

February 3, 2026  
 File No. 25-466

Artoush Fanaiyan  
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 Bellevue, WA 98005  
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**Subject: Response to Geotechnical Review Comments  
 Proposed SFR  
 5818 West Mercer Way, Mercer Island, WA**

Dear Artoush,

We received Sub 5 geotechnical review comments dated January 23, 2026 from the City of Mercer Island for the above project. The following are our responses to the review comments related to the geotechnical aspect of the project.

**PERMANENT ULTRABLOCK WALLS**

Based on current design plans, we understand that permanent ultrablock walls are proposed on the south side of the house to retain the cuts and along the driveway to retain the fill, and the walls have the maximum exposed height of 6 feet. We used Ultrablock software to design the walls for 4-foot and 6-foot exposed wall heights. The following soil properties were derived from the subsurface data at the site and were used in the wall design. For the seismic design, a peak ground acceleration (PGA) of 0.627 with  $F_{PGA} = 1.1$  were used in the design.

**Table 1. Soil Properties for Ultrablock Wall Design**

Soil Type	Unit Weight (pcf)	Cohesion (psf)	Friction (Degree)
Retained Soil	110	0	32
Foundation Soil	130	0	36
Leveling Pad	135	0	40

Based on the calculations, for the 6-foot exposed wall height, a 3-row block configuration with base block 5 feet deep should be used. For the 4-foot exposed wall height, a 2-row block configuration may be used. The detailed calculations are attached in Appendix A at the end of this letter.

Additionally, we recommend adding one soldier pile to the south soldier pile E1 to eliminate the most east block wall. All other ultrablock walls will have a level ground behind the walls. As such, there is no slope surcharge for these walls.

### **SHORING DESIGN RECOMMENDATIONS**

#### ***1. Pressure Diagram for Tiebacked Shoring Wall***

We have revised Figure 2 and  $P_a = 35H$  (psf)

#### ***2. Earth Pressure Factor for Shoring Walls with Backslope***

We have indicated earth pressure factors to be used in areas on Figures 1 and 2.

#### ***3. Reduced Passive Pressure in Front of Shoring Walls***

For the temporary conditions, the passive pressure for sloped cuts in front of Piles E1 through E9 should be disconnected and bottom of the excavations should be assumed at the bottom of basement foundation levels. We will coordinate with the shoring designer to revise the shoring design after the geotechnical design recommendations are approved.

#### ***4. Soil Properties for Earth Pressures***

We used the following soil properties to calculate the earth pressures for the shoring design.

Soil Type	Unit Weight (pcf)	Cohesion (psf)	Friction (Degree)
Retained Soil above Excavation Bottom	110	0	32
Native soil below Excavation	130	0	36

We used Coulomb's earth pressure formula to calculate the earth pressure coefficient, and the active earth pressure coefficient  $k_a$  is 0.307, which yielded an equivalent fluid pressure of 33.8 pcf (less than 35 pcf). The calculated equivalent fluid passive pressure is 462 pcf (allowable value of 308 pcf). These equivalent fluid pressures are used for cantilever soldier pile design.

For the tiebacked shoring walls and for the cohesive soil, the formula of  $(0.3\gamma H)$  recommended by FHWA was used, which yielded  $33H$  (psf), less than  $35H$  (psf) recommended.

**5. Other Sub 5 Comments Regarding Shoring Design**

The shoring revisions will be completed after the geotechnical reviews are approved.

**CLOSURE**

We appreciate the opportunity to assist you with this project. If you have any questions, please do not hesitate to contact us.

Sincerely,



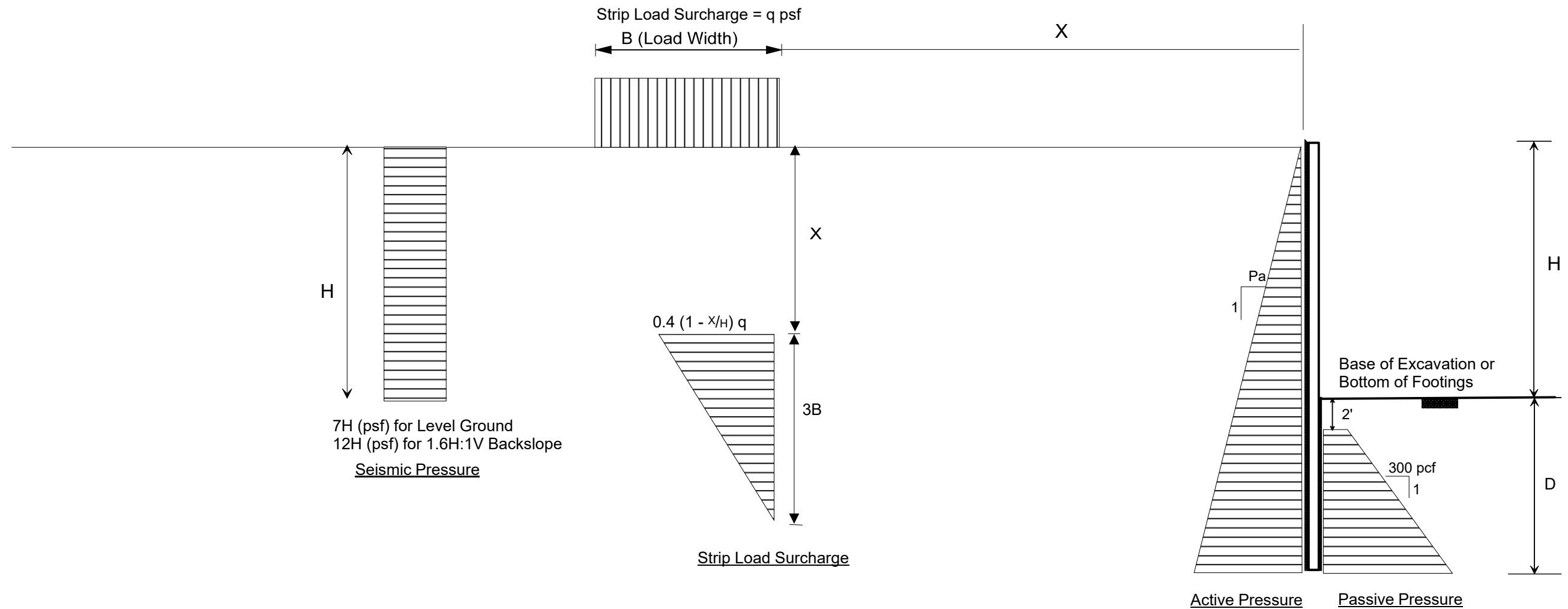
*2/3/2026*

Michael H. Xue, P.E.  
Principal Geotechnical Engineer

**Attachments:**

- Figure 1 Design Lateral Pressures, Cantilever Soldier Pile Wall
- Figure 2 Design Lateral Pressures, Soldier Pile Wall, One or Multiple Levels of Tiebacks

**Appendix A – Summary Ultrablock Design Calculations**



7H (psf) for Level Ground  
 12H (psf) for 1.6H:1V Backslope  
Seismic Pressure

Strip Load Surcharge

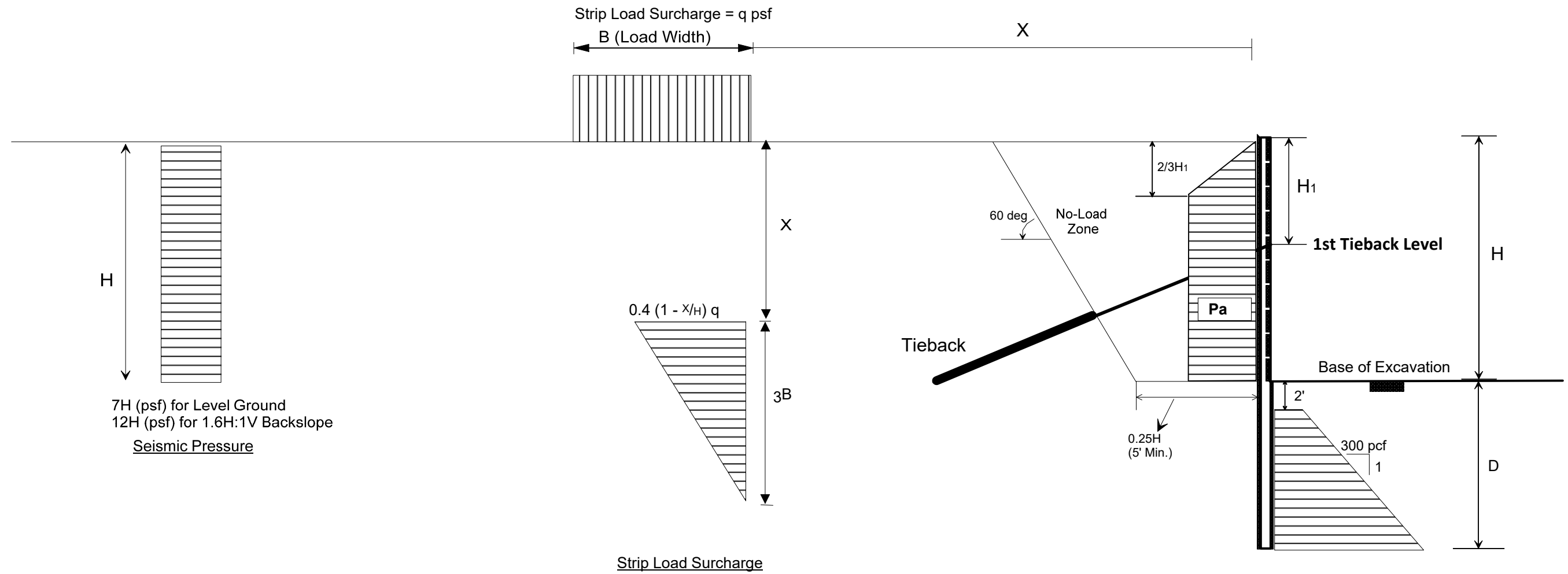
Active Pressure      Passive Pressure

**Temporary Shoring Walls:**  
 $P_a = 35$  pcf (Level Background)

**Permanent Shoring Walls:**  
 $P_a = 50$  pcf (Level Background)

Earth Pressure Factor for Backslope		
Backslope, X:1	Earth Pressure Factor (A)	Pile Locations
Level	1	S1 - S7
3H:1V	1.2	
2H:1V	1.4	E12 - E14
1.6H:1V	1.55	E1 - E11

- Notes:
1. Minimum embedment should be at least 8 feet below bottom of excavation.
  2. A factor of safety of 1.5 has been applied to the recommended passive pressure values. No factor of safety has been applied to the recommended active earth pressure values.
  3. Active pressures should be applied over the full width of the pile spacing above the base of the excavation, and over one pile diameter below the base of the excavation.
  4. Surcharge pressures should be applied over the entire length of the loaded area.
  5. Passive pressure should be applied to 2.5 times the diameter of the soldier piles, or pile center-to-center spacing, whichever is less.
  6. For lagging design, refer to report text.



$P_a = 35H$  psf (Level Background)

Earth Pressure Factor for Backslope		
Backslope, X:1	Earth Pressure Factor (A)	Pile Locations
Level	1	S1 - S7
3H:1V	1.2	
2H:1V	1.4	E12 - E14
1.6H:1V	1.55	E1 - E11

**Tiebacks:**  
 Minimum Bond Length: 12 feet  
 Assume Maximum Allowable Capacity:  
 2.0 kip / foot

- Notes:
1. Minimum embedment should be at least 8 feet below bottom of excavation.
  2. A factor of safety of 1.5 has been applied to the recommended passive pressure values. No factor of safety has been applied to the recommended active earth pressure values.
  3. Active pressures should be applied over the full width of the pile spacing above the base of the excavation, and over one pile diameter below the base of the excavation.
  4. Surcharge pressures should be applied over the entire length of the loaded area.
  5. Passive pressure should be applied to 2.5 times the diameter of the soldier piles, or pile center-to-center spacing, whichever is less.
  6. For lagging design, refer to report text.

13-052\_Figure 3.grf 2/3/26 (6:17:22) JCR

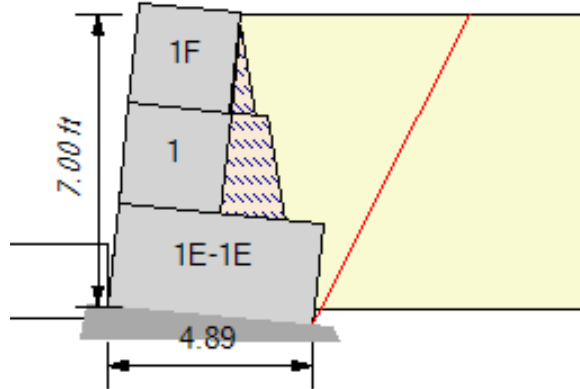
**APPENDIX A**  
**SUMMARY ULTRABLOCK DESIGN CALCULATIONS**



# UltraWall

Project: 5818 W Mercer Way SFR  
 Location: 5818 W Mercer Way, MI  
 Designer: HMX  
 Date: 2/2/2026  
 Section: Section 1  
 Design Method: NCMA\_09\_3rd\_Ed  
 Design Unit: UltraBlock: 1

Seismic Acc: 0.690g  
 Design Method: AASHTO 2020, Kavazanjian  
 Design Equation: AASHTO 2020, A11.5.1-1



SOIL PARAMETERS	$\Phi$	coh	$\gamma$
Drainage Zone:	34 deg	0 lbf/ft <sup>2</sup>	120 lbf/ft <sup>3</sup>
Retained Soil:	32 deg	0 lbf/ft <sup>2</sup>	110 lbf/ft <sup>3</sup>
Foundation Soil:	36 deg	0 lbf/ft <sup>2</sup>	130 lbf/ft <sup>3</sup>
Leveling Pad:	40 deg	0 lbf/ft <sup>2</sup>	135 lbf/ft <sup>3</sup>
Crushed Stone Lvlng Pad			

## GEOMETRY

Design Height:	7.00 ft	Live Load:	0.00 lbf/ft <sup>2</sup>
Wall Batter/Tilt:	0.00/ 5.70 deg	Live Load Offset:	0.00 ft
Embedment:	1.50 ft*	Live Load Width:	0.00 ft
Leveling Pad Depth:	0.30 ft	Dead Load:	0.0 lbf/ft <sup>2</sup>
Slope Angle:	0.0 deg	Dead Load Offset:	0.0 ft
Slope Length:	0.0 ft	Dead Load Width:	0.00 ft
Slope Toe Offset:	0.0 ft	D.L. Embedment:	0.00 ft
Leveling Pad Width:	5.92 ft		

Vert  $\delta$  on Single Dpth

\* Note: For all designs the passive resistance in front of the wall units is ignored for sliding calculations.

## FACTORS OF SAFETY (Static / Seismic)

Sliding:	1.50 / 1.125	Overtopping:	1.50 / 1.125
Bearing:	3.00 / 1.5		

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



**RESULTS (Static / Seismic)**

FoS Sliding: 4.46 (lvlpd) / 2.76      FoS Overturning: 8.56 / 2.47  
 Bearing: 1961.69 / 1050.88      FoS Bearing: 9.56 / 26.63

Name	Elev.	ka	kae	Pa	Pae	Pif	PaT	PaTs	Fssl	seisFssl	FoS OT	FoS SeisOT
1F	4.84	0.237	0.479	60	122	251	60	374	73.78	35.72	24.43	3.04
1	2.42	0.237	0.479	273	552	503	273	1054	18.94	9.09	5.88	1.21
1E-1E	0.00	0.407	0.741	1096	1997	1005	1096	3003	4.46	2.76	8.56	2.47

**Design Approach:**

The design is a 'top down' approach. The values shown in the table[ka, kae, Pa, etc.] are the values from the top of wall to the base of that row. For trial wedge analysis, the ka and kae are back-calculated from the Pa, Pae values.

**Column Descriptions:**

- ka: active earth pressure coefficient
- kae: active seismic earth pressure coefficient
- Pa: active earth pressure
- Pae: dynamic earth pressure
- Pir: inertia force
- Paq: live surcharge earth pressure
- Paq2: live load 2 surcharge earth pressure
- Paqd: dead surcharge earth pressure
- (PaC): reduction in load due to cohesion
- PaT: sum of all earth pressures
- Fssl(lvl Pad): factor of safety for sliding at each layer. (FS sliding below the leveling pad)
- FSot: factor of safety of overturning about the toe.

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



DESIGN DATA

TARGET DESIGN VALUES (Factors of Safety - Static / Seismic)

Minimum Factor of Safety for the sliding along the base	FSsl = 1.50 /1.125
Minimum Factor of Safety for overturning about the toe	FSot = 1.50 /1.125
Minimum Factor of Safety for bearing (foundation shear failure)	FSbr = 2.00 /1.500

MINIMUM DESIGN REQUIREMENTS

Minimum embedment depth	Min_emb = 1.50 ft
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INPUT DATA

Geometry

Wall Geometry

Design Height, top of leveling pad to top of wall	H = 7.00 ft
Design Height External, top of leveling pad to finished grade at top of wall	he = 7.00 ft
Embedment, measured from top of leveling pad to finished grade	emb = 1.50 ft
Leveling Pad Depth	Thickness = 0.30 ft
Face Batter, measured from vertical	i = 0.00 deg

Slope Geometry

Back Slope Angle, measured from horizontal	$\beta$ = 0.00 deg
Back Slope Toe Offset, measured from back of the face unit	STL_offset = 0.00 ft
Back Slope Length, measured from toe to crest	SL_Length = 0.00 ft

NOTE: If the back slope toe is offset or the slope breaks within three times the wall height, a Coulomb Trial Wedge method of analysis is used.

Toe Slope Angle, measured from horizontal	$\beta$ = 0.00 deg
Toe Slope Crest Offset, measured from front of the face unit	STL_offset = 0.00 ft
Toe Slope Length, measured from crest to toe	SL_Length = 0.00 ft

Surcharge Loading

Live Load, assumed transient loading (e.g. traffic)	LL = 0.00 lbf/ft <sup>2</sup>
Live Load Offset, measured from back face of wall	LL_offset = 0.00 ft
Live Load Width, assumed strip loading	LL_width = 0.00 ft

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



## Soil Parameters

### Retained Zone

Angle of Internal Friction	$\Phi = 32.00$ deg
Cohesion	coh = 0.00 lbf/ft <sup>2</sup>
Moist Unit Weight	$\gamma = 110.00$ lbf/ft <sup>3</sup>

### Foundation

Angle of Internal Friction	$\Phi = 36.00$ deg
Cohesion	coh = 0.00 lbf/ft <sup>2</sup>
Moist Unit Weight	$\gamma = 130.00$ lbf/ft <sup>3</sup>

### Leveling Pad

Angle of Internal Friction	$\Phi = 40.00$ deg
Cohesion	coh = 0.00 lbf/ft <sup>2</sup>
Moist Unit Weight	$\gamma = 135.00$ lbf/ft <sup>3</sup>

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final design or construction without the independent review, verification, and approval by a qualified professional engineer.



## RETAINING WALL UNITS

### STRUCTURAL PROPERTIES:

N is the normal force [or factored normal load] on the base unit

The default leveling pad to base unit shear is  $0.8 \tan(\Phi)$  [AASHTO 10.6.3.4] or

may be the manufacturer supplied data.  $\Phi$  is assumed to be 40 degrees for a stone leveling pad.

Unit	Aggr_Vol (cf)	Aggr_Density (pcf)	Aggr_CG (in)	Equiv_Density (pcf)	Equiv_CG (in)
Cap	0.00	105	14.75, 7.37	0	NaN
Full Cap	0.00	105	14.75, 14.75	0	NaN
Full	0.00	105	14.75, 14.75	0	NaN
Double	0.00	105	29.50, 14.75	0	NaN

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final design or construction without the independent review, verification, and approval by a qualified professional engineer.



## CALCULATION RESULTS

### OVERVIEW

UltraWall calculates stability assuming the wall is a rigid body. Forces and moments are calculated about the base and the front toe of the wall. The base block width is used in the calculations. The concrete units and granular fill over the blocks are used as resisting forces.

### EARTH PRESSURES

The method of analysis uses the Coulomb Earth Pressure equation (below) to calculate active earth pressures. Wall friction is assumed to act at the back of the wall face. The component of earth pressure is assumed to act perpendicular to the boundary surface. The effective  $\delta$  angle is  $\delta$  minus the wall batter at the back face. If the slope breaks within the failure zone, a trial wedge method of analysis is used.

### EXTERNAL EARTH PRESSURES

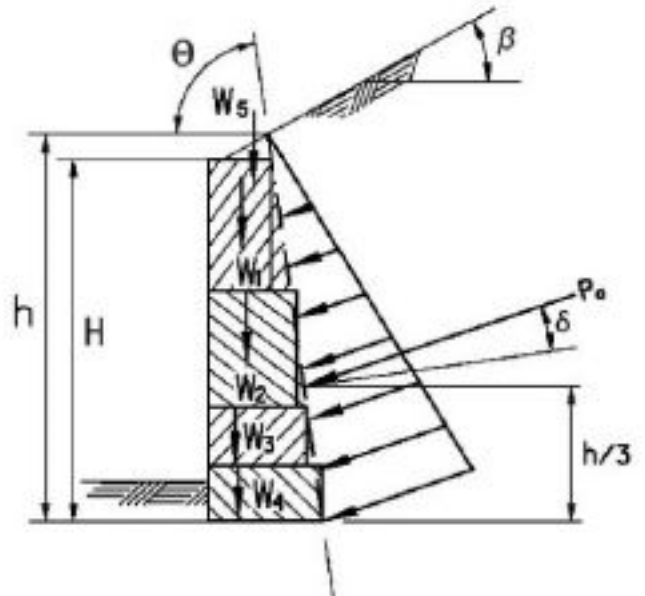
Effective  $\delta$  angle (3/4 retained phi)  
Coefficient of active earth pressure

$\delta = 24.0$  deg  
 $k_a = 0.407$

External failure plane  
Effective Angle from horizontal  
Coefficient of passive earth pressure:  $k_p = (1 + \sin(\Phi)) / (1 - \sin(\Phi))$

$\rho = 62$  deg  
 $\theta = 74.84$  deg  
 $k_p = 0.00$

$$K_a := \frac{\cos(\phi_1 + i)^2}{\cos(i)^2 \cdot \cos(\delta_1 - i) \left( 1 + \sqrt{\frac{\sin(\phi_1 + \delta_1) \cdot \sin(\phi_1 - \beta)}{\cos(\delta_1 - i) \cdot \cos(i + \beta)}} \right)^2}$$



where:

- $\delta$  = friction angle between fill and wall (degrees)
- $\beta$  = angle of fill to the horizontal (degrees)
- $\theta$  = angle of back face of wall to the horizontal (degrees)
- $\omega$  = angle of wall batter (degrees) =  $\theta - 90$
- $\Phi'$  = effective angle of internal friction (degrees)

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final design or construction without the independent review, verification, and approval by a qualified professional engineer.



## FORCE DETAILS

The details below shown how the forces are calculated for each force component. The values shown are not factored. All loads are based on a unit width (lbf/ft or kN/m).

Layer	Block Wt lbf	Soil Infill Wt lbf	Soil Wedge Wt lbf
1	846.08	0	83
2	846.08	0	357
3	1692.15	0	

Block Weight = 3384.31 lbf/ft

X-Arm = 4.02 ft

Soil Infill Weight = 0.00 lbf/ft

X-Arm = 0.00 ft

Soils Wedge Weight = volume x Drain rock density

$$3.67 * 120.00 = 439.87 \text{ lbf/ft}$$

X-Arm = 3.66 ft

Active Earth Pressure  $P_a = 1095.69 \text{ lbf/ft}$

$$P_{a\_h} (W9) = P_a \cos(\delta - \omega) = 1095.69 \times \cos(24.00 - (-15.16)) = 850 \text{ lbf/ft}$$

Y-Arm = 2.50 ft

$$P_{a\_v} (W9) = P_a \sin(\delta - \omega) = 1095.69 \times \sin(24.00 - (-15.16)) = 692 \text{ lbf/ft}$$

X-Arm = 4.24 ft

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



**FORCES AND MOMENTS**

The program resolves all the geometry into simple geometric shapes to make checking easier. All x and y coordinates are referenced to a zero point at the toe of the bottom unit.

**LOADS FOR OVERTURNING ABOUT THE TOE**

Name	Force(V) lbf	Force(H) lbf	X-len ft	Y-len ft	Mo ft-lbf	Mr ft-lbf
Face Blocks (W1)	3384.31		4.024			13617.82
Soil Wedge (W2)	439.87		3.663			1611.16
Pa_h (W9)		849.57		2.496	2120.61	
Pa_v (W9)	691.94		4.240			2934.01
Sum V / H	4,516	850		Sum Mom	2,121	18,163

W0: stone within units

W1: facing units

W2: soil wedge behind the face

X-Len: is measured from the front of the base block (+) Driving, (-) Resisting.

Pa\_h (W9): horizontal earth pressure

Pa\_v (W9): vertical earth pressure

Pq\_h: horizontal surcharge pressure

Pq\_v: vertical surcharge pressure

**BEARING LOADS: NCMA**

All x and y coordinates are referenced to a zero point at the middle of the base block for eccentricity calculations.

Name	Force(V) lbf	Force(H) lbf	X-len ft	Y-len ft	Mo ft-lbf	Mr ft-lbf
Face Blocks (W1)	3384.31		-1.578			-6515.65
Soil Wedge (W2)	439.87		-1.217			-535.50
Pa_h (W9)		849.57		2.496	2120.61	
Pa_v (W9)	691.94		-1.796			-1414.40
Sum V / H	4516	850		Sum Mom	2121	-8466

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



### BASE SLIDING

Sliding at the base is checked at the block to leveling pad interface between the base block and the leveling pad. Sliding is also checked between the leveling pad and the foundation soils.

$$\begin{aligned} \text{Forces Resisting sliding} &= W1 + W2 + Pav \\ 3384.31 + 439.87 + 691.94 & \qquad \qquad \qquad N = 4516.12 \text{ lbf/ft} \end{aligned}$$

### Sliding between Concrete Units and Leveling Pad/Drain Mat (Rf1)

$$\begin{aligned} \text{Resisting force at pad} &= ( N \times \phi \times \tan(\text{slope}) + \text{intercept} ) \\ (4516 \times 0.8 + \tan(40.00) + 0.0) & \qquad \qquad \qquad RF(lvIPd) = 3789 \text{ lbf} \end{aligned}$$

Driving force is the horizontal component of

$$\begin{aligned} &Pah \\ 849.57 & \qquad \qquad \qquad Df = 849.57 \end{aligned}$$

$$FSsl = Rf / Df \qquad \qquad \qquad FSsl = 4.46 \text{ lbf}$$

$$FSslfndn = Rf1 / Df \qquad \qquad \qquad FSslfndn = 100.00$$

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### ROW TO ROW SLIDING

Sliding between rows is checked at the interface between two adjacent rows.

Details of the calculation are shown on the previous page. The leveling pad interaction is now replaced with the unit/unit interaction.

Resisting Force = Normal Force x 0.8 + intercept )

Units: All units are in lbf/ft or ft-lbf/ft of wall.

### RESULTS TABLE

Elev[ ft]	Normal[ lbf/ft]	RF Concrete	Shear Intcpt	Resisting Force	Driving Force[ lbf/ft]	FS Sliding/Shear
4.84	846.08	676.86	3619.55	4296.41	58.24	73.78
2.42	1692.15	1353.72	3619.55	4973.27	262.58	18.94

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



### OVERTURNING ABOUT THE TOE

Overturning at the base is checked by assuming rotation about the front toe by the block mass and the soil retained on the blocks. Allowable overturning can be defined by factor of safety of overturning. For concrete leveling pads overturning is checked at the base of the pad.

$$\begin{aligned} \text{Moments Resisting Overturning} &= M1 + M2 + MPav \\ 13617.82 + 1611.16 + 2934.01 \end{aligned}$$

$$Mr = 18163.00 \text{ ft-lbs}$$

$$\begin{aligned} \text{Moments causing Overturning} &= MPah \\ 2120.61 \end{aligned}$$

$$Mo = 2120.61 \text{ ft-lbs}$$

$$FSot = Mr / Mo$$

$$FSot = 18163.00 / 2120.61$$

$$FSot = 8.56$$

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



### OVERTURNING ABOUT THE ROW BELOW

Overturning at the row below is checked by assuming rotation about the front toe by the block mass and the soil retained on the blocks. Allowable overturning can be defined by Factor of safety of Overturning. For concrete leveling pads overturning is checked at the base of the pad.

$$\text{Factor of Safety Overturning} = \text{Moment Resisting} / \text{Moment Driving}$$

### RESULTS TABLE

Elev[ ft]	Mr[ ft-lbf]	Mo[ lbf/ft]	FS Overturning
4.84	1138.12	46.59	24.43
2.42	2480.01	422.06	5.88

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



### ECCENTRICITY AND BEARING

Eccentricity is the calculation of the distance of the resultant measured from the centroid of base. In wall design the eccentricity is used to calculate an effective footing width and bearing pressure.

Calculation of Eccentricity

$$\text{SumV} = + W1 + W2 + P_{av}$$

$$+ 3384.31 + 439.87 + 691.94$$

Moment Resisting

Moment Driving

$$\text{SumV} = 4516.12 \text{ lbf}$$

$$M_r = 8465.55 \text{ ft-lbf}$$

$$M_d = 2120.61 \text{ ft-lbf}$$

$$e = (\text{Sum}M_r + \text{Sum}M_d) / (\text{SumV})$$

$$e = ( 8465.55 - 2120.61 ) / 4516.12$$

$$e = 1.405 \text{ ft}$$

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



BEARING

Bearing Capacity Factors [Foundation]

Nc = 50.59 Myerhoff Eqn  
Nq = 37.75 Myerhoff Eqn  
Ng = 56.31 Vesic Eqn

Shape Factors [Foundation]

Sc = 1.07  
Sq = 1.07  
Sg = 0.96

Depth Correction Factor

df = 1.09

Modified Bearing Capacity Factors [Foundation]

Ncm = Nc x Sc = 54.36  
Nqm = Nq x Sq x df = 44.00  
Ngm = Ng x Sg = 54.06

Water Correction Factor

Cwq = 1.00  
Cwg = 1.00

Base width at foundation, B'f

B'f = B - 2e + l/Pad Thickness (Bearing area at foundation)  
4.92 - 2 x 1.40 + 0.30

B'f = 2.41 ft

q = embedment \* γ  
= 1.50 x 130.00

q = 195.00 lbf/ft2

Calculation of Bearing Pressures on Foundation

qr = (c \* Ncm) + (q \* Nqm \* Cwq) + 0.5 \* γ \* B'f \* Ngm \* Cwg  
[(0.00 x 54.36) + (195.00 x 44.00 x 1.00) + (0.5 x 130.00 x 2.41 x 54.06 x 1.00)]

qult = 18753.85 lbf/ft2

Nbrg = Bearing at Foundation Level

NBrg = 4721 lbf/ft2

Calculate Ultimate Bearing, qult

qult = 18753.85 lbf/ft2

Bearing Pressures (σ)

Nbrg/B'f = 1961.69 lbf/ft2

Calculated Factor of safety for bearing

qult/σ = 9.56

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



## SEISMIC CALCULATIONS

The loads considered under seismic loading are primarily inertial loadings. The wave passes the structure putting the mass into motion and then the mass will try to continue in the direction of the initial wave. In the calculations you see the one dynamic earth pressure from the wedge of the soil behind the reinforced mass, and then all the other forces come from inertia calculations of the face put into motion and then trying to be held in place.

$$k_{max} = PGA \times F_{pga} = 0.627 \times 1.1$$

$$\text{Displacement (d)}$$

$$k_{hint} = k_{hext} = 0.74 A (A/d)^{0.25}$$

$$k_{max} = 0.690g$$

$$d = 6.0 \text{ in}$$

$$k_{h(ext)} = 0.297$$

Vertical Acceleration

$$k_v = 0.000$$

### EXTERNAL $K_{ae\_ext}$

$$K_{ae\_ext}$$

$$D_{K_{ae\_ext}} = K_{ae\_ext} - K_a = (0.741 - 0.407)$$

$$P_{ae\_ext} = 0.5 \times \gamma \times (H)^2 \times D_{K_{ae\_ext}}$$

$$P_{ae\_h/2} = P_{ae} \times \cos(\delta)/2$$

$$P_{ae\_v/2} = P_{ae} \times \sin(\delta)/2$$

$$K_{ae\_ext} = 0.741$$

$$D_{K_{ae\_ext}} = 0.335$$

$$P_{ae} = 902 \text{ lbf/ft}$$

$$P_{ae\_h/2} = 412 \text{ lbf/ft}$$

$$P_{ae\_v/2} = 183 \text{ lbf/ft}$$

### INERTIA FORCES OF THE STRUCTURE

$$\text{Face (Pir)} = (W_0 + W_1) \times k_{h(ext)} = (0 + 3,384) \times 0.297$$

$$Pir = 1,005 \text{ lbf/ft}$$

### MONONOBE-OKABE EQ (REF AASHTO A11.3.1.1)

$$K_{AE} = \frac{\cos^2(\phi - \theta_{MO} - \beta)}{\cos \theta_{MO} \cos^2 \beta \cos(\delta + \beta + \theta_{MO})} \times \left[ 1 + \sqrt{\frac{\sin(\phi + \delta) \sin(\phi - \theta_{MO} - i)}{\cos(\delta + \beta + \theta_{MO}) \cos(i - \beta)}} \right]^{-2} \quad (A11.3.1-1)$$

where:

- $K_{AE}$  = seismic active earth pressure coefficient (dim)
- $\gamma$  = unit weight of soil (kcf)
- $H$  = height of wall (ft)
- $h$  = vertical distance between ground surface and wall base at the back of wall heel (ft)
- $\phi_f$  = friction angle of soil (degrees)
- $\theta_{MO}$  = arc tan  $[k_h/(1 - k_v)]$  (degrees)
- $\delta$  = wall backfill interface friction angle (degrees)
- $k_h$  = horizontal seismic acceleration coefficient (dim.)
- $k_v$  = vertical seismic acceleration coefficient (dim.)
- $i$  = backfill slope angle (degrees)
- $\beta$  = slope of wall to the vertical, negative as shown (degrees)

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



### SEISMIC SLIDING

The target factor of safety for seismic is 75% of the static value. Live loads are ignored in these analysis based on the basic premise that the probability of the maximum acceleration occurring at the exact same instant as the maximum live load is small.

Details are only shown for sliding at the base of blocks, a check is made at the foundation level with the answer only shown.

The vertical resisting forces is  $W1 + W2 + Pav + Paev$

$$3384 + 440 + 692 + 569$$

$$\text{SumVs} = 5085.58$$

Resisting force =  $\text{SumVs} * \tan(\phi) + \text{intercept} * L$

$$\text{FRe} = 4267.31 \text{ lbf/ft}$$

Driving force =  $Pa\_h + Pae\_h + Pir$

$$= 849.57 + 699.19 + 1005.14$$

$$\text{FDr} = 1548.76 \text{ lbf/ft}$$

FOS =  $\text{FRe}/\text{FDr}$  [leveling pad / foundation]

$$\text{FoS} = 2.76 / 2.48$$

### SEISMIC OVERTURNING

Overturning is rotation about the front toe of the wall. Eccentricity is also a check on overturning

Resisting Moment =  $M1 + M2 + MPav + MPaev$

$$13618 + 1611 + 2934 + 2260$$

$$\text{SumMrS} = 20422.78 \text{ ft lbf/ft}$$

Driving Moment =  $MPah + MPaeh + MPif$

$$2121 + 2618 + 3518$$

$$\text{SumMoS} = 8256.49 \text{ ft lbf/ft}$$

Factor of Safety =  $\text{SumMrS}/\text{SumMoS}$

$$\text{FoS} = 2.47$$

### SEISMIC BEARING

Bearing is the ability of the foundation to support the mass of the structure.

$$Qult = c * Nc + q * Nq + 0.5 * \gamma * (B') * Ng$$

where:

$$Nc = 50.59 \text{ Myerhoff Eqn}$$

$$Nq = 37.75 \text{ Myerhoff Eqn}$$

$$Ng = 56.31 \text{ Vesic Eqn}$$

$$c = 0.00 \text{ lbf/ft}^2$$

$$q = 234.00 \text{ lbf/ft}^2$$

Calculate Ultimate Bearing,  $Qult$  (seismic)  
eccentricity (e)

$$Qult = 27987.56 \text{ lbf/ft}^2$$

$$e = 0.091$$

Equivalent Footing Width,  $B' = L - 2e + |e|$  pad

$$B' = 5.03 \text{ ft}$$

Bearing Pressure =  $\text{sumVs}/B'$

$$\sigma = 1050.88 \text{ lbf/ft}^2$$

Factor of Safety for Bearing =  $Qult/\text{Bearing}$

$$\text{FoS} = 26.63$$

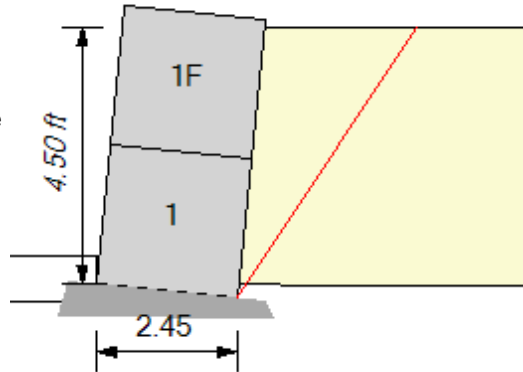
Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



# UltraWall

Project: 5818 W Mercer Way SFR  
 Location: 5818 W Mercer Way, MI  
 Designer: HMX  
 Date: 2/2/2026  
 Section: Section 2  
 Design Method: NCMA\_09\_3rd\_Ed, Ignore Vert. Force  
 Design Unit: UltraBlock: 1

Seismic Acc: 0.690g  
 Design Method: AASHTO 2020, Kavazanjian  
 Design Equation: AASHTO 2020, A11.5.1-1



SOIL PARAMETERS	$\phi$	coh	$\gamma$
Drainage Zone:	34 deg	0 lbf/ft <sup>2</sup>	120 lbf/ft <sup>3</sup>
Retained Soil:	32 deg	0 lbf/ft <sup>2</sup>	110 lbf/ft <sup>3</sup>
Foundation Soil:	36 deg	0 lbf/ft <sup>2</sup>	130 lbf/ft <sup>3</sup>
Leveling Pad:	40 deg	0 lbf/ft <sup>2</sup>	135 lbf/ft <sup>3</sup>
Crushed Stone Lvlng Pad			

## GEOMETRY

Design Height:	4.50 ft	Live Load:	0.00 lbf/ft <sup>2</sup>
Wall Batter/Tilt:	0.00/ 5.70 deg	Live Load Offset:	0.00 ft
Embedment:	0.50 ft*	Live Load Width:	0.00 ft
Leveling Pad Depth:	0.30 ft	Dead Load:	0.0 lbf/ft <sup>2</sup>
Slope Angle:	0.0 deg	Dead Load Offset:	0.0 ft
Slope Length:	0.0 ft	Dead Load Width:	0.00 ft
Slope Toe Offset:	0.0 ft	D.L. Embedment:	0.00 ft
Leveling Pad Width:	3.46 ft		

Vert  $\delta$  on Single Dpth

\* Note: For all designs the passive resistance in front of the wall units is ignored for sliding calculations.

## FACTORS OF SAFETY (Static / Seismic)

Sliding:	1.50 / 1.125	Overtopping:	1.50 / 1.125
Bearing:	3.00 / 1.5		

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



**RESULTS (Static / Seismic)**

FoS Sliding: 5.60 (lvlpd) / 2.88      FoS Overturning: 6.18 / 1.25  
 Bearing: 781.45 / 1675.76      FoS Bearing: 16.15 / 5.05

Name	Elev.	ka	kae	Pa	Pae	Pir	PaT	PaTs	Fssl	seisFssl	FoS OT	FoS SeisOT
1F	2.42	0.237	0.479	56	114	251	56	365	79.42	38.45	27.18	3.21
1	0.00	0.237	0.479	263	533	503	263	1036	5.60	2.88	6.18	1.25

**Design Approach:**

The design is a 'top down' approach. The values shown in the table[ka, kae, Pa, etc.] are the values from the top of wall to the base of that row. For trial wedge analysis, the ka and kae are back-calculated from the Pa, Pae values.

**Column Descriptions:**

- ka: active earth pressure coefficient
- kae: active seismic earth pressure coefficient
- Pa: active earth pressure
- Pae: dynamic earth pressure
- Pir: inertia force
- Paq: live surcharge earth pressure
- Paq2: live load 2 surcharge earth pressure
- Paqd: dead surcharge earth pressure
- (PaC): reduction in load due to cohesion
- PaT: sum of all earth pressures
- Fssl(lvl Pad): factor of safety for sliding at each layer. (FS sliding below the leveling pad)
- FSot: factor of safety of overturning about the toe.

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



DESIGN DATA

TARGET DESIGN VALUES (Factors of Safety - Static / Seismic)

Minimum Factor of Safety for the sliding along the base	FSsl = 1.50 /1.125
Minimum Factor of Safety for overturning about the toe	FSot = 1.50 /1.125
Minimum Factor of Safety for bearing (foundation shear failure)	FSbr = 2.00 /1.500

MINIMUM DESIGN REQUIREMENTS

Minimum embedment depth	Min_emb = 0.50 ft
-------------------------	-------------------

INPUT DATA

Geometry

Wall Geometry

Design Height, top of leveling pad to top of wall	H = 4.50 ft
Design Height External, top of leveling pad to finished grade at top of wall	he = 4.50 ft
Embedment, measured from top of leveling pad to finished grade	emb = 0.50 ft
Leveling Pad Depth	Thickness = 0.30 ft
Face Batter, measured from vertical	i = 0.00 deg

Slope Geometry

Back Slope Angle, measured from horizontal	$\beta$ = 0.00 deg
Back Slope Toe Offset, measured from back of the face unit	STL_offset = 0.00 ft
Back Slope Length, measured from toe to crest	SL_Length = 0.00 ft

NOTE: If the back slope toe is offset or the slope breaks within three times the wall height, a Coulomb Trial Wedge method of analysis is used.

Toe Slope Angle, measured from horizontal	$\beta$ = 0.00 deg
Toe Slope Crest Offset, measured from front of the face unit	STL_offset = 0.00 ft
Toe Slope Length, measured from crest to toe	SL_Length = 0.00 ft

Surcharge Loading

Live Load, assumed transient loading (e.g. traffic)	LL = 0.00 lbf/ft <sup>2</sup>
Live Load Offset, measured from back face of wall	LL_offset = 0.00 ft
Live Load Width, assumed strip loading	LL_width = 0.00 ft

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final design or construction without the independent review, verification, and approval by a qualified professional engineer.



Soil Parameters

Retained Zone

Angle of Internal Friction	$\Phi = 32.00$ deg
Cohesion	coh = 0.00 lbf/ft <sup>2</sup>
Moist Unit Weight	$\gamma = 110.00$ lbf/ft <sup>3</sup>

Foundation

Angle of Internal Friction	$\Phi = 36.00$ deg
Cohesion	coh = 0.00 lbf/ft <sup>2</sup>
Moist Unit Weight	$\gamma = 130.00$ lbf/ft <sup>3</sup>

Leveling Pad

Angle of Internal Friction	$\Phi = 40.00$ deg
Cohesion	coh = 0.00 lbf/ft <sup>2</sup>
Moist Unit Weight	$\gamma = 135.00$ lbf/ft <sup>3</sup>

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## RETAINING WALL UNITS

### STRUCTURAL PROPERTIES:

N is the normal force [or factored normal load] on the base unit

The default leveling pad to base unit shear is  $0.8 \tan(\Phi)$  [AASHTO 10.6.3.4] or

may be the manufacturer supplied data.  $\Phi$  is assumed to be 40 degrees for a stone leveling pad.

Unit	Aggr_Vol (cf)	Aggr_Density (pcf)	Aggr_CG (in)	Equiv_Density (pcf)	Equiv_CG (in)
Cap	0.00	105	14.75, 7.37	0	NaN
Full Cap	0.00	105	14.75, 14.75	0	NaN
Full	0.00	105	14.75, 14.75	0	NaN
Double	0.00	105	29.50, 14.75	0	NaN

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final design or construction without the independent review, verification, and approval by a qualified professional engineer.



## CALCULATION RESULTS

### OVERVIEW

UltraWall calculates stability assuming the wall is a rigid body. Forces and moments are calculated about the base and the front toe of the wall. The base block width is used in the calculations. The concrete units and granular fill over the blocks are used as resisting forces.

### EARTH PRESSURES

The method of analysis uses the Coulomb Earth Pressure equation (below) to calculate active earth pressures. Wall friction is assumed to act at the back of the wall face. The component of earth pressure is assumed to act perpendicular to the boundary surface. The effective  $\delta$  angle is  $\delta$  minus the wall batter at the back face. If the slope breaks within the failure zone, a trial wedge method of analysis is used.

### EXTERNAL EARTH PRESSURES

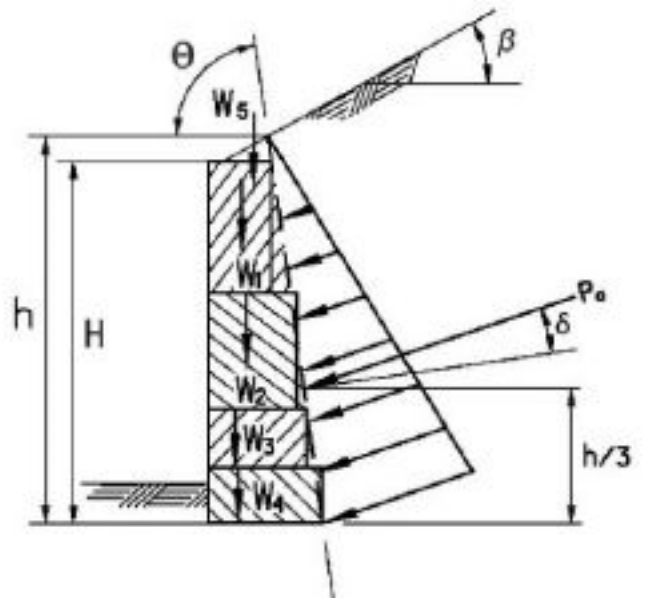
Effective  $\delta$  angle (2/3 retained phi)  
Coefficient of active earth pressure

$\delta = 21.3$  deg  
 $k_a = 0.237$

External failure plane  
Effective Angle from horizontal  
Coefficient of passive earth pressure:  $k_p = (1 + \sin(\Phi)) / (1 - \sin(\Phi))$

$\rho = 55$  deg  
 $\theta = 95.70$  deg  
 $k_p = 0.00$

$$K_a := \frac{\cos^2(\phi_1 + i)}{\cos^2(i) \cdot \cos(\delta_1 - i) \left( 1 + \frac{\sin(\phi_1 + \delta_1) \cdot \sin(\phi_1 - \beta)}{\cos(\delta_1 - i) \cdot \cos(i + \beta)} \right)^2}$$



where:

- $\delta$  = friction angle between fill and wall (degrees)
- $\beta$  = angle of fill to the horizontal (degrees)
- $\theta$  = angle of back face of wall to the horizontal (degrees)
- $\omega$  = angle of wall batter (degrees) =  $\theta - 90$
- $\Phi'$  = effective angle of internal friction (degrees)

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



## FORCE DETAILS

The details below shown how the forces are calculated for each force component. The values shown are not factored. All loads are based on a unit width (lbf/ft or kN/m).

Layer	Block Wt lbf	Soil Infill Wt lbf	Soil Wedge Wt lbf
1	846.08	0	0
2	846.08	0	

Block Weight = 1692.15 lbf/ft

X-Arm = 1.47 ft

Soil Infill Weight = 0.00 lbf/ft

X-Arm = 0.00 ft

Soils Wedge Weight = volume x Drain rock density

0.00 \* 120.00 = 0.00 lbf/ft

X-Arm = 0.00 ft

Active Earth Pressure Pa = 263.45 lbf/ft

$Pa_h (W9) = Pa \cos(\delta - \omega) = 263.45 \times \cos(21.33 - (5.70)) = 254 \text{ lbf/ft}$

Y-Arm = 1.58 ft

$Pa_v (W9) = Pa \sin(\delta - \omega) = 263.45 \times \sin(21.33 - (5.70)) = 0 \text{ lbf/ft}$

X-Arm = 2.62 ft

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



**FORCES AND MOMENTS**

The program resolves all the geometry into simple geometric shapes to make checking easier. All x and y coordinates are referenced to a zero point at the toe of the bottom unit.

**LOADS FOR OVERTURNING ABOUT THE TOE**

Name	Force(V) lbf	Force(H) lbf	X-len ft	Y-len ft	Mo ft-lbf	Mr ft-lbf
Face Blocks (W1)	1692.15		1.466			2480.01
Pa_h (W9)		253.71		1.581	401.21	
Pa_v (W9)	0.00		2.616			0.00
Sum V / H	1,692	254		Sum Mom	401	2,480

W0: stone within units

W1: facing units

W2: soil wedge behind the face

X-Len: is measured from the front of the base block (+) Driving, (-) Resisting.

Pa\_h (W9): horizontal earth pressure

Pa\_v (W9): vertical earth pressure

Pq\_h: horizontal surcharge pressure

Pq\_v: vertical surcharge pressure

**BEARING LOADS: NCMA**

All x and y coordinates are referenced to a zero point at the middle of the base block for eccentricity calculations.

Name	Force(V) lbf	Force(H) lbf	X-len ft	Y-len ft	Mo ft-lbf	Mr ft-lbf
Face Blocks (W1)	1692.15		-0.243			-788.51
Pa_h (W9)		253.71		1.581	401.21	
Pa_v (W9)	0.00		-1.308			0.00
Sum V / H	1692	254		Sum Mom	401	-789

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**BASE SLIDING**

Sliding at the base is checked at the block to leveling pad interface between the base block and the leveling pad. Sliding is also checked between the leveling pad and the foundation soils.

Forces Resisting sliding =  $W1$   
1692.15

$N = 1692.15 \text{ lbf/ft}$

**Sliding between Concrete Units and Leveling Pad/Drain Mat (Rf1)**

Resisting force at pad =  $( N \times \phi \times \tan(\text{slope}) + \text{intercept} )$   
 $(1692 \times 0.8 + \tan(40.00) + 0.0)$

$RF(lVIPd) = 1420 \text{ lbf}$

Driving force is the horizontal component of

$Pah$   
253.71

$Df = 253.71$

$FSsl = Rf / Df$

$FSsl = 5.60 \text{ lbf}$

$FSslfndn = Rf1 / Df$

$FSslfndn = 100.00$

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



### ROW TO ROW SLIDING

Sliding between rows is checked at the interface between two adjacent rows.

Details of the calculation are shown on the previous page. The leveling pad interaction is now replaced with the unit/unit interaction.

Resisting Force = Normal Force x 0.8 + intercept )

Units: All units are in lbf/ft or ft-lbf/ft of wall.

### RESULTS TABLE

Elev[ ft]	Normal[ lbf/ft]	RF Concrete	Shear Intcpt	Resisting Force	Driving Force[ lbf/ft]	FS Sliding/Shear
2.42	846.08	676.86	3619.55	4296.41	54.10	79.42

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



### OVERTURNING ABOUT THE TOE

Overturning at the base is checked by assuming rotation about the front toe by the block mass and the soil retained on the blocks. Allowable overturning can be defined by factor of safety of overturning. For concrete leveling pads overturning is checked at the base of the pad.

Moments Resisting Overturning = M1  
2480.01

Mr = 2480.01 ft-lbs

Moments causing Overturning = MPah  
401.21

Mo = 401.21 ft-lbs

FSot = Mr / Mo  
FSot = 2480.01 / 401.21

FSot = 6.18

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



### OVERTURNING ABOUT THE ROW BELOW

Overturning at the row below is checked by assuming rotation about the front toe by the block mass and the soil retained on the blocks. Allowable overturning can be defined by Factor of safety of Overturning. For concrete leveling pads overturning is checked at the base of the pad.

$$\text{Factor of Safety Overturning} = \text{Moment Resisting} / \text{Moment Driving}$$

### RESULTS TABLE

Elev[ ft]	Mr[ ft-lbf]	Mo[ lbf/ft]	FS Overturning
2.42	1138.12	41.88	27.18

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



## ECCENTRICITY AND BEARING

Eccentricity is the calculation of the distance of the resultant measured from the centroid of base. In wall design the eccentricity is used to calculate an effective footing width and bearing pressure.

Calculation of Eccentricity

SumV = + W1

+ 1692.15

Moment Resisting

Moment Driving

SumV = 1692.15 lbf

Mr = 788.51 ft-lbf

Md = 401.21 ft-lbf

$$e = (\text{SumMr} + \text{SumMd}) / (\text{SumV})$$

$$e = (788.51 - 401.21) / 1692.15$$

$$e = 0.229 \text{ ft}$$

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final design or construction without the independent review, verification, and approval by a qualified professional engineer.



BEARING

Bearing Capacity Factors [Foundation]

Nc = 50.59 Myerhoff Eqn  
Nq = 37.75 Myerhoff Eqn  
Ng = 56.31 Vesic Eqn

Shape Factors [Foundation]

Sc = 1.07  
Sq = 1.07  
Sg = 0.96

Depth Correction Factor

df = 1.08

Modified Bearing Capacity Factors [Foundation]

Ncm = Nc x Sc = 54.36  
Nqm = Nq x Sq x df = 43.64  
Ngm = Ng x Sg = 54.06

Water Correction Factor

Cwq = 1.00  
Cwg = 1.00

Base width at foundation, B'f

B'f = B - 2e + l/Pad Thickness (Bearing area at foundation)  
2.46 - 2 x 0.23 + 0.30

B'f = 2.30 ft

q = embedment \* γ  
= 0.50 x 130.00

q = 65.00 lbf/ft2

Calculation of Bearing Pressures on Foundation

qr = (c \* Ncm) + (q \* Nqm \* Cwq) + 0.5 \* γ \* B'f \* Ngm \* Cwg  
[(0.00 x 54.36) + (65.00 x 43.64 x 1.00) + (0.5 x 130.00 x 2.30 x 54.06 x 1.00)]

qult = 12622.41 lbf/ft2

Nbrg = Bearing at Foundation Level

NBrg = 1798 lbf/ft2

Calculate Ultimate Bearing, qult

qult = 12622.41 lbf/ft2

Bearing Pressures (σ)

Nbrg/B'f = 781.45 lbf/ft2

Calculated Factor of safety for bearing

qult/σ = 16.15

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



## SEISMIC CALCULATIONS

The loads considered under seismic loading are primarily inertial loadings. The wave passes the structure putting the mass into motion and then the mass will try to continue in the direction of the initial wave. In the calculations you see the one dynamic earth pressure from the wedge of the soil behind the reinforced mass, and then all the other forces come from inertia calculations of the face put into motion and then trying to be held in place.

$$k_{max} = PGA \times F_{pga} = 0.627 \times 1.1$$

$$\text{Displacement (d)}$$

$$k_{hint} = k_{hext} = 0.74 A (A/d)^{0.25}$$

$$k_{max} = 0.690g$$

$$d = 6.0 \text{ in}$$

$$k_{h(ext)} = 0.297$$

Vertical Acceleration

$$k_v = 0.000$$

### EXTERNAL $K_{ae\_ext}$

$$K_{ae\_ext}$$

$$D_{K_{ae\_ext}} = K_{ae\_ext} - K_a = (0.479 - 0.237)$$

$$P_{ae\_ext} = 0.5 \times \gamma \times (H)^2 \times D_{K_{ae\_ext}}$$

$$P_{ae\_h/2} = P_{ae} \times \cos(\delta)/2$$

$$P_{ae\_v/2} = P_{ae} \times \sin(\delta)/2$$

$$K_{ae\_ext} = 0.479$$

$$D_{K_{ae\_ext}} = 0.242$$

$$P_{ae} = 270 \text{ lbf/ft}$$

$$P_{ae\_h/2} = 126 \text{ lbf/ft}$$

$$P_{ae\_v/2} = 49 \text{ lbf/ft}$$

### INERTIA FORCES OF THE STRUCTURE

$$\text{Face (Pir)} = (W_0 + W_1) \times k_{h(ext)} = (0 + 1,692) \times 0.297$$

$$P_{ir} = 503 \text{ lbf/ft}$$

### MONONOBE-OKABE EQ (REF AASHTO A11.3.1.1)

$$K_{AE} = \frac{\cos^2(\phi - \theta_{MO} - \beta)}{\cos \theta_{MO} \cos^2 \beta \cos(\delta + \beta + \theta_{MO})} \times \left[ 1 + \sqrt{\frac{\sin(\phi + \delta) \sin(\phi - \theta_{MO} - i)}{\cos(\delta + \beta + \theta_{MO}) \cos(i - \beta)}} \right]^{-2} \quad (A11.3.1-1)$$

where:

- $K_{AE}$  = seismic active earth pressure coefficient (dim)
- $\gamma$  = unit weight of soil (kcf)
- $H$  = height of wall (ft)
- $h$  = vertical distance between ground surface and wall base at the back of wall heel (ft)
- $\phi_f$  = friction angle of soil (degrees)
- $\theta_{MO}$  = arc tan  $[k_h/(1 - k_v)]$  (degrees)
- $\delta$  = wall backfill interface friction angle (degrees)
- $k_h$  = horizontal seismic acceleration coefficient (dim.)
- $k_v$  = vertical seismic acceleration coefficient (dim.)
- $i$  = backfill slope angle (degrees)
- $\beta$  = slope of wall to the vertical, negative as shown (degrees)

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.



## SEISMIC SLIDING

The target factor of safety for seismic is 75% of the static value. Live loads are ignored in these analysis based on the basic premise that the probability of the maximum acceleration occurring at the exact same instant as the maximum live load is small.

Details are only shown for sliding at the base of blocks, a check is made at the foundation level with the answer only shown.

The vertical resisting forces is  $W1 + W2 + Pav + Paev$

$$1692 + 0 + 0 + 73$$

$$\text{SumVs} = 1764.83$$

Resisting force =  $\text{SumVs} * \tan(\phi) + \text{intercept} * L$

$$\text{FRe} = 1480.87 \text{ lbf/ft}$$

Driving force =  $Pa\_h + Pae\_h + Pir$

$$= 253.71 + 259.71 + 502.57$$

$$\text{FDr} = 513.41 \text{ lbf/ft}$$

FOS =  $\text{FRe}/\text{FDr}$  [leveling pad / foundation]

$$\text{FoS} = 2.88 / 2.65$$

## SEISMIC OVERTURNING

Overturning is rotation about the front toe of the wall. Eccentricity is also a check on overturning

Resisting Moment =  $M1 + M2 + MPav + MPaev$

$$2480 + 0 + 0 + 195$$

$$\text{SumMrS} = 2674.99 \text{ ft lbf/ft}$$

Driving Moment =  $MPah + MPaeh + MPif$

$$401 + 616 + 1131$$

$$\text{SumMoS} = 2148.04 \text{ ft lbf/ft}$$

Factor of Safety =  $\text{SumMrS}/\text{SumMoS}$

$$\text{FoS} = 1.25$$

## SEISMIC BEARING

Bearing is the ability of the foundation to support the mass of the structure.

$$Qult = c * Nc + q * Nq + 0.5 * \gamma * (B') * Ng$$

where:

$$Nc = 50.59 \text{ Myerhoff Eqn}$$

$$Nq = 37.75 \text{ Myerhoff Eqn}$$

$$Ng = 56.31 \text{ Vesic Eqn}$$

$$c = 0.00 \text{ lbf/ft}^2$$

$$q = 104.00 \text{ lbf/ft}^2$$

Calculate Ultimate Bearing,  $Qult$  (seismic)

$$Qult = 8460.74 \text{ lbf/ft}^2$$

eccentricity (e)

$$e = 0.821$$

Equivalent Footing Width,  $B' = L - 2e + |e|$  pad

$$B' = 1.12 \text{ ft}$$

Bearing Pressure =  $\text{sumVs}/B'$

$$\sigma = 1675.76 \text{ lbf/ft}^2$$

Factor of Safety for Bearing =  $Qult/\text{Bearing}$

$$\text{FoS} = 5.05$$

Note: Calculations and quantities are for PRELIMINARY ANALYTICAL USE ONLY and MUST NOT be used for final n or construction without the independent review, verification, and approval by a qualified professional engineer.