



Client: ODOT/District 6  
Project: FRA-70 Project 4B  
Subject: Wall 4W22 Design

Job No.: 2015370  
Page No.: 1 Of 3  
Designed: DJC Date: 1/18/2022  
Checked: MOJ Date: 7/11/2022

### Spread Footing Retaining Wall Design

Based on AASHTO LRFD Bridge Design Specifications (9th edition) and the 2020 ODOT BDM.

#### Wall Data:

Concrete Unit Weight,  $\gamma_c$  = 0.150 kcf  
Toe Height,  $H_{toe}$  = 2.25 ft  
Heel Height,  $H_h$  = 2.00 ft  
Wall Height,  $H_w$  = 11.35 ft  
Total Height,  $H_T = H_w + H_{toe}$  = 13.60 ft  
Soil Height over Heel,  $H_1 = H_T - H_h + (W_h \cdot S_d)$  = 11.60 ft  
Max. Soil Height over Toe,  $H_2$  = 4.00 ft  
Future Loss of Soil over Toe,  $H_L$  = 0.00 ft  
Min. Soil Height over Toe,  $H_3 = \max(0, H_2 - H_L)$  = 4.00 ft  
Depth of Disturbance,  $H_d$  = 2.67 ft  
Wall Width,  $W_w$  = 4.26 ft  
Toe Width,  $W_{toe}$  = 2.41 ft  
Heel Width,  $W_h$  = 2.83 ft  
Additional Wall,  $W_{w1}$  = 0.00 ft  
Theta,  $\theta$  = 90.00 deg.  
Footing Width,  $W_f$  = 9.50 ft

#### Soil Data:

Is Retained Soil Sloped? No  
Slope of Embankment,  $S_e$  = 0.00  
Beta,  $\beta$  = 0.00 deg.  
Include Surcharge over Heel? Yes  
Include Surcharge over Toe? Yes  
Is traffic less than  $(H_h + H_1)/2$  from back of ftg.? Yes  
Dist. from back of ftg. to edge of traffic = -2.83 ft  
Minimum Soil Unit Weight for LLS,  $\gamma_{soil LLS}$  = 0.125 kcf  
Surcharge Height behind Wall,  $H_s$  = 2.96 ft  
Surcharge Height in front of Wall,  $H_{sf}$  = 4.63 ft  
 $P_{soil LLS} = \gamma_{soil LLS} \cdot (K_a \text{ or } K_p)$  = 37.16 pcf  
Active or At Rest Pressure? Active  
Retained Soil Unit Weight,  $\gamma_{soil}$  = 0.120 kcf  
Footing Resting On? Granular  
Internal Friction Angle of Soil,  $\delta$  = 35.00 deg.  
Internal Friction Angle of Fill,  $\phi_{fill}$  = 30.00 deg.  
Friction Angle between Fill & Wall,  $\delta$  = 20.00 deg.  
Active Lateral Earth Press. Coefficient,  $K_a$  = 0.30  
 $P_{soil} = \gamma_{soil} \cdot (K_a \text{ or } K_p)$  = 35.68 pcf  
Bearing on soil or rock? Soil  
Factor Bearing Resistance (Strength) = 15.155 ksf  
Bearing Capacity (Service) = 5.060 ksf  
Consider Passive Force on Toe? No  
Passive Lat. Earth Pressure Coeff.,  $K_p$  = 3.00

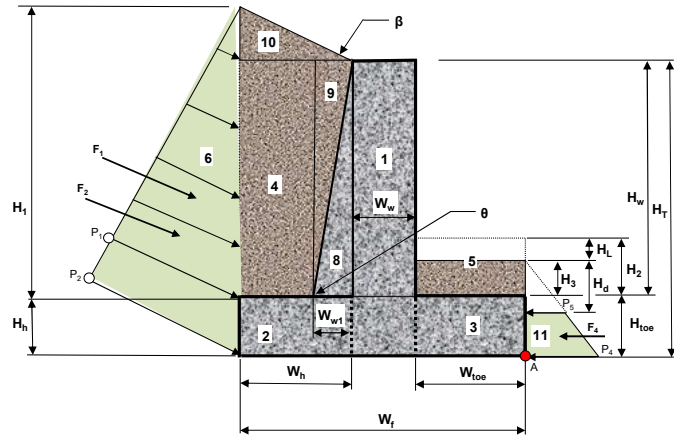
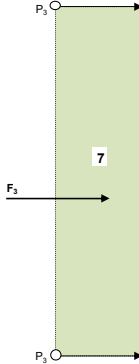
#### Soil Pressure Calculations:

$P_1 = P_{soil} \cdot H_T / 1000$  = 0.41 ksf  
 $P_2 = P_{soil} \cdot (H_1 + H_h) / 1000$  = 0.49 ksf  
 $P_3 = H_s \cdot P_{soil LLS} / 1000$  = 0.11 ksf  
 $P_4 = \gamma_{soil} \cdot K_p \cdot (H_{toe} + H_2 - H_L)$  = 2.25 ksf  
 $P_5 = \gamma_{soil} \cdot K_p \cdot H_d$  = 0.96 ksf

#### Soil Sliding Force Calculations:

$F_1 = P_1 \cdot H_T \cdot 0.5$  = 2.40 kips  
 $F_2 = P_2 \cdot (H_1 + H_h) \cdot 0.5$  = 3.30 kips  
 $F_3 = P_3 \cdot H_1$  = 1.50 kips  
 $F_4$  (Trapezoid 11) = 0.00 kips

Additional Dead Load = 0.92 kips  
Moment Arm for Additional Dead Load = 5.59 ft



LRFD 3.11.6.4  
BDM 307.1.1  
LRFD Table 3.11.6.4-1

BDM Table 307-1

@ Base of the Footer

LRFD 3.11.5.3  
LRFD 3.11.5.3-1 (Coulomb)

LRFD 10.6.1.4

To Check Settlement

$K_p = \tan^2(45^\circ + \phi/2)$

#### Horizontal Sliding Resistance:

LRFD 10.6.3.4

For cohesionless soils:

$V_{min} = 16.09$  kips  
Resistance,  $R_t = V_{min} \cdot \tan(\delta)$  = 11.27 kips

For cohesive soils:

The lesser of:  
 $C_u = N.A.$  ksf  
 $0.5 \cdot c_u = N.A.$  ksf  
Unit Shear Resistance: Use = N.A. ksf  
Resistance,  $R_t = N.A.$  kips

Manual Override:

Override Friction Factor = N.A.  
Resistance,  $R_t = N.A.$  kips

#### Typical values for friction factor:

LRFD Table C3.11.5.3-1

rock = 0.70  
course grained soil w/out silt = 0.55  
course grained soil w/silt = 0.45

Additional friction factors for other common substrates  
shale = 0.55  
silt = 0.35

Assumes 1.25 max. & 0.90 min. load factors.  
from Point A

#### Force and Moment Arm Calculations:

Area 1 = $\gamma_c \times W_w \times H_T$ =	0.150 kcf	x	4.26 ft.	x	13.60 ft.	x	1.00 ft.	=	8.69 kips	
Arm 1 = $W_{toe} + W_w / 2$ =	2.41 ft.	+	4.26 ft.		/	2.00	=	4.71 ft.		
Area 2 = $\gamma_c \times W_h \times H_h$ =	0.150 kcf	x	2.83 ft.	x	2.00 ft.	x	1.00 ft.	=	0.85 kips	
Arm 2 = $W_{toe} + W_w + W_h / 2$ =	2.41 ft.	+	4.26 ft.	+	2.83 ft.	/	2.00	=	8.08 ft.	
Area 3 = $\gamma_c \times W_{toe} \times H_{toe}$ =	0.150 kcf	x	2.41 ft.	x	2.25 ft.	x	1.00 ft.	=	0.81 kips	
Arm 3 = $W_{toe} / 2$ =	2.41 ft.		/	2.00	=				1.20 ft.	
Area 4 = $\gamma_h \times (W_h - W_{w1}) \times H_w$ =	0.120 kcf	x	( 2.83 ft. -	0.00 ft. )	x	11.35 ft.	x	1.00 ft.	=	3.86 kips
Arm 4 = $W_{toe} + W_w + W_{w1} + (W_h - W_{w1}) / 2$ =	2.41 ft.	+	4.26 ft.	+	0.00 ft.	+	( 2.83 ft. -	0.00 ft. ) / 2	=	8.08 ft.
Area 5 (Max.) = $\gamma_s \times W_{toe} \times H_2$ =	0.120 kcf	x	2.41 ft.	x	4.00 ft.	x	1.00 ft.	=	1.16 kips	
Area 5 (Min.) = $\gamma_s \times W_{toe} \times H_3$ =	0.120 kcf	x	2.41 ft.	x	4.00 ft.	x	1.00 ft.	=	1.16 kips	
Arm 5 = $W_{toe} / 2$ =	2.41 ft.		/	2.00	=				1.20 ft.	
Area 6 (Horiz. Comp.) = $F_2 \times \cos(\delta)$ =	3.30 kips	x	cos (	20.00 deg. )	=				3.10 kips	
Arm 6 = $(H_1 + H_h) / 3$ =	( 11.60 ft. +		2.00 ft. )	/	3.00	=			4.53 ft.	
Area 6 (Vertical Comp.) = $F_2 \times \sin(\delta)$ =	3.30 kips	x	sin (	20.00 deg. )	=				1.13 kips	
Arm 6 = $W_f$ =	9.50 ft.								9.50 ft.	
Area 7 = $F_3$ =	1.50 kips								1.50 kips	

Revised for wall geometry.



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Arm 7 = $(H_1 + H_2) / 2 =$	( 11.60 ft. + 2.00 ft. ) / 2.00 =	6.80 ft.
Area 8 = $0.5 \times \gamma_c \times W_{w1} \times H_{w1} =$	0.5 x 0.150 kcf x 0.00 ft. x 11.35 ft. x 1.00 ft. =	0.00 kips
Arm 8 = $W_{toe} + W_w + W_{w1} / 3 =$	2.41 ft. + 4.26 ft. + 0.00 ft. / 3.00 =	6.67 ft.

#### Force and Moment Arm Calculations (Continued):

Area 9 = $0.5 \times \gamma_c \times W_{w1} \times H_{w1} =$	0.5 x 0.120 kcf x 0.00 ft. x 11.35 ft. x 1.00 ft. =	0.00 kips
Arm 9 = $W_{toe} + W_w + W_{w1} \times 2/3 =$	2.41 ft. + 4.26 ft. + 0.00 ft. x 2.00 / 3.00 =	6.67 ft.
Area 10 = $0.5 \times \gamma_c \times (S_u \times W_{h1}) \times W_{h1} =$	0.5 x 0.120 kcf x ( 0.00 x 2.83 ft. ) x 2.83 ft. x 1.00 ft. =	0.00 kips
Arm 10 = $W_F - W_{h1} / 3 =$	9.50 ft. - 2.83 ft. / 3.00 =	8.56 ft.
Area 11 = $F_d =$	0.00 kips	0.00 kips
Surcharge on Heel = $\gamma_{soil} \times W_h \times H_s =$	0.125 kcf x 2.83 ft. x 2.96 ft. x 1.00 ft. =	1.05 kips
Arm for Heel Surcharge = $W_F - W_{h1} / 2 =$	9.50 ft. - 2.83 ft. / 2.00 =	8.08 ft.
Surcharge on Toe = $\gamma_{soil} \times W_{toe} \times H_{toe} =$	0.125 kcf x 2.41 ft. x 4.63 ft. x 1.00 ft. =	1.39 kips
Arm for Toe Surcharge = $W_{toe} / 2 =$	2.41 ft. / 2.00 =	1.20 ft.

#### Check Bearing Pressure:

per BDM 307.1.5 and LRFD 11.6.3.2.

Factored Bearing Resistance = 15.15 ksf

Maximum Strength Load Pressures:

Bearing pressure at Toe = 3.31 ksf OK  
Bearing pressure at Heel = 3.31 ksf OK

#### Check Eccentricity:

per BDM 307.1.4 and LRFD 11.6.3.3.

Maximum Allowable e = B/3 = 3.17 ft  
Controlling Eccentricity = 1.35 ft OK

#### Check Sliding:

per BDM 307.1.3 and LRFD 11.6.3.6.

Resistance factor,  $\phi_r$  (Sliding) = 1.00 LRFD Table 11.5.7-1

Resistance factor,  $\phi_{ep}$  (Passive pressure) = 0.50 LRFD Table 10.5.5.2.2-1

Sliding Resistance:

Unfactored Horizontal Sliding Resistance = 11.27 kips  
Factored Horizontal Sliding Resistance = 11.27 kips

Passive Resistance on Footing Toe:

Unfactored Passive Resistance = 0.00 kips  
Factored Passive Resistance = 0.00 kips

Passive Resistance on Footing Key or Sheet Piling (Below bottom of Footing):

Vertical Projection Below Footing = 0.00 ft

Pressure at Bottom of Footing ( $P_d$ ) = 2.25 ksf  
Pressure at Bottom of Disturbance ( $P_d$ ) = 0.96 ksf  
Pressure at Bottom of Key or Sheet Piling = 2.25 ksf

Unfactored Passive Resistance = 0.00 kips  
Factored Passive Resistance = 0.00 kips

Total Factored Resisting Force = 11.27 kips  
Driving Force = 7.27 kips OK

#### Check Settlement:

Service Bearing Capacity = 5.06 ksf  
Service Bearing Pressure at Toe = 2.28 ksf OK  
Service Bearing Pressure at Heel = 2.28 ksf OK

#### Summary of Load Effects:

	MAX. BEARING PRESSURE	MIN. BEARING PRESSURE	ECCENTRICITY MAX. LF	ECCENTRICITY MIN. LF	SLIDING FORCES MAX. LF	VERTICAL FORCES MIN. LF
STRENGTH I	3.31	3.31	1.13	1.35	7.27	16.09
SERVICE I	2.28	2.28	0.81	N/A	4.60	16.57

#### Load Modification Factors:

LRFD 1.3.3, LRFD 1.3.4, LRFD 1.3.5, & BDM 1001

Ductility  $\eta_D = 1.00$  (use 1.00 for all limit states)  
Redundancy  $\eta_R = 1.00$  (use 1.00 for redundant structures and 1.05 for non-redundant structures)  
Operational importance  $\eta_I = 1.00$  (use 1.00 for all limit states)



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### STRENGTH I Load Combination

#### Sliding Forces & Overturning Moments

1.50\*EH+1.75\*LS(H). Ignores resisting moments from passive force on toe/key/sheeting, which is conservative.

ΣM about point "A"

Area/Force	Unfactored Load	Load Factor	Force (k)	Moment Arm (ft)	Moment (k-ft)	Max. Load Factor
6 (Horizontal comp.)	3.10	1.50	4.65	4.53	21.08	
7	1.50	1.75	2.62	6.80	17.80	
Σ Sliding Forces, F <sub>s</sub> =						7.27 kips
Σ Overturning Moments =						38.89 k*ft.

#### Vertical Forces & Resisting Moments

1.5\*DC+1.35\*EV+1.75\*LS<sub>v</sub> (Max.) 0.9\*DC+1.0\*EV (Min.)

ΣM about point "A"

Note: Area 1 load factors revised for wall geometry.

Area/Force	Force (k)			Force (k)			Force (k)			Moment (k-ft)			Moment (k-ft)			
	Unfactored Load	Max. Load Factor		Max. Load Factor	Min. Load Factor		Min. Load Factor			Max. Load Factor			Min. Load Factor			
1	8.69	1.13		9.80	0.81		7.06		4.71		46.19		33.26			Dead Loads From Concrete
2	0.85	1.25		1.06	0.90		0.77		8.08		8.59		6.18			
3	0.81	1.25		1.02	0.90		0.73		1.20		1.22		0.88			
8	0.00	1.25		0.00	0.90		0.00		6.67		0.00		0.00			
4	3.86	1.35		5.21	1.00		3.86		8.08		42.11		31.19			Dead Loads From Soil (Do not include 5 (Min.) and 5 (Max.) simultaneously)
5 (Max.)	1.16	1.35		1.56	1.00		1.16		1.20		1.88		1.39			
5 (Min.)	1.16	1.35		1.56	1.00		1.16		1.20		1.88		1.39			
6 (Vertical comp.)	1.13	1.50		1.69	1.50		1.69		9.50		16.08		16.08			
9	0.00	1.35		0.00	1.00		0.00		6.67		0.00		0.00			External Loads
10	0.00	1.35		0.00	1.00		0.00		8.56		0.00		0.00			
Surcharge on Heel	1.05	1.75		1.83	0.00		0.00		8.08		14.83		0.00			
Surcharge on Toe	1.39	1.75		2.43	0.00		0.00		1.20		2.93		0.00			
DC	0.92	1.25		1.16	0.90		0.83		5.59		6.46		4.65			
Σ Vert. Forces =			23.93 kips			Σ Vert. Forces =			16.09 kips			Σ Resist. Moments =			125.46 k*ft.	
															93.64 k*ft.	

Note: Calculations for each controlling load case are not necessarily shown below, but have been included in the design checks.

Max. Load Factor Calculations (Worst case bearing pressure shown.)				Min. Load Factor Calculations (Worst case eccentricity shown.)			
Overturning Moment = Σ Overturning Moments =	38.89 k-ft.			Overturning Moment = Σ Overturning Moments =	38.89 k-ft.		
Resisting Moment = Σ Max. Resisting Moments =	125.46 k-ft.			Resisting Moment = Σ Min. Resisting Moments =	93.64 k-ft.		
Net Moment = Resisting Moment - Overturning Moment =	86.57 k-ft.			Net Moment = Resisting Moment - Overturning Moment =	54.75 k-ft.		
Total Vertical Force (TVF) = Σ Vert. Forces =	23.93 kips			Total Vertical Force (TVF) = Σ Vert. Forces =	16.09 kips		
Dist. from Point A (Ā) = Net. Moment / TVF =	3.62 ft.			Dist. from Point A (Ā) = Net. Moment / TVF =	3.40 ft.		
Eccentricity "e" = (0.5*W <sub>t</sub> ) - Ā =	1.13 ft.			Eccentricity "e" = (0.5*W <sub>t</sub> ) - Ā =	1.35 ft.		
Maximum Bearing Pressure = TVF/(Wf-2*e) =	3.31 ksf						
Minimum Bearing Pressure = TVF/(Wf+2*e) =	3.31 ksf						

### SERVICE I Load Combination

#### Sliding Forces & Overturning Moments

1.0\*EH+1.0\*LS<sub>H</sub>. Ignores resisting moments from passive force on toe/key/sheeting, which is conservative.

ΣM about point "A"

Area/Force	Unfactored Load	Load Factor	Force (k)	Moment Arm (ft)	Moment (k-ft)	Max. Load Factor
6 (Horizontal comp.)	3.10	1.00	3.10	4.53	14.06	
7	1.50	1.00	1.50	6.80	10.17	
Σ Sliding Forces, F <sub>s</sub> =						4.60 kips
Σ Overturning Moments =						24.23 k*ft.

#### Vertical Forces & Resisting Moments

1.0\*DC+1.0\*EV+1.0\*LS<sub>v</sub>

ΣM about point "A"

Note: Area 1 load factor revised for wall geometry.

Dead Load (kips)						
Area/Force	Force (k)		Force (k)	Moment Arm (ft)	Moment (k-ft)	
1	8.69	0.90	7.84	4.71	36.95	Dead Loads From Concrete
2	0.85	1.00	0.85	8.08	6.87	
3	0.81	1.00	0.81	1.20	0.98	
8	0.00	1.00	0.00	6.67	0.00	
4	3.86	1.00	3.86	8.08	31.19	Dead Loads From Soil (Do not include 5 (Min.) and 5 (Max.) simultaneously)
5 (Max.)	1.16	1.00	1.16	1.20	1.39	
5 (Min.)	1.16	1.00	1.16	1.20	1.39	
6 (Vertical comp.)	1.13	1.00	1.13	9.50	10.72	
9	0.00	1.00	0.00	6.67	0.00	
10	0.00	1.00	0.00	8.56	0.00	External Loads
Surcharge on Heel	1.05	1.00	1.05	8.08	8.47	
Surcharge on Toe	1.39	1.00	1.39	1.20	1.67	
DC	0.92	1.00	0.92	5.59	5.17	
Σ Vert. Forces =			19.01 kips	Σ Resisting Moments =		103.42 k-ft.

Note: Calculations for each controlling load case are not necessarily shown below, but have been included in the design checks.

#### Calculations for worst case bearing pressure shown.

Overturning Moment = Σ Overturning Moments =	24.23 k-ft.
Resisting Moment = Σ Max. Resisting Moments =	103.42 k-ft.
Net Moment = Resisting Moment - Overturning Moment =	79.19 k-ft.
Total Vertical Force (TVF) = Σ Vert. Forces =	19.01 kips
Dist. from Point A (Ā) = Net. Moment / TVF =	4.17 ft.
Eccentricity "e" = (0.5*W <sub>t</sub> ) - Ā =	0.58 ft.
Maximum Bearing Pressure = TVF/(Wf-2*e) =	2.28 ksf
Minimum Bearing Pressure = TVF/(Wf+2*e) =	2.28 ksf

- Where the wall is supported by a soil foundation:
  - the vertical stress shall be calculated assuming a linearly distributed pressure over an effective base area as shown in Figure 11.6.3.2-1.
  - The vertical stress shall be calculated as follows:
$$\sigma_v = \frac{\sum V}{B - 2e} \quad (11.6.3.2-1)$$
- Where the wall is supported by a rock foundation:
  - the vertical stress shall be calculated assuming a linearly distributed pressure over an effective base area as shown in Figure 11.6.3.2-2. If the resultant is outside the middle one-third of the base:
$$\sigma_{min} = \frac{\sum V}{B} \left( 1 + 6 \frac{e}{B} \right) \quad (11.6.3.2-2)$$
  - where the variables are as defined in Figure 11.6.3.2-2.
  - where the resultant is inside the middle one-third of the base:
$$\sigma_{min} = \frac{2 \sum V}{3(B/2 - e)} \quad (11.6.3.2-4)$$
  - where the variables are as defined in Figure 11.6.3.2-2.
  - where the resultant is outside the middle one-third of the base:
$$\sigma_{min} = 0 \quad (11.6.3.2-5)$$
  - where the variables are as defined in Figure 11.6.3.2-2.