



Client: ODOT/District 6
Project: FRA-70 Project 4B
Subject: Wall 4W14 Design
Sections up to 29.50 feet tall.

Job No.: 2015370
Page No.: 1 Of 3
Designed: RFV Date: 3/18/2019
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, $H_{toe} = 4.25$ ft
Heel Height, $H_h = 4.00$ ft
Wall Height, $H_w = 29.50$ ft
Total Height, $H_T = H_w + H_{toe} = 33.75$ ft
Soil Height over Heel, $H_1 = H_T - H_h + (W_h \cdot S_d) = 29.75$ ft
Max. Soil Height over Toe, $H_2 = 5.00$ ft
Future Loss of Soil over Toe, $H_3 = 0.00$ ft
Min. Soil Height over Toe, $H_3 = \max(0, H_2 - H_L) = 5.00$ ft
Depth of Disturbance, $H_d = 2.67$ ft
Wall Width, $W_w = 1.50$ ft
Toe Width, $W_{toe} = 4.00$ ft
Heel Width, $W_h = 12.00$ ft
Additional Wall Width, $W_{w1} = 2.50$ ft
Theta, $\theta = 85.20$ deg.
Footing Width, $W_f = 17.50$ 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 < $H_T / 2$ from back of wall? Yes
Dist. from back of wall to edge of traffic = 0.00 ft
Minimum Soil Unit Weight for LLS, $\gamma_{soil LLS} = 0.125$ kcf
Surcharge Height behind Wall, $H_s = 2.00$ ft
Surcharge Height in front of Wall, $H_{sf} = 3.73$ ft
 $P_{soil LLS} = \gamma_{soil LLS} \cdot (k_a \text{ or } k_o) = 41.67$ 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, $\delta = 40.00$ 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, $k_a = 0.33$
 $P_{soil} = \gamma_{soil} \cdot (k_a \text{ or } k_o) = 40.00$ pcf
Bearing on soil or rock? Soil
Factor Bearing Resistance (Strength) = 17.368 ksf
Bearing Capacity (Service) = 10.931 ksf
Consider Passive Force on Toe? No
Passive Lat. Earth Pressure Coeff., $k_p = 3.00$

Soil Pressure Calculations:

$P_1 = P_{soil} \cdot H_T / 1000 = 1.19$ ksf
 $P_2 = P_{soil} \cdot (H_1 + H_h) / 1000 = 1.35$ ksf
 $P_3 = H_s \cdot P_{soil LLS} / 1000 = 0.08$ ksf
 $P_4 = \gamma_{soil} \cdot k_p \cdot (H_{toe} + H_2 - H_L) = 3.33$ ksf
 $P_5 = \gamma_{soil} \cdot k_p \cdot H_d = 0.96$ ksf

Soil Sliding Force Calculations:

$F_1 = P_1 \cdot H_1 \cdot 0.5 = 17.70$ kips
 $F_2 = P_2 \cdot (H_1 + H_h) \cdot 0.5 = 22.78$ kips
 $F_3 = P_3 \cdot H_1 = 2.81$ kips
 F_4 (Trapezoid 11) = 0.00 kips

Additional Dead Load = 0.70 kips
Moment Arm for Additional Dead Load = 4.71 ft

$H_T / 2 = 16.88$ 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

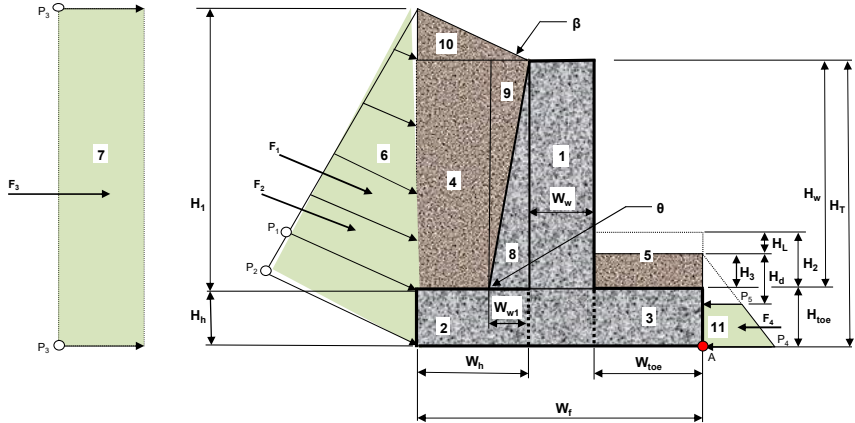
LRFD 3.11.5.3
LRFD 3.11.5.3-1 (Coulomb)

LRFD 10.6.1.4

To Check Settlement

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

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



Horizontal Sliding Resistance:

LRFD 10.6.3.4

For cohesionless soils:

Resistance, $R_t = V_{min} \cdot \tan(\delta) = 61.56$ kips

For cohesive soils:

The lesser of:
 $C_u = N.A.$ ksf
 $0.5 \cdot \sigma'_v = N.A.$ 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

Force and Moment Arm Calculations:

Area 1 = $\gamma_c \times W_w \times H_T =$	0.150 kcf	x	1.50 ft.	x	33.75 ft.	x	1.00 ft.	=	7.59 kips
Arm 1 = $W_{toe} + W_w / 2 =$	4.00 ft.	+	1.50 ft.	/	2.00	=			4.75 ft.
Area 2 = $\gamma_c \times W_h \times H_h =$	0.150 kcf	x	12.00 ft.	x	4.00 ft.	x	1.00 ft.	=	7.20 kips
Arm 2 = $W_{toe} + W_w + W_h / 2 =$	4.00 ft.	+	1.50 ft.	+	12.00 ft.	/	2.00	=	11.50 ft.
Area 3 = $\gamma_c \times W_{toe} \times H_{toe} =$	0.150 kcf	x	4.00 ft.	x	4.25 ft.	x	1.00 ft.	=	2.55 kips
Arm 3 = $W_{toe} / 2 =$	4.00 ft.	/	2.00	=					2.00 ft.
Area 4 = $\gamma_s \times (W_h - W_{w1}) \times H_w =$	0.120 kcf	x	(12.00 ft. -	2.50 ft.)	x	29.50 ft.	x	1.00 ft.	= 33.63 kips
Arm 4 = $W_{toe} + W_w + W_{w1} + (W_h - W_{w1}) / 2 =$	4.00 ft.	+	1.50 ft.	+	2.50 ft.	+	(12.00 ft. -	2.50 ft.) / 2 =	12.75 ft.
Area 5 (Max.) = $\gamma_s \times W_{toe} \times H_2 =$	0.120 kcf	x	4.00 ft.	x	5.00 ft.	x	1.00 ft.	=	2.40 kips
Area 5 (Min.) = $\gamma_s \times W_{toe} \times H_3 =$	0.120 kcf	x	4.00 ft.	x	5.00 ft.	x	1.00 ft.	=	2.40 kips
Arm 5 = $W_{toe} / 2 =$	4.00 ft.	/	2.00	=					2.00 ft.
Area 6 (Horiz. Comp.) = $F_2 \times \cos(\delta) =$	22.78 kips	x	cos (20.00 deg.)	=				21.41 kips
Arm 6 = $(H_1 + H_h) / 3 =$	(29.75 ft. +		4.00 ft.)	/	3.00	=			11.25 ft.
Area 6 (Vertical Comp.) = $F_2 \times \sin(\delta) =$	22.78 kips	x	sin (20.00 deg.)	=				7.79 kips
Arm 6 = $W_f =$	17.50 ft.								17.50 ft.
Area 7 = $F_3 =$	2.81 kips								2.81 kips
Arm 7 = $(H_1 + H_h) / 2 =$	(29.75 ft. +		4.00 ft.)	/	2.00	=			16.88 ft.
Area 8 = $0.5 \times \gamma_c \times W_{w1} \times H_w =$	0.5 x 0.150 kcf	x	2.50 ft.	x	29.50 ft.	x	1.00 ft.	=	5.53 kips
Arm 8 = $W_{toe} + W_w + W_{w1} / 3 =$	4.00 ft.	+	1.50 ft.	+	2.50 ft.	/	3.00	=	6.33 ft.



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Force and Moment Arm Calculations (Continued):

Area 9 = $0.5 \times \gamma_s \times W_{w1} \times H_{w1} =$	$0.5 \times 0.120 \text{ kcf} \times$	$2.50 \text{ ft.} \times$	$29.50 \text{ ft.} \times$	$1.00 \text{ ft.} =$	4.43 kips	
Arm 9 = $W_{toe} + W_w + W_{w1} \times 2/3 =$	$4.00 \text{ ft.} +$	$1.50 \text{ ft.} +$	$2.50 \text{ ft.} \times$	$2.00 / 3.00 =$	7.17 ft.	
Area 10 = $0.5 \times \gamma_s \times (S_a \times W_h) \times W_h =$	$0.5 \times 0.120 \text{ kcf} \times$	$(0.00 \times$	$12.00 \text{ ft.}) \times$	$12.00 \text{ ft.} \times$	$1.00 \text{ ft.} =$	0.00 kips
Arm 10 = $W_F - W_h / 3 =$	$17.50 \text{ ft.} -$	$12.00 \text{ ft.} /$	$3.00 =$		13.50 ft.	
Area 11 = $F_d =$	0.00 kips				0.00 kips	
Surcharge on Heel = $\gamma_{soil} \text{ LLS} \times W_h \times H_s =$	$0.125 \text{ kcf} \times$	$12.00 \text{ ft.} \times$	$2.00 \text{ ft.} \times$	$1.00 \text{ ft.} =$	3.00 kips	
Arm for Heel Surcharge = $W_F - W_h / 2 =$	$17.50 \text{ ft.} -$	$12.00 \text{ ft.} /$	$2.00 =$		11.50 ft.	
Surcharge on Toe = $\gamma_{soil} \text{ LLS} \times W_{toe} \times H_{st} =$	$0.125 \text{ kcf} \times$	$4.00 \text{ ft.} \times$	$3.73 \text{ ft.} \times$	$1.00 \text{ ft.} =$	1.86 kips	
Arm for Toe Surcharge = $W_{toe} / 2 =$	$4.00 \text{ ft.} /$	$2.00 =$			2.00 ft.	

Check Bearing Pressure:

per BDM 307.1.5 and LRFD 11.6.3.2.

Factored Bearing Resistance = **17.37 ksf**

Maximum Strength Load Pressures:

Bearing pressure at Toe = **8.26 ksf** **OK**
Bearing pressure at Heel = **8.26 ksf** **OK**

Check Eccentricity:

per BDM 307.1.4 and LRFD 11.6.3.3.

Maximum Allowable $e = B/3 =$ **5.83 ft**
Controlling Eccentricity = **3.68 ft** **OK**

Check Sliding:

per BDM 307.1.3 and LRFD 11.6.3.6.

Resistance factor, ϕ_t (Sliding) = **1.00** LRFD Table 11.5.7-1

Resistance factor, ϕ_{wp} (Passive pressure) = **0.50** LRFD Table 10.5.5.2.2-1

Sliding Resistance:

Unfactored Horizontal Sliding Resistance = **61.56 kips**
Factored Horizontal Sliding Resistance = **61.56 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) = **3.33 ksf**
Pressure at Bottom of Disturbance (P_d) = **0.96 ksf**
Pressure at Bottom of Key or Sheet Piling = **3.33 ksf**

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

Total Factored Resisting Force = **61.56 kips**
Driving Force = **37.03 kips** **OK**

Check Settlement:

Service Bearing Capacity = **10.93 ksf**
Service Bearing Pressure at Toe = **5.72 ksf** **OK**
Service Bearing Pressure at Heel = **5.72 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	8.26	8.26	2.71	3.68	37.03	73.36
SERVICE I	5.72	5.72	2.24	N/A	24.22	71.83

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.)	21.41	1.50	32.11	11.25	361.27	
7	2.81	1.75	4.92	16.88	83.06	
Σ Sliding Forces, F _s =			37.03 kips	Σ Overturning Moments =		
				444.33 k*ft.		

Vertical Forces & Resisting Moments

1.5*DC+1.35*EV+1.75*LS_v (Max.) 0.9*DC+1.0*EV (Min.)

ΣM about point "A"

This column is for stability										This column is for stability			
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	Moment Arm (ft)	Max. Load Factor	Min. Load Factor					
1	7.59	1.25	9.49	0.90	6.83	4.75	45.09	32.46	Dead Loads From Concrete				
2	7.20	1.25	9.00	0.90	6.48	11.50	103.50	74.52					
3	2.55	1.25	3.19	0.90	2.30	2.00	6.38	4.59					
8	5.53	1.25	6.91	0.90	4.98	6.33	43.79	31.53					
4	33.63	1.35	45.40	1.00	33.63	12.75	578.86	428.78	Dead Loads				
5 (Max.)	2.40	1.35	3.24	1.00	2.40	2.00	6.48	4.80	From Soil (Do				
5 (Min.)	2.40	1.35	3.24	1.00	2.40	2.00	6.48	4.80	not include 5				
6 (Vertical comp.)	7.79	1.50	11.69	1.50	11.69	17.50	204.54	204.54	(Min.) and 5				
9	4.43	1.35	5.97	1.00	4.43	7.17	42.81	31.71	(Max.)				
10	0.00	1.35	0.00	1.00	0.00	13.50	0.00	0.00	simultaneously)				
Surcharge on Heel	3.00	1.75	5.25	0.00	0.00	11.50	60.38	0.00	External Loads				
Surcharge on Toe	1.86	1.75	3.26	0.00	0.00	2.00	6.52	0.00					
DC	0.70	1.25	0.88	0.90	0.63	4.71	4.14	2.98					
Σ Vert. Forces =		104.29 kips		Σ Vert. Forces =		73.36 kips		Σ Resist. Moments =		1102.48 k'ft.		815.92 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 =	444.33 k-ft.	Overturning Moment = Σ Overturning Moments =	444.33 k-ft.
Resisting Moment = Σ Max. Resisting Moments =	1102.48 k-ft.	Resisting Moment = Σ Min. Resisting Moments =	815.92 k-ft.
Net Moment = Resisting Moment - Overturning Moment =	658.15 k-ft.	Net Moment = Resisting Moment - Overturning Moment =	371.59 k-ft.
Total Vertical Force (TVF) = Σ Vert. Forces =	104.29 kips	Total Vertical Force (TVF) = Σ Vert. Forces =	73.36 kips
Dist. from Point A (Ā) = Net. Moment / TVF =	6.31 ft.	Dist. from Point A (Ā) = Net. Moment / TVF =	5.07 ft.
Eccentricity "e" = (0.5*W _t) - Ā =	2.44 ft.	Eccentricity "e" = (0.5*W _t) - Ā =	3.68 ft.
Maximum Bearing Pressure = TVF/(Wf-2*e) =	8.26 ksf		
Minimum Bearing Pressure = TVF/(Wf+2*e) =	8.26 ksf		

SERVICE I Load Combination

Sliding Forces & Overturning Moments

1.0*EH+1.0*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.)	21.41	1.00	21.41	11.25	240.84	
7	2.81	1.00	2.81	16.88	47.46	
Σ Sliding Forces, F _s =			24.22 kips	Σ Overturning Moments =		
				288.31 k*ft.		

Vertical Forces & Resisting Moments

1.0*DC+1.0*EV+1.0*LS_v

ΣM about point "A"

Area/Force	Force (k)	Unfactored Load	Load Factor	Force (k)	Moment Arm (ft)	Moment (k-ft)
1	7.59		1.00	7.59	4.75	36.07
2	7.20		1.00	7.20	11.50	82.80
3	2.55		1.00	2.55	2.00	5.10
8	5.53		1.00	5.53	6.33	35.03
4	33.63		1.00	33.63	12.75	428.78
5 (Max.)	2.40		1.00	2.40	2.00	4.80
5 (Min.)	2.40		1.00	2.40	2.00	4.80
6 (Vertical comp.)	7.79		1.00	7.79	17.50	136.36
9	4.43		1.00	4.43	7.17	31.71
10	0.00		1.00	0.00	13.50	0.00
Surcharge on Heel	3.00		1.00	3.00	11.50	34.50
Surcharge on Toe	1.86		1.00	1.86	2.00	3.73
DC	0.70		1.00	0.70	4.71	3.32
Σ Vert. Forces =			76.69 kips		Σ Resisting Moments =	
					802.20 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 =	288.31 k-ft.
Resisting Moment = Σ Max. Resisting Moments =	802.20 k-ft.
Net Moment = Resisting Moment - Overturning Moment =	513.89 k-ft.
Total Vertical Force (TVF) = Σ Vert. Forces =	76.69 kips
Dist. from Point A (Ā) = Net. Moment / TVF =	6.70 ft.
Eccentricity "e" = (0.5*W _t) - Ā =	2.05 ft.
Maximum Bearing Pressure = TVF/(Wf-2*e) =	5.72 ksf
Minimum Bearing Pressure = TVF/(Wf+2*e) =	5.72 ksf

- Where the wall is supported by a soil foundation:
the vertical stress shall be calculated assuming a uniformly distributed pressure over an effective base area as shown in Figure 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 within the middle one-third of the base:
$$\sigma_{max} = \frac{\sum V}{B} \left(1 + \frac{6e}{B} \right) \quad (11.6.3.2-2)$$

The vertical stress shall be calculated as follows:
$$\sigma_e = \frac{\sum V}{B - 2e} \quad (11.6.3.2-1)$$

$$\sigma_{min} = \frac{\sum V}{B} \left(1 - \frac{6e}{B} \right) \quad (11.6.3.2-3)$$
- where the variables are as defined in Figure 11.6.3.2-2. If the resultant is outside the middle one-third of the base:
$$\sigma_{max} = -\frac{2 \sum V}{3[(B/2) - e]} \quad (11.6.3.2-4)$$

$$\sigma_{min} = 0 \quad (11.6.3.2-5)$$

where the variables are as defined in Figure 11.6.3.2-2.