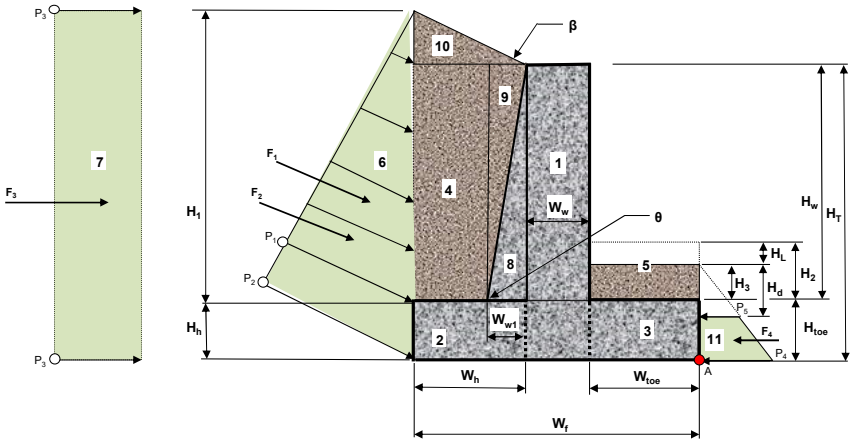
Client:	ODOT/District 6	Job No.:	2015370
Project:	FRA-70 Project 4B	Page No.:	1 Of 3
Subject:	Wall 4W15 Design	Designed:	RFV Date: 3/19/2019
	Sections up to 28.25 feet tall.	Checked:	MOJ Date: 7/11/2022

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} =	3.75	ft
Heel Height, H_h =	3.50	ft
Wall Height, H_w =	28.25	ft
Total Height, $H_T = H_w+H_{toe}$ =	32.00	ft
Soil Height over Heel, $H_1 = H_T-H_h+(W_h*S_e)$ =	28.50	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 =	1.50	ft
Toe Width, W_{toe} =	3.75	ft
Heel Width, W_h =	11.00	ft
Additional Wall Width, W_{w1} =	2.40	ft
Theta, θ =	85.19	deg.
Footing Width, W_f =	16.25	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 < H_T / 2 from back of wall?	Yes		*HT / 2 = 16 ft*
Dist. from back of wall to edge of traffic =	0.00	ft	*LRFD 3.11.6.4*
Minimum Soil Unit Weight for LLS, $\gamma_{soil\ LLS}$ =	0.125	kcf	*BDM 307.1.1*
Surcharge Height behind Wall, H_s =	2.00	ft	*LRFD Table 3.11.6.4-1*
Surcharge Height in front of Wall, H_{sf} =	4.18	ft	
$P_{soil\ LLS} = \gamma_{soil\ LLS} * (k_a \text{ or } k_0)$ =	41.67	pcf	
Active or At Rest Pressure?	Active		
Retained Soil Unit Weight, γ_{soil} =	0.120	kcf	*BDM Table 307-1*
Footing Resting On?	Granular		
Internal Friction Angle of Soil, δ =	38.00	deg.	*@ Base of the Footer*
Internal Friction Angle of Fill, ϕ'_{fill} =	30.00	deg.	
Friction Angle between Fill & Wall, δ =	20.00	deg.	*LRFD 3.11.5.3*
Active Lateral Earth Press. Coefficient, ka =	0.33		*LRFD 3.11.5.3-1 (Coulomb)*
$P_{soil} = \gamma_{soil} * (k_a \text{ or } k_0)$ =	40.00	pcf	
Bearing on soil or rock?	Soil		*LRFD 10.6.1.4*
Factor Bearing Resistance (Strength) =	12.602	ksf	
Bearing Capacity (Service) =	6.544	ksf	*To Check Settlement*
Consider Passive Force on Toe?	No		
Passive Lat. Earth Pressure Coeff., k_p =	3.00		$k_p = \tan^2(45°+\phi'_f/2)$

Soil Pressure Calculations:

$P_1 = P_{soil}*H_1/1000$ =	1.14	ksf
$P_2 = P_{soil}*(H_1+H_h)/1000$ =	1.28	ksf
$P_3 = H_s*P_{soil\ LLS}/1000$ =	0.08	ksf
$P_4 = \gamma_{soil}*k_p*(H_{toe}+H_2-H_L)$ =	2.79	ksf
$P_5 = \gamma_{soil}*k_p*H_d$ =	0.96	ksf

Soil Sliding Force Calculations:

$F_1 = P_1*H_1*0.5$ =	16.25	kips
$F_2 = P_2*(H_1+H_h)*0.5$ =	20.48	kips
$F_3 = P_3*H_1$ =	2.67	kips
F_4 (Trapezoid 11) =	0.00	kips
Additional Dead Load =	0.70	kips
Moment Arm for Additional Dead Load =	4.46	ft

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} =	64.32	kips
Resistance, $R_\tau = V_{min}* \tan(\delta)$ =	50.25	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, Rτ =	N.A.	kips

Manual Override:

Override Friction Factor =		
Resistance, Rτ =	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 = γ_c x W_w x H_T =	0.150 kcf x	1.50 ft. x	32.00 ft. x	1.00 ft. =	**7.20 kips**
Arm 1 = W_{toe} + W_w / 2 =	3.75 ft. +	1.50 ft.	/ 2.00 =		**4.50 ft.**
Area 2 = γ_c x W_h x H_h =	0.150 kcf x	11.00 ft. x	3.50 ft. x	1.00 ft. =	**5.78 kips**
Arm 2 = W_{toe} + W_w + W_h / 2 =	3.75 ft. +	1.50 ft. +	11.00 ft.	/ 2.00 =	**10.75 ft.**
Area 3 = γ_c x W_{toe} x H_{toe} =	0.150 kcf x	3.75 ft. x	3.75 ft. x	1.00 ft. =	**2.11 kips**
Arm 3 = W_{toe} / 2 =	3.75 ft.	/ 2.00 =			**1.88 ft.**
Area 4 = γ_s x (W_h -W_{w1}) x H_W =	0.120 kcf x	(11.00 ft. -	2.40 ft.) x	28.25 ft. x 1.00 ft. =	**29.17 kips**
Arm 4 = W_{toe} + W_w + W_{w1} + (W_h -W_{w1}) / 2 =	3.75 ft. +	1.50 ft. +	2.40 ft. +	(11.00 ft. - 2.40 ft.) / 2 =	**11.95 ft.**
Area 5 **(Max.)** = γ_s x W_{toe} x H_2 =	0.120 kcf x	3.75 ft. x	4.00 ft. x	1.00 ft. =	**1.80 kips**
Area 5 **(Min.)** = γ_s x W_{toe} x H_3 =	0.120 kcf x	3.75 ft. x	4.00 ft. x	1.00 ft. =	**1.80 kips**
Arm 5 = W_{toe} / 2 =	3.75 ft.	/ 2.00 =			**1.88 ft.**
Area 6 **(Horiz. Comp.)** = F_2 x cos(δ) =	20.48 kips x	cos (	20.00 deg.) =		**19.25 kips**
Arm 6 = (H_1 + H_h) / 3 =	(28.50 ft. +	3.50 ft.)	/ 3.00 =		**10.67 ft.**
Area 6 **(Vertical Comp.)** = F_2 x sin(δ) =	20.48 kips x	sin (	20.00 deg.) =		**7.01 kips**
Arm 6 = Wf =	16.25 ft.				**16.25 ft.**
Area 7 = F_3 =	2.67 kips				**2.67 kips**

Client:	ODOT/District 6	Job No.:	2015370
Project:	FRA-70 Project 4B	Page No.:	1 Of 3
Subject:	Wall 4W15 Design	Designed:	RFV Date: 3/19/2019
	Sections up to 28.25 feet tall.	Checked:	MOJ Date: 7/11/2022

Arm 7 = $(H_1 + H_h) / 2$ =	(28.50 ft.	+	3.50 ft.)	/	2.00	=			**16.00 ft.**
Area 8 = 0.5 x γ_c x W_{w1} x H_W =	0.5 x 0.150 kcf	x	2.40 ft.	x	28.25 ft.	x	1.00 ft.	=	**5.08 kips**
Arm 8 = $W_{toe} + W_w + W_{w1} / 3$ =	3.75 ft.	+	1.50 ft.	+	2.40 ft.	/	3.00	=	**6.05 ft.**

Force and Moment Arm Calculations (Continued):

Area 9 = 0.5 x γ_s x W_{w1} x H_W =	0.5 x 0.120 kcf	x	2.40 ft.	x	28.25 ft.	x	1.00 ft.	=			**4.06 kips**
Arm 9 = $W_{toe} + W_w + W_{w1}$ x 2/3 =	3.75 ft.	+	1.50 ft.	+	2.40 ft.	x	2.00	/	3.00	=	**6.85 ft.**
Area 10 = 0.5 x γ_s x $(S_e$ x $W_h)$ x W_h =	0.5 x 0.120 kcf	x	(0.00	x	11.00 ft.)	x	11.00 ft.	x	1.00 ft.	=	**0.00 kips**
Arm 10 = $W_F - W_h / 3$ =	16.25 ft.	-	11.00 ft.	/	3.00	=					**12.58 ft.**
Area 11 = F_4 =	0.00 kips										**0.00 kips**
Surcharge on Heel = $\gamma_{soil\ LLS}$ x W_h x H_s =	0.125 kcf	x	11.00 ft.	x	2.00 ft.	x	1.00 ft.	=			**2.75 kips**
Arm for Heel Surcharge = $W_F - W_h / 2$ =	16.25 ft.	-	11.00 ft.	/	2.00	=					**10.75 ft.**
Surcharge on Toe = $\gamma_{soil\ LLS}$ x W_{toe} x H_{sf} =	0.125 kcf	x	3.75 ft.	x	4.18 ft.	x	1.00 ft.	=			**1.96 kips**
Arm for Toe Surcharge = $W_{toe} / 2$ =	3.75 ft.	/	2.00	=							**1.88 ft.**

Check Bearing Pressure:

per BDM 307.1.5 and LRFD 11.6.3.2.

Factored Bearing Resistance = **12.60 ksf**

Maximum Strength Load Pressures:

Bearing pressure at Toe = **8.09 ksf** **OK**

Bearing pressure at Heel = **8.09 ksf** **OK**

Check Eccentricity:

per BDM 307.1.4 and LRFD 11.6.3.3.

Maximum Allowable e = B/3 = **5.42 ft**

Controlling Eccentricity = **3.66 ft** **OK**

Check Sliding:

per BDM 307.1.3 and LRFD 11.6.3.6.

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

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

Sliding Resistance:

Unfactored Horizontal Sliding Resistance = 50.25 kips

Factored Horizontal Sliding Resistance = 50.25 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_4) = 2.79 ksf

Pressure at Bottom of Disturbance (P_5) = 0.96 ksf

Pressure at Bottom of Key or Sheeting = 2.79 ksf

Unfactored Passive Resistance = 0.00 kips

Factored Passive Resistance = 0.00 kips

Total Factored Resisting Force = **50.25 kips**

Driving Force = **33.54 kips** **OK**

Check Settlement:

Service Bearing Capacity = **6.54 ksf**

Service Bearing Pressure at Toe = **5.56 ksf** **OK**

Service Bearing Pressure at Heel = **5.56 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	8.09	8.09	2.71	3.66	33.54	64.32
SERVICE I	5.56	5.56	2.24	N/A	21.91	62.90

Load Modification Factors:

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

Ductility η_D = *1.00* *(use 1.00 for all limit states)*

Redundancy η_R = *1.00* *(use 1.00 for redundant structures and 1.05 for non-redundant structures)*

Operational importance η_I = *1.00* *(use 1.00 for all limit states)*

Client:	ODOT/District 6	Job No.:	2015370		
Project:	FRA-70 Project 4B	Page No.:	1	Of	3
Subject:	Wall 4W15 Design	Designed:	RFV	Date:	3/19/2019
	Sections up to 28.25 feet tall.	Checked:	MOJ	Date:	7/11/2022

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.)	19.25	1.50	28.87	10.67	307.95	Horiz. Forces
7	2.67	1.75	4.67	16.00	74.67	
		Σ Sliding Forces, F_s =	33.54 kips	Σ Overturning Moments =	382.62 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"

Area/Force	Force (k) Unfactored Load	Max. Load Factor	Force (k) Max. Load Factor	Min. Load Factor	*This column is for stability* Force (k) Min. Load Factor	Moment Arm (ft)	Moment (k-ft) Max. Load Factor	*This column is for stability* Moment (k-ft) Min. Load Factor	
1	7.20	1.25	9.00	0.90	6.48	4.50	40.50	29.16	
2	5.78	1.25	7.22	0.90	5.20	10.75	77.60	55.87	Dead Loads
3	2.11	1.25	2.64	0.90	1.90	1.88	4.94	3.56	From Concrete
8	5.08	1.25	6.35	0.90	4.57	6.05	38.38	27.63	
4	29.17	1.35	39.38	1.00	29.17	11.95	470.47	348.50	Dead Loads
5 (Max.)	1.80	1.35	2.43	1.00	1.80	1.88	4.56	3.38	From Soil *(Do*
5 (Min.)	1.80	1.35	2.43	1.00	1.80	1.88	4.56	3.38	*not include 5*
6 (Vertical comp.)	7.01	1.50	10.51	1.50	10.51	16.25	170.75	170.75	*(Min.) and 5*
9	4.06	1.35	5.48	1.00	4.06	6.85	37.54	27.81	*(Max.)*
10	0.00	1.35	0.00	1.00	0.00	12.58	0.00	0.00	*simultaneously)*
Surcharge on Heel	2.75	1.75	4.81	0.00	0.00	10.75	51.73	0.00	
Surcharge on Toe	1.96	1.75	3.42	0.00	0.00	1.88	6.42	0.00	External Loads
DC	0.70	1.25	0.88	0.90	0.63	4.46	3.92	2.83	
		Σ Vert. Forces =	92.12 kips	Σ Vert. Forces =	64.32 kips	Σ Resist. Moments =	906.82 k*ft.	669.48 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 =	382.62 k-ft.	Overturning Moment = Σ Overturning Moments =	382.62 k-ft.
Resisting Moment = Σ Max. Resisting Moments =	906.82 k-ft.	Resisting Moment = Σ Min. Resisting Moments =	669.48 k-ft.
Net Moment = Resisting Moment - Overturning Moment =	524.21 k-ft.	Net Moment = Resisting Moment - Overturning Moment =	286.86 k-ft.
Total Vertical Force (TVF) = Σ Vert. Forces =	92.12 kips	Total Vertical Force (TVF) = Σ Vert. Forces =	64.32 kips
Dist. from Point A (Ā) = Net. Moment / TVF =	5.69 ft.	Dist. from Point A (Ā) = Net. Moment / TVF =	4.46 ft.
Eccentricity "e" = (0.5*W_f) - Ā =	2.43 ft.	Eccentricity "e" = (0.5*W_f) - Ā =	3.66 ft.
Maximum Bearing Pressure = TVF/(Wf-2*e) =	8.09 ksf		
Minimum Bearing Pressure = TVF/(Wf-2*e) =	8.09 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.)	19.25	1.00	19.25	10.67	205.30	Horiz. Forces
7	2.67	1.00	2.67	16.00	42.67	
		Σ Sliding Forces, F_s =	21.91 kips	Σ Overturning Moments =	247.97 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	7.20	1.00	7.20	4.50	32.40	
2	5.78	1.00	5.78	10.75	62.08	Dead Loads From
3	2.11	1.00	2.11	1.88	3.96	Concrete
8	5.08	1.00	5.08	6.05	30.70	
4	29.17	1.00	29.17	11.95	348.50	
5 (Max.)	1.80	1.00	1.80	1.88	3.38	Dead Loads
5 (Min.)	1.80	1.00	1.80	1.88	3.38	From Soil (Do not
6 (Vertical comp.)	7.01	1.00	7.01	16.25	113.83	include 5 (Min.) and
9	4.06	1.00	4.06	6.85	27.81	5 (Max.)
10	0.00	1.00	0.00	12.58	0.00	simultaneously)
Surcharge on Heel	2.75	1.00	2.75	10.75	29.56	
Surcharge on Toe	1.96	1.00	1.96	1.88	3.67	External Loads
DC	0.70	1.00	0.70	4.46	3.14	
		Σ Vert. Forces =	67.61 kips	Σ Resisting Moments =	659.03 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 =	247.97 k-ft.
Resisting Moment = Σ Max. Resisting Moments =	659.03 k-ft.
Net Moment = Resisting Moment - Overturning Moment =	411.06 k-ft.
Total Vertical Force (TVF) = Σ Vert. Forces =	67.61 kips
Dist. from Point A (Ā) = Net. Moment / TVF =	6.08 ft.
Eccentricity "e" = (0.5*W_f) - Ā =	2.04 ft.
Maximum Bearing Pressure = TVF/(Wf-2*e) =	5.56 ksf
Minimum Bearing Pressure = TVF/(Wf-2*e) =	5.56 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.

The vertical stress shall be calculated as follows:

$$\sigma_v = \frac{\sum V}{B - 2e} \qquad (11.6.3.2\text{-}1)$$

- 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:

$$\sigma_{vmax} = \frac{\sum V}{B}\left(1 + 6\frac{e}{B}\right) \qquad (11.6.3.2\text{-}2)$$

$$\sigma_{vmin} = \frac{\sum V}{B}\left(1 - 6\frac{e}{B}\right) \qquad (11.6.3.2\text{-}3)$$

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:

$$\sigma_{vmax} = \frac{2\sum V}{3[(B/2) - e)]} \qquad (11.6.3.2\text{-}4)$$

$$\sigma_{vmin} = 0 \qquad (11.6.3.2\text{-}5)$$

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