



Client: ODOT/District 6
Project: FRA-70 Project 4A
Subject: Wall 4W3 Transition Design

Job No.: 2012048
Page No.: 1 Of 3
Designed: DJC Date: 12/30/2019
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, γ_c =	0.150 kcf
Toe Height, H_{toe} =	2.25 ft
Heel Height, H_h =	2.00 ft
Wall Height, H_w =	9.64 ft
Total Height, $H_T = H_w + H_{toe}$ =	11.89 ft
Soil Height over Heel, $H_1 = H_T - H_h + (W_h \cdot S_d)$ =	9.89 ft
Max. Soil Height over Toe, H_2 =	5.10 ft
Future Loss of Soil over Toe, H_3 =	0.00 ft
Min. Soil Height over Toe, $H_3 = \max(0, H_2 - H_L)$ =	5.10 ft
Depth of Disturbance, H_d =	2.67 ft
Wall Width, W_w =	6.24 ft
Toe Width, W_{toe} =	1.01 ft
Heel Width, W_h =	1.51 ft
Additional Wall, W_{w1} =	0.00 ft
Theta, θ =	90.00 deg.
Footing Width, W_f =	8.75 ft

Soil Data:

Is Retained Soil Sloped?	No
Slope of Embankment, S_e =	0.00
Beta, β =	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 =	-1.51 ft
Minimum Soil Unit Weight for LLS, $\gamma_{soil\ LLS}$ =	0.125 kcf
Surcharge Height behind Wall, H_s =	3.22 ft
Surcharge Height in front of Wall, H_{sf} =	4.30 ft
$P_{soil\ LLS} = \gamma_{soil\ LLS} \cdot (k_a \text{ or } k_o)$ =	37.16 pcF
Active or At Rest Pressure?	Active
Retained Soil Unit Weight, γ_{soil} =	0.120 kcf
Footing Resting On?	Granular
Internal Friction Angle of Soil, δ =	35.00 deg.
Internal Friction Angle of Fill, ϕ_{fill} =	30.00 deg.
Friction Angle between Fill & Wall, δ =	20.00 deg.
Active Lateral Earth Press. Coefficient, k_a =	0.30
$P_{soil} = \gamma_{soil} \cdot (k_a \text{ or } k_o)$ =	35.68 pcF
Bearing on soil or rock?	Soil
Factor Bearing Resistance (Strength) =	15.049 ksf
Bearing Capacity (Service) =	4.359 ksf
Consider Passive Force on Toe?	No
Passive Lat. Earth Pressure Coeff., k_p =	3.00

Soil Pressure Calculations:

$P_1 = P_{soil} \cdot H_1 / 1000 =$	0.35 ksf
$P_2 = P_{soil} \cdot (H_1 + H_h) / 1000 =$	0.42 ksf
$P_3 = H_s \cdot P_{soil\ LLS} / 1000 =$	0.12 ksf
$P_4 = \gamma_{soil} \cdot k_p \cdot (H_{toe} + H_2 - H_L) =$	2.65 ksf
$P_5 = \gamma_{soil} \cdot k_p \cdot H_d =$	0.96 ksf

Soil Sliding Force Calculations:

$F_1 = P_1 \cdot H_1 \cdot 0.5 =$	1.74 kips
$F_2 = P_2 \cdot (H_1 + H_h) \cdot 0.5 =$	2.52 kips
$F_3 = P_3 \cdot H_1 =$	1.42 kips
F_4 (Trapezoid 11) =	0.00 kips

Additional Dead Load =	1.69 kips
Moment Arm for Additional Dead Load =	5.62 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

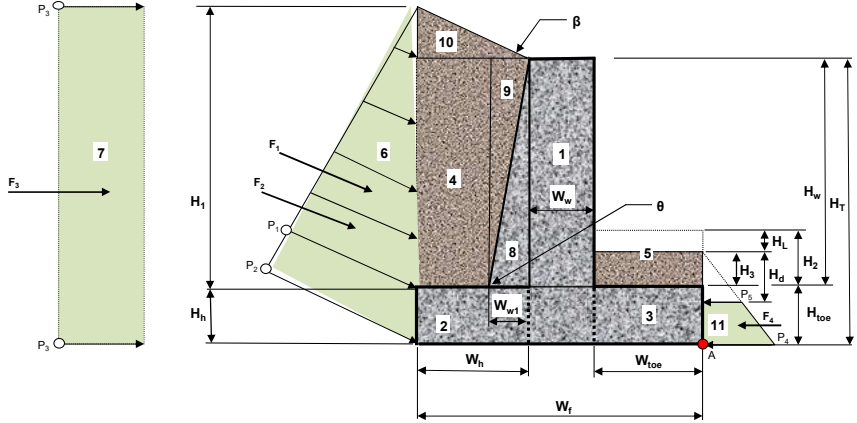
LRFD 3.11.5.3
LRFD 3.11.5.3-1 (Coulomb)

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:

$V_{min} =$	15.58	kips
Resistance, $R_t = V_{min} \cdot \tan(\delta) =$	10.91	kips

For cohesive soils:

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

Manual Override:

Override Friction Factor =		
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	6.24 ft.	x	11.89 ft.	x	1.00 ft.	=	11.13 kips			
Arm 1 = $W_{toe} + W_w / 2 =$	1.01 ft.	+	6.24 ft.		/	2.00	=	4.22 ft.				
Area 2 = $\gamma_c \times W_h \times H_h =$	0.150 kcf	x	1.51 ft.	x	2.00 ft.	x	1.00 ft.	=	0.45 kips			
Arm 2 = $W_{toe} + W_w + W_h / 2 =$	1.01 ft.	+	6.24 ft.	+	1.51 ft.		/	2.00	=	8.00 ft.		
Area 3 = $\gamma_c \times W_{toe} \times H_{toe} =$	0.150 kcf	x	1.01 ft.	x	2.25 ft.	x	1.00 ft.	=	0.34 kips			
Arm 3 = $W_{toe} / 2 =$	1.01 ft.			/	2.00	=			0.50 ft.			
Area 4 = $\gamma_s \times (W_h - W_{w1}) \times H_w =$	0.120 kcf	x	(1.51 ft. -		0.00 ft.)	x	9.64 ft.	x	1.00 ft.	=	1.75 kips	
Arm 4 = $W_{toe} + W_w + W_{w1} + (W_h - W_{w1}) / 2 =$	1.01 ft.	+	6.24 ft.	+	0.00 ft.	+	(1.51 ft. -		0.00 ft.)	/	2 =	8.00 ft.
Area 5 (Max.) = $\gamma_s \times W_{toe} \times H_2 =$	0.120 kcf	x	1.01 ft.	x	5.10 ft.	x	1.00 ft.	=	0.62 kips			
Area 5 (Min.) = $\gamma_s \times W_{toe} \times H_3 =$	0.120 kcf	x	1.01 ft.	x	5.10 ft.	x	1.00 ft.	=	0.62 kips			
Arm 5 = $W_{toe} / 2 =$	1.01 ft.			/	2.00	=			0.50 ft.			
Area 6 (Horiz. Comp.) = $F_2 \times \cos(\delta) =$	2.52 kips	x	cos (20.00 deg.)	=			2.37 kips			
Arm 6 = $(H_1 + H_h) / 3 =$	(9.89 ft. +		2.00 ft.)	/	3.00	=			3.96 ft.			
Area 6 (Vertical Comp.) = $F_2 \times \sin(\delta) =$	2.52 kips	x	sin (20.00 deg.)	=			0.86 kips			
Arm 6 = $W_f =$	8.75 ft.								8.75 ft.			
Area 7 = $F_3 =$	1.42 kips								1.42 kips			
Arm 7 = $(H_1 + H_h) / 2 =$	(9.89 ft. +		2.00 ft.)	/	2.00	=			5.95 ft.			
Area 8 = $0.5 \times \gamma_c \times W_w \times H_w =$	0.5 x 0.150 kcf	x	0.00 ft.	x	9.64 ft.	x	1.00 ft.	=	0.00 kips			
Arm 8 = $W_{toe} + W_w + W_{w1} / 3 =$	1.01 ft.	+	6.24 ft.	+	0.00 ft.	/	3.00	=	7.25 ft.			

Revised for wall geometry.



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Force and Moment Arm Calculations (Continued):

Area 9 = $0.5 \times \gamma_s \times W_{w1} \times H_{w1} =$	$0.5 \times 0.120 \text{ kcf} \times$	$0.00 \text{ ft.} \times$	$9.64 \text{ ft.} \times$	$1.00 \text{ ft.} =$	0.00 kips	
Arm 9 = $W_{toe} + W_w + W_{w1} \times 2/3 =$	$1.01 \text{ ft.} +$	$6.24 \text{ ft.} +$	$0.00 \text{ ft.} \times$	$\frac{x \times 2.00}{3.00} =$	7.25 ft.	
Area 10 = $0.5 \times \gamma_s \times (S_a \times W_h) \times W_h =$	$0.5 \times 0.120 \text{ kcf} \times$	$(0.00 \times$	$1.51 \text{ ft.}) \times$	$1.51 \text{ ft.} \times$	$1.00 \text{ ft.} =$	0.00 kips
Arm 10 = $W_f - W_h / 3 =$	$8.75 \text{ ft.} -$	$1.51 \text{ ft.} /$	$3.00 =$		8.25 ft.	
Area 11 = $F_d =$	0.00 kips				0.00 kips	
Surcharge on Heel = $\gamma_{soil} \text{ LLS} \times W_h \times H_s =$	$0.125 \text{ kcf} \times$	$1.51 \text{ ft.} \times$	$3.22 \text{ ft.} \times$	$1.00 \text{ ft.} =$	0.61 kips	
Arm for Heel Surcharge = $W_f - W_h / 2 =$	$8.75 \text{ ft.} -$	$1.51 \text{ ft.} /$	$2.00 =$		8.00 ft.	
Surcharge on Toe = $\gamma_{soil} \text{ LLS} \times W_{toe} \times H_{st} =$	$0.125 \text{ kcf} \times$	$1.01 \text{ ft.} \times$	$4.30 \text{ ft.} \times$	$1.00 \text{ ft.} =$	0.54 kips	
Arm for Toe Surcharge = $W_{toe} / 2 =$	$1.01 \text{ ft.} /$	$2.00 =$			0.50 ft.	

Check Bearing Pressure:

per BDM 307.1.5 and LRFD 11.6.3.2.

Factored Bearing Resistance = **15.05 ksf**

Maximum Strength Load Pressures:

Bearing pressure at Toe = **3.20 ksf** **OK**

Bearing pressure at Heel = **3.20 ksf** **OK**

Check Eccentricity:

per BDM 307.1.4 and LRFD 11.6.3.3.

Maximum Allowable $e = B/3 =$ **2.92 ft**

Controlling Eccentricity = **1.20 ft** **OK**

Check Sliding:

per BDM 307.1.3 and LRFD 11.6.3.6.

Resistance factor, ϕ_r (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 = **10.91 kips**

Factored Horizontal Sliding Resistance = **10.91 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) = **2.65 ksf**

Pressure at Bottom of Disturbance (P_d) = **0.96 ksf**

Pressure at Bottom of Key or Sheet Piling = **2.65 ksf**

Unfactored Passive Resistance = **0.00 kips**

Factored Passive Resistance = **0.00 kips**

Total Factored Resisting Force = **10.91 kips**

Driving Force = **6.04 kips** **OK**

Check Settlement:

Service Bearing Capacity = **4.36 ksf**

Service Bearing Pressure at Toe = **2.30 ksf** **OK**

Service Bearing Pressure at Heel = **2.30 ksf** **OK**

Summary of Load Effects:

STRENGTH I
SERVICE I

MAX. BEARING PRESSURE	MIN. BEARING PRESSURE	ECCENTRICITY MAX. LF	ECCENTRICITY MIN. LF	SLIDING FORCES MAX. LF	VERTICAL FORCES MIN. LF
3.20	3.20	0.94	1.20	6.04	15.58
2.30	2.30	0.68	N/A	3.79	16.48

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.)	2.37	1.50	3.55	3.96	14.09	Horiz. Forces
7	1.42	1.75	2.49	5.95	14.79	
Σ Sliding Forces, F _s =			6.04 kips	Σ Overturning Moments =		
				28.88 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"

Note: Area 1 load factors revised for wall geometry.

Area/Force	Force (k)			Force (k)			Moment Arm (ft)	Moment (k-ft)		
	Unfactored Load	Max. Load Factor	Force (k)	Min. Load Factor	Max. Load Factor	Force (k)		Max. Load Factor	Min. Load Factor	
1	11.13	1.21	13.46	0.87	9.69	4.22	56.76	40.87		
2	0.45	1.25	0.57	0.90	0.41	8.00	4.53	3.26		Dead Loads
3	0.34	1.25	0.42	0.90	0.31	0.50	0.21	0.15		From Concrete
8	0.00	1.25	0.00	0.90	0.00	7.25	0.00	0.00		
4	1.75	1.35	2.36	1.00	1.75	8.00	18.85	13.97		Dead Loads
5 (Max.)	0.62	1.35	0.83	1.00	0.62	0.50	0.42	0.31		From Soil (Do
5 (Min.)	0.62	1.35	0.83	1.00	0.62	0.50	0.42	0.31		not include 5
6 (Vertical comp.)	0.86	1.50	1.29	1.50	1.29	8.75	11.33	11.33		(Min.) and 5
9	0.00	1.35	0.00	1.00	0.00	7.25	0.00	0.00		(Max.)
10	0.00	1.35	0.00	1.00	0.00	8.25	0.00	0.00		simultaneously)
Surcharge on Heel	0.61	1.75	1.06	0.00	0.00	8.00	8.50	0.00		
Surcharge on Toe	0.54	1.75	0.94	0.00	0.00	0.50	0.48	0.00		External Loads
DC	1.69	1.25	2.11	0.90	1.52	5.62	11.87	8.54		
Σ Vert. Forces =			21.99 kips	Σ Vert. Forces =			104.44 k*ft.	78.42 k*ft.		
							Σ Resist. Moments =			

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 =	28.88 k-ft.			Overturning Moment = Σ Overturning Moments =	28.88 k-ft.		
Resisting Moment = Σ Max. Resisting Moments =	104.44 k-ft.			Resisting Moment = Σ Min. Resisting Moments =	78.42 k-ft.		
Net Moment = Resisting Moment - Overturning Moment =	75.56 k-ft.			Net Moment = Resisting Moment - Overturning Moment =	49.55 k-ft.		
Total Vertical Force (TVF) = Σ Vert. Forces =	21.99 kips			Total Vertical Force (TVF) = Σ Vert. Forces =	15.58 kips		
Dist. from Point A (Ā) = Net. Moment / TVF =	3.44 ft.			Dist. from Point A (Ā) = Net. Moment / TVF =	3.18 ft.		
Eccentricity "e" = (0.5*W _t) - Ā =	0.94 ft.			Eccentricity "e" = (0.5*W _t) - Ā =	1.20 ft.		
Maximum Bearing Pressure = TVF/(Wf-2*e) =	3.20 ksf						
Minimum Bearing Pressure = TVF/(Wf+2*e) =	3.20 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.)	2.37	1.00	2.37	3.96	9.39	Horiz. Forces
7	1.42	1.00	1.42	5.95	8.45	
Σ Sliding Forces, F _s =			3.79 kips	Σ Overturning Moments =		
				17.84 k*ft.		

Vertical Forces & Resisting Moments

1.0*DC+1.0*EV+1.0*LS_v

ΣM about point "A"

Note: Area 1 load factor revised for wall geometry.

Area/Force	Force (k)	Load Factor	Force (k)	Moment Arm (ft)	Moment (k-ft)	
1	11.13	0.97	10.77	4.22	45.41	
2	0.45	1.00	0.45	8.00	3.62	Dead Loads From
3	0.34	1.00	0.34	0.50	0.17	Concrete
8	0.00	1.00	0.00	7.25	0.00	
4	1.75	1.00	1.75	8.00	13.97	
5 (Max.)	0.62	1.00	0.62	0.50	0.31	Dead Loads
5 (Min.)	0.62	1.00	0.62	0.50	0.31	From Soil (Do not
6 (Vertical comp.)	0.86	1.00	0.86	8.75	7.55	include 5 (Min.) and
9	0.00	1.00	0.00	7.25	0.00	5 (Max.)
10	0.00	1.00	0.00	8.25	0.00	simultaneously)
Surcharge on Heel	0.61	1.00	0.61	8.00	4.85	
Surcharge on Toe	0.54	1.00	0.54	0.50	0.27	External Loads
DC	1.69	1.00	1.69	5.62	9.49	
Σ Vert. Forces =			17.02 kips	Σ Resisting Moments =		
				80.79 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 =	17.84 k-ft.		
Resisting Moment = Σ Max. Resisting Moments =	80.79 k-ft.		
Net Moment = Resisting Moment - Overturning Moment =	62.95 k-ft.		
Total Vertical Force (TVF) = Σ Vert. Forces =	17.02 kips		
Dist. from Point A (Ā) = Net. Moment / TVF =	3.70 ft.		
Eccentricity "e" = (0.5*W _t) - Ā =	0.68 ft.		
Maximum Bearing Pressure = TVF/(Wf-2*e) =	2.30 ksf		
Minimum Bearing Pressure = TVF/(Wf+2*e) =	2.30 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:
$$\sigma_{max} = \frac{\sum V}{B} \left(1 + \frac{6e}{B} \right) \quad (11.6.3.2-2)$$
$$\sigma_{min} = \frac{\sum V}{B} \left(1 - \frac{6e}{B} \right) \quad (11.6.3.2-3)$$

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.