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Technical Memorandum

Date:	9-17-15	**Project Manager:**	Matt Miller
To:	Tuttle Engineering	**Principal in Charge:**	Matt Miller
Attn:	John Tuttle	**Project Name:**	61st Culvert Replacement
Address:		**Project No:**	KE 140704A
Subject:	Gabion Wall Design		

Attached is a plan sheet and wall calculation for the Gabion Wall section located at the upstream and downstream headwalls of the new culvert.

If you have any question please feel free to contact Matt Miller, PE at 425-827-7701

Project: 61st Street Culvert replacemnet   **Date:** 9/15/2015   **Checked:** M. Miller

Structural Dimensions

ENTER VALUES IN BLUE.   SHADED CELLS ARE CALCULATED.

Parameter	Value	Units	Description
H_w	9.00	ft	inclined wall height
H_{emb}	1.00	ft	wall embedment
H_e	7.97	ft	exposed vertical wall height
H	9.47	ft	design wall height
B_b	6.00	ft	bottom width of wall
B_t	3.00	ft	top width of wall
θ	76.3	deg	inclination of back of wall measured clockwise from horiz plane
β	18	deg	inclin. of ground slope behind wall - counterclockwise from horiz plane
α	4.75	deg	wall batter measured clockwise from the vertical
γ_{blocks}	0.115	kcf	unit weight of blocks

Soil Parameters

Parameter	Value	Units	Description
$\gamma_{retained}$	0.130	kcf	retained soil unit weight (total)
$\phi_{retained}$	32	deg	friction angle of retained soil
$\delta_{retained}$	24.0	deg	friction angle retained/wall (sands=3/4θ, sandy silts/clays=1/2θ)
$c_{retained}$	0.00	ksf	soil cohesion of backfill
k_a	0.533	-	active earth pressure coefficient
P	3.11	kip/ft	resultant of active earth pressure
P_H	2.46	kip/ft	horizontal component of P
P_V	1.90	kip/ft	vertical component of P

Surcharges

Parameter	Value	Units	Description		
q_{LL}	0.250	ksf	traffic or other uniform live load		
Pq_{LL}	0.95	k/ft	resultant horizontal load from uniform live load based on p = 0.4q_{LL}		
Q_{line}	0.00	k/ft	continuous footing or other dead line load		
X_{LINE}	0.00	ft	distance of line load from face of wall	m =	0.000
P_{LINE}	0.00	k/ft	horiz. resultant from line load (NAVFAC 7.2-74) applied at R = H *		0.56

Seismic Parameters

a	0.25	g	design horizontal ground acceleration
A_m	0.30	g	AASHTO recommended adjustment, A_m = (1.45-A)A
P_{IR}	1.75	k/ft	horizontal inertial force, applied at 0.5H
P_{AE}	1.31	k/ft	dynamic horizontal thrust, 50% applied at 0.6H

Moment Arms

Parameter	Value	Units	Description
a	2.74	ft	horizontal arm of W measured from toe in XY planes
b	2.66	ft	vertical arm of P_h measured from toe in XY planes
e	5.21	ft	horizontal arm of P_v measured from toe in XY planes
b_{qLL}	4.73	ft	vertical arm of P_{QLL} measured from toe in XY planes
b_{Qline}	5.30	ft	vertical arm of P_v measured from toe in XY planes
b_{PIR}	4.73	ft	vertical arm of P_v measured from toe in XY planes
b_{PAE}	5.68	ft	vertical arm of P_v measured from toe in XY planes

Geometry

# Blocks	Height (ft)
8	20

Y   USE "BORDER" TOOL TO OUTLINE FULL OR HALF BLOCKS

7

6

5

3H:1V Backfill

4

3   9

3

2   6
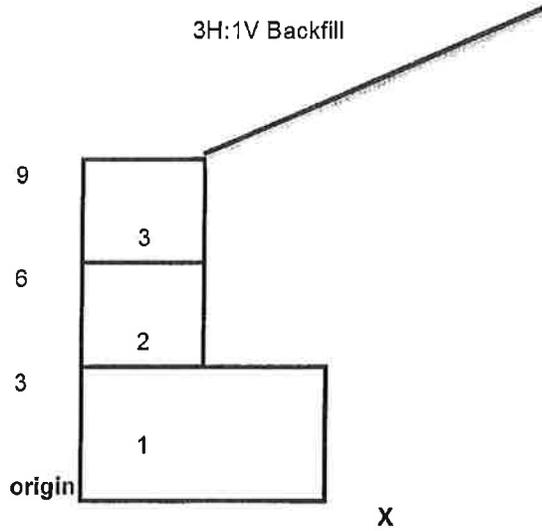
2

1   3

1

origin

X

Center of Gravity of Wall

Mass Unit	Area (sq ft)	X'I (ft)	Y'I (ft)	Weight (k/ft)	Mass Moment X' (k-ft per linear ft)	Mass Moment Y' (k-ft per linear ft)
Block 1	36.00	3	1.5	4.14	12.42	6.21
Block 2	9.00	1.5	4.5	1.04	1.55	4.66
Block 3	9.00	1.5	7.5	1.04	1.55	7.76
Block 4				0.00	0.00	0.00
Block 5				0.00	0.00	0.00
Block 6				0.00	0.00	0.00
Block 7				0.00	0.00	0.00
Block 8				0.00	0.00	0.00
Soil 1				0.00	0.00	0.00
Soil 2				0.00	0.00	0.00
		Total	13.50	6.21	15.53	18.63
		x'			2.50	
		y'				3.00

Evaluation of Overturning Stability

Parameter	Value	Units	Description
M_r	26.91	k-ft / ft	resisting moment
$M_{d,static}$	11.01	k-ft / ft	driving moment, static
$M_{d,seismic}$	23.01	k-ft / ft	driving moment, seismic
$FS_{o,static}$	2.44	OK	static > 2 ?
$FS_{o,seismic}$	1.2	OK	seismic > 1.1 ?

Evaluation of Sliding Stability

Parameter	Value	Units	Description
ϕ_{fdn}	45	deg	friction angle of base pad soils (min. 6 in. of crushed rock recommended)
$\delta_{subgrade}$	33.8	deg	friction angle blocks/subgrade (sands and gravels = 0.75θ)
F	0.67	-	coefficient of friction between wall and foundation soil
N_{static}	8.28	k/ft	reaction at base of wall, static
$N_{seismic}$	8.48	k/ft	reaction at base of wall, seismic
$F_{r,static}$	6.21	k/ft	sum of forces providing resistance to sliding, static
$F_{r,seismic}$	6.34	k/ft	sum of forces providing resistance to sliding, seismic
$F_{d,static}$	3.39	k/ft	sum of forces driving the wall in sliding, static
$F_{d,seismic}$	5.79	k/ft	sum of forces driving the wall in sliding, seismic
$FS_{s,static}$	1.83	OK	static > 1.5 ?
$FS_{s,seismic}$	1.10	OK	seismic > 1.1 ?

Evaluation of Bearing Capacity and Foundation Stability

Parameter	Value	Units	Description
B_f	6.50	-	width of wall footing
γ_{fdn}	0.130	kcf	subgrade soil unit weight (total)
ϕ_{fdn}	34	deg	friction angle of subgrade soil (crushed rock base pad)
$\delta_{subgrade}$	25.5	deg	friction angle blocks/subgrade (sands=0.75θ, sandy silts/clays=0.5θ)
c_{fdn}	0	psf	soil cohesion of subgrade
q	0.195	ksf	overburden surcharge (assume 6" base pad)
N_c	42.16	-	bearing cap. factor, Eqn. 12.5, *Fund. Of Geotech. Eng.*, (Das 2005)
N_q	29.44	-	bearing cap. Factor, Eqn. 12.4, *Fund. Of Geotech. Eng.*, (Das 2005)
N_γ	41.06	-	bearing cap. Factor, Eqn. 12.6, *Fund. Of Geotech. Eng.*, (Das 2005)
q_{ult}	23.09	ksf	ultimate bearing capacity
q_{all}	9.24	ksf	allowable bearing capacity (q_{ult}/2.5)

Eccentricity and Bearing Pressures

Parameter	Static	Seismic	Units	Description
N	8.28	8.48	k/ft	reaction at base of wall
N_V	8.26	8.45	k/ft	vertical component of reaction at base of wall
N_H	0.69	0.70	k/ft	horizontal component of reaction at base of wall
X	1.91	0.46	ft	horizontal distance of normal force from toe
e_x	1.08	2.54	ft	eccent. of base rxn from ctr of wall base meas. along plane || to base
check	Not OK	check bearing	-	$B_b/3 <= X / \cos\alpha$?
check	Not OK	check bearing	-	$B_b - X / \cos\alpha <= 2B_b/3$?
q_{toe}	2.874	5.005	ksf	maximum bearing pressure
q_{heel}	-0.112	-2.177	ksf	minimum bearing pressure
$FS_{bearing}$	3.21	1.85	-	factor of safety for bearing capacity (min. 2.5 static, 1.5 seismic)

GABION GRAVITY WALL CALCULATIONS

Project: 61st Street Culvert replacemnet   **Date:** 9/15/2015   **Checked:** M. Miller

Structural Dimensions
ENTER VALUES IN BLUE.   SHADED CELLS ARE CALCULATED.

Parameter	Value	Units	Description
H_w	6.00	ft	inclined wall height
H_{emb}	1.00	ft	wall embedment
H_e	4.98	ft	exposed vertical wall height
H	6.48	ft	design wall height
B_b	6.00	ft	bottom width of wall
B_t	3.00	ft	top width of wall
θ	68.2	deg	inclination of back of wall measured clockwise from horiz plane
β	18	deg	inclin. of ground slope behind wall - counterclockwise from horiz plane
α	4.75	deg	wall batter measured clockwise from the vertical
γ_{blocks}	0.115	kcf	unit weight of blocks

Soil Parameters

Parameter	Value	Units	Description
$\gamma_{retained}$	0.130	kcf	retained soil unit weight (total)
$\phi_{retained}$	32	deg	friction angle of retained soil
$\delta_{retained}$	24.0	deg	friction angle retained/wall (sands=3/4θ, sandy silts/clays=1/2θ)
$c_{retained}$	0.00	ksf	soil cohesion of backfill
k_a	0.683	-	active earth pressure coefficient
P	1.86	kip/ft	resultant of active earth pressure
P_H	1.30	kip/ft	horizontal component of P
P_V	1.33	kip/ft	vertical component of P

Surcharges

Parameter	Value	Units	Description		
q_{LL}	0.000	ksf	traffic or other uniform live load		
Pq_{LL}	0.00	k/ft	resultant horizontal load from uniform live load based on p = 0.4q_{LL}		
Q_{line}	0.00	k/ft	continuous footing or other dead line load		
X_{LINE}	0.00	ft	distance of line load from face of wall	m =	0.000
P_{LINE}	0.00	k/ft	horiz. resultant from line load (NAVFAC 7.2-74) applied at R = H *		0.56

Seismic Parameters

Parameter	Value	Units	Description
a	0.25	g	design horizontal ground acceleration
A_m	0.30	g	AASHTO recommended adjustment, A_m = (1.45-A)A
P_{IR}	0.82	k/ft	horizontal inertial force, applied at 0.5H
P_{AE}	0.61	k/ft	dynamic horizontal thrust, 50% applied at 0.6H

Moment Arms

Parameter	Value	Units	Description
a	2.70	ft	horizontal arm of W measured from toe in XY planes
b	1.66	ft	vertical arm of P_h measured from toe in XY planes
e	5.12	ft	horizontal arm of P_v measured from toe in XY planes
b_{qLL}	3.24	ft	vertical arm of P_{QLL} measured from toe in XY planes
b_{Qline}	3.63	ft	vertical arm of P_v measured from toe in XY planes
b_{PIR}	3.24	ft	vertical arm of P_v measured from toe in XY planes
b_{PAE}	3.89	ft	vertical arm of P_v measured from toe in XY planes

Geometry

# Blocks	Height (ft)
8	20
7	17.5
6	15
5	12.5
4	10
3	10
2	6
1	3

Y

USE "BORDER" TOOL TO OUTLINE FULL OR HALF BLOCKS

3H:1V Backfill

2

2

1

origin

X

Center of Gravity of Wall

Mass Unit	Area (sq ft)	X'l (ft)	Y'l (ft)	Weight (k/ft)	Mass Moment X' (k-ft per linear ft)	Mass Moment Y' (k-ft per linear ft)
Block 1	18.00	3	1.5	2.07	6.21	3.11
Block 2	9.00	1.5	4.5	1.04	1.55	4.66
Block 3				0.00	0.00	0.00
Block 4				0.00	0.00	0.00
Block 5				0.00	0.00	0.00
Block 6				0.00	0.00	0.00
Block 7				0.00	0.00	0.00
Block 8				0.00	0.00	0.00
Soil 1				0.00	0.00	0.00
Soil 2				0.00	0.00	0.00
		Total	6.00	3.11	7.76	7.76
		x'			2.50	
		y'				2.50

Evaluation of Overturning Stability

Parameter	Value	Units	Description
M_r	15.20	k-ft / ft	resisting moment
$M_{d,static}$	2.16	k-ft / ft	driving moment, static
$M_{d,seismic}$	6.00	k-ft / ft	driving moment, seismic
$FS_{o,static}$	7.05	OK	static > 2 ?
$FS_{o,seismic}$	2.5	OK	seismic > 1.1 ?

Evaluation of Sliding Stability

Parameter	Value	Units	Description
ϕ_{fdn}	45	deg	friction angle of base pad soils (min. 6 in. of crushed rock recommended)
$\delta_{subgrade}$	33.8	deg	friction angle blocks/subgrade (sands and gravels = 0.75θ)
F	0.67	-	coefficient of friction between wall and foundation soil
N_{static}	4.53	k/ft	reaction at base of wall, static
$N_{seismic}$	4.62	k/ft	reaction at base of wall, seismic
$F_{r,static}$	3.40	k/ft	sum of forces providing resistance to sliding, static
$F_{r,seismic}$	3.46	k/ft	sum of forces providing resistance to sliding, seismic
$F_{d,static}$	1.29	k/ft	sum of forces driving the wall in sliding, static
$F_{d,seismic}$	2.41	k/ft	sum of forces driving the wall in sliding, seismic
$FS_{s,static}$	2.63	OK	static > 1.5 ?
$FS_{s,seismic}$	1.43	OK	seismic > 1.1 ?

Evaluation of Bearing Capacity and Foundation Stability

Parameter	Value	Units	Description
B_f	6.50	-	width of wall footing
γ_{fdn}	0.130	kcf	subgrade soil unit weight (total)
ϕ_{fdn}	34	deg	friction angle of subgrade soil (crushed rock base pad)
$\delta_{subgrade}$	25.5	deg	friction angle blocks/subgrade (sands=0.75θ, sandy silts/clays=0.5θ)
c_{fdn}	0	psf	soil cohesion of subgrade
q	0.195	ksf	overburden surcharge (assume 6" base pad)
N_c	42.16	-	bearing cap. factor, Eqn. 12.5, *Fund. Of Geotech. Eng.*, (Das 2005)
N_q	29.44	-	bearing cap. Factor, Eqn. 12.4, *Fund. Of Geotech. Eng.*, (Das 2005)
N_γ	41.06	-	bearing cap. Factor, Eqn. 12.6, *Fund. Of Geotech. Eng.*, (Das 2005)
q_{ult}	23.09	ksf	ultimate bearing capacity
q_{all}	9.24	ksf	allowable bearing capacity (q_{ult}/2.5)

Eccentricity and Bearing Pressures

Parameter	Static	Seismic	Units	Description
N	4.53	4.62	k/ft	reaction at base of wall
N_V	4.52	4.61	k/ft	vertical component of reaction at base of wall
N_H	0.38	0.38	k/ft	horizontal component of reaction at base of wall
X	2.87	1.98	ft	horizontal distance of normal force from toe
e_x	0.12	1.01	ft	eccent. of base rxn from ctr of wall base meas. along plane ‖ to base
check	OK	check bearing	-	$B_b/3 <= X / \cos\alpha$?
check	OK	check bearing	-	$B_b - X / \cos\alpha <= 2B_b/3$?
q_{toe}	0.846	1.548	ksf	maximum bearing pressure
q_{heel}	0.664	-0.007	ksf	minimum bearing pressure
$FS_{bearing}$	10.91	5.97	-	factor of safety for bearing capacity (min. 2.5 static, 1.5 seismic)

GABION GRAVITY WALL CALCULATIONS

Parameters and methodology based on *Ultrablock Design Manual for Lock-Block Gravity and MSE Wall Systems* (Adettiwar, 2003).

Project: 61st Street Culvert replacemnet   **Date:** 9/15/2015   **Checked:** M. Miller

Structural Dimensions

ENTER VALUES IN BLUE.   SHADED CELLS ARE CALCULATED.

Parameter	Value	Units	Description
H_w	3.00	ft	inclined wall height
H_{emb}	0.50	ft	wall embedment
H_e	2.49	ft	exposed vertical wall height
H	3.24	ft	design wall height
B_b	3.00	ft	bottom width of wall
B_t	3.00	ft	top width of wall
θ	94.8	deg	inclination of back of wall measured clockwise from horiz plane
β	18	deg	inclin. of ground slope behind wall - counterclockwise from horiz plane
α	4.75	deg	wall batter measured clockwise from the vertical
γ_{blocks}	0.115	kcf	unit weight of blocks

Soil Parameters

Parameter	Value	Units	Description
$\gamma_{retained}$	0.130	kcf	retained soil unit weight (total)
$\phi_{retained}$	32	deg	friction angle of retained soil
$\delta_{retained}$	24.0	deg	friction angle retained/wall (sands=3/4θ, sandy silts/clays=1/2θ)
$c_{retained}$	0.00	ksf	soil cohesion of backfill
k_a	0.313	-	active earth pressure coefficient
P	0.21	kip/ft	resultant of active earth pressure
P_H	0.20	kip/ft	horizontal component of P
P_V	0.07	kip/ft	vertical component of P

Surcharges

Parameter	Value	Units	Description		
q_{LL}	0.000	ksf	traffic or other uniform live load		
Pq_{LL}	0.00	k/ft	resultant horizontal load from uniform live load based on p = 0.4q_{LL}		
Q_{line}	0.00	k/ft	continuous footing or other dead line load		
X_{LINE}	0.00	ft	distance of line load from face of wall	m =	0.000
P_{LINE}	0.00	k/ft	horiz. resultant from line load (NAVFAC 7.2-74) applied at R = H *		0.56

Seismic Parameters

Parameter	Value	Units	Description
a	0.25	g	design horizontal ground acceleration
A_m	0.30	g	AASHTO recommended adjustment, $A_m = (1.45-A)A$
P_{IR}	0.20	k/ft	horizontal inertial force, applied at 0.5H
P_{AE}	0.15	k/ft	dynamic horizontal thrust, 50% applied at 0.6H

Moment Arms

Parameter	Value	Units	Description
a	3.11	ft	horizontal arm of W measured from toe in XY planes
b	0.83	ft	vertical arm of P_h measured from toe in XY planes
e	3.08	ft	horizontal arm of P_v measured from toe in XY planes
b_{qLL}	1.62	ft	vertical arm of P_{QLL} measured from toe in XY planes
b_{Qline}	1.81	ft	vertical arm of P_v measured from toe in XY planes
b_{PIR}	1.62	ft	vertical arm of P_v measured from toe in XY planes
b_{PAE}	1.94	ft	vertical arm of P_v measured from toe in XY planes

GABION GRAVITY WALL CALCULATIONS Associated Earth Sciences, Inc.

Geometry

# Blocks	Height (ft)
8	20
7	17.5
6	15
5	12.5
4	10
3	10
2	6
1	3

Y

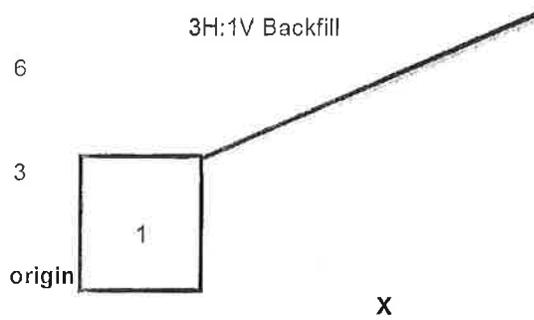USE "BORDER" TOOL TO OUTLINE FULL OR HALF BLOCKS

3H:1V Backfill

1

origin

X

Center of Gravity of Wall

Mass Unit	Area (sq ft)	X'l (ft)	Y'l (ft)	Weight (k/ft)	Mass Moment X' (k-ft per linear ft)	Mass Moment Y' (k-ft per linear ft)
Block 1	9.00	3	1.5	1.04	3.11	1.55
Block 2				0.00	0.00	0.00
Block 3				0.00	0.00	0.00
Block 4				0.00	0.00	0.00
Block 5				0.00	0.00	0.00
Block 6				0.00	0.00	0.00
Block 7				0.00	0.00	0.00
Block 8				0.00	0.00	0.00
Soil 1				0.00	0.00	0.00
Soil 2				0.00	0.00	0.00
		Total	1.50	1.04	3.11	1.55
		x'			3.00	
		y'				1.50

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Evaluation of Overturning Stability

Parameter	Value	Units	Description
M_r	3.44	k-ft / ft	resisting moment
$M_{d,static}$	0.17	k-ft / ft	driving moment, static
$M_{d,seismic}$	0.65	k-ft / ft	driving moment, seismic
$FS_{o,static}$	20.58	OK	static > 2 ?
$FS_{o,seismic}$	5.3	OK	seismic > 1.1 ?

Evaluation of Sliding Stability

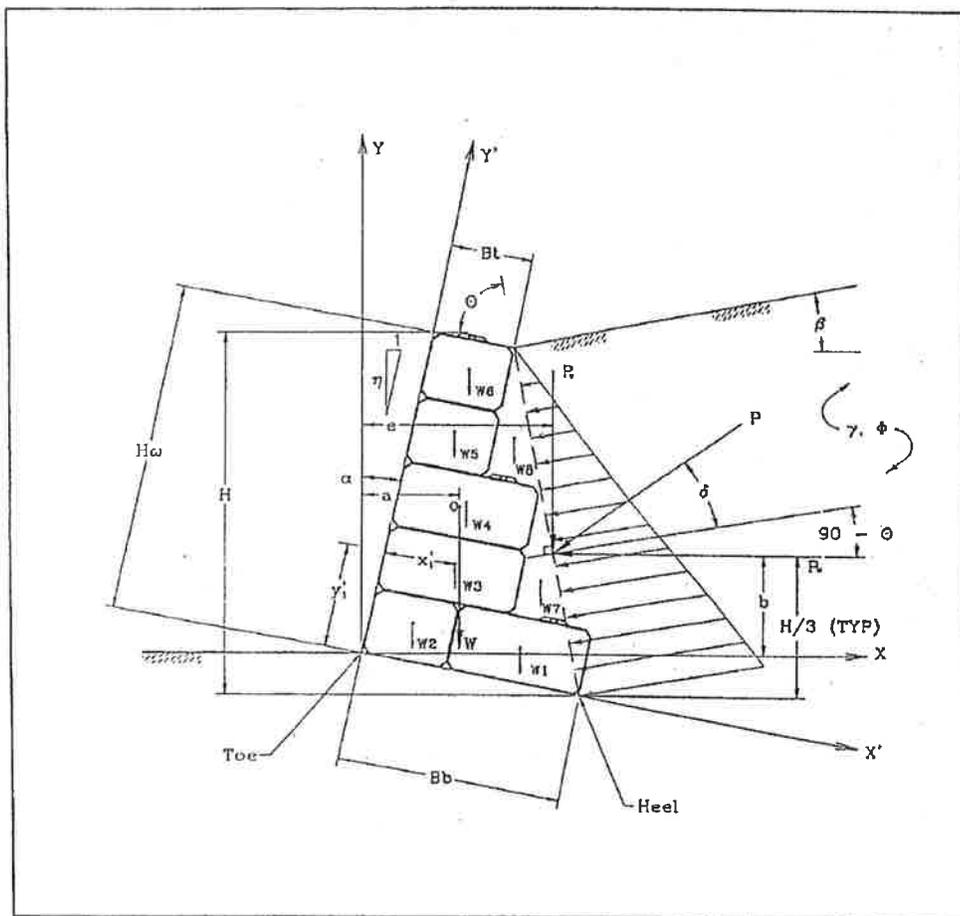| Parameter	Value	Units	Description
ϕ_{fdn}	45	deg	friction angle of base pad soils (min. 6 in. of crushed rock recommended)
$\delta_{subgrade}$	33.8	deg	friction angle blocks/subgrade (sands and gravels = 0.75θ)
F	0.67	-	coefficient of friction between wall and foundation soil
N_{static}	1.12	k/ft	reaction at base of wall, static
$N_{seismic}$	1.14	k/ft	reaction at base of wall, seismic
$F_{r,static}$	0.84	k/ft	sum of forces providing resistance to sliding, static
$F_{r,seismic}$	0.85	k/ft	sum of forces providing resistance to sliding, seismic
$F_{d,static}$	0.20	k/ft	sum of forces driving the wall in sliding, static
$F_{d,seismic}$	0.48	k/ft	sum of forces driving the wall in sliding, seismic
$FS_{s,static}$	4.18	OK	static > 1.5 ?
$FS_{s,seismic}$	1.78	OK	seismic > 1.1 ?

Evaluation of Bearing Capacity and Foundation Stability

Parameter	Value	Units	Description
B_f	3.50	-	width of wall footing
γ_{fdn}	0.130	kcf	subgrade soil unit weight (total)
ϕ_{fdn}	34	deg	friction angle of subgrade soil (crushed rock base pad)
$\delta_{subgrade}$	25.5	deg	friction angle blocks/subgrade (sands=0.75θ, sandy silts/clays=0.5θ)
c_{fdn}	0	psf	soil cohesion of subgrade
q	0.130	ksf	overburden surcharge (assume 6" base pad)
N_c	42.16	-	bearing cap. factor, Eqn. 12.5, *Fund. Of Geotech. Eng.*, (Das 2005)
N_q	29.44	-	bearing cap. Factor, Eqn. 12.4, *Fund. Of Geotech. Eng.*, (Das 2005)
N_γ	41.06	-	bearing cap. Factor, Eqn. 12.6, *Fund. Of Geotech. Eng.*, (Das 2005)
q_{ult}	13.17	ksf	ultimate bearing capacity
q_{all}	5.27	ksf	allowable bearing capacity (q_{ult}/2.5)

Eccentricity and Bearing Pressures

Parameter	Static	Seismic	Units	Description
N	1.12	1.14	k/ft	reaction at base of wall
N_V	1.11	1.14	k/ft	vertical component of reaction at base of wall
N_H	0.09	0.09	k/ft	horizontal component of reaction at base of wall
X	2.92	2.44	ft	horizontal distance of normal force from toe
e_x	-1.43	-0.95	ft	eccent. of base rxn from ctr of wall base meas. along plane || to base
check	OK	OK	-	$B_b/3 <= X / \cos\alpha$?
check	OK	OK	-	$B_b - X / \cos\alpha <= 2B_b/3$?
q_{toe}	-0.691	-0.340	ksf	maximum bearing pressure
q_{heel}	1.436	1.100	ksf	minimum bearing pressure
$FS_{bearing}$	3.67	4.79	-	factor of safety for bearing capacity (min. 2.5 static, 1.5 seismic)

DESIGN EXAMPLE

Wall Cross-Section