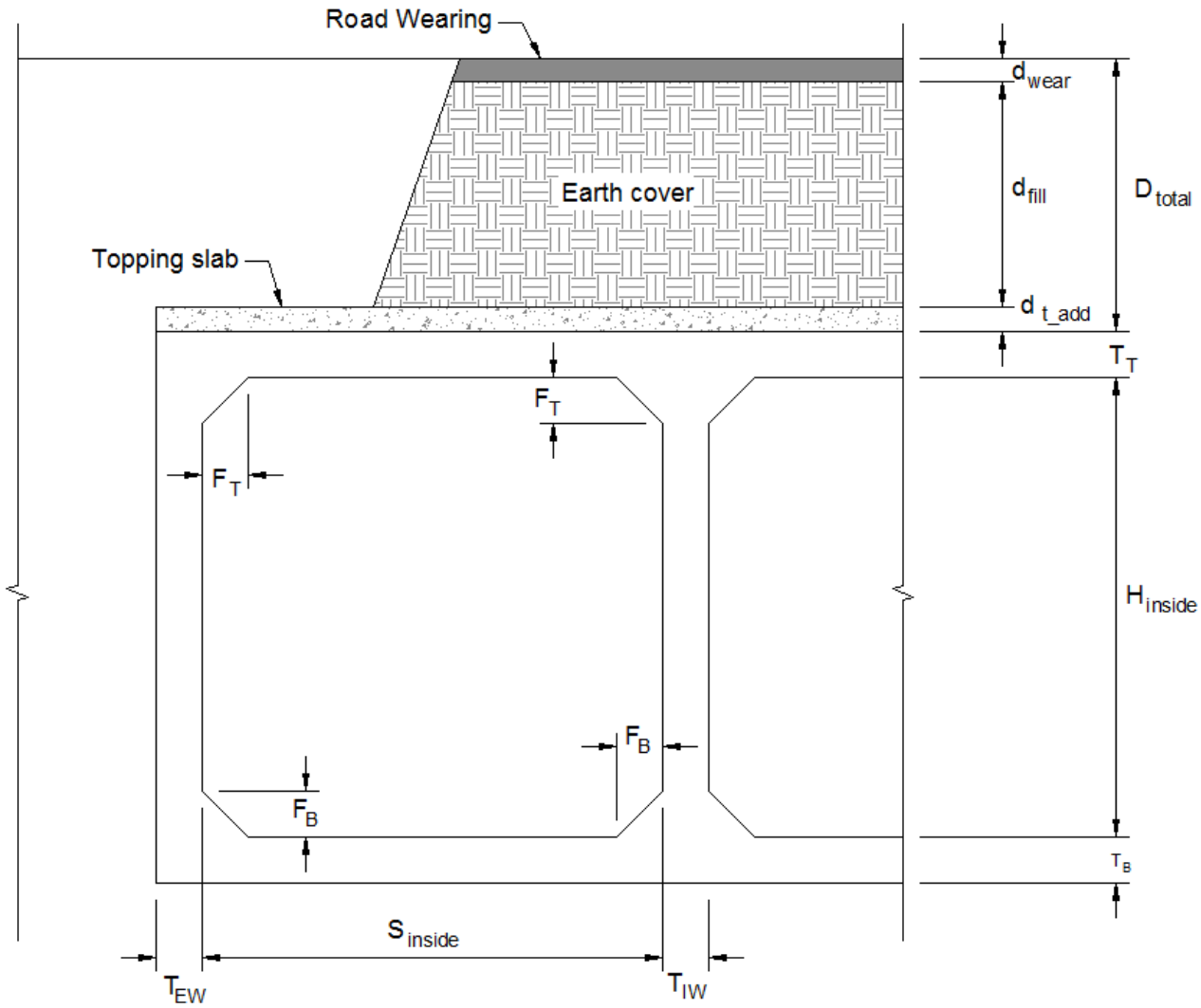
DIMENSIONS

$T_T := 12in$	(top slab thickness)	$T_{EW} := 24in$	(exterior sidewall width)
$T_B := 30in$	(bottom slab thickness)	$T_{IW} := 0in$	(interior sidewall width)
$F_T := 0in$	(top haunch dimension)	$n_{span} := 1$	(number of box spans)
$F_B := 0in$	(bottom haunch dimension)	$H_{inside} := 21.5ft$	(inside height)
$d_{t_add} := 0ft$	(additional topping slab thickness)	$S_{inside} := 78.5ft$	(inside width)
$d_{fill} := 5ft$	(earth fill over top slab)	$d_{DW} := 6in$	(wearing surface)



MATERIAL PROPERTIES

$E_s := 29000ksi$ (steel modulus)

$f'_c := 4000psi$

$F_y := 60ksi$ (yield strength)

$\gamma_{conc} := 150pcf$ (unit weight of concrete, LRFD Table 3.5.1-1)

$\gamma_s := 0.120\frac{kip}{ft^3}$ (unit weight of soil, LRFD Table 3.5.1-1)

$\gamma_{wear} := 140pcf$ (unit weight of asphalt, LRFD Table 3.5.1-1)

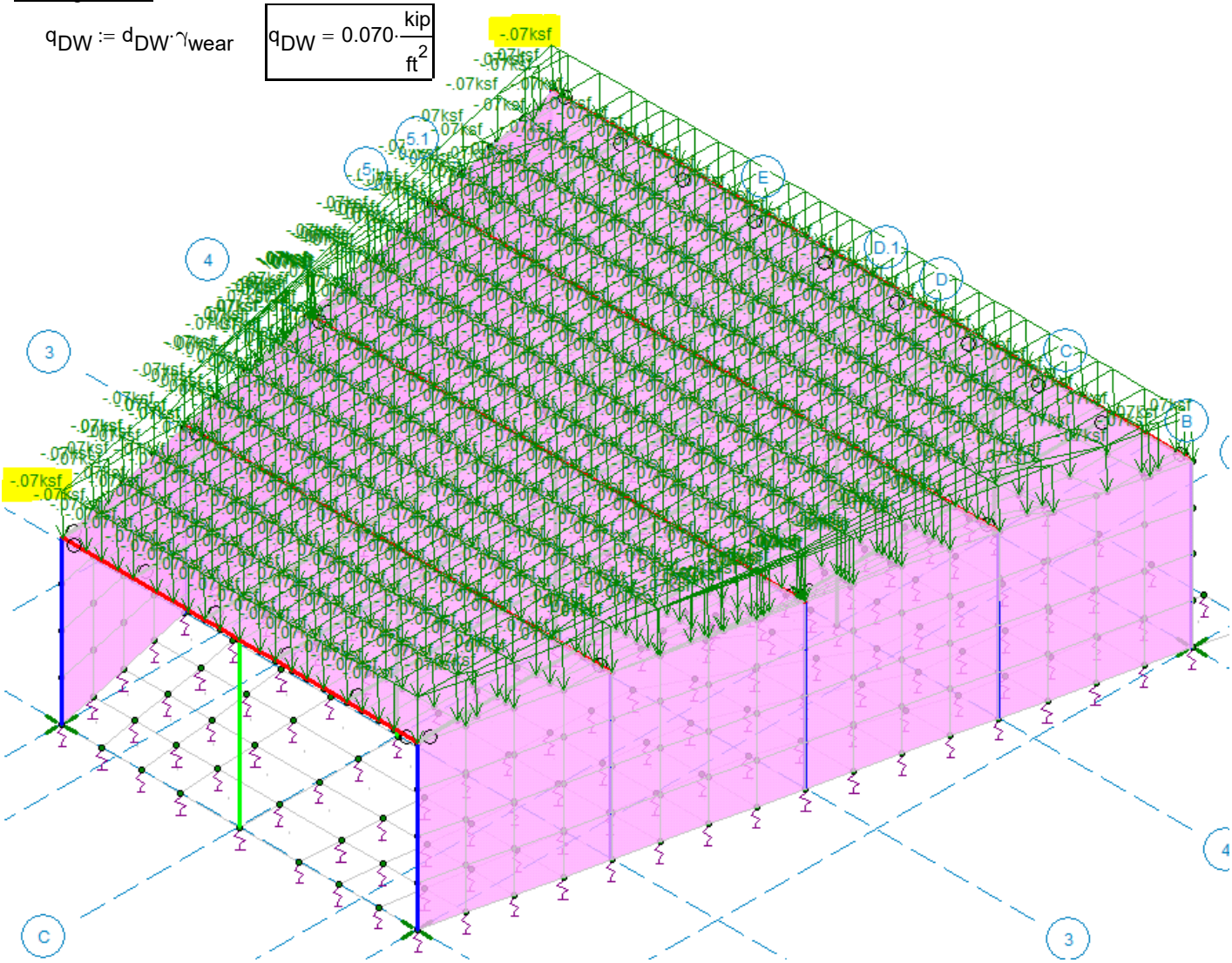
DEAD LOADS, LRFR 6A.5.12.10.1

Self weight:

Self weight DL will be calculated from computer model. (Basic Load Case, **BLC 1**)

Wearing surface:

$q_{DW} := d_{DW} \cdot \gamma_{wear}$ $\quad q_{DW} = 0.070 \cdot \frac{kip}{ft^2}$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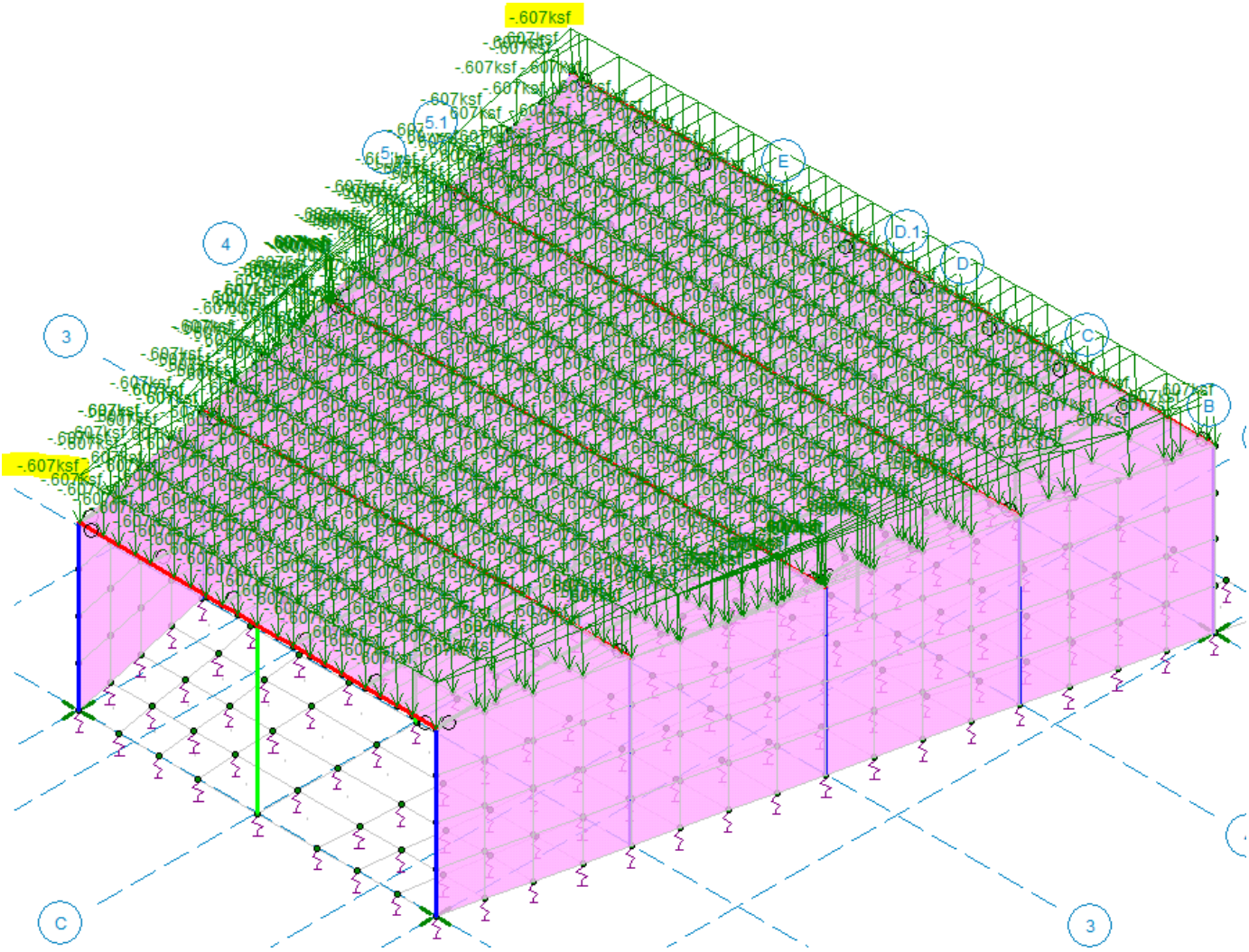
VERTICAL EARTH LOAD, LRFR 6A.5.12.10.2a

$B_{total} := n_{span} \cdot S_{inside} + 2 \cdot T_{EW} + (n_{span} - 1) \cdot T_{IW}$ $\quad B_{total} = 82.5\,ft$ (out to out width of the culvert)

$Fe_v := 1 + 0.20 \cdot \left(\frac{d_{fill}}{B_{total}}\right)$ $\quad Fe_v = 1.01$ (vertical earth load factor, LRFD Eq. 12.11.2.2.1-2)

$q_{ev} := Fe_v \cdot \gamma_s \cdot d_{fill}$ $\quad \boxed{q_{ev} = 0.607 \cdot \frac{kip}{ft^2}}$ (vertical earth load, LRFD Eq. 12.11.2.2.1-1)



Vertical Earth Load Used in RISA 3D (**BLC 3**)

HORIZONTAL EARTH LOAD, LRFR 6A.5.12.10.2b

$k_o := 0.55$ (LRFD C3.11.5.2 assumed typical value)

$z_{top} := d_{fill} + d_{t_add} = 5 \cdot ft$ (effective soil height at top with topping slab)

$z_{bot} := d_{fill} + d_{t_add} + H_{inside} + T_B + T_T = 30 \cdot ft$ (effective soil height at bottom with topping slab)

Earth load on the side of culvert, LRFD 3.11.5.1-1 pg 3-104:

$P_{top_L} := k_o \cdot \gamma_s \cdot z_{top}$ $\quad P_{top_L} = 0.330 \cdot \frac{kip}{ft^2}$

$P_{bot_L} := k_o \cdot \gamma_s \cdot z_{bot}$ $\quad P_{bot_L} = 1.980 \cdot \frac{kip}{ft^2}$

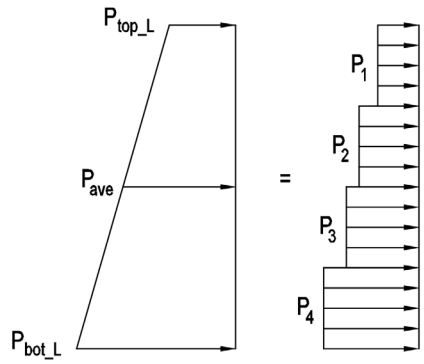
$P_{ave} := \frac{P_{top_L} + P_{bot_L}}{2}$ $\quad P_{ave} = 1.155 \cdot \frac{kip}{ft^2}$

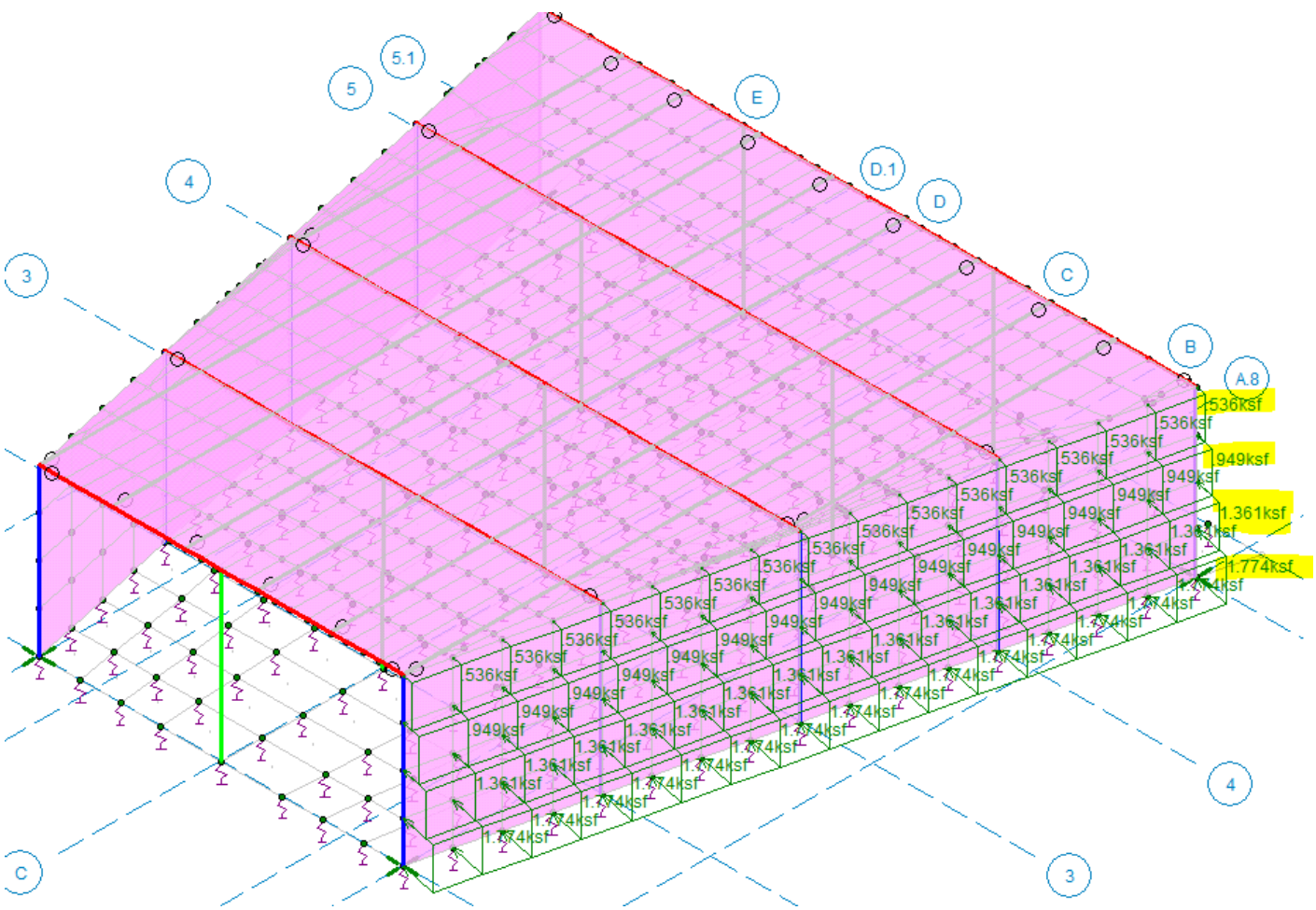
$P_1 := \frac{3P_{top_L} + P_{ave}}{4}$ $\quad P_1 = 0.536 \cdot \frac{kip}{ft^2}$

$P_2 := \frac{P_{top_L} + 3P_{ave}}{4}$ $\quad P_2 = 0.949 \cdot \frac{kip}{ft^2}$

$P_3 := \frac{P_{bot_L} + 3P_{ave}}{4}$ $\quad P_3 = 1.361 \cdot \frac{kip}{ft^2}$

$P_4 := \frac{3P_{bot_L} + P_{ave}}{4}$ $\quad P_4 = 1.774 \cdot \frac{kip}{ft^2}$

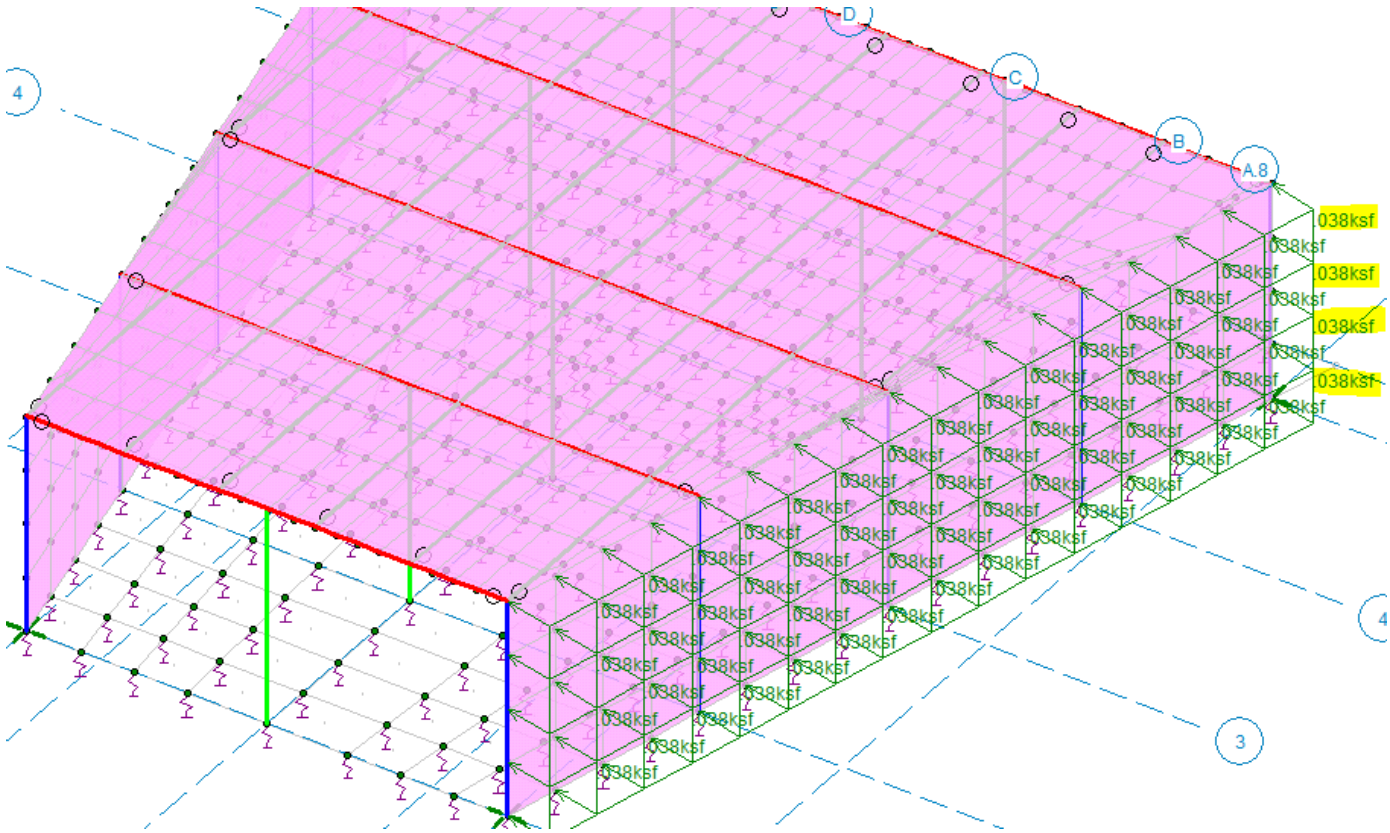




Horizontal Earth Load Used in RISA3D on the left side
(**BLC 4**; similar load applied the right side with **BLC 5**)

SURCHARGE EARTH LOAD, LRFR 6A.5.12.10.2c

$q_{es} := k_o \cdot q_{DW}$ $\quad q_{es} = 0.038 \cdot \frac{kip}{ft^2}$



Surcharge Earth Load Used in RISA 3D on the left side
(**BLC 6**; similar load applied the right side with **BLC 7**)

LIVE LOAD, LRFR 6A.5.12.10.3 and LRFD 3.6.1.2.6

$LLDF := 1.15$ (live load distribution factor, LRFD Table 3.6.1.2.6a-1)

$w_t := 20in$ (tire patch width, LRFD 3.6.1.2.6b pg 3-27)

$s_w := 6ft$ (wheel spacing, LRFD 3.6.1.2.6b pg 3-27)

$L_{tire} := 10in$ (tire patch length, LRFD 3.6.1.2.6b pg 3-28)

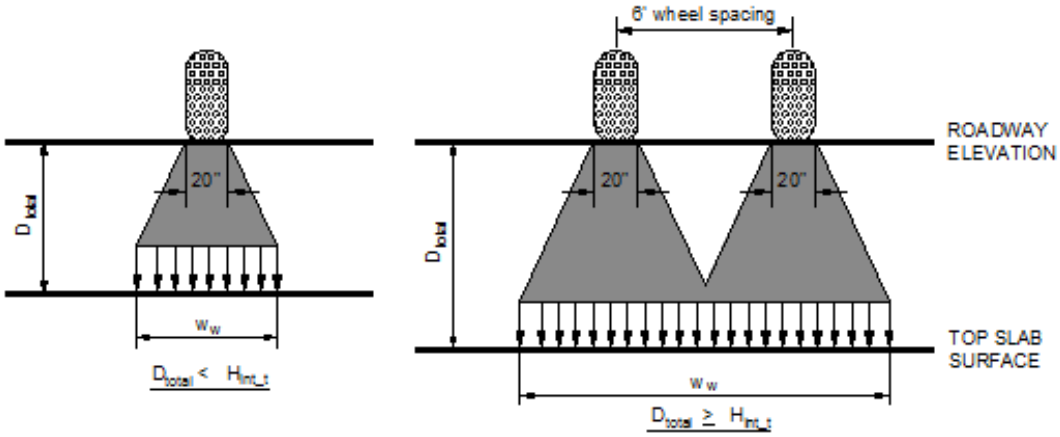
Transverse truck loading width at interaction depth, LRFD 3.6.1.2.6b-1 through 3.6.1.2.6b-3, pg 3-27:

$$H_{int_t} := \frac{(s_w - w_t - 0.06 \cdot S_{inside})}{LLDF} \qquad H_{int_t} = -0.33 \cdot ft$$

$$D_{total} := d_{DW} + d_{fill} \qquad D_{total} = 5.5\,ft$$

(total depth of fill over culvert)

$$w_w := \begin{cases} w_t + LLDF \cdot D_{total} + 0.06 \cdot S_{inside} & \text{if } D_{total} < H_{int_t} \\ (w_t + s_w + LLDF \cdot D_{total} + 0.06 \cdot S_{inside}) & \text{otherwise} \end{cases} \qquad w_w = 18.7\,ft$$



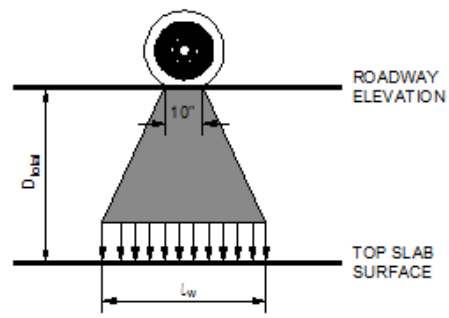
CONTACT AREA PROJECTION OF ONE WHEEL IN TRANSVERSE DIRECTION

Parallel truck loading width at interaction depth, LRFD 3.6.1.2.6b-4 through 3.6.1.2.6b-6, pg 3-27:

$$Liveload := \begin{pmatrix} \text{"truck axle spacing"} \\ \text{"tandem axle spacing"} \end{pmatrix} \qquad s_a := \begin{pmatrix} 14 \\ 4 \end{pmatrix} ft$$

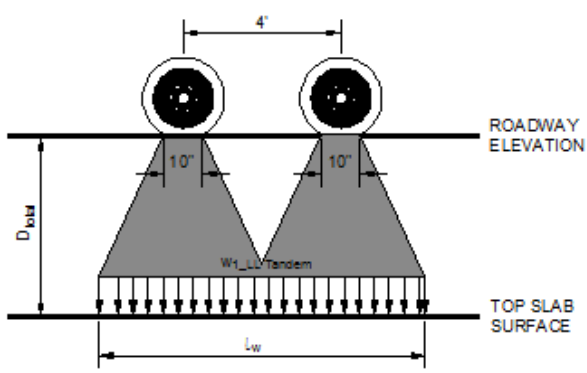
$$H_{int_p} := \frac{(s_a - L_{tire})}{LLDF} \qquad H_{int_p} = \begin{pmatrix} 11.45 \\ 2.75 \end{pmatrix} \cdot ft$$

$$L_w := \left| \begin{array}{l} \text{for } k \in 0 .. last(H_{int_p}) \\ \quad \left| \begin{array}{l} L_{w_k} \leftarrow L_{tire} + LLDF \cdot D_{total} \quad \text{if } D_{total} < H_{int_p_k} \\ L_{w_k} \leftarrow L_{tire} + s_{a_k} + LLDF \cdot D_{total} \quad \text{otherwise} \end{array} \right. \\ L_w \end{array} \right. \qquad L_w = \begin{pmatrix} 7.16 \\ 11.16 \end{pmatrix} ft$$

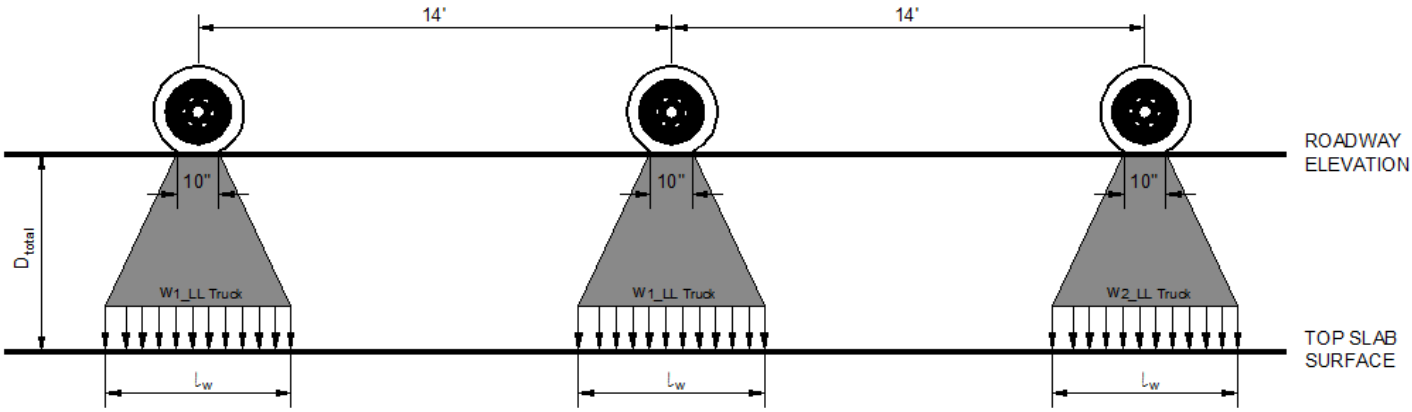


CONTACT AREA PROJECTION OF ONE WHEEL IN LONGITUDINAL DIRECTION

Design live loads:



HL-93 TANDEM AXLE PROJECTION IN LONGITUDINAL DIRECTION



HL-93 DESIGN TRUCK AXLE PROJECTIONS IN LONGITUDINAL DIRECTION

$$IM := 33 \cdot \frac{\left(1 - 0.125 \cdot \frac{D_{total}}{ft}\right)}{100} = 10.3125 \cdot \%$$ (LRFD, Eq. 3.6.2.2-1)

Note: multiple Presence Factor, LRFR 6A.5.12.10.3, will be input in load combination of RISA 3D model

$$W_{LL_tandem} := 4 \cdot 12.5kip \cdot \frac{(1 + IM)}{\left(w_w \cdot L_{w_{01}}\right)} \qquad W_{LL_tandem} = 0.264 \cdot \frac{kip}{ft^2}$$

$$W_{LL_truck} := 2 \cdot 16kip \cdot \frac{(1 + IM)}{\left(w_w \cdot L_{w_{00}}\right)} \qquad W_{LL_truck} = 0.264 \cdot \frac{kip}{ft^2}$$

$$W_{LL} := \begin{pmatrix} W_{LL_truck} \\ W_{LL_tandem} \end{pmatrix} \qquad W_{LL} = \begin{pmatrix} 0.264 \\ 0.264 \end{pmatrix} \cdot \frac{kip}{ft^2} \qquad L_w = \begin{pmatrix} 7.16 \\ 11.16 \end{pmatrix} ft \qquad w_w = 18.7\,ft$$

Determine magnitude and distance between concentrated loads used in model:

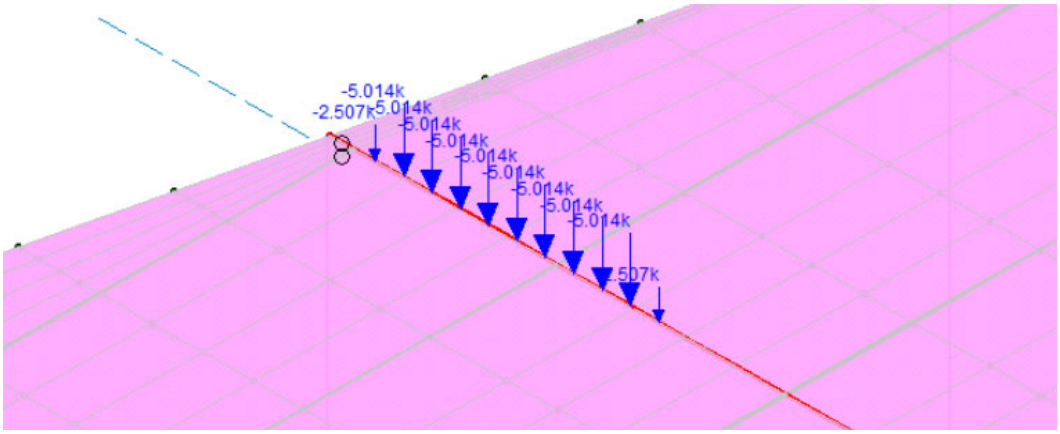
$n := 11$ (number of concentrated loads)

$$P_{LL} := \frac{\overrightarrow{W_{LL} \cdot w_w \cdot L_w}}{n} \qquad \boxed{P_{LL} = \begin{pmatrix} 3.209 \\ 5.014 \end{pmatrix} \cdot kip}$$ (magnitude of intermediate concentrated loads)

$$dist_{LL} := \frac{L_w}{n - 1} \qquad \boxed{dist_{LL} = \begin{pmatrix} 0.716 \\ 1.116 \end{pmatrix} ft}$$ (spacing of the concentrated loads)

Note: Magnitude of first and last concentrated load is equal to: $\frac{P_{LL}}{2} = \begin{pmatrix} 1.605 \\ 2.507 \end{pmatrix} \cdot kip$ $\qquad$ Liveload = ("truck axle spacing" / "tandem axle spacing")

By inspection, Tandem load will control the result. Thus, live load by HS2- truck will be ignored in RISA 3D model.

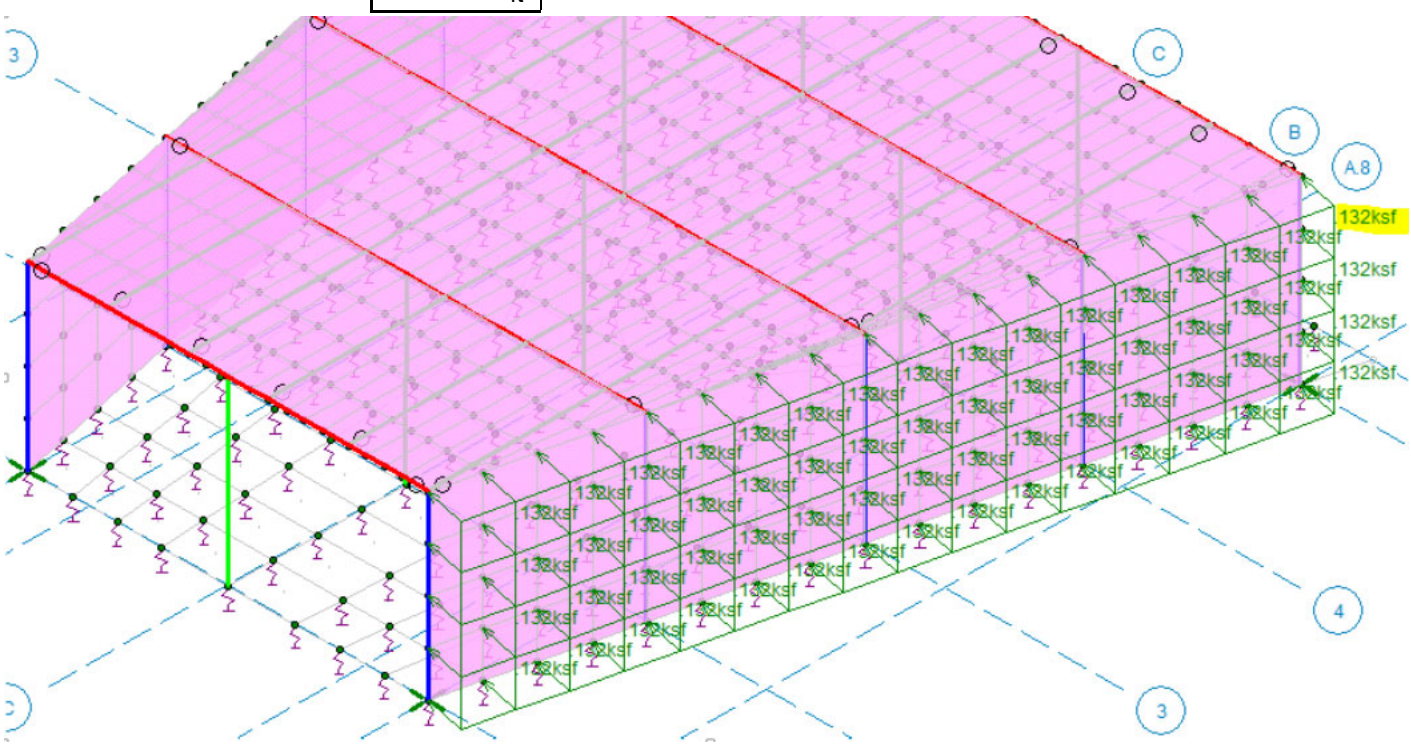


Tandem Live Load Used in RISA 3D
(Moving load **M2**)

SURCHARGE LIVE LOAD, LRFD 3.11.6.4-1

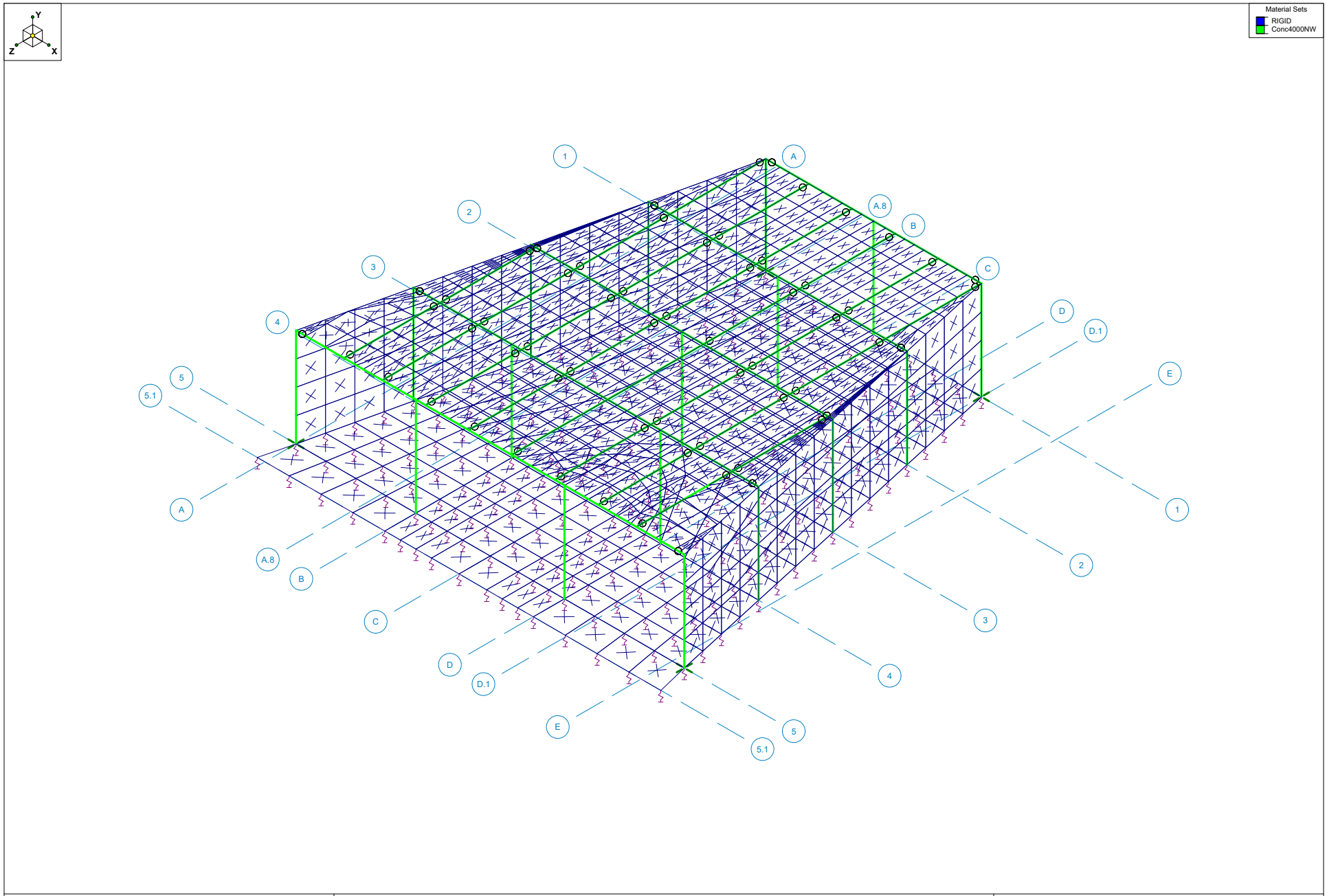
$h_{eq} := 2.00ft$ (equivalent soil height for vehicular load by interpolation with the Height = $z_{bot} = 30\,ft$, LRFD Table 3.11.6.4-1)

$q_{ls} := k_o \cdot h_{eq} \cdot \gamma_s$ $\boxed{q_{ls} = 0.132 \cdot \frac{kip}{ft^2}}$

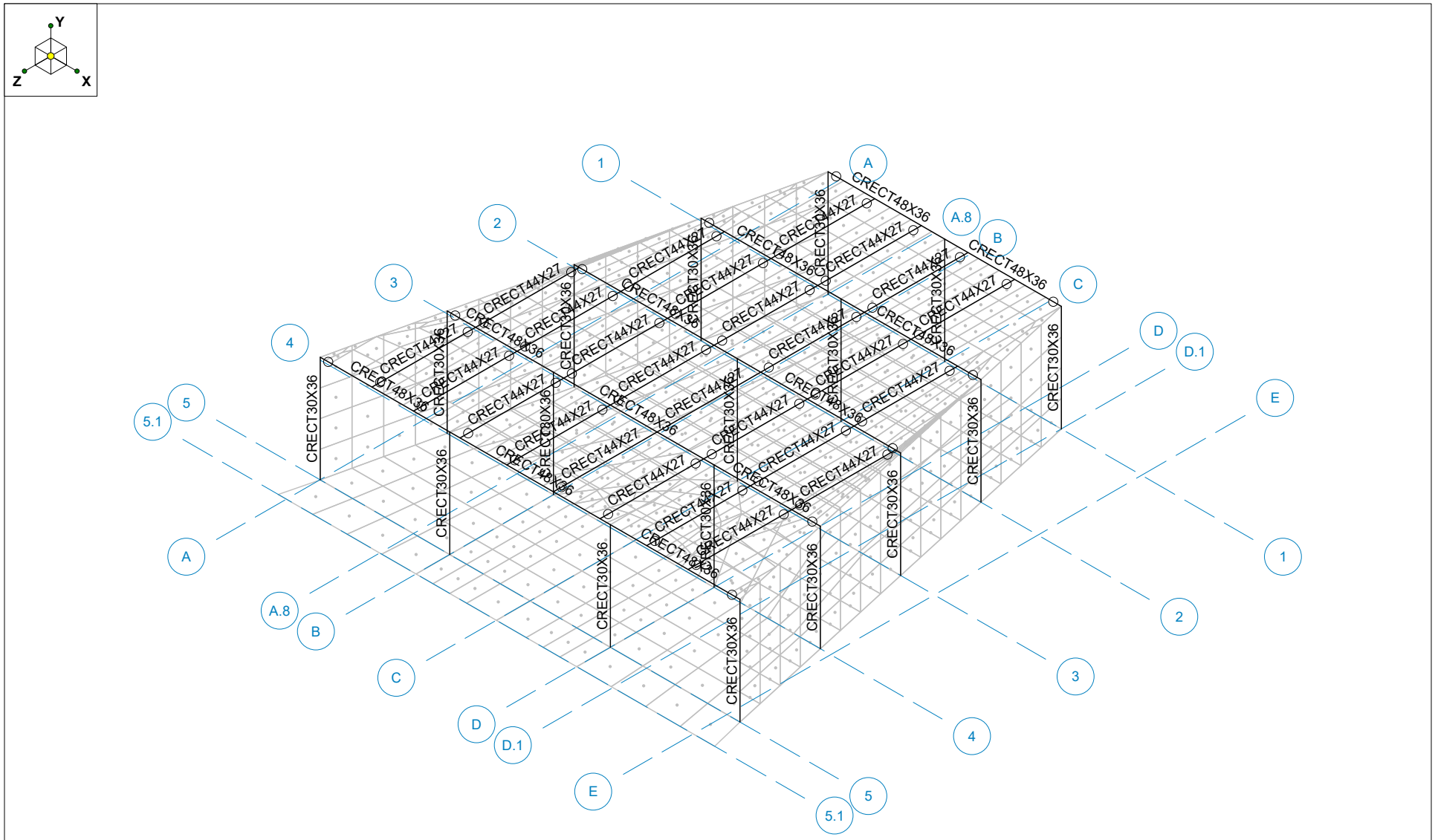


Surcharge Live Load Used in RISA 3D on the left side
(**BLC 8**; similar load applied the right side with **BLC 9**)

Notes: Refer RISA 3D results for culvert analysis.



		SK - 1
TH	Peckman Diversion culvert	June 14, 2019 at 8:59 AM
	CULVERT ENTRANCE MODEL	Peckman_Culvert_Entrance.r3d



		SK - 1
TH	Peckman Diversion culvert	June 14, 2019 at 9:07 AM
	CULVERT ENTRANCE MODEL	Peckman_Culvert_Entrance.r3d

Joint Coordinates and Temperatures

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
1	N1	38	20.5	20	0	
2	N2	20	20.5	100	0	
3	N3	83	20.5	20	0	
4	N4	101	20.5	100	0	
5	N5	60.5	20.5	20	0	
6	N6	33.5	20.5	40	0	
7	N7	60.5	20.5	40	0	
8	N8	87.5	20.5	40	0	
9	N9	29	20.5	60	0	
10	N10	60.5	20.5	60	0	
11	N11	92	20.5	60	0	
12	N12	24.5	20.5	80	0	
13	N13	45	20.5	80	0	
14	N14	76	20.5	80	0	
15	N15	96.5	20.5	80	0	
16	N16	45	20.5	100	0	
17	N17	76	20.5	100	0	
18	N18	38	0	20	0	
19	N19	20	0	100	0	
20	N20	83	0	20	0	
21	N21	101	0	100	0	
22	N22	60.5	0	20	0	
23	N23	33.5	0	40	0	
24	N24	60.5	0	40	0	
25	N25	87.5	0	40	0	
26	N26	29	0	60	0	
27	N27	60.5	0	60	0	
28	N28	92	0	60	0	
29	N29	24.5	0	80	0	
30	N30	45	0	80	0	
31	N31	76	0	80	0	
32	N32	96.5	0	80	0	
33	N33	45	0	100	0	
34	N34	76	0	100	0	
35	N35	60.5	0	80	0	
36	N36	60.5	0	100	0	
37	N37	65	20.5	20	0	
38	N38	65	20.5	40	0	
39	N39	65	20.5	60	0	
40	N40	65	20.5	80	0	
41	N41	65	20.5	100	0	
42	N42	74	20.5	20	0	
43	N43	74	20.5	40	0	
44	N44	74	20.5	60	0	
45	N45	74	20.5	80	0	
46	N46	74	20.5	100	0	
47	N47	83	20.5	40	0	
48	N48	83	20.5	60	0	
49	N49	83	20.5	80	0	
50	N50	83	20.5	100	0	
51	N51	91	20.5	60	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
52	N52	91	20.5	80	0	
53	N53	91	20.5	100	0	
54	N54	56	20.5	20	0	
55	N55	56	20.5	40	0	
56	N56	56	20.5	60	0	
57	N57	56	20.5	80	0	
58	N58	56	20.5	100	0	
59	N59	47	20.5	20	0	
60	N60	47	20.5	40	0	
61	N61	47	20.5	60	0	
62	N62	47	20.5	80	0	
63	N63	47	20.5	100	0	
64	N64	38	20.5	40	0	
65	N65	38	20.5	60	0	
66	N66	38	20.5	80	0	
67	N67	38	20.5	100	0	
68	N68	30	20.5	60	0	
69	N69	30	20.5	80	0	
70	N70	30	20.5	100	0	
71	N71	99	20.5	100	0	
72	N72	22	20.5	100	0	
73	N73	99	20.5	91.111111	0	
74	N74	22	20.5	91.111111	0	
75	N75	69.5	0	70	0	
76	N76	69.5	0	80	0	
77	N77	60.5	0	70	0	
78	N78	67.333333	0	73.333333	0	
79	N79	51.5	0	80	0	
80	N80	51.5	0	70	0	
81	N81	53.666667	0	73.333333	0	
82	N82	66.25	0	80	0	
83	N83	72.75	0	80	0	
84	N84	60.5	0	85	0	
85	N85	66.25	0	85	0	
86	N86	69.5	0	85	0	
87	N87	72.75	0	85	0	
88	N88	76	0	85	0	
89	N89	60.5	0	90	0	
90	N90	66.25	0	90	0	
91	N91	69.5	0	90	0	
92	N92	72.75	0	90	0	
93	N93	76	0	90	0	
94	N94	60.5	0	95	0	
95	N95	66.25	0	95	0	
96	N96	69.5	0	95	0	
97	N97	72.75	0	95	0	
98	N98	76	0	95	0	
99	N99	66.25	0	100	0	
100	N100	69.5	0	100	0	
101	N101	72.75	0	100	0	
102	N102	48.25	0	80	0	
103	N103	54.75	0	80	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
104	N104	45	0	85	0	
105	N105	48.25	0	85	0	
106	N106	51.5	0	85	0	
107	N107	54.75	0	85	0	
108	N108	45	0	90	0	
109	N109	48.25	0	90	0	
110	N110	51.5	0	90	0	
111	N111	54.75	0	90	0	
112	N112	45	0	95	0	
113	N113	48.25	0	95	0	
114	N114	51.5	0	95	0	
115	N115	54.75	0	95	0	
116	N116	48.25	0	100	0	
117	N117	51.5	0	100	0	
118	N118	54.75	0	100	0	
119	N119	29.625	0	80	0	
120	N120	34.75	0	80	0	
121	N121	39.875	0	80	0	
122	N122	23.375	0	85	0	
123	N123	28.78125	0	85	0	
124	N124	34.1875	0	85	0	
125	N125	39.59375	0	85	0	
126	N126	22.25	0	90	0	
127	N127	27.9375	0	90	0	
128	N128	33.625	0	90	0	
129	N129	39.3125	0	90	0	
130	N130	21.125	0	95	0	
131	N131	27.09375	0	95	0	
132	N132	33.0625	0	95	0	
133	N133	39.03125	0	95	0	
134	N134	26.25	0	100	0	
135	N135	32.5	0	100	0	
136	N136	38.75	0	100	0	
137	N137	36.25	0	60	0	
138	N138	43.5	0	60	0	
139	N139	50.75	0	60	0	
140	N140	27.875	0	65	0	
141	N141	34.59375	0	65	0	
142	N142	41.3125	0	65	0	
143	N143	48.03125	0	65	0	
144	N144	54.75	0	65	0	
145	N145	26.75	0	70	0	
146	N146	32.9375	0	70	0	
147	N147	39.125	0	70	0	
148	N148	45.3125	0	70	0	
149	N149	25.625	0	75	0	
150	N150	31.28125	0	75	0	
151	N151	36.9375	0	75	0	
152	N152	42.59375	0	75	0	
153	N153	48.25	0	75	0	
154	N154	39.625	0	40	0	
155	N155	45.75	0	40	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
156	N156	51.875	0	40	0	
157	N157	32.375	0	45	0	
158	N158	38.78125	0	45	0	
159	N159	45.1875	0	45	0	
160	N160	51.59375	0	45	0	
161	N161	60.5	0	45	0	
162	N162	31.25	0	50	0	
163	N163	37.9375	0	50	0	
164	N164	44.625	0	50	0	
165	N165	51.3125	0	50	0	
166	N166	60.5	0	50	0	
167	N167	30.125	0	55	0	
168	N168	37.09375	0	55	0	
169	N169	44.0625	0	55	0	
170	N170	51.03125	0	55	0	
171	N171	60.5	0	55	0	
172	N172	43	0	20	0	
173	N173	48	0	20	0	
174	N174	53	0	20	0	
175	N175	36.875	0	25	0	
176	N176	42.15625	0	25	0	
177	N177	47.4375	0	25	0	
178	N178	52.71875	0	25	0	
179	N179	60.5	0	25	0	
180	N180	35.75	0	30	0	
181	N181	41.3125	0	30	0	
182	N182	46.875	0	30	0	
183	N183	52.4375	0	30	0	
184	N184	60.5	0	30	0	
185	N185	34.625	0	35	0	
186	N186	40.46875	0	35	0	
187	N187	46.3125	0	35	0	
188	N188	52.15625	0	35	0	
189	N189	60.5	0	35	0	
190	N190	68	0	20	0	
191	N191	73	0	20	0	
192	N192	78	0	20	0	
193	N193	68.28125	0	25	0	
194	N194	73.5625	0	25	0	
195	N195	78.84375	0	25	0	
196	N196	84.125	0	25	0	
197	N197	68.5625	0	30	0	
198	N198	74.125	0	30	0	
199	N199	79.6875	0	30	0	
200	N200	85.25	0	30	0	
201	N201	68.84375	0	35	0	
202	N202	74.6875	0	35	0	
203	N203	80.53125	0	35	0	
204	N204	86.375	0	35	0	
205	N205	69.125	0	40	0	
206	N206	75.25	0	40	0	
207	N207	81.375	0	40	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
208	N208	69.40625	0	45	0	
209	N209	75.8125	0	45	0	
210	N210	82.21875	0	45	0	
211	N211	88.625	0	45	0	
212	N212	69.6875	0	50	0	
213	N213	76.375	0	50	0	
214	N214	83.0625	0	50	0	
215	N215	89.75	0	50	0	
216	N216	69.96875	0	55	0	
217	N217	76.9375	0	55	0	
218	N218	83.90625	0	55	0	
219	N219	90.875	0	55	0	
220	N220	70.25	0	60	0	
221	N221	77.5	0	60	0	
222	N222	84.75	0	60	0	
223	N223	66.25	0	65	0	
224	N224	72.96875	0	65	0	
225	N225	79.6875	0	65	0	
226	N226	86.40625	0	65	0	
227	N227	93.125	0	65	0	
228	N228	75.6875	0	70	0	
229	N229	81.875	0	70	0	
230	N230	88.0625	0	70	0	
231	N231	94.25	0	70	0	
232	N232	72.75	0	75	0	
233	N233	78.40625	0	75	0	
234	N234	84.0625	0	75	0	
235	N235	89.71875	0	75	0	
236	N236	95.375	0	75	0	
237	N237	81.125	0	80	0	
238	N238	86.25	0	80	0	
239	N239	91.375	0	80	0	
240	N240	81.40625	0	85	0	
241	N241	86.8125	0	85	0	
242	N242	92.21875	0	85	0	
243	N243	97.625	0	85	0	
244	N244	81.6875	0	90	0	
245	N245	87.375	0	90	0	
246	N246	93.0625	0	90	0	
247	N247	98.75	0	90	0	
248	N248	81.96875	0	95	0	
249	N249	87.9375	0	95	0	
250	N250	93.90625	0	95	0	
251	N251	99.875	0	95	0	
252	N252	82.25	0	100	0	
253	N253	88.5	0	100	0	
254	N254	94.75	0	100	0	
255	N255	68.416667	0	71.666667	0	
256	N256	70.583333	0	75.833333	0	
257	N257	68.416667	0	76.666667	0	
258	N258	65.166667	0	71.666667	0	
259	N259	60.5	0	75	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
260	N260	65.708333	0	75.833333	0	
261	N261	55.833333	0	71.666667	0	
262	N262	55.291667	0	75.833333	0	
263	N263	52.583333	0	76.666667	0	
264	N264	60.5	0	65	0	
265	N265	55.291667	0	68.333333	0	
266	N266	52.583333	0	71.666667	0	
267	N267	65.708333	0	68.333333	0	
268	N268	50.416667	0	75.833333	0	
269	N269	26	20.5	100	0	
270	N270	22	20.5	95.555556	0	
271	N271	21	20.5	100	0	
272	N272	21	20.5	95.555556	0	
273	N273	38	20.5	30	0	
274	N274	35.75	20.5	30	0	
275	N275	38	20.5	50	0	
276	N276	34	20.5	60	0	
277	N277	95	20.5	100	0	
278	N278	91	20.5	90	0	
279	N279	100	20.5	95.555556	0	
280	N280	100	20.5	100	0	
281	N281	99	20.5	95.555556	0	
282	N282	83	20.5	30	0	
283	N283	87	20.5	60	0	
284	N284	83	20.5	50	0	
285	N285	93.75	20.5	80	0	
286	N286	97.75	20.5	85.555556	0	
287	N287	91	20.5	70	0	
288	N288	94.25	20.5	70	0	
289	N289	83	20.5	70	0	
290	N290	87	20.5	80	0	
291	N291	83	20.5	90	0	
292	N292	87	20.5	100	0	
293	N293	78	20.5	20	0	
294	N294	74	20.5	30	0	
295	N295	78	20.5	30	0	
296	N296	78	20.5	40	0	
297	N297	74	20.5	50	0	
298	N298	78	20.5	50	0	
299	N299	78	20.5	60	0	
300	N300	74	20.5	70	0	
301	N301	78	20.5	70	0	
302	N302	78	20.5	80	0	
303	N303	74	20.5	90	0	
304	N304	78	20.5	100	0	
305	N305	69	20.5	80	0	
306	N306	65	20.5	90	0	
307	N307	69	20.5	100	0	
308	N308	69	20.5	60	0	
309	N309	65	20.5	70	0	
310	N310	69	20.5	70	0	
311	N311	69	20.5	40	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
312	N312	65	20.5	50	0	
313	N313	69	20.5	50	0	
314	N314	69	20.5	20	0	
315	N315	65	20.5	30	0	
316	N316	69	20.5	30	0	
317	N317	56	20.5	30	0	
318	N318	60.5	20.5	30	0	
319	N319	56	20.5	50	0	
320	N320	60.5	20.5	50	0	
321	N321	56	20.5	70	0	
322	N322	60.5	20.5	70	0	
323	N323	60.5	20.5	80	0	
324	N324	56	20.5	90	0	
325	N325	60.5	20.5	90	0	
326	N326	60.5	20.5	100	0	
327	N327	52	20.5	80	0	
328	N328	47	20.5	90	0	
329	N329	52	20.5	90	0	
330	N330	52	20.5	100	0	
331	N331	52	20.5	60	0	
332	N332	47	20.5	70	0	
333	N333	52	20.5	70	0	
334	N334	52	20.5	40	0	
335	N335	47	20.5	50	0	
336	N336	52	20.5	50	0	
337	N337	52	20.5	20	0	
338	N338	47	20.5	30	0	
339	N339	52	20.5	30	0	
340	N340	43	20.5	20	0	
341	N341	43	20.5	30	0	
342	N342	43	20.5	40	0	
343	N343	43	20.5	50	0	
344	N344	43	20.5	60	0	
345	N345	38	20.5	70	0	
346	N346	43	20.5	70	0	
347	N347	43	20.5	80	0	
348	N348	38	20.5	90	0	
349	N349	43	20.5	90	0	
350	N350	43	20.5	100	0	
351	N351	34	20.5	80	0	
352	N352	30	20.5	90	0	
353	N353	34	20.5	90	0	
354	N354	34	20.5	100	0	
355	N355	30	20.5	70	0	
356	N356	34	20.5	70	0	
357	N357	26.75	20.5	70	0	
358	N358	27.25	20.5	80	0	
359	N359	23.25	20.5	85.555556	0	
360	N360	85.25	20.5	30	0	
361	N361	84.125	20.5	30	0	
362	N362	83	20.5	35	0	
363	N363	84.6875	20.5	35	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
364	N364	86.375	20.5	35	0	
365	N365	85.25	20.5	40	0	
366	N366	36.875	20.5	30	0	
367	N367	34.625	20.5	35	0	
368	N368	36.3125	20.5	35	0	
369	N369	38	20.5	35	0	
370	N370	35.75	20.5	40	0	
371	N371	76	20.5	20	0	
372	N372	80	20.5	20	0	
373	N373	74	20.5	25	0	
374	N374	76	20.5	25	0	
375	N375	78	20.5	25	0	
376	N376	80	20.5	25	0	
377	N377	83	20.5	25	0	
378	N378	76	20.5	30	0	
379	N379	80	20.5	30	0	
380	N380	74	20.5	35	0	
381	N381	76	20.5	35	0	
382	N382	78	20.5	35	0	
383	N383	80	20.5	35	0	
384	N384	76	20.5	40	0	
385	N385	80	20.5	40	0	
386	N386	67	20.5	20	0	
387	N387	71	20.5	20	0	
388	N388	65	20.5	25	0	
389	N389	67	20.5	25	0	
390	N390	69	20.5	25	0	
391	N391	71	20.5	25	0	
392	N392	67	20.5	30	0	
393	N393	71	20.5	30	0	
394	N394	65	20.5	35	0	
395	N395	67	20.5	35	0	
396	N396	69	20.5	35	0	
397	N397	71	20.5	35	0	
398	N398	67	20.5	40	0	
399	N399	71	20.5	40	0	
400	N400	58	20.5	20	0	
401	N401	63	20.5	20	0	
402	N402	56	20.5	25	0	
403	N403	58	20.5	25	0	
404	N404	60.5	20.5	25	0	
405	N405	63	20.5	25	0	
406	N406	58	20.5	30	0	
407	N407	63	20.5	30	0	
408	N408	56	20.5	35	0	
409	N409	58	20.5	35	0	
410	N410	60.5	20.5	35	0	
411	N411	63	20.5	35	0	
412	N412	58	20.5	40	0	
413	N413	63	20.5	40	0	
414	N414	50	20.5	20	0	
415	N415	54	20.5	20	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
416	N416	47	20.5	25	0	
417	N417	50	20.5	25	0	
418	N418	52	20.5	25	0	
419	N419	54	20.5	25	0	
420	N420	50	20.5	30	0	
421	N421	54	20.5	30	0	
422	N422	47	20.5	35	0	
423	N423	50	20.5	35	0	
424	N424	52	20.5	35	0	
425	N425	54	20.5	35	0	
426	N426	50	20.5	40	0	
427	N427	54	20.5	40	0	
428	N428	41	20.5	20	0	
429	N429	45	20.5	20	0	
430	N430	38	20.5	25	0	
431	N431	41	20.5	25	0	
432	N432	43	20.5	25	0	
433	N433	45	20.5	25	0	
434	N434	41	20.5	30	0	
435	N435	45	20.5	30	0	
436	N436	41	20.5	35	0	
437	N437	43	20.5	35	0	
438	N438	45	20.5	35	0	
439	N439	41	20.5	40	0	
440	N440	45	20.5	40	0	
441	N441	36.875	20.5	25	0	
442	N442	37.25	20.5	26.666667	0	
443	N443	84.125	20.5	25	0	
444	N444	83.75	20.5	26.666667	0	
445	N445	74	20.5	45	0	
446	N446	76	20.5	45	0	
447	N447	78	20.5	45	0	
448	N448	80	20.5	45	0	
449	N449	83	20.5	45	0	
450	N450	76	20.5	50	0	
451	N451	80	20.5	50	0	
452	N452	74	20.5	55	0	
453	N453	76	20.5	55	0	
454	N454	78	20.5	55	0	
455	N455	80	20.5	55	0	
456	N456	83	20.5	55	0	
457	N457	76	20.5	60	0	
458	N458	80	20.5	60	0	
459	N459	65	20.5	45	0	
460	N460	67	20.5	45	0	
461	N461	69	20.5	45	0	
462	N462	71	20.5	45	0	
463	N463	67	20.5	50	0	
464	N464	71	20.5	50	0	
465	N465	65	20.5	55	0	
466	N466	67	20.5	55	0	
467	N467	69	20.5	55	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
468	N468	71	20.5	55	0	
469	N469	67	20.5	60	0	
470	N470	71	20.5	60	0	
471	N471	56	20.5	45	0	
472	N472	58	20.5	45	0	
473	N473	60.5	20.5	45	0	
474	N474	63	20.5	45	0	
475	N475	58	20.5	50	0	
476	N476	63	20.5	50	0	
477	N477	56	20.5	55	0	
478	N478	58	20.5	55	0	
479	N479	60.5	20.5	55	0	
480	N480	63	20.5	55	0	
481	N481	58	20.5	60	0	
482	N482	63	20.5	60	0	
483	N483	47	20.5	45	0	
484	N484	50	20.5	45	0	
485	N485	52	20.5	45	0	
486	N486	54	20.5	45	0	
487	N487	50	20.5	50	0	
488	N488	54	20.5	50	0	
489	N489	47	20.5	55	0	
490	N490	50	20.5	55	0	
491	N491	52	20.5	55	0	
492	N492	54	20.5	55	0	
493	N493	50	20.5	60	0	
494	N494	54	20.5	60	0	
495	N495	38	20.5	45	0	
496	N496	41	20.5	45	0	
497	N497	43	20.5	45	0	
498	N498	45	20.5	45	0	
499	N499	41	20.5	50	0	
500	N500	45	20.5	50	0	
501	N501	38	20.5	55	0	
502	N502	41	20.5	55	0	
503	N503	43	20.5	55	0	
504	N504	45	20.5	55	0	
505	N505	41	20.5	60	0	
506	N506	45	20.5	60	0	
507	N507	31.75	20.5	50	0	
508	N508	32.625	20.5	45	0	
509	N509	35.3125	20.5	45	0	
510	N510	34.875	20.5	50	0	
511	N511	30.875	20.5	55	0	
512	N512	34.4375	20.5	55	0	
513	N513	29.5	20.5	60	0	
514	N514	31.25	20.5	50	0	
515	N515	30.833333	20.5	53.333333	0	
516	N516	32.375	20.5	45	0	
517	N517	31.833333	20.5	48.333333	0	
518	N518	31.291667	20.5	51.666667	0	
519	N519	31.041667	20.5	51.666667	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
520	N520	30.125	20.5	55	0	
521	N521	30.145833	20.5	55.833333	0	
522	N522	30.166667	20.5	56.666667	0	
523	N523	29.25	20.5	60	0	
524	N524	30.520833	20.5	55.833333	0	
525	N525	29.75	20.5	60	0	
526	N526	89.25	20.5	50	0	
527	N527	85.6875	20.5	45	0	
528	N528	88.375	20.5	45	0	
529	N529	86.125	20.5	50	0	
530	N530	86.5625	20.5	55	0	
531	N531	90.125	20.5	55	0	
532	N532	87	20.5	70	0	
533	N533	91.5	20.5	60	0	
534	N534	92.625	20.5	70	0	
535	N535	91.25	20.5	60	0	
536	N536	91	20.5	65	0	
537	N537	91.53125	20.5	65	0	
538	N538	92.0625	20.5	65	0	
539	N539	91.8125	20.5	70	0	
540	N540	91.75	20.5	60	0	
541	N541	92.59375	20.5	65	0	
542	N542	93.125	20.5	65	0	
543	N543	93.4375	20.5	70	0	
544	N544	93.1875	20.5	75	0	
545	N545	94.28125	20.5	75	0	
546	N546	95.375	20.5	75	0	
547	N547	95.125	20.5	80	0	
548	N548	91	20.5	75	0	
549	N549	92.09375	20.5	75	0	
550	N550	92.375	20.5	80	0	
551	N551	89	20.5	70	0	
552	N552	87	20.5	75	0	
553	N553	89	20.5	75	0	
554	N554	89	20.5	80	0	
555	N555	89	20.5	60	0	
556	N556	87	20.5	65	0	
557	N557	89	20.5	65	0	
558	N558	85	20.5	60	0	
559	N559	83	20.5	65	0	
560	N560	85	20.5	65	0	
561	N561	85	20.5	70	0	
562	N562	83	20.5	75	0	
563	N563	85	20.5	75	0	
564	N564	85	20.5	80	0	
565	N565	78	20.5	65	0	
566	N566	80	20.5	65	0	
567	N567	80	20.5	70	0	
568	N568	74	20.5	65	0	
569	N569	76	20.5	65	0	
570	N570	76	20.5	70	0	
571	N571	74	20.5	75	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
572	N572	76	20.5	75	0	
573	N573	78	20.5	75	0	
574	N574	76	20.5	80	0	
575	N575	80	20.5	75	0	
576	N576	80	20.5	80	0	
577	N577	69	20.5	65	0	
578	N578	71	20.5	65	0	
579	N579	71	20.5	70	0	
580	N580	69	20.5	75	0	
581	N581	71	20.5	75	0	
582	N582	71	20.5	80	0	
583	N583	67	20.5	70	0	
584	N584	65	20.5	75	0	
585	N585	67	20.5	75	0	
586	N586	67	20.5	80	0	
587	N587	65	20.5	65	0	
588	N588	67	20.5	65	0	
589	N589	63	20.5	70	0	
590	N590	60.5	20.5	75	0	
591	N591	63	20.5	75	0	
592	N592	63	20.5	80	0	
593	N593	58	20.5	70	0	
594	N594	56	20.5	75	0	
595	N595	58	20.5	75	0	
596	N596	58	20.5	80	0	
597	N597	56	20.5	65	0	
598	N598	58	20.5	65	0	
599	N599	60.5	20.5	65	0	
600	N600	63	20.5	65	0	
601	N601	54	20.5	70	0	
602	N602	52	20.5	75	0	
603	N603	54	20.5	75	0	
604	N604	54	20.5	80	0	
605	N605	52	20.5	65	0	
606	N606	54	20.5	65	0	
607	N607	47	20.5	65	0	
608	N608	50	20.5	65	0	
609	N609	50	20.5	70	0	
610	N610	47	20.5	75	0	
611	N611	50	20.5	75	0	
612	N612	50	20.5	80	0	
613	N613	43	20.5	65	0	
614	N614	45	20.5	65	0	
615	N615	45	20.5	70	0	
616	N616	43	20.5	75	0	
617	N617	45	20.5	75	0	
618	N618	45	20.5	80	0	
619	N619	41	20.5	70	0	
620	N620	38	20.5	75	0	
621	N621	41	20.5	75	0	
622	N622	41	20.5	80	0	
623	N623	38	20.5	65	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
624	N624	41	20.5	65	0	
625	N625	36	20.5	60	0	
626	N626	34	20.5	65	0	
627	N627	36	20.5	65	0	
628	N628	36	20.5	70	0	
629	N629	34	20.5	75	0	
630	N630	36	20.5	75	0	
631	N631	36	20.5	80	0	
632	N632	32	20.5	70	0	
633	N633	30	20.5	75	0	
634	N634	32	20.5	75	0	
635	N635	32	20.5	80	0	
636	N636	32	20.5	60	0	
637	N637	30	20.5	65	0	
638	N638	32	20.5	65	0	
639	N639	28.375	20.5	70	0	
640	N640	28.9375	20.5	65	0	
641	N641	29.46875	20.5	65	0	
642	N642	29.1875	20.5	70	0	
643	N643	27.875	20.5	65	0	
644	N644	28.40625	20.5	65	0	
645	N645	27.5625	20.5	70	0	
646	N646	27.8125	20.5	75	0	
647	N647	28.90625	20.5	75	0	
648	N648	28.625	20.5	80	0	
649	N649	25.625	20.5	75	0	
650	N650	26.71875	20.5	75	0	
651	N651	25.875	20.5	80	0	
652	N652	89.75	20.5	50	0	
653	N653	90.166667	20.5	53.333333	0	
654	N654	88.625	20.5	45	0	
655	N655	89.166667	20.5	48.333333	0	
656	N656	89.958333	20.5	51.666667	0	
657	N657	89.708333	20.5	51.666667	0	
658	N658	90.479167	20.5	55.833333	0	
659	N659	90.833333	20.5	56.666667	0	
660	N660	90.875	20.5	55	0	
661	N661	90.854167	20.5	55.833333	0	
662	N662	99.666667	20.5	97.037037	0	
663	N663	91	20.5	85	0	
664	N664	94.375	20.5	85.277778	0	
665	N665	95	20.5	90.555556	0	
666	N666	91	20.5	95	0	
667	N667	95	20.5	95.277778	0	
668	N668	83	20.5	85	0	
669	N669	85	20.5	85	0	
670	N670	87	20.5	85	0	
671	N671	89	20.5	85	0	
672	N672	85	20.5	90	0	
673	N673	87	20.5	90	0	
674	N674	89	20.5	90	0	
675	N675	83	20.5	95	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
676	N676	85	20.5	95	0	
677	N677	87	20.5	95	0	
678	N678	89	20.5	95	0	
679	N679	85	20.5	100	0	
680	N680	89	20.5	100	0	
681	N681	74	20.5	85	0	
682	N682	76	20.5	85	0	
683	N683	78	20.5	85	0	
684	N684	80	20.5	85	0	
685	N685	76	20.5	90	0	
686	N686	78	20.5	90	0	
687	N687	80	20.5	90	0	
688	N688	74	20.5	95	0	
689	N689	76	20.5	95	0	
690	N690	78	20.5	95	0	
691	N691	80	20.5	95	0	
692	N692	76	20.5	100	0	
693	N693	80	20.5	100	0	
694	N694	65	20.5	85	0	
695	N695	67	20.5	85	0	
696	N696	69	20.5	85	0	
697	N697	71	20.5	85	0	
698	N698	67	20.5	90	0	
699	N699	69	20.5	90	0	
700	N700	71	20.5	90	0	
701	N701	65	20.5	95	0	
702	N702	67	20.5	95	0	
703	N703	69	20.5	95	0	
704	N704	71	20.5	95	0	
705	N705	67	20.5	100	0	
706	N706	71	20.5	100	0	
707	N707	56	20.5	85	0	
708	N708	58	20.5	85	0	
709	N709	60.5	20.5	85	0	
710	N710	63	20.5	85	0	
711	N711	58	20.5	90	0	
712	N712	63	20.5	90	0	
713	N713	56	20.5	95	0	
714	N714	58	20.5	95	0	
715	N715	60.5	20.5	95	0	
716	N716	63	20.5	95	0	
717	N717	58	20.5	100	0	
718	N718	63	20.5	100	0	
719	N719	47	20.5	85	0	
720	N720	50	20.5	85	0	
721	N721	52	20.5	85	0	
722	N722	54	20.5	85	0	
723	N723	50	20.5	90	0	
724	N724	54	20.5	90	0	
725	N725	47	20.5	95	0	
726	N726	50	20.5	95	0	
727	N727	52	20.5	95	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
728	N728	54	20.5	95	0	
729	N729	50	20.5	100	0	
730	N730	54	20.5	100	0	
731	N731	38	20.5	85	0	
732	N732	41	20.5	85	0	
733	N733	43	20.5	85	0	
734	N734	45	20.5	85	0	
735	N735	41	20.5	90	0	
736	N736	45	20.5	90	0	
737	N737	38	20.5	95	0	
738	N738	41	20.5	95	0	
739	N739	43	20.5	95	0	
740	N740	45	20.5	95	0	
741	N741	41	20.5	100	0	
742	N742	45	20.5	100	0	
743	N743	30	20.5	85	0	
744	N744	32	20.5	85	0	
745	N745	34	20.5	85	0	
746	N746	36	20.5	85	0	
747	N747	32	20.5	90	0	
748	N748	36	20.5	90	0	
749	N749	30	20.5	95	0	
750	N750	32	20.5	95	0	
751	N751	34	20.5	95	0	
752	N752	36	20.5	95	0	
753	N753	32	20.5	100	0	
754	N754	36	20.5	100	0	
755	N755	24.625	20.5	85.555556	0	
756	N756	24.583333	20.5	83.703704	0	
757	N757	21.333333	20.5	97.037037	0	
758	N758	26	20.5	90.555556	0	
759	N759	26	20.5	95.277778	0	
760	N760	27.3125	20.5	85.277778	0	
761	N761	92.375	20.5	85	0	
762	N762	91.916667	20.5	83.333333	0	
763	N763	95.0625	20.5	85.277778	0	
764	N764	36.875	20.5	40	0	
765	N765	36.65625	20.5	45	0	
766	N766	36.4375	20.5	50	0	
767	N767	36.21875	20.5	55	0	
768	N768	33.3125	20.5	50	0	
769	N769	32.65625	20.5	55	0	
770	N770	34.625	20.5	40	0	
771	N771	33.96875	20.5	45	0	
772	N772	86.375	20.5	40	0	
773	N773	87.03125	20.5	45	0	
774	N774	87.6875	20.5	50	0	
775	N775	88.34375	20.5	55	0	
776	N776	84.5625	20.5	50	0	
777	N777	84.78125	20.5	55	0	
778	N778	84.125	20.5	40	0	
779	N779	84.34375	20.5	45	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
780	N780	101	5.125	100	0	
781	N781	101	10.25	100	0	
782	N782	101	15.375	100	0	
783	N783	99.875	5.125	95	0	
784	N784	99.875	10.25	95	0	
785	N785	99.875	15.375	95	0	
786	N786	99.875	20.5	95	0	
787	N787	98.75	5.125	90	0	
788	N788	98.75	10.25	90	0	
789	N789	98.75	15.375	90	0	
790	N790	98.75	20.5	90	0	
791	N791	97.625	5.125	85	0	
792	N792	97.625	10.25	85	0	
793	N793	97.625	15.375	85	0	
794	N794	97.625	20.5	85	0	
795	N795	96.5	5.125	80	0	
796	N796	96.5	10.25	80	0	
797	N797	96.5	15.375	80	0	
798	N798	95.375	5.125	75	0	
799	N799	95.375	10.25	75	0	
800	N800	95.375	15.375	75	0	
801	N801	94.25	5.125	70	0	
802	N802	94.25	10.25	70	0	
803	N803	94.25	15.375	70	0	
804	N804	93.125	5.125	65	0	
805	N805	93.125	10.25	65	0	
806	N806	93.125	15.375	65	0	
807	N807	92	5.125	60	0	
808	N808	92	10.25	60	0	
809	N809	92	15.375	60	0	
810	N810	90.875	5.125	55	0	
811	N811	90.875	10.25	55	0	
812	N812	90.875	15.375	55	0	
813	N813	89.75	5.125	50	0	
814	N814	89.75	10.25	50	0	
815	N815	89.75	15.375	50	0	
816	N816	88.625	5.125	45	0	
817	N817	88.625	10.25	45	0	
818	N818	88.625	15.375	45	0	
819	N819	87.5	5.125	40	0	
820	N820	87.5	10.25	40	0	
821	N821	87.5	15.375	40	0	
822	N822	86.375	5.125	35	0	
823	N823	86.375	10.25	35	0	
824	N824	86.375	15.375	35	0	
825	N825	85.25	5.125	30	0	
826	N826	85.25	10.25	30	0	
827	N827	85.25	15.375	30	0	
828	N828	84.125	5.125	25	0	
829	N829	84.125	10.25	25	0	
830	N830	84.125	15.375	25	0	
831	N831	83	5.125	20	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
832	N832	83	10.25	20	0	
833	N833	83	15.375	20	0	
834	N834	33.5	5.125	40	0	
835	N835	33.5	10.25	40	0	
836	N836	33.5	15.375	40	0	
837	N837	34.625	5.125	35	0	
838	N838	34.625	10.25	35	0	
839	N839	34.625	15.375	35	0	
840	N840	35.75	5.125	30	0	
841	N841	35.75	10.25	30	0	
842	N842	35.75	15.375	30	0	
843	N843	36.875	5.125	25	0	
844	N844	36.875	10.25	25	0	
845	N845	36.875	15.375	25	0	
846	N846	38	5.125	20	0	
847	N847	38	10.25	20	0	
848	N848	38	15.375	20	0	
849	N849	29	5.125	60	0	
850	N850	29	10.25	60	0	
851	N851	29	15.375	60	0	
852	N852	30.125	5.125	55	0	
853	N853	30.125	10.25	55	0	
854	N854	30.125	15.375	55	0	
855	N855	31.25	5.125	50	0	
856	N856	31.25	10.25	50	0	
857	N857	31.25	15.375	50	0	
858	N858	32.375	5.125	45	0	
859	N859	32.375	10.25	45	0	
860	N860	32.375	15.375	45	0	
861	N861	24.5	5.125	80	0	
862	N862	24.5	10.25	80	0	
863	N863	24.5	15.375	80	0	
864	N864	25.625	5.125	75	0	
865	N865	25.625	10.25	75	0	
866	N866	25.625	15.375	75	0	
867	N867	26.75	5.125	70	0	
868	N868	26.75	10.25	70	0	
869	N869	26.75	15.375	70	0	
870	N870	27.875	5.125	65	0	
871	N871	27.875	10.25	65	0	
872	N872	27.875	15.375	65	0	
873	N873	20	5.125	100	0	
874	N874	20	10.25	100	0	
875	N875	20	15.375	100	0	
876	N876	21.125	5.125	95	0	
877	N877	21.125	10.25	95	0	
878	N878	21.125	15.375	95	0	
879	N879	21.125	20.5	95	0	
880	N880	22.25	5.125	90	0	
881	N881	22.25	10.25	90	0	
882	N882	22.25	15.375	90	0	
883	N883	22.25	20.5	90	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
884	N884	23.375	5.125	85	0	
885	N885	23.375	10.25	85	0	
886	N886	23.375	15.375	85	0	
887	N887	23.375	20.5	85	0	
888	N888	18.391	0	106.5	0	
889	N889	45	0	106.5	0	
890	N890	76	0	106.5	0	
891	N891	102.609	0	106.5	0	
892	N892	25.04325	0	106.5	0	
893	N893	31.6955	0	106.5	0	
894	N894	38.34775	0	106.5	0	
895	N895	82.65225	0	106.5	0	
896	N896	89.3045	0	106.5	0	
897	N897	95.95675	0	106.5	0	
898	N898	48.25	0	106.5	0	
899	N899	51.5	0	106.5	0	
900	N900	54.75	0	106.5	0	
901	N901	60.5	0	106.5	0	
902	N902	66.25	0	106.5	0	
903	N903	69.5	0	106.5	0	
904	N904	72.75	0	106.5	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]
1	N18	Reaction	S45.844	Reaction			
2	N19	Reaction	S55.875	Reaction			
3	N20	Reaction	S45.844	Reaction			
4	N21	Reaction	S55.875	Reaction			
5	N22		S91.688				
6	N23		S110.76				
7	N24		S221.521				
8	N25		S110.76				
9	N26		S129.268				
10	N27		S312.408				
11	N28		S129.268				
12	N29		S94.514				
13	N30		S150.836				
14	N31		S150.836				
15	N32		S94.514				
16	N33		S85.26				
17	N34		S85.26				
18	N35		S112.644				
19	N36		S58.771				
20	N75		S151.071				
21	N76		S97.951				
22	N77		S78.361				
23	N78		S36.732				
24	N79		S97.951				
25	N80		S151.071				
26	N81		S36.732				

Joint Boundary Conditions (Continued)

	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]
27	N82		S105.298				
28	N83		S105.298				
29	N84		S117.542				
30	N85		S117.542				
31	N86		S117.542				
32	N87		S117.542				
33	N88		S156.534				
34	N89		S117.542				
35	N90		S117.542				
36	N91		S117.542				
37	N92		S117.542				
38	N93		S161.62				
39	N94		S117.542				
40	N95		S117.542				
41	N96		S117.542				
42	N97		S117.542				
43	N98		S166.706				
44	N99		S58.771				
45	N100		S58.771				
46	N101		S58.771				
47	N102		S105.298				
48	N103		S105.298				
49	N104		S156.534				
50	N105		S117.542				
51	N106		S117.542				
52	N107		S117.542				
53	N108		S161.62				
54	N109		S117.542				
55	N110		S117.542				
56	N111		S117.542				
57	N112		S166.706				
58	N113		S117.542				
59	N114		S117.542				
60	N115		S117.542				
61	N116		S58.771				
62	N117		S58.771				
63	N118		S58.771				
64	N119		S189.027				
65	N120		S189.027				
66	N121		S189.027				
67	N122		S97.763				
68	N123		S195.526				
69	N124		S195.526				
70	N125		S195.526				
71	N126		S102.849				
72	N127		S205.698				
73	N128		S205.698				
74	N129		S205.698				
75	N130		S107.935				
76	N131		S215.87				
77	N132		S215.87				
78	N133		S215.87				

Joint Boundary Conditions (Continued)

	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]
79	N134		S111.749				
80	N135		S111.749				
81	N136		S111.749				
82	N137		S258.535				
83	N138		S258.535				
84	N139		S258.535				
85	N140		S121.497				
86	N141		S242.995				
87	N142		S242.995				
88	N143		S242.995				
89	N144		S168.024				
90	N145		S111.891				
91	N146		S223.781				
92	N147		S223.781				
93	N148		S223.781				
94	N149		S102.284				
95	N150		S204.568				
96	N151		S204.568				
97	N152		S204.568				
98	N153		S148.811				
99	N154		S221.521				
100	N155		S221.521				
101	N156		S221.521				
102	N157		S115.846				
103	N158		S231.693				
104	N159		S231.693				
105	N160		S231.693				
106	N161		S231.693				
107	N162		S120.932				
108	N163		S241.865				
109	N164		S241.865				
110	N165		S241.865				
111	N166		S241.865				
112	N167		S126.018				
113	N168		S252.036				
114	N169		S252.036				
115	N170		S252.036				
116	N171		S252.036				
117	N172		S91.688				
118	N173		S91.688				
119	N174		S91.688				
120	N175		S95.503				
121	N176		S191.005				
122	N177		S191.005				
123	N178		S191.005				
124	N179		S191.005				
125	N180		S100.589				
126	N181		S201.177				
127	N182		S201.177				
128	N183		S201.177				
129	N184		S201.177				
130	N185		S105.674				

Joint Boundary Conditions (Continued)

	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]
131	N186		S211.349				
132	N187		S211.349				
133	N188		S211.349				
134	N189		S211.349				
135	N190		S91.688				
136	N191		S91.688				
137	N192		S91.688				
138	N193		S191.005				
139	N194		S191.005				
140	N195		S191.005				
141	N196		S95.503				
142	N197		S201.177				
143	N198		S201.177				
144	N199		S201.177				
145	N200		S100.589				
146	N201		S211.349				
147	N202		S211.349				
148	N203		S211.349				
149	N204		S105.674				
150	N205		S221.521				
151	N206		S221.521				
152	N207		S221.521				
153	N208		S231.693				
154	N209		S231.693				
155	N210		S231.693				
156	N211		S115.846				
157	N212		S241.865				
158	N213		S241.865				
159	N214		S241.865				
160	N215		S120.932				
161	N216		S252.036				
162	N217		S252.036				
163	N218		S252.036				
164	N219		S126.018				
165	N220		S258.535				
166	N221		S258.535				
167	N222		S258.535				
168	N223		S168.024				
169	N224		S242.995				
170	N225		S242.995				
171	N226		S242.995				
172	N227		S121.497				
173	N228		S223.781				
174	N229		S223.781				
175	N230		S223.781				
176	N231		S111.891				
177	N232		S148.811				
178	N233		S204.568				
179	N234		S204.568				
180	N235		S204.568				
181	N236		S102.284				
182	N237		S189.027				

Joint Boundary Conditions (Continued)

	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]
183	N238		S189.027				
184	N239		S189.027				
185	N240		S195.526				
186	N241		S195.526				
187	N242		S195.526				
188	N243		S97.763				
189	N244		S205.698				
190	N245		S205.698				
191	N246		S205.698				
192	N247		S102.849				
193	N248		S215.87				
194	N249		S215.87				
195	N250		S215.87				
196	N251		S107.935				
197	N252		S111.749				
198	N253		S111.749				
199	N254		S111.749				
200	N255		S63.668				
201	N256		S78.361				
202	N257		S63.668				
203	N258		S63.668				
204	N259		S93.054				
205	N260		S78.361				
206	N261		S63.668				
207	N262		S78.361				
208	N263		S63.668				
209	N264		S93.054				
210	N265		S78.361				
211	N266		S63.668				
212	N267		S78.361				
213	N268		S78.361				
214	N888		S78.607				
215	N889		S117.6				
216	N890		S117.6				
217	N891		S78.607				
218	N892		S157.213				
219	N893		S157.213				
220	N894		S157.213				
221	N895		S157.213				
222	N896		S157.213				
223	N897		S157.213				
224	N898		S77.986				
225	N899		S77.986				
226	N900		S77.986				
227	N901		S77.986				
228	N902		S77.986				
229	N903		S77.986				
230	N904		S77.986				

Member Primary Data

	Label	I Joint	J Joint	K Joint	Rotate(...	Section/Sh...	Type	Design List	Material	Design Rules
1	M1	N1	N5			Primary. BM	Beam	Rectangular	Conc4000NW	Primary Beam
2	M2	N5	N3			Primary. BM	Beam	Rectangular	Conc4000NW	Primary Beam
3	M3	N6	N7			Primary. BM	Beam	Rectangular	Conc4000NW	Primary Beam
4	M4	N7	N8			Primary. BM	Beam	Rectangular	Conc4000NW	Primary Beam
5	M5	N9	N10			Primary. BM	Beam	Rectangular	Conc4000NW	Primary Beam
6	M6	N10	N11			Primary. BM	Beam	Rectangular	Conc4000NW	Primary Beam
7	M7	N12	N13			Primary. BM	Beam	Rectangular	Conc4000NW	Primary Beam
8	M8	N13	N14			Primary. BM	Beam	Rectangular	Conc4000NW	Primary Beam
9	M9	N14	N15			Primary. BM	Beam	Rectangular	Conc4000NW	Primary Beam
10	M10	N2	N16			Primary. BM	Beam	Rectangular	Conc4000NW	Primary Beam
11	M11	N16	N17			Primary. BM	Beam	Rectangular	Conc4000NW	Primary Beam
12	M12	N17	N4			Primary. BM	Beam	Rectangular	Conc4000NW	Primary Beam
13	M13	N18	N1			Ext. Column	Column	Rectangular	Conc4000NW	Column
14	M14	N23	N6			Ext. Column	Column	Rectangular	Conc4000NW	Column
15	M15	N26	N9			Ext. Column	Column	Rectangular	Conc4000NW	Column
16	M16	N29	N12			Ext. Column	Column	Rectangular	Conc4000NW	Column
17	M17	N19	N2			Ext. Column	Column	Rectangular	Conc4000NW	Column
18	M18	N20	N3			Ext. Column	Column	Rectangular	Conc4000NW	Column
19	M19	N25	N8			Ext. Column	Column	Rectangular	Conc4000NW	Column
20	M20	N28	N11			Ext. Column	Column	Rectangular	Conc4000NW	Column
21	M21	N32	N15			Ext. Column	Column	Rectangular	Conc4000NW	Column
22	M22	N21	N4			Ext. Column	Column	Rectangular	Conc4000NW	Column
23	M23	N22	N5			Int. Column	Column	Rectangular	Conc4000NW	Column
24	M24	N24	N7			Int. Column	Column	Rectangular	Conc4000NW	Column
25	M25	N27	N10			Int. Column	Column	Rectangular	Conc4000NW	Column
26	M26	N30	N13			Int. Column	Column	Rectangular	Conc4000NW	Column
27	M27	N31	N14			Int. Column	Column	Rectangular	Conc4000NW	Column
28	M28	N33	N16			Int. Column	Column	Rectangular	Conc4000NW	Column
29	M29	N34	N17			Int. Column	Column	Rectangular	Conc4000NW	Column
30	M30	N37	N38			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
31	M31	N38	N39			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
32	M32	N39	N40			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
33	M33	N40	N41			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
34	M34	N42	N43			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
35	M35	N43	N44			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
36	M36	N44	N45			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
37	M37	N45	N46			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
38	M39	N47	N48			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
39	M40	N48	N49			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
40	M41	N49	N50			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
41	M42	N51	N52			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
42	M43	N52	N53			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
43	M44	N54	N55			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
44	M45	N55	N56			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
45	M46	N56	N57			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
46	M47	N57	N58			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
47	M48	N59	N60			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
48	M49	N60	N61			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
49	M50	N61	N62			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
50	M51	N62	N63			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
51	M53	N64	N65			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM

Member Primary Data (Continued)

	Label	I Joint	J Joint	K Joint	Rotate(...	Section/Sh...	Type	Design List	Material	Design Rules
52	M54	N65	N66			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
53	M55	N66	N67			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
54	M56	N68	N69			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
55	M57	N69	N70			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
56	M65	N357	N645			RIGID	None	None	RIGID	Secondary BM
57	M66	N645	N639			RIGID	None	None	RIGID	Secondary BM
58	M67	N639	N642			RIGID	None	None	RIGID	Secondary BM
59	M68	N642	N355			RIGID	None	None	RIGID	Secondary BM
60	M69	N355	N632			RIGID	None	None	RIGID	Secondary BM
61	M70	N632	N356			RIGID	None	None	RIGID	Secondary BM
62	M71	N356	N628			RIGID	None	None	RIGID	Secondary BM
63	M72	N628	N345			RIGID	None	None	RIGID	Secondary BM
64	M73	N345	N619			RIGID	None	None	RIGID	Secondary BM
65	M74	N619	N346			RIGID	None	None	RIGID	Secondary BM
66	M75	N346	N615			RIGID	None	None	RIGID	Secondary BM
67	M76	N615	N332			RIGID	None	None	RIGID	Secondary BM
68	M77	N332	N609			RIGID	None	None	RIGID	Secondary BM
69	M78	N609	N333			RIGID	None	None	RIGID	Secondary BM
70	M79	N333	N601			RIGID	None	None	RIGID	Secondary BM
71	M80	N601	N321			RIGID	None	None	RIGID	Secondary BM
72	M81	N321	N593			RIGID	None	None	RIGID	Secondary BM
73	M82	N593	N322			RIGID	None	None	RIGID	Secondary BM
74	M83	N322	N589			RIGID	None	None	RIGID	Secondary BM
75	M84	N589	N309			RIGID	None	None	RIGID	Secondary BM
76	M85	N309	N583			RIGID	None	None	RIGID	Secondary BM
77	M86	N583	N310			RIGID	None	None	RIGID	Secondary BM
78	M87	N310	N579			RIGID	None	None	RIGID	Secondary BM
79	M88	N579	N300			RIGID	None	None	RIGID	Secondary BM
80	M89	N300	N570			RIGID	None	None	RIGID	Secondary BM
81	M90	N570	N301			RIGID	None	None	RIGID	Secondary BM
82	M91	N301	N567			RIGID	None	None	RIGID	Secondary BM
83	M92	N567	N289			RIGID	None	None	RIGID	Secondary BM
84	M93	N289	N561			RIGID	None	None	RIGID	Secondary BM
85	M94	N561	N532			RIGID	None	None	RIGID	Secondary BM
86	M95	N532	N551			RIGID	None	None	RIGID	Secondary BM
87	M96	N551	N287			RIGID	None	None	RIGID	Secondary BM
88	M97	N287	N539			RIGID	None	None	RIGID	Secondary BM
89	M98	N539	N534			RIGID	None	None	RIGID	Secondary BM
90	M99	N534	N543			RIGID	None	None	RIGID	Secondary BM
91	M100	N543	N288			RIGID	None	None	RIGID	Secondary BM
92	M95A	N275	N499			RIGID	None	None	RIGID	Secondary BM
93	M96A	N499	N343			RIGID	None	None	RIGID	Secondary BM
94	M97A	N343	N500			RIGID	None	None	RIGID	Secondary BM
95	M98A	N500	N335			RIGID	None	None	RIGID	Secondary BM
96	M99A	N335	N487			RIGID	None	None	RIGID	Secondary BM
97	M100A	N487	N336			RIGID	None	None	RIGID	Secondary BM
98	M101	N336	N488			RIGID	None	None	RIGID	Secondary BM
99	M102	N488	N319			RIGID	None	None	RIGID	Secondary BM
100	M103	N319	N475			RIGID	None	None	RIGID	Secondary BM
101	M104	N475	N320			RIGID	None	None	RIGID	Secondary BM
102	M105	N320	N476			RIGID	None	None	RIGID	Secondary BM
103	M106	N476	N312			RIGID	None	None	RIGID	Secondary BM

Member Primary Data (Continued)

	Label	I Joint	J Joint	K Joint	Rotate(...	Section/Sh...	Type	Design List	Material	Design Rules
104	M107	N312	N463			RIGID	None	None	RIGID	Secondary BM
105	M108	N463	N313			RIGID	None	None	RIGID	Secondary BM
106	M109	N313	N464			RIGID	None	None	RIGID	Secondary BM
107	M110	N464	N297			RIGID	None	None	RIGID	Secondary BM
108	M111	N297	N450			RIGID	None	None	RIGID	Secondary BM
109	M112	N450	N298			RIGID	None	None	RIGID	Secondary BM
110	M113	N298	N451			RIGID	None	None	RIGID	Secondary BM
111	M114	N451	N284			RIGID	None	None	RIGID	Secondary BM
112	M115	N507	N768			RIGID	None	None	RIGID	Secondary BM
113	M116	N768	N510			RIGID	None	None	RIGID	Secondary BM
114	M117	N510	N766			RIGID	None	None	RIGID	Secondary BM
115	M118	N766	N275			RIGID	None	None	RIGID	Secondary BM
116	M119	N284	N776			RIGID	None	None	RIGID	Secondary BM
117	M120	N776	N529			RIGID	None	None	RIGID	Secondary BM
118	M121	N529	N774			RIGID	None	None	RIGID	Secondary BM
119	M122	N774	N526			RIGID	None	None	RIGID	Secondary BM
120	M120A	N3	N47			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM
121	M121A	N1	N64			Second. Be...	Beam	Rectangular	Conc4000NW	Secondary BM

Concrete Beam Design Parameters

	Label	Shape	Length[ft]	B-eff Left[in]	B-eff Right...	Slab Th...	Slab Th...	Icr Fact...	Flexural Layout	Shear Layout
1	M1	Primary. BM	22.5						Use Design Rule	Use Design Rule
2	M2	Primary. BM	22.5						Use Design Rule	Use Design Rule
3	M3	Primary. BM	27						Use Design Rule	Use Design Rule
4	M4	Primary. BM	27						Use Design Rule	Use Design Rule
5	M5	Primary. BM	31.5						Use Design Rule	Use Design Rule
6	M6	Primary. BM	31.5						Use Design Rule	Use Design Rule
7	M7	Primary. BM	20.5						Use Design Rule	Use Design Rule
8	M8	Primary. BM	31						Use Design Rule	Use Design Rule
9	M9	Primary. BM	20.5						Use Design Rule	Use Design Rule
10	M10	Primary. BM	25						Use Design Rule	Use Design Rule
11	M11	Primary. BM	31						Use Design Rule	Use Design Rule
12	M12	Primary. BM	25						Use Design Rule	Use Design Rule
13	M30	Second. B...	20						Use Design Rule	Use Design Rule
14	M31	Second. B...	20						Use Design Rule	Use Design Rule
15	M32	Second. B...	20						Use Design Rule	Use Design Rule
16	M33	Second. B...	20						Use Design Rule	Use Design Rule
17	M34	Second. B...	20						Use Design Rule	Use Design Rule
18	M35	Second. B...	20						Use Design Rule	Use Design Rule
19	M36	Second. B...	20						Use Design Rule	Use Design Rule
20	M37	Second. B...	20						Use Design Rule	Use Design Rule
21	M39	Second. B...	20						Use Design Rule	Use Design Rule
22	M40	Second. B...	20						Use Design Rule	Use Design Rule
23	M41	Second. B...	20						Use Design Rule	Use Design Rule
24	M42	Second. B...	20						Use Design Rule	Use Design Rule
25	M43	Second. B...	20						Use Design Rule	Use Design Rule
26	M44	Second. B...	20						Use Design Rule	Use Design Rule
27	M45	Second. B...	20						Use Design Rule	Use Design Rule
28	M46	Second. B...	20						Use Design Rule	Use Design Rule
29	M47	Second. B...	20						Use Design Rule	Use Design Rule

Concrete Beam Design Parameters (Continued)

	Label	Shape	Length[ft]	B-eff Left[in]	B-eff Right...	Slab Th...	Slab Th...	Icr Fact...	Flexural Layout	Shear Layout
30	M48	Second. B...	20						Use Design Rule	Use Design Rule
31	M49	Second. B...	20						Use Design Rule	Use Design Rule
32	M50	Second. B...	20						Use Design Rule	Use Design Rule
33	M51	Second. B...	20						Use Design Rule	Use Design Rule
34	M53	Second. B...	20						Use Design Rule	Use Design Rule
35	M54	Second. B...	20						Use Design Rule	Use Design Rule
36	M55	Second. B...	20						Use Design Rule	Use Design Rule
37	M56	Second. B...	20						Use Design Rule	Use Design Rule
38	M57	Second. B...	20						Use Design Rule	Use Design Rule
39	M120A	Second. B...	20						Use Design Rule	Use Design Rule
40	M121A	Second. B...	20						Use Design Rule	Use Design Rule

Concrete Section Sets

	Label	Shape	Type	Design List	Material	Design Rules	A [in2]	Iyy [in4]	Izz [in4]	J [in4]
1	Ext. Column	CRECT30X36	Column	Rectangular	Conc4000NW	Column	1080	1.166e+5	81000	1.539e+5
2	Int. Column	CRECT30X36	Column	Rectangular	Conc4000NW	Column	1080	1.166e+5	81000	1.539e+5
3	Primary. BM	CRECT48X36	Beam	Rectangular	Conc4000NW	Primary Beam	1728	1.866e+5	3.318e+5	3.938e+5
4	Second. Beam	CRECT44X27	Beam	Rectangular	Conc4000NW	Secondary BM	1188	72171	1.917e+5	1.771e+5

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	Conc3000LW	2085	907	.15	.6	.11	3	.75	60	60
5	Conc3500LW	2252	979	.15	.6	.11	3.5	.75	60	60
6	Conc4000LW	2408	1047	.15	.6	.11	4	.75	60	60

Concrete Rebar Parameters

	Label	Optimi...	Min...	Ma...	She...	Legs p...	Top (Column) ...	Bottom Cov...	Side Cove...	Top/Botto...	Add'l Side Bars	Shear Bar Spa...
1	Column	Optimize	#6	#9	#5	2	4	4	4	2	1	12
2	Primary Beam	Explicit	#11	#11	#5	4	4	4	4	6	1	6
3	Secondary BM	Explicit	#9	#10	#5	3	4	4	4	5	1	6

Moving Loads

	Tag	Pattern	Increment[...	Both Ways	1st Jo...	2nd J...	3rd J...	4th Jo...	5th Jo...	6th Jo...	7th Jo...	8th Jo...	9th Jo...	10th J...
1	M1	PECKMAN_TANDEM_DIV...	1		N9	N11								
2	M2	PECKMAN_TANDEM_DIV...	1		N357	N288								
3	M3	PECKMAN_TANDEM_DIV...	1		N507	N526								
4	M4	PECKMAN_TANDEM_DIV...	1		N507	N526								

Moving Load Patterns

Pattern Label	Load (k)	Direction	Distance (ft)

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Pattern Label	Load (k)	Direction	Distance (ft)
PECKMAN_TANDEM_DIVERSION	-2.507	Y	0
	-5.014	Y	1.116
	-5.014	Y	1.116
	-5.014	Y	1.116
	-5.014	Y	1.116
	-5.014	Y	1.116
	-5.014	Y	1.116
	-5.014	Y	1.116
	-5.014	Y	1.116
	-5.014	Y	1.116
	-2.507	Y	1.116

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distribu...	Area(M...	Surface...
1	DC - Self Weight	DL		-1						
2	DW - Wearing Surface	OL1								518
3	EV - Vertical Earth	OL2								518
4	EH - Horizontal Earth (wall A)	OL3								64
5	EH - Horizontal Earth (wall E)	OL3								64
6	ES- Surcharge Earth (wall A)	OL4								64
7	ES- Surcharge Earth (wall E)	OL4								64
8	LS - Surcharge Live (wall A)	OL5								64
9	LS - Surcharge Live (wall E)	OL5								64
10	WS - Water (wall A)	OL6								64
11	WS - Water (wall E)	OL6								64
12	HL-93 Truck	None								
13	HL-93 Tandem	None								

Load Combinations

	Description	S...	P...	S...	BLC	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	BLC	Fa...	B...	Fa...	B...	Fa...	B...	Fa...
1	DC	Yes	C		DL	1																		
2	DW	Yes	C		OL1	1																		
3	EV	Yes	C		OL2	1																		
4	EH	Yes	C		4	1	5																	
5	ES	Yes	C		6	1	7																	
6	LS	Yes	C		8	1	9																	
7	HL93 Truck	Yes	C		M1																			
8	HL93 Tandem	Yes	C		M2																			
9																								
10	L10= 1.25DC+1.5DW+1.3EV+...	Yes	C		1	1.25	2	1.5	3	1.3	4	1.35	5	1.35	6	1.3	7	1.3	8	1.75	9	1.75	O...	1
11	L2	Yes	C		1	1.25	2	1.5	3	1.3	4	1.35	5		6	1.3	7		8	1.75	9		10	1
12																								
13	L1 + tandem (1 lane loaded)	Yes	C		L10	1	M1	2.1	M2		M3													
14	L1 + tandem (2 lanes loaded)	Yes	C		L10	1	M1	1.75	M2	1.75	M3													
15	L1 + tandem (3 lanes loaded)	Yes	C		L10	1	M1	1.4	M2	1.4	M3	1.4												
16																								
17																								
18																								

Envelope Member Section Forces

	Member	Sec		Axial[k]	LC	y Shear[k]	LC	z Shear[k]	LC	Torque[k-...	LC	y-y Mome...	LC	z-z Mome...	LC
1	M1	1	max	61.101	15-44	96.183	11	2.051	15-28	6.969	4	0	13-1	0	13-1
2			min	-7.961	1	-17.371	15-49	-.222	1	-214.348	15-24	0	13-1	0	13-1
3		2	max	81.97	10	0	7	1.112	10	16.152	4	.647	15-13	0	7
4			min	-8.655	1	-34.438	11	-.075	1	-108.551	15-44	-.313	1	-383.82	15-26
5		3	max	89.351	15-36	0	7	1.502	1	110.004	11	3.711	1	912.925	11
6			min	-10.316	1	-164.285	11	-.451	3	-2.628	1	-1.026	3	0	7
7	M2	1	max	88.736	15-40	137.552	15-58	.451	3	27.885	4	3.711	1	618.205	15-58
8			min	-10.315	1	-11.331	4	-1.502	1	-52.17	15-49	-1.026	3	-127.333	4
9		2	max	82.193	10	14.573	15-60	.075	1	146.307	11	.595	15-58	3.257	4
10			min	-8.657	1	-8.327	4	-1.112	10	0	7	-.313	1	-382.417	15-47
11		3	max	62.085	15-31	65.314	11	.223	1	219.19	11	0	13-1	0	13-1
12			min	-7.961	1	-32.063	1	-2.011	15-46	0	7	0	13-1	0	13-1
13	M3	1	max	80.423	15-28	38.542	4	.398	3	8.861	4	0	13-1	0	13-1
14			min	-7.685	1	-298.397	15-25	-2.022	14-55	-284.052	15-20	0	13-1	0	13-1
15		2	max	78.257	15-29	0	7	.133	1	120.625	15-19	2.45	15-13	0	7
16			min	-7.865	1	-70.7	11	-1.088	15-13	0	7	-.316	1	-883.927	15-24
17		3	max	73.303	15-27	0	7	.423	1	76.007	15-27	1.033	1	1841.387	11
18			min	-7.352	1	-322.01	11	-.933	15-36	-9.511	15-48	-2.338	15-36	0	7
19	M4	1	max	72.407	15-47	296.301	15-44	.93	15-36	12.413	4	1.033	1	1520.257	15-50
20			min	-7.352	1	-18.215	4	-.423	1	-73.23	15-46	-2.338	15-36	-161.073	4
21		2	max	74.644	15-46	50.465	15-53	1.066	14-64	9.255	4	2.371	15-59	58.838	4
22			min	-7.868	1	-10.333	4	-.131	1	-121.354	15-54	-.312	1	-877.973	15-49
23		3	max	64.603	15-46	317.633	11	2.44	14-23	287.144	15-53	0	13-1	0	13-1
24			min	-7.375	1	-23.512	1	-.541	3	0	7	0	13-1	0	13-1
25	M5	1	max	94.111	15-21	35.162	4	7.039	14-13	18.782	4	0	13-1	0	13-1
26			min	-8.255	1	-212.372	15-22	-.403	1	-141.237	14-19	0	13-1	0	13-1
27		2	max	40.67	14-18	28.007	15-28	.007	1	82.424	15-20	.113	1	0	7
28			min	-3.328	1	-10.341	13-16	-.035	13-68	0	7	-.196	15-13	-782.513	15-22
29		3	max	37.675	11	0	7	.122	4	91.858	11	.24	4	2026.385	11
30			min	-1.887	1	-391.358	15-33	-.898	14-40	-19.175	15-22	-1.967	14-40	0	7
31	M6	1	max	23.608	15-51	391.758	15-43	.9	14-40	77.982	11	.238	4	1796.39	15-50
32			min	-15.135	11	-19.929	4	-.108	4	-43.043	14-48	-1.967	14-40	-165.934	4
33		2	max	41.484	14-60	10.778	13-59	.035	15-13	4.638	4	.113	1	62.563	4
34			min	-3.324	1	-28.544	15-48	-.007	1	-71.89	14-65	-.167	15-58	-776.276	15-54
35		3	max	96.024	14-58	264.639	11	.655	4	144.159	14-61	0	13-1	0	13-1
36			min	-8.246	1	-19.302	1	-7.094	14-65	-18.738	1	0	13-1	0	13-1
37	M7	1	max	193.307	14-26	107.626	11	6.206	11	40.498	4	0	13-1	0	13-1
38			min	-19.567	1	-143.173	14-20	0	7	-163.23	13-52	0	13-1	0	13-1
39		2	max	108.547	10	0	7	.026	1	235.617	14-21	.911	14-70	0	7
40			min	-10.558	1	-31.503	11	-.312	15-25	0	7	-.072	3	-517.984	11
41		3	max	78.248	11	0	7	2.791	14-25	23.51	14-35	5.499	14-25	1477.496	11
42			min	-5.066	1	-415.185	11	0	2	-33.028	14-16	-.012	3	0	7
43	M8	1	max	75.689	14-37	504.696	14-28	.042	3	108.136	14-29	5.499	14-25	1469.078	14-35
44			min	-11.094	1	-35.423	4	-3.952	14-25	-1.293	1	-.012	3	-251.073	4
45		2	max	59.954	14-40	10.564	14-48	.17	14-13	94.569	11	.635	10	0	7
46			min	-7.724	1	-22.014	11	-.169	15-62	-64.954	14-29	-.064	1	-645.18	14-40
47		3	max	77.263	14-42	0	7	3.859	14-54	1.376	1	5.392	14-54	2010.505	11
48			min	-11.122	1	-549.857	11	-1.794	11	-108.075	14-50	-2.299	11	0	7
49	M9	1	max	70.255	14-60	396.576	14-60	1.536	11	30.691	14-63	5.392	14-54	1355.448	14-64
50			min	-15.909	11	-19.623	4	-2.725	14-54	-27.946	11	-2.301	11	-73.875	4
51		2	max	109.364	10	12.223	1	.289	15-54	7.416	4	.878	15-9	59.254	4

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y Shear[k]	LC	z Shear[k]	LC	Torque[k-...	LC	y-y Mome...	LC	z-z Mome...	LC
52			min	-10.632	1	-8.051	4	-.026	1	-231.881	14-58	-.073	3	-425.57	14-64
53		3	max	206.812	14-51	237.702	11	.99	11	336.43	11	0	13-1	0	13-1
54			min	-20.699	1	-47.661	1	-6.103	15-21	-4.888	1	0	13-1	0	13-1
55	M10	1	max	107.292	15-32	145.854	11	3.228	10	376.956	11	0	13-1	0	13-1
56			min	-15.511	1	-27.352	10	-2.102	3	0	7	0	13-1	0	13-1
57		2	max	86.51	10	0	7	.126	11	133.457	11	.194	14-63	0	7
58			min	-10.97	1	-55.012	11	-.277	15-13	0	7	-1.268	11	-455.599	11
59		3	max	84.875	10	0	7	10.91	11	0	7	20.967	11	1202.313	11
60			min	-7.76	1	-232.527	11	0	7	-72.917	11	0	7	0	7
61	M11	1	max	84.348	10	243.023	14-39	0	7	271.375	14-37	20.964	11	1059.769	15-10
62			min	-10.714	1	-22.117	4	-13.431	11	0	7	0	7	-253.859	4
63		2	max	80.632	10	5.166	15-10	.156	10	50.769	11	.095	1	0	7
64			min	-9.775	1	-38.043	11	-.147	14-6	-8.059	14-30	-.759	14-44	-558.885	14-40
65		3	max	85.985	10	0	7	12.101	14-48	5.398	4	19.692	14-47	1686.401	11
66			min	-10.715	1	-297.912	11	-.786	4	-270.895	14-42	-.89	4	0	7
67	M12	1	max	84.246	10	199.322	14-68	.445	4	65.083	14-64	19.692	14-47	1033.058	14-68
68			min	-7.755	1	-13.794	4	-10.286	14-48	-5.746	4	-.891	4	-72.829	4
69		2	max	87.761	10	43.065	14-68	.32	11	19.869	4	.701	11	30.039	4
70			min	-11.025	1	-5.057	4	-.054	1	-87.303	14-41	-.414	3	-385.383	14-63
71		3	max	108.737	15-44	158.372	11	2.357	11	60.97	4	0	13-1	0	13-1
72			min	-15.486	1	-28.511	1	-3.221	10	-226.659	14-66	0	13-1	0	13-1
73	M13	1	max	61.514	15-17	22.29	11	1.3	3	19.794	11	101.66	11	216.014	11
74			min	0	7	-2.149	3	-19.05	14-68	-1.678	3	0	7	0	7
75		2	max	59.133	15-29	13.533	11	2.863	15-47	8.457	11	17.902	1	56.696	1
76			min	-.244	6	-8.875	15-43	-1.862	11	-5.814	15-58	-19.237	15-49	-61.226	15-49
77		3	max	32.454	10	4.762	1	29.545	11	9.864	15-32	141.031	15-23	146.733	15-32
78			min	-1.188	4	-21.492	15-48	0	7	-1.941	4	-5.098	4	-30.507	4
79	M14	1	max	69.71	15-13	23.428	11	.769	3	5.954	15-13	61.576	11	249.35	11
80			min	-.235	4	-.814	3	-5.38	10	-10.095	11	0	7	0	7
81		2	max	65.391	15-16	13.325	11	0	7	6.707	15-13	20.203	1	63.832	1
82			min	0	7	-.886	3	-6.002	11	-16.83	11	-21.419	15-46	-71.281	15-47
83		3	max	43.048	11	2.537	1	41.407	15-22	1.316	13-1	198.981	15-22	104.764	15-22
84			min	-.599	4	-15.595	10	-3.284	4	-13.242	11	-28.086	4	-15.22	4
85	M15	1	max	68.087	15-13	24.313	11	1.315	3	0	7	62.5	11	253.363	11
86			min	-1.373	4	-.583	3	-4.346	15-46	-20.353	11	0	7	0	7
87		2	max	74.062	14-13	13.411	11	2.941	15-15	4.143	15-16	18.951	1	60.253	1
88			min	-.924	4	-8.127	14-20	-5.98	11	-23.703	11	-22.572	15-43	-72.226	15-43
89		3	max	52.257	11	1.463	1	16.571	14-20	3.841	15-21	92.792	14-19	171.516	15-18
90			min	0	7	-24.51	15-19	-8.257	11	-12.768	11	-37.929	11	-25.295	4
91	M16	1	max	49.689	14-10	23.31	11	.793	1	0	7	66.984	11	232.908	11
92			min	0	7	-.81	3	-6.478	11	-23.274	11	0	7	0	7
93		2	max	58.312	14-12	14.131	11	0	7	3.793	1	14.634	1	47.218	1
94			min	0	7	-.939	3	-6.008	11	-45.365	11	-35.333	14-37	-116.157	14-39
95		3	max	65.8	11	3.676	1	52.001	10	5.519	3	220.725	10	57.963	14-18
96			min	0	7	-23.993	14-20	-5.168	4	-33.887	11	-41.201	4	-20.71	4
97	M17	1	max	68.53	14-13	44.641	11	6.441	4	11.622	14-28	167.25	14-13	392.304	11
98			min	-4.539	4	-.125	3	-36.302	14-13	-19.339	11	-7.038	4	0	7
99		2	max	45.943	11	21.415	11	2.282	3	37.011	13-32	13.87	1	41.949	1
100			min	-2.036	4	0	7	-14.495	11	-30.633	11	-34.275	14-36	-108.366	14-37
101		3	max	51.352	15-1	2.58	1	0	7	39.965	15-32	0	7	94.884	10
102			min	-2.774	4	-36.988	10	-74.651	11	-6.064	1	-378.818	11	-28.239	4
103	M18	1	max	61.748	15-58	13.295	11	1.304	3	19.837	11	67.262	15-59	57.352	11

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y Shear[k]	LC	z Shear[k]	LC	Torque[k-...	LC	y-y Mome...	LC	z-z Mome...	LC
104			min	0	7	-13.413	15-59	-19.095	14-10	-2.01	15-59	-14.481	4	-85.45	15-58
105		2	max	59.578	15-54	9.184	15-33	2.933	15-29	19.085	11	18.581	11	61.601	15-26
106			min	0	7	-3.089	1	-1.415	1	-.461	1	-19.404	15-26	-64.687	11
107		3	max	36.584	11	21.846	15-29	26.323	15-51	0	7	146.694	11	.527	1
108			min	0	7	-4.772	1	-2.029	4	-14.449	11	-2.139	4	-222.021	11
109	M19	1	max	69.076	15-59	3.552	11	.765	3	0	7	37.367	15-64	48.239	4
110			min	0	7	-20.068	14-68	-5.391	10	-16.93	11	-9.763	4	-135.811	15-64
111		2	max	63.643	15-56	8.163	15-49	0	7	.914	1	22.513	11	69.534	15-28
112			min	-1.885	4	-7.444	14-67	-3.35	14-69	-20.792	11	-20.724	15-28	-66.084	11
113		3	max	36.597	15-55	12.265	10	45.81	15-52	1.081	1	242.567	11	0	7
114			min	-3.134	4	-2.675	1	-1.904	1	-13.305	11	0	7	-112.851	11
115	M20	1	max	67.6	14-65	2.833	11	3.048	11	7.444	15-55	31.312	15-64	49.109	4
116			min	0	7	-20.919	15-9	-4.366	15-30	-5.748	4	-12.862	4	-135.284	15-65
117		2	max	75.292	14-65	8.321	14-59	2.976	15-52	3.294	15-13	19.162	11	72.623	14-35
118			min	0	7	-7.223	15-9	-3.439	15-9	-26.752	11	-22.676	15-32	-60.254	1
119		3	max	51.254	13-65	24.702	15-54	16.883	14-61	0	7	103.598	11	0	7
120			min	-7.288	4	-1.463	1	-5.98	1	-23.185	11	-19.357	1	-202.267	11
121	M21	1	max	49.571	14-68	3.176	11	1.646	11	14.473	14-63	34.825	14-68	56.628	11
122			min	0	7	-20.727	15-13	-6.049	14-65	-4.305	11	-16.405	11	-111.235	14-68
123		2	max	58.395	14-68	6.347	11	0	7	26.259	15-13	14.627	1	117.119	14-40
124			min	0	7	-8.263	15-10	-4.958	11	-27.635	11	-35.57	14-42	-47.221	1
125		3	max	57.903	14-67	23.079	14-59	67.805	11	11.104	15-13	335.813	11	.212	1
126			min	-3.396	4	-3.726	1	-1.303	1	-35.425	11	-.289	1	-93.612	11
127	M22	1	max	75.772	11	20.514	11	0	7	.657	1	174.167	11	132.969	11
128			min	0	7	-23.018	15-10	-50.546	11	-31.274	11	0	7	-175.83	14-67
129		2	max	46.493	11	5.492	11	16.509	11	6.919	1	13.859	1	110.176	15-41
130			min	-4.415	4	-12.052	14-67	-1	1	-42.382	11	-34.925	15-42	-41.948	1
131		3	max	58.146	11	37.37	10	6.877	4	6.069	1	34.629	4	0	7
132			min	0	7	-2.602	1	-57.401	14-66	-40.618	15-45	-291.455	14-66	-166.163	11
133	M23	1	max	380.841	11	46.956	11	2.032	3	0	15-13	191.717	11	503.045	11
134			min	-7.107	4	-.606	15-55	-6.259	1	-.001	11	-1.332	4	-3.875	15-55
135		2	max	366.907	11	46.956	11	2.032	3	0	15-13	160.542	11	21.748	11
136			min	-7.107	4	-.606	15-55	-6.259	1	-.001	11	-2.884	4	-2.147	15-21
137		3	max	352.974	11	46.956	11	2.032	3	0	15-13	129.367	11	8.541	15-55
138			min	-7.107	4	-.606	15-55	-6.259	1	-.001	11	-4.435	4	-459.55	11
139	M24	1	max	872.342	15-35	64.004	11	4.186	15-36	0	15-13	24.459	1	687.198	11
140			min	-12.311	4	-2.527	15-50	-2.174	1	-.002	11	-30.577	3	-13.445	15-51
141		2	max	858.409	15-35	64.004	11	4.186	15-36	0	15-13	15.453	15-32	31.155	11
142			min	-12.311	4	-2.527	15-50	-2.174	1	-.002	11	0	7	-12.315	15-25
143		3	max	844.475	15-35	64.004	11	4.186	15-36	0	15-13	58.046	15-36	38.363	15-50
144			min	-12.311	4	-2.527	15-50	-2.174	1	-.002	11	-20.116	1	-624.889	11
145	M25	1	max	1111.795	15-38	76.366	11	5.613	14-40	0	15-13	9.565	4	811.335	11
146			min	-4.933	4	-4.319	15-49	-.7	4	-.003	11	-25.991	3	-24.51	15-49
147		2	max	1097.862	15-38	76.366	11	5.613	14-40	0	15-13	38.25	14-40	28.584	11
148			min	-4.933	4	-4.319	15-49	-.7	4	-.003	11	0	7	-18.675	15-27
149		3	max	1083.928	15-38	76.366	11	5.613	14-40	0	15-13	95.783	14-40	64.032	15-49
150			min	-4.933	4	-4.319	15-49	-.7	4	-.003	11	-4.784	4	-754.168	11
151	M26	1	max	923.812	14-25	71.772	11	.063	3	0	15-13	52.124	11	800.632	11
152			min	-26.615	4	-6.062	14-36	-6.712	14-25	-.002	11	-7.799	3	-31.038	3
153		2	max	909.879	14-25	71.772	11	.063	3	0	15-13	6.041	4	64.967	11
154			min	-26.615	4	-6.062	14-36	-6.712	14-25	-.002	11	-27.584	14-24	0	7
155		3	max	895.945	14-25	71.772	11	.063	3	0	15-13	0	7	121.513	14-36

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y Shear[k]	LC	z Shear[k]	LC	Torque[k-...	LC	y-y Mome...	LC	z-z Mome...	LC
156			min	-26.615	4	-6.062	14-36	-6.712	14-25	-.002	11	-96.35	14-25	-670.698	11
157	M27	1	max	925.272	14-54	76.984	11	3.593	11	0	15-13	39.285	14-53	773.322	11
158			min	0	7	-6.024	1	-6.55	14-54	-.002	11	-61.467	11	-67.051	1
159		2	max	911.339	14-54	76.984	11	3.593	11	0	15-13	0	7	5.881	4
160			min	0	7	-6.024	1	-6.55	14-54	-.002	11	-27.931	14-55	-58.871	14-45
161		3	max	897.405	14-54	76.984	11	3.593	11	0	15-13	14.131	4	56.448	1
162			min	0	7	-6.024	1	-6.55	14-54	-.002	11	-95.034	14-54	-804.858	11
163	M28	1	max	470.486	14-10	81.82	11	0	7	0	15-13	157.495	11	895.238	11
164			min	-8.946	4	-2.701	3	-24.363	11	-.002	11	0	7	-19.095	3
165		2	max	456.552	14-10	81.82	11	0	7	0	15-13	2.39	4	56.578	11
166			min	-8.946	4	-2.701	3	-24.363	11	-.002	11	-96.395	15-43	-.015	1
167		3	max	442.619	14-10	81.82	11	0	7	0	15-13	0	7	36.269	3
168			min	-8.946	4	-2.701	3	-24.363	11	-.002	11	-341.951	11	-782.082	11
169	M29	1	max	491.72	11	83.555	11	1.235	4	0	15-13	134.859	14-52	872.177	11
170			min	0	7	-2.96	1	-22.365	14-48	-.002	11	-14.176	4	-30.308	1
171		2	max	477.787	11	83.555	11	1.235	4	0	15-13	0	7	15.74	11
172			min	0	7	-2.96	1	-22.365	14-48	-.002	11	-101.936	11	-29.154	14-42
173		3	max	463.853	11	83.555	11	1.235	4	0	15-13	11.144	4	30.379	1
174			min	0	7	-2.96	1	-22.365	14-48	-.002	11	-324.592	14-44	-840.697	11
175	M30	1	max	.199	3	30.106	11	.059	11	48.424	15-50	0	13-1	0	13-1
176			min	-6.027	10	-.762	4	-.036	15-13	-7.69	4	0	13-1	0	13-1
177		2	max	.368	3	1.036	4	.007	15-10	123.397	15-50	.338	11	9.016	4
178			min	-8.184	10	-32.064	15-27	-.003	3	-7.986	4	-.245	15-10	-280.472	14-10
179		3	max	.542	3	18.684	15-40	.049	15-46	119.777	15-49	0	13-1	0	13-1
180			min	-4.478	10	-.281	4	-.066	11	-7.335	4	0	13-1	0	13-1
181	M31	1	max	3.027	15-58	.64	4	.004	1	20.072	15-47	0	13-1	0	13-1
182			min	-1.526	1	-9.911	11	-.063	14-67	-40.468	15-33	0	13-1	0	13-1
183		2	max	11.227	15-52	0	7	.216	4	55.261	14-50	2.393	11	13.842	4
184			min	-2.244	1	-43.779	15-38	-.54	11	-28.514	11	-.173	1	-389.102	15-38
185		3	max	10.145	15-35	11.749	14-40	.076	14-64	47.225	14-51	0	13-1	0	13-1
186			min	-2.022	1	-2.064	1	-.007	1	-7.673	4	0	13-1	0	13-1
187	M32	1	max	10.299	15-52	2.611	1	.008	1	0	7	0	13-1	0	13-1
188			min	-1.805	1	-13.356	15-41	-.059	15-58	-262.53	11	0	13-1	0	13-1
189		2	max	11.513	15-53	85.824	14-44	.39	11	0	7	1.778	11	42.009	4
190			min	-1.737	1	-5.436	4	-.047	1	-269.219	11	-.194	1	-716.419	14-45
191		3	max	4.913	15-58	2.298	11	.072	11	0	7	0	13-1	0	13-1
192			min	-.611	1	-2.864	14-36	-.008	1	-236.061	14-51	0	13-1	0	13-1
193	M33	1	max	.887	3	13.668	10	0	1	1.745	14-34	0	13-1	0	13-1
194			min	-.374	4	0	7	-.014	15-64	-34.315	11	0	13-1	0	13-1
195		2	max	.685	3	19.782	11	.015	11	18.968	14-35	.052	11	0	7
196			min	-2.674	10	-.268	4	-.021	4	-13.779	11	-.03	14-13	-268.556	11
197		3	max	.326	1	.388	4	.043	11	20.788	14-35	0	13-1	0	13-1
198			min	-3.091	10	-32.376	11	0	7	-6.028	4	0	13-1	0	13-1
199	M34	1	max	.427	1	7.182	1	.013	1	9.683	1	0	13-1	0	13-1
200			min	-6.925	10	-1.316	4	-.142	15-13	-30.324	11	0	13-1	0	13-1
201		2	max	.652	3	1.026	4	.053	15-15	76.99	15-57	.131	1	11.999	4
202			min	-10.005	10	-11.631	15-24	-.005	11	-7.233	4	-1.12	15-36	-155.383	14-10
203		3	max	.903	3	2.413	15-50	.174	15-45	91.389	15-57	0	13-1	0	13-1
204			min	-3.61	10	-1.973	1	-.025	1	0	7	0	13-1	0	13-1
205	M35	1	max	6.482	15-59	1.275	1	.026	1	56.332	15-56	0	13-1	0	13-1
206			min	-1.651	1	-3.648	11	-.182	15-58	-3.258	4	0	13-1	0	13-1
207		2	max	13.11	15-59	29.281	15-50	1.04	15-19	44.727	14-59	4.332	15-19	0	7

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y Shear[k]	LC	z Shear[k]	LC	Torque[k-...	LC	y-y Mome...	LC	z-z Mome...	LC
208			min	-2.283	1	-14.898	11	-1.046	14-25	-1.627	4	-.599	1	-303.183	15-50
209		3	max	10.517	15-59	0	7	.207	14-64	39.213	14-60	0	13-1	0	13-1
210			min	-1.943	1	-14.889	11	-.026	1	-.545	1	0	13-1	0	13-1
211	M36	1	max	9.85	15-59	23.302	14-48	.023	1	8.205	4	0	13-1	0	13-1
212			min	-1.677	1	-1.166	4	-.198	14-62	-146.448	14-48	0	13-1	0	13-1
213		2	max	11.677	15-59	0	7	.129	1	13.648	4	3.989	14-14	0	7
214			min	-1.602	1	-92.27	14-54	-.972	14-13	-169.638	14-59	-.585	1	-785.555	14-54
215		3	max	5.867	15-58	32.416	15-54	.178	14-61	14.296	4	0	13-1	0	13-1
216			min	-.823	4	-.856	4	-.012	1	-199.086	14-60	0	13-1	0	13-1
217	M37	1	max	2.107	3	0	7	.113	11	59.46	14-45	0	13-1	0	13-1
218			min	-.686	4	-17.042	11	-.02	14-65	0	7	0	13-1	0	13-1
219		2	max	3.894	11	33.098	11	.029	14-66	62.155	14-45	.051	10	0	7
220			min	-.821	4	0	7	-.115	11	-3.007	1	-.012	11	-359.523	11
221		3	max	6.043	14-64	0	7	.018	15-12	20.147	11	0	13-1	0	13-1
222			min	-1.113	4	-33.779	11	-.119	11	-5.789	1	0	13-1	0	13-1
223	M39	1	max	15.181	15-59	4.679	15-45	.034	1	0	7	0	13-1	0	13-1
224			min	-3.518	1	-.461	3	-.214	15-58	-128.112	15-53	0	13-1	0	13-1
225		2	max	15.788	15-59	27.216	15-57	1.622	15-55	72.725	15-51	7.056	15-53	35.972	4
226			min	-3.367	1	-3.689	4	-1.686	14-62	-12.447	4	-1.024	1	-244.357	15-57
227		3	max	6.852	15-64	0	7	.287	15-59	128.269	15-51	0	13-1	0	13-1
228			min	-2.985	11	-22.418	11	-.043	1	-2.527	4	0	13-1	0	13-1
229	M40	1	max	4.117	15-64	23.994	14-55	.047	1	137.796	13-54	0	13-1	0	13-1
230			min	-3.6	11	-3.067	4	-.465	14-64	-6.545	4	0	13-1	0	13-1
231		2	max	7.187	14-64	1.398	4	.273	1	224.448	14-56	7.782	14-16	15.154	4
232			min	-2.164	11	-63.859	14-61	-1.89	14-59	-3.872	4	-1.115	1	-495.795	14-61
233		3	max	2.267	3	26.766	14-61	.342	14-64	249.011	14-56	0	13-1	0	13-1
234			min	-3.488	15-10	-2.227	4	-.05	1	0	7	0	13-1	0	13-1
235	M41	1	max	1.86	3	0	7	.027	11	52.054	14-53	0	13-1	0	13-1
236			min	-5.367	15-10	-14.908	11	-.035	14-55	0	7	0	13-1	0	13-1
237		2	max	1.533	3	24.954	11	.121	14-50	59.129	14-50	.432	15-42	4.239	4
238			min	-2.162	15-12	0	7	-.027	4	-3.564	1	-.088	1	-258.73	15-13
239		3	max	.544	3	0	7	0	1	53.666	14-48	0	13-1	0	13-1
240			min	-1.57	10	-37.507	11	-.092	14-42	0	7	0	13-1	0	13-1
241	M42	1	max	5.532	14-65	5.512	1	.115	1	25.987	13-61	0	13-1	0	13-1
242			min	-5.37	14-9	-3.575	11	-1.315	14-66	-19.6	14-68	0	13-1	0	13-1
243		2	max	4.399	3	36.892	14-67	4.152	14-65	112.779	14-64	14.232	14-61	245.606	15-22
244			min	-11.627	14-12	-7.226	4	-3.295	14-63	-25.938	4	-1.993	1	-224.509	14-67
245		3	max	2.383	3	7.779	15-22	.452	14-65	155.141	14-64	0	13-1	0	13-1
246			min	-17.379	14-13	-1.874	4	-.115	1	-18.091	4	0	13-1	0	13-1
247	M43	1	max	2.093	3	1.17	1	.065	11	85.599	14-62	0	13-1	0	13-1
248			min	-11.991	15-15	-15.947	11	-.022	1	-9.196	4	0	13-1	0	13-1
249		2	max	2.893	14-68	30.868	11	.434	10	99.626	14-62	2.16	10	0	7
250			min	-6.121	11	0	7	-.043	1	-9.148	4	-.323	1	-284.303	11
251		3	max	.302	1	0	7	.023	3	30.202	14-62	0	13-1	0	13-1
252			min	-2.46	11	-40.9	11	-.183	10	-8.988	4	0	13-1	0	13-1
253	M44	1	max	.203	3	31.122	11	.096	11	0	7	0	13-1	0	13-1
254			min	-6.042	10	-.349	4	-.004	3	-55.292	11	0	13-1	0	13-1
255		2	max	.379	3	.682	4	.012	4	0	7	.564	11	0	7
256			min	-8.215	10	-34.1	11	-.002	15-64	-124.433	11	-.051	1	-302.689	11
257		3	max	.547	3	18.959	15-31	.01	1	0	7	0	13-1	0	13-1
258			min	-4.592	10	-.066	4	-.113	11	-120.595	15-24	0	13-1	0	13-1
259	M45	1	max	3.007	15-13	.67	4	.07	14-12	34.516	15-38	0	13-1	0	13-1

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y Shear[k]	LC	z Shear[k]	LC	Torque[k-...	LC	y-y Mome...	LC	z-z Mome...	LC
260			min	-1.525	1	-9.89	14-56	-.004	1	-23.198	15-25	0	13-1	0	13-1
261		2	max	11.468	15-26	0	7	.377	15-57	6.204	1	1.024	11	0	7
262			min	-2.243	1	-42.615	15-30	-.192	11	-56.236	14-27	-1.54	15-57	-385.942	15-29
263		3	max	10.304	15-27	12.613	14-39	.007	1	0	7	0	13-1	0	13-1
264			min	-2.021	1	-2.064	1	-.075	14-13	-49.834	15-35	0	13-1	0	13-1
265	M46	1	max	10.346	15-39	2.611	1	.063	15-20	247.452	14-42	0	13-1	0	13-1
266			min	-1.804	1	-13.086	15-37	-.008	1	-18.874	4	0	13-1	0	13-1
267		2	max	11.535	14-31	87.831	14-38	.116	11	251.98	15-24	.653	11	0	7
268			min	-1.736	1	0	7	-.339	14-67	-18.87	4	-1.405	14-66	-727.759	14-38
269		3	max	4.967	15-13	1.495	13-59	.016	11	232.358	14-29	0	13-1	0	13-1
270			min	-.61	1	-2.942	14-44	-.063	14-67	-19.671	4	0	13-1	0	13-1
271	M47	1	max	.958	11	13.697	14-78	.013	15-13	23.446	14-25	0	13-1	0	13-1
272			min	-.145	4	0	7	0	1	-8.952	4	0	13-1	0	13-1
273		2	max	.683	3	19.082	15-20	.01	11	3.224	15-24	.093	11	.107	6
274			min	-2.676	10	-.516	4	-.009	15-13	-24.617	11	0	7	-267.647	10
275		3	max	.327	1	.374	4	.031	11	0	7	0	13-1	0	13-1
276			min	-3.089	10	-32.408	11	-.009	14-65	-26.939	11	0	13-1	0	13-1
277	M48	1	max	.427	1	9.537	11	.144	15-59	19.046	15-31	0	13-1	0	13-1
278			min	-6.973	10	0	7	-.013	1	-15.233	11	0	13-1	0	13-1
279		2	max	.711	3	.365	4	.04	4	0	7	1.156	15-57	0	7
280			min	-10.124	10	-13.768	11	-.05	15-58	-77.849	11	-.132	1	-185.147	11
281		3	max	.938	3	2.284	15-23	.026	1	0	7	0	13-1	0	13-1
282			min	-3.799	10	-1.987	1	-.183	15-33	-91.239	15-15	0	13-1	0	13-1
283	M49	1	max	6.618	15-13	1.267	1	.195	15-15	0	7	0	13-1	0	13-1
284			min	-1.649	1	-3.795	14-24	-.026	1	-59.554	15-16	0	13-1	0	13-1
285		2	max	13.768	15-13	29.554	15-23	1.055	14-53	0	7	.599	1	21.353	4
286			min	-2.281	1	-13.059	14-50	-1.064	15-56	-47.35	15-17	-4.39	15-56	-304.982	15-23
287		3	max	11.239	15-13	3.011	4	.026	1	.542	1	0	13-1	0	13-1
288			min	-1.939	1	-13.883	13-24	-.208	15-13	-41.788	15-26	0	13-1	0	13-1
289	M50	1	max	10.474	15-13	23.972	14-20	.199	15-16	146.129	14-34	0	13-1	0	13-1
290			min	-1.673	1	0	7	-.023	1	0	7	0	13-1	0	13-1
291		2	max	12.117	15-13	5.663	4	.984	14-65	175.275	11	.585	1	52.05	4
292			min	-1.598	1	-91.861	14-26	-.129	1	0	7	-4.034	14-65	-781.659	14-26
293		3	max	6.072	15-17	32.468	15-25	.012	1	198.778	14-20	0	13-1	0	13-1
294			min	-.284	1	0	7	-.182	14-19	0	7	0	13-1	0	13-1
295	M51	1	max	2.101	3	2.799	4	.131	11	0	7	0	13-1	0	13-1
296			min	-.616	4	-16.481	14-25	-.004	3	-59.198	14-35	0	13-1	0	13-1
297		2	max	4.71	11	31.613	14-25	.003	3	4.664	4	0	1	7.428	4
298			min	-.722	4	-1.295	4	-.145	11	-61.629	14-35	-.072	11	-340.7	15-1
299		3	max	8.217	11	1.809	4	0	7	14.462	11	0	13-1	0	13-1
300			min	0	7	-29.283	15-57	-.155	11	-17.98	14-36	0	13-1	0	13-1
301	M53	1	max	16.525	15-13	3.854	11	.224	15-14	123.689	15-20	0	13-1	0	13-1
302			min	-3.55	1	-.71	3	-.033	1	-8.372	4	0	13-1	0	13-1
303		2	max	17.442	15-13	27.928	15-15	1.715	15-21	0	7	1.021	1	0	7
304			min	-3.372	1	0	7	-1.66	15-18	-80.197	15-15	-7.197	15-20	-249.242	15-15
305		3	max	8.793	15-13	2.921	4	.043	1	0	7	0	13-1	0	13-1
306			min	-1.865	1	-20.467	13-19	-.288	15-13	-135.825	15-17	0	13-1	0	13-1
307	M54	1	max	5.567	15-13	23.812	11	.46	14-15	.942	4	0	13-1	0	13-1
308			min	-1.215	1	0	7	-.047	1	-145.099	15-15	0	13-1	0	13-1
309		2	max	8.152	15-13	1.562	4	1.883	14-21	2.746	4	1.113	1	0	7
310			min	-1.147	1	-64.609	14-19	-.399	4	-225.402	14-23	-7.764	14-62	-500.936	14-19
311		3	max	2.629	11	29.71	11	.049	1	3.729	4	0	13-1	0	13-1

Envelope Member Section Forces (Continued)

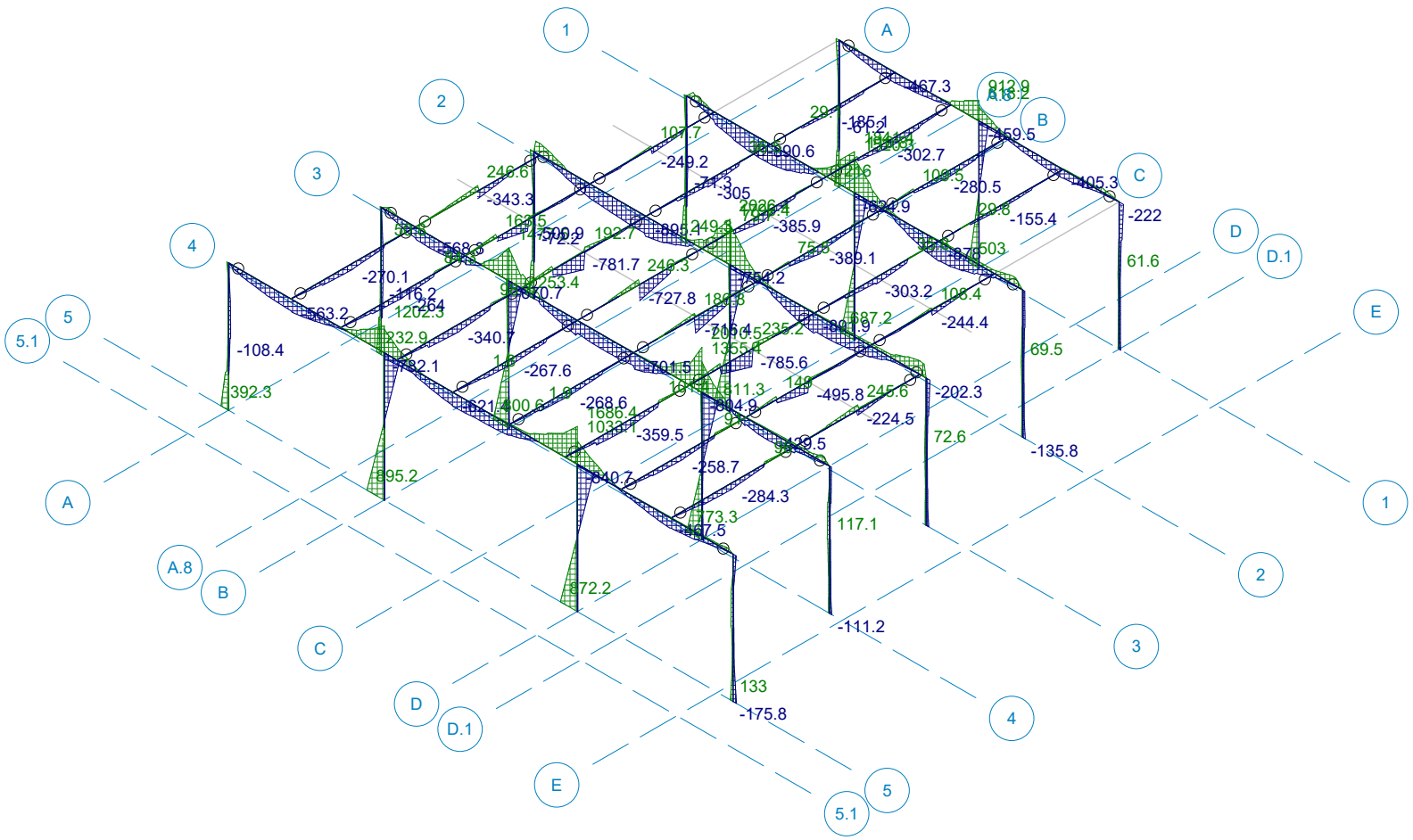
	Member	Sec		Axial[k]	LC	y Shear[k]	LC	z Shear[k]	LC	Torque[k-...	LC	y-y Mome...	LC	z-z Mome...	LC
312			min	-3.169	14-68	0	7	-.338	14-15	-249.87	14-24	0	13-1	0	13-1
313	M55	1	max	1.857	3	2.445	4	.066	11	1.017	4	0	13-1	0	13-1
314			min	-5.169	14-68	-13.557	14-21	0	7	-51.416	14-27	0	13-1	0	13-1
315		2	max	3.043	11	24.529	14-23	.013	1	3.643	1	.081	1	0	7
316			min	-2.164	14-67	-1.532	4	-.105	14-29	-59.239	14-29	-.379	14-37	-263.993	11
317		3	max	.708	11	2.664	4	.089	14-36	0	7	0	13-1	0	13-1
318			min	-1.664	10	-31.052	15-47	0	1	-54.004	14-30	0	13-1	0	13-1
319	M56	1	max	5.796	14-13	7.268	11	1.306	14-14	11.264	14-14	0	13-1	0	13-1
320			min	-5.346	14-69	-1.242	14-9	-.115	1	-33.75	11	0	13-1	0	13-1
321		2	max	5.259	11	44.58	11	3.255	14-19	0	7	1.99	1	246.623	15-23
322			min	-11.853	14-67	0	7	-4.128	14-15	-139.087	11	-14.143	14-18	-343.323	11
323		3	max	2.414	3	10.893	11	.114	1	0	7	0	13-1	0	13-1
324			min	-17.731	14-65	0	7	-.433	14-14	-159.658	14-16	0	13-1	0	13-1
325	M57	1	max	4.546	11	2.131	4	.036	1	0	7	0	13-1	0	13-1
326			min	-10.335	14-64	-6.712	14-23	-.134	14-13	-105.724	11	0	13-1	0	13-1
327		2	max	8.146	11	25.228	14-29	.01	3	0	7	.219	1	4.181	4
328			min	0	7	-1.171	4	-.175	10	-94.073	11	-1.449	10	-270.053	13-50
329		3	max	2.978	11	2.884	4	.224	10	0	7	0	13-1	0	13-1
330			min	-.063	14-62	-33.875	15-45	-.024	3	-46.094	11	0	13-1	0	13-1
331	M120A	1	max	11.695	15-52	1.41	1	.039	1	0	7	0	13-1	0	13-1
332			min	-.778	1	-1.715	3	-.643	15-31	-239.69	11	0	13-1	0	13-1
333		2	max	10.055	15-58	3.471	1	.226	11	0	7	.387	11	111.445	11
334			min	-3.336	1	-17.01	11	0	7	-202.546	11	-2.244	15-27	0	7
335		3	max	12.647	15-59	27.774	11	2.366	15-16	12.689	1	7.89	15-15	1.976	1
336			min	-3.592	1	-3.519	1	-.249	1	-41.764	15-51	-.808	1	-147.72	11
337	M121A	1	max	11.88	15-22	1.366	1	.638	15-42	204.267	15-25	0	13-1	0	13-1
338			min	-.769	1	-2.057	3	-.037	1	-17.626	4	0	13-1	0	13-1
339		2	max	10.451	15-13	14.282	10	.269	14-10	192.154	15-23	2.46	15-46	103.59	15-23
340			min	-3.335	1	-15.15	15-23	-.158	15-13	-11.934	4	-.363	1	-8.376	4
341		3	max	12.632	15-13	22.262	15-24	.259	1	41.012	15-22	.827	1	10.988	4
342			min	-3.522	1	-3.363	1	-2.31	15-58	-25.335	11	-7.758	15-58	-113.942	10

Envelope Concrete Beam Design Results

	Member	Shape	UC M...	Loc[ft]	UC LC	UC M...	Loc[ft]	UC LC	Shear ...	Loc[ft]	UC LC	Phi*M...	Phi*Mnz...	Phi*V...
1	M1	CRECT48X36	.412	21.352	11	.266	8.954	11	.156	17.679	11	1759.6...	1759.682	555.2...
2	M2	CRECT48X36	.262	1.148	15	.23	13.316	15	.119	4.821	15	1759.6...	1759.682	555.2...
3	M3	CRECT48X36	.796	25.622	11	.506	11.571	11	.33	22.041	11	1759.6...	1759.682	555.2...
4	M4	CRECT48X36	.636	1.378	15	.499	13.5	15	.294	4.959	15	1759.6...	1759.682	555.2...
5	M5	CRECT48X36	.875	30.214	11	.509	18	15	.693	30.214	15	1759.6...	1759.682	555.2...
6	M6	CRECT48X36	.753	1.286	15	.507	13.5	15	.693	1.286	15	1759.6...	1759.682	555.2...
7	M7	CRECT48X36	.544	19.245	11	.323	7.531	11	.28	15.48	11	1759.6...	1759.682	555.2...
8	M8	CRECT48X36	.748	29.735	11	.399	20.245	14	.263	25.939	11	1759.6...	1759.682	555.2...
9	M9	CRECT48X36	.497	1.255	14	.244	10.878	14	.261	5.02	14	1759.6...	1759.682	555.2...
10	M10	CRECT48X36	.516	23.724	11	.32	10.204	11	.245	20.153	11	1759.6...	1759.682	555.2...
11	M11	CRECT48X36	.745	29.735	11	.353	11.071	11	.25	25.939	11	1759.6...	1759.682	555.2...
12	M12	CRECT48X36	.444	1.276	14	.266	14.796	14	.217	4.847	14	1759.6...	1759.682	555.2...
13	M30	CRECT44X27	.127	15.102	15	.325	10	14	.104	14.898	15	863.056	863.056	378.5...
14	M31	CRECT44X27	.087	15.102	14	.451	10	15	.135	14.898	15	863.056	863.056	378.5...
15	M32	CRECT44X27	.216	10.204	15	.83	10	14	.246	5.102	14	863.056	863.056	378.5...
16	M33	CRECT44X27	.002	15.102	4	.311	10	11	.072	5.102	11	863.056	863.056	378.5...

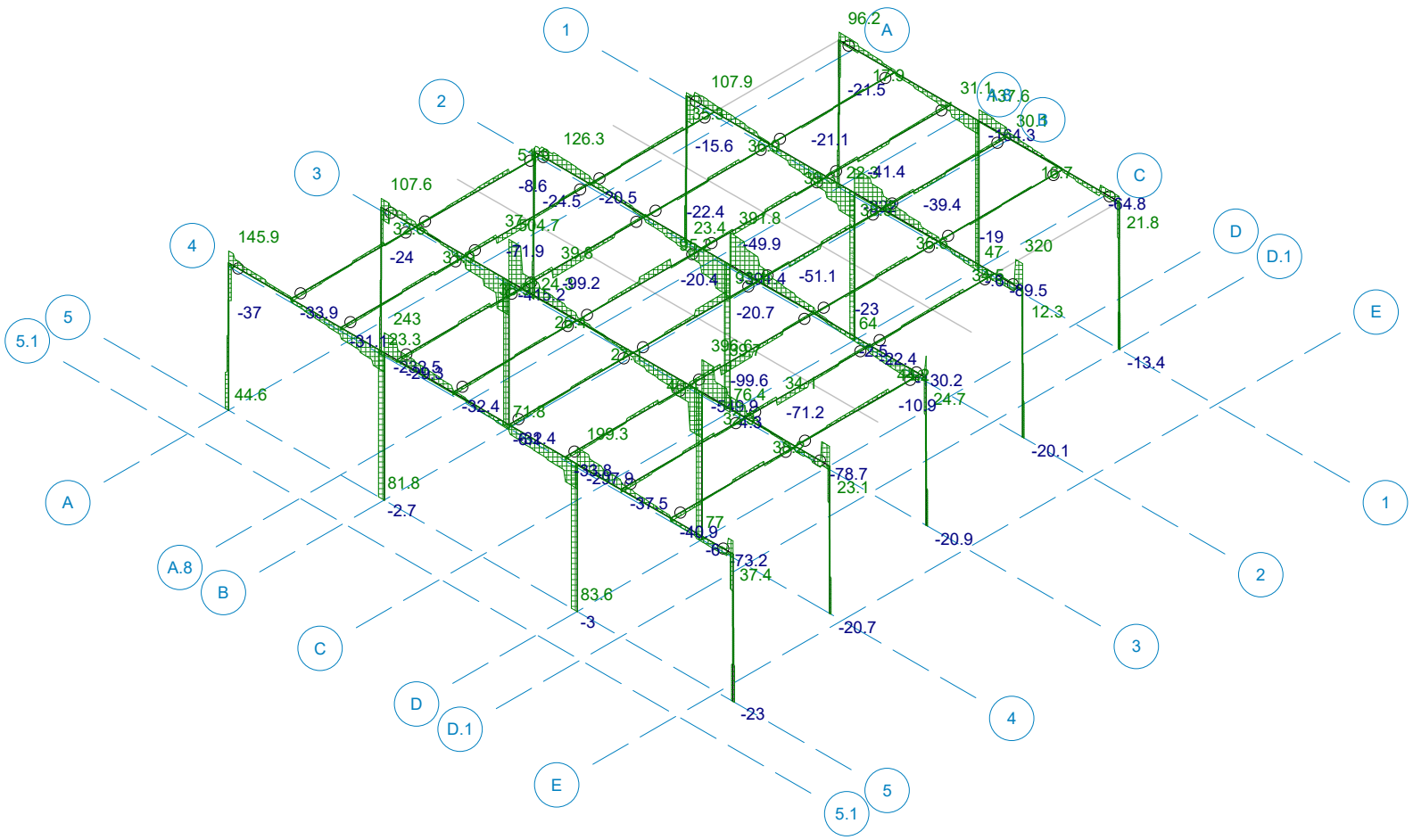
Envelope Concrete Beam Design Results (Continued)

	Member	Shape	UC M...	Loc[ft]	UC LC	UC M...	Loc[ft]	UC LC	Shear ...	Loc[ft]	UC LC	Phi*M...	Phi*Mnz...	Phi*V...
17	M34	CRECT44X27	.034	15.102	15	.18	10	14	.05	14.898	15	863.056	863.056	378.5...
18	M35	CRECT44X27	.041	4.898	11	.351	10	15	.097	5.102	15	863.056	863.056	378.5...
19	M36	CRECT44X27	.272	9.796	11	.91	10	14	.263	14.898	14	863.056	863.056	378.5...
20	M37	CRECT44X27	.117	4.898	11	.417	10	11	.107	5.102	11	863.056	863.056	378.5...
21	M39	CRECT44X27	.126	10.204	14	.283	10	15	.091	5.102	15	863.056	863.056	378.5...
22	M40	CRECT44X27	.173	15.102	14	.574	10	14	.188	14.898	14	863.056	863.056	378.5...
23	M41	CRECT44X27	.105	4.898	11	.3	10	15	.085	5.102	11	863.056	863.056	378.5...
24	M42	CRECT44X27	.285	10	15	.26	10	14	.117	5.102	14	863.056	863.056	378.5...
25	M43	CRECT44X27	.111	4.898	11	.329	10	11	.101	5.102	11	863.056	863.056	378.5...
26	M44	CRECT44X27	.128	15.102	15	.351	10	11	.109	14.898	11	863.056	863.056	378.5...
27	M45	CRECT44X27	.092	15.102	14	.447	10	15	.132	14.898	15	863.056	863.056	378.5...
28	M46	CRECT44X27	.285	10.204	11	.843	10	14	.251	5.102	14	863.056	863.056	378.5...
29	M47	CRECT44X27	.002	15.102	4	.31	10	10	.07	5.102	15	863.056	863.056	378.5...
30	M48	CRECT44X27	.034	15.102	15	.215	10	11	.056	14.898	11	863.056	863.056	378.5...
31	M49	CRECT44X27	.042	4.898	14	.353	10	15	.097	5.102	15	863.056	863.056	378.5...
32	M50	CRECT44X27	.223	9.796	13	.906	10	14	.262	14.898	14	863.056	863.056	378.5...
33	M51	CRECT44X27	.114	4.898	14	.395	10	15	.103	5.102	14	863.056	863.056	378.5...
34	M53	CRECT44X27	.125	10.204	14	.289	10	15	.093	5.102	15	863.056	863.056	378.5...
35	M54	CRECT44X27	.189	15.102	11	.58	10	14	.19	14.898	14	863.056	863.056	378.5...
36	M55	CRECT44X27	.098	4.898	14	.306	10	11	.084	5.102	14	863.056	863.056	378.5...
37	M56	CRECT44X27	.286	10	15	.398	10	11	.137	5.102	11	863.056	863.056	378.5...
38	M57	CRECT44X27	.059	4.898	14	.313	10	13	.086	5.102	14	863.056	863.056	378.5...
39	M120A	CRECT44X27	.129	10	11	.123	18.571	11	.093	15.102	11	863.056	863.056	378.5...
40	M121A	CRECT44X27	.12	10	15	.096	18.571	10	.078	15.102	15	863.056	863.056	378.5...



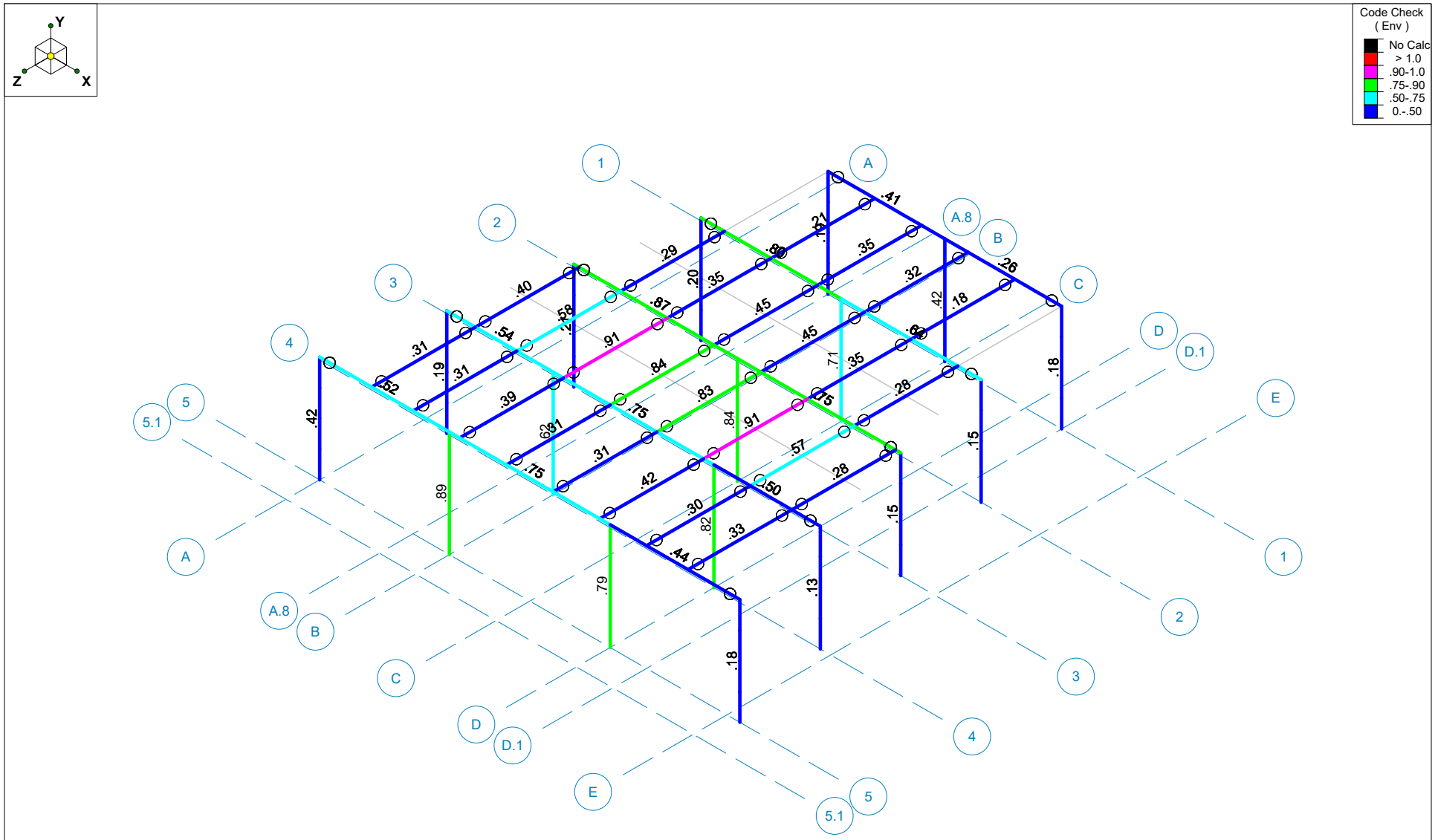
Member z Bending Moments (k-ft) (Enveloped)

		SK - 3
TH	Peckman Diversion culvert	June 24, 2019 at 4:07 PM
	Bending Moment Diagram	Peckman_Culvert_Entrance.r3d



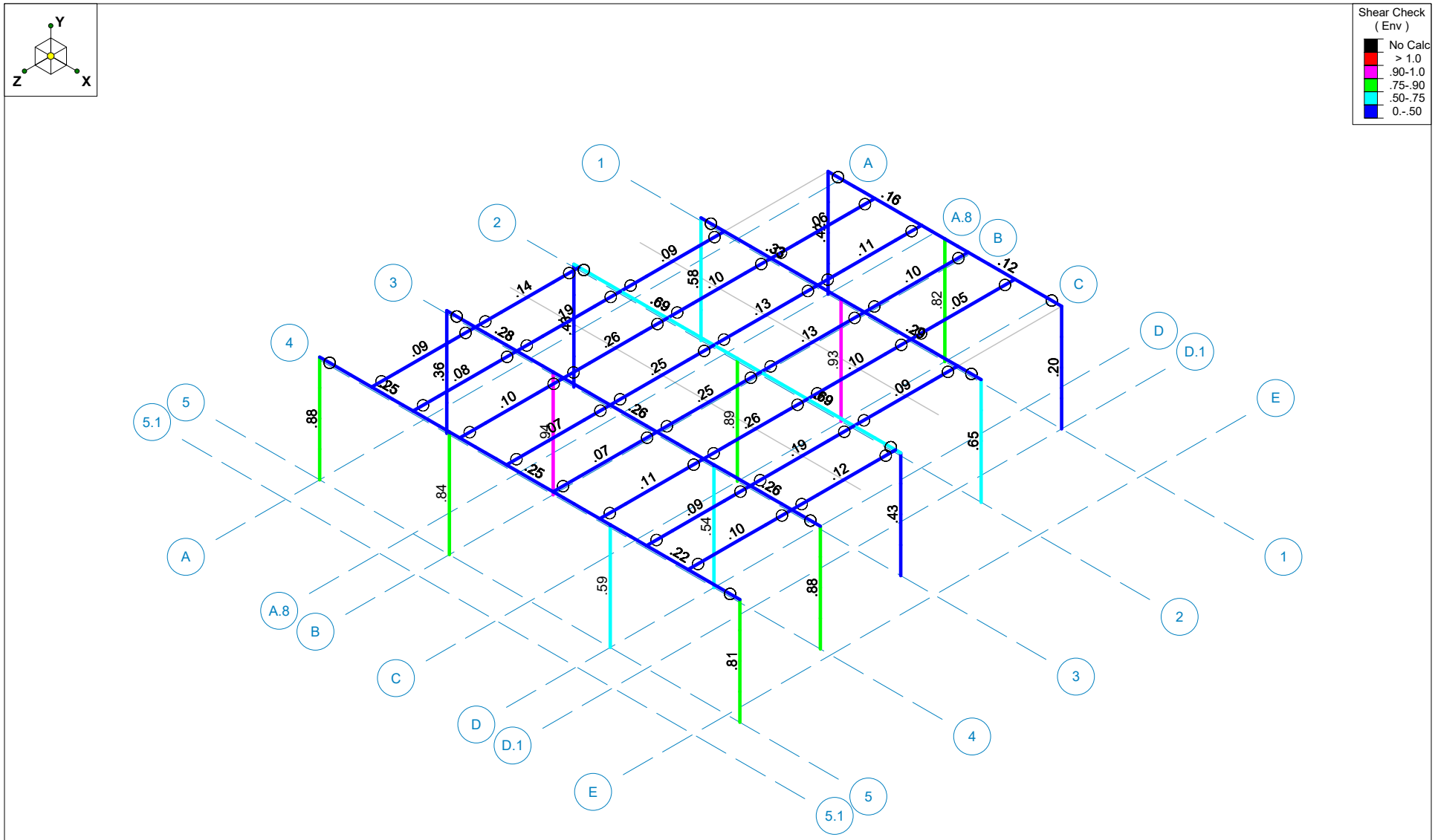
Member y Shear Forces (k) (Enveloped)

		SK - 4
TH	Peckman Diversion culvert	June 24, 2019 at 4:09 PM
	Shear Diagram	Peckman_Culvert_Entrance.r3d



Member Code Checks Displayed (Enveloped)
Results for LC 1, DC

		SK - 5
TH	Peckman Diversion culvert	June 24, 2019 at 4:11 PM
	Bending Design Results	Peckman_Culvert_Entrance.r3d



Member Shear Checks Displayed (Enveloped)
Results for LC 1, DC

		SK - 6
TH	Peckman Diversion culvert	June 24, 2019 at 4:12 PM
	Shear Design Results	Peckman_Culvert_Entrance.r3d

Peckman River
Flood Risk Management Study

Double Box Culvert

Preliminary Analysis

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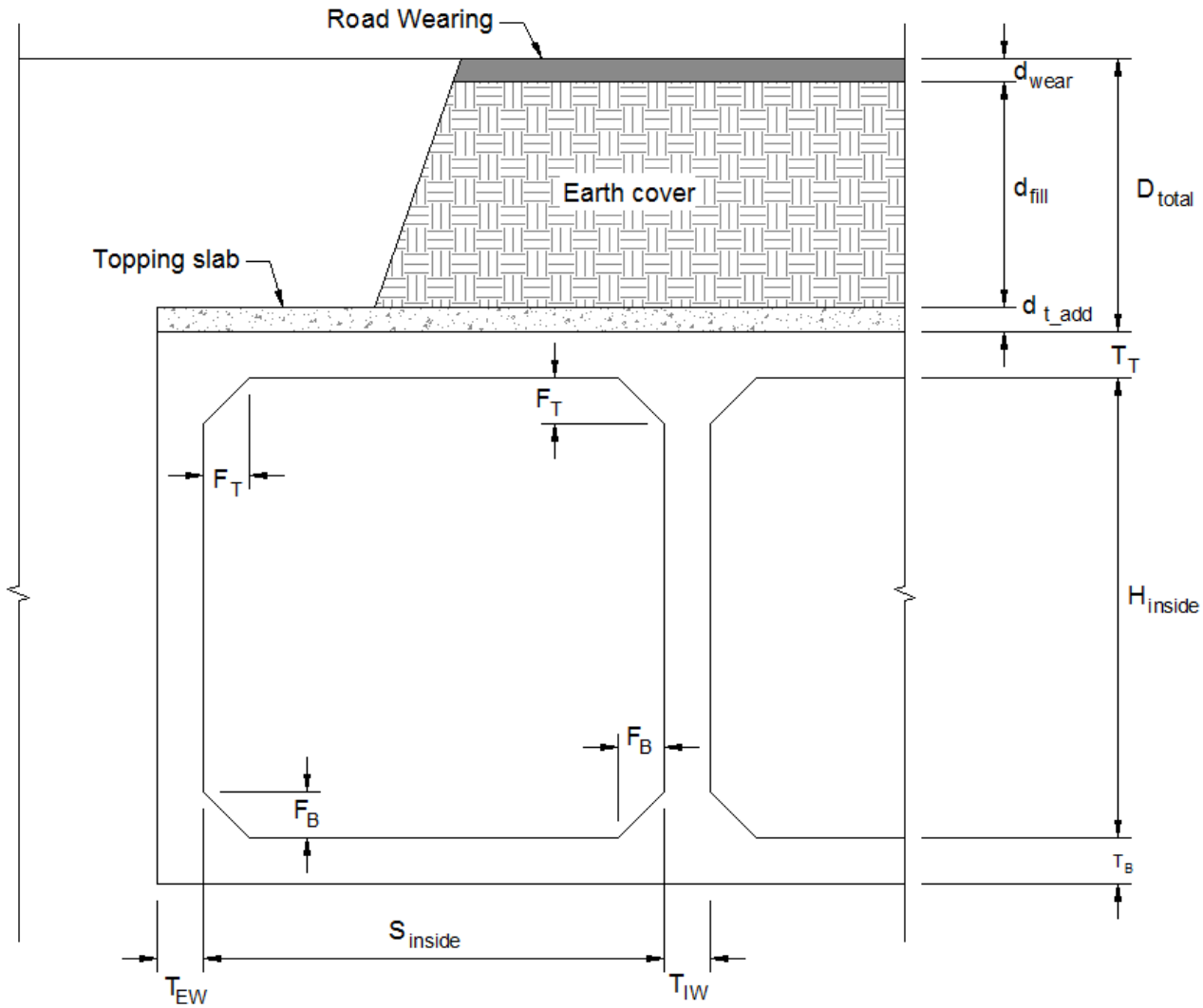
DIMENSIONS

$L_{strip} := 1ft$	(LRFR evaluation strip length)	$T_{EW} := 24in$	(exterior sidewall width)
$T_T := 21in$	(top slab thickness)	$T_{IW} := 18in$	(interior sidewall width)
$T_B := 24in$	(bottom slab thickness)	$n_{span} := 2$	(number of box spans)
$F_T := 0in$	(top haunch dimension)	$H_{inside} := 15ft$	(inside height)
$F_B := 0in$	(bottom haunch dimension)	$S_{inside} := 19.25ft$	(inside width)
$d_{t_add} := 0ft$	(additional topping slab thickness)	$d_{DW} := 6in$	(wearing surface)
$d_{fill} := 60in$	(earth fill over top slab)		



MATERIAL PROPERTIES

$E_s := 29000ksi$ (steel modulus)

$f'_c := 4000psi$

$F_y := 60ksi$ (yield strength)

$\gamma_{conc} := 150pcf$ (unit weight of concrete, LRFD Table 3.5.1-1)

$\gamma_s := 0.120\frac{kip}{ft^3}$ (unit weight of soil, LRFD Table 3.5.1-1)

$\gamma_{wear} := 140pcf$ (unit weight of asphalt, LRFD Table 3.5.1-1)

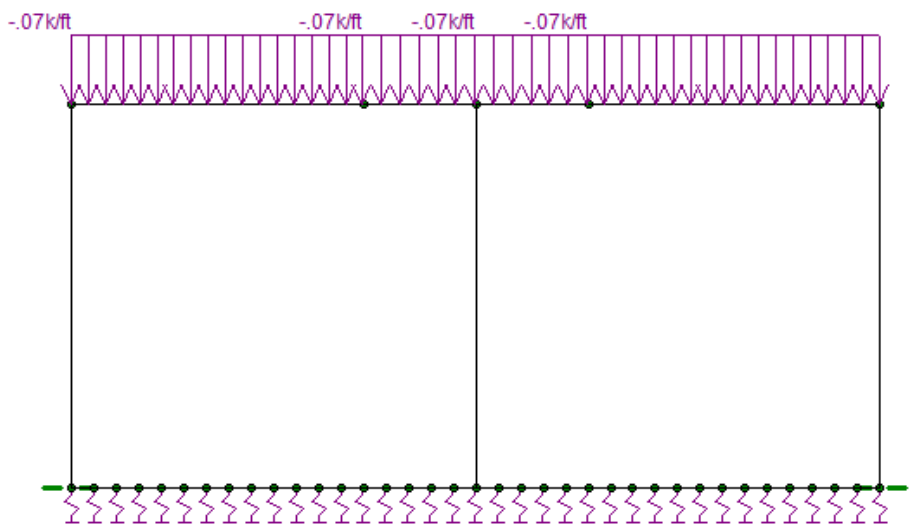
DEAD LOADS, LRFR 6A.5.12.10.1

Self weight:

Self weight DL will be calculated from computer model. (Basic Load Case, **BLC 1**)

Wearing surface:

$q_{DW} := d_{DW} \cdot L_{strip} \cdot \gamma_{wear}$ $\boxed{q_{DW} = 0.070 \cdot \frac{kip}{ft}}$



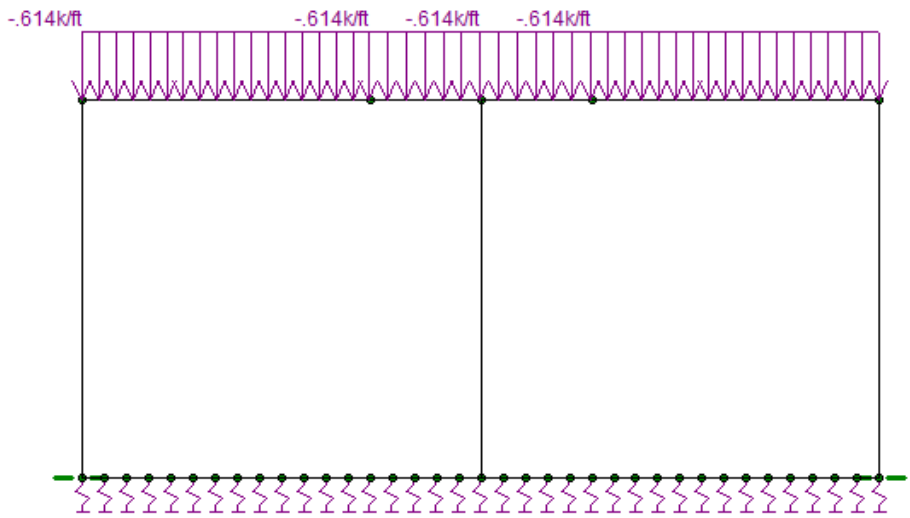
Wearing Surface Load Used in RISA3D (**BLC 2**)

VERTICAL EARTH LOAD, LRFR 6A.5.12.10.2a

$B_{total} := n_{span} \cdot S_{inside} + 2 \cdot T_{EW} + (n_{span} - 1) \cdot T_{IW}$ $B_{total} = 44\,ft$ (out to out width of the culvert)

$Fe_v := 1 + 0.20 \cdot \left(\frac{d_{fill}}{B_{total}}\right)$ $Fe_v = 1.02$ (vertical earth load factor, LRFD Eq. 12.11.2.2.1-2)

$q_{ev} := Fe_v \cdot \gamma_s \cdot d_{fill} \cdot L_{strip}$ $\boxed{q_{ev} = 0.614 \cdot \frac{kip}{ft}}$ (vertical earth load, LRFD Eq. 12.11.2.2.1-1)



Vertical Earth Load Used in RISA 3D (**BLC 3**)

HORIZONTAL EARTH LOAD, LRFR 6A.5.12.10.2b

$k_o := 0.55$ (LRFD C3.11.5.2 assumed typical value)

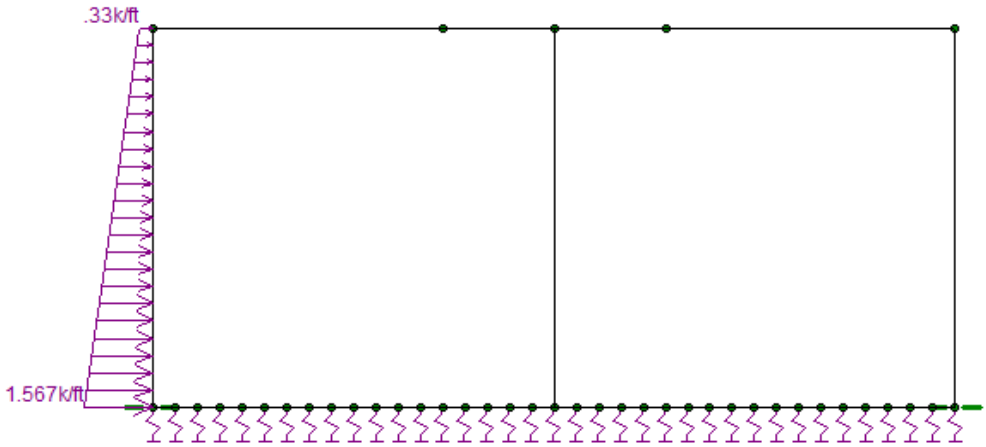
$z_{top} := d_{fill} + d_{t_add} = 5 \cdot ft$ (effective soil height at top with topping slab)

$z_{bot} := d_{fill} + d_{t_add} + H_{inside} + T_B + T_T = 23.75 \cdot ft$ (effective soil height at bottom with topping slab)

Earth load on the side of culvert, LRFD 3.11.5.1-1 pg 3-104:

$P_{top_L} := k_o \cdot \gamma_s \cdot z_{top} \cdot L_{strip}$ $\boxed{P_{top_L} = 0.330 \cdot \frac{kip}{ft}}$

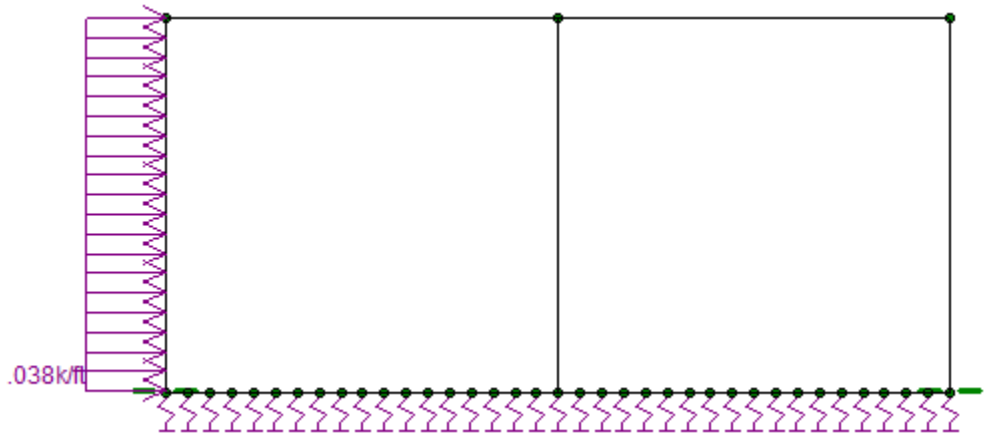
$P_{bot_L} := k_o \cdot \gamma_s \cdot z_{bot} \cdot L_{strip}$ $\boxed{P_{bot_L} = 1.567 \cdot \frac{kip}{ft}}$



Horizontal Earth Load Used in RISA3D on the left side
(**BLC 4**; similar load applied the right side with **BLC 5**)

SURCHARGE EARTH LOAD, LRFR 6A.5.12.10.2c

$q_{es} := k_o \cdot q_{DW} = 0.038 \cdot \frac{kip}{ft}$ $\qquad$ $q_{es} = 0.038 \cdot \frac{kip}{ft}$



Surcharge Earth Load Used in RISA 3D on the left side
(**BLC 6**; similar load applied the right side with **BLC 7**)

LIVE LOAD, LRFR 6A.5.12.10.3 and LRFD 3.6.1.2.6

$LLDF := 1.15$ (live load distribution factor, LRFD Table 3.6.1.2.6a-1)

$w_t := 20in$ (tire patch width, LRFD 3.6.1.2.6b pg 3-27)

$s_w := 6ft$ (wheel spacing, LRFD 3.6.1.2.6b pg 3-27)

$L_{tire} := 10in$ (tire patch length, LRFD 3.6.1.2.6b pg 3-28)

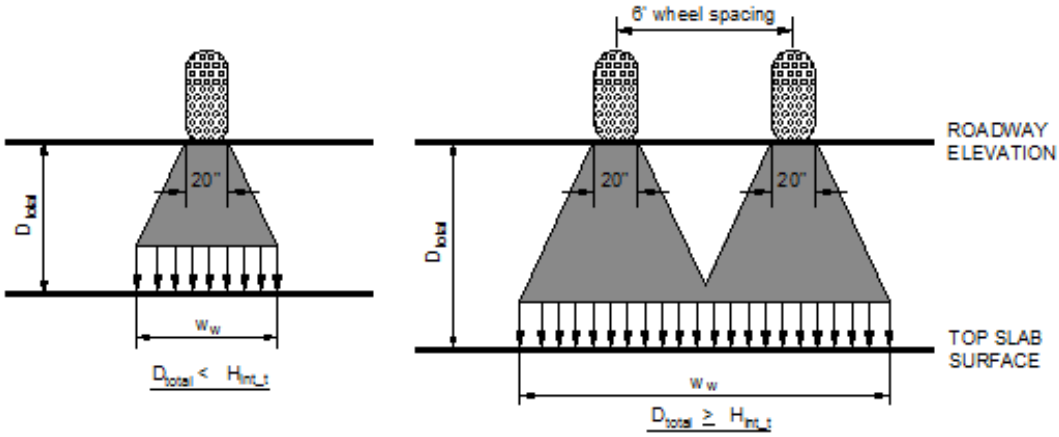
Transverse truck loading width at interaction depth, LRFD 3.6.1.2.6b-1 through 3.6.1.2.6b-3, pg 3-27:

$$H_{int_t} := \frac{(s_w - w_t - 0.06 \cdot S_{inside})}{LLDF} \qquad H_{int_t} = 2.76 \cdot ft$$

$$D_{total} := d_{DW} + d_{fill} \qquad D_{total} = 5.5\,ft$$

(total depth of fill over culvert)

$$w_w := \begin{cases} w_t + LLDF \cdot D_{total} + 0.06 \cdot S_{inside} & \text{if } D_{total} < H_{int_t} \\ (w_t + s_w + LLDF \cdot D_{total} + 0.06 \cdot S_{inside}) & \text{otherwise} \end{cases} \qquad w_w = 15.15\,ft$$



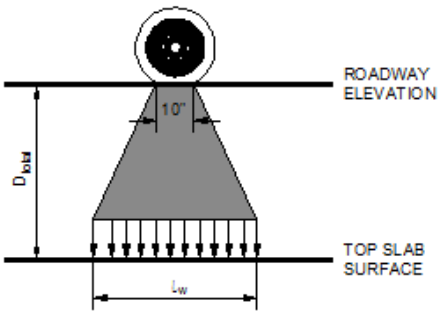
CONTACT AREA PROJECTION OF ONE WHEEL IN TRANSVERSE DIRECTION

Parallel truck loading width at interaction depth, LRFD 3.6.1.2.6b-4 through 3.6.1.2.6b-6, pg 3-27:

$$\text{Liveload} := \begin{pmatrix} \text{"truck axle spacing"} \\ \text{"tandem axle spacing"} \end{pmatrix} \qquad s_a := \begin{pmatrix} 14 \\ 4 \end{pmatrix} \text{ft}$$

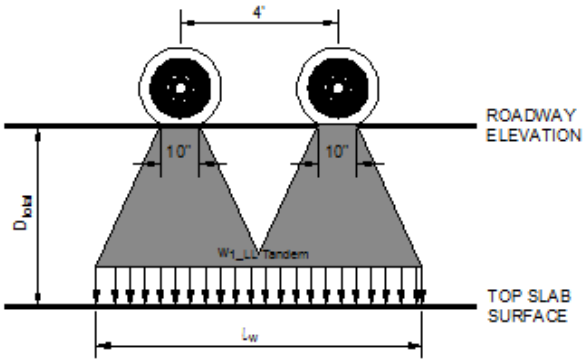
$$H_{int_p} := \frac{(s_a - L_{tire})}{LLDF} \qquad H_{int_p} = \begin{pmatrix} 11.45 \\ 2.75 \end{pmatrix} \cdot \text{ft}$$

$$L_w := \left| \begin{array}{l} \text{for } k \in 0 .. \text{last}(H_{int_p}) \\ \quad \left| \begin{array}{l} L_{w_k} \leftarrow L_{tire} + LLDF \cdot D_{total} \quad \text{if } D_{total} < H_{int_p_k} \\ L_{w_k} \leftarrow L_{tire} + s_{a_k} + LLDF \cdot D_{total} \quad \text{otherwise} \end{array} \right. \\ L_w \end{array} \right. \qquad L_w = \begin{pmatrix} 7.16 \\ 11.16 \end{pmatrix} \text{ft}$$

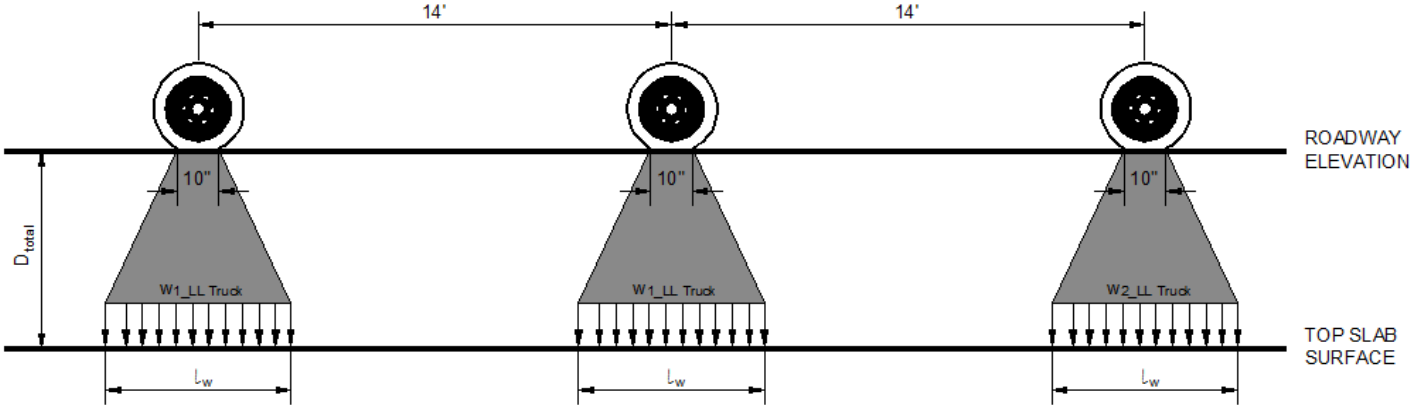


CONTACT AREA PROJECTION OF ONE WHEEL IN LONGITUDINAL DIRECTION

Design live loads:



HL-93 TANDEM AXLE PROJECTION IN LONGITUDINAL DIRECTION



HL-93 DESIGN TRUCK AXLE PROJECTIONS IN LONGITUDINAL DIRECTION

$$IM := 33 \cdot \frac{(L_{strip} - 0.125 \cdot D_{total})}{100\text{ft}} = 10.3 \cdot \%$$ (LRFD, Eq. 3.6.2.2-1)

$MPF := 1.2$ (multiple Presence Factor, LRFR 6A.5.12.10.3)

$$W_{LL_tandem} := 4 \cdot 12.5kip \cdot MPF \cdot \frac{(1 + IM)}{\left(w_w \cdot L_{w_{01}}\right)} \qquad W_{LL_tandem} = 0.392 \cdot \frac{kip}{ft^2}$$

$$W_{LL_truck} := 2 \cdot 16kip \cdot MPF \cdot \frac{(1 + IM)}{\left(w_w \cdot L_{w_{00}}\right)} \qquad W_{LL_truck} = 0.391 \cdot \frac{kip}{ft^2}$$

$$W_{LL} := \begin{pmatrix} W_{LL_truck} \\ W_{LL_tandem} \end{pmatrix} \qquad W_{LL} = \begin{pmatrix} 0.391 \\ 0.392 \end{pmatrix} \cdot \frac{kip}{ft^2} \qquad L_w = \begin{pmatrix} 7.16 \\ 11.16 \end{pmatrix} ft \qquad w_w = 15.15\,ft$$

Determine magnitude and distance between concentrated loads used in model:

$n := 11$ (number of concentrated loads)

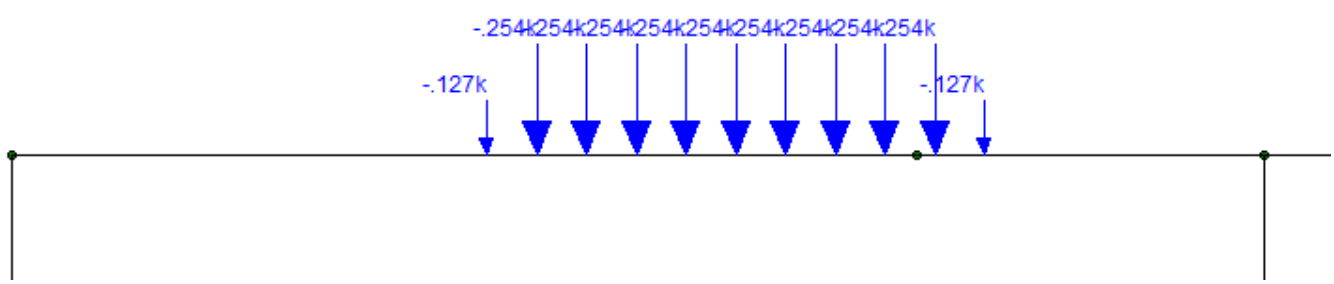
$$P_{LL} := \frac{\overrightarrow{W_{LL} \cdot L_{strip} \cdot L_w}}{n} \qquad \boxed{P_{LL} = \begin{pmatrix} 0.254 \\ 0.397 \end{pmatrix} \cdot kip}$$

(magnitude of intermediate concentrated loads)

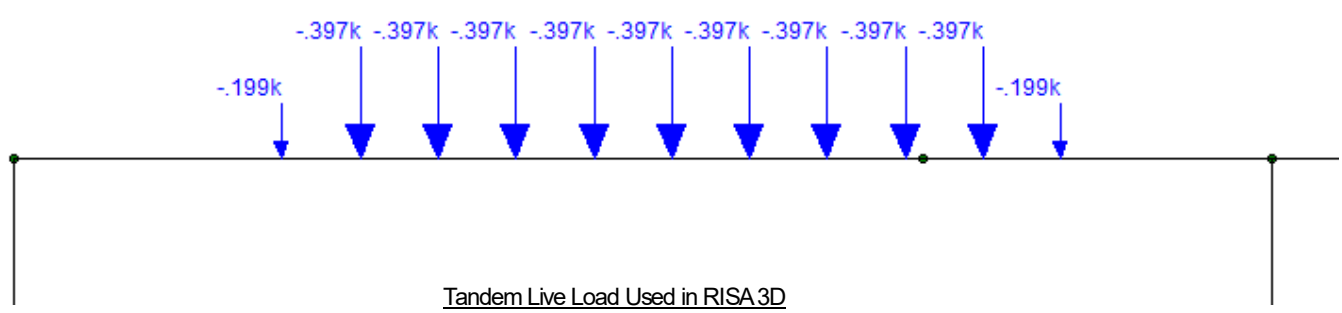
$$dist_{LL} := \frac{L_w}{n - 1} \qquad \boxed{dist_{LL} = \begin{pmatrix} 0.716 \\ 1.116 \end{pmatrix} ft}$$

(spacing of the concentrated loads)

Note: Magnitude of first and last concentrated load is equal to: $\frac{P_{LL}}{2} = \begin{pmatrix} 0.127 \\ 0.199 \end{pmatrix} \cdot kip$ $\qquad$ Liveload = ("truck axle spacing" / "tandem axle spacing")



HS20 Truck Live Load Used in RISA 3D
(Moving load **M1**)

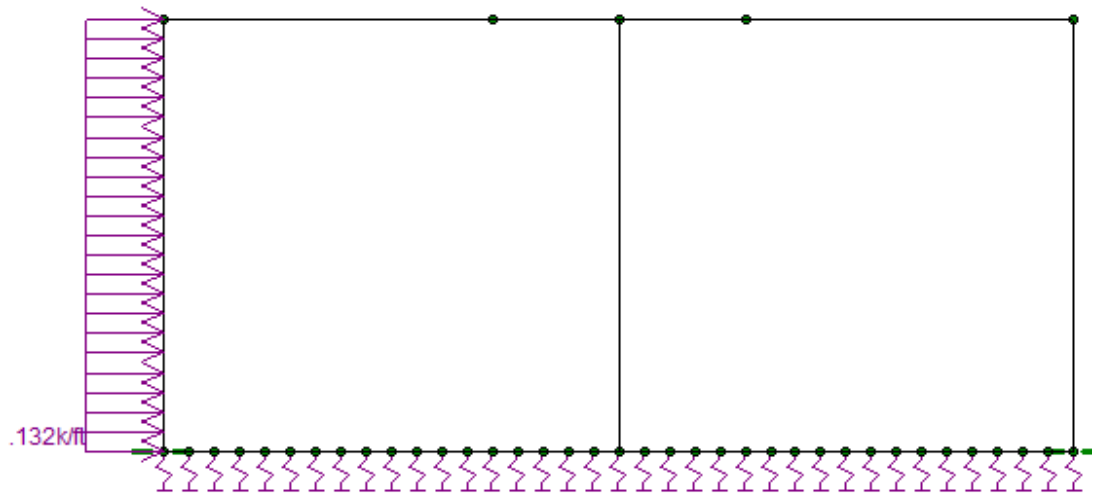


Tandem Live Load Used in RISA 3D
(Moving load **M2**)

SURCHARGE LIVE LOAD, LRFD 3.11.6.4-1

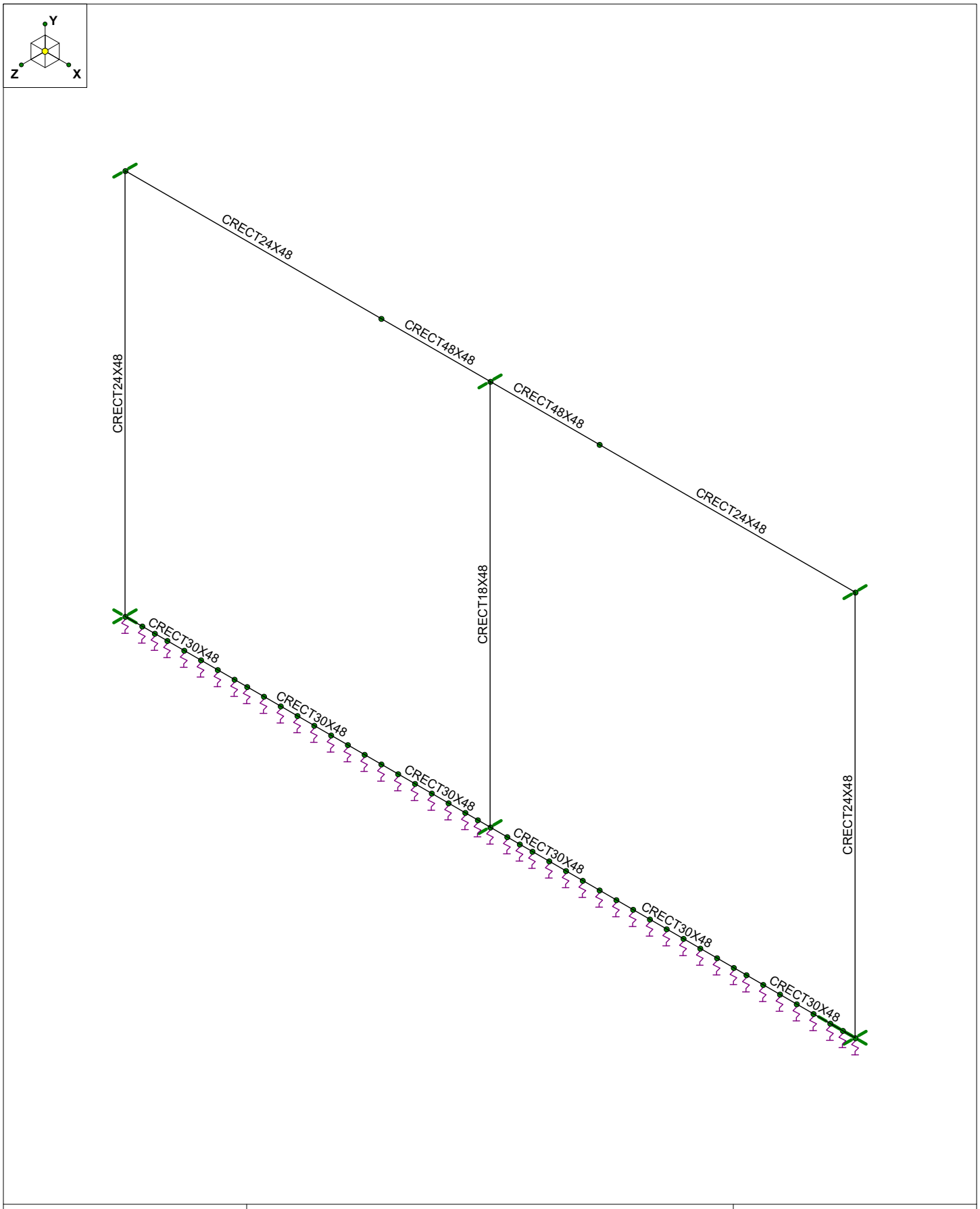
$h_{eq} := 2.00ft$ (equivalent soil height for vehicular load by interpolation with the Height $= z_{bot} = 23.75\,ft$, LRFD Table 3.11.6.4-1)

$q_{ls} := L_{strip} \cdot k_o \cdot h_{eq} \cdot \gamma_s$ $\boxed{q_{ls} = 0.132 \cdot \frac{kip}{ft}}$



Surcharge Live Load Used in RISA 3D on the left side
(**BLC 8**; similar load applied the right side with **BLC 9**)

Notes: Refer RISA 3D results for culvert analysis.



		SK - 1
TH	Peckman 40-ft Dbl box culvert	June 15, 2019 at 11:17 AM
	Double Box Culvert 2D Model	Peckman River DBL Box Culvert.r3d

Joint Coordinates and Temperatures

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
1	N1	0	0	0	0	
2	N2	0	23	0	0	
3	N3	21.75	23	0	0	
4	N4	43.5	23	0	0	
5	N5	43.5	0	0	0	
6	N6	21.75	0	0	0	
7	N7	4.5	0	0	0	
8	N8	6.5	0	0	0	
9	N9	8.25	0	0	0	
10	N10	10.25	0	0	0	
11	N11	12.25	0	0	0	
12	N12	14.25	0	0	0	
13	N13	16.25	0	0	0	
14	N14	18.25	0	0	0	
15	N15	25.25	0	0	0	
16	N16	27.25	0	0	0	
17	N17	29.25	0	0	0	
18	N18	31.25	0	0	0	
19	N19	33.25	0	0	0	
20	N20	35.25	0	0	0	
21	N21	37	0	0	0	
22	N22	39	0	0	0	
23	N23	5.5	0	0	0	
24	N24	7.25	0	0	0	
25	N25	9.25	0	0	0	
26	N26	11.25	0	0	0	
27	N27	13.25	0	0	0	
28	N28	15.25	0	0	0	
29	N29	17.25	0	0	0	
30	N30	19.25	0	0	0	
31	N31	26.25	0	0	0	
32	N32	28.25	0	0	0	
33	N33	30.25	0	0	0	
34	N34	32.25	0	0	0	
35	N35	34.25	0	0	0	
36	N36	36.25	0	0	0	
37	N37	38	0	0	0	
38	N38	40	0	0	0	
39	N39	3.5	0	0	0	
40	N40	24.25	0	0	0	
41	N41	15.25	23	0	0	
42	N42	28.25	23	0	0	
43	N43	2.5	0	0	0	
44	N44	41	0	0	0	
45	N45	42.75	0	0	0	
46	N46	21	0	0	0	
47	N47	23.5	0	0	0	
48	N48	1.75	0	0	0	
49	N49	42	0	0	0	
50	N50	20.25	0	0	0	
51	N51	22.75	0	0	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
52	N52	1	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]
1	N2			Reaction			
2	N4			Reaction			
3	N3			Reaction			
4	N1	Reaction	S28.8	Reaction			
5	N6		S28.8	Reaction			
6	N5	Reaction	S28.8	Reaction			
7	N7		S28.8				
8	N8		S28.8				
9	N9		S28.8				
10	N10		S28.8				
11	N11		S28.8				
12	N12		S28.8				
13	N13		S28.8				
14	N14		S28.8				
15	N15		S28.8				
16	N16		S28.8				
17	N17		S28.8				
18	N18		S28.8				
19	N19		S28.8				
20	N20		S28.8				
21	N21		S28.8				
22	N22		S28.8				
23	N23		S28.8				
24	N24		S28.8				
25	N25		S28.8				
26	N26		S28.8				
27	N27		S28.8				
28	N28		S28.8				
29	N29		S28.8				
30	N30		S28.8				
31	N31		S28.8				
32	N32		S28.8				
33	N33		S28.8				
34	N34		S28.8				
35	N35		S28.8				
36	N36		S28.8				
37	N37		S28.8				
38	N38		S28.8				
39	N39		S28.8				
40	N40		S28.8				
41	N43		S28.8				
42	N44		S28.8				
43	N45	Reaction	S28.8				
44	N46		S28.8				
45	N47		S28.8				
46	N48		S28.8				

Joint Boundary Conditions (Continued)

	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]
47	N49	Reaction	S28.8				
48	N50		S28.8				
49	N51		S28.8				
50	N52		S28.8				

Member Primary Data

	Label	I Joint	J Joint	K Joint	Rotate(...	Section/Sh...	Type	Design List	Material	Design Rules
1	M1	N1	N2			Ext. Wall	Beam	Rectangular	Conc4000NW	Ext. Wall
2	M2	N2	N41			Top Slab 1	Beam	Rectangular	Conc4000NW	Top Slab 1
3	M3	N3	N42			Top Slab 2	Beam	Rectangular	Conc4000NW	Top Slab 2
4	M4	N5	N4			Ext. Wall	Beam	Rectangular	Conc4000NW	Ext. Wall
5	M5	N6	N32			Bot. Slab 2	Beam	Rectangular	Conc4000NW	Bottom Slab 2
6	M6	N1	N8			Bot. Slab 2	Beam	Rectangular	Conc4000NW	Bottom Slab 2
7	M7	N6	N3			Int. Wall	Beam	Rectangular	Conc4000NW	Int. Wall
8	M8	N41	N3			Top Slab 2	Beam	Rectangular	Conc4000NW	Top Slab 2
9	M9	N42	N4			Top Slab 1	Beam	Rectangular	Conc4000NW	Top Slab 1
10	M10	N8	N28			Bot. Slab 1	Beam	Rectangular	Conc4000NW	Bottom Slab 1
11	M11	N32	N21			Bot. Slab 1	Beam	Rectangular	Conc4000NW	Bottom Slab 1
12	M12	N28	N6			Bot. Slab 2	Beam	Rectangular	Conc4000NW	Bottom Slab 2
13	M13	N21	N5			Bot. Slab 2	Beam	Rectangular	Conc4000NW	Bottom Slab 2

Concrete Beam Design Parameters

	Label	Shape	Length[ft]	B-eff Left[in]	B-eff Right...	Slab Th...	Slab Th...	Icr Fact...	Flexural Layout	Shear Layout
1	M1	Ext. Wall	23						Use Design Rule	Use Design Rule
2	M2	Top Slab 1	15.25						Use Design Rule	Use Design Rule
3	M3	Top Slab 2	6.5						Use Design Rule	Use Design Rule
4	M4	Ext. Wall	23						Use Design Rule	Use Design Rule
5	M5	Bot. Slab 2	6.5						Use Design Rule	Use Design Rule
6	M6	Bot. Slab 2	6.5						Use Design Rule	Use Design Rule
7	M7	Int. Wall	23						Use Design Rule	Use Design Rule
8	M8	Top Slab 2	6.5						Use Design Rule	Use Design Rule
9	M9	Top Slab 1	15.25						Use Design Rule	Use Design Rule
10	M10	Bot. Slab 1	8.75						Use Design Rule	Use Design Rule
11	M11	Bot. Slab 1	8.75						Use Design Rule	Use Design Rule
12	M12	Bot. Slab 2	6.5						Use Design Rule	Use Design Rule
13	M13	Bot. Slab 2	6.5						Use Design Rule	Use Design Rule

Concrete Section Sets

	Label	Shape	Type	Design List	Material	Design Rules	A [in2]	Iyy [in4]	Izz [in4]	J [in4]
1	Top Slab 1	CRECT24X48	Beam	Rectangular	Conc4000NW	Top Slab 1	1152	2.212e+5	55296	1.515e+5
2	Top Slab 2	CRECT48X48	Beam	Rectangular	Conc4000NW	Top Slab 2	2304	4.424e+5	4.424e+5	6.547e+5
3	Bot. Slab 1	CRECT30X48	Beam	Rectangular	Conc4000NW	Bottom Slab 1	1440	2.765e+5	1.08e+5	2.619e+5
4	Bot. Slab 2	CRECT30X48	Beam	Rectangular	Conc4000NW	Bottom Slab 2	1440	2.765e+5	1.08e+5	2.619e+5
5	Ext. Wall	CRECT24X48	Beam	Rectangular	Conc4000NW	Ext. Wall	1152	2.212e+5	55296	1.515e+5
6	Int. Wall	CRECT18X48	Beam	Rectangular	Conc4000NW	Int. Wall	864	1.659e+5	23328	71267.04

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	Conc3000LW	2085	907	.15	.6	.11	3	.75	60	60
5	Conc3500LW	2252	979	.15	.6	.11	3.5	.75	60	60
6	Conc4000LW	2408	1047	.15	.6	.11	4	.75	60	60

Concrete Rebar Parameters

	Label	Optimi...	Min...	Ma...	She...	Legs p...	Top (Column) ...	Bottom Cov...	Side Cove...	Top/Botto...	Add'l Side Bars	Shear Bar Spa...
1	Ext. Wall	Explicit	#8	#8	#3	1	4.75	4.75	3	6	1	60
2	Int. Wall	Explicit	#6	#6	#3	1	4.75	4.75	3	5	1	60
3	Top Slab 1	Explicit	#8	#9	#3	1	4.75	3.75	3	3	1	60
4	Top Slab 2	Explicit	#8	#9	#3	1	4.75	4.75	3	6	1	60
5	Bottom Slab 1	Explicit	#9	#9	#3	1	4.75	4.75	3	4	1	60
6	Bottom Slab 2	Explicit	#9	#10	#6	4	4.75	4.75	3	7	1	24

Moving Loads

	Tag	Pattern	Increment[...	Both Ways	1st Jo...	2nd J...	3rd J...	4th Jo...	5th Jo...	6th Jo...	7th Jo...	8th Jo...	9th Jo...	10th J...
1	M1	PECKMAN_TRUCK	1	Yes	N2	N3	N4							
2	M2	PECKMAN_TANDEM	1	Yes	N2	N3	N4							

Moving Load Patterns

Pattern Label	Load (k)	Direction	Distance (ft)
PECKMAN_TRUCK	-.1	Y	0
	-.21	Y	.946
	-.21	Y	.946
	-.21	Y	.946
	-.21	Y	.946
	-.21	Y	.946
	-.21	Y	.946
	-.21	Y	.946
	-.21	Y	.946
	-.21	Y	.946
	-.1	Y	.946

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Pattern Label	Load (k)	Direction	Distance (ft)
PECKMAN_TANDEM	-.16	Y	0
	-.32	Y	1.346
	-.32	Y	1.346
	-.32	Y	1.346
	-.32	Y	1.346
	-.32	Y	1.346
	-.32	Y	1.346
	-.32	Y	1.346
	-.32	Y	1.346
	-.32	Y	1.346
	-.16	Y	1.346

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distribu...	Area(M...	Surface...
1	DC - Self Weight	DL		-1						
2	DW - Wearing Surface	OL1						4		
3	EV - Vertical Earth	OL2						4		
4	EH - Horizontal Earth (left)	OL3						1		
5	EH - Horizontal Earth (right)	OL3						1		
6	ES- Surcharge Earth Load (left)	OL4						1		
7	ES- Surcharge Earth Load (right)	OL4						1		
8	LS - Surcharge Live Load (left)	OL5						1		
9	LS - Surcharge Live Load (right)	OL5						1		
10	WT - Water (left)	OL6						1		
11	WT - Water (right)	OL6						1		
12	HL-93 Truck	None								
13	HL-93 Tandem	None								

Load Combinations

	Description	S...	P...	S...	BLC	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	BLC	Fa...	B...	Fa...	B...	Fa...	B...	Fa...
1	DC	Yes	C		DL	1																		
2	DW	Yes	C		OL1	1																		
3	EV	Yes	C		OL2	1																		
4	EH	Yes	C		4	1	5																	
5	ES	Yes	C		6	1	7																	
6	LS	Yes	C		8	1	9																	
7	HL93 Truck	Yes	C		M1																			
8	HL93 Tandem	Yes	C		M2																			
9																								
10	1.25DC+1.5DW+1.3EV+1.35...	Yes	C		1	1.25	2	1.5	3	1.3	4	1.35	5	1.35	6	1.3	7	1.3	8	1.75	9	1.75	O...	
11	1.25DC+1.5DW+1.3EV+1.35...	Yes	C		1	1.25	2	1.5	3	1.3	4	1.35	5		6	1.3	7		8	1.75	9		10	1
12																								
13	[L1 + HL93 truck_inv] x 4 LF	Yes	C		L10	4	M1	7																
14	[L1 + HL93 tandem_inv] x 4 LF	Yes	C		L10	4	M2	7																
15	Note: LC13 & LC14 were multi...																							
16	to account for the actual width,...																							
17	used in RISA 3D model																							
18																								

Envelope Member Section Forces

	Member	Sec		Axial[k]	LC	y Shear[k]	LC	z Shear[k]	LC	Torque[k-...	LC	y-y Mome...	LC	z-z Mome...	LC
1	M1	1	max	226.286	14-1...	105.191	14-47	0	13-1	0	13-1	0	13-1	485.304	14-1...
2			min	-.206	4	-.286	3	0	13-1	0	13-1	0	13-1	0	7
3		2	max	159.586	14-1...	6.65	11	0	13-1	0	13-1	0	13-1	16.516	1
4			min	-.206	4	-.286	3	0	13-1	0	13-1	0	13-1	-113.195	14-42
5		3	max	92.886	14-1...	2.15	1	0	13-1	0	13-1	0	13-1	227.638	14-19
6			min	-.206	4	-51.714	14-22	0	13-1	0	13-1	0	13-1	-8.206	1
7	M2	1	max	51.704	14-93	92.88	14-1...	0	13-1	0	13-1	0	13-1	227.638	14-19
8			min	-2.15	1	-.205	4	0	13-1	0	13-1	0	13-1	-8.206	1
9		2	max	51.704	14-93	12.5	14-95	0	13-1	0	13-1	0	13-1	0	7
10			min	-2.15	1	-3.458	11	0	13-1	0	13-1	0	13-1	-163.783	14-99
11		3	max	51.704	14-93	0	7	0	13-1	0	13-1	0	13-1	144.709	14-73
12			min	-2.15	1	-78.052	14-16	0	13-1	0	13-1	0	13-1	-.353	4
13	M3	1	max	51.777	14-79	184.377	14-81	0	13-1	0	13-1	0	13-1	939.889	14-42
14			min	-2.14	1	-2.958	4	0	13-1	0	13-1	0	13-1	-31.126	4
15		2	max	51.777	14-79	131.201	14-76	0	13-1	0	13-1	0	13-1	455.422	14-1...
16			min	-2.14	1	-2.958	4	0	13-1	0	13-1	0	13-1	-21.512	4
17		3	max	51.777	14-79	78.102	14-73	0	13-1	0	13-1	0	13-1	145.171	14-16
18			min	-2.14	1	-2.958	4	0	13-1	0	13-1	0	13-1	-11.899	4
19	M4	1	max	225.336	14-44	4.487	11	0	13-1	0	13-1	0	13-1	32.997	4
20			min	0	7	-105.155	14-1...	0	13-1	0	13-1	0	13-1	-482.759	14-47
21		2	max	158.636	14-44	4.487	11	0	13-1	0	13-1	0	13-1	114.847	14-99
22			min	0	7	-4.343	14-1...	0	13-1	0	13-1	0	13-1	-26.829	11
23		3	max	91.936	14-44	51.774	14-79	0	13-1	0	13-1	0	13-1	8.309	1
24			min	0	7	-2.14	1	0	13-1	0	13-1	0	13-1	-226.657	14-76
25	M5	1	max	3.323	11	0	7	0	13-1	0	13-1	0	13-1	0	7
26			min	-.443	14-76	-212.523	14-82	0	13-1	0	13-1	0	13-1	-804.703	14-27
27		2	max	3.323	11	0	7	0	13-1	0	13-1	0	13-1	0	7
28			min	-.443	14-76	-154.184	14-35	0	13-1	0	13-1	0	13-1	-201.58	14-24
29		3	max	3.323	11	0	7	0	13-1	0	13-1	0	13-1	204.248	14-47
30			min	-.443	14-76	-100.511	14-78	0	13-1	0	13-1	0	13-1	0	7
31	M6	1	max	.412	14-76	0	7	0	13-1	0	13-1	0	13-1	0	7
32			min	-3.094	11	-195.267	14-1...	0	13-1	0	13-1	0	13-1	-485.304	14-1...
33		2	max	.412	14-76	0	7	0	13-1	0	13-1	0	13-1	56.101	14-1...
34			min	-3.094	11	-130.543	14-1...	0	13-1	0	13-1	0	13-1	-91.931	11
35		3	max	.412	14-76	0	7	0	13-1	0	13-1	0	13-1	356.28	14-1...
36			min	-3.094	11	-73.861	14-1...	0	13-1	0	13-1	0	13-1	-52.873	4
37	M7	1	max	454.729	14-29	6.574	11	0	13-1	0	13-1	0	13-1	77.915	11
38			min	-2.752	4	-.852	14-76	0	13-1	0	13-1	0	13-1	-6.236	14-39
39		2	max	404.704	14-29	6.574	11	0	13-1	0	13-1	0	13-1	3.67	14-41
40			min	-2.752	4	-.852	14-76	0	13-1	0	13-1	0	13-1	-3.738	14-98
41		3	max	354.679	14-29	6.574	11	0	13-1	0	13-1	0	13-1	13.429	14-76
42			min	-2.752	4	-.852	14-76	0	13-1	0	13-1	0	13-1	-73.295	11
43	M8	1	max	51.704	14-93	0	7	0	13-1	0	13-1	0	13-1	144.709	14-73
44			min	-2.15	1	-78.099	14-16	0	13-1	0	13-1	0	13-1	-.353	4
45		2	max	51.704	14-93	0	7	0	13-1	0	13-1	0	13-1	454.824	14-43
46			min	-2.15	1	-131.195	14-19	0	13-1	0	13-1	0	13-1	0	7
47		3	max	51.704	14-93	0	7	0	13-1	0	13-1	0	13-1	939.232	14-99
48			min	-2.15	1	-183.734	14-24	0	13-1	0	13-1	0	13-1	0	7
49	M9	1	max	51.777	14-79	78.055	14-73	0	13-1	0	13-1	0	13-1	145.171	14-16
50			min	-2.14	1	-2.958	4	0	13-1	0	13-1	0	13-1	-11.899	4
51		2	max	51.777	14-79	2.64	1	0	13-1	0	13-1	0	13-1	10.654	4

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y Shear[k]	LC	z Shear[k]	LC	Torque[k-...	LC	y-y Mome...	LC	z-z Mome...	LC
52			min	-2.14	1	-12.491	14-38	0	13-1	0	13-1	0	13-1	-163.652	14-42
53		3	max	51.777	14-79	0	7	0	13-1	0	13-1	0	13-1	226.657	14-76
54			min	-2.14	1	-91.933	14-44	0	13-1	0	13-1	0	13-1	-8.309	1
55	M10	1	max	.412	14-76	0	7	0	13-1	0	13-1	0	13-1	356.28	14-1...
56			min	-3.094	11	-48.858	14-1...	0	13-1	0	13-1	0	13-1	-52.873	4
57		2	max	.412	14-76	15.136	14-21	0	13-1	0	13-1	0	13-1	434.189	14-1...
58			min	-3.094	11	-5.2	4	0	13-1	0	13-1	0	13-1	-30.433	4
59		3	max	.412	14-76	77.818	14-20	0	13-1	0	13-1	0	13-1	203.177	14-1...
60			min	-3.094	11	-5.095	4	0	13-1	0	13-1	0	13-1	-7.939	4
61	M11	1	max	3.323	11	0	7	0	13-1	0	13-1	0	13-1	204.248	14-47
62			min	-.443	14-76	-76.003	14-77	0	13-1	0	13-1	0	13-1	0	7
63		2	max	3.323	11	0	7	0	13-1	0	13-1	0	13-1	427.946	14-44
64			min	-.443	14-76	-13.68	14-78	0	13-1	0	13-1	0	13-1	0	7
65		3	max	3.323	11	49.792	14-47	0	13-1	0	13-1	0	13-1	344.734	14-44
66			min	-.443	14-76	-2.048	4	0	13-1	0	13-1	0	13-1	0	7
67	M12	1	max	.412	14-76	102.4	14-21	0	13-1	0	13-1	0	13-1	203.177	14-1...
68			min	-3.094	11	-5.082	4	0	13-1	0	13-1	0	13-1	-7.939	4
69		2	max	.412	14-76	156.253	14-92	0	13-1	0	13-1	0	13-1	8.603	4
70			min	-3.094	11	-5.126	4	0	13-1	0	13-1	0	13-1	-209.224	14-81
71		3	max	.412	14-76	214.844	14-25	0	13-1	0	13-1	0	13-1	25.469	4
72			min	-3.094	11	-5.261	4	0	13-1	0	13-1	0	13-1	-805.659	14-84
73	M13	1	max	3.323	11	74.622	14-45	0	13-1	0	13-1	0	13-1	344.734	14-44
74			min	-.443	14-76	-1.766	4	0	13-1	0	13-1	0	13-1	0	7
75		2	max	3.323	11	130.603	14-44	0	13-1	0	13-1	0	13-1	137.493	11
76			min	-.443	14-76	-.406	4	0	13-1	0	13-1	0	13-1	0	7
77		3	max	0	13-1	194.746	14-44	0	13-1	0	13-1	0	13-1	32.997	4
78			min	0	13-1	0	7	0	13-1	0	13-1	0	13-1	-482.759	14-47

Envelope Joint Displacements

	Joint		X [in]	LC	Y [in]	LC	Z [in]	LC	X Rotation [...	LC	Y Rotation [...	LC	Z Rotation [...	LC
1	N1	max	0	14-...	.042	4	0	13-1	0	13-1	0	13-1	2.178e-03	14-...
2		min	0	3	-1.077	14-...	0	13-1	0	13-1	0	13-1	-7.347e-04	11
3	N2	max	.439	11	.042	4	0	13-1	0	13-1	0	13-1	0	7
4		min	-.043	14-...	-1.088	14-...	0	13-1	0	13-1	0	13-1	-8.981e-04	11
5	N3	max	.439	11	.002	4	0	13-1	0	13-1	0	13-1	4.587e-04	14-...
6		min	-.045	14-...	-1.001	14-...	0	13-1	0	13-1	0	13-1	-4.001e-04	14-...
7	N4	max	.439	11	0	7	0	13-1	0	13-1	0	13-1	5.3e-04	14-...
8		min	-.048	14-...	-1.073	14-...	0	13-1	0	13-1	0	13-1	-5.523e-04	11
9	N5	max	0	11	0	7	0	13-1	0	13-1	0	13-1	0	7
10		min	0	14-...	-1.062	14-...	0	13-1	0	13-1	0	13-1	-2.04e-03	14-...
11	N6	max	0	11	.002	4	0	13-1	0	13-1	0	13-1	5.803e-05	14-...
12		min	0	14-...	-.966	14-...	0	13-1	0	13-1	0	13-1	-5.246e-05	11
13	N7	max	0	11	.014	4	0	13-1	0	13-1	0	13-1	2.659e-03	14-...
14		min	0	14-...	-.928	14-...	0	13-1	0	13-1	0	13-1	-3.653e-04	4
15	N8	max	0	11	.007	4	0	13-1	0	13-1	0	13-1	2.078e-03	14-...
16		min	0	14-...	-.87	14-...	0	13-1	0	13-1	0	13-1	-2.45e-04	4
17	N9	max	0	11	.003	4	0	13-1	0	13-1	0	13-1	1.359e-03	14-...
18		min	0	14-...	-.833	14-...	0	13-1	0	13-1	0	13-1	-1.562e-04	4
19	N10	max	0	11	0	6	0	13-1	0	13-1	0	13-1	4.433e-04	14-...
20		min	0	14-...	-.812	14-...	0	13-1	0	13-1	0	13-1	-1.604e-04	11

Envelope Joint Displacements (Continued)

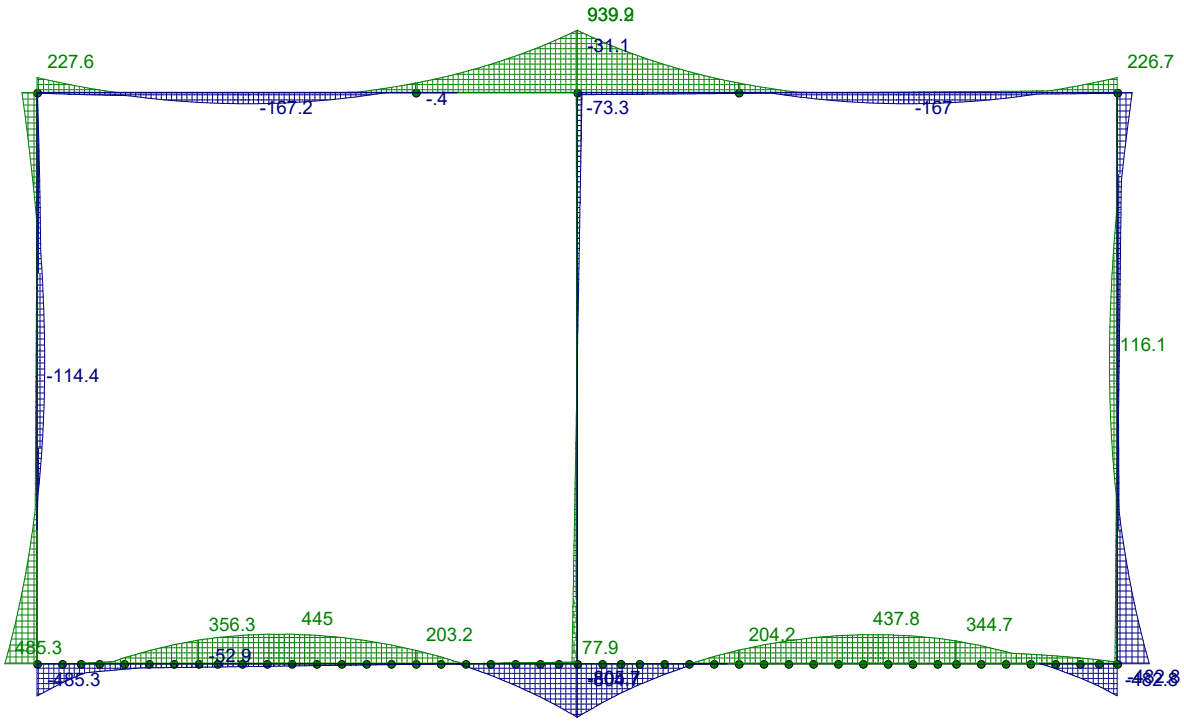
	Joint		X [in]	LC	Y [in]	LC	Z [in]	LC	X Rotation [...	LC	Y Rotation [...	LC	Z Rotation [...	LC
21	N11	max	0	11	0	6	0	13-1	0	13-1	0	13-1	0	7
22		min	0	14-...	-.813	14-...	0	13-1	0	13-1	0	13-1	-7.466e-04	14-...
23	N12	max	0	11	0	6	0	13-1	0	13-1	0	13-1	2.259e-05	4
24		min	0	14-...	-.837	14-...	0	13-1	0	13-1	0	13-1	-1.406e-03	14-...
25	N13	max	0	11	0	6	0	13-1	0	13-1	0	13-1	3.92e-05	4
26		min	0	14-...	-.875	14-...	0	13-1	0	13-1	0	13-1	-1.765e-03	14-...
27	N14	max	0	11	.001	4	0	13-1	0	13-1	0	13-1	3.454e-05	4
28		min	0	14-...	-.919	14-...	0	13-1	0	13-1	0	13-1	-1.679e-03	14-...
29	N15	max	0	11	0	4	0	13-1	0	13-1	0	13-1	1.709e-03	14-...
30		min	0	14-...	-.917	14-...	0	13-1	0	13-1	0	13-1	-9.969e-06	4
31	N16	max	0	11	0	4	0	13-1	0	13-1	0	13-1	1.784e-03	14-...
32		min	0	14-...	-.873	14-...	0	13-1	0	13-1	0	13-1	-1.646e-05	4
33	N17	max	0	11	0	4	0	13-1	0	13-1	0	13-1	1.422e-03	14-...
34		min	0	14-...	-.834	14-...	0	13-1	0	13-1	0	13-1	-3.431e-05	4
35	N18	max	0	11	0	7	0	13-1	0	13-1	0	13-1	7.671e-04	14-...
36		min	0	14-...	-.81	14-...	0	13-1	0	13-1	0	13-1	-6.363e-05	4
37	N19	max	0	11	0	7	0	13-1	0	13-1	0	13-1	4.291e-05	3
38		min	0	14-...	-.808	14-...	0	13-1	0	13-1	0	13-1	-4.099e-04	14-...
39	N20	max	0	11	0	7	0	13-1	0	13-1	0	13-1	8.73e-06	3
40		min	0	14-...	-.829	14-...	0	13-1	0	13-1	0	13-1	-1.307e-03	14-...
41	N21	max	0	11	0	7	0	13-1	0	13-1	0	13-1	7.813e-07	2
42		min	0	14-...	-.864	14-...	0	13-1	0	13-1	0	13-1	-2.007e-03	14-...
43	N22	max	0	11	0	7	0	13-1	0	13-1	0	13-1	0	7
44		min	0	14-...	-.92	14-...	0	13-1	0	13-1	0	13-1	-2.563e-03	14-...
45	N23	max	0	11	.01	4	0	13-1	0	13-1	0	13-1	2.41e-03	14-...
46		min	0	14-...	-.897	14-...	0	13-1	0	13-1	0	13-1	-3.027e-04	4
47	N24	max	0	11	.005	4	0	13-1	0	13-1	0	13-1	1.785e-03	14-...
48		min	0	14-...	-.852	14-...	0	13-1	0	13-1	0	13-1	-2.05e-04	4
49	N25	max	0	11	.001	4	0	13-1	0	13-1	0	13-1	9.054e-04	14-...
50		min	0	14-...	-.82	14-...	0	13-1	0	13-1	0	13-1	-1.179e-04	11
51	N26	max	0	11	0	6	0	13-1	0	13-1	0	13-1	0	7
52		min	0	14-...	-.81	14-...	0	13-1	0	13-1	0	13-1	-3.477e-04	14-...
53	N27	max	0	11	0	6	0	13-1	0	13-1	0	13-1	6.288e-06	4
54		min	0	14-...	-.822	14-...	0	13-1	0	13-1	0	13-1	-1.105e-03	14-...
55	N28	max	0	11	0	6	0	13-1	0	13-1	0	13-1	3.355e-05	4
56		min	0	14-...	-.855	14-...	0	13-1	0	13-1	0	13-1	-1.632e-03	14-...
57	N29	max	0	11	0	4	0	13-1	0	13-1	0	13-1	3.953e-05	4
58		min	0	14-...	-.897	14-...	0	13-1	0	13-1	0	13-1	-1.788e-03	14-...
59	N30	max	0	11	.001	4	0	13-1	0	13-1	0	13-1	2.42e-05	4
60		min	0	14-...	-.939	14-...	0	13-1	0	13-1	0	13-1	-1.42e-03	14-...
61	N31	max	0	11	0	4	0	13-1	0	13-1	0	13-1	1.811e-03	14-...
62		min	0	14-...	-.895	14-...	0	13-1	0	13-1	0	13-1	-1.181e-05	4
63	N32	max	0	11	0	4	0	13-1	0	13-1	0	13-1	1.648e-03	14-...
64		min	0	14-...	-.852	14-...	0	13-1	0	13-1	0	13-1	-2.396e-05	4
65	N33	max	0	11	0	7	0	13-1	0	13-1	0	13-1	1.122e-03	14-...
66		min	0	14-...	-.819	14-...	0	13-1	0	13-1	0	13-1	-4.754e-05	4
67	N34	max	0	11	0	7	0	13-1	0	13-1	0	13-1	3.729e-04	14-...
68		min	0	14-...	-.806	14-...	0	13-1	0	13-1	0	13-1	-8.258e-05	4
69	N35	max	0	11	0	7	0	13-1	0	13-1	0	13-1	2.611e-05	3
70		min	0	14-...	-.816	14-...	0	13-1	0	13-1	0	13-1	-8.638e-04	14-...
71	N36	max	0	11	0	7	0	13-1	0	13-1	0	13-1	1.886e-06	2
72		min	0	14-...	-.847	14-...	0	13-1	0	13-1	0	13-1	-1.724e-03	14-...

Envelope Joint Displacements (Continued)

	Joint		X [in]	LC	Y [in]	LC	Z [in]	LC	X Rotation [...	LC	Y Rotation [...	LC	Z Rotation [...	LC
73	N37	max	0	11	0	7	0	13-1	0	13-1	0	13-1	0	7
74		min	0	14-...	-.89	14-...	0	13-1	0	13-1	0	13-1	-2.327e-03	14-...
75	N38	max	0	11	0	7	0	13-1	0	13-1	0	13-1	0	7
76		min	0	14-...	-.952	14-...	0	13-1	0	13-1	0	13-1	-2.695e-03	14-...
77	N39	max	0	11	.019	4	0	13-1	0	13-1	0	13-1	2.805e-03	14-...
78		min	0	14-...	-.962	14-...	0	13-1	0	13-1	0	13-1	-4.324e-04	4
79	N40	max	0	11	.001	4	0	13-1	0	13-1	0	13-1	1.458e-03	14-...
80		min	0	14-...	-.937	14-...	0	13-1	0	13-1	0	13-1	-1.092e-05	4
81	N41	max	.439	11	.013	4	0	13-1	0	13-1	0	13-1	1.231e-03	14-...
82		min	-.045	14-...	-1.072	14-...	0	13-1	0	13-1	0	13-1	-1.398e-04	4
83	N42	max	.439	11	0	7	0	13-1	0	13-1	0	13-1	0	7
84		min	-.046	14-...	-1.067	14-...	0	13-1	0	13-1	0	13-1	-1.172e-03	14-...
85	N43	max	0	11	.024	4	0	13-1	0	13-1	0	13-1	2.829e-03	14-...
86		min	0	14-...	-.996	14-...	0	13-1	0	13-1	0	13-1	-5.034e-04	4
87	N44	max	0	11	0	7	0	13-1	0	13-1	0	13-1	0	7
88		min	0	14-...	-.986	14-...	0	13-1	0	13-1	0	13-1	-2.705e-03	14-...
89	N45	max	0	11	0	7	0	13-1	0	13-1	0	13-1	0	7
90		min	0	14-...	-1.041	14-...	0	13-1	0	13-1	0	13-1	-2.359e-03	14-...
91	N46	max	0	11	.002	4	0	13-1	0	13-1	0	13-1	0	7
92		min	0	14-...	-.962	14-...	0	13-1	0	13-1	0	13-1	-5.556e-04	14-...
93	N47	max	0	11	.001	4	0	13-1	0	13-1	0	13-1	1.161e-03	14-...
94		min	0	14-...	-.95	14-...	0	13-1	0	13-1	0	13-1	-1.345e-05	4
95	N48	max	0	11	.029	4	0	13-1	0	13-1	0	13-1	2.753e-03	14-...
96		min	0	14-...	-1.022	14-...	0	13-1	0	13-1	0	13-1	-5.589e-04	4
97	N49	max	0	11	0	7	0	13-1	0	13-1	0	13-1	0	7
98		min	0	14-...	-1.018	14-...	0	13-1	0	13-1	0	13-1	-2.57e-03	14-...
99	N50	max	0	11	.002	4	0	13-1	0	13-1	0	13-1	8.491e-06	4
100		min	0	14-...	-.954	14-...	0	13-1	0	13-1	0	13-1	-9.91e-04	14-...
101	N51	max	0	11	.001	4	0	13-1	0	13-1	0	13-1	7.626e-04	14-...
102		min	0	14-...	-.96	14-...	0	13-1	0	13-1	0	13-1	-1.751e-05	4
103	N52	max	0	11	.034	4	0	13-1	0	13-1	0	13-1	2.58e-03	14-...
104		min	0	14-...	-1.047	14-...	0	13-1	0	13-1	0	13-1	-6.159e-04	4

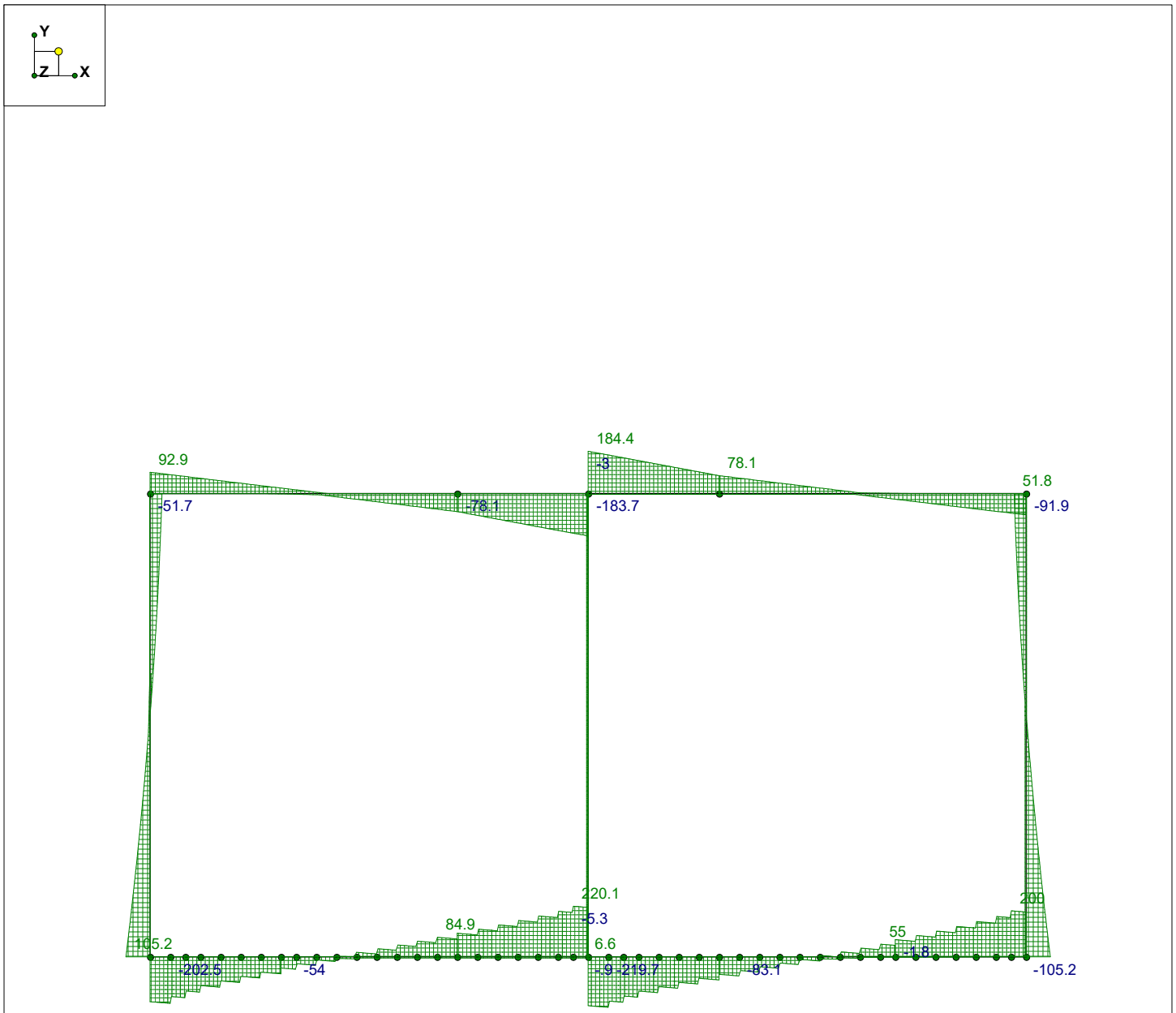
Envelope Concrete Beam Design Results

	Member	Shape	UC M...	Loc[ft]	UC LC	UC M...	Loc[ft]	UC LC	Shear ...	Loc[ft]	UC LC	Phi*M...	Phi*Mnz...	Phi*V...
1	M1	CRECT24X48	.874	1.173	14	.271	12.204	14	.854	2.816	14	422.739	422.739	89.253
2	M2	CRECT24X48	.664	.934	14	.678	8.559	14	.928	.934	14	225.497	246.702	89.253
3	M3	CRECT48X48	.873	.73	14	.031	.73	4	.861	.73	14	931.677	931.677	200.5...
4	M4	CRECT24X48	.275	12.204	14	.868	1.173	14	.854	2.816	14	422.739	422.739	89.253
5	M5	CRECT30X48	.265	6.5	14	.84	.73	14	.783	3.449	14	771.309	771.309	198.6...
6	M6	CRECT30X48	.462	6.5	14	.376	.995	14	.664	3.449	14	771.309	771.309	198.6...
7	M7	CRECT18X48	.431	1.173	11	.365	20.888	11	.107	2.347	11	162.779	162.779	61.434
8	M8	CRECT48X48	.873	5.77	14	0	0	4	.86	5.77	14	931.677	931.677	200.5...
9	M9	CRECT24X48	.663	14.316	14	.677	6.691	14	.922	14.316	14	225.497	246.702	89.253
10	M10	CRECT30X48	.929	3.75	14	.11	0	4	.439	5.804	14	479.098	479.098	117.0...
11	M11	CRECT30X48	.914	5	14	0	0	N/A	.425	2.946	14	479.098	0	117.0...
12	M12	CRECT30X48	.263	0	14	.839	5.77	14	.794	3.051	14	771.309	771.309	198.6...
13	M13	CRECT30X48	.447	0	14	.382	5.505	14	.665	3.051	14	771.309	771.309	198.6...



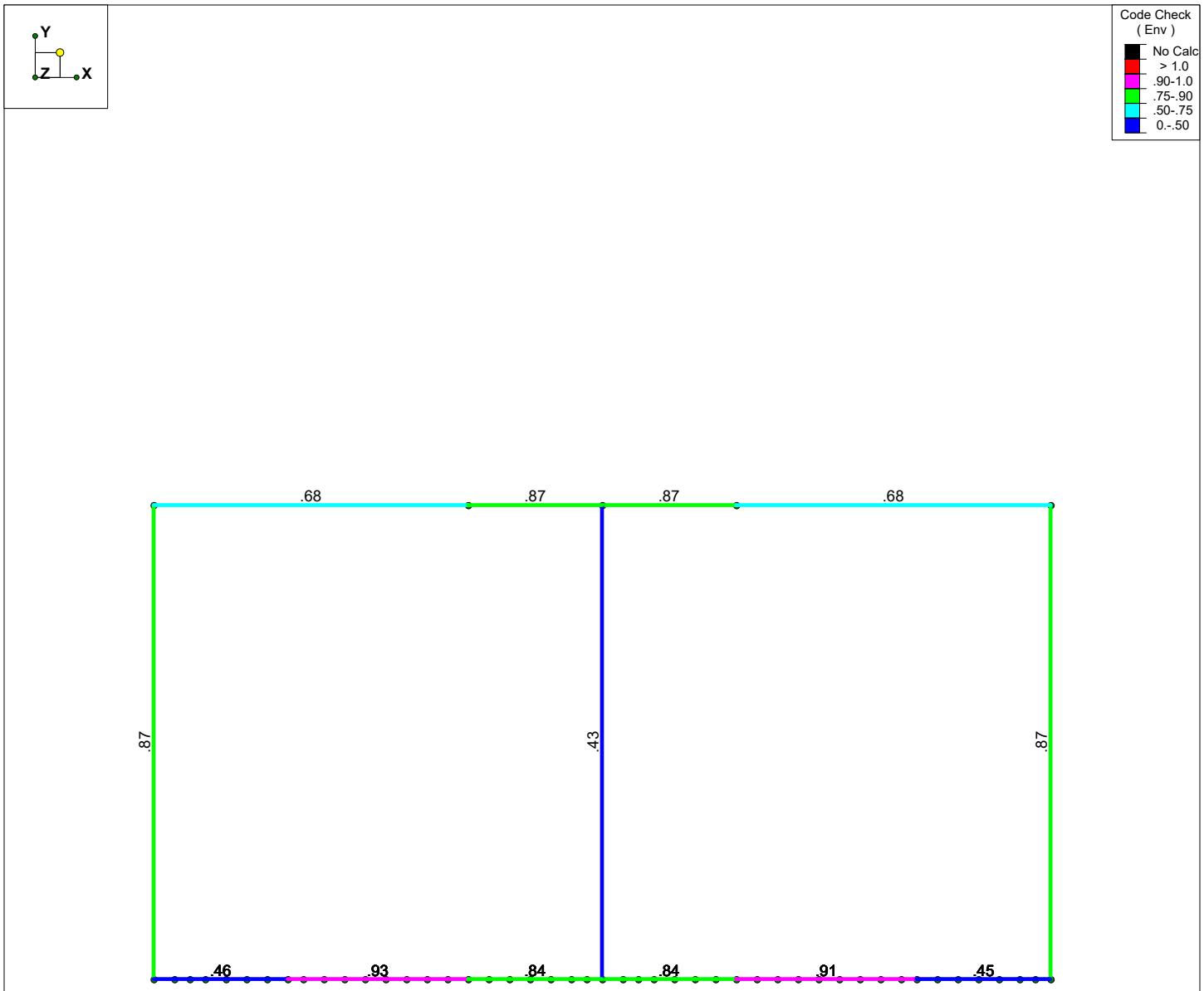
Member z Bending Moments (k-ft) (Enveloped)

		SK - 2
TH	Peckman 40-ft Dbl box culvert	June 24, 2019 at 4:19 PM
	Bending Moment Diagram	Peckman River DBL Box Culvert.r3d



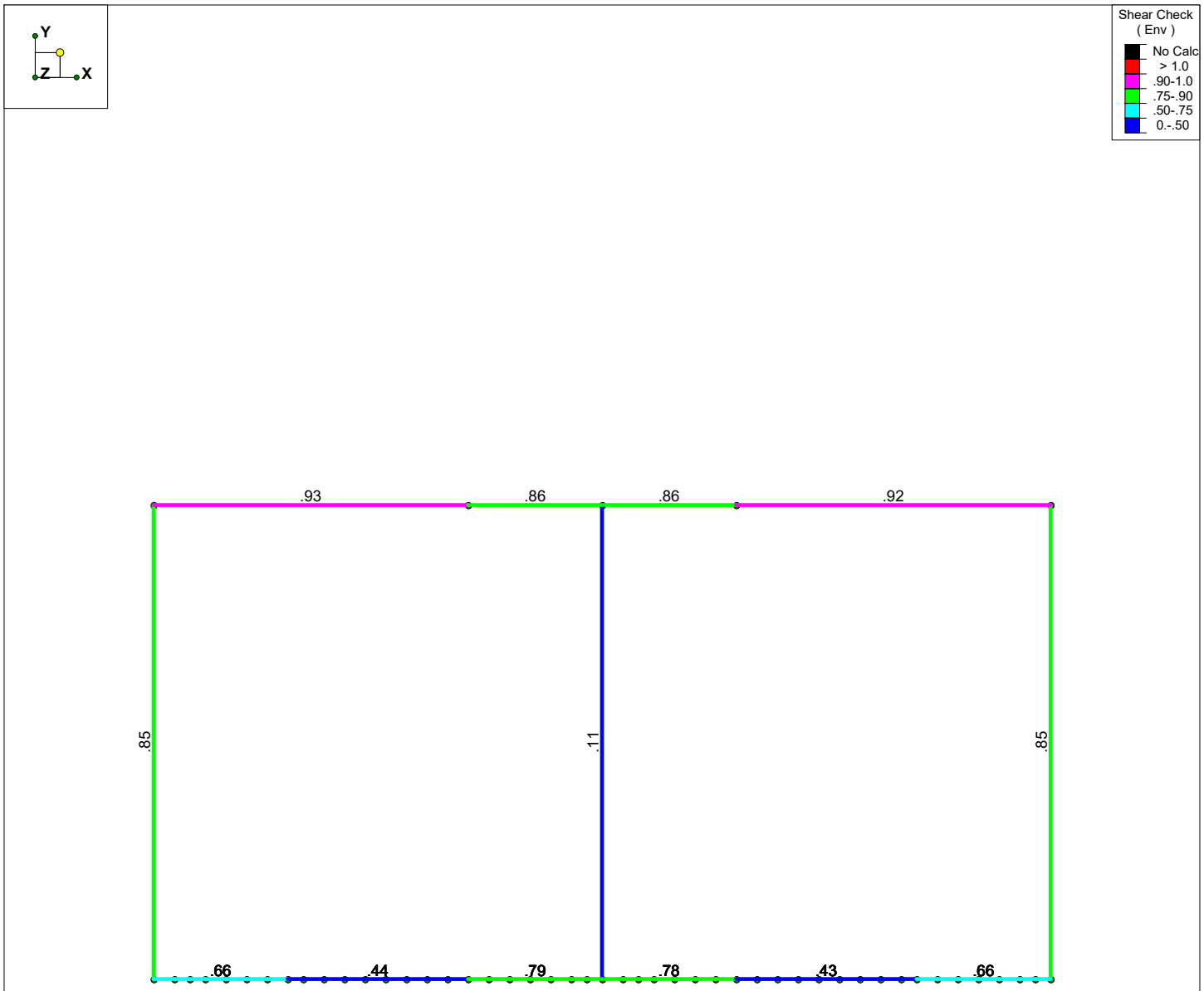
Member y Shear Forces (k) (Enveloped)

		SK - 3
TH	Peckman 40-ft Dbl box culvert	June 24, 2019 at 4:20 PM
	Shear Diagram	Peckman River DBL Box Culvert.r3d



Member Code Checks Displayed (Enveloped)
Results for LC 1, DC

		SK - 4
TH	Peckman 40-ft Dbl box culvert	June 24, 2019 at 4:21 PM
	Bending Design Results	Peckman River DBL Box Culvert.r3d



Member Shear Checks Displayed (Enveloped)
Results for LC 1, DC

		SK - 5
TH	Peckman 40-ft Dbl box culvert	June 24, 2019 at 4:21 PM
	Shear Design Results	Peckman River DBL Box Culvert.r3d

Peckman River
Flood Risk Management Study

Retaining Walls and Weirs

Preliminary Analysis

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REFERENCES

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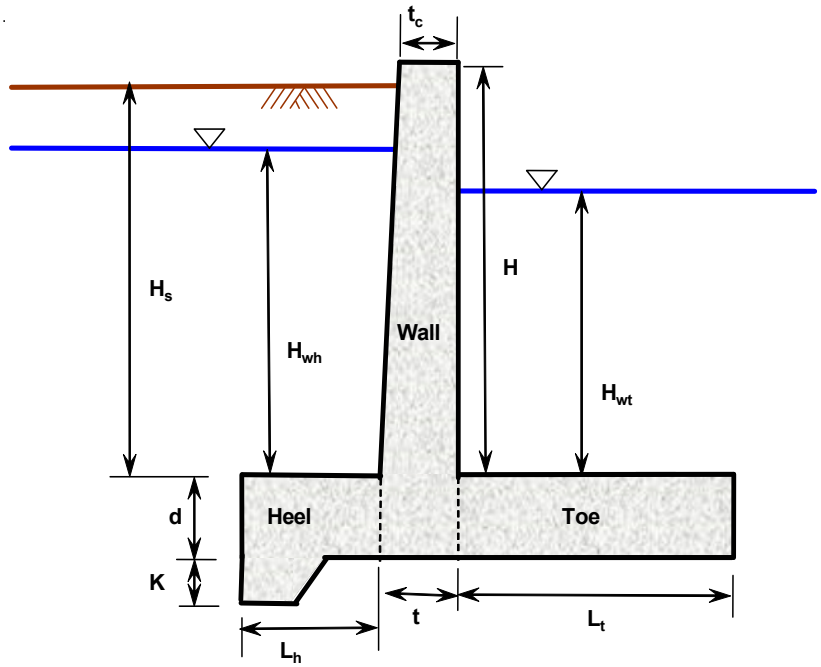
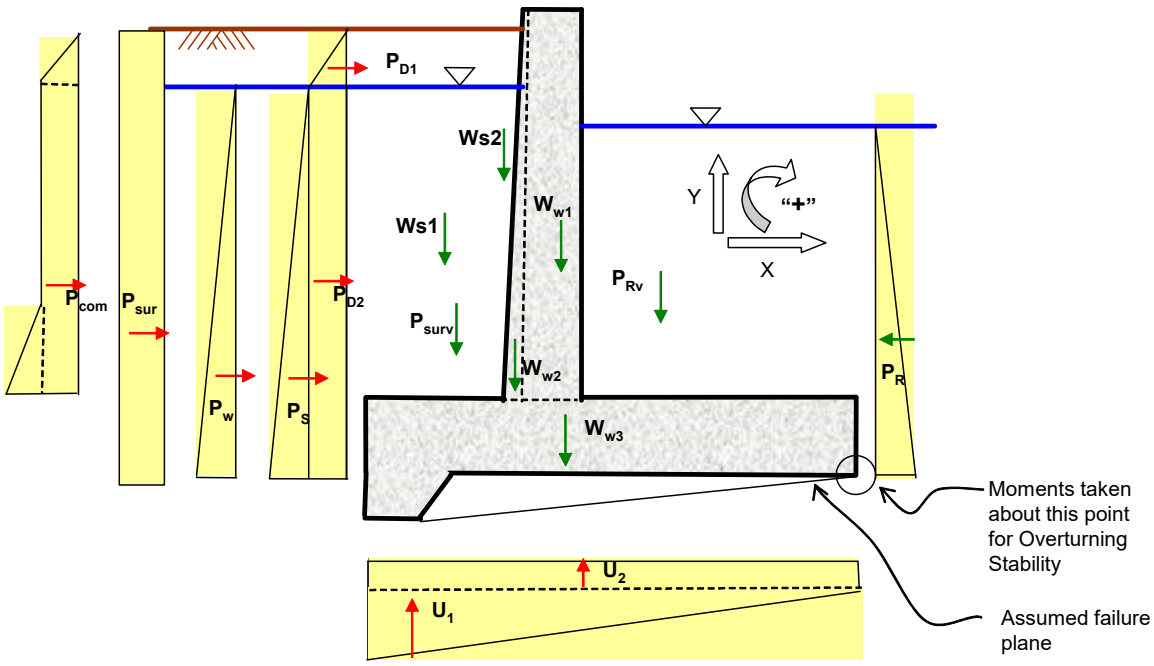
2. ACI 318-14, ACI 530-13 and UFC 3-301-01 with changes on May 15, 2014
3. AASHTO LRFD Bridge Design Specifications, 7th Edition, 2014 with 2016 Interim Revisions (referred to as LRFD)
4. EM 1110-2-2100: Stability Analysis of Concrete Structures
5. EM 1110-2-2502: Retaining and Flood Walls
6. EM 1110-2-2104: Strength Design for Reinforced Concrete Hydraulic Structures.
7. Engineering and Construction Bulletin (ECB) No. 2017-2: Revision and Clarification of EM 2100 and EM 2502



Notes:
$H_s = H_{wh}$
$H_{wh} = H_{wt}$

General Nomenclature



WALL DIMENSIONS

Wall height $H := 16ft$

Soil height $H_s := 15ft$

Water height (heel) $H_{wh} := H_s - 5ft$ (average water table based on soil report)

Water height (toe) $H_{wt} := 0ft$

Equipment Surcharge $S := 0plf$

Wall thickness at crest $t_c := 1ft$

Wall thickness at base $t := t_c + 1ft = 2\,ft$

Footing thickness $d := 2ft$

Heel length $L_h := 6ft$

Toe length $L_t := 6ft$

Key depth $K := 3 \cdot ft$

Key thickness $t_k := t$

Base Length $L_{base} := L_t + L_h + t = 14\,ft$

Compaction load $C_{load} := 0plf$

Wall Batter $Bat := \frac{t - t_c}{H} = 0.06$

Sliding factor of safety $FS_{sliding} := 1.5$

PROPERTIES AND COEFFICIENTS

Soil moist unit weight $\gamma_m := 130psf$

Soil saturated unit weight $\gamma_s := 130psf$

Concrete unit weight $\gamma_c := 150psf$ (for stability) $\gamma_{cb} := 150psf$ (for bearing stress)

Water unit weight $\gamma_w := 62.4psf$

Shear strength parameter (backfill) $\phi_1 := 32deg$

Cohesion (backfill) $c := 0psf$

Sliding parameter $\phi_s := 32deg$

Cohesion (Footing Soil Material) $c_s := 0psf$

Bearing Capacity $Q_{allowable} := 2000plf$ See Bearing Capacity Calculations

Horizontal Seismic Coefficients $k_h := 0.0$

Slope inclination Angle $\beta_a := 0deg$ $\beta_p := 0$ (passive)

At-rest coefficient $K_o := (1 - \sin(\phi_1)) \cdot (1 + \sin(\beta_a))$ $K_o = 0.47$

WALL FORCES FOR STABILITY

Wall section

$W_{w1} := -\gamma_c \cdot H \cdot t_c$ $\quad W_{w1} = -2400\ lbf$ $\quad W_{w2} := -\gamma_c \cdot H \cdot (t - t_c) \cdot \frac{1}{2}$ $\quad W_{w2} = -1200\ lbf$

$x_{w1} := L_t + \frac{t_c}{2}$ $\quad x_{w1} = 6.5\ ft$ $\quad x_{w2} := L_t + t_c + \frac{t - t_c}{3}$ $\quad x_{w2} = 7.3\ ft$

Footing section

$W_{w3} := -\gamma_c \cdot (L_{base}) \cdot d$ $\quad W_{w3} = -4200\ lbf$ $\quad x_{w3} := \frac{L_{base}}{2}$ $\quad x_{w3} = 7\ ft$

WALL FORCES FOR BEARING STRESS

Wall section

$W_{w1b} := -\gamma_{cb} \cdot H \cdot t_c$ $\quad W_{w1b} = -2400\ lbf$ $\quad W_{w2b} := -\gamma_{cb} \cdot H \cdot (t - t_c) \cdot \frac{1}{2}$ $\quad W_{w2b} = -1200\ lbf$

Footing section

$W_{w3b} := -\gamma_c \cdot (L_{base}) \cdot d$ $\quad W_{w3b} = -4200\ lbf$ $\quad x_{w3b} := \frac{L_{base}}{2}$ $\quad x_{w3b} = 7\ ft$

WATER FORCES

$L_{atw} := (t - t_c) - (H_s - H_{wh}) \cdot Bat$ $\quad L_{atw} = 0.7\ ft$

$W_{water1} := -\gamma_w \cdot H_{wh} \cdot L_h$ $\quad W_{water1} = -3744\ lbf$ $\quad x_{water1} := L_t + t + \frac{L_h}{2}$ $\quad x_{water1} = 11\ ft$

$W_{water2} := -\gamma_w \cdot H_{wh} \cdot L_{atw} \cdot \frac{1}{2}$ $\quad W_{water2} = -214.5\ lbf$ $\quad x_{water2} := L_t + t_c + (t - t_c) \cdot \frac{2}{3}$ $\quad x_{water2} = 7.7\ ft$

SOIL FORCES

Vertical Forces

$W_{s1} := -\gamma_s \cdot H_{wh} \cdot L_h + -\gamma_m \cdot (H_s - H_{wh}) \cdot L_h$ $\quad W_{s1} = -11700\ lbf$ $\quad x_{s1} := L_t + t + \frac{L_h}{2}$ $\quad x_{s1} = 11\ ft$

$W_{s2} := -\gamma_s \cdot H_{wh} \cdot L_{atw} \cdot \frac{1}{2} + -\gamma_m \cdot (H_s - H_{wh}) \cdot \left[(t - t_c) + L_{atw}\right] \cdot \frac{1}{2}$ $\quad x_{s2} := L_t + t_c + (t - t_c) \cdot \frac{2}{3}$ $\quad x_{s2} = 7.7\ ft$

$W_{s2} = -995.313\ lbf$

$P_{surv} := -S \cdot L_h$ $\quad P_{surv} = 0$ $\quad x_{surv} := L_t + t + \frac{L_h}{2}$ $\quad x_{surv} = 11\ ft$

Horizontal Forces

Seismic Forces

Driving / Active Wedge

Computation of Critical Value of Slip-Plane Angle (α_a) by Trial and Error:

Assume $\alpha_a := 61deg$

$$d_c := \min\left[\frac{\dfrac{c}{\gamma_m\cdot\left(\frac{1}{ft}\right)}}{\cos(\alpha_a)\cdot\left(\sin(\alpha_a)-\tan(\phi_1)\cdot\cos(\alpha_a)\right)}, H_s + d\right] \qquad d_c = 0\cdot ft$$

$$A_a := \left(1+k_h\cdot\tan(\phi_1)\right)\cdot\tan(\phi_1) + \frac{2\cdot c\cdot\left(1-\tan(\phi_1)\cdot\tan(\beta_a)\right)}{\gamma_m\cdot\left(\frac{1}{ft}\right)\cdot\left(H_s+d_c\right)} \qquad A_a = 0.6$$

$$c_{1a} := \frac{2\cdot\tan(\phi_1)\cdot\left(\tan(\phi_1)-k_h\right) + \dfrac{4\cdot c\cdot\tan(\phi_1+\beta_a)}{\gamma_m\cdot\left(\frac{1}{ft}\right)\cdot\left(H_s+d_c\right)}}{A_a} \qquad c_{1a} = 1.2$$

$$c_{2a} := \frac{\tan(\phi_1)\cdot\left(1-\tan(\phi_1)\cdot\tan(\beta_a)\right) - \left(\tan(\beta_a)+k_h\right) + \dfrac{2\cdot c\cdot\left(1-\tan(\phi_1)\cdot\tan(\beta_a)\right)}{\gamma_m\cdot\left(\frac{1}{ft}\right)\cdot\left(H_s+d_c\right)}}{A_a} \qquad c_{2a} = 1$$

$$\alpha_{a_new} := \operatorname{atan}\left(\frac{c_{1a}+\sqrt{c_{1a}^2+4c_{2a}}}{2}\right) \qquad \alpha_{a_new} = 61\cdot deg$$

Active pressure for seismic (Moist condition)

$$K_{AO} := \left(\frac{1-\tan(\phi_1)\cdot\cot(\alpha_a)}{1+\tan(\phi_1)\cdot\tan(\alpha_a)}\right)\cdot\left(\frac{\tan(\alpha_a)}{\tan(\alpha_a)-\tan(\beta_a)}\right) = 0.307$$

For static case, at rest

$$K_A := \text{if}\left(k_h > .001, K_{AO}, K_o\right) \qquad K_A = 0.47$$

Active pressure for seismic (Saturated condition)

$$K_{BO} := \left(\frac{1-\tan(\phi_1)\cdot\cot(\alpha_a)}{1+\tan(\phi_1)\cdot\tan(\alpha_a)}\right)\cdot\left[1+\left(\frac{\tan(\alpha_a)}{\tan(\alpha_a)-\tan(\beta_a)}-1\right)\cdot\left(\frac{\gamma_m}{\gamma_s-\gamma_w}\right)\right] = 0.307$$

$$K_B := \text{if}\left(k_h > .001, K_{BO}, K_o\right) \qquad K_B = 0.47$$

<u>Dynamic Components</u>

$$\Delta P_{AE1} := k_h\cdot\left[\frac{\gamma_m\cdot\left[\left(H_s+d\right)^2-d_c^2\right]}{2\cdot\tan(\alpha_a)-\tan(\beta_a)}\right] \qquad \Delta P_{AE1} = 0 \qquad y_{\Delta PAE1} := \frac{2}{3}\cdot\left(H_s+d\right) \qquad y_{\Delta PAE1} = 11.3\,ft$$

$$\Delta P_{AE2} := k_h\cdot\left[\frac{\left(\gamma_s-\gamma_m\right)\cdot\left(H_{wh}+d\right)^2}{2\cdot\tan(\alpha_a)}\right] \qquad \Delta P_{AE2} = 0 \qquad y_{\Delta PAE2} := \frac{2}{3}\cdot\left(H_{wh}+d\right) \qquad y_{\Delta PAE2} = 8\,ft$$

$$y_{\Delta PAE} := \begin{cases} \dfrac{\Delta P_{AE1}\cdot y_{\Delta PAE1}+\Delta P_{AE2}\cdot y_{\Delta PAE2}}{\Delta P_{AE1}+\Delta P_{AE2}} & \text{if } \left(\Delta P_{AE}\right) > 0 \\ 0 & \text{otherwise} \end{cases} \qquad y_{\Delta PAE} = 0$$

Active Earth Pressure

Calculation of earth pressure based on location of crack (d_c) in relation to water table

$$\sigma_{A1} := K_A \cdot \gamma_m \cdot \left[\left(H_s + d\right) - d_c - \left(d + H_{wh}\right)\right] \qquad \sigma_{A1} = 305.6\,ft \cdot psf$$

$$P_{A1} := \begin{cases} \frac{1}{2} \cdot \sigma_{A1} \cdot \left[\left(H_s + d\right) - d_c - \left(d + H_{wh}\right)\right] & \text{if } d_c < \left(H_s - H_{wh}\right) \\ 0 & \text{otherwise} \end{cases} \qquad P_{A1} = 763.9 \cdot lbf$$

$$y_{PA1} := H_{wh} + d + \frac{\left(H_s + d\right) - d_c - \left(d + H_{wh}\right)}{3} \qquad y_{PA1} = 13.7\,ft$$

$$\sigma_{A2} := \begin{cases} K_A \cdot \gamma_m \cdot \left[\left(H_s + d\right) - d_c - \left(d + H_{wh}\right)\right] + K_B \cdot \left(\gamma_s - \gamma_w\right) \cdot \left(H_{wh} + d\right) & \text{if } d_c < \left(H_s - H_{wh}\right) \\ K_B \cdot \left(\gamma_s - \gamma_w\right) \cdot \left[\left(H_s + d\right) - d_c\right] & \text{otherwise} \end{cases} \qquad \sigma_{A2} = 686.9\,ft \cdot psf$$

$$P_{A2} := \begin{cases} \sigma_{A1} \cdot \left(H_{wh} + d\right) & \text{if } d_c < \left[\left(H_s\right) - H_{wh}\right] \\ \frac{1}{2} \cdot \sigma_{A2} \cdot \left[\left(H_s + d\right) - d_c\right] & \text{otherwise} \end{cases} \qquad P_{A2} = 3666.6 \cdot lbf$$

$$y_{PA2} := \begin{cases} \frac{H_{wh} + d}{2} & \text{if } d_c < \left[\left(H_s\right) - H_{wh}\right] \\ \frac{\left(H_s + d\right) - d_c}{3} & \text{otherwise} \end{cases} \qquad y_{PA2} = 6\,ft$$

$$P_{A3} := \begin{cases} \frac{1}{2} \cdot \left(\sigma_{A2} - \sigma_{A1}\right) \cdot \left(H_{wh} + d\right) & \text{if } d_c < \left(H_s - H_{wh}\right) \\ 0 & \text{otherwise} \end{cases} \qquad P_{A3} = 2288 \cdot lbf$$

$$y_{PA3} := \frac{H_{wh} + d}{3} \qquad y_{PA3} = 4\,ft$$

Resisting / Passive Wedge (From Footing Key)

$$A_p := \left(1 + k_h \cdot \tan\left(\phi_s\right)\right) \cdot \tan\left(\phi_s\right) + \frac{2 \cdot c_s \cdot \left(1 + \tan\left(\phi_s\right) \cdot \tan\left(\beta_p\right)\right)}{\gamma_m \cdot \left(\frac{1}{ft}\right) \cdot (K)} \qquad A_p = 0.6$$

$$c_{1p} := \frac{2 \cdot \tan\left(\phi_s\right) \cdot \left(\tan\left(\phi_s\right) - k_h\right) + \frac{4 \cdot c_s \cdot \left(\tan\left(\phi_s\right) - \tan\left(\beta_p\right)\right)}{\gamma_m \cdot \left(\frac{1}{ft}\right) \cdot (K)}}{A_p} \qquad c_{1p} = 1.2$$

$$c_{2p} := \frac{\tan\left(\phi_s\right) \cdot \left(1 + \tan\left(\phi_s\right) \cdot \tan\left(\beta_p\right)\right) + \left(\tan\left(\beta_p\right) - k_h\right) + \frac{2 \cdot c_s \cdot \left(1 + \tan\left(\phi_s\right) \cdot \tan\left(\beta_p\right)\right)}{\gamma_m \cdot \left(\frac{1}{ft}\right) \cdot (K)}}{A_p} \qquad c_{2p} = 1$$

$$\alpha_p := \operatorname{atan}\left(\frac{-c_{1p} + \sqrt{c_{1p}^2 + 4c_{2p}}}{2}\right) \qquad \alpha_p = 29 \cdot deg$$

Passive pressure coefficient for seismic (Moist condition)

$$K_{PO} := \left(\frac{1 + \tan(\phi_s)\cdot\cot(\alpha_p)}{1 - \tan(\phi_s)\cdot\tan(\alpha_p)}\right)\cdot\left(\frac{\tan(\alpha_p)}{\tan(\alpha_p) - \tan(\beta_p)}\right) \qquad K_{PO} = 3.3$$

$$K_P := \text{if}(k_h > .001, K_{PO}, K_{PO}) \qquad K_P = 3.3$$

Passive pressure for seismic (Saturated condition)

$$K_{PBO} := \left(\frac{1 + \tan(\phi_s)\cdot\cot(\alpha_p)}{1 - \tan(\phi_s)\cdot\tan(\alpha_p)}\right)\cdot\left[1 + \left(\frac{\tan(\alpha_p)}{\tan(\alpha_p) - \tan(\beta_p)} - 1\right)\cdot\left(\frac{\gamma_m}{\gamma_s - \gamma_w}\right)\right]$$

$$K_{PBO} = 3.3$$

$$K_{PB} := \text{if}(k_h > .001, K_{PBO}, K_{PBO}) \qquad K_{PB} = 3.3$$

Dynamic Component

$$\Delta P_{PE2} := k_h\cdot\left[\frac{(\gamma_s - \gamma_m)\cdot K^2}{2\cdot\tan(\alpha_p)}\right] \qquad \Delta P_{PE2} = 0 \qquad y_{\Delta PPE2} := -\frac{1}{3}\cdot(K) \qquad y_{\Delta PPE2} = -1\,ft$$

Passive Earth Pressure

$$K_c := \frac{1}{2\sin(\alpha_p)\cos(\alpha_p)(1 - \tan(\phi_s)\cos(\alpha_p))}\cdot\frac{\tan(\alpha_p)}{\tan(\alpha_p) - \tan(\beta_p)} \qquad K_c = 2.6$$

$$P_{P1} := -(2\cdot K_c\cdot c_s\cdot K)\cdot ft \qquad P_{P1} = 0 \qquad y_{PP1} := -\frac{1}{2}K \qquad y_{PP1} = -1.5\,ft$$

$$P_{P2} := -\left[\left(\frac{1}{2}\right)\cdot K_{PB}\cdot(\gamma_s - \gamma_w)\cdot K^2\right] \qquad P_{P2} = -990\,lbf \qquad y_{PP2} := -\frac{2}{3}K \qquad y_{PP2} = -2\,ft$$

Concrete Inertia

$$W_{w1_e} := -k_h\cdot W_{w1b} \qquad y_{w1_e} := \frac{H}{2} + d$$

$$W_{w1_e} = 0 \qquad y_{w1_e} = 10\,ft$$

$$W_{w2_e} := -k_h\cdot W_{w2b} \qquad y_{w2_e} := \frac{H}{3} + d$$

$$W_{w2_e} = 0 \qquad y_{w2_e} = 7.3\,ft$$

$$W_{w3_e} := -k_h\cdot W_{w3b} \qquad y_{w3_e} := \frac{d}{2}$$

$$W_{w3_e} = 0 \qquad y_{w3_e} = 1\,ft$$

Surcharge Pressure

$$P_{sur} := \begin{cases} K_B\cdot S\cdot[(H_s + d) - d_c] & \text{if } d_c > (H_s - H_{wh}) \\ K_A\cdot S\cdot(H_s - H_{wh} - d_c) + K_B\cdot S\cdot(H_{wh} + d) & \text{otherwise} \end{cases} \qquad P_{sur} = 0$$

$$y_{sur} := \begin{cases} \dfrac{(H_s + d) - d_c}{2} & \text{if } d_c > H_s - H_{wh} \\ \dfrac{K_A \cdot S \cdot (H_s - H_{wh} - d_c) \cdot \left[(H_{wh} + d) + \dfrac{H_s - H_{wh} - d_c}{2} \right] + K_B \cdot S \cdot (H_{wh} + d) \cdot \dfrac{H_{wh} + d}{2}}{K_A \cdot S \cdot (H_s - H_{wh} - d_c) + K_B \cdot S \cdot (H_{wh} + d)} & \text{if } S > 0 \\ 0 & \text{otherwise} \end{cases} \qquad y_{sur} = 0\,\text{ft}$$

Water Pressure

$$P_w := \frac{1}{2} \cdot \gamma_w \cdot (H_{wh} + d)^2 \qquad P_w = 4492.8\,\text{lbf} \qquad y_w := \frac{H_{wh} + d}{3} \qquad y_w = 4\,\text{ft}$$

Water Pressure considering depth of crack

$$P_{wdc} := \begin{cases} \dfrac{1}{2} \cdot \gamma_w \cdot d_c^{\,2} & \text{if } d_c < (H_s - H_{wh}) \\ \dfrac{1}{2} \cdot \gamma_w \cdot (H_s - H_{wh})^2 & \text{otherwise} \end{cases} \qquad P_{wdc} = 0\,\text{lbf}$$

$$y_{wdc} := \begin{cases} (H_s + d) - \dfrac{2 \cdot d_c}{3} & \text{if } d_c < (H_s - H_{wh}) \\ (H_s + d) - \dfrac{2 \cdot \left[(H_s + d) - H_{wh} \right]}{3} & \text{otherwise} \end{cases} \qquad y_{wdc} = 17\,\text{ft}$$

Uplift Forces

Uplift at heel $\quad U_h := \text{if}(H_{wh} > 0.1\text{ft}, H_{wh} + d, 0) \qquad U_h = 12\,\text{ft}$

Uplift at toe $\quad U_t := \text{if}(H_{wt} > 0.1\text{ft}, H_{wt} + d, 0) \qquad U_t = 0\,\text{ft}$

$$U_1 := \gamma_w \cdot \frac{1}{2} \cdot (U_h - U_t) \cdot (L_{base}) \qquad U_1 = 5241.6\,\text{lbf} \qquad x_{U1} := \frac{1}{3} \cdot (L_{base}) \qquad x_{U1} = 4.7\,\text{ft}$$

$$U_2 := \gamma_w \cdot U_t \cdot (L_{base}) \qquad U_2 = 0\,\text{lbf} \qquad x_{U2} := \frac{1}{2} \cdot (L_{base}) \qquad x_{U2} = 7\,\text{ft}$$

Reservoir Forces

Horizontal Forces

$$P_R := \frac{-1}{2} \cdot \gamma_w \cdot (H_{wt} + d)^2 \qquad P_R = -124.8\,\text{lbf} \qquad y_R := \frac{1}{3}(H_{wt} + d) \qquad y_R = 0.7\,\text{ft}$$

Vertical Forces

$$P_{Rv} := -\gamma_w \cdot L_t \cdot H_{wt} \qquad P_{Rv} = 0 \qquad x_{Rv} := \frac{L_t}{2} \qquad x_{Rv} = 3\,\text{ft}$$

Wave Forces

$$P_{wave} := 0\text{lbf} \qquad y_{wave} := 0\text{ft}$$

Check Stability

Moments about toe

Resisting Moment

$$M_r := W_{w1}\cdot x_{w1} + W_{w2}\cdot x_{w2} + W_{w3}\cdot x_{w3} + P_R\cdot y_R + P_{Rv}\cdot x_{Rv} + P_{wave}\cdot y_{wave} + W_{s1}\cdot x_{s1} + W_{s2}\cdot x_{s2} + W_{water1}\cdot x_{water1} \cdots + W_{water2}\cdot x_{water2} + P_{surv}\cdot x_{surv} + \Delta P_{PE2}\cdot y_{\Delta PPE2}$$

$M_r = -233\cdot kip\cdot ft$

Overturning Moment

$$M_o := P_{A1}\cdot y_{PA1} + P_{A2}\cdot y_{PA2} + P_{A3}\cdot y_{PA3} + \Delta P_{AE}\cdot y_{\Delta PAE} + W_{w1_e}\cdot y_{w1_e} + W_{w2_e}\cdot y_{w2_e} + W_{w3_e}\cdot y_{w3_e} \cdots + P_{sur}\cdot y_{sur} + P_w\cdot y_w + P_{wdc}\cdot y_{wdc} + U_1\cdot x_{U1} + U_2\cdot x_{U2} + P_{P1}\cdot y_{PP1} + P_{P2}\cdot y_{PP2}$$

$M_o = 86\cdot kip\cdot ft$

ΣF_y Vertical Force

$$F_y := W_{w1} + W_{w2} + W_{w3} + W_{s1} + W_{s2} + W_{water1} + W_{water2} + U_1 + U_2 + P_{Rv} + P_{surv}$$

$F_y = -19.2\cdot kip$

ΣF_x Horizontal Force

$$F_x := P_{A1} + P_{A2} + P_{A3} + \Delta P_{AE} + P_w + W_{w1_e} + W_{w2_e} + W_{w3_e} + P_{sur} + P_{wdc} + P_R + P_{wave} + P_{P1} + P_{P2} + \Delta P_{PE2}$$

$F_x = 10.1\cdot kip$

Location of Resultant

$$Resultant := \frac{M_r + M_o}{F_y}$$ $Resultant = 7.65\,ft$

$$Eccentricity := \frac{L_{base}}{2} - Resultant$$ $Eccentricity = -0.65\,ft$

$$Middle_Third := \frac{L_{base}}{6}$$ $Middle_Third = 2.3\,ft$

$$Check_R := if(Middle_Third > |Eccentricity|, "OK", "NOT_GOOD")$$

Check compression at Base

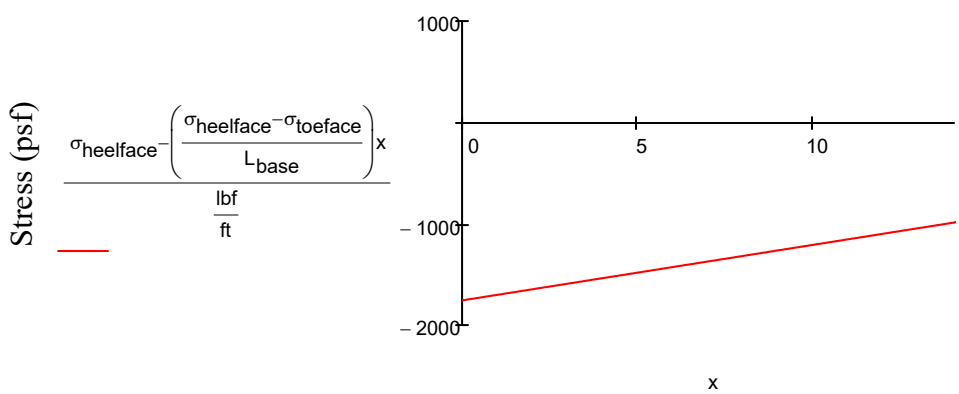
$Check_R = "OK"$

Pressure distribution Under the Footing (Negative is compression)

$$\sigma_{toeface} := \frac{F_y}{L_{base}}\cdot\left(1 + \frac{6\cdot Eccentricity}{L_{base}}\right)$$ *The stress at the toe* $\sigma_{toeface} = -988\cdot\frac{lbf}{ft}$

$$\sigma_{heelface} := \frac{F_y}{L_{base}}\cdot\left(1 - \frac{6\cdot Eccentricity}{L_{base}}\right)$$ *The stress at the heel* $\sigma_{heelface} = -1757\cdot\frac{lbf}{ft}$

Stress Distribution:



Footing in ft (The toe is set at zero)

Sliding Factor of Safety:

$\theta := \operatorname{atan}\left(\frac{K}{L_{base}}\right)$ $\theta = 12.1 \cdot deg$

$F_{xn} := F_x \cdot \sin(\theta)$ $F_{xn} = 2.1 \cdot kip$

$F_{xs} := F_x \cdot \cos(\theta)$ $F_{xs} = 9.9 \cdot kip$

$F_{ys} := F_y \cdot \sin(\theta)$ $F_{ys} = -4 \cdot kip$

$F_{yn} := -F_y \cdot \cos(\theta)$ $F_{yn} = 18.8 \cdot kip$

$$FS_s := \left| \frac{\tan(\phi_s) \cdot (F_{xn} + F_{yn}) + c_s \cdot L_{base} \cdot (1ft)}{F_{xs} + F_{ys}} \right|$$ $FS_s = 2.23$

$Check_{FS} := if(FS_s > FS_{sliding}, "OK", "NOT_GOOD")$

Check Sliding

$Check_{FS} = "OK"$

Check Bearing Stress

Moments about toe

Resisting Moment

$$M_{rb} := W_{w1b} \cdot x_{w1} + W_{w2b} \cdot x_{w2} + W_{w3b} \cdot x_{w3} + P_R \cdot y_R + P_{Rv} \cdot x_{Rv} + P_{wave} \cdot y_{wave} + W_{s1} \cdot x_{s1} + W_{s2} \cdot x_{s2} + W_{water1} \cdot x_{water1} \cdots + W_{water2} \cdot x_{water2} + P_{surv} \cdot x_{surv} + \Delta P_{PE2} \cdot y_{\Delta PPE2}$$

$M_{rb} = -233 \cdot kip \cdot ft$

SF_y Vertical Force

$F_{yb} := W_{w1b} + W_{w2b} + W_{w3b} + W_{s1} + W_{s2} + W_{water1} + W_{water2} + U_1 + U_2 + P_{Rv} + P_{surv}$ $F_{yb} = -19.2 \cdot kip$

Location of Resultant

$$Eccentricity_b := \frac{L_{base}}{2} - \frac{M_{rb} + M_o}{F_{yb}}$$ $Eccentricity_b = -0.65\,ft$

Stress distribution Under the Footing (Negative is compression)

$$\sigma_{toeface.b} := \frac{F_{yb}}{L_{base}} \cdot \left(1 + \frac{6 \cdot Eccentricity_b}{L_{base}}\right)$$ *The stress at the toe* $\sigma_{toeface.b} = -988 \cdot \frac{lbf}{ft}$

$$\sigma_{heelface.b} := \frac{F_{yb}}{L_{base}} \cdot \left(1 - \frac{6 \cdot Eccentricity_b}{L_{base}}\right)$$ *The stress at the heel* $\sigma_{heelface.b} = -1757 \cdot \frac{lbf}{ft}$

Bearing Factor of Safety

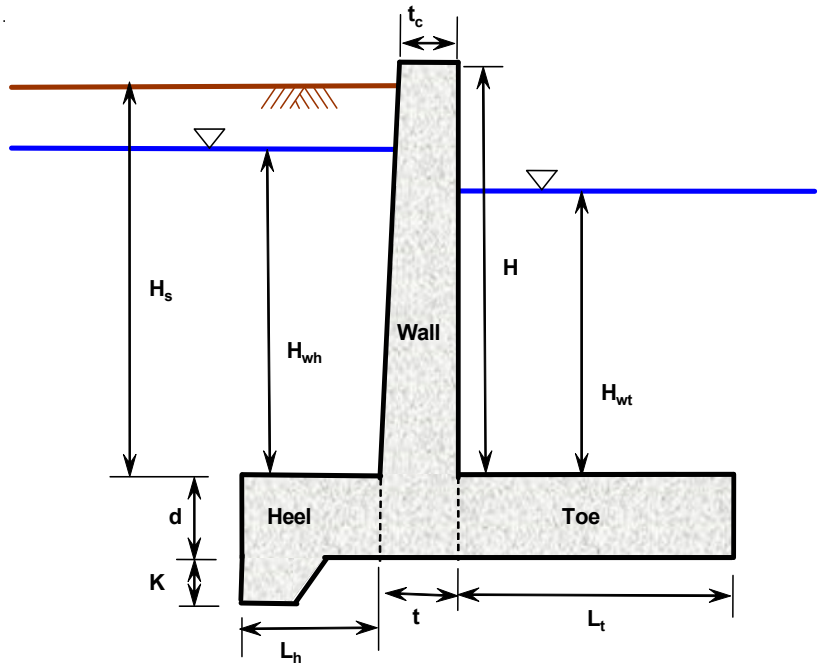
$Check_B := if(Q_{allowable} > \max(|\sigma_{toeface.b}|, |\sigma_{heelface.b}|), "OK", "NO_GOOD")$

Check bearing stress

$Check_B = "OK"$

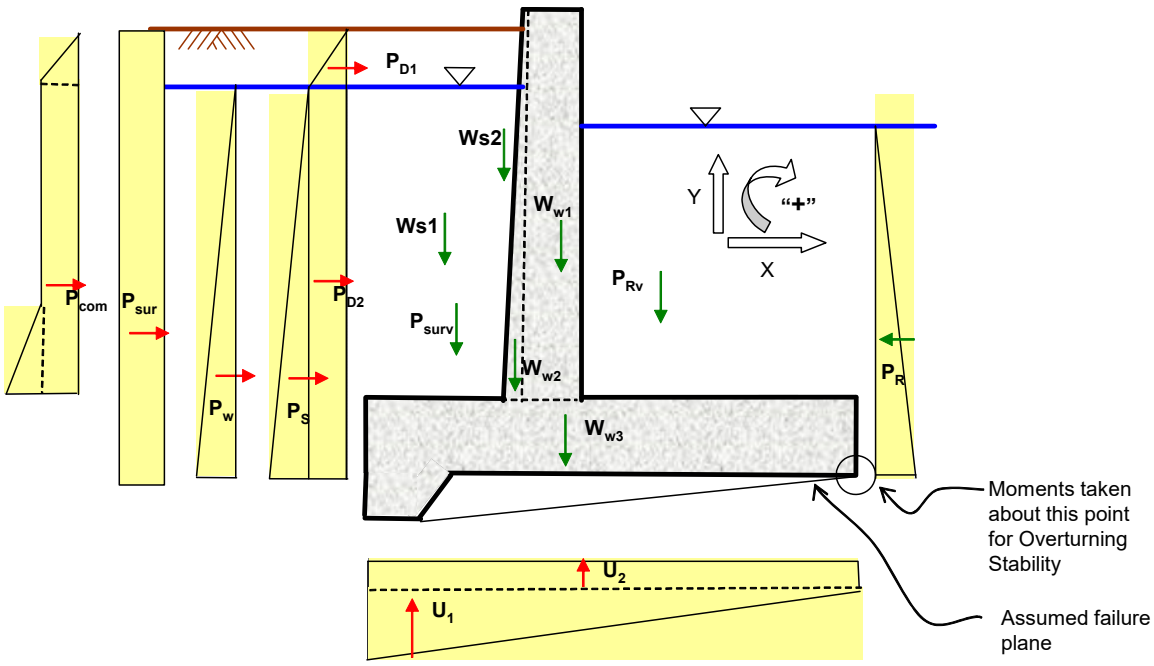
REFERENCES

1. IBC 2012 with reference on ASCE7-10
2. ACI 318-14, ACI 530-13 and UFC 3-301-01 with changes on May 15, 2014
3. AASHTO LRFD Bridge Design Specifications, 7th Edition, 2014 with 2016 Interim Revisions (referred to as LRFD)
4. EM 1110-2-2100: Stability Analysis of Concrete Structures
5. EM 1110-2-2502: Retaining and Flood Walls
6. EM 1110-2-2104: Strength Design for Reinforced Concrete Hydraulic Structures.
7. Engineering and Construction Bulletin (ECB) No. 2017-2: Revision and Clarification of EM 2100 and EM 2502



Notes:
$H_s = H_{wh}$
$H_{wh} = H_{wt}$

General Nomenclature



WALL DIMENSIONS

Wall height $H := 21ft$

Soil height $H_s := 20ft$

Water height (heel) $H_{wh} := H_s - 5ft$ (average water table based on soil report)

Water height (toe) $H_{wt} := 0ft$

Equipment Surcharge $S := 0plf$

Wall thickness at crest $t_c := 1ft$

Wall thickness at base $t := t_c + 2ft = 3\,ft$

Footing thickness $d := 3.0ft$

Heel length $L_h := 6ft$

Toe length $L_t := 8ft$

Key depth $K := 4 \cdot ft$

Key thickness $t_k := t$

Base Length $L_{base} := L_t + L_h + t = 17\,ft$

Compaction load $C_{load} := 0plf$

Wall Batter $Bat := \frac{t - t_c}{H} = 0.1$

Sliding factor of safety $FS_{sliding} := 1.5$

PROPERTIES AND COEFFICIENTS

Soil moist unit weight $\gamma_m := 130psf$

Soil saturated unit weight $\gamma_s := 130psf$

Concrete unit weight $\gamma_c := 150psf$ (for stability) $\gamma_{cb} := 150psf$ (for bearing stress)

Water unit weight $\gamma_w := 62.4psf$

Shear strength parameter (backfill) $\phi_1 := 32deg$

Cohesion (backfill) $c := 0psf$

Sliding parameter $\phi_s := 32deg$

Cohesion (Footing Soil Material) $c_s := 0psf$

Bearing Capacity $Q_{allowable} := 2000plf$ See Bearing Capacity Calculations

Horizontal Seismic Coefficients $k_h := 0.0$

Slope inclination Angle $\beta_a := 0deg$ $\beta_p := 0$ (passive)

At-rest coefficient $K_o := (1 - \sin(\phi_1)) \cdot (1 + \sin(\beta_a))$ $K_o = 0.47$

WALL FORCES FOR STABILITY

Wall section

$W_{w1} := -\gamma_c \cdot H \cdot t_c$ $\quad W_{w1} = -3150\ lbf$ $\quad W_{w2} := -\gamma_c \cdot H \cdot (t - t_c) \cdot \frac{1}{2}$ $\quad W_{w2} = -3150\ lbf$

$x_{w1} := L_t + \frac{t_c}{2}$ $\quad x_{w1} = 8.5\ ft$ $\quad x_{w2} := L_t + t_c + \frac{t - t_c}{3}$ $\quad x_{w2} = 9.7\ ft$

Footing section

$W_{w3} := -\gamma_c \cdot (L_{base}) \cdot d$ $\quad W_{w3} = -7650\ lbf$ $\quad x_{w3} := \frac{L_{base}}{2}$ $\quad x_{w3} = 8.5\ ft$

WALL FORCES FOR BEARING STRESS

Wall section

$W_{w1b} := -\gamma_{cb} \cdot H \cdot t_c$ $\quad W_{w1b} = -3150\ lbf$ $\quad W_{w2b} := -\gamma_{cb} \cdot H \cdot (t - t_c) \cdot \frac{1}{2}$ $\quad W_{w2b} = -3150\ lbf$

Footing section

$W_{w3b} := -\gamma_c \cdot (L_{base}) \cdot d$ $\quad W_{w3b} = -7650\ lbf$ $\quad x_{w3b} := \frac{L_{base}}{2}$ $\quad x_{w3b} = 8.5\ ft$

WATER FORCES

$L_{atw} := (t - t_c) - (H_s - H_{wh}) \cdot Bat$ $\quad L_{atw} = 1.5\ ft$

$W_{water1} := -\gamma_w \cdot H_{wh} \cdot L_h$ $\quad W_{water1} = -5616\ lbf$ $\quad x_{water1} := L_t + t + \frac{L_h}{2}$ $\quad x_{water1} = 14\ ft$

$W_{water2} := -\gamma_w \cdot H_{wh} \cdot L_{atw} \cdot \frac{1}{2}$ $\quad W_{water2} = -713.1\ lbf$ $\quad x_{water2} := L_t + t_c + (t - t_c) \cdot \frac{2}{3}$ $\quad x_{water2} = 10.3\ ft$

SOIL FORCES

Vertical Forces

$W_{s1} := -\gamma_s \cdot H_{wh} \cdot L_h + -\gamma_m \cdot (H_s - H_{wh}) \cdot L_h$ $\quad W_{s1} = -15600\ lbf$ $\quad x_{s1} := L_t + t + \frac{L_h}{2}$ $\quad x_{s1} = 14\ ft$

$W_{s2} := -\gamma_s \cdot H_{wh} \cdot L_{atw} \cdot \frac{1}{2} + -\gamma_m \cdot (H_s - H_{wh}) \cdot \left[(t - t_c) + L_{atw}\right] \cdot \frac{1}{2}$ $\quad x_{s2} := L_t + t_c + (t - t_c) \cdot \frac{2}{3}$ $\quad x_{s2} = 10.3\ ft$

$W_{s2} = -2630.952\ lbf$

$P_{surv} := -S \cdot L_h$ $\quad P_{surv} = 0$ $\quad x_{surv} := L_t + t + \frac{L_h}{2}$ $\quad x_{surv} = 14\ ft$

Horizontal Forces

Seismic Forces

Driving / Active Wedge

Computation of Critical Value of Slip-Plane Angle (α_a) by Trial and Error:

Assume $\alpha_a := 61deg$

$$d_c := \min\left[\frac{\dfrac{c}{\gamma_m\cdot\left(\frac{1}{ft}\right)}}{\cos(\alpha_a)\cdot\left(\sin(\alpha_a)-\tan(\phi_1)\cdot\cos(\alpha_a)\right)}, H_s + d\right] \qquad d_c = 0\cdot ft$$

$$A_a := \left(1+k_h\cdot\tan(\phi_1)\right)\cdot\tan(\phi_1) + \frac{2\cdot c\cdot\left(1-\tan(\phi_1)\cdot\tan(\beta_a)\right)}{\gamma_m\cdot\left(\frac{1}{ft}\right)\cdot\left(H_s+d_c\right)} \qquad A_a = 0.6$$

$$c_{1a} := \frac{2\cdot\tan(\phi_1)\cdot\left(\tan(\phi_1)-k_h\right) + \dfrac{4\cdot c\cdot\tan(\phi_1+\beta_a)}{\gamma_m\cdot\left(\frac{1}{ft}\right)\cdot\left(H_s+d_c\right)}}{A_a} \qquad c_{1a} = 1.2$$

$$c_{2a} := \frac{\tan(\phi_1)\cdot\left(1-\tan(\phi_1)\cdot\tan(\beta_a)\right) - \left(\tan(\beta_a)+k_h\right) + \dfrac{2\cdot c\cdot\left(1-\tan(\phi_1)\cdot\tan(\beta_a)\right)}{\gamma_m\cdot\left(\frac{1}{ft}\right)\cdot\left(H_s+d_c\right)}}{A_a} \qquad c_{2a} = 1$$

$$\alpha_{a_new} := \operatorname{atan}\left(\frac{c_{1a}+\sqrt{c_{1a}^2+4c_{2a}}}{2}\right) \qquad \alpha_{a_new} = 61\cdot deg$$

Active pressure for seismic (Moist condition)

$$K_{AO} := \left(\frac{1-\tan(\phi_1)\cdot\cot(\alpha_a)}{1+\tan(\phi_1)\cdot\tan(\alpha_a)}\right)\cdot\left(\frac{\tan(\alpha_a)}{\tan(\alpha_a)-\tan(\beta_a)}\right) = 0.307$$

For static case, at rest

$$K_A := \text{if}\left(k_h > .001, K_{AO}, K_o\right) \qquad K_A = 0.47$$

Active pressure for seismic (Saturated condition)

$$K_{BO} := \left(\frac{1-\tan(\phi_1)\cdot\cot(\alpha_a)}{1+\tan(\phi_1)\cdot\tan(\alpha_a)}\right)\cdot\left[1+\left(\frac{\tan(\alpha_a)}{\tan(\alpha_a)-\tan(\beta_a)}-1\right)\cdot\left(\frac{\gamma_m}{\gamma_s-\gamma_w}\right)\right] = 0.307$$

$$K_B := \text{if}\left(k_h > .001, K_{BO}, K_o\right) \qquad K_B = 0.47$$

<u>Dynamic Components</u>

$$\Delta P_{AE1} := k_h\cdot\left[\frac{\gamma_m\cdot\left[\left(H_s+d\right)^2-d_c^2\right]}{2\cdot\tan(\alpha_a)-\tan(\beta_a)}\right] \qquad \Delta P_{AE1} = 0 \qquad y_{\Delta PAE1} := \frac{2}{3}\cdot\left(H_s+d\right) \qquad y_{\Delta PAE1} = 15.3\,ft$$

$$\Delta P_{AE2} := k_h\cdot\left[\frac{\left(\gamma_s-\gamma_m\right)\cdot\left(H_{wh}+d\right)^2}{2\cdot\tan(\alpha_a)}\right] \qquad \Delta P_{AE2} = 0 \qquad y_{\Delta PAE2} := \frac{2}{3}\cdot\left(H_{wh}+d\right) \qquad y_{\Delta PAE2} = 12\,ft$$

$$y_{\Delta PAE} := \begin{cases} \dfrac{\Delta P_{AE1}\cdot y_{\Delta PAE1}+\Delta P_{AE2}\cdot y_{\Delta PAE2}}{\Delta P_{AE1}+\Delta P_{AE2}} & \text{if } \left(\Delta P_{AE}\right) > 0 \\ 0 & \text{otherwise} \end{cases} \qquad y_{\Delta PAE} = 0$$

Active Earth Pressure

Calculation of earth pressure based on location of crack (d_c) in relation to water table

$$\sigma_{A1} := K_A \cdot \gamma_m \cdot \left[\left(H_s + d\right) - d_c - \left(d + H_{wh}\right)\right] \qquad \sigma_{A1} = 305.6\,ft \cdot psf$$

$$P_{A1} := \begin{cases} \frac{1}{2} \cdot \sigma_{A1} \cdot \left[\left(H_s + d\right) - d_c - \left(d + H_{wh}\right)\right] & \text{if } d_c < \left(H_s - H_{wh}\right) \\ 0 & \text{otherwise} \end{cases} \qquad P_{A1} = 763.9 \cdot lbf$$

$$y_{PA1} := H_{wh} + d + \frac{\left(H_s + d\right) - d_c - \left(d + H_{wh}\right)}{3} \qquad y_{PA1} = 19.7\,ft$$

$$\sigma_{A2} := \begin{cases} K_A \cdot \gamma_m \cdot \left[\left(H_s + d\right) - d_c - \left(d + H_{wh}\right)\right] + K_B \cdot \left(\gamma_s - \gamma_w\right) \cdot \left(H_{wh} + d\right) & \text{if } d_c < \left(H_s - H_{wh}\right) \\ K_B \cdot \left(\gamma_s - \gamma_w\right) \cdot \left[\left(H_s + d\right) - d_c\right] & \text{otherwise} \end{cases} \qquad \sigma_{A2} = 877.5\,ft \cdot psf$$

$$P_{A2} := \begin{cases} \sigma_{A1} \cdot \left(H_{wh} + d\right) & \text{if } d_c < \left[\left(H_s\right) - H_{wh}\right] \\ \frac{1}{2} \cdot \sigma_{A2} \cdot \left[\left(H_s + d\right) - d_c\right] & \text{otherwise} \end{cases} \qquad P_{A2} = 5499.9 \cdot lbf$$

$$y_{PA2} := \begin{cases} \frac{H_{wh} + d}{2} & \text{if } d_c < \left[\left(H_s\right) - H_{wh}\right] \\ \frac{\left(H_s + d\right) - d_c}{3} & \text{otherwise} \end{cases} \qquad y_{PA2} = 9\,ft$$

$$P_{A3} := \begin{cases} \frac{1}{2} \cdot \left(\sigma_{A2} - \sigma_{A1}\right) \cdot \left(H_{wh} + d\right) & \text{if } d_c < \left(H_s - H_{wh}\right) \\ 0 & \text{otherwise} \end{cases} \qquad P_{A3} = 5147.9 \cdot lbf$$

$$y_{PA3} := \frac{H_{wh} + d}{3} \qquad y_{PA3} = 6\,ft$$

Resisting / Passive Wedge (From Footing Key)

$$A_p := \left(1 + k_h \cdot \tan\left(\phi_s\right)\right) \cdot \tan\left(\phi_s\right) + \frac{2 \cdot c_s \cdot \left(1 + \tan\left(\phi_s\right) \cdot \tan\left(\beta_p\right)\right)}{\gamma_m \cdot \left(\frac{1}{ft}\right) \cdot (K)} \qquad A_p = 0.6$$

$$c_{1p} := \frac{2 \cdot \tan\left(\phi_s\right) \cdot \left(\tan\left(\phi_s\right) - k_h\right) + \frac{4 \cdot c_s \cdot \left(\tan\left(\phi_s\right) - \tan\left(\beta_p\right)\right)}{\gamma_m \cdot \left(\frac{1}{ft}\right) \cdot (K)}}{A_p} \qquad c_{1p} = 1.2$$

$$c_{2p} := \frac{\tan\left(\phi_s\right) \cdot \left(1 + \tan\left(\phi_s\right) \cdot \tan\left(\beta_p\right)\right) + \left(\tan\left(\beta_p\right) - k_h\right) + \frac{2 \cdot c_s \cdot \left(1 + \tan\left(\phi_s\right) \cdot \tan\left(\beta_p\right)\right)}{\gamma_m \cdot \left(\frac{1}{ft}\right) \cdot (K)}}{A_p} \qquad c_{2p} = 1$$

$$\alpha_p := \operatorname{atan}\left(\frac{-c_{1p} + \sqrt{c_{1p}^2 + 4c_{2p}}}{2}\right) \qquad \alpha_p = 29 \cdot deg$$

Passive pressure coefficient for seismic (Moist condition)

$$K_{PO} := \left(\frac{1 + \tan(\phi_s)\cdot\cot(\alpha_p)}{1 - \tan(\phi_s)\cdot\tan(\alpha_p)}\right)\cdot\left(\frac{\tan(\alpha_p)}{\tan(\alpha_p) - \tan(\beta_p)}\right) \qquad K_{PO} = 3.3$$

$$K_P := \text{if}(k_h > .001, K_{PO}, K_{PO}) \qquad K_P = 3.3$$

Passive pressure for seismic (Saturated condition)

$$K_{PBO} := \left(\frac{1 + \tan(\phi_s)\cdot\cot(\alpha_p)}{1 - \tan(\phi_s)\cdot\tan(\alpha_p)}\right)\cdot\left[1 + \left(\frac{\tan(\alpha_p)}{\tan(\alpha_p) - \tan(\beta_p)} - 1\right)\cdot\left(\frac{\gamma_m}{\gamma_s - \gamma_w}\right)\right]$$

$$K_{PBO} = 3.3$$

$$K_{PB} := \text{if}(k_h > .001, K_{PBO}, K_{PBO}) \qquad K_{PB} = 3.3$$

Dynamic Component

$$\Delta P_{PE2} := k_h\cdot\left[\frac{(\gamma_s - \gamma_m)\cdot K^2}{2\cdot\tan(\alpha_p)}\right] \qquad \Delta P_{PE2} = 0 \qquad y_{\Delta PPE2} := -\frac{1}{3}\cdot(K) \qquad y_{\Delta PPE2} = -1.3\,ft$$

Passive Earth Pressure

$$K_c := \frac{1}{2\sin(\alpha_p)\cos(\alpha_p)(1 - \tan(\phi_s)\cos(\alpha_p))}\cdot\frac{\tan(\alpha_p)}{\tan(\alpha_p) - \tan(\beta_p)} \qquad K_c = 2.6$$

$$P_{P1} := -(2\cdot K_c\cdot c_s\cdot K)\cdot ft \qquad P_{P1} = 0 \qquad y_{PP1} := -\frac{1}{2}K \qquad y_{PP1} = -2\,ft$$

$$P_{P2} := -\left[\left(\frac{1}{2}\right)\cdot K_{PB}\cdot(\gamma_s - \gamma_w)\cdot K^2\right] \qquad P_{P2} = -1760.1\,lbf \qquad y_{PP2} := -\frac{2}{3}K \qquad y_{PP2} = -2.7\,ft$$

Concrete Inertia

$$W_{w1_e} := -k_h\cdot W_{w1b} \qquad y_{w1_e} := \frac{H}{2} + d$$

$$W_{w1_e} = 0 \qquad y_{w1_e} = 13.5\,ft$$

$$W_{w2_e} := -k_h\cdot W_{w2b} \qquad y_{w2_e} := \frac{H}{3} + d$$

$$W_{w2_e} = 0 \qquad y_{w2_e} = 10\,ft$$

$$W_{w3_e} := -k_h\cdot W_{w3b} \qquad y_{w3_e} := \frac{d}{2}$$

$$W_{w3_e} = 0 \qquad y_{w3_e} = 1.5\,ft$$

Surcharge Pressure

$$P_{sur} := \begin{cases} K_B\cdot S\cdot[(H_s + d) - d_c] & \text{if } d_c > (H_s - H_{wh}) \\ K_A\cdot S\cdot(H_s - H_{wh} - d_c) + K_B\cdot S\cdot(H_{wh} + d) & \text{otherwise} \end{cases} \qquad P_{sur} = 0$$

$$y_{sur} := \begin{cases} \dfrac{(H_s + d) - d_c}{2} & \text{if } d_c > H_s - H_{wh} \\ \dfrac{K_A \cdot S \cdot (H_s - H_{wh} - d_c) \cdot \left[(H_{wh} + d) + \dfrac{H_s - H_{wh} - d_c}{2}\right] + K_B \cdot S \cdot (H_{wh} + d) \cdot \dfrac{H_{wh} + d}{2}}{K_A \cdot S \cdot (H_s - H_{wh} - d_c) + K_B \cdot S \cdot (H_{wh} + d)} & \text{if } S > 0 \\ 0 & \text{otherwise} \end{cases} \qquad y_{sur} = 0\,ft$$

Water Pressure

$$P_w := \frac{1}{2} \cdot \gamma_w \cdot (H_{wh} + d)^2 \qquad P_w = 10108.8\,lbf \qquad y_w := \frac{H_{wh} + d}{3} \qquad y_w = 6\,ft$$

Water Pressure considering depth of crack

$$P_{wdc} := \begin{cases} \dfrac{1}{2} \cdot \gamma_w \cdot d_c^{\,2} & \text{if } d_c < (H_s - H_{wh}) \\ \dfrac{1}{2} \cdot \gamma_w \cdot (H_s - H_{wh})^2 & \text{otherwise} \end{cases} \qquad P_{wdc} = 0\,lbf$$

$$y_{wdc} := \begin{cases} (H_s + d) - \dfrac{2 \cdot d_c}{3} & \text{if } d_c < (H_s - H_{wh}) \\ (H_s + d) - \dfrac{2 \cdot \left[(H_s + d) - H_{wh}\right]}{3} & \text{otherwise} \end{cases} \qquad y_{wdc} = 23\,ft$$

Uplift Forces

Uplift at heel $\quad U_h := \text{if}(H_{wh} > 0.1\,ft, H_{wh} + d, 0) \qquad U_h = 18\,ft$

Uplift at toe $\quad U_t := \text{if}(H_{wt} > 0.1\,ft, H_{wt} + d, 0) \qquad U_t = 0\,ft$

$$U_1 := \gamma_w \cdot \frac{1}{2} \cdot (U_h - U_t) \cdot (L_{base}) \qquad U_1 = 9547.2\,lbf \qquad x_{U1} := \frac{1}{3} \cdot (L_{base}) \qquad x_{U1} = 5.7\,ft$$

$$U_2 := \gamma_w \cdot U_t \cdot (L_{base}) \qquad U_2 = 0\,lbf \qquad x_{U2} := \frac{1}{2} \cdot (L_{base}) \qquad x_{U2} = 8.5\,ft$$

Reservoir Forces

Horizontal Forces

$$P_R := \frac{-1}{2} \cdot \gamma_w \cdot (H_{wt} + d)^2 \qquad P_R = -280.8\,lbf \qquad y_R := \frac{1}{3}(H_{wt} + d) \qquad y_R = 1\,ft$$

Vertical Forces

$$P_{Rv} := -\gamma_w \cdot L_t \cdot H_{wt} \qquad P_{Rv} = 0 \qquad x_{Rv} := \frac{L_t}{2} \qquad x_{Rv} = 4\,ft$$

Wave Forces

$$P_{wave} := 0\,lbf \qquad y_{wave} := 0\,ft$$

Check Stability

Moments about toe

Resisting Moment

$$M_r := W_{w1}\cdot x_{w1} + W_{w2}\cdot x_{w2} + W_{w3}\cdot x_{w3} + P_R\cdot y_R + P_{Rv}\cdot x_{Rv} + P_{wave}\cdot y_{wave} + W_{s1}\cdot x_{s1} + W_{s2}\cdot x_{s2} + W_{water1}\cdot x_{water1} \cdots + W_{water2}\cdot x_{water2} + P_{surv}\cdot x_{surv} + \Delta P_{PE2}\cdot y_{\Delta PPE2}$$

$M_r = -454.1\cdot kip\cdot ft$

Overturning Moment

$$M_o := P_{A1}\cdot y_{PA1} + P_{A2}\cdot y_{PA2} + P_{A3}\cdot y_{PA3} + \Delta P_{AE}\cdot y_{\Delta PAE} + W_{w1_e}\cdot y_{w1_e} + W_{w2_e}\cdot y_{w2_e} + W_{w3_e}\cdot y_{w3_e} \cdots + P_{sur}\cdot y_{sur} + P_w\cdot y_w + P_{wdc}\cdot y_{wdc} + U_1\cdot x_{U1} + U_2\cdot x_{U2} + P_{P1}\cdot y_{PP1} + P_{P2}\cdot y_{PP2}$$

$M_o = 214.9\cdot kip\cdot ft$

ΣF_y Vertical Force

$$F_y := W_{w1} + W_{w2} + W_{w3} + W_{s1} + W_{s2} + W_{water1} + W_{water2} + U_1 + U_2 + P_{Rv} + P_{surv}$$

$F_y = -29\cdot kip$

ΣF_x Horizontal Force

$$F_x := P_{A1} + P_{A2} + P_{A3} + \Delta P_{AE} + P_w + W_{w1_e} + W_{w2_e} + W_{w3_e} + P_{sur} + P_{wdc} + P_R + P_{wave} + P_{P1} + P_{P2} + \Delta P_{PE2}$$

$F_x = 19.5\cdot kip$

Location of Resultant

$$Resultant := \frac{M_r + M_o}{F_y}$$ $Resultant = 8.26\,ft$

$$Eccentricity := \frac{L_{base}}{2} - Resultant$$ $Eccentricity = 0.24\,ft$

$$Middle_Third := \frac{L_{base}}{6}$$ $Middle_Third = 2.8\,ft$

$$Check_R := if(Middle_Third > |Eccentricity|, "OK", "NOT_GOOD")$$

Check compression at Base

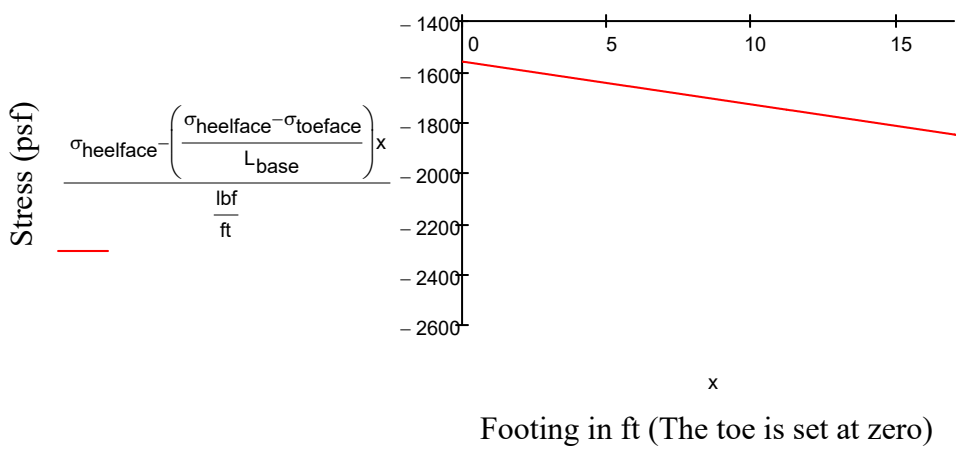
$Check_R = "OK"$

Pressure distribution Under the Footing (Negative is compression)

$$\sigma_{toeface} := \frac{F_y}{L_{base}}\cdot\left(1 + \frac{6\cdot Eccentricity}{L_{base}}\right)$$ *The stress at the toe* $\sigma_{toeface} = -1848\cdot\frac{lbf}{ft}$

$$\sigma_{heelface} := \frac{F_y}{L_{base}}\cdot\left(1 - \frac{6\cdot Eccentricity}{L_{base}}\right)$$ *The stress at the heel* $\sigma_{heelface} = -1560\cdot\frac{lbf}{ft}$

Stress Distribution:



Footing in ft (The toe is set at zero)

Sliding Factor of Safety:

$\theta := \operatorname{atan}\left(\frac{K}{L_{base}}\right)$ $\theta = 13.2 \cdot deg$

$F_{xn} := F_x \cdot \sin(\theta)$ $F_{xn} = 4.5 \cdot kip$

$F_{xs} := F_x \cdot \cos(\theta)$ $F_{xs} = 19 \cdot kip$

$F_{ys} := F_y \cdot \sin(\theta)$ $F_{ys} = -6.6 \cdot kip$

$F_{yn} := -F_y \cdot \cos(\theta)$ $F_{yn} = 28.2 \cdot kip$

$$FS_s := \left| \frac{\tan(\phi_s) \cdot (F_{xn} + F_{yn}) + c_s \cdot L_{base} \cdot (1ft)}{F_{xs} + F_{ys}} \right|$$ $FS_s = 1.66$

$Check_{FS} := if(FS_s > FS_{sliding}, "OK", "NOT_GOOD")$

Check Sliding

$Check_{FS} = "OK"$

Check Bearing Stress

Moments about toe

Resisting Moment

$$M_{rb} := W_{w1b} \cdot x_{w1} + W_{w2b} \cdot x_{w2} + W_{w3b} \cdot x_{w3} + P_R \cdot y_R + P_{Rv} \cdot x_{Rv} + P_{wave} \cdot y_{wave} + W_{s1} \cdot x_{s1} + W_{s2} \cdot x_{s2} + W_{water1} \cdot x_{water1} \cdots + W_{water2} \cdot x_{water2} + P_{surv} \cdot x_{surv} + \Delta P_{PE2} \cdot y_{\Delta PPE2}$$

$M_{rb} = -454.1 \cdot kip \cdot ft$

SF_y Vertical Force

$F_{yb} := W_{w1b} + W_{w2b} + W_{w3b} + W_{s1} + W_{s2} + W_{water1} + W_{water2} + U_1 + U_2 + P_{Rv} + P_{surv}$ $F_{yb} = -29 \cdot kip$

Location of Resultant

$$Eccentricity_b := \frac{L_{base}}{2} - \frac{M_{rb} + M_o}{F_{yb}}$$ $Eccentricity_b = 0.24\,ft$

Stress distribution Under the Footing (Negative is compression)

$$\sigma_{toeface.b} := \frac{F_{yb}}{L_{base}} \cdot \left(1 + \frac{6 \cdot Eccentricity_b}{L_{base}}\right)$$ *The stress at the toe* $\sigma_{toeface.b} = -1848 \cdot \frac{lbf}{ft}$

$$\sigma_{heelface.b} := \frac{F_{yb}}{L_{base}} \cdot \left(1 - \frac{6 \cdot Eccentricity_b}{L_{base}}\right)$$ *The stress at the heel* $\sigma_{heelface.b} = -1560 \cdot \frac{lbf}{ft}$

Bearing Factor of Safety

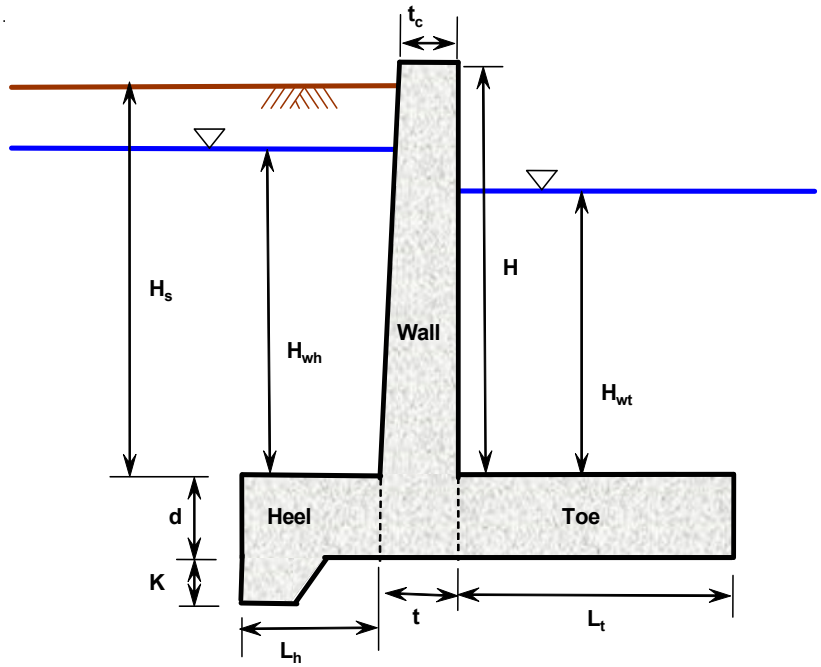
$Check_B := if(Q_{allowable} > \max(|\sigma_{toeface.b}|, |\sigma_{heelface.b}|), "OK", "NO_GOOD")$

Check bearing stress

$Check_B = "OK"$

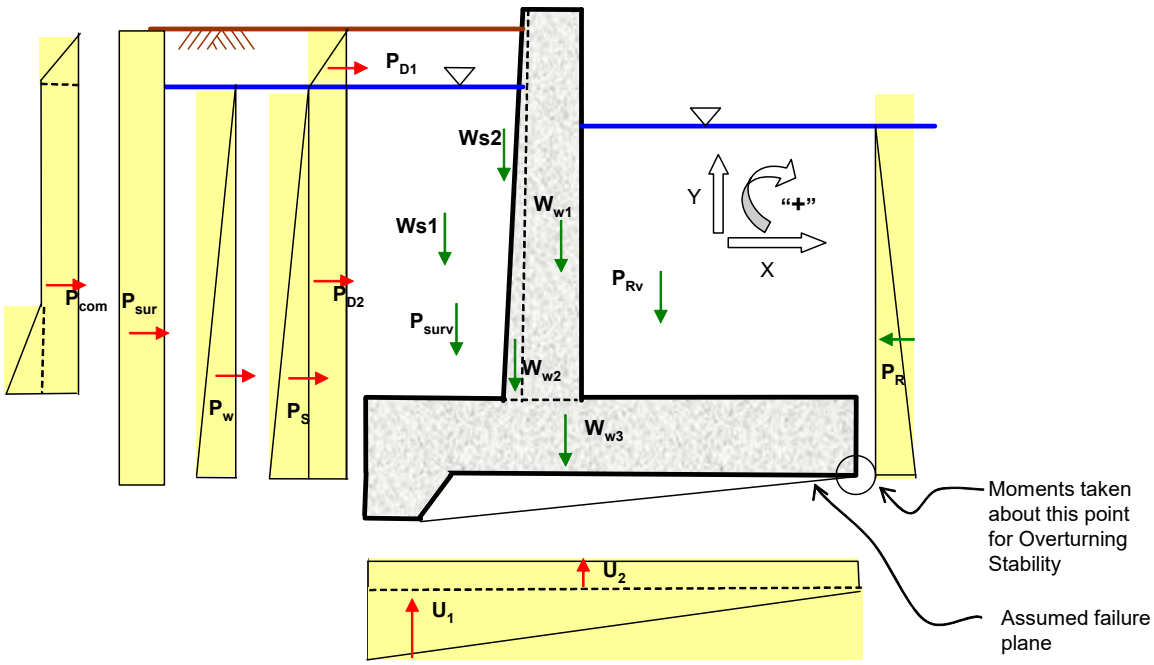
REFERENCES

1. IBC 2012 with reference on ASCE7-10
2. ACI 318-14, ACI 530-13 and UFC 3-301-01 with changes on May 15, 2014
3. AASHTO LRFD Bridge Design Specifications, 7th Edition, 2014 with 2016 Interim Revisions (referred to as LRFD)
4. EM 1110-2-2100: Stability Analysis of Concrete Structures
5. EM 1110-2-2502: Retaining and Flood Walls
6. EM 1110-2-2104: Strength Design for Reinforced Concrete Hydraulic Structures.
7. Engineering and Construction Bulletin (ECB) No. 2017-2: Revision and Clarification of EM 2100 and EM 2502



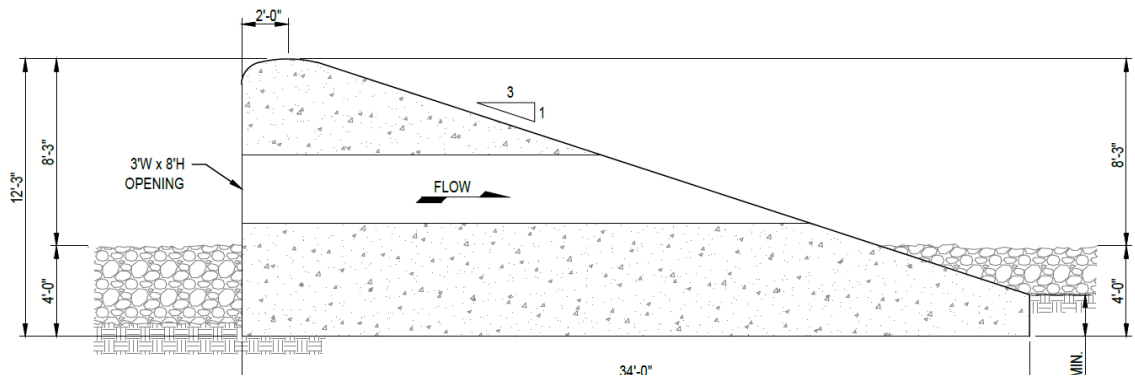
Notes:
$H_s = H_{wh}$
$H_{wh} = H_{wt}$

General Nomenclature



WALL DIMENSIONS

Wall height	$H := 10.25ft$	Footing thickness	$d := 2ft$
Soil height	$H_s := 2ft$	Heel length	$L_h := .0001ft$
Water height (heel)	$H_{wh} := 15ft$	Toe length	$L_t := .0001ft$
Water height (toe)	$H_{wt} := 0ft$	Key depth	$K := 0.001 \cdot ft$
Equipment Surcharge	$S := 0plf$	Key thickness	$t_k := 0 \cdot ft$
Wall thickness at crest	$t_c := 2ft$	Compaction load	$C_{load} := 0plf$
Wall thickness at base	$t := 34ft$	Sliding factor of safety	$FS_{sliding} := 1.5$
Base Length	$L_{base} := L_t + L_h + t = 34\,ft$	Wall Batter	$Bat := \frac{t - t_c}{H} = 3.12$



PROPERTIES AND COEFFICIENTS

Soil moist unit weight	$\gamma_m := 130psf$			
Soil saturated unit weight	$\gamma_s := 130psf$			
Concrete unit weight	$\gamma_c := 150psf$	(for stability)	$\gamma_{cb} := 150psf$	(for bearing stress)
Water unit weight	$\gamma_w := 62.4psf$			
Shear strength parameter (backfill)	$\phi_1 := 32deg$			
Cohesion (backfill)	$c := 0psf$			
Sliding parameter	$\phi_s := 32deg$			
Cohesion (Footing Soil Material)	$c_s := 0psf$			
Bearing Capacity	$Q_{allowable} := 2000plf$	See Bearing Capacity Calculations		
Horizontal Seismic Coefficients	$k_h := 0.0$			
Slope inclination Angle	$\beta_a := 0deg$	$\beta_p := 0$	(passive)	
At-rest coefficient	$K_o := (1 - \sin(\phi_1)) \cdot (1 + \sin(\beta_a))$	$K_o = 0.47$		

WALL FORCES FOR STABILITY

Wall section

$W_{w1} := -\gamma_c \cdot H \cdot t_c$ $\quad W_{w1} = -3075\,lbf$ $\quad W_{w2} := -\gamma_c \cdot H \cdot (t - t_c) \cdot \frac{1}{2}$ $\quad W_{w2} = -24600\,lbf$

$x_{w1} := L_t + \frac{t_c}{2}$ $\quad x_{w1} = 1\,ft$ $\quad x_{w2} := L_t + t_c + \frac{t - t_c}{3}$ $\quad x_{w2} = 12.7\,ft$

Footing section

$W_{w3} := -\gamma_c \cdot (L_{base}) \cdot d$ $\quad W_{w3} = -10200.1\,lbf$ $\quad x_{w3} := \frac{L_{base}}{2}$ $\quad x_{w3} = 17\,ft$

WALL FORCES FOR BEARING STRESS

Wall section

$W_{w1b} := -\gamma_{cb} \cdot H \cdot t_c$ $\quad W_{w1b} = -3075\,lbf$ $\quad W_{w2b} := -\gamma_{cb} \cdot H \cdot (t - t_c) \cdot \frac{1}{2}$ $\quad W_{w2b} = -24600\,lbf$

Footing section

$W_{w3b} := -\gamma_c \cdot (L_{base}) \cdot d$ $\quad W_{w3b} = -10200.1\,lbf$ $\quad x_{w3b} := \frac{L_{base}}{2}$ $\quad x_{w3b} = 17\,ft$

WATER FORCES

$L_{atw} := (t - t_c) - (H_s - H_{wh}) \cdot Bat$ $\quad L_{atw} = 72.6\,ft$

$W_{water1} := -\gamma_w \cdot H_{wh} \cdot L_h$ $\quad W_{water1} = -0.094\,lbf$ $\quad x_{water1} := L_t + t + \frac{L_h}{2}$ $\quad x_{water1} = 34\,ft$

$W_{water2} := -\gamma_w \cdot H_{wh} \cdot L_{atw} \cdot \frac{1}{2}$ $\quad W_{water2} = -33970\,lbf$ $\quad x_{water2} := L_t + t_c + (t - t_c) \cdot \frac{2}{3}$ $\quad x_{water2} = 23.3\,ft$

SOIL FORCES

Vertical Forces

$W_{s1} := -\gamma_s \cdot H_{wh} \cdot L_h + -\gamma_m \cdot (H_s - H_{wh}) \cdot L_h$ $\quad W_{s1} = -0.026\,lbf$ $\quad x_{s1} := L_t + t + \frac{L_h}{2}$ $\quad x_{s1} = 34\,ft$

$W_{s2} := -\gamma_s \cdot H_{wh} \cdot L_{atw} \cdot \frac{1}{2} + -\gamma_m \cdot (H_s - H_{wh}) \cdot \left[(t - t_c) + L_{atw}\right] \cdot \frac{1}{2}$ $\quad x_{s2} := L_t + t_c + (t - t_c) \cdot \frac{2}{3}$ $\quad x_{s2} = 23.3\,ft$

$W_{s2} = 17603.902\,lbf$

$P_{surv} := -S \cdot L_h$ $\quad P_{surv} = 0$ $\quad x_{surv} := L_t + t + \frac{L_h}{2}$ $\quad x_{surv} = 34\,ft$

Horizontal Forces

Seismic Forces

Driving / Active Wedge

Computation of Critical Value of Slip-Plane Angle (α_a) by Trial and Error:

Assume $\alpha_a := 61deg$

$$d_c := \min\left[\frac{\dfrac{c}{\gamma_m\cdot\left(\frac{1}{ft}\right)}}{\cos(\alpha_a)\cdot\left(\sin(\alpha_a)-\tan(\phi_1)\cdot\cos(\alpha_a)\right)}, H_s + d\right] \qquad d_c = 0\cdot ft$$

$$A_a := \left(1+k_h\cdot\tan(\phi_1)\right)\cdot\tan(\phi_1) + \frac{2\cdot c\cdot\left(1-\tan(\phi_1)\cdot\tan(\beta_a)\right)}{\gamma_m\cdot\left(\frac{1}{ft}\right)\cdot\left(H_s+d_c\right)} \qquad A_a = 0.6$$

$$c_{1a} := \frac{2\cdot\tan(\phi_1)\cdot\left(\tan(\phi_1)-k_h\right) + \dfrac{4\cdot c\cdot\tan(\phi_1+\beta_a)}{\gamma_m\cdot\left(\frac{1}{ft}\right)\cdot\left(H_s+d_c\right)}}{A_a} \qquad c_{1a} = 1.2$$

$$c_{2a} := \frac{\tan(\phi_1)\cdot\left(1-\tan(\phi_1)\cdot\tan(\beta_a)\right) - \left(\tan(\beta_a)+k_h\right) + \dfrac{2\cdot c\cdot\left(1-\tan(\phi_1)\cdot\tan(\beta_a)\right)}{\gamma_m\cdot\left(\frac{1}{ft}\right)\cdot\left(H_s+d_c\right)}}{A_a} \qquad c_{2a} = 1$$

$$\alpha_{a_new} := \operatorname{atan}\left(\frac{c_{1a}+\sqrt{c_{1a}^2+4c_{2a}}}{2}\right) \qquad \alpha_{a_new} = 61\cdot deg$$

Active pressure for seismic (Moist condition)

$$K_{AO} := \left(\frac{1-\tan(\phi_1)\cdot\cot(\alpha_a)}{1+\tan(\phi_1)\cdot\tan(\alpha_a)}\right)\cdot\left(\frac{\tan(\alpha_a)}{\tan(\alpha_a)-\tan(\beta_a)}\right) = 0.307$$

For static case, at rest

$$K_A := \text{if}\left(k_h > .001, K_{AO}, K_o\right) \qquad K_A = 0.47$$

Active pressure for seismic (Saturated condition)

$$K_{BO} := \left(\frac{1-\tan(\phi_1)\cdot\cot(\alpha_a)}{1+\tan(\phi_1)\cdot\tan(\alpha_a)}\right)\cdot\left[1+\left(\frac{\tan(\alpha_a)}{\tan(\alpha_a)-\tan(\beta_a)}-1\right)\cdot\left(\frac{\gamma_m}{\gamma_s-\gamma_w}\right)\right] = 0.307$$

$$K_B := \text{if}\left(k_h > .001, K_{BO}, K_o\right) \qquad K_B = 0.47$$

<u>Dynamic Components</u>

$$\Delta P_{AE1} := k_h\cdot\left[\frac{\gamma_m\cdot\left[\left(H_s+d\right)^2-d_c^2\right]}{2\cdot\tan(\alpha_a)-\tan(\beta_a)}\right] \qquad \Delta P_{AE1} = 0 \qquad y_{\Delta PAE1} := \frac{2}{3}\cdot\left(H_s+d\right) \qquad y_{\Delta PAE1} = 2.7\,ft$$

$$\Delta P_{AE2} := k_h\cdot\left[\frac{\left(\gamma_s-\gamma_m\right)\cdot\left(H_{wh}+d\right)^2}{2\cdot\tan(\alpha_a)}\right] \qquad \Delta P_{AE2} = 0 \qquad y_{\Delta PAE2} := \frac{2}{3}\cdot\left(H_{wh}+d\right) \qquad y_{\Delta PAE2} = 11.3\,ft$$

$$y_{\Delta PAE} := \begin{cases} \dfrac{\Delta P_{AE1}\cdot y_{\Delta PAE1}+\Delta P_{AE2}\cdot y_{\Delta PAE2}}{\Delta P_{AE1}+\Delta P_{AE2}} & \text{if } \left(\Delta P_{AE}\right) > 0 \\ 0 & \text{otherwise} \end{cases} \qquad y_{\Delta PAE} = 0$$

Active Earth Pressure

Calculation of earth pressure based on location of crack (d_c) in relation to water table

$$\sigma_{A1} := K_A \cdot \gamma_m \cdot \left[\left(H_s + d\right) - d_c - \left(d + H_{wh}\right)\right] \qquad \sigma_{A1} = -794.4\,ft \cdot psf$$

$$P_{A1} := \begin{cases} \frac{1}{2} \cdot \sigma_{A1} \cdot \left[\left(H_s + d\right) - d_c - \left(d + H_{wh}\right)\right] & \text{if } d_c < \left(H_s - H_{wh}\right) \\ 0 & \text{otherwise} \end{cases} \qquad P_{A1} = 0 \cdot lbf$$

$$y_{PA1} := H_{wh} + d + \frac{\left(H_s + d\right) - d_c - \left(d + H_{wh}\right)}{3} \qquad y_{PA1} = 12.7\,ft$$

$$\sigma_{A2} := \begin{cases} K_A \cdot \gamma_m \cdot \left[\left(H_s + d\right) - d_c - \left(d + H_{wh}\right)\right] + K_B \cdot \left(\gamma_s - \gamma_w\right) \cdot \left(H_{wh} + d\right) & \text{if } d_c < \left(H_s - H_{wh}\right) \\ K_B \cdot \left(\gamma_s - \gamma_w\right) \cdot \left[\left(H_s + d\right) - d_c\right] & \text{otherwise} \end{cases} \qquad \sigma_{A2} = 127.1\,ft \cdot psf$$

$$P_{A2} := \begin{cases} \sigma_{A1} \cdot \left(H_{wh} + d\right) & \text{if } d_c < \left[\left(H_s\right) - H_{wh}\right] \\ \frac{1}{2} \cdot \sigma_{A2} \cdot \left[\left(H_s + d\right) - d_c\right] & \text{otherwise} \end{cases} \qquad P_{A2} = 254.2 \cdot lbf$$

$$y_{PA2} := \begin{cases} \frac{H_{wh} + d}{2} & \text{if } d_c < \left[\left(H_s\right) - H_{wh}\right] \\ \frac{\left(H_s + d\right) - d_c}{3} & \text{otherwise} \end{cases} \qquad y_{PA2} = 1.3\,ft$$

$$P_{A3} := \begin{cases} \frac{1}{2} \cdot \left(\sigma_{A2} - \sigma_{A1}\right) \cdot \left(H_{wh} + d\right) & \text{if } d_c < \left(H_s - H_{wh}\right) \\ 0 & \text{otherwise} \end{cases} \qquad P_{A3} = 0 \cdot lbf$$

$$y_{PA3} := \frac{H_{wh} + d}{3} \qquad y_{PA3} = 5.7\,ft$$

Resisting / Passive Wedge (From Footing Key)

$$A_p := \left(1 + k_h \cdot \tan\left(\phi_s\right)\right) \cdot \tan\left(\phi_s\right) + \frac{2 \cdot c_s \cdot \left(1 + \tan\left(\phi_s\right) \cdot \tan\left(\beta_p\right)\right)}{\gamma_m \cdot \left(\frac{1}{ft}\right) \cdot (K)} \qquad A_p = 0.6$$

$$c_{1p} := \frac{2 \cdot \tan\left(\phi_s\right) \cdot \left(\tan\left(\phi_s\right) - k_h\right) + \frac{4 \cdot c_s \cdot \left(\tan\left(\phi_s\right) - \tan\left(\beta_p\right)\right)}{\gamma_m \cdot \left(\frac{1}{ft}\right) \cdot (K)}}{A_p} \qquad c_{1p} = 1.2$$

$$c_{2p} := \frac{\tan\left(\phi_s\right) \cdot \left(1 + \tan\left(\phi_s\right) \cdot \tan\left(\beta_p\right)\right) + \left(\tan\left(\beta_p\right) - k_h\right) + \frac{2 \cdot c_s \cdot \left(1 + \tan\left(\phi_s\right) \cdot \tan\left(\beta_p\right)\right)}{\gamma_m \cdot \left(\frac{1}{ft}\right) \cdot (K)}}{A_p} \qquad c_{2p} = 1$$

$$\alpha_p := \operatorname{atan}\left(\frac{-c_{1p} + \sqrt{c_{1p}^2 + 4c_{2p}}}{2}\right) \qquad \alpha_p = 29 \cdot deg$$

Passive pressure coefficient for seismic (Moist condition)

$$K_{PO} := \left(\frac{1 + \tan(\phi_s)\cdot\cot(\alpha_p)}{1 - \tan(\phi_s)\cdot\tan(\alpha_p)}\right)\cdot\left(\frac{\tan(\alpha_p)}{\tan(\alpha_p) - \tan(\beta_p)}\right) \qquad K_{PO} = 3.3$$

$$K_P := \text{if}(k_h > .001, K_{PO}, K_{PO}) \qquad K_P = 3.3$$

Passive pressure for seismic (Saturated condition)

$$K_{PBO} := \left(\frac{1 + \tan(\phi_s)\cdot\cot(\alpha_p)}{1 - \tan(\phi_s)\cdot\tan(\alpha_p)}\right)\cdot\left[1 + \left(\frac{\tan(\alpha_p)}{\tan(\alpha_p) - \tan(\beta_p)} - 1\right)\cdot\left(\frac{\gamma_m}{\gamma_s - \gamma_w}\right)\right]$$

$$K_{PBO} = 3.3$$

$$K_{PB} := \text{if}(k_h > .001, K_{PBO}, K_{PBO}) \qquad K_{PB} = 3.3$$

Dynamic Component

$$\Delta P_{PE2} := k_h\cdot\left[\frac{(\gamma_s - \gamma_m)\cdot K^2}{2\cdot\tan(\alpha_p)}\right] \qquad \Delta P_{PE2} = 0 \qquad y_{\Delta PPE2} := -\frac{1}{3}\cdot(K) \qquad y_{\Delta PPE2} = -0\,ft$$

Passive Earth Pressure

$$K_c := \frac{1}{2\sin(\alpha_p)\cos(\alpha_p)(1 - \tan(\phi_s)\cos(\alpha_p))}\cdot\frac{\tan(\alpha_p)}{\tan(\alpha_p) - \tan(\beta_p)} \qquad K_c = 2.6$$

$$P_{P1} := -(2\cdot K_c\cdot c_s\cdot K)\cdot ft \qquad P_{P1} = 0 \qquad y_{PP1} := -\frac{1}{2}K \qquad y_{PP1} = -0\,ft$$

$$P_{P2} := -\left[\left(\frac{1}{2}\right)\cdot K_{PB}\cdot(\gamma_s - \gamma_w)\cdot K^2\right] \qquad P_{P2} = -0\,lbf \qquad y_{PP2} := -\frac{2}{3}K \qquad y_{PP2} = -0\,ft$$

Concrete Inertia

$$W_{w1_e} := -k_h\cdot W_{w1b} \qquad y_{w1_e} := \frac{H}{2} + d$$

$$W_{w1_e} = 0 \qquad y_{w1_e} = 7.1\,ft$$

$$W_{w2_e} := -k_h\cdot W_{w2b} \qquad y_{w2_e} := \frac{H}{3} + d$$

$$W_{w2_e} = 0 \qquad y_{w2_e} = 5.4\,ft$$

$$W_{w3_e} := -k_h\cdot W_{w3b} \qquad y_{w3_e} := \frac{d}{2}$$

$$W_{w3_e} = 0 \qquad y_{w3_e} = 1\,ft$$

Surcharge Pressure

$$P_{sur} := \begin{cases} K_B\cdot S\cdot[(H_s + d) - d_c] & \text{if } d_c > (H_s - H_{wh}) \\ K_A\cdot S\cdot(H_s - H_{wh} - d_c) + K_B\cdot S\cdot(H_{wh} + d) & \text{otherwise} \end{cases} \qquad P_{sur} = 0$$

$$y_{sur} := \begin{cases} \dfrac{(H_s + d) - d_c}{2} & \text{if } d_c > H_s - H_{wh} \\ \dfrac{K_A \cdot S \cdot (H_s - H_{wh} - d_c) \cdot \left[(H_{wh} + d) + \dfrac{H_s - H_{wh} - d_c}{2} \right] + K_B \cdot S \cdot (H_{wh} + d) \cdot \dfrac{H_{wh} + d}{2}}{K_A \cdot S \cdot (H_s - H_{wh} - d_c) + K_B \cdot S \cdot (H_{wh} + d)} & \text{if } S > 0 \\ 0 & \text{otherwise} \end{cases} \qquad y_{sur} = 2\,ft$$

Water Pressure

$$P_w := \frac{1}{2} \cdot \gamma_w \cdot (H_{wh} + d)^2 \qquad P_w = 9016.8\,lbf \qquad y_w := \frac{H_{wh} + d}{3} \qquad y_w = 5.7\,ft$$

Water Pressure considering depth of crack

$$P_{wdc} := \begin{cases} \dfrac{1}{2} \cdot \gamma_w \cdot d_c^{\,2} & \text{if } d_c < (H_s - H_{wh}) \\ \dfrac{1}{2} \cdot \gamma_w \cdot (H_s - H_{wh})^2 & \text{otherwise} \end{cases} \qquad P_{wdc} = 5272.8\,lbf$$

$$y_{wdc} := \begin{cases} (H_s + d) - \dfrac{2 \cdot d_c}{3} & \text{if } d_c < (H_s - H_{wh}) \\ (H_s + d) - \dfrac{2 \cdot \left[(H_s + d) - H_{wh} \right]}{3} & \text{otherwise} \end{cases} \qquad y_{wdc} = 11.3\,ft$$

Uplift Forces

Uplift at heel $\quad U_h := \text{if}(H_{wh} > 0.1\,ft, H_{wh} + d, 0) \qquad U_h = 17\,ft$

Uplift at toe $\quad U_t := \text{if}(H_{wt} > 0.1\,ft, H_{wt} + d, 0) \qquad U_t = 0\,ft$

$$U_1 := \gamma_w \cdot \frac{1}{2} \cdot (U_h - U_t) \cdot (L_{base}) \qquad U_1 = 18033.7\,lbf \qquad x_{U1} := \frac{1}{3} \cdot (L_{base}) \qquad x_{U1} = 11.3\,ft$$

$$U_2 := \gamma_w \cdot U_t \cdot (L_{base}) \qquad U_2 = 0\,lbf \qquad x_{U2} := \frac{1}{2} \cdot (L_{base}) \qquad x_{U2} = 17\,ft$$

Reservoir Forces

Horizontal Forces

$$P_R := \frac{-1}{2} \cdot \gamma_w \cdot (H_{wt} + d)^2 \qquad P_R = -124.8\,lbf \qquad y_R := \frac{1}{3}(H_{wt} + d) \qquad y_R = 0.7\,ft$$

Vertical Forces

$$P_{Rv} := -\gamma_w \cdot L_t \cdot H_{wt} \qquad P_{Rv} = 0 \qquad x_{Rv} := \frac{L_t}{2} \qquad x_{Rv} = 0\,ft$$

Wave Forces

$$P_{wave} := 0\,lbf \qquad y_{wave} := 0\,ft$$

Check Stability

Moments about toe

Resisting Moment

$$M_r := W_{w1}\cdot x_{w1} + W_{w2}\cdot x_{w2} + W_{w3}\cdot x_{w3} + P_R\cdot y_R + P_{Rv}\cdot x_{Rv} + P_{wave}\cdot y_{wave} + W_{s1}\cdot x_{s1} + W_{s2}\cdot x_{s2} + W_{water1}\cdot x_{water1} \cdots + W_{water2}\cdot x_{water2} + P_{surv}\cdot x_{surv} + \Delta P_{PE2}\cdot y_{\Delta PPE2}$$

$M_r = -870\cdot kip\cdot ft$

Overturning Moment

$$M_o := P_{A1}\cdot y_{PA1} + P_{A2}\cdot y_{PA2} + P_{A3}\cdot y_{PA3} + \Delta P_{AE}\cdot y_{\Delta PAE} + W_{w1_e}\cdot y_{w1_e} + W_{w2_e}\cdot y_{w2_e} + W_{w3_e}\cdot y_{w3_e} \cdots + P_{sur}\cdot y_{sur} + P_w\cdot y_w + P_{wdc}\cdot y_{wdc} + U_1\cdot x_{U1} + U_2\cdot x_{U2} + P_{P1}\cdot y_{PP1} + P_{P2}\cdot y_{PP2}$$

$M_o = 315.6\cdot kip\cdot ft$

ΣF_y Vertical Force

$$F_y := W_{w1} + W_{w2} + W_{w3} + W_{s1} + W_{s2} + W_{water1} + W_{water2} + U_1 + U_2 + P_{Rv} + P_{surv}$$

$F_y = -36.2\cdot kip$

ΣF_x Horizontal Force

$$F_x := P_{A1} + P_{A2} + P_{A3} + \Delta P_{AE} + P_w + W_{w1_e} + W_{w2_e} + W_{w3_e} + P_{sur} + P_{wdc} + P_R + P_{wave} + P_{P1} + P_{P2} + \Delta P_{PE2}$$

$F_x = 14.4\cdot kip$

Location of Resultant

$$Resultant := \frac{M_r + M_o}{F_y} \qquad Resultant = 15.31\,ft \qquad Eccentricity := \frac{L_{base}}{2} - Resultant \qquad Eccentricity = 1.69\,ft$$

$$Middle_Third := \frac{L_{base}}{6} \qquad Middle_Third = 5.7\,ft$$

$$Check_R := if(Middle_Third > |Eccentricity|, "OK", "NOT_GOOD")$$

Check compression at Base

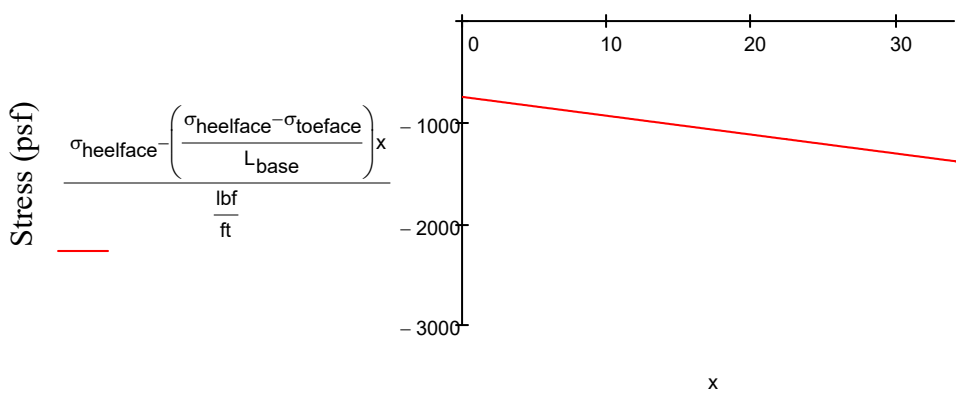
$Check_R = "OK"$

Pressure distribution Under the Footing (Negative is compression)

$$\sigma_{toeface} := \frac{F_y}{L_{base}}\cdot\left(1 + \frac{6\cdot Eccentricity}{L_{base}}\right)$$ *The stress at the toe* $\sigma_{toeface} = -1382\cdot\frac{lbf}{ft}$

$$\sigma_{heelface} := \frac{F_y}{L_{base}}\cdot\left(1 - \frac{6\cdot Eccentricity}{L_{base}}\right)$$ *The stress at the heel* $\sigma_{heelface} = -748\cdot\frac{lbf}{ft}$

Stress Distribution:



Footing in ft (The toe is set at zero)

Sliding Factor of Safety:

$\theta := \operatorname{atan}\left(\frac{K}{L_{base}}\right)$ $\theta = 0 \cdot deg$

$F_{xn} := F_x \cdot \sin(\theta)$ $F_{xn} = 0 \cdot kip$

$F_{xs} := F_x \cdot \cos(\theta)$ $F_{xs} = 14.4 \cdot kip$

$F_{ys} := F_y \cdot \sin(\theta)$ $F_{ys} = -0 \cdot kip$

$F_{yn} := -F_y \cdot \cos(\theta)$ $F_{yn} = 36.2 \cdot kip$

$$FS_s := \left| \frac{\tan(\phi_s) \cdot (F_{xn} + F_{yn}) + c_s \cdot L_{base} \cdot (1ft)}{F_{xs} + F_{ys}} \right|$$ $FS_s = 1.57$

$Check_{FS} := if(FS_s > FS_{sliding}, "OK", "NOT_GOOD")$

Check Sliding

$Check_{FS} = "OK"$

Check Bearing Stress

Moments about toe

Resisting Moment

$$M_{rb} := W_{w1b} \cdot x_{w1} + W_{w2b} \cdot x_{w2} + W_{w3b} \cdot x_{w3} + P_R \cdot y_R + P_{Rv} \cdot x_{Rv} + P_{wave} \cdot y_{wave} + W_{s1} \cdot x_{s1} + W_{s2} \cdot x_{s2} + W_{water1} \cdot x_{water1} \cdots + W_{water2} \cdot x_{water2} + P_{surv} \cdot x_{surv} + \Delta P_{PE2} \cdot y_{\Delta PPE2}$$

$M_{rb} = -870 \cdot kip \cdot ft$

SF_y Vertical Force

$F_{yb} := W_{w1b} + W_{w2b} + W_{w3b} + W_{s1} + W_{s2} + W_{water1} + W_{water2} + U_1 + U_2 + P_{Rv} + P_{surv}$ $F_{yb} = -36.2 \cdot kip$

Location of Resultant

$Eccentricity_b := \frac{L_{base}}{2} - \frac{M_{rb} + M_o}{F_{yb}}$ $Eccentricity_b = 1.69\,ft$

Stress distribution Under the Footing (Negative is compression)

$\sigma_{toeface.b} := \frac{F_{yb}}{L_{base}} \cdot \left(1 + \frac{6 \cdot Eccentricity_b}{L_{base}}\right)$ *The stress at the toe* $\sigma_{toeface.b} = -1382 \cdot \frac{lbf}{ft}$

$\sigma_{heelface.b} := \frac{F_{yb}}{L_{base}} \cdot \left(1 - \frac{6 \cdot Eccentricity_b}{L_{base}}\right)$ *The stress at the heel* $\sigma_{heelface.b} = -748 \cdot \frac{lbf}{ft}$

Bearing Factor of Safety

$Check_B := if(Q_{allowable} > \max(|\sigma_{toeface.b}|, |\sigma_{heelface.b}|), "OK", "NO_GOOD")$

Check bearing stress

$Check_B = "OK"$

Peckman River
Flood Risk Management Study

Floatation Check

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$\gamma_{soil} := 130pcf$ (unit weight of soil)

$\gamma_{conc} := 145pcf$ (unit weight of concrete)

$\gamma_{water} := 62.4pcf$ (unit weight of water)

$b := 1ft$ (consider 1 ft)

$B_{total} := 45.5ft$ (total width of the culvert)

$A_{conc} := 302ft^2$ (calculated in Autocad)

$W_{conc} := A_{conc} \cdot b \cdot \gamma_{conc} = 43.79\,kip$

$$H_{soil} := \begin{pmatrix} 0.5 \\ 0.5 \\ 5.0 \\ 5.0 \end{pmatrix} ft \qquad W_{soil} := b \cdot H_{soil} \cdot \gamma_{soil} \cdot B_{total} = \begin{pmatrix} 2.96 \\ 2.96 \\ 29.58 \\ 29.58 \end{pmatrix} kip$$

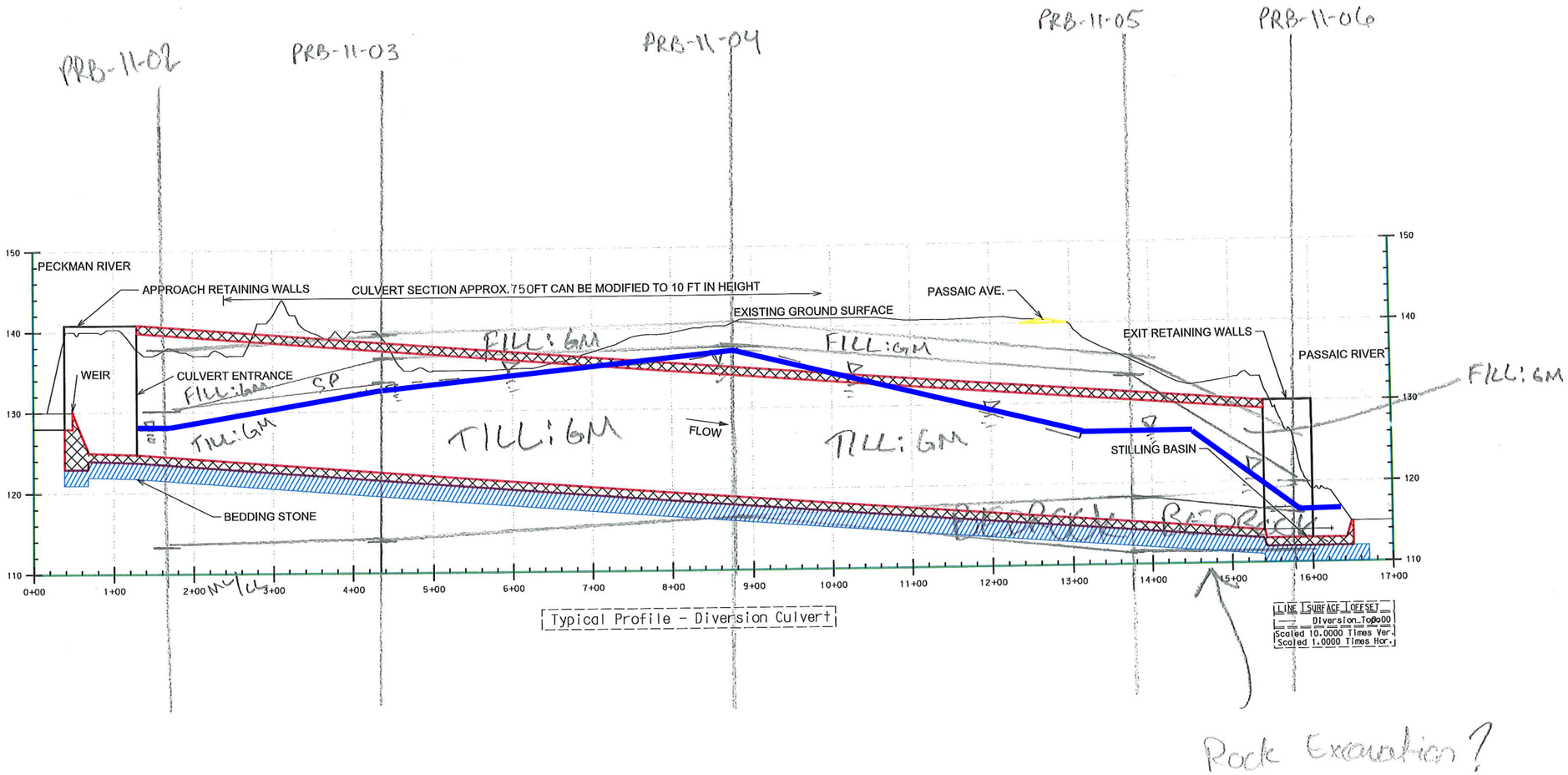
$$W_{total} := W_{soil} + W_{conc} = \begin{pmatrix} 46.75 \\ 46.75 \\ 73.37 \\ 73.37 \end{pmatrix} kip$$

$$H_{water} := \begin{pmatrix} 10 \\ 16 \\ 25 \\ 25 \end{pmatrix} ft \qquad H_{culvert} := 20ft$$

$$H_b := \left| \begin{array}{l} \text{for } i \in ORIGIN .. last(H_{water}) \\ \quad H_{b_i} \leftarrow \min(H_{water_i}, H_{culvert}) \\ \text{return } H_b \end{array} \right. \qquad H_b = \begin{pmatrix} 10 \\ 16 \\ 20 \\ 20 \end{pmatrix} ft$$

$$W_{water} := B_{total} \cdot H_b \cdot b \cdot \gamma_{water} = \begin{pmatrix} 28.39 \\ 45.43 \\ 56.78 \\ 56.78 \end{pmatrix} kip \qquad \boxed{DOC := \frac{W_{water}}{W_{total}} = \begin{pmatrix} 0.61 \\ 0.97 \\ 0.77 \\ 0.77 \end{pmatrix}}$$

Note: The culvert was divided into 4 segments to check for floatation. Since this is a preliminary design for cost estimating and constructability evaluation, there are several unknown parameters, such as final grading plan, that affect floatation check. The height of soil over the top of the culvert were based on the existing natural ground. As shown in the results, positive uplift does not exist along the culvert. However, the second segment has demand over capacity ratio close to one, which is 0.97. Therefore, during the next design of the project, if positive uplift exists, it is recommended to use a drain system to lower the groundwater level.



Typical Profile - Diversion Culvert

Approximate water level from test borings

EMO 7/11/2019 Peckman River Feasibility

SCALE 1"=75'

US Army Corps of Engineers

PECKMAN RIVER BASIN
ESSEX & PASSAIC COUNTIES
NEW JERSEY
FLOOD RISK MANAGEMENT STUDY

Sheet reference number

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