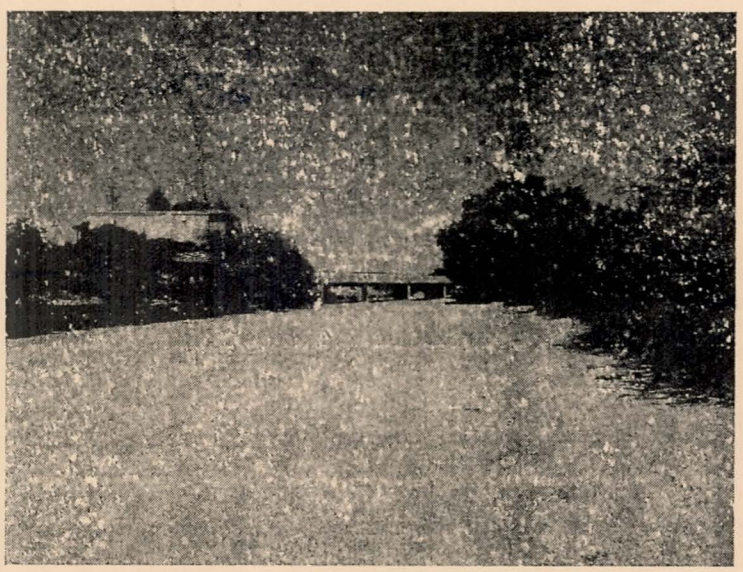
FINAL STRUCTURAL CALCULATIONS

WICKENBURG DOWNTOWN FLOODING HAZARD MITIGATION PROJECT

MCFCD PROJECT NO. 2005C006



Prepared By:

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September 5, 2006

Registered Professional Engineer (Civil)
CERTIFICATE NO
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JOHN ANDREW
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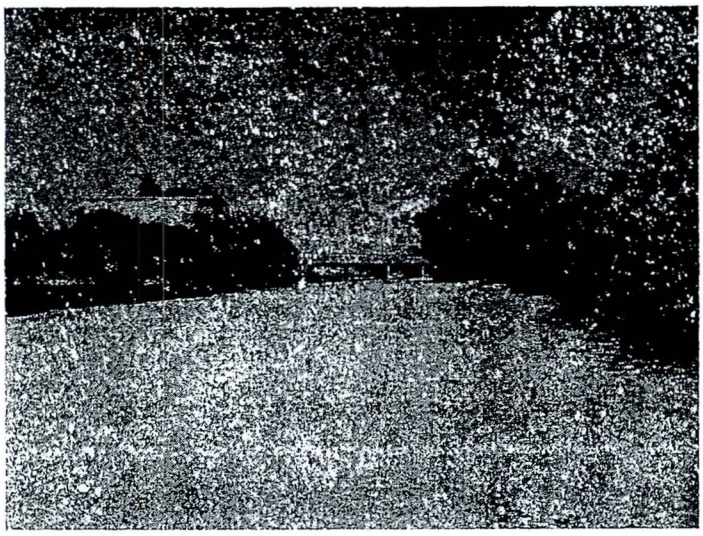

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TABLE OF CONTENTS

Section	Title	Page
1.0	Basis for Design	1
2.0	Type A Floodwall Design	2
3.0	Type B Floodwall Design	43
4.0	Concrete Drop Structure Design	72
5.0	Modifications to Tegner Street Bridge Design	79
	Northwest Wing Wall	80
	Southwest Headwall	90
	Southeast Wing Wall	97
	Debris Fins	107
	Parapet Floodwall	112
6.0	Sheet Pile Wall for Sewer Line Protection Design	118
7.0	Stability Check of Existing Tegner Street Bridge	142
8.0	Tractive Force Analysis	151
9.0	Seepage Analysis and Global Stability for Levee	157
10.0	Seepage Analysis and Global Stability for Type B Floodwalls	162
11.0	Global Stability of Gabion Walls	166
12.0	Settlement Analysis for Type A Floodwalls	283
13.0	Settlement Analysis for Type B Floodwalls	287
14.0	Reinforced Soil Slope Design	290
15.0	Quantities and Costs	314

1.0 BASIS FOR DESIGN

Design Specifications

1. AASHTO Standard Specifications for Highway Bridges, 17th Edition, 2002
2. US Army Corps of Engineers EM 1110-2-2502 Retaining and Floodwalls, 1989
3. US Army Corps of Engineers EM 1110-2-2104 Strength Design for Reinforced Concrete Hydraulic Structures, 2003

Construction Specifications

1. Maricopa Association of Governments (MAG) Uniform Standard Specifications for Public Works Construction
2. Arizona Department of Transportation (ADOT) Standard Specifications for Road and Bridge Construction, 2000 Edition, and the Special Provisions

Concrete

All concrete shall be MAG Class 'A'

$f'_c = 3{,}000$ psi

Reinforcing Steel

All reinforcing steel shall conform to ASTM A615/A615M Grade 60

$f_s = 24{,}000$ psi

Foundations

Geotechnical Study Report, May 2006 by Kleinfelder, Inc., Project No. 63683 (1)

2.0 TYPE A FLOODWALL DESIGN

Design of Type A Flood Wall

References:

(1) EM 1110-2-2502 "Retaining and Flood Walls" of Sept 1989, US Army Corps of Engineers
(2) EM 1110-2-2104 "Strength Design for Reinforced Concrete Hydraulic Structures" June 1992, US Army Corps of Engineers and Change 1 dated August 2003
(3) Geotechnical Study Report Project No 63683 (1) dated January 2006 by Kleinfelder Inc.

I Data

1. Unit Weights:

Unit weight of water	$\gamma_w := 62.4 \cdot pcf$
Unit weight of concrete	$\gamma_{conc} := 150 \cdot pcf$
Unit weight of steel	$\gamma_{steel} := 490 \cdot pcf$
Unit width of wall	$b := 1.0 \cdot ft$
Load factor	$\gamma_u := 2.21$
Load factor for extreme loads	$\gamma_{ux} := 0.75\gamma_u$
Flexural resistance factor	$\phi_b := 0.90$
Shear resistance factor	$\phi_v := 0.85$

2. Materials:

Class A concrete:

Min 28 day compressive strength $f'_c := 3000 \cdot psi$

Elastic modulus of concrete $E_c := 33 \cdot \left(\frac{\gamma_{conc}}{pcf}\right)^{1.5} \cdot \sqrt{\frac{f'_c}{psi}} \cdot psi$ $\quad E_c = 3321\ ksi$

Stress block factor

$$\beta_1 := \begin{cases} 0.85 & \text{if } f'_c \le 4000 \cdot psi \\ 0.65 & \text{if } f'_c \ge 8000 \cdot psi \\ 0.85 - 0.05 \cdot \left(\frac{f'_c - 4000 \cdot psi}{1000 \cdot psi}\right) & \text{otherwise} \end{cases} \qquad \beta_1 = 0.85$$

$$\beta_m := \begin{cases} 0.55 & \text{if } f'_c \le 4000 \cdot psi \\ 0.50 & \text{otherwise} \end{cases} \qquad \beta_m = 0.55$$

Strain in concrete at balanced condition $\varepsilon_c := 0.003$

Steel:

Elastic modulus of steel	$E_s := 29000 \cdot ksi$	
Yield strength of rebar	$f_y := 60.00 ksi$	
Strain in steel at yield of concrete	$\varepsilon_m := 0.003$	
Ductility coefficient (fraction of balanced reinf)	$\lambda := 0.50$	
Modular ratio	$n := \text{floor}\left(\frac{E_s}{E_c}\right)$	$n = 8$

Structural Backfill:

Unit weight of moist backfill	$\gamma_{back} := 120 \cdot pcf$	

Native Soil:

Unit weight of moist soil	$\gamma_m := 105 \cdot pcf$	
Unit weight of submerged soil	$\gamma_b := 56 \cdot pcf$	
Angle of internal friction	$\phi := 31 \cdot deg$	$\phi = 0.54\ rad$
Coefficient of at-rest earth pressure	$K_o := 1 - \sin(\phi)$	$K_o = 0.48$
Coefficient of active earth pressure	$K_a := \tan\left(45deg - \frac{\phi}{2}\right)^2$	$K_a = 0.32$
Coefficient of passive earth pressure	$K_p := \tan\left(45deg + \frac{\phi}{2}\right)^2$	$K_p = 3.12$

3. Geometry:

Wall Control Elevations

Top of wall	$TW := 2069.00 \cdot ft$	
Top of footing	$TF := 2048.00 \cdot ft$	
Min freeboard required	$FB_{min} := 3.50 \cdot ft$	
Water surface elevation	$WSEL := TW - FB_{min}$	
Backfill elevation	$TBack := 2061.00 \cdot ft$	
Channel bed elevation	$Bed := 2050.50 \cdot ft$	
Freeboard	$FB := TW - WSEL$	$FB = 3.50\ ft$
Freeboard at extreme condition	$FB_x := 0.00$	
Assumed elevation of backfill seepage	$SeepEL := TF$	

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Subject : Sols Wash Flood Wall
Computed : JAL
Checked :

Gannett Fleming

Date: 05-Sep-2006
Sheet No.:

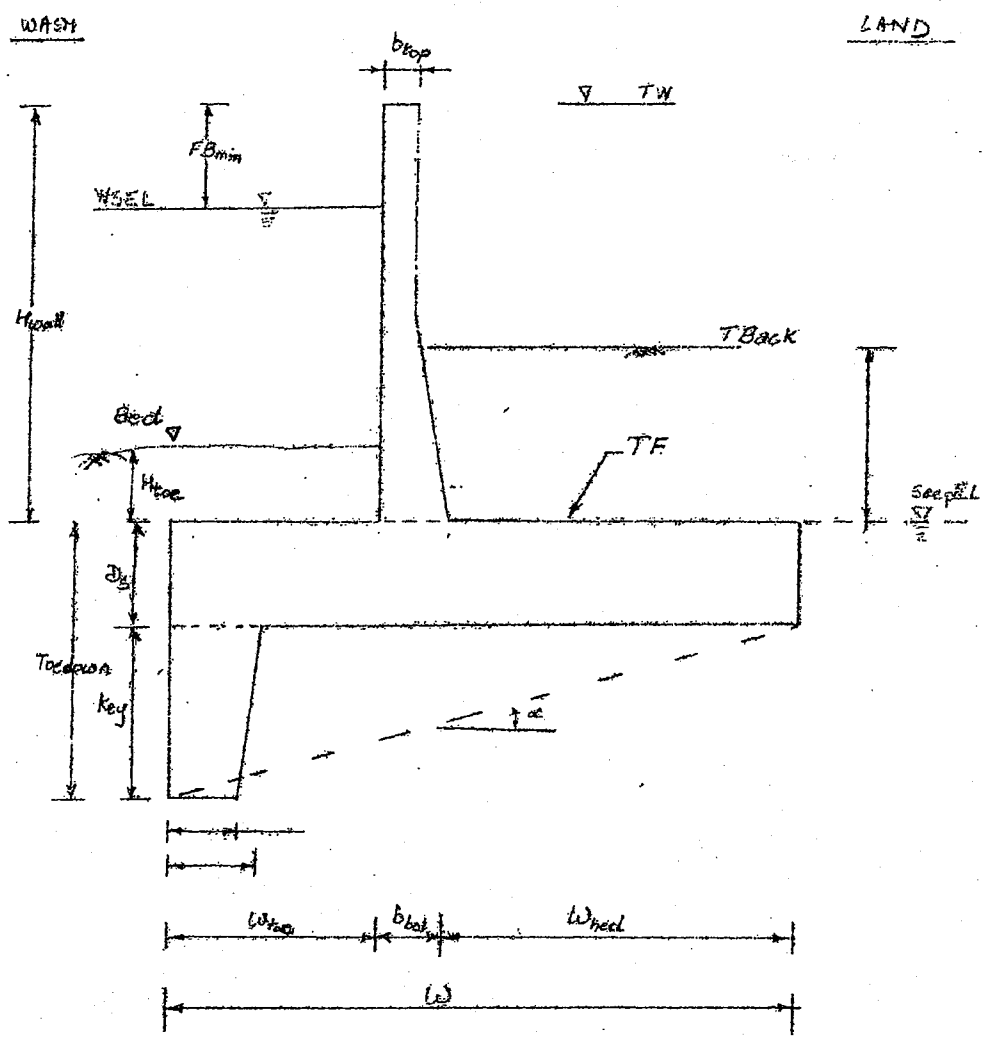

Fig. 1: Control Elevations & Geometry

Wall Section

Width of stem wall at top	$b_{top} := 10 \cdot in$	$b_{top} = 0.83\ ft$
Width of stem at base	$b_{bot} := 22 \cdot in$	$b_{bot} = 1.833\ ft$
Width of toe	$W_{toe} := 10.50 \cdot ft$	
Width of toe (beyond stem)	$W_{heel} := 11.667 \cdot ft$	
Thickness of base slab	$D_s := 3.00 \cdot ft$	
Width of base slab	$W := W_{toe} + b_{bot} + W_{heel}$	$W = 24.00\ ft$
Length of toe down	$Toedown := D_s + 5 \cdot ft$	$Toedown = 8.00\ ft$
Height of wall	$H_{wall} := TW - TF$	$H_{wall} = 21.00\ ft$
Height of soil on heel	$H_{soil} := TBack - TF$	$H_{soil} = 13.00\ ft$
Height of soil behind toedown	$H_{tdn} := Toedown - D_s$	$H_{tdn} = 5.00\ ft$
Height of soil above toe	$H_{toe} := Bed - TF$	$H_{toe} = 2.50\ ft$
Height of soil in channel	$H_{ch} := H_{toe} + Toedown$	$H_{ch} = 10.50\ ft$
Height of moist soil over heel	$H_m := TBack - SeepEL$	$H_m = 13.00\ ft$
Height of submerged soil over heel	$H_{subheel} := SeepEL - TF$	$H_{subheel} = 0.00\ ft$
Height of submerged soil over foundation	$H_{sub} := (SeepEL - TF) + D_s$	$H_{sub} = 3.00\ ft$
Width of key at bot of toedown	$Key_{bot} := 2.00 \cdot ft$	
Width of key at top of toedown	$Key_{top} := 2.50 \cdot ft$	
Length of key	$Key := Toedown - D_s$	$Key = 5.00\ ft$
Angle of sliding plane	$\alpha := atan\left(\frac{Key}{W}\right)$	$\alpha = 11.77\ deg$
Height of soil above foundation base	$H_{fnd} := Key$	$H_{fnd} = 5.00\ ft$

4. Wall Weights:

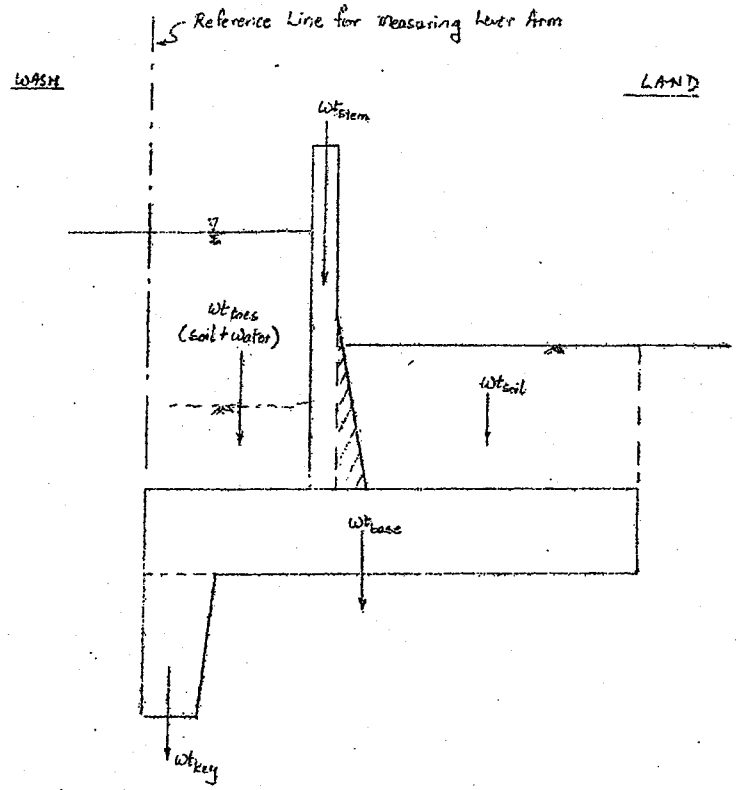

FIG 2: Weight of wall structure

Weight of stem (ignore batter)	$Wt_{stem} := \gamma_{conc} \cdot H_{wall} \cdot b_{top} \cdot ft$	$Wt_{stem} = 2625\ lbf$
Weight of base slab	$Wt_{base} := \gamma_{conc} \cdot D_s \cdot W \cdot ft$	$Wt_{base} = 10800\ lbf$
Weight of soil over heel slab (ignore batter)	$Wt_{soil} := \gamma_{back} \cdot H_{soil} \cdot (W - W_{toe} - b_{top}) \cdot ft$	$Wt_{soil} = 19761\ lbf$
Lever arm of stem wall w.r.t. toe	$LA_{stem} := W_{toe} + \frac{b_{top}}{2}$	$LA_{stem} = 10.92\ ft$
Lever arm of base slab w.r.t. toe	$LA_{base} := \frac{W}{2}$	$LA_{base} = 12.00\ ft$
Lever arm of soil on heel w.r.t. toe	$LA_{soil} := W - \frac{W - W_{toe} - b_{top}}{2}$	$LA_{soil} = 17.67\ ft$
Weight of soil and water over toe slab	$Wt_{toes} := \left[\gamma_w (TW - FB - TF) + \gamma_b \cdot H_{toe}\right] \cdot W_{toe} \cdot ft$	$Wt_{toes} = 12936\ lbf$

Lever arm of soil on toe w.r.t. toe $LA_{toes} := \frac{W_{toe}}{2}$ $LA_{toes} = 5.25\ ft$

Weight of key $Wt_{key} := \gamma_{conc} \cdot \frac{Key_{top} + Key_{bot}}{2} \cdot Key \cdot ft$ $Wt_{key} = 1688\ lbf$

Lever arm of key w.r.t. toe $LA_{key} := \frac{Key_{bot}}{2}$ $LA_{key} = 1.00\ ft$

Total weight of wall $Wt_{wall} := Wt_{stem} + Wt_{base} + Wt_{soil} + Wt_{toes} + Wt_{key}$ $Wt_{wall} = 47809\ lbf$

LA of wall w.r.t. toe $LA_{toe} := \frac{Wt_{stem} \cdot LA_{stem} + Wt_{base} \cdot LA_{base} + Wt_{soil} \cdot LA_{soil} + Wt_{toes} \cdot LA_{toes} + Wt_{key} \cdot LA_{key}}{Wt_{wall}}$

$LA_{toe} = 12.07\ ft$

LA of wall w.r.t. heel $LA_{heel} := W - LA_{toe}$ $LA_{heel} = 11.93\ ft$

II Stability Check - Normal Condition:

Normal flood condition, water at top of wall, less freeboard

1. Safety Factors:

Factor of safety against sliding $FS_s := 1.50$

Factor of safety for bearing $FS_b := 3.00$

2. Forces on Wall:

Height of water in front of wall $H_w := (TW - FB - TF) + Toedown$ $H_w = 25.50\ ft$

Force of channel water $P_w := \frac{1}{2}\gamma_w \cdot H_w^2 \cdot ft$ $P_w = 20288\ lbf$

Moment about base $M_w := P_w \frac{H_w}{3}$ $M_w = 172446\ ft \cdot lbf$

Pressure of channel soil $p_{ach} := K_a \cdot \gamma_b \cdot H_{ch}$ $p_{ach} = 188.22\ psf$

Force of channel soil $P_{ach} := \frac{1}{2} p_{ach} \cdot H_{ch} \cdot ft$ $P_{ach} = 988\ lbf$

Pressure of moist backfill $p_{o_1} := K_o \cdot \gamma_m \cdot H_m$ $p_{o_1} = 662\ psf$

Pressure of submerged backfill $p_{o_2} := K_o \cdot \gamma_b \cdot H_{sub}$ $p_{o_2} = 81\ psf$

Force of backfill above seepage line $P_{o_1} := \frac{1}{2} p_{o_1} \cdot H_m \cdot ft$ $P_{o_1} = 4303\ lbf$

Moment about base $M_{o_1} := P_{o_1} \cdot \left(\frac{H_m}{3} + H_{sub} + H_{fnd}\right)$ $M_{o_1} = 53068\ ft \cdot lbf$

Force of backfill below seepage line $P_{o_2} := \left(p_{o_1} + \frac{1}{2} \cdot p_{o_2}\right) \cdot H_{sub} \cdot ft$ $P_{o_2} = 2108\ lbf$

Moment about base $M_{o_2} := \left(\frac{p_{o_1}}{2} + \frac{1}{6} \cdot p_{o_2}\right) \cdot H_{sub}^2 \cdot ft$ $M_{o_2} = 3101\ ft \cdot lbf$

LA of backfill above base $LA_{back} := \frac{\sum M_o}{\sum P_o}$ $LA_{back} = 8.76\ ft$

3. Uplift Forces

Maximum uplift pressure	$Up_{max} := \gamma_w H_w$	$Up_{max} = 1591\,psf$
Head difference across wall	$\Delta_h := (TW - FB) - SeepEL$	$\Delta_h = 17.50\,ft$
Length of seepage path along width of key	$L_{CD} := Key_{bot}$	$L_{CD} = 2.00\,ft$
Length of seepage path along height of key	$L_{DE} := \sqrt{(Key_{bot} - Key_{top})^2 + Key^2}$	$L_{DE} = 5.02\,ft$
Length of seepage path along base of slab	$L_{EF} := W - Key_{top}$	$L_{EF} = 21.50\,ft$
Length of seepage plane	$L_s := \sqrt{Key^2 + W^2}$	$L_s = 24.52\,ft$
Total length of seepage path	$L_{seep} := L_{CD} + L_{DE} + L_{EF}$	$L_{seep} = 28.53\,ft$
Minimum uplift pressure	$Up_{min} := \gamma_w \left[(H_w - Key) - \frac{\Delta_h \cdot L_s}{L_{seep} + H_{sub}} \right]$	$Up_{min} = 430\,psf$
Total loss along seepage path	$Loss := \frac{\Delta_h \cdot L_s}{L_s + H_{sub}}$	$Loss = 15.59\,ft$
Uplift pressure at bot of key	$Up_d := Up_{max} - \frac{L_{CD}}{L_{seep}} \cdot Loss \cdot \gamma_w$	$Up_d = 1523\,psf$
	$H_e := TW - FB - TF + D_s$	$H_e = 20.50\,ft$
Uplift pressure at top of key	$Up_e := \left(H_e - \frac{L_{CD} + L_{DE}}{L_{seep}} \cdot Loss \right) \cdot \gamma_w$	$Up_e = 1040\,psf$

4. Overturning Check

Uplift force below key	$Up_1 := (Up_{max} + Up_d) \cdot \frac{Key_{bot}}{2} \cdot ft$	$Up_1 = 3114\ lbf$
Uplift force against slope of key	$Up_2 := (Up_d + Up_e) \cdot \frac{Key_{top} - Key_{bot}}{2} \cdot ft$	$Up_2 = 641\ lbf$
Uplift force on heel	$Up_3 := (Up_{min} + Up_e) \cdot \frac{L_{EF}}{2} \cdot ft$	$Up_3 = 15798\ lbf$
Total uplift force	$Uplift := \sum Up$	$Uplift = 19553\ lbf$
Approx LA of uplift w.r.t. heel	$LA_{up} := \frac{2Up_{max} + Up_{min}}{Up_{max} + Up_{min}} \cdot \frac{W}{3}$	$LA_{up} = 14.30\,ft$
Water pressure at base of slab	$pw_g := Up_{min}$	$pw_g = 430\,psf$
Water pressure at top of foundation soil	$pw'_g := Up_e$	$pw'_g = 1040\,psf$
Water pressure at bot of foundation soil	$pw_f := Up_d$	$pw_f = 1523\,psf$
Force of water behind wall	$P_{wback} := \left(\frac{1}{2} pw_g \cdot H_{sub} + \frac{pw'_g + pw_f}{2} \cdot H_{fnd}\right) \cdot ft$	$P_{wback} = 7051\ lbf$
Overturning moment about heel	$M_{wback} := \left[\frac{1}{2} pw_g \cdot H_{sub} \cdot \left(\frac{H_{sub}}{3}\right) - \frac{pw'_g + pw_f}{4} \cdot H_{fnd}^2\right] \cdot ft$	$M_{wback} = -15371\ ft \cdot lbf$

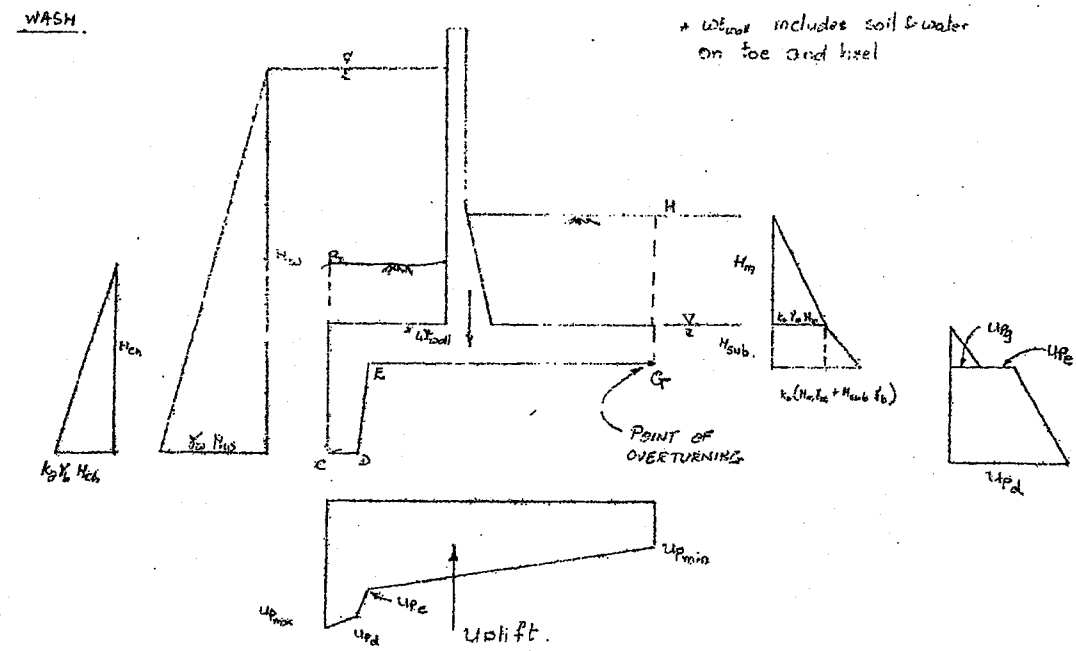

FIG. 3: Overturning of wall

Total vertical force	$Ver := Wt_{wall} - Uplift$	$Ver = 28256\ lbf$
Total horizontal force	$Hor := P_w + P_{ach} - \left(\sum P_o + P_{wback}\right)$	$Hor = 7814\ lbf$
Passive pressure to balance sliding	$P_{pas} := \begin{cases} Hor & \text{if } Hor - Ver \cdot \tan(\phi) \ge 0 \\ 0 & \text{otherwise} \end{cases}$	$P_{pas} = 0\ lbf$
LA of passive pressure about base of slab	$LA_{pas} := \frac{-Key}{2}$	$LA_{pas} = -2.50\ ft$
Coefficient of passive pressure induced	$K_{pin} := \frac{P_{pas}}{\gamma_b \cdot Key^2 \cdot ft}$	$K_{pin} = 0.00$
Check for max induced passive pressure	$Check_passive := \begin{cases} \text{"Okay"} & \text{if } K_{pin} \le 0.5 \cdot K_p \\ \text{"NG"} & \text{otherwise} \end{cases}$	

[redacted]

Moment of wall about heel	$M_1 := Wt_{wall} \cdot LA_{heel}$	$M_1 = 570469\ ft \cdot lbf$
Moment of uplift force about heel	$M_2 := -Uplift \cdot LA_{up}$	$M_2 = -279577\ ft \cdot lbf$
Moment of water in channel about base	$M_3 := -P_w \cdot \left(\frac{H_w}{3} - Key\right)$	$M_3 = -71007\ ft \cdot lbf$
Moment of soil in channel about base	$M_4 := -P_{ach} \cdot \left(\frac{H_{ch}}{3} - Key\right)$	$M_4 = 1482\ ft \cdot lbf$
Moment of backfill above base	$M_5 := \sum P_o \cdot LA_{back}$	$M_5 = 56169\ ft \cdot lbf$
Moment of backfill below base	$M_6 := -P_{pas} \cdot LA_{pas}$	$M_6 = 0\ ft \cdot lbf$
Moment of water in backfill	$M_7 := M_{wback}$	$M_7 = -15371\ ft \cdot lbf$
Net moment about base	$M_{net} := \sum M$	$M_{net} = 262165\ ft \cdot lbf$
Location of resultant from heel	$x_{edge} := \frac{M_{net}}{Ver}$	$x_{edge} = 9.28\ ft$
Location of resultant w.r.t. center of slab	$ecc := \frac{W}{2} - x_{edge}$	$ecc = 2.722\ ft$
Check for foundation contact	$Contact := \begin{cases} \text{"Okay"} & \text{if } \lvert ecc \rvert \le \frac{W}{6} \\ \text{"NA"} & \text{otherwise} \end{cases}$	
	Contact = "Okay"	
Maximum stress beneath foundation	$\sigma_{max} := \frac{Ver}{b \cdot W} \cdot \left(1 + \frac{6 \cdot ecc}{W}\right)$	$\sigma_{max} = 1978\ psf$
Maximum stress beneath foundation	$\sigma_{min} := \frac{Ver}{b \cdot W} \cdot \left(1 - \frac{6 \cdot ecc}{W}\right)$	$\sigma_{min} = 376\ psf$
Pressure on toe at face of stem	$\sigma_{stoe} := \sigma_{min} + \left(\frac{\sigma_{max} - \sigma_{min}}{W}\right) \cdot W_{toe}$	$\sigma_{stoe} = 1077\ psf$
Pressure on heel at face of stem	$\sigma_{sheel} := \sigma_{min} + \left(\frac{\sigma_{max} - \sigma_{min}}{W}\right) \cdot (W_{toe} + b_{bot})$	$\sigma_{sheel} = 1200\ psf$

5. Structural Forces on Wall Components:

A Stem Wall

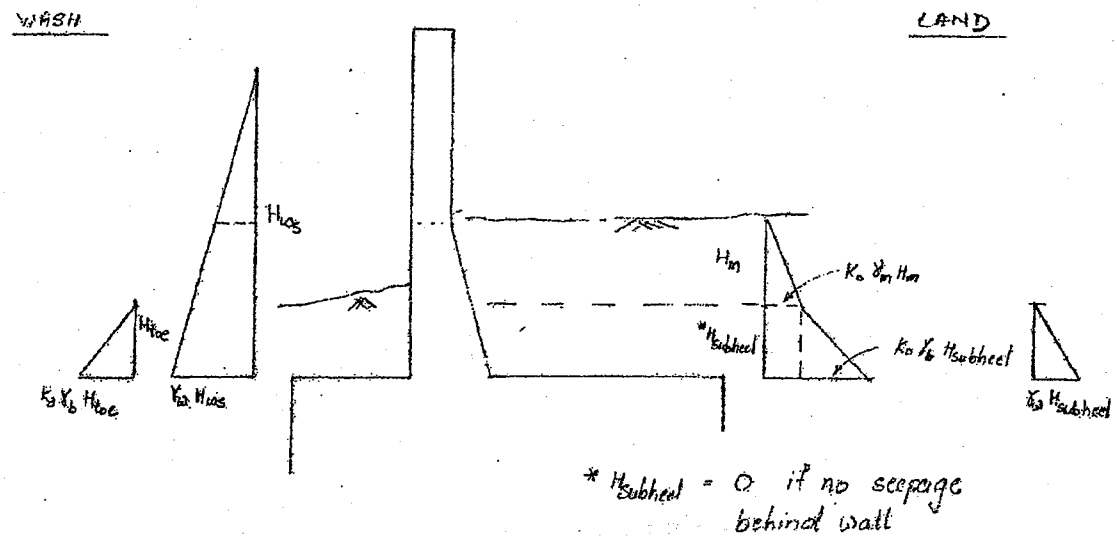

FIG 4: Structural Forces on Stem

Height of water acting on stem $H_{ws} := (TW - TF) - FB$ $H_{ws} = 17.50\ ft$

Moment at stem base on water side $M_{water} := \frac{1}{6}\cdot\left(\gamma_w \cdot H_{ws}^3 + K_a \cdot \gamma_b \cdot H_{toe}^3\right)\cdot b$ $M_{water} = 55.78\ ft\cdot kip$

Moment on land side

$$M_{land} := \left[\frac{K_o \gamma_m \cdot H_m^2}{2}\cdot\left(\frac{H_m}{3} + H_{subheel}\right) + \frac{1}{6}\gamma_w \cdot H_{subheel}^3 \ldots + K_o \cdot\left(\frac{\gamma_b \cdot H_{subheel}^3}{6} + \frac{\gamma_m \cdot H_m \cdot H_{subheel}^2}{2}\right)\right]\cdot b$$

$M_{land} = 18646\ ft\cdot lbf$

Shear at stem base on water side $V_{water} := \frac{1}{2}\cdot\left(\gamma_w \cdot H_{ws}^2 + K_a \cdot \gamma_b \cdot H_{toe}^2\right)\cdot b$ $V_{water} = 9.61\ kip$

Shear on land side

$$V_{land} := \left[\frac{K_o \gamma_m \cdot H_m^2}{2} + \frac{1}{2}\gamma_w \cdot H_{subheel}^2 \ldots + K_o \cdot\left(\frac{\gamma_b \cdot H_{subheel}^2}{2} + \gamma_m \cdot H_m \cdot H_{subheel}\right)\right]\cdot b$$

$V_{land} = 4303\ lbf$

Net shear on wall $V_{stem_1} := V_{water} - V_{land}$ $V_{stem_1} = 5308\ lbf$

Net moment on stem wall $M_{stem_1} := M_{water} - M_{land}$ $M_{stem_1} = 37.14\ ft\cdot kips$

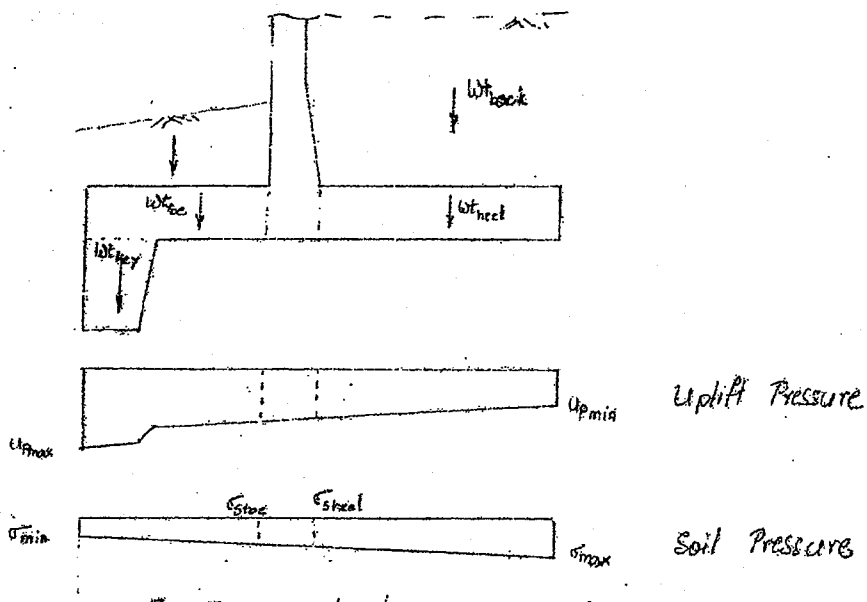

Fig. 5: Structural Forces on Footing

B Toe Slab

Upward soil pressure on toe	$S_{toe} := \left(\frac{\sigma_{min} + \sigma_{stoe}}{2}\right) \cdot W_{toe} \cdot ft$	$S_{toe} = 7630\ lbf$
Weight of toe	$Wt_{toe} := \gamma_{conc} \cdot W_{toe} \cdot D_s \cdot ft + Wt_{key}$	$Wt_{toe} = 6413\ lbf$
Weight of soil on toe	$Soil_{toe} := \gamma_b \cdot H_{toe} \cdot W_{toe} \cdot ft$	$Soil_{toe} = 1470\ lbf$
Moment due to weight of key	$M_{key} := Wt_{key} \cdot \left(W_{toe} - \frac{Key_{top}}{2}\right)$	$M_{key} = 15609\ ft \cdot lbf$
Moment due to uplift on key base	$M_{upt_1} := Up_1 \cdot \left(W_{toe} - \frac{L_{CD}}{2}\right)$	$M_{upt_1} = 29585\ ft \cdot lbf$
Moment due to uplift on key side	$M_{upt_2} := Up_2 \cdot \left(W_{toe} - \frac{Key_{top} + Key_{bot}}{2}\right)$	$M_{upt_2} = 5285\ ft \cdot lbf$
Uplift force on toe	$Up_{toe} := Up_d \cdot (W_{toe} - Key_{top}) \cdot ft$	$Up_{toe} = 12184\ lbf$
Moment due to uplift on base of toe	$M_{upt_3} := Up_{toe} \cdot \frac{W_{toe} - Key_{top}}{2}$	$M_{upt_3} = 48735\ ft \cdot lbf$
Shear on toe at face of stem	$V_{toe_1} := S_{toe} + Up_1 + Up_2 + Up_{toe} - Wt_{toe} - Soil_{toe}$	$V_{toe_1} = 15.69\ kips$
Moment on toe at face of stem	$M_{toe_1} := (S_{toe} - Wt_{toe} - Soil_{toe}) \cdot \frac{W_{toe}}{2} + \sum M_{upt} - M_{key}$	$M_{toe_1} = 66.67\ ft \cdot kips$

C Heel Slab

Weight of heel slab	$Wt_{heel} := \gamma_{conc} \cdot W_{heel} \cdot D_s \cdot ft$	$Wt_{heel} = 5250\ lbf$
Moment of heel slab	$M_{wheel} := Wt_{heel} \cdot \frac{W_{heel}}{2}$	$M_{wheel} = 30627\ ft \cdot lbf$
Weight of soil and water on heel slab	$Wt_{back} := \gamma_{back} \cdot W_{heel} \cdot H_{soil} \cdot ft$	$Wt_{back} = 18201\ lbf$
Moment of heel slab	$M_{back} := Wt_{back} \cdot \frac{W_{heel}}{2}$	$M_{back} = 106173\ ft \cdot lbf$
Upward soil pressure on heel	$S_{heel} := \left(\frac{\sigma_{sheel} + \sigma_{max}}{2}\right) \cdot W_{heel} \cdot ft$	$S_{heel} = 18539\ lbf$
Lever arm of soil pressure on heel	$la_{sheel} := \left(\frac{\sigma_{sheel} + 2\sigma_{max}}{\sigma_{sheel} + \sigma_{max}}\right) \cdot \frac{W_{heel}}{3}$	$la_{sheel} = 6.31\ ft$
Moment of soil pressure on heel	$M_{sheel} := S_{heel} \cdot la_{sheel}$	$M_{sheel} = 116981\ ft \cdot lbf$
Uplift force on heel slab	$Up_{heel} := \frac{Up_e + Up_{min}}{2} \cdot W_{heel} \cdot ft$	$Up_{heel} = 8573\ lbf$
Lever arm of uplift pressure on heel	$la_{uheel} := \left(\frac{Up_e + 2Up_{min}}{Up_e + Up_{min}}\right) \cdot \frac{W_{heel}}{3}$	$la_{uheel} = 5.03\ ft$
Moment of uplift pressure on heel	$M_{upheel} := Up_{heel} \cdot la_{uheel}$	$M_{upheel} = 43095\ ft \cdot lbf$
Shear force on heel slab	$V_{heel_1} := \lvert Wt_{heel} + Wt_{back} - S_{heel} - Up_{heel} \rvert$	$V_{heel_1} = 3661\ lbf$
Moment on heel slab	$M_{heel_1} := \lvert M_{wheel} + M_{back} - M_{sheel} - M_{upheel} \rvert$	$M_{heel_1} = 23.28\ ft \cdot kips$

D Shear Key

Water pressure at top of key	$Water_{top} := \gamma_w (TW - TF - FB + D_s)$	$Water_{top} = 1279\ psf$
Water pressure at bottom of key	$Water_{bot} := \gamma_w (TW - TF + Toedown)$	$Water_{bot} = 1810\ psf$
Soil pressure at top of key	$Soil_{top} := K_a \cdot \gamma_b \cdot (TW - TF - FB + D_s)$	$Soil_{top} = 367\ psf$
Soil pressure at bottom of key	$Soil_{bot} := K_a \cdot \gamma_b \cdot (TW - TF + Toedown)$	$Soil_{bot} = 520\ psf$

Water side hydraulic force on key	$Hyd_{key} := \frac{Water_{top} + Water_{bot}}{2} \cdot Toedown \cdot ft$	$Hyd_{key} = 12355\ lbf$
Water side soil force on key	$Soil_{key} := \frac{Soil_{top} + Soil_{bot}}{2} \cdot Toedown \cdot ft$	$Soil_{key} = 3549\ lbf$
Landside water force on key	$W_{kylnd} := \frac{Up_d + Up_e}{2} \cdot Key \cdot ft$	$W_{kylnd} = 6406\ lbf$
Soil pressure at top of key	$Soil_{top} := K_o \cdot \gamma_m \cdot (TBack - TF + D_s)$	$Soil_{top} = 815\ psf$
Soil pressure at bottom of key	$Soil_{bot} := K_o \cdot \gamma_m \cdot (TBack - TF + Toedown)$	$Soil_{bot} = 1069\ psf$
Landside soil force on key	$S_{kylnd} := \frac{Soil_{top} + Soil_{bot}}{2} \cdot Toedown \cdot ft$	$S_{kylnd} = 7536\ lbf$
<u>Shear force at top of key</u>	$V_{key_1} := Hyd_{key} + Soil_{key} - W_{kylnd} - S_{kylnd}$	$V_{key_1} = 1962\ lbf$
<u>Moment at top of key</u>	$M_{key_1} := V_{key_1} \cdot \frac{Key}{2}$	$M_{key_1} = 4.90\ ft \cdot kips$

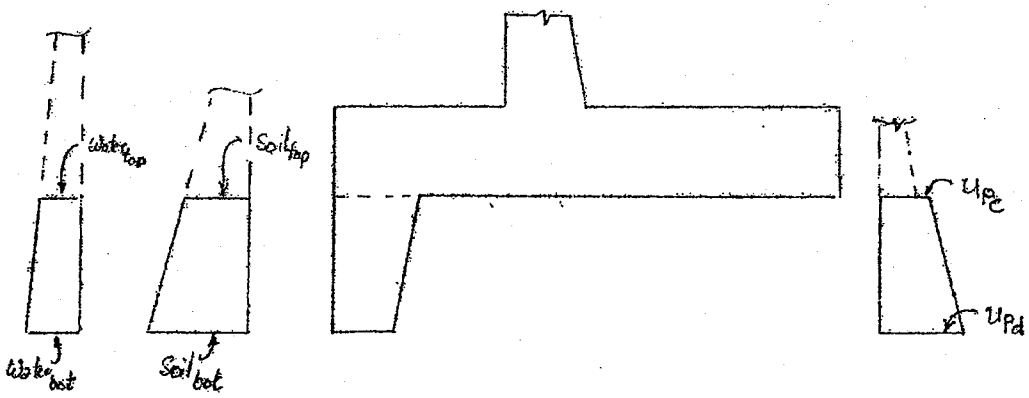

Fig. 6: Structural Forces on Key

6. Sliding on Inclined Plane:

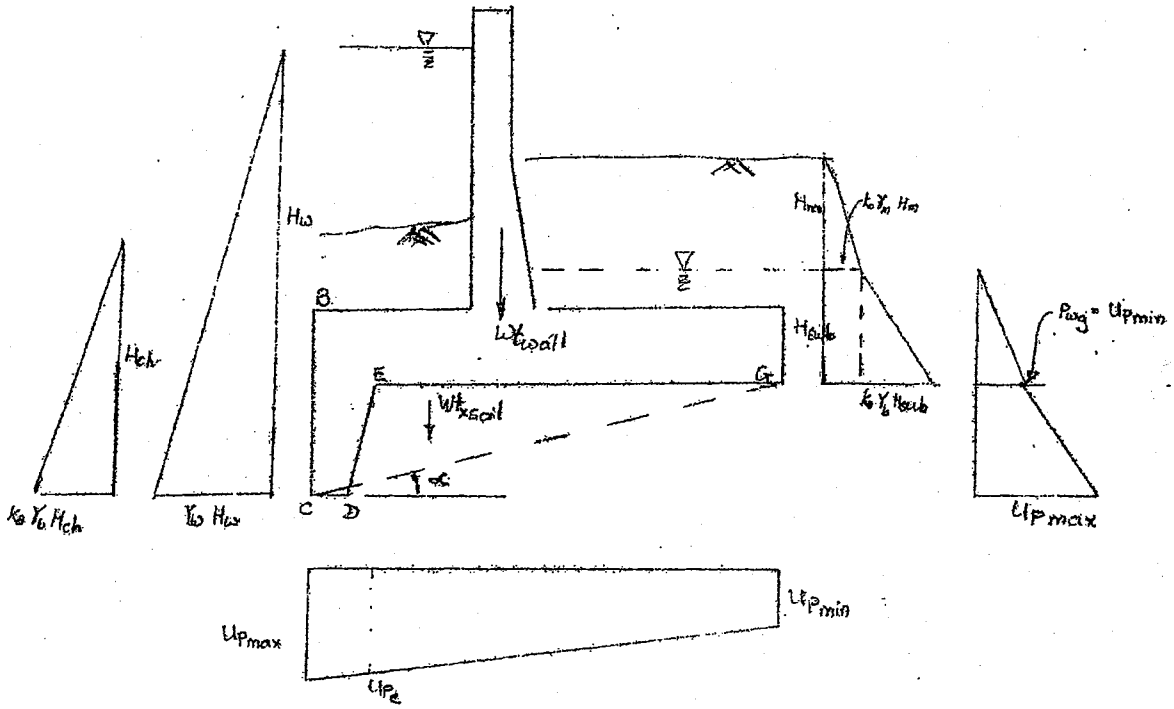

Fig. 7: Sliding on Inclined Plane

Weight of additional soil below slab	$Wt_{xsoil} := \frac{1}{2} \cdot \gamma_b \cdot Key \cdot W \cdot ft$	$Wt_{xsoil} = 3360$ lbf
Uplift force on inclined sliding plane	$Uplift := \frac{Up_{max} + Up_{min}}{2} \cdot W \cdot ft$	$Uplift = 24255$ lbf
Force due to water behind wall	$P'_{wback} := \left(\frac{1}{2} Up_{min} \cdot H_{sub} + \frac{Up_{min} + Up_{max}}{2} \cdot H_{fnd}\right) \cdot ft$	$P'_{wback} = 5698$ lbf
Total vertical force	$Ver := Wt_{wall} + Wt_{xsoil} - Uplift$	$Ver = 26914$ lbf
Total horizontal force	$Hor := P_w + P_{ach} - \left(\sum P_o + P'_{wback}\right)$	$Hor = 9167$ lbf
Normal force on sliding plane	$N := Ver \cdot \cos(\alpha) + Hor \cdot \sin(\alpha)$	$N = 28218$ lbf
Tangential force on sliding plane	$T := Hor \cdot \cos(\alpha) - Ver \cdot \sin(\alpha)$	$T = 3485$ lbf

Tangential capacity with given FS $T_{cap} := \frac{N \cdot \tan(\phi)}{FS_s}$ $T_{cap} = 11304$ lbf

$$Check_Sliding := \begin{cases} \text{"Okay"} & \text{if } T_{cap} \geq |T| \\ \text{"NG"} & \text{otherwise} \end{cases}$$

Check_Sliding = "Okay"

7. Sliding on Horizonal Plane below Key:

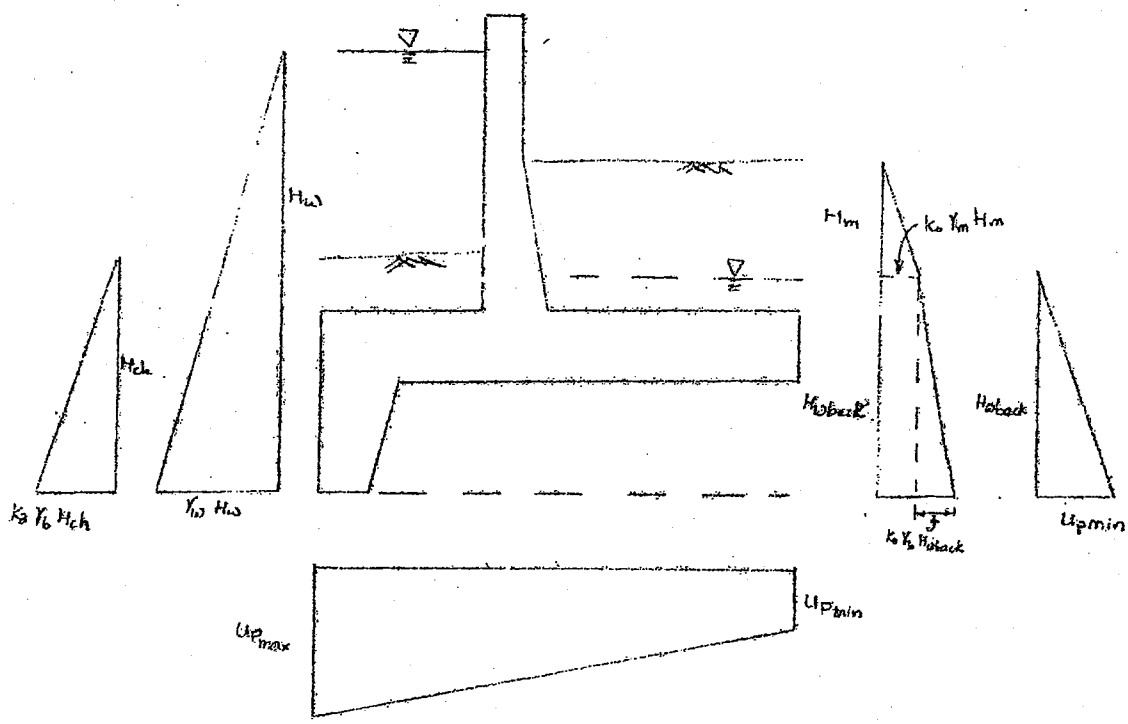

Fig. 8: Sliding on Horz Plane Below Key

Weight of additional soil below slab $Wt_{xsoil} := \gamma_b \cdot Key \cdot W \cdot ft$ $Wt_{xsoil} = 6720$ lbf

Length of seepage plane $L_s := W + H_{sub} + H_{fnd}$ $L_s = 32.00$ ft

Minimum uplift pressure $Up_{min} := \gamma_w \left(H_w - \frac{\Delta_h \cdot W}{L_s} \right)$ $Up_{min} = 772$ psf

Uplift force on inclined sliding plane	$Uplift := \frac{Up_{max} + Up_{min}}{2} \cdot W \cdot ft$	$Uplift = 28361\ lbf$
Water behind wall	$H_{wback} := H_{sub} + H_{fnd}$	$H_{wback} = 8.00\ ft$
Water pressure behind wall	$P_{wback} := \frac{1}{2} \cdot Up_{min} \cdot H_{wback} \cdot ft$	$P_{wback} = 3089\ lbf$
At rest pressure behind wall	$P_o := \left[\frac{1}{2} \cdot \gamma_m \cdot H_m^2 + K_o \cdot \left(\gamma_m \cdot H_m \cdot H_{wback} + \frac{\gamma_b \cdot H_{wback}^2}{2}\right)\right] \cdot ft$	
Total vertical force	$Ver := Wt_{wall} + Wt_{xsoil} - Uplift$	$Ver = 26168\ lbf$
Total horizontal force	$Hor := P_w + P_{ach} - (P_o + P_{wback})$	$Hor = 3150\ lbf$
Normal force on sliding plane	$N := Ver$	$N = 26168\ lbf$
Tangential force on sliding plane	$T := Hor$	$T = 3150\ lbf$
Tangential capacity with given FS	$T_{cap} := \frac{N \cdot \tan(\phi)}{FS_s}$	$T_{cap} = 10482\ lbf$
	$Check_Sliding := \begin{cases} \text{"Okay"} & \text{if } T_{cap} \geq \lvert T \rvert \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	Check_Sliding = "Okay"	

8. Bearing on Inclined Plane

Length of inclined bearing plane	$L_{cg} := \sqrt{Key^2 + W^2}$	$L_{cg} = 24.52\ ft$
LA of uplift w.r.t. heel	$LA_{up} := \frac{2Up_{max} + Up_{min}}{Up_{max} + Up_{min}} \cdot \frac{W}{3}$	$LA_{up} = 13.39\ ft$
Moment of uplift force about heel	$M_2 := -Uplift \cdot LA_{up}$	$M_2 = -379652\ ft \cdot lbf$
Total vertical force	$Ver := Wt_{wall} + Wt_{xsoil} - Uplift$	$Ver = 26168\ lbf$
Total horizontal force	$Hor := P_w + P_{ach} - (P_o + P_{wback})$	$Hor = 3150\ lbf$

Normal force on sliding plane	$N := Ver \cdot \cos(\alpha) + Hor \cdot \sin(\alpha)$	$N = 26260\ lbf$
Tangential force on sliding plane	$T := Hor \cdot \cos(\alpha) - Ver \cdot \sin(\alpha)$	$T = -2253\ lbf$
Net moment about base	$M_{net} := \sum M$	$M_{net} = 162090\ ft \cdot lbf$
Location of resultant on inclined plane w.r.t. heel	$x_e := \frac{M_{net}}{N}$	$x_{edge} = 9.28\ ft$
Location of resultant w.r.t. center of plane	$e_{cg} := \frac{L_{cg}}{2} - x_e$	$e_{cg} = 6.09\ ft$

9. Bearing Capacity of Foundation:

Depth of embedment	$D := Toedown$	
Width of foundation in contact	$L' := L_{cg} - 2 \cdot e_{cg}$	$L' = 12.34\ ft$
Bearing capacity factors	$N_q := e^{\pi \cdot \tan(\phi)} \cdot \tan\left(45deg + \frac{\phi}{2}\right)^2$	$N_q = 20.63$
	$N_\gamma := (N_q - 1) \cdot \tan(1.4 \cdot \phi)$	$N_\gamma = 18.56$
Depth modification factors	$\xi_{qd} := 1 + 0.1\left(\frac{D}{L'}\right)\tan\left(45deg + \frac{\phi}{2}\right)^2$	$\xi_{qd} = 1.20$
	$\xi_{\gamma d} := \xi_{qd}$	
Angle of inclination of load	$\delta := atan\left(\frac{\lvert T \rvert}{N}\right)$	$\delta = 4.90\ deg$
Load inclination modification factors	$\xi_{qi} := \left(1 - \frac{\delta}{90 \cdot deg}\right)^2$	$\xi_{qi} = 0.89$
	$\xi_{\gamma i} := \left(1 - \frac{\delta}{\phi}\right)^2$	$\xi_{\gamma i} = 0.71$
Failure plane inclination modification factors	$\xi_{qt} := (1 - \alpha \cdot \tan(\phi))^2$	$\xi_{qt} = 0.77$
	$\xi_{\gamma t} := \xi_{qt}$	
	$\xi_{qg} := 1.0$	
	$\xi_{\gamma g} := 1.0$	
Overburden pressure	$q_o := \gamma_b \cdot D$	$q_o = 448\ psf$

Ultimate load bearing capacity

$$Q := L' \cdot \left(\xi_{qd} \cdot \xi_{qi} \cdot \xi_{qt} \cdot \xi_{qg} \cdot q_o \cdot N_q + \frac{1}{2} \xi_{\gamma d} \cdot \xi_{\gamma i} \cdot \xi_{\gamma t} \cdot \xi_{\gamma g} \cdot L' \cdot \gamma_b \cdot N_\gamma \right) \cdot ft$$

$Q = 146110\,lbf$

Bearing factor of safety

$$FS_{act} := \frac{Q}{N}$$

$FS_{act} = 5.56$

$$Check_bearing := \begin{cases} \text{"Okay"} & \text{if } FS_{act} \geq FS_b \\ \text{"NG"} & \text{otherwise} \end{cases}$$

[redacted]

Bearing capacity of foundation

$$q := \frac{Q}{L' \cdot ft}$$

$q = 11836\,psf$

Allowable bearing capacity of foundation

$$q_{all} := \frac{q}{FS_b}$$

$q_{all} = 3945\,psf$

III Stability Check - Flood Condition:

Extreme flood condition, water at top of wall (no freeboard)
All loads and conditions are similar to Normal Flood Case.

1. Safety Factors:

Factor of safety against sliding $FS_s := 1.33$

Factor of safety for bearing $FS_b := 2.00$

2. Forces on Wall:

Height of water in front of wall $H_w := (TW - FB_x - TF) + Toedown$ $H_w = 29.00\ ft$

Force of channel water $P_w := \frac{1}{2}\gamma_w H_w^2 \cdot ft$ $P_w = 26239\ lbf$

Moment about base $M_w := P_w \frac{H_w}{3}$ $M_w = 253646\ ft \cdot lbf$

Pressure of channel soil $p_{ach} := K_a \cdot \gamma_b \cdot H_{ch}$ $p_{ach} = 188.22\ psf$

Force of channel soil $P_{ach} := \frac{1}{2} p_{ach} \cdot H_{ch} \cdot ft$ $P_{ach} = 988\ lbf$

Pressure of moist backfill $p_{o_1} := K_o \cdot \gamma_m \cdot H_m$ $p_{o_1} = 662\ psf$

Pressure of submerged backfill $p_{o_2} := K_o \cdot \gamma_b \cdot H_{sub}$ $p_{o_2} = 81\ psf$

Force of backfill above seepage line $P_{o_1} := \frac{1}{2} p_{o_1} \cdot H_m \cdot ft$ $P_{o_1} = 4303\ lbf$

Moment about base $M_{o_1} := P_{o_1} \cdot \left(\frac{H_m}{3} + H_{sub} + H_{fnd}\right)$ $M_{o_1} = 53068\ ft \cdot lbf$

Force of backfill below seepage line $P_{o_2} := \left(p_{o_1} + \frac{1}{2} \cdot p_{o_2}\right) \cdot H_{sub} \cdot ft$ $P_{o_2} = 2108\ lbf$

Moment about base $M_{o_2} := \left(\frac{p_{o_1}}{2} + \frac{1}{6} \cdot p_{o_2}\right) \cdot H_{sub}^2 \cdot ft$ $M_{o_2} = 3101\ ft \cdot lbf$

LA of backfill above base $LA_{back} := \frac{\sum M_o}{\sum P_o}$ $LA_{back} = 8.76\ ft$

3. Uplift Forces

Maximum uplift pressure	$Up_{max} := \gamma_w \cdot H_w$	$Up_{max} = 1810\,psf$
Head difference across wall	$\Delta_h := (TW - FB_x) - SeepEL$	$\Delta_h = 21.00\,ft$
Length of seepage path along width of key	$L_{CD} := Key_{bot}$	$L_{CD} = 2.00\,ft$
Length of seepage path along height of key	$L_{DE} := \sqrt{(Key_{bot} - Key_{top})^2 + Key^2}$	$L_{DE} = 5.02\,ft$
Length of seepage path along base of slab	$L_{EF} := W - Key_{top}$	$L_{EF} = 21.50\,ft$
Length of seepage plane	$L_s := \sqrt{Key^2 + W^2}$	$L_s = 24.52\,ft$
Total length of seepage path	$L_{seep} := L_{CD} + L_{DE} + L_{EF}$	$L_{seep} = 28.53\,ft$
Minimum uplift pressure	$Up_{min} := \gamma_w \left[(H_w - Key) - \frac{\Delta_h \cdot L_s}{L_{seep} + H_{sub}} \right]$	$Up_{min} = 479\,psf$
Total loss along seepage path	$Loss := \frac{\Delta_h \cdot L_s}{L_s + H_{sub}}$	$Loss = 18.71\,ft$
Uplift pressure at bot of key	$Up_d := Up_{max} - \frac{L_{CD}}{L_{seep}} \cdot Loss \cdot \gamma_w$	$Up_d = 1728\,psf$
	$H_e := TW - FB_x - TF + D_s$	$H_e = 24.00\,ft$
Uplift pressure at top of key	$Up_e := \left(H_e - \frac{L_{CD} + L_{DE}}{L_{seep}} \cdot Loss \right) \cdot \gamma_w$	$Up_e = 1210\,psf$

4. Overturning Check

Uplift force below key	$Up_1 := (Up_{max} + Up_d) \cdot \frac{Key_{bot}}{2} \cdot ft$	$Up_1 = 3537\,lbf$
Uplift force against slope of key	$Up_2 := (Up_d + Up_e) \cdot \frac{Key_{top} - Key_{bot}}{2} \cdot ft$	$Up_2 = 734\,lbf$
Uplift force on heel	$Up_3 := (Up_{min} + Up_e) \cdot \frac{L_{EF}}{2} \cdot ft$	$Up_3 = 18153\,lbf$
Total uplift force	$Uplift := \sum Up$	$Uplift = 22425\,lbf$
Approx LA of uplift w.r.t. heel	$LA_{up} := \frac{2Up_{max} + Up_{min}}{Up_{max} + Up_{min}} \cdot \frac{W}{3}$	$LA_{up} = 14.33\,ft$
Water pressure at base of slab	$pw_g := Up_{min}$	$pw_g = 479\,psf$

Water pressure at top of foundation soil	$pw'_g := Up_e$	$pw'_g = 1210\,psf$
Water pressure at bot of foundation soil	$pw_f := Up_d$	$pw_f = 1728\,psf$
Force of water behind wall	$P_{wback} := \left(\frac{1}{2} pw_g \cdot H_{sub} + \frac{pw'_g + pw_f}{2} \cdot H_{fnd}\right) \cdot ft$	$P_{wback} = 8062\ lbf$
Overturning moment about heel	$M_{wback} := \left[\frac{1}{2} pw_g \cdot H_{sub} \cdot \left(\frac{H_{sub}}{3}\right) - \frac{pw'_g + pw_f}{4} \cdot H_{fnd}^2\right] \cdot ft$ $M_{wback} = -17643\ ft \cdot lbf$	
Total vertical force	$Ver := Wt_{wall} - Uplift$	$Ver = 25384\ lbf$
Total horizontal force	$Hor := P_w + P_{ach} - \left(\sum P_o + P_{wback}\right)$	$Hor = 12754\ lbf$
Passive pressure to balance sliding	$P_{pas} := \begin{cases} Hor & \text{if } Hor - Ver \cdot \tan(\phi) \ge 0 \\ 0 & \text{otherwise} \end{cases}$	$P_{pas} = 0\ lbf$
LA of passive pressure about base of slab	$LA_{pas} := \frac{-Key}{2}$	$LA_{pas} = -2.50\ ft$
Coefficient of passive pressure induced	$K_{pin} := \frac{P_{pas}}{\gamma_b \cdot Key^2 \cdot ft}$	$K_{pin} = 0.00$
Check for max induced passive pressure	$Check_passive := \begin{cases} \text{"Okay"} & \text{if } K_{pin} \le 0.5 \cdot K_p \\ \text{"NG"} & \text{otherwise} \end{cases}$ $Check_passive = \text{"Okay"}$	
Moment of wall about heel	$M_1 := Wt_{wall} \cdot LA_{heel}$	$M_1 = 570469\ ft \cdot lbf$
Moment of uplift force about heel	$M_2 := -Uplift \cdot LA_{up}$	$M_2 = -321282\ ft \cdot lbf$
Moment of water in channel about base	$M_3 := -P_w \cdot \left(\frac{H_w}{3} - Key\right)$	$M_3 = -122450\ ft \cdot lbf$
Moment of soil in channel about base	$M_4 := -P_{ach} \cdot \left(\frac{H_{ch}}{3} - Key\right)$	$M_4 = 1482\ ft \cdot lbf$
Moment of backfill above base	$M_5 := \sum P_o \cdot LA_{back}$	$M_5 = 56169\ ft \cdot lbf$
Moment of backfill below base	$M_6 := P_{pas} \cdot LA_{pas}$	$M_6 = 0\ ft \cdot lbf$
Moment of water in backfill	$M_7 := M_{wback}$	$M_7 = -17643\ ft \cdot lbf$

Net moment about base $M_{net} := \sum M$ $M_{net} = 166745\ ft \cdot lbf$

Location of resultant from heel $x_{edge} := \frac{M_{net}}{Ver}$ $x_{edge} = 6.57\ ft$

Location of resultant w.r.t. center of slab $ecc := \frac{W}{2} - x_{edge}$ $ecc = 5.431\ ft$

Check for foundation contact $Contact := \begin{cases} \text{"Okay"} & \text{if } \frac{x_{edge}}{W} \geq 0.25 \wedge \frac{x_{edge}}{W} \leq 0.75 \\ \text{"NG"} & \text{otherwise} \end{cases}$

$Contact = \text{"Okay"}$

At least 75% of foundation is in contact.

Maximum stress beneath foundation $\sigma_{max} := \frac{Ver}{b \cdot W} \cdot \left(1 + \frac{6 \cdot ecc}{W}\right)$ $\sigma_{max} = 2494\ psf$

Maximum stress beneath foundation $\sigma_{min} := \frac{Ver}{b \cdot W} \cdot \left(1 - \frac{6 \cdot ecc}{W}\right)$ $\sigma_{min} = -378\ psf$

Pressure on toe at face of stem $\sigma_{stoe} := \sigma_{min} + \left(\frac{\sigma_{max} - \sigma_{min}}{W}\right) \cdot W_{toe}$ $\sigma_{stoe} = 878\ psf$

Pressure on heel at face of stem $\sigma_{sheel} := \sigma_{min} + \left(\frac{\sigma_{max} - \sigma_{min}}{W}\right) \cdot (W_{toe} + b_{bot})$ $\sigma_{sheel} = 1098\ psf$

5. Structural Forces on Wall Components:

A Stem Wall

Height of water acting on stem $H_{ws} := (TW - TF) - FB_x$ $H_{ws} = 21.00\ ft$

Moment at stem base on water side $M_{water} := \frac{1}{6}\cdot\left(\gamma_w \cdot H_{ws}^3 + K_a \cdot \gamma_b \cdot H_{toe}^3\right)\cdot b$ $M_{water} = 96.36\ ft\cdot kip$

Moment on land side

$$M_{land} := \left[\frac{K_o \gamma_m \cdot H_m^2}{2}\cdot\left(\frac{H_m}{3} + H_{subheel}\right) + \frac{1}{6}\gamma_w \cdot H_{subheel}^3 + K_o\cdot\left(\frac{\gamma_b \cdot H_{subheel}^3}{6} + \frac{\gamma_m \cdot H_m \cdot H_{subheel}^2}{2}\right)\right]\cdot b$$

$M_{land} = 18646\ ft\cdot lbf$

Shear at stem base on water side $V_{water} := \frac{1}{2}\cdot\left(\gamma_w \cdot H_{ws}^2 + K_a \cdot \gamma_b \cdot H_{toe}^2\right)\cdot b$ $V_{water} = 13.82\ kip$

Shear on land side $V_{land} := \left[\frac{K_o \gamma_m \cdot H_m^2}{2} + \frac{1}{2}\gamma_w \cdot H_{subheel}^2 + K_o\cdot\left(\frac{\gamma_b \cdot H_{subheel}^2}{2} + \gamma_m \cdot H_m \cdot H_{subheel}\right)\right]\cdot b$

Net moment on stem wall $M_{stem_2} := M_{water} - M_{land}$ $M_{stem_2} = 77.72\ ft\cdot kips$

Net shear on wall $V_{stem_2} := V_{water} - V_{land}$ $V_{stem_2} = 9512\ lbf$

B Toe Slab

Upward soil pressure on toe $S_{toe} := \left(\frac{\sigma_{min} + \sigma_{stoe}}{2}\right)\cdot W_{toe}\cdot ft$ $S_{toe} = 2623\ lbf$

Weight of toe $Wt_{toe} := \gamma_{conc}\cdot W_{toe}\cdot D_s\cdot ft + Wt_{key}$ $Wt_{toe} = 6413\ lbf$

Wt of soil on toe $Soil_{toe} := \gamma_b \cdot H_{toe}\cdot W_{toe}\cdot ft$ $Soil_{toe} = 1470\ lbf$

Moment due to weight of key $M_{key} := Wt_{key}\cdot\left(W_{toe} - \frac{Key_{top}}{2}\right)$ $M_{key} = 15609\ ft\cdot lbf$

Moment due to uplift on key base $M_{upt_1} := Up_1\cdot\left(W_{toe} - \frac{L_{CD}}{2}\right)$ $M_{upt_1} = 33605\ ft\cdot lbf$

Moment due to uplift on key side $M_{upt_2} := Up_2\cdot\left(W_{toe} - \frac{Key_{top} + Key_{bot}}{2}\right)$ $M_{upt_2} = 6059\ ft\cdot lbf$

Uplift force on toe $Up_{toe} := Up_d\cdot\left(W_{toe} - Key_{top}\right)\cdot ft$ $Up_{toe} = 13822\ lbf$

Moment due to uplift on base of toe $M_{upt_3} := Up_{toe}\cdot\frac{W_{toe} - Key_{top}}{2}$ $M_{upt_3} = 55288\ ft\cdot lbf$

Shear on toe at face of stem	$V_{toe_2} := S_{toe} + Up_1 + Up_2 + Up_{toe} - Wt_{toe} - Soil_{toe}$	$V_{toe_2} = 12.83\,kips$
Moment on toe at face of stem	$M_{toe_2} := (S_{toe} - Wt_{toe} - Soil_{toe}) \cdot \frac{W_{toe}}{2} + \sum M_{upt} - M_{key}$	$M_{toe_2} = 51.73\,ft \cdot kips$

C Heel Slab

Weight of heel slab	$Wt_{heel} := \gamma_{conc} \cdot W_{heel} \cdot D_s \cdot ft$	$Wt_{heel} = 5250\,lbf$
Moment of heel slab	$M_{wheel} := Wt_{heel} \cdot \frac{W_{heel}}{2}$	$M_{wheel} = 30627\,ft \cdot lbf$
Weight of soil and water on heel slab	$Wt_{back} := \gamma_{back} \cdot W_{heel} \cdot H_{soil} \cdot ft$	$Wt_{back} = 18201\,lbf$
Moment of heel slab	$M_{back} := Wt_{back} \cdot \frac{W_{heel}}{2}$	$M_{back} = 106173\,ft \cdot lbf$
Upward soil pressure on heel	$S_{heel} := \left(\frac{\sigma_{sheel} + \sigma_{max}}{2}\right) \cdot W_{heel} \cdot ft$	$S_{heel} = 20950\,lbf$
Lever arm of soil pressure on heel	$la_{sheel} := \left(\frac{\sigma_{sheel} + 2\sigma_{max}}{\sigma_{sheel} + \sigma_{max}}\right) \cdot \frac{W_{heel}}{3}$	$la_{sheel} = 6.59\,ft$
Moment of soil pressure on heel	$M_{sheel} := S_{heel} \cdot la_{sheel}$	$M_{sheel} = 138049\,ft \cdot lbf$
Uplift force on heel slab	$Up_{heel} := \frac{Up_e + Up_{min}}{2} \cdot W_{heel} \cdot ft$	$Up_{heel} = 9851\,lbf$
Lever arm of uplift pressure on heel	$la_{uheel} := \left(\frac{Up_e + 2Up_{min}}{Up_e + Up_{min}}\right) \cdot \frac{W_{heel}}{3}$	$la_{uheel} = 4.99\,ft$
Moment of uplift pressure on heel	$M_{upheel} := Up_{heel} \cdot la_{uheel}$	$M_{upheel} = 49166\,ft \cdot lbf$
Shear force on heel slab	$V_{heel_2} := Wt_{heel} + Wt_{back} - S_{heel} - Up_{heel}$	$V_{heel_2} = -7350\,lbf$
Moment on heel slab	$M_{heel_2} := \lvert M_{wheel} + M_{back} - M_{sheel} - M_{upheel} \rvert$	$M_{heel_2} = 50416\,ft \cdot lbf$

D Shear Key

Water pressure at top of key	$Water_{top} := \gamma_w \cdot (TW - TF - FB_x + D_s)$	$Water_{top} = 1498\,psf$
Water pressure at bottom of key	$Water_{bot} := \gamma_w \cdot (TW - TF + Toedown)$	$Water_{bot} = 1810\,psf$
Soil pressure at top of key	$Soil_{top} := K_a \cdot \gamma_b \cdot (TW - TF - FB_x + D_s)$	$Soil_{top} = 430\,psf$

Soil pressure at bottom of key	$Soil_{bot} := K_a \cdot \gamma_b \cdot (TW - TF + Toedown)$	$Soil_{bot} = 520\ psf$
Water side hydraulic force on key	$Hyd_{key} := \frac{Water_{top} + Water_{bot}}{2} \cdot Toedown \cdot ft$	$Hyd_{key} = 13229\ lbf$
Water side soil force on key	$Soil_{key} := \frac{Soil_{top} + Soil_{bot}}{2} \cdot Toedown \cdot ft$	$Soil_{key} = 3800\ lbf$
Landside water force on key	$W_{kylnd} := \frac{Up_d + Up_e}{2} \cdot Key \cdot ft$	$W_{kylnd} = 7345\ lbf$
Soil pressure at top of key	$Soil_{top} := K_o \cdot \gamma_m \cdot (TBack - TF + D_s)$	$Soil_{top} = 815\ psf$
Soil pressure at bottom of key	$Soil_{bot} := K_o \cdot \gamma_m \cdot (TBack - TF + Toedown)$	$Soil_{bot} = 1069\ psf$
Landside passive soil force on key	$S_{kylnd} := \frac{Soil_{top} + Soil_{bot}}{2} \cdot Toedown \cdot ft$	$S_{kylnd} = 7536\ lbf$
Shear force at top of key	$V_{key_2} := Hyd_{key} + Soil_{key} - W_{kylnd} - S_{kylnd}$	$V_{key_2} = 2148\ lbf$
Moment at top of key	$M_{key_2} := V_{key_2} \cdot \frac{Key}{2}$	$M_{key_2} = 5.37\ ft \cdot kips$

6. Sliding on Inclined Plane:

Weight of additional soil below slab	$Wt_{xsoil} := \frac{1}{2} \cdot \gamma_b \cdot Key \cdot W \cdot ft$	$Wt_{xsoil} = 3360\ lbf$
Uplift force on inclined sliding plane	$Uplift := \frac{Up_{max} + Up_{min}}{2} \cdot W \cdot ft$	$Uplift = 27458\ lbf$
Foce due to water behind wall	$P'_{wback} := \left(\frac{1}{2} Up_{min} \cdot H_{sub} + \frac{Up_{min} + Up_{max}}{2} \cdot H_{fnd}\right) \cdot 1$	$P'_{wback} = 6438\ lbf$
Total vertical force	$Ver := Wt_{wall} + Wt_{xsoil} - Uplift$	$Ver = 23711\ lbf$
Total horizontal force	$Hor := P_w + P_{ach} - \left(\sum P_o + P'_{wback}\right)$	$Hor = 14378\ lbf$
Normal force on sliding plane	$N := Ver \cdot \cos(\alpha) + Hor \cdot \sin(\alpha)$	$N = 26145\ lbf$
Tangential force on sliding plane	$T := \lvert Hor \cdot \cos(\alpha) - Ver \cdot \sin(\alpha) \rvert$	$T = 9240\ lbf$
Tangential capacity with given FS	$T_{cap} := \frac{N \cdot \tan(\phi)}{FS_s}$	$T_{cap} = 11812\ lbf$
Check for sliding	$Check_Sliding := \begin{cases} \text{"Okay"} & \text{if } T_{cap} \geq T \\ \text{"NG"} & \text{otherwise} \end{cases}$	

$Check_Sliding = \text{"Okay"}$

7. Sliding on Horizonal Plane below Key:

Wt of additional soil below slab	$Wt_{xsoil} := \gamma_b \cdot Key \cdot W \cdot ft$	$Wt_{xsoil} = 6720$ lbf
Length of seepage plane	$L_s := W + H_{sub} + H_{fnd}$	$L_s = 32.00$ ft
Minimum uplift pressure	$Up_{min} := \gamma_w \left(H_w - \frac{\Delta_h \cdot W}{L_s} \right)$	$Up_{min} = 827$ psf
Uplift force on inclined sliding plane	$Uplift := \frac{Up_{max} + Up_{min}}{2} \cdot W \cdot ft$	$Uplift = 31637$ lbf
Water behind wall	$H_{wback} := H_{sub} + H_{fnd}$	$H_{wback} = 8.00$ ft
Water pressure behind wall	$P_{wback} := \frac{1}{2} \cdot Up_{min} \cdot H_{wback} \cdot ft$	$P_{wback} = 3307$ lbf
At rest pressure behind wall	$P_o := \left[\frac{1}{2} \cdot \gamma_m \cdot H_m^2 + K_o \cdot \left(\gamma_m \cdot H_m \cdot H_{wback} + \frac{\gamma_b \cdot H_{wback}^2}{2} \right) \right] \cdot ft$	
Total vertical force	$Ver := Wt_{wall} + Wt_{xsoil} - Uplift$	$Ver = 22892$ lbf
Total horizontal force	$Hor := P_w + P_{ach} - (P_o + P_{wback})$	$Hor = 8883$ lbf
Normal force on sliding plane	$N := Ver$	$N = 22892$ lbf
Tangential force on sliding plane	$T := \lvert Hor \rvert$	$T = 8883$ lbf
Tangential capacity with given FS	$T_{cap} := \frac{N \cdot \tan(\phi)}{FS_s}$	$T_{cap} = 10342$ lbf

$$Check_Sliding := \begin{cases} \text{"Okay"} & \text{if } T_{cap} \geq T \\ \text{"NG"} & \text{otherwise} \end{cases}$$

Check_Sliding = "Okay"

8. Bearing on Inclined Plane

Length of inclined bearing plane	$L_{cg} := \sqrt{Key^2 + W^2}$	$L_{cg} = 24.52$ ft
LA of uplift w.r.t. heel	$LA_{up} := \frac{2Up_{max} + Up_{min}}{Up_{max} + Up_{min}} \cdot \frac{W}{3}$	$LA_{up} = 13.49$ ft
Moment of uplift force about heel	$M_2 := -Uplift \cdot LA_{up}$	$M_2 = -426828$ ft·lbf

Total vertical force	$Ver := Wt_{wall} + Wt_{xsoil} - Uplift$	$Ver = 22892\ lbf$
Total horizontal force	$Hor := P_w + P_{ach} - (P_o + P_{wback})$	$Hor = 8883\ lbf$
Normal force on sliding plane	$N := Ver \cdot \cos(\alpha) + Hor \cdot \sin(\alpha)$	$N = 24223\ lbf$
Tangential force on sliding plane	$T := Hor \cdot \cos(\alpha) - Ver \cdot \sin(\alpha)$	$T = 4027\ lbf$
Net moment about base	$M_{net} := \sum M$	$M_{net} = 61200\ ft \cdot lbf$
Location of resultant on inclined plane w.r.t. heel	$x_e := \frac{M_{net}}{N}$	$x_{edge} = 6.57\ ft$
Location of resultant w.r.t. center of plane	$e_{cg} := \frac{L_{cg}}{2} - x_e$	$e_{cg} = 9.73\ ft$

9. Bearing Capacity of Foundation:

Width of foundation in contact	$L' := L_{cg} - 2 \cdot e_{cg}$	$L' = 5.05\ ft$
Bearing capacity factors	$N_q := e^{\pi \cdot \tan(\phi)} \cdot \tan\left(45deg + \frac{\phi}{2}\right)^2$	$N_q = 20.63$
	$N_\gamma := (N_q - 1) \cdot \tan(1.4 \cdot \phi)$	$N_\gamma = 18.56$
Depth modification factors	$\xi_{qd} := 1 + 0.1\left(\frac{D}{L'}\right)\tan\left(45deg + \frac{\phi}{2}\right)^2$	$\xi_{qd} = 1.49$
	$\xi_{\gamma d} := \xi_{qd}$	
Angle of inclination of load	$\delta := atan\left(\frac{\lvert T \rvert}{N}\right)$	$\delta = 9.44\ deg$
Load inclination modification factors	$\xi_{qi} := \left(1 - \frac{\delta}{90 \cdot deg}\right)^2$	$\xi_{qi} = 0.80$
	$\xi_{\gamma i} := \left(1 - \frac{\delta}{\phi}\right)^2$	$\xi_{\gamma i} = 0.48$
Failure plane inclination modification factors	$\xi_{qt} := (1 - \alpha \cdot \tan(\phi))^2$	$\xi_{qt} = 0.77$
	$\xi_{\gamma t} := \xi_{qt}$	
	$\xi_{qg} := 1.0$	

Failure plane inclination modification factors $\xi_{\gamma g} := 1.0$

Overburden pressure $q_o := \gamma_b \cdot D$ $q_o = 448\ \text{psf}$

Ultimate load bearing capacity $Q := L' \cdot \left(\xi_{qd} \cdot \xi_{qi} \cdot \xi_{qt} \cdot \xi_{qg} \cdot q_o \cdot N_q + \frac{1}{2} \xi_{\gamma d} \cdot \xi_{\gamma i} \cdot \xi_{\gamma t} \cdot \xi_{\gamma g} \cdot L' \cdot \gamma_b \cdot N_\gamma \right) \cdot ft$

$Q = 50349\ \text{lbf}$

Bearing factor of safety $FS_{act} := \frac{Q}{N}$ $FS_{act} = 2.08$

$$\text{Check_bearing} := \begin{cases} \text{"Okay"} & \text{if } FS_{act} \geq FS_b \\ \text{"NG"} & \text{otherwise} \end{cases}$$

Check_bearing = "Okay"

IV Structural Design of Flood Wall:

Balanced reinforcement ratio	$\rho_b := \frac{0.85 \cdot f'_c}{f_y} \cdot \beta_1 \cdot \left(\frac{\varepsilon_c}{\varepsilon_m + \frac{f_y}{E_s}} \right)$	$\rho_b = 0.0214$
Maximum reinforcement ratio	$\rho_{max} := \lambda \cdot \rho_b$	$\rho_{max} = 0.0107$
Minimum reinforcement	$\rho_{min} := \frac{200 \cdot psi}{f_y}$	$\rho_{min} = 0.0033$

1. Structural Design of Stem Wall

Design ultimate shear on stem	$V_u := \max(\gamma_u \cdot V_{stem_1}, \gamma_{ux} V_{stem_2})$	$V_u = 15767\ lbf$
Design ultimate moment on stem	$M_u := \max(\gamma_u \cdot M_{stem_1}, \gamma_{ux} M_{stem_2})$	$M_u = 128.81\ ft \cdot kips$
Try rebar no	$Rebar := 9$	
Clear cover to reinforcement	$clr := 2 \cdot in$	
Rustication allowance	$rust := \frac{3}{4} \cdot in$	
Diameter of bar	$d_b := d_{bar_{Rebar}}$	$d_b = 1.13\ in$
Area of bar	$A_b := A_{bar_{Rebar}}$	$A_b = 1.00\ in^2$
Effective depth of stem	$d := b_{bot} - clr - rust - \frac{d_b}{2}$	$d = 18.69\ in$
Neutral axis factor	$k_u := 1 - \sqrt{1 - \frac{M_u}{\phi_b \cdot 0.425 \cdot f'_c \cdot b \cdot d^2}}$	$k_u = 0.18$
Ultimate internal force in member	$C_u := 0.85 \cdot f'_c \cdot k_u \cdot b \cdot d$	$C_u = 100.80\ kips$
Area of steel required	$A_{req} := \frac{C_u}{f_y}$	$A_{req} = 1.68\ in^2$
Provide reinforcement at	$spacing := 6 \cdot in$	
Area of steel provided	$A_s := \frac{A_b \cdot b}{spacing}$	$A_s = 2.00\ in^2$

Reinforcement ratio $\rho := \frac{A_s}{b \cdot d}$ $\rho = 0.0089$

Check for area of reinforcement $Check_reinf := \begin{cases} \text{"Okay"} & \text{if } A_{req} \le A_s \\ \text{"NG"} & \text{otherwise} \end{cases}$

$Check_reinf = \text{"Okay"}$

Check for max reinforcement $Check_ductility := \begin{cases} \text{"Okay"} & \text{if } \rho \le \rho_{max} \\ \text{"NG"} & \text{otherwise} \end{cases}$

$Check_ductility = \text{"Okay"}$

Check for min reinforcement $Check_reinf := \begin{cases} \text{"Okay"} & \text{if } \rho \ge \rho_{min} \vee \frac{4\rho}{3} \le \rho_{max} \\ \text{"NG"} & \text{otherwise} \end{cases}$

$Check_reinf = \text{"Okay"}$

Shear capacity of concrete $\phi V_c := \phi_v \cdot 2\sqrt{f'_c \cdot psi} \cdot b \cdot d$ $\phi V_c = 20879\ lbf$

Check for shear capacity $Check_shear := \begin{cases} \text{"Okay"} & \text{if } \phi V_c \ge V_u \\ \text{"NG"} & \text{otherwise} \end{cases}$

$Check_shear = \text{"Okay"}$

2. Design of Straight Stem Wall

Height of straight stem $Stem := H_{wall} - 12 \cdot ft$ $Stem = 9.00\ ft$

Hydraulic head at normal flood $H_{wn} := Stem - FB_{min}$ $H_{wn} = 5.50\ ft$

Hydraulic head at extreme flood $H_{wx} := Stem - FB_x$ $H_{wx} = 9.00\ ft$

Shear due to normal flood $V_{wn} := \frac{1}{2} \cdot \gamma_w \cdot H_{wn}^2 \cdot ft$ $V_{wn} = 944\ lbf$

Shear due to extreme flood $V_{wx} := \frac{1}{2} \cdot \gamma_w \cdot H_{wx}^2 \cdot ft$ $V_{wx} = 2527.20\ lbf$

Moment due to normal flood $M_{wn} := \frac{1}{6} \cdot \gamma_w \cdot H_{wn}^3 \cdot ft$ $M_{wn} = 1730\ ft \cdot lbf$

Moment due to extreme flood $M_{wx} := \frac{1}{6} \cdot \gamma_w \cdot H_{wx}^3 \cdot ft$ $M_{wx} = 7582\ ft \cdot lbf$

Design ultimate shear on stem	$V_u := \max(\gamma_u \cdot V_{wn}, \gamma_{ux} V_{wx})$	$V_u = 4189\ \text{lbf}$
Design ultimate moment on stem	$M_u := \max(\gamma_u \cdot M_{wn}, \gamma_{ux} M_{wx})$	$M_u = 12.57\ \text{ft}\cdot\text{kips}$
Try rebar no	$Rebar := 7$	
Diameter of bar	$d_b := d_{bar_{Rebar}}$	$d_b = 0.88\ \text{in}$
Area of bar	$A_b := A_{bar_{Rebar}}$	$A_b = 0.60\ \text{in}^2$
Effective depth of stem	$d := b_{top} - clr - rust - \frac{d_b}{2}$	$d = 6.81\ \text{in}$
Neutral axis factor	$k_u := 1 - \sqrt{1 - \frac{M_u}{\phi_b \cdot 0.425 \cdot f'_c \cdot b \cdot d^2}}$	$k_u = 0.13$
Area of steel required	$A_{req} := \frac{0.85 \cdot f'_c \cdot k_u \cdot b \cdot d}{f_y}$	$A_{req} = 0.44\ \text{in}^2$
Spacing of steel required	$spacing := \frac{A_b \cdot b}{A_{req}}$	$spacing = 16.46\ \text{in}$
Use spacing of reinforcement	$spacing := 12 \cdot \text{in}$	
Area of steel provided	$A_s := \frac{A_b \cdot b}{spacing}$	$A_s = 0.60\ \text{in}^2$
Reinforcement ratio	$\rho := \frac{A_s}{b \cdot d}$	$\rho = 0.0073$
Check for area of reinforcement	$Check_reinf := \begin{cases} \text{"Okay"} & \text{if } A_{req} \le A_s \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	$Check_reinf = \text{"Okay"}$	
Check for max reinforcement	$Check_ductility := \begin{cases} \text{"Okay"} & \text{if } \rho \le \rho_{max} \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	$Check_ductility = \text{"Okay"}$	
Check for min reinforcement	$Check_reinf := \begin{cases} \text{"Okay"} & \text{if } \rho \ge \rho_{min} \vee \frac{4\rho}{3} \le \rho_{max} \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	$Check_reinf = \text{"Okay"}$	

Shear capacity of concrete	$\phi V_c := \phi_v \cdot 2\sqrt{f'_c \cdot psi} \cdot b \cdot d$	$\phi V_c = 7612\ lbf$
Check shear capacity	$Check_shear := \begin{cases} "Okay" & \text{if } \phi V_c \geq V_u \\ "NG" & \text{otherwise} \end{cases}$	
	Check_shear = "Okay"	

3. Structural Design of Toe

Design ultimate shear on toe	$V_u := \max(\gamma_u \cdot V_{toe_1}, \gamma_{ux} V_{toe_2})$	$V_u = 34667\ lbf$
Design ultimate moment on toe	$M_u := \max(\gamma_u \cdot M_{toe_1}, \gamma_{ux} M_{toe_2})$	$M_u = 147.34\ ft \cdot kips$
Try rebar no	$Rebar := 7$	
Clear cover to reinforcement	$clr := 3 \cdot in$	
Diameter of bar	$d_b := d_{bar_{Rebar}}$	$d_b = 0.88\ in$
Area of bar	$A_b := A_{bar_{Rebar}}$	$A_b = 0.60\ in^2$
Effective depth of toe slab	$d := D_s - clr - \frac{d_b}{2}$	$d = 32.56\ in$
Neutral axis factor	$k_u := 1 - \sqrt{1 - \frac{M_u}{\phi_b \cdot 0.425 \cdot f'_c \cdot b \cdot d^2}}$	$k_u = 0.0625$
Ultimate internal force in member	$C_u := 0.85 \cdot f'_c \cdot k_u \cdot b \cdot d$	$C_u = 62.28\ kips$
Area of steel required	$A_{req} := \frac{C_u}{f_y}$	$A_{req} = 1.04\ in^2$
Provide reinforcement at	spacing = 6 in	
Area of steel provided	$A_s := \frac{A_b \cdot b}{spacing}$	$A_s = 1.20\ in^2$
Reinforcement ratio	$\rho := \frac{A_s}{b \cdot d}$	$\rho = 0.0031$
Check for area of reinforcement	$Check_reinf := \begin{cases} "Okay" & \text{if } A_{req} \leq A_s \\ "NG" & \text{otherwise} \end{cases}$	
	Check_reinf = "Okay"	

Check for reinforcement	$Check_ductility := \begin{cases} \text{"Okay"} & \text{if } \rho \le \rho_{max} \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	Check_ductility = "Okay"	
Check for min reinforcement	$Check_reinf := \begin{cases} \text{"Okay"} & \text{if } \rho \ge \rho_{min} \vee \frac{4\rho}{3} \le \rho_{max} \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	Check_reinf = "Okay"	
Shear capacity of concrete	$\phi V_c := \phi_v \cdot 2\sqrt{f'_c \cdot psi} \cdot b \cdot d$	$\phi V_c = 36384\ lbf$
Check shear in toe slab	$Check_shear := \begin{cases} \text{"Okay"} & \text{if } \phi V_c \ge V_u \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	Check_shear = "Okay"	

4. Structural Design of Heel

Design ultimate shear on heel	$V_u := \max(\gamma_u \cdot V_{heel_1}, \gamma_{ux} V_{heel_2})$	$V_u = 8091\ lbf$
Design ultimate moment on heel	$M_u := \max(\gamma_u \cdot M_{heel_1}, \gamma_{ux} M_{heel_2})$	$M_u = 83.56\ ft \cdot kips$
Try rebar no	Rebar := 7	
Clear cover to reinforcement	$clr := 3 \cdot in$	
Diameter of bar	$d_b := d_{bar_{Rebar}}$	$d_b = 0.88\ in$
Area of bar	$A_b := A_{bar_{Rebar}}$	$A_b = 0.60\ in^2$
Effective depth of heel slab	$d := D_s - clr - \frac{d_b}{2}$	$d = 32.56\ in$
Neutral axis factor	$k_u := 1 - \sqrt{1 - \frac{M_u}{\phi_b \cdot 0.425 \cdot f'_c \cdot b \cdot d^2}}$	$k_u = 0.03$
Ultimate internal force in member	$C_u := 0.85 \cdot f'_c \cdot k_u \cdot b \cdot d$	$C_u = 34.83\ kips$
Area of steel required	$A_{req} := \frac{C_u}{f_y}$	$A_{req} = 0.58\ in^2$
Provide reinforcement at	spacing := 12·in	

Area of steel provided $A_s := \frac{A_b \cdot b}{spacing}$ $A_s = 0.60\,in^2$

Reinforcement ratio $\rho := \frac{A_s}{b \cdot d}$ $\rho = 0.0015$

Check for area of reinforcement

$$Check_reinf := \begin{cases} \text{"Okay"} & \text{if } A_{req} \le A_s \\ \text{"NG"} & \text{otherwise} \end{cases}$$

Check_reinf = "Okay"

Check for reinforcement

$$Check_ductility := \begin{cases} \text{"Okay"} & \text{if } \rho \le \rho_{max} \\ \text{"NG"} & \text{otherwise} \end{cases}$$

Check_ductility = "Okay"

Check for min reinforcement

$$Check_reinf := \begin{cases} \text{"Okay"} & \text{if } \rho \ge \rho_{min} \vee \frac{4\rho}{3} \le \rho_{max} \\ \text{"NG"} & \text{otherwise} \end{cases}$$

Check_reinf = "Okay"

Shear capacity of concrete $\phi V_c := \phi_v \cdot 2\sqrt{f'_c \cdot psi} \cdot b \cdot d$ $\phi V_c = 36384\ lbf$

Check shear in heel slab

$$Check_shear := \begin{cases} \text{"Okay"} & \text{if } \phi V_c \ge V_u \\ \text{"NG"} & \text{otherwise} \end{cases}$$

Check_shear = "Okay"

5. Structural Design of Key

Design ultimate shear on heel $V_u := \max(\gamma_u \cdot V_{key_1}, \gamma_{ux} V_{key_2})$ $V_u = 4335\ lbf$

Design ultimate moment on heel $M_u := \max(\gamma_u \cdot M_{key_1}, \gamma_{ux} M_{key_2})$ $M_u = 8.90\ ft \cdot kips$

Try rebar no $Rebar := 6$

Clear cover to reinforcement $clr := 3 \cdot in$

Diameter of bar	$d_b := d_{bar_{Rebar}}$	$d_b = 0.75\,in$
Area of bar	$A_b := A_{bar_{Rebar}}$	$A_b = 0.44\,in^2$
Effective depth of key	$d := Key_{top} - clr - \frac{d_b}{2}$	$d = 26.63\,in$
Neutral axis factor	$k_u := 1 - \sqrt{1 - \frac{M_u}{\phi_b \cdot 0.425 \cdot f'_c \cdot b \cdot d^2}}$	$k_u = 0.01$
Ultimate internal force in member	$C_u := 0.85 \cdot f'_c \cdot k_u \cdot b \cdot d$	$C_u = 4.47\,kips$
Area of steel required	$A_{req} := \frac{C_u}{f_y}$	$A_{req} = 0.07\,in^2$
Provide reinforcement at	spacing := 12 in	
Area of steel provided	$A_s := \frac{A_b \cdot b}{spacing}$	$A_s = 0.44\,in^2$
Check for area of reinforcement	$Check_reinf := \begin{cases} \text{"Okay"} & \text{if } A_{req} \le A_s \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	Check_reinf = "Okay"	
Check for reinforcement	$Check_ductility := \begin{cases} \text{"Okay"} & \text{if } \rho \le \rho_{max} \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	Check_ductility = "Okay"	
Check for min reinforcement	$Check_reinf := \begin{cases} \text{"Okay"} & \text{if } \rho \ge \rho_{min} \vee \frac{4\rho}{3} \le \rho_{max} \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	Check_reinf = "Okay"	
Shear capacity of concrete	$\phi V_c := \phi_v \cdot 2\sqrt{f'_c \cdot psi} \cdot b \cdot d$	$\phi V_c = 29750\,lbf$
Check shear in key	$Check_shear := \begin{cases} \text{"Okay"} & \text{if } \phi V_c \ge V_u \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	Check_shear = "Okay"	

Title : Sols Wash Flood Walls Job # 046308-400
Dsgnr: J. Lobo Date: 8:59AM, 5 SEP 06
Description : Ret. wall analysis of walls for no-flood condition

Scope :

Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Cantilevered Retaining Wall Design

Description 21 ft Type A Wall - no flood condition

Criteria

Retained Height	=	13.00 ft
Wall height above soil	=	8.00 ft
Slope Behind Wall	=	0.00 : 1
Height of Soil over Toe	=	0.00 in
Soil Density	=	120.00 pcf
Wind on Stem	=	0.0 psf

Soil Data

Allow Soil Bearing	=	3,000.0 psf
Coulomb Soil Pressure calculation		
Soil Friction Angle	=	31.0 deg
Active Pressure:Ka*Gamma=		33.5
Passive Pressure:Kp*Gamma=		374.9
Footing||Soil Friction	=	0.300
Soil height to ignore for passive pressure	=	0.00 in

Footing Strengths & Dimensions

f'c = 3,000 psi	Fy =	60,000 psi
Min. As %	=	0.0000
Toe Width	=	10.50 ft
Heel Width	=	13.50
Total Footing Width	=	24.00
Footing Thickness	=	36.00 in
Key Width	=	27.00 in
Key Depth	=	60.00 in
Key Distance from Toe	=	0.00 ft
Cover @ Top = 3.00 in	@ Btm.=	3.00 in

Design Summary

Total Bearing Load	=	36,161 lbs
...resultant ecc.	=	27.29 in
Soil Pressure @ Toe	=	650 psf OK
Soil Pressure @ Heel	=	2,363 psf OK
Allowable	=	3,000 psf
Soil Pressure Less Than Allowable		
ACI Factored @ Toe	=	864 psf
ACI Factored @ Heel	=	3,139 psf
Footing Shear @ Toe	=	12.1 psi OK
Footing Shear @ Heel	=	89.4 psi OK
Allowable	=	93.1 psi
Wall Stability Ratios		
Overturning	=	23.58 OK
Sliding	=	5.33 OK
Sliding Calcs (Vertical Component Used)		
Lateral Sliding Force	=	4,286.2 lbs
less 100% Passive Force	=	- 11,996.3 lbs
less 100% Friction Force	=	- 10,848.3 lbs
Added Force Req'd	=	0.0 lbs OK
....for 1.5 : 1 Stability	=	0.0 lbs OK

Footing Design Results

		Toe	Heel
Factored Pressure	=	864	3,139 psf
Mu' : Upward	=	0	0 ft-#
Mu' : Downward	=	0	0 ft-#
Mu: Design	=	20,844	20,844 ft-#
Actual 1-Way Shear	=	12.05	89.36 psi
Allow 1-Way Shear	=	93.11	93.11 psi

Toe Reinforcing = # 8 @ 12.00 in
Heel Reinforcing = # 8 @ 6.00 in
Key Reinforcing = None Spec'd

Stem Construction

		Top Stem	2nd	3rd	4th	Bottom
Design height	ft =	Stem OK 12.00	Stem OK 9.00	Stem OK 6.00	Stem OK 3.00	Stem OK 0.00
Wall Material Above "Ht"	=	Concrete	Concrete	Concrete	Concrete	Concrete
Thickness	=	10.00	13.00	16.00	19.00	22.00
Rebar Size	=	# 4	# 5	# 5	# 5	# 5
Rebar Spacing	=	18.00	18.00	18.00	9.00	9.00
Rebar Placed at	=	Edge	Edge	Edge	Edge	Edge
Design Data						
fb/FB + fa/Fa	=	0.002	0.059	0.250	0.304	0.567
Total Force @ Section	lbs =	28.5	455.4	1,394.7	2,846.3	4,810.2
Moment....Actual	ft-# =	9.5	607.2	3,254.3	9,487.7	20,844.4
Moment.....Allowable	ft-# =	4,871.3	10,215.4	13,005.4	31,212.8	36,792.8
Shear.....Actual	psi =	0.3	3.4	8.2	13.8	19.9
Shear.....Allowable	psi =	93.1	93.1	93.1	93.1	93.1
Bar Develop ABOVE Ht.	in =	17.09	12.00	12.00	12.00	21.36
Bar Lap/Hook BELOW Ht.	in =	17.09	21.36	21.36	12.00	6.00
Wall Weight	psf =	120.8	157.1	193.3	229.6	265.8
Rebar Depth 'd'	in =	8.25	11.19	14.19	17.19	20.19
Masonry Data						
f'm	psi =					
Fs	psi =					
Solid Grouting	=					
Special Inspection	=					
Modular Ratio 'n'	=					
Short Term Factor	=					
Equiv. Solid Thick.	=					
Masonry Block Type = Normal Weight						
Concrete Data						
f'c	psi =	3,000.0	3,000.0	3,000.0	3,000.0	3,000.0
Fy	psi =	60,000.0	60,000.0	60,000.0	60,000.0	60,000.0

Other Acceptable Sizes & Spacings
Toe: Not req'd, Mu < S * Fr
Heel: Not req'd, Mu < S * Fr
Key: #4@ 48.25 in, #5@ 48.25 in, #6@ 48.

Rev: 580000
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Cantilevered Retaining Wall Design

Description 21 ft Type A Wall - no flood condition

Summary of Overturning & Resisting Forces & Moments

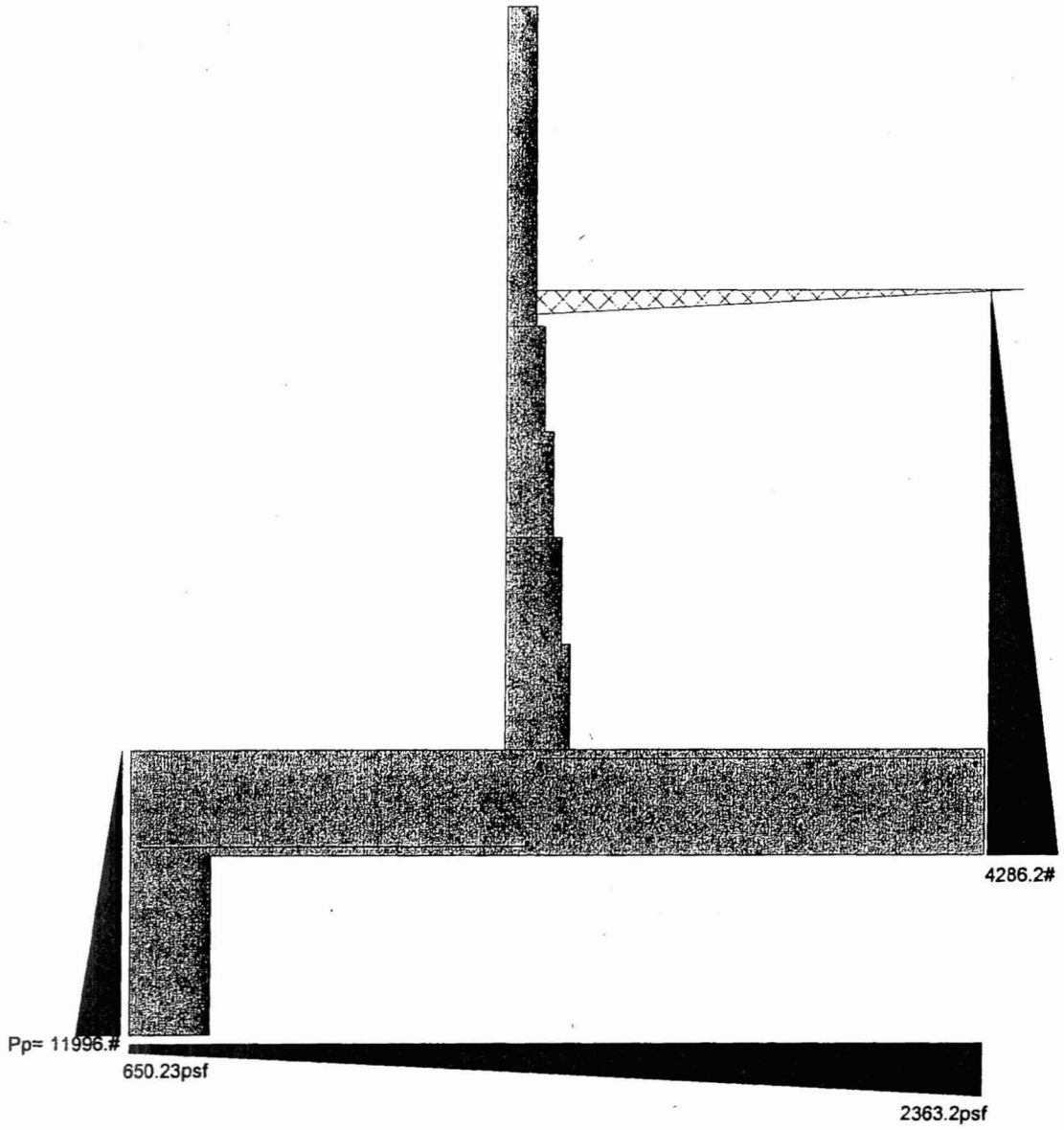
Item		.....OVERTURNING..... Force lbs	Distance ft	Moment ft-#
Heel Active Pressure	=	4,286.2	5.33	22,859.7
Toe Active Pressure	=			
Surcharge Over Toe	=			
Adjacent Footing Load	=			
Added Lateral Load	=			
Load @ Stem Above Soil	=			
SeismicLoad	=			
Total	=	4,286.2	O.T.M. =	22,859.7

Resisting/Overturning Ratio = **23.58**

Vertical Loads used for Soil Pressure = 36,161.1 lbs

Vertical component of active pressure used for soil pressure

		.....RESISTING..... Force lbs	Distance ft	Moment ft-#
Soil Over Heel	=	18,200.0	18.17	330,633.3
Sloped Soil Over Heel	=			
Surcharge Over Heel	=			
Adjacent Footing Load	=			
Axial Dead Load on Stem	=		0.00	
Soil Over Toe	=			
Surcharge Over Toe	=			
Stem Weight(s)	=	3,625.0	11.15	40,433.9
Earth @ Stem Transitions	=	660.0	12.00	7,922.5
Footing Weight	=	10,799.9	12.00	129,599.2
Key Weight	=	1,687.5	1.13	1,898.4
Vert. Component	=	1,188.7	24.00	28,528.0
	Total =	36,161.1 lbs	**R.M.=**	539,015.3


4286.2#
Pp= 11996.#
650.23psf
2363.2psf

3.0 TYPE B FLOODWALL DESIGN

Design of Type B Flood Wall

References:

(1) EM 1110-2-2502 "Retaining and Flood Walls" of Sept 1989, US Army Corps of Engineers
(2) EM 1110-2-2104 "Strength Design for Reinforced Concrete Hydraulic Structures" June 1992, US Army Corps of Engineers and Change 1 dated August 2003
(3) Geotechnical Study Report Project No 63683 (1) dated January 2006 by Kleinfelder Inc.

I Wall Data

1. Unit Weights:

Unit weight of water $\gamma_w := 62.4 \cdot pcf$

Unit weight of concrete $\gamma_{conc} := 150 \cdot pcf$

Unit weight of steel $\gamma_{steel} := 490 \cdot pcf$

Unit width of wall $b := 1.0 \cdot ft$

Load factor $\gamma_u := 2.21$

Load factor for extreme case $\gamma_{ux} := 0.75\gamma_u$

Flexural resistance factor $\phi_b := 0.90$

Shear resistance factor $\phi_v := 0.85$

2. Materials:

Class A concrete:

Min 28 day compressive strength $f'_c := 3000 \cdot psi$

Elastic modulus of concrete $E_c := 33 \cdot \left(\frac{\gamma_{conc}}{pcf}\right)^{1.5} \cdot \sqrt{\frac{f'_c}{psi}} \cdot psi$ $\quad E_c = 3321\,ksi$

Stress block factor

$$\beta_1 := \begin{cases} 0.85 & \text{if } f'_c \le 4000 \cdot psi \\ 0.65 & \text{if } f'_c \ge 8000 \cdot psi \\ 0.85 - 0.05 \cdot \left(\frac{f'_c - 4000 \cdot psi}{1000 \cdot psi}\right) & \text{otherwise} \end{cases} \qquad \beta_1 = 0.85$$

$$\beta_m := \begin{cases} 0.55 & \text{if } f'_c \le 4000 \cdot psi \\ 0.50 & \text{otherwise} \end{cases} \qquad \beta_m = 0.55$$

Strain in concrete at balanced condition $\varepsilon_c := 0.003$

Steel:

Elastic modulus of steel	$E_s := 29000 \cdot ksi$	
Yield strength of rebar	$f_y := 60.00 ksi$	
Strain in steel at yield of concrete	$\varepsilon_m := 0.003$	
Ductility coefficient (fraction of balanced reinf)	$\lambda := 0.25$	
Modular ratio	$n := \text{floor}\left(\frac{E_s}{E_c}\right)$	$n = 8$

Structural Backfill:

Unit weight of moist backfill	$\gamma_{back} := 120 \cdot pcf$	

Native Soil:

Unit weight of moist soil	$\gamma_m := 120 \cdot pcf$	
Unit weight of submerged soil	$\gamma_b := 64 \cdot pcf$	
Angle of internal friction	$\phi := 31 \cdot deg$	$\phi = 0.54\, rad$
Coefficient of at-rest earth pressure	$K_o := 1 - \sin(\phi)$	$K_o = 0.48$
Coefficient of active earth pressure	$K_a := \tan\left(45deg - \frac{\phi}{2}\right)^2$	$K_a = 0.32$
Coefficient of passive earth pressure	$K_p := \tan\left(45deg + \frac{\phi}{2}\right)^2$	$K_p = 3.12$

3. Geometry:

Wall Control Elevations

Top of wall	$TW := 2078.00 \cdot ft$	
Top of footing	$TF := 2066.00 \cdot ft$	
Water surface elevation	$WSEL := TW - 3.50 \cdot ft$	
Channel bed elevation	$Bed := 2068.50 \cdot ft$	
Backfill elevation	$TBack := 2068.50 \cdot ft$	
Freeboard	$FB := 3.50 \cdot ft$	$FB = 3.50\, ft$
Freeboard at extreme condition	$FB_x := 0.00$	
Assumed elevation of backfill seepage	$SeepEL := TF$	

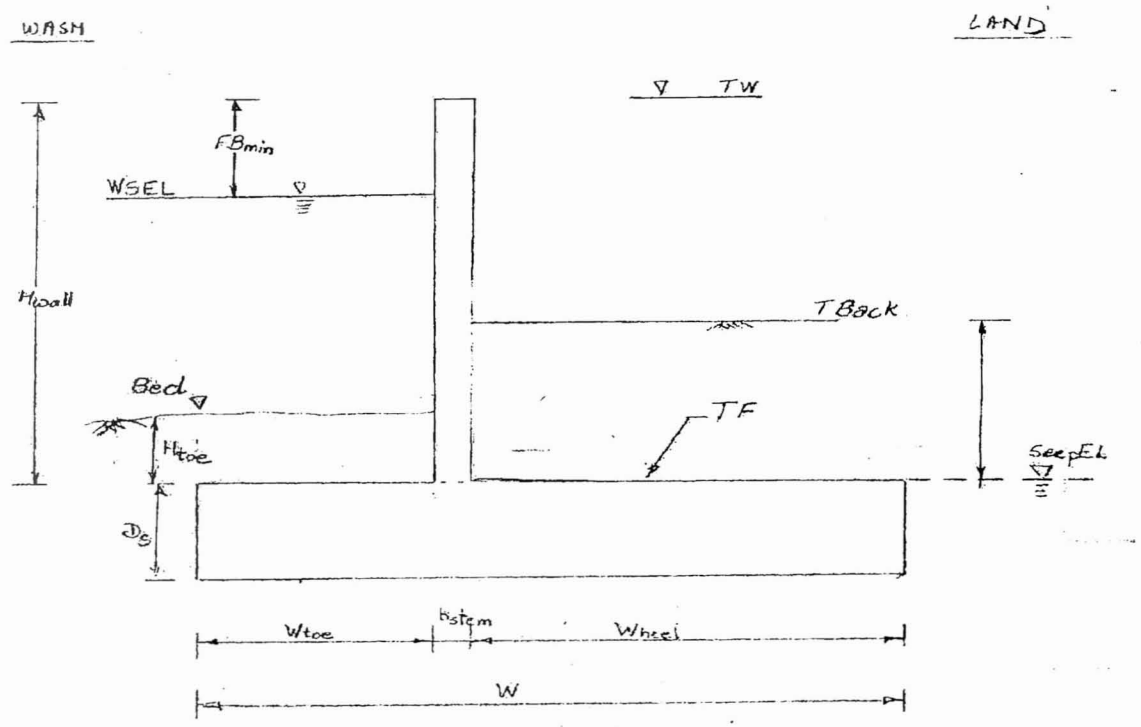


Fig. 1: Wall Geometry And Elevations

Wall Section

Width of stem wall at top	$b_{stem} := 10 \cdot in$	$b_{stem} = 0.83$ ft
Width of toe	$W_{toe} := 5.75 \cdot ft$	
Width of toe (beyond stem)	$W_{heel} := 6.667 ft$	
Thickness of base slab	$D_s := 2.50 \cdot ft$	
Width of base slab	$W := W_{toe} + b_{stem} + W_{heel}$	$W = 13.25$ ft

Height of wall above backfill (straight portion)	$H_{wall} := TW - TF$	$H_{wall} = 12.00$ ft
Height of soil on heel	$H_{soil} := TBack - TF$	$H_{soil} = 2.50$ ft
Height of soil above toe	$H_{toe} := Bed - TF$	$H_{toe} = 2.50$ ft
Height of soil in channel	$H_{ch} := Bed - TF + D_s$	$H_{ch} = 5.00$ ft
Height of moist soil over heel	$H_m := TBack - SeepEL$	$H_m = 2.50$ ft
Height of submerged soil over heel	$H_{subheel} := SeepEL - TF$	$H_{subheel} = 0.00$ ft
Height of submerged soil over foundation	$H_{sub} := (SeepEL - TF) + D_s$	$H_{sub} = 2.50$ ft
Angle of plane w.r.t. horizontal	$\alpha := 0$	

4. Wall Weights:

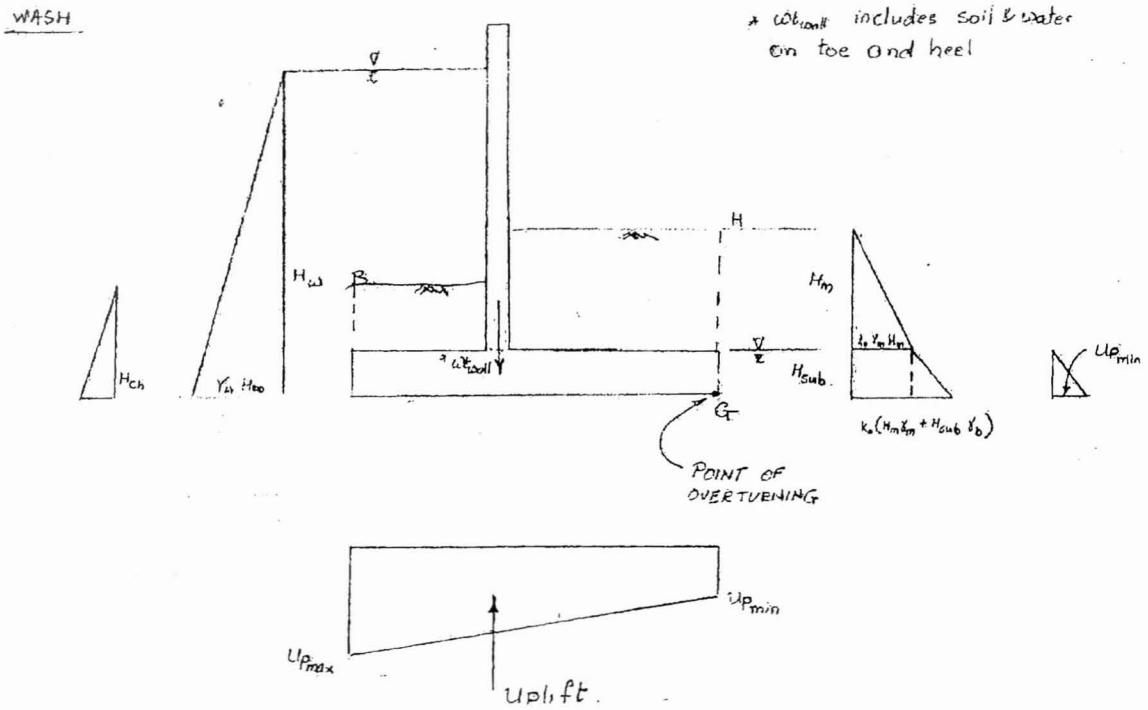


FIG 3 : Sliding and Overturning of Wall

Weight of stem (ignore batter)	$Wt_{stem} := \gamma_{conc} \cdot H_{wall} \cdot b_{stem} \cdot ft$	$Wt_{stem} = 1500$ lbf
Weight of base slab	$Wt_{base} := \gamma_{conc} \cdot D_s \cdot W \cdot ft$	$Wt_{base} = 4969$ lbf
Weight of soil over heel slab (ignore batter)	$Wt_{soil} := \gamma_{back} \cdot H_{soil} \cdot W_{heel} \cdot ft$	$Wt_{soil} = 2000$ lbf
Lever arm of stem wall w.r.t. toe	$LA_{stem} := W_{toe} + \frac{b_{stem}}{2}$	$LA_{stem} = 6.17$ ft
Lever arm of base slab w.r.t. toe	$LA_{base} := \frac{W}{2}$	$LA_{base} = 6.63$ ft
Lever arm of soil on heel w.r.t. toe	$LA_{soil} := W - \frac{W - W_{toe} - b_{stem}}{2}$	$LA_{soil} = 9.92$ ft
Weight of soil and water over toe slab	$Wt_{toes} := \left[\gamma_w (TW - FB - TF) + \gamma_b \cdot H_{toe}\right] \cdot W_{toe} \cdot ft$	$Wt_{toes} = 3970$ lbf
Lever arm of soil on toe w.r.t. toe	$LA_{toes} := \frac{W_{toe}}{2}$	$LA_{toes} = 2.88$ ft
Total weight of wall	$Wt_{wall} := Wt_{stem} + Wt_{base} + Wt_{soil} + Wt_{toes}$	$Wt_{wall} = 12439$ lbf
LA of wall w.r.t. toe	$LA_{toe} := \frac{Wt_{stem} \cdot LA_{stem} + Wt_{base} \cdot LA_{base} + Wt_{soil} \cdot LA_{soil} + Wt_{toes} \cdot LA_{toes}}{Wt_{wall}}$	$LA_{toe} = 5.90$ ft
LA of wall w.r.t. heel	$LA_{heel} := W - LA_{toe}$	$LA_{heel} = 7.35$ ft

II Stability Analysis

Case 1 - Normal Condition:

Normal flood condition, water at top of wall, less freeboard

1. Safety Factors:

Factor of safety against sliding $FS_s := 1.50$

Factor of safety for bearing $FS_b := 3.00$

2. Forces on Wall:

Height of water in front of wall $H_w := TW - FB - TF + D_s$ $H_w = 11.00$ ft

Force of channel water $P_w := \frac{1}{2}\gamma_w \cdot H_w^2 \cdot ft$ $P_w = 3775$ lbf

Moment about base $M_w := \frac{1}{6}\gamma_w \cdot H_w^3 \cdot ft$ $M_w = 13842$ ft·lbf

Pressure of channel soil $p_{ach} := K_a \cdot \gamma_b \cdot (H_{ch})$ $p_{ach} = 102.43$ psf

Force of channel soil $P_{ach} := \frac{1}{2} p_{ach} \cdot H_{ch} \cdot ft$ $P_{ach} = 256$ lbf

Pressure of moist backfill $p_{o_1} := K_p \cdot \gamma_m \cdot H_m$ $p_{o_1} = 937$ psf

Pressure of submerged backfill $p_{o_2} := K_p \cdot \gamma_b \cdot H_{sub}$ $p_{o_2} = 500$ psf

At-rest force of backfill above seepage line $P_{o_1} := \frac{1}{2} p_{o_1} \cdot H_m \cdot ft$ $P_{o_1} = 1172$ lbf

Moment about base $M_{o_1} := P_{o_1} \cdot \left(\frac{H_m}{3} + H_{sub}\right)$ $M_{o_1} = 3905$ ft·lbf

At-rest force of backfill below seepage line $P_{o_2} := \left(p_{o_1} + \frac{1}{2} \cdot p_{o_2}\right) \cdot H_{sub} \cdot ft$ $P_{o_2} = 2968$ lbf

Moment about base $M_{o_2} := \left(\frac{p_{o_1}}{2} + \frac{1}{6} \cdot p_{o_2}\right) \cdot H_{sub}^2 \cdot ft$ $M_{o_2} = 3449$ ft·lbf

LA of backfill above base $LA_{back} := \frac{\sum M_o}{\sum P_o}$ $LA_{back} = 1.78$ ft

3. Uplift Forces

Head difference across wall	$\Delta_h := \max[(TW - FB) - SeepEL, 0]$	$\Delta_h = 8.50$ ft
Total length of seepage path	$L_s := W$	$L_s = 13.25$ ft
Maximum uplift pressure	$Up_{max} := \gamma_w H_w$	$Up_{max} = 686$ psf
Minimum uplift pressure	$Up_{min} := \gamma_w \left(H_w - \frac{\Delta_h \cdot L_s}{L_s + H_{sub}} \right)$	$Up_{min} = 240$ psf
Total uplift force	$Uplift := (Up_{max} + Up_{min}) \cdot \frac{W}{2} \cdot ft$	$Uplift = 6139$ lbf
Approx LA of uplift w.r.t. heel	$LA_{up} := \frac{2Up_{max} + Up_{min}}{Up_{max} + Up_{min}} \cdot \frac{W}{3}$	$LA_{up} = 7.69$ ft
Uplift pressure on toe at face of stem	$Up_{toe} := Up_{min} + \left(\frac{Up_{max} - Up_{min}}{W} \right) \cdot W_{toe}$	$Up_{toe} = 434$ psf
Uplift pressure on heel at face of stem	$Up_{heel} := Up_{min} + \left(\frac{Up_{max} - Up_{min}}{W} \right) \cdot (W_{toe} + b_{stem})$	$Up_{heel} = 462$ psf
Uplift force on toe	$Uplift_{toe} := \left(\frac{Up_{max} + Up_{toe}}{2} \right) \cdot W_{toe} \cdot ft$	$Uplift_{toe} = 3221$ lbf
Uplift force on heel	$Uplift_{heel} := \left(\frac{Up_{heel} + Up_{min}}{2} \right) \cdot W_{heel} \cdot ft$	$Uplift_{heel} = 2340$ lbf
LA of uplift on toe @ face of stem	$LA_{uptoe} := \frac{2Up_{max} + Up_{toe}}{Up_{max} + Up_{toe}} \cdot \frac{W_{toe}}{3}$	$LA_{uptoe} = 3.09$ ft
LA of uplift on heel @ face of stem	$LA_{upheel} := \frac{2Up_{toe} + Up_{min}}{Up_{toe} + Up_{min}} \cdot \frac{W_{heel}}{3}$	$LA_{upheel} = 3.65$ ft
Force of water behind wall	$P_{wback} := \frac{1}{2} Up_{min} \cdot H_{sub} \cdot ft$	$P_{wback} = 300$ lbf
Overturning moment about heel	$M_{wback} := \frac{1}{2} Up_{min} \cdot H_{sub} \cdot \frac{H_{sub}}{3} \cdot ft$	$M_{wback} = 250$ ft·lbf

4. Overturning Check

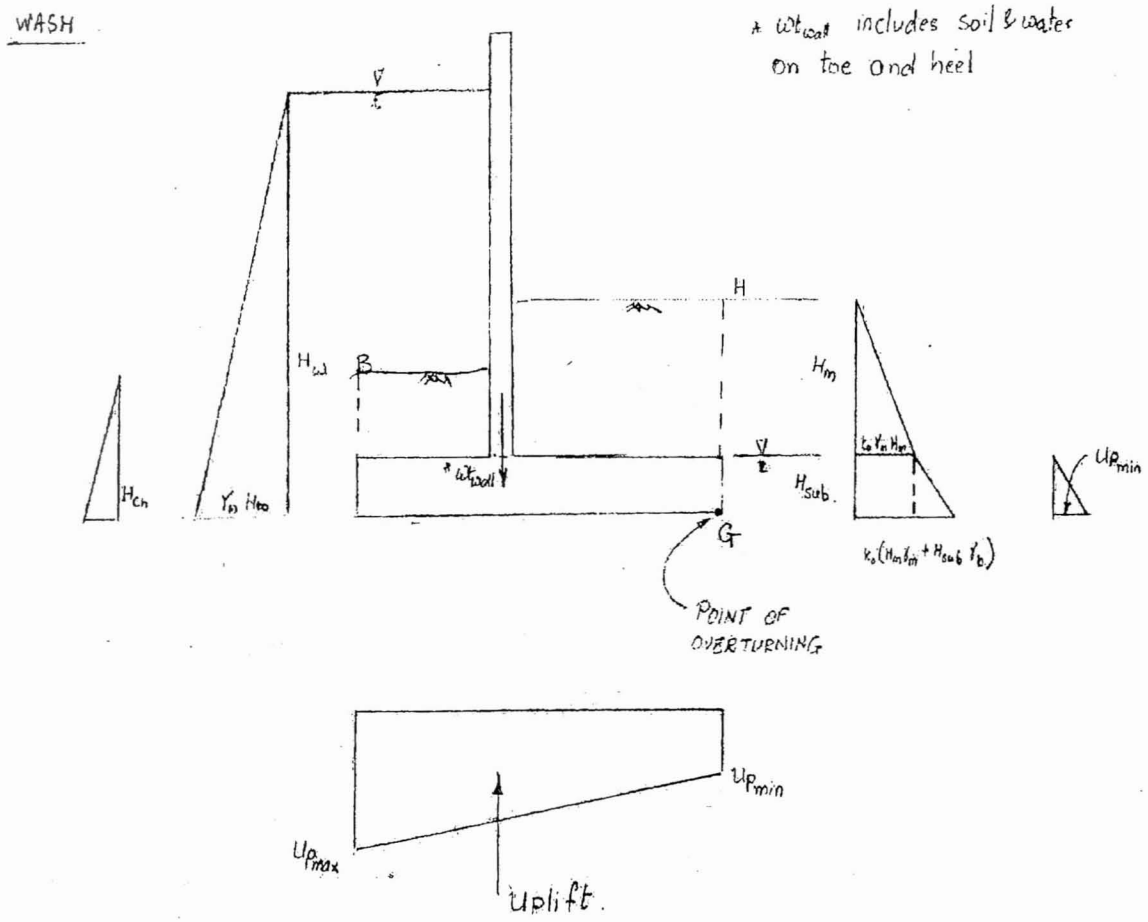


FIG.3 : Sliding and Overturning of Wall

Total vertical force	$Ver := Wt_{wall} - Uplift$	$Ver = 6300$ lbf
Total horizontal force	$Hor := \max\left[P_w + P_{ach} - \left(\sum P_o + P_{wback}\right), 0\right]$	$Hor = 0$ lbf
Net force on wall	$\Sigma P_o := \begin{cases} P_w + P_{ach} - P_{wback} & \text{if } Hor = 0 \\ \sum P_o & \text{otherwise} \end{cases}$	$\Sigma P_o = 3731$ lbf

Moment of wall about heel	$M_1 := Wt_{wall} \cdot LA_{heel}$	$M_1 = 91400$ ft·lbf
Moment of uplift force about heel	$M_2 := -Uplift \cdot LA_{up}$	$M_2 = -47199$ ft·lbf
Moment of water in channel about base	$M_3 := -P_w \cdot \frac{H_w}{3}$	$M_3 = -13842$ ft·lbf
Moment of soil in channel about base	$M_4 := -P_{ach} \cdot \frac{H_{ch}}{3}$	$M_4 = -427$ ft·lbf
Moment of backfill above base	$M_5 := \Sigma P_o \cdot LA_{back}$	$M_5 = 6629$ ft·lbf
Moment of water in backfill	$M_6 := M_{wback}$	$M_6 = 250$ ft·lbf
Net moment about base	$M_{net} := \sum M$	$M_{net} = 36811$ ft·lbf
Location of resultant from heel	$x_{edge} := \frac{M_{net}}{Ver}$	$x_{edge} = 5.84$ ft
Location of resultant w.r.t. center of slab	$ecc := \frac{W}{2} - x_{edge}$	$ecc = 0.782$ ft
Ratio of eccentricity to base width	$Ratio := \frac{W}{ecc}$	$Ratio = 16.94$
Check for foundation contact	$Contact := \begin{cases} "Okay" & \text{if } \lvert ecc \rvert \le \frac{W}{6} \\ "NA" & \text{otherwise} \end{cases}$	
	Contact = "Okay"	
Maximum stress beneath foundation	$\sigma_{max} := \frac{Ver}{b \cdot W} \cdot \left(1 + \frac{6 \cdot ecc}{W}\right)$	$\sigma_{max} = 644$ psf
Maximum stress beneath foundation	$\sigma_{min} := \frac{Ver}{b \cdot W} \cdot \left(1 - \frac{6 \cdot ecc}{W}\right)$	$\sigma_{min} = 307$ psf
Pressure on toe at face of stem	$\sigma_{stoe} := \sigma_{min} + \left(\frac{\sigma_{max} - \sigma_{min}}{W}\right) \cdot W_{toe}$	$\sigma_{stoe} = 453$ psf
Pressure on heel at face of stem	$\sigma_{sheel} := \sigma_{min} + \left(\frac{\sigma_{max} - \sigma_{min}}{W}\right) \cdot (W_{toe} + b_{stem})$	$\sigma_{sheel} = 474$ psf

5. Sliding on Foundation Plane:

Normal force on sliding plane $N := Ver \cdot \cos(\alpha) + Hor \cdot \sin(\alpha)$ $N = 6300$ lbf

Tangential force on sliding plane $T := Hor \cdot \cos(\alpha) - Ver \cdot \sin(\alpha)$ $T = 0$ lbf

Tangential capacity with given FS $T_{cap} := \frac{N \cdot \tan(\phi)}{FS_s}$ $T_{cap} = 2524$ lbf

$$Check_Sliding := \begin{cases} \text{"Okay"} & \text{if } T_{cap} \geq |T| \\ \text{"NG"} & \text{otherwise} \end{cases}$$

Check_Sliding = "Okay"

6. Bearing Capacity of Foundation:

Depth of embedment $D := D_s + H_{sub}$ $D = 5.00$ ft

Width of foundation in contact $L' := W - 2 \cdot ecc$ $L' = 11.69$ ft

Bearing capacity factors $N_q := e^{\pi \cdot \tan(\phi)} \cdot \tan\left(45deg + \frac{\phi}{2}\right)^2$ $N_q = 20.63$

$N_\gamma := (N_q - 1) \cdot \tan(1.4 \cdot \phi)$ $N_\gamma = 18.56$

Depth modification factors $\xi_{qd} := 1 + 0.1\left(\frac{D}{L'}\right)\tan\left(45deg + \frac{\phi}{2}\right)^2$ $\xi_{qd} = 1.13$

$\xi_{\gamma d} := \xi_{qd}$

Angle of inclination of load $\delta := atan\left(\frac{T}{N}\right)$ $\delta = 0.00$ deg

Load inclination modification factors $\xi_{qi} := \left(1 - \frac{\delta}{90 \cdot deg}\right)^2$ $\xi_{qi} = 1.00$

$$\xi_{\gamma i} := \begin{cases} \left(1 - \frac{\delta}{\phi}\right)^2 & \text{if } \delta \leq \phi \\ 0 & \text{otherwise} \end{cases}$$ $\xi_{\gamma i} = 1.00$

Failure plane inclination modification factors	$\xi_{qt} := (1 - \alpha \cdot \tan(\phi))^2$	$\xi_{qt} = 1.00$
	$\xi_{\gamma t} := \xi_{qt}$	
	$\xi_{qg} := 1.0$	
	$\xi_{\gamma g} := 1.0$	
Overburden pressure	$q_o := \gamma_b \cdot D$	$q_o = 320$ psf
Ultimate load bearing capacity	$Q := L' \cdot \left(\xi_{qd} \cdot \xi_{qi} \cdot \xi_{qt} \cdot \xi_{qg} \cdot q_o \cdot N_q + \frac{1}{2} \xi_{\gamma d} \cdot \xi_{\gamma i} \cdot \xi_{\gamma t} \cdot \xi_{\gamma g} \cdot L' \cdot \gamma_b \cdot N_\gamma \right) \cdot ft$	
	$Q = 179434$ lbf	
Bearing factor of safety	$FS_{act} := \frac{Q}{N}$	$FS_{act} = 28.48$
Check bearing capacity of foundation	$Check_bearing := \begin{cases} \text{"Okay"} & \text{if } FS_{act} \geq FS_b \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	[redacted]	
Ultimate bearing stress capacity	$q_u := \frac{Q}{b \cdot L'}$	$q_u = 15354$ psf
Allowable bearing stress capacity	$q_{all} := \frac{q_u}{FS_b}$	$q_{all} = 5118$ psf

7. Structural Forces on Wall Components:

A Stem Wall

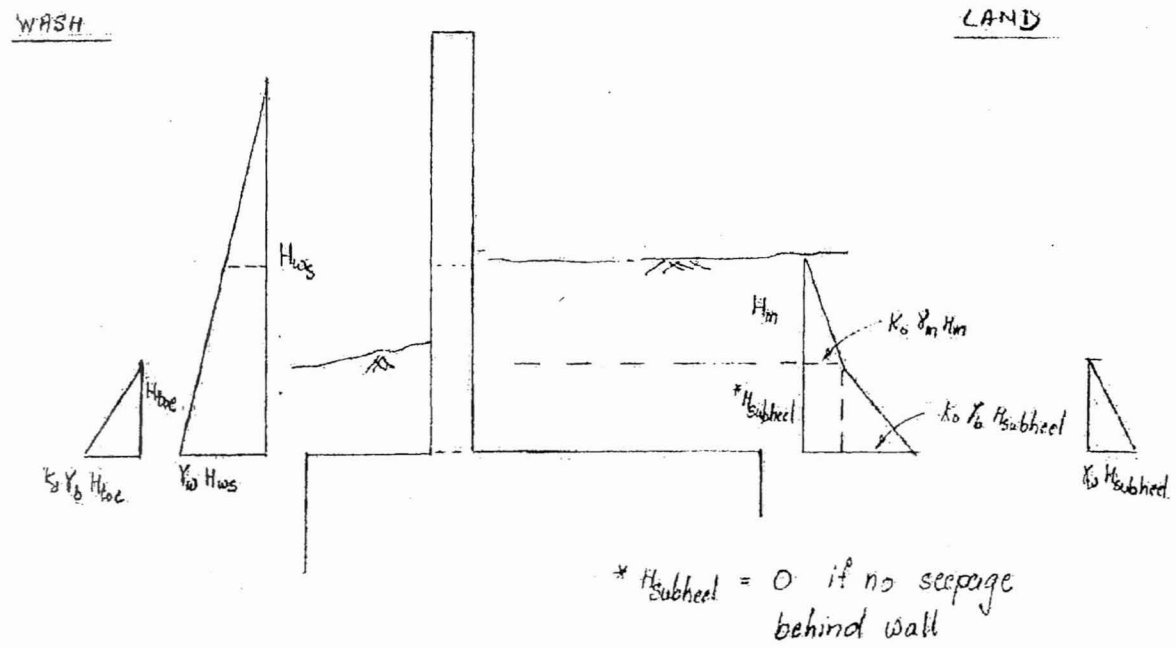


FIG. 4: Structural Forces on Stem

Height of water acting on stem $H_{ws} := (TW - TF) - FB$ $H_{ws} = 8.50$ ft

Moment at stem base on water side $M_{water} := \frac{1}{6}\cdot\left(\gamma_w \cdot H_{ws}^3 + K_o \cdot \gamma_b \cdot H_{toe}^3\right)\cdot b$ $M_{water} = 6.47$ ft·kip

Moment on land side
$$M_{land} := \left[\frac{K_p \gamma_m \cdot H_m^2}{2}\cdot\left(\frac{H_m}{3} + H_{subheel}\right) + \frac{1}{6}\gamma_w \cdot H_{subheel}^3 \ldots + K_p \cdot\left(\frac{\gamma_b \cdot H_{subheel}^3}{6} + \frac{\gamma_m \cdot H_m \cdot H_{subheel}^2}{2}\right)\right]\cdot b$$
$M_{land} = 976$ ft·lbf

Shear at stem base on water side $V_{water} := \frac{1}{2}\cdot\left(\gamma_w \cdot H_{ws}^2 + K_o \cdot \gamma_b \cdot H_{toe}^2\right)\cdot b$ $V_{water} = 2.35$ kip

Shear on land side
$$V_{land} := \left[\frac{K_p \gamma_m \cdot H_m^2}{2} + \frac{1}{2}\gamma_w \cdot H_{subheel}^2 \ldots + K_p \cdot\left(\frac{\gamma_b \cdot H_{subheel}^2}{2} + \gamma_m \cdot H_m \cdot H_{subheel}\right)\right]\cdot b$$
$V_{land} = 1172$ lbf

Net shear on wall	$V_{stem_1} := V_{water} - V_{land}$	$V_{stem_1} = 1180$ lbf
Net moment on stem wall	$M_{stem_1} := M_{water} - M_{land}$	$M_{stem_1} = 5.49$ ft·kips

B Toe Slab

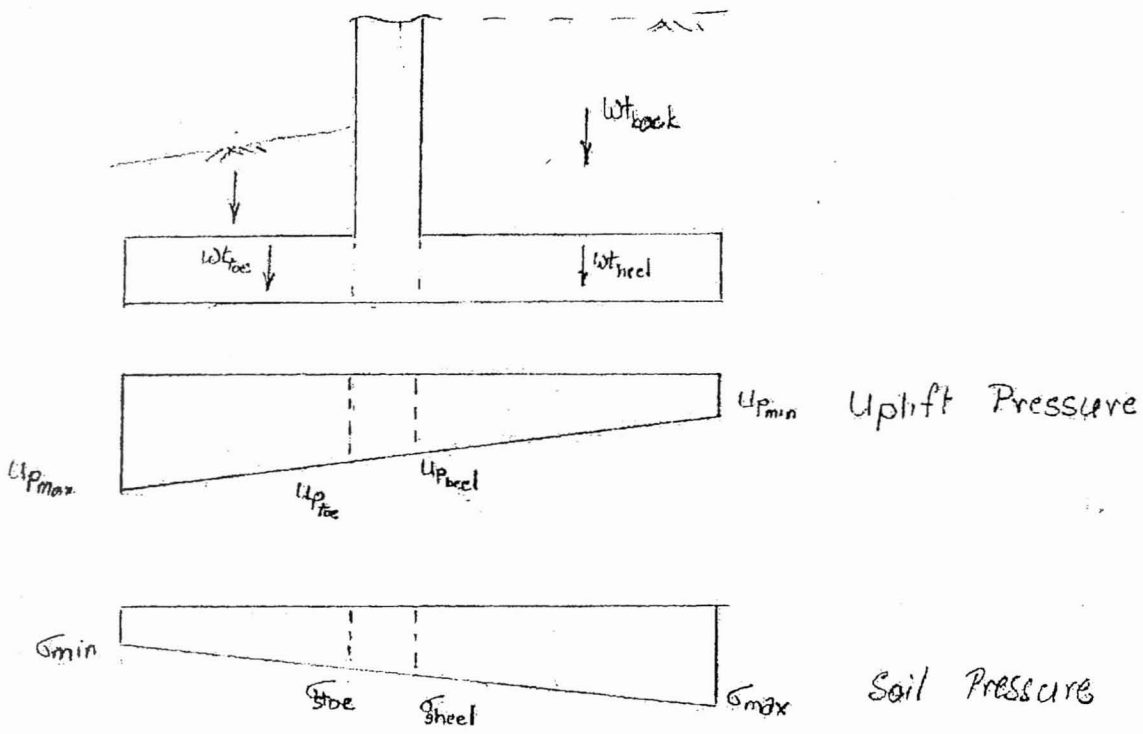


FIG. 5 : Structural Forces on Footing

Upward soil pressure on toe	$S_{toe} := \left(\frac{\sigma_{min} + \sigma_{stoe}}{2}\right) \cdot W_{toe} \cdot ft$	$S_{toe} = 2186$ lbf
Weight of toe	$Wt_{toe} := \gamma_{conc} \cdot W_{toe} \cdot D_s \cdot ft$	$Wt_{toe} = 2156$ lbf
Weight of soil on toe	$Soil_{toe} := \gamma_b \cdot H_{toe} \cdot W_{toe} \cdot ft$	$Soil_{toe} = 920$ lbf
Moment due to uplift on base of toe	$M_{upt} := Uplift_{toe} \cdot LA_{uptoe}$	$M_{upt} = 9955$ ft·lbf

Shear on toe at face of stem	$V_{toe_1} := S_{toe} + Uplift_{toe} - Wt_{toe} - Soil_{toe}$	$V_{toe_1} = 2.33$ kips
Moment on toe at face of stem	$M_{toe_1} := (S_{toe} - Wt_{toe} - Soil_{toe}) \cdot \frac{W_{toe}}{2} + M_{upt}$	$M_{toe_1} = 7.40$ ft·kips

C Heel Slab

Weight of heel slab	$Wt_{heel} := \gamma_{conc} \cdot W_{heel} \cdot D_s \cdot ft$	$Wt_{heel} = 2500$ lbf
Moment of heel slab	$M_{wheel} := Wt_{heel} \cdot \frac{W_{heel}}{2}$	$M_{wheel} = 8334$ ft·lbf
Weight of soil and water on heel slab	$Wt_{back} := \gamma_{back} \cdot W_{heel} \cdot H_{soil} \cdot ft$	$Wt_{back} = 2000$ lbf
Moment of heel slab	$M_{back} := Wt_{back} \cdot \frac{W_{heel}}{2}$	$M_{back} = 6667$ ft·lbf
Upward soil pressure on heel	$S_{heel} := \left(\frac{\sigma_{sheel} + \sigma_{max}}{2}\right) \cdot W_{heel} \cdot ft$	$S_{heel} = 3728$ lbf
Lever arm of soil pressure on heel	$la_{sheel} := \left(\frac{\sigma_{sheel} + 2\sigma_{max}}{\sigma_{sheel} + \sigma_{max}}\right) \cdot \frac{W_{heel}}{3}$	$la_{sheel} = 3.50$ ft
Moment of soil pressure on heel	$M_{sheel} := S_{heel} \cdot la_{sheel}$	$M_{sheel} = 13054$ ft·lbf
Moment of uplift pressure on heel	$M_{upheel} := Uplift_{heel} \cdot LA_{upheel}$	$M_{upheel} = 8549$ ft·lbf
Shear force on heel slab	$V_{heel_1} := \lvert Wt_{heel} + Wt_{back} - S_{heel} - Uplift_{heel} \rvert$	$V_{heel_1} = 1568$ lbf
Moment on heel slab	$M_{heel_1} := \lvert M_{wheel} + M_{back} - M_{sheel} - M_{upheel} \rvert$	$M_{heel_1} = 6601$ ft·lbf

Case 2- Flood Condition:

Extreme flood condition, water at top of wall (no freeboard)

1. Safety Factors:

Factor of safety against sliding $FS_s := 1.33$

Factor of safety for bearing $FS_b := 2.00$

2. Forces on Wall:

Height of water in front of wall $H_w := TW - FB_x - TF + D_s$ $H_w = 14.50$ ft

Force of channel water $P_w := \frac{1}{2}\gamma_w H_w^2 \cdot ft$ $P_w = 6560$ lbf

Moment about base $M_w := P_w \cdot \frac{H_w}{3}$ $M_w = 31706$ ft·lbf

Pressure of channel soil $p_{ach} := K_a \cdot \gamma_b \cdot H_{ch}$ $p_{ach} = 102.43$ psf

Force of channel soil $P_{ach} := \frac{1}{2} p_{ach} \cdot H_{ch} \cdot ft$ $P_{ach} = 256$ lbf

Pressure of moist backfill $p_{o_1} := K_p \cdot \gamma_m \cdot H_m$ $p_{o_1} = 937$ psf

Pressure of submerged backfill $p_{o_2} := K_p \cdot \gamma_b \cdot H_{sub}$ $p_{o_2} = 500$ psf

At-rest force of backfill above seepage line $P_{o_1} := \frac{1}{2} p_{o_1} \cdot H_m \cdot ft$ $P_{o_1} = 1172$ lbf

Moment about base $M_{o_1} := P_{o_1} \cdot \left(\frac{H_m}{3} + H_{sub}\right)$ $M_{o_1} = 3905$ ft·lbf

At-rest force of backfill below seepage line $P_{o_2} := \left(p_{o_1} + \frac{1}{2} \cdot p_{o_2}\right) \cdot H_{sub} \cdot ft$ $P_{o_2} = 2968$ lbf

Moment about base $M_{o_2} := \left(\frac{p_{o_1}}{2} + \frac{1}{6} \cdot p_{o_2}\right) \cdot H_{sub}^2 \cdot ft$ $M_{o_2} = 3449$ ft·lbf

LA of backfill above base $LA_{back} := \frac{\sum M_o}{\sum P_o}$ $LA_{back} = 1.78$ ft

Weight of soil over toe slab	$Wt_{toes} := \left[\gamma_w \cdot (TW - FB_x - TF) + \gamma_b \cdot H_{toe}\right] \cdot W_{toe} \cdot ft$	$Wt_{toes} = 5226$ lbf
Total weight of wall	$Wt_{wall} := Wt_{stem} + Wt_{base} + Wt_{soil} + Wt_{toes}$	$Wt_{wall} = 13695$ lbf
LA of wall w.r.t. toe	$LA_{toe} := \dfrac{Wt_{stem} \cdot LA_{stem} + Wt_{base} \cdot LA_{base} + Wt_{soil} \cdot LA_{soil} + Wt_{toes} \cdot LA_{toes}}{Wt_{wall}}$	$LA_{toe} = 5.62$ ft
LA of wall w.r.t. heel	$LA_{heel} := W - LA_{toe}$	$LA_{heel} = 7.63$ ft

3. Uplift Forces

Head difference across wall	$\Delta_h := (TW - FB_x) - SeepEL$	$\Delta_h = 12.00$ ft
Total length of seepage path	$L_s := W$	$L_s = 13.25$ ft
Maximum uplift pressure	$Up_{max} := \gamma_w \cdot H_w$	$Up_{max} = 905$ psf
Minimum uplift pressure	$Up_{min} := \gamma_w \cdot (H_w - \Delta_h)$	$Up_{min} = 156$ psf
Total uplift force	$Uplift := (Up_{max} + Up_{min}) \cdot \dfrac{W}{2} \cdot ft$	$Uplift = 7028$ lbf
Approx LA of uplift w.r.t. heel	$LA_{up} := \dfrac{2Up_{max} + Up_{min}}{Up_{max} + Up_{min}} \cdot \dfrac{W}{3}$	$LA_{up} = 8.18$ ft
Uplift pressure on toe at face of stem	$Up_{toe} := Up_{min} + \left(\dfrac{Up_{max} - Up_{min}}{W}\right) \cdot W_{toe}$	$Up_{toe} = 481$ psf
Uplift pressure on heel at face of stem	$Up_{heel} := Up_{min} + \left(\dfrac{Up_{max} - Up_{min}}{W}\right) \cdot (W_{toe} + b_{stem})$	$Up_{heel} = 528$ psf
Uplift force on toe	$Uplift_{toe} := \left(\dfrac{Up_{max} + Up_{toe}}{2}\right) \cdot W_{toe} \cdot ft$	$Uplift_{toe} = 3984$ lbf
Uplift force on heel	$Uplift_{heel} := \left(\dfrac{Up_{heel} + Up_{min}}{2}\right) \cdot W_{heel} \cdot ft$	$Uplift_{heel} = 2280$ lbf
LA of uplift on toe @ face of stem	$LA_{uptoe} := \dfrac{2Up_{max} + Up_{toe}}{Up_{max} + Up_{toe}} \cdot \dfrac{W_{toe}}{3}$	$LA_{uptoe} = 3.17$ ft
LA of uplift on heel @ face of stem	$LA_{upheel} := \dfrac{2Up_{toe} + Up_{min}}{Up_{toe} + Up_{min}} \cdot \dfrac{W_{heel}}{3}$	$LA_{upheel} = 3.90$ ft
Force of water behind wall	$P_{wback} := \dfrac{1}{2} Up_{min} \cdot H_{sub} \cdot ft$	$P_{wback} = 195$ lbf

Overturning moment about heel $M_{wback} := \frac{1}{2} Up_{min} \cdot H_{sub} \cdot \left(\frac{H_{sub}}{3}\right) \cdot ft$ $M_{wback} = 162\ ft \cdot lbf$

4. Overturning Check

Total vertical force $Ver := Wt_{wall} - Uplift$ $Ver = 6667\ lbf$

Total horizontal force $Hor := max\left[P_w + P_{ach} - \left(\sum P_o + P_{wback}\right), 0\right]$ $Hor = 2482\ lbf$

$$\Sigma P_o := \begin{cases} P_w + P_{ach} - P_{wback} & \text{if } Hor = 0 \\ \sum P_o & \text{otherwise} \end{cases}$$ $\Sigma P_o = 4139\ lbf$

Moment of wall about heel $M_1 := Wt_{wall} \cdot LA_{heel}$ $M_1 = 104430\ ft \cdot lbf$

Moment of uplift force about heel $M_2 := -Uplift \cdot LA_{up}$ $M_2 = -57517\ ft \cdot lbf$

Moment of water in channel about base $M_3 := -P_w \cdot \frac{H_w}{3}$ $M_3 = -31706\ ft \cdot lbf$

Moment of soil in channel about base $M_4 := -P_{ach} \cdot \frac{H_{ch}}{3}$ $M_4 = -427\ ft \cdot lbf$

Moment of backfill above base $M_5 := \Sigma P_o \cdot LA_{back}$ $M_5 = 7354\ ft \cdot lbf$

Moment of water in backfill $M_6 := M_{wback}$ $M_6 = 162\ ft \cdot lbf$

Net moment about base $M_{net} := \sum M$ $M_{net} = 22297\ ft \cdot lbf$

Location of resultant from heel $x_{edge} := \left|\frac{M_{net}}{Ver}\right|$ $x_{edge} = 3.34\ ft$

Ratio of eccentricity to base width $Ratio := \frac{x_{edge}}{W}$ $Ratio = 0.252$

Check for foundation contact

$$Contact := \begin{cases} \text{"Okay"} & \text{if } \frac{x_{edge}}{W} \ge 0.250 \wedge \frac{x_{edge}}{W} \le 0.750 \\ \text{"NA"} & \text{otherwise} \end{cases}$$

$Contact = \text{"Okay"}$

Maximum stress beneath foundation	$\sigma_{max} := \frac{Ver}{b \cdot W} \cdot \left(1 + \frac{6 \cdot ecc}{W}\right)$	$\sigma_{max} = 681$ psf
Maximum stress beneath foundation	$\sigma_{min} := \frac{Ver}{b \cdot W} \cdot \left(1 - \frac{6 \cdot ecc}{W}\right)$	$\sigma_{min} = 325$ psf
Pressure on toe at face of stem	$\sigma_{stoe} := \sigma_{min} + \left(\frac{\sigma_{max} - \sigma_{min}}{W}\right) \cdot W_{toe}$	$\sigma_{stoe} = 480$ psf
Pressure on heel at face of stem	$\sigma_{sheel} := \sigma_{min} + \left(\frac{\sigma_{max} - \sigma_{min}}{W}\right) \cdot (W_{toe} + b_{stem})$	$\sigma_{sheel} = 502$ psf

5. Sliding on Foundation Plane:

Angle of plane w.r.t. horizontal	$\alpha := 0$	
Normal force on sliding plane	$N := Ver \cdot \cos(\alpha) + Hor \cdot \sin(\alpha)$	$N = 6667$ lbf
Tangential force on sliding plane	$T := Hor \cdot \cos(\alpha) - Ver \cdot \sin(\alpha)$	$T = 2482$ lbf
Tangential capacity with given FS	$T_{cap} := \frac{N \cdot \tan(\phi)}{FS_s}$	$T_{cap} = 3012$ lbf

$$Check_Sliding := \begin{cases} \text{"Okay"} & \text{if } T_{cap} \geq |T| \\ \text{"NG"} & \text{otherwise} \end{cases}$$

Check_Sliding = "Okay"

6. Bearing Capacity of Foundation:

Depth of embedment	$D := D_s + H_{sub}$	$D = 5.00$ ft
Width of foundation in contact	$L' := W - 2 \cdot ecc$	$L' = 11.69$ ft
Depth modification factors	$\xi_{qd} := 1 + 0.1\left(\frac{D}{L'}\right)\tan\left(45deg + \frac{\phi}{2}\right)^2$	$\xi_{qd} = 1.13$
	$\xi_{\gamma d} := \xi_{qd}$	
Angle of inclination of load	$\delta := atan\left(\frac{T}{N}\right)$	$\delta = 20.42$ deg
Load inclination modification factors	$\xi_{qi} := \left(1 - \frac{\delta}{90 \cdot deg}\right)^2$	$\xi_{qi} = 0.60$

$$\xi_{\gamma i} := \begin{cases} \left(1 - \frac{\delta}{\phi}\right)^2 & \text{if } \delta \le \phi \\ 0 & \text{otherwise} \end{cases}$$ $\xi_{\gamma i} = 0.12$

Ultimate load bearing capacity

$$Q := L' \cdot \left(\xi_{qd} \cdot \xi_{qi} \cdot \xi_{qt} \cdot \xi_{qg} \cdot q_o \cdot N_q + \frac{1}{2} \xi_{\gamma d} \cdot \xi_{\gamma i} \cdot \xi_{\gamma t} \cdot \xi_{\gamma g} \cdot L' \cdot \gamma_b \cdot N_\gamma\right) \cdot ft$$

$Q = 63000$ lbf

Bearing factor of safety

$$FS_{act} := \frac{Q}{N}$$ $FS_{act} = 9.45$

$$\text{Check_bearing} := \begin{cases} \text{"Okay"} & \text{if } FS_{act} \ge FS_b \\ \text{"NG"} & \text{otherwise} \end{cases}$$

Check_Bearing = "Okay"

7. Structural Forces on Wall Components:

A Stem Wall

Height of water acting on stem

$$H_{ws} := (TW - TF) - FB_x$$ $H_{ws} = 12.00$ ft

Moment at stem base on water side

$$M_{water} := \frac{1}{6} \cdot \left(\gamma_w \cdot H_{ws}^3 + K_a \cdot \gamma_b \cdot H_{toe}^3\right) \cdot b$$ $M_{water} = 18.02$ ft·kip

Moment on land side

$$M_{land} := \left[\frac{K_p \gamma_m \cdot H_m^2}{2} \cdot \left(\frac{H_m}{3} + H_{subheel}\right) + \frac{1}{6} \gamma_w \cdot H_{subheel}^3 \ldots + K_p \cdot \left(\frac{\gamma_b \cdot H_{subheel}^3}{6} + \frac{\gamma_m \cdot H_m \cdot H_{subheel}^2}{2}\right)\right] \cdot b$$

$M_{land} = 976$ ft·lbf

Shear at stem base on water side

$$V_{water} := \frac{1}{2} \cdot \left(\gamma_w \cdot H_{ws}^2 + K_o \cdot \gamma_b \cdot H_{toe}^2\right) \cdot b$$ $V_{water} = 4.59$ kip

Shear on land side

$$V_{land} := \left[\frac{K_p \gamma_m \cdot H_m^2}{2} + \frac{1}{2} \gamma_w \cdot H_{subheel}^2 \ldots + K_p \cdot \left(\frac{\gamma_b \cdot H_{subheel}^2}{2} + \gamma_m \cdot H_m \cdot H_{subheel}\right)\right] \cdot b$$ $V_{land} = 1172$ lbf

Net shear on wall

$$V_{stem_2} := V_{water} - V_{land}$$ $V_{stem_2} = 3418$ lbf

Net moment on stem wall

$$M_{stem_2} := M_{water} - M_{land}$$ $M_{stem_2} = 17.05$ ft·kips

B Toe Slab

Upward soil pressure on toe	$S_{toe} := \left(\frac{\sigma_{min} + \sigma_{stoe}}{2}\right) \cdot W_{toe} \cdot ft$	$S_{toe} = 2313$ lbf
Weight of toe	$Wt_{toe} := \gamma_{conc} \cdot W_{toe} \cdot D_s \cdot ft$	$Wt_{toe} = 2156$ lbf
Weight of soil on toe	$Soil_{toe} := \gamma_b \cdot H_{toe} \cdot W_{toe} \cdot ft$	$Soil_{toe} = 920$ lbf
Moment due to uplift on base of toe	$M_{upt} := Uplift_{toe} \cdot LA_{uptoe}$	$M_{upt} = 12622$ ft·lbf
Shear on toe at face of stem	$V_{toe_2} := S_{toe} + Uplift_{toe} - Wt_{toe} - Soil_{toe}$	$V_{toe_2} = 3.22$ kips
Moment on toe at face of stem	$M_{toe_2} := (S_{toe} - Wt_{toe} - Soil_{toe}) \cdot \frac{W_{toe}}{2} + M_{upt}$	$M_{toe_2} = 10.43$ ft·kips

C Heel Slab

Weight of heel slab	$Wt_{heel} := \gamma_{conc} \cdot W_{heel} \cdot D_s \cdot ft$	$Wt_{heel} = 2500$ lbf
Moment of heel slab	$M_{wheel} := Wt_{heel} \cdot \frac{W_{heel}}{2}$	$M_{wheel} = 8334$ ft·lbf
Weight of soil and water on heel slab	$Wt_{back} := \gamma_{back} \cdot W_{heel} \cdot H_{soil} \cdot ft$	$Wt_{back} = 2000$ lbf
Moment of heel slab	$M_{back} := Wt_{back} \cdot \frac{W_{heel}}{2}$	$M_{back} = 6667$ ft·lbf
Upward soil pressure on heel	$S_{heel} := \left(\frac{\sigma_{sheel} + \sigma_{max}}{2}\right) \cdot W_{heel} \cdot ft$	$S_{heel} = 3945$ lbf
Lever arm of soil pressure on heel	$la_{sheel} := \left(\frac{\sigma_{sheel} + 2\sigma_{max}}{\sigma_{sheel} + \sigma_{max}}\right) \cdot \frac{W_{heel}}{3}$	$la_{sheel} = 3.50$ ft
Moment of soil pressure on heel	$M_{sheel} := S_{heel} \cdot la_{sheel}$	$M_{sheel} = 13813$ ft·lbf
Moment of uplift pressure on heel	$M_{upheel} := Uplift_{heel} \cdot LA_{upheel}$	$M_{upheel} = 8894$ ft·lbf
Shear force on heel slab	$V_{heel_2} := \lvert Wt_{heel} + Wt_{back} - S_{heel} - Uplift_{heel} \rvert$	$V_{heel_2} = 1725$ lbf
Moment on heel slab	$M_{heel_2} := \lvert M_{wheel} + M_{back} - M_{sheel} - M_{upheel} \rvert$	$M_{heel_2} = 7705$ ft·lbf

III Structural Design of Flood Walls

Balanced reinforcement ratio $\rho_b := \frac{0.85 \cdot f'_c}{f_y} \cdot \beta_1 \cdot \left(\frac{\varepsilon_c}{\varepsilon_m + \frac{f_y}{E_s}} \right)$ $\rho_b = 0.0214$

Minimum reinforcement $\rho_{min} := \frac{200 \cdot psi}{f_y}$ $\rho_{min} = 0.0033$

1. Structural Design of Stem Wall

Design ultimate shear on stem $V_u := \max(\gamma_u \cdot V_{stem_1}, \gamma_{ux} V_{stem_2})$ $V_u = 5666$ lbf

Design ultimate moment on stem $M_u := \left| \max(\gamma_u \cdot M_{stem_1}, \gamma_{ux} M_{stem_2}) \right|$ $M_u = 28.26$ ft·kips

Try rebar no $Rebar := 7$

Clear cover to reinforcement $clr := 2.00 \cdot in$

Rustication allowance $rust := \frac{3}{4} \cdot in$

Diameter of bar $d_b := d_{bar_{Rebar}}$ $d_b = 0.88$ in

Area of bar $A_b := A_{bar_{Rebar}}$ $A_b = 0.60\ in^2$

Effective depth of stem $d := b_{stem} - clr - rust - \frac{d_b}{2}$ $d = 6.81$ in

Neutral axis factor $k_u := 1 - \sqrt{1 - \frac{M_u}{\phi_b \cdot 0.425 \cdot f'_c \cdot b \cdot d^2}}$ $k_u = 0.31$

Area of steel required $A_s := \frac{0.85 \cdot f'_c \cdot k_u \cdot b \cdot d}{f_y}$ $A_s = 1.09\ in^2$

Spacing of steel required $spacing := \frac{A_b \cdot b}{A_s}$ [redacted]

Use spacing of reinforcement $spacing := 6 \cdot in$

Area of steel provided $A_s := \frac{A_b \cdot b}{spacing}$ $A_s = 1.20\ in^2$

Reinforcement ratio	$\rho := \frac{A_s}{b \cdot d}$	$\rho = 0.0147$
Check for min reinforcement	$Check_reinf := \begin{cases} "Okay" & \text{if } \rho \ge \rho_{min} \vee \frac{4\rho}{3} \le \rho_{max} \\ "NG" & \text{otherwise} \end{cases}$	
	$Check_reinf = "Okay"$	
Shear capacity of concrete	$\phi V_c := \phi_v \cdot 2\sqrt{f'_c \cdot psi} \cdot b \cdot d$	$\phi V_c = 7612$ lbf
	$Check_shear := \begin{cases} "Okay" & \text{if } \phi V_c \ge V_u \\ "NG" & \text{otherwise} \end{cases}$	
	$Check_shear = "Okay"$	

2. Design of Cut-off Point for Reinforcement

Try elevation of theoretical cut-off	$TPC := 2068.50 \cdot ft$	
Hydraulic head at normal flood	$H_{wn} := WSEL - TPC$	$H_{wn} = 6.00$ ft
Hydraulic head at extreme flood	$H_{wx} := TW - TPC$	$H_{wx} = 9.50$ ft
Shear due to normal flood	$V_{wn} := \frac{1}{2} \cdot \gamma_w \cdot H_{wn}^2 \cdot ft$	$V_{wn} = 1123$ lbf
Shear due to extreme flood	$V_{wx} := \frac{1}{2} \cdot \gamma_w \cdot H_{wx}^2 \cdot ft$	$V_{wx} = 2815.80$ lbf
Moment due to normal flood	$M_{wn} := \frac{1}{6} \cdot \gamma_w \cdot H_{wn}^3 \cdot ft$	$M_{wn} = 2246$ ft·lbf
Moment due to extreme flood	$M_{wx} := \frac{1}{6} \cdot \gamma_w \cdot H_{wx}^3 \cdot ft$	$M_{wx} = 8917$ ft·lbf
Design ultimate shear on stem	$V_u := \max(\gamma_u \cdot V_{wn}, \gamma_{ux} V_{wx})$	$V_u = 4667$ lbf
Design ultimate moment on stem	$M_u := \max(\gamma_u \cdot M_{wn}, \gamma_{ux} M_{wx})$	$M_u = 14.78$ ft·kips
Diameter of bar	$d_b := d_{bar_{Rebar}}$	$d_b = 0.88$ in
Area of bar	$A_b := A_{bar_{Rebar}}$	$A_b = 0.60\ in^2$

Effective depth of stem	$d := b_{stem} - clr - rust - \frac{d_b}{2}$	$d = 6.81\,in$
Neutral axis factor	$k_u := 1 - \sqrt{1 - \frac{M_u}{\phi_b \cdot 0.425 \cdot f'_c \cdot b \cdot d^2}}$	$k_u = 0.15$
Area of steel required	$A_s := \frac{0.85 \cdot f'_c \cdot k_u \cdot b \cdot d}{f_y}$	$A_s = 0.52\,in^2$
Spacing of steel required	$spacing := \frac{A_b \cdot b}{A_s}$	[redacted]
Use spacing of reinforcement	$spacing := 12 \cdot in$	
Area of steel provided	$A_s := \frac{A_b \cdot b}{spacing}$	$A_s = 0.60\,in^2$
Reinforcement ratio	$\rho := \frac{A_s}{b \cdot d}$	$\rho = 0.0073$
Check for min reinforcement	$Check_reinf := \begin{cases} "Okay" & \text{if } \rho \ge \rho_{min} \vee \frac{4\rho}{3} \le \rho_{max} \\ "NG" & \text{otherwise} \end{cases}$	
	[redacted]	
Shear capacity of concrete	$\phi V_c := \phi_v \cdot 2\sqrt{f'_c \cdot psi} \cdot b \cdot d$	$\phi V_c = 7612\,lbf$
	$Check_shear := \begin{cases} "Okay" & \text{if } \phi V_c \ge V_u \\ "NG" & \text{otherwise} \end{cases}$	
	[redacted]	

3. Structural Design of Toe

Design ultimate shear on toe	$V_u := \max(\gamma_u \cdot V_{toe_1}, \gamma_{ux} V_{toe_2})$	$V_u = 5339$ lbf
Design ultimate moment on toe	$M_u := \max(\gamma_u \cdot M_{toe_1}, \gamma_{ux} M_{toe_2})$	$M_u = 17.28$ ft·kips
Try rebar no	$Rebar := 5$	
Clear cover to reinforcement	$clr := 3 \cdot in$	
Diameter of bar	$d_b := d_{bar_{Rebar}}$	$d_b = 0.63$ in
Area of bar	$A_b := A_{bar_{Rebar}}$	$A_b = 0.31\ in^2$
Effective depth of toe slab	$d := D_s - clr - \frac{d_b}{2}$	$d = 26.69$ in
Neutral axis factor	$k_u := 1 - \sqrt{1 - \frac{M_u}{\phi_b \cdot 0.425 \cdot f'_c \cdot b \cdot d^2}}$	$k_u = 0.0106$
Area of steel required	$A_s := \frac{0.85 \cdot f'_c \cdot k_u \cdot b \cdot d}{f_y}$	$A_s = 0.14\ in^2$
Spacing of steel required	$spacing := \frac{A_b \cdot b}{A_s}$	spacing = 25.71 in
Use spacing of reinforcement	$spacing := 18 \cdot in$	
Area of steel provided	$A_s := \frac{A_b \cdot b}{spacing}$	$A_s = 0.21\ in^2$
Reinforcement ratio	$\rho := \frac{A_s}{b \cdot d}$	$\rho = 0.0006$
Check for min reinforcement	$Check_reinf := \begin{cases} \text{"Okay"} & \text{if } \rho \ge \rho_{min} \vee \frac{4\rho}{3} \le \rho_{max} \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	$Check_reinf = \text{"Okay"}$	
Shear capacity of concrete	$\phi V_c := \phi_v \cdot 2\sqrt{f'_c \cdot psi} \cdot b \cdot d$	$\phi V_c = 29819$ lbf
Check shear in toe slab	$Check_shear := \begin{cases} \text{"Okay"} & \text{if } \phi V_c \ge V_u \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	$Check_shear = \text{"Okay"}$	

4. Structural Design of Heel

Design ultimate shear on heel	$V_u := \max(\gamma_u \cdot V_{heel_1}, \gamma_{ux} V_{heel_2})$	$V_u = 3465$ lbf
Design ultimate moment on heel	$M_u := \max(\gamma_u \cdot M_{heel_1}, \gamma_{ux} M_{heel_2})$	$M_u = 14.59$ ft·kips
Try rebar no	$Rebar := 5$	
Clear cover to reinforcement	$clr := 3 \cdot in$	
Diameter of bar	$d_b := d_{bar_{Rebar}}$	$d_b = 0.63$ in
Area of bar	$A_b := A_{bar_{Rebar}}$	$A_b = 0.31\ in^2$
Effective depth of heel slab	$d := D_s - clr - \frac{d_b}{2}$	$d = 26.69$ in
Neutral axis factor	$k_u := 1 - \sqrt{1 - \frac{M_u}{\phi_b \cdot 0.425 \cdot f'_c \cdot b \cdot d^2}}$	$k_u = 0.01$
Area of steel required	$A_s := \frac{0.85 \cdot f'_c \cdot k_u \cdot b \cdot d}{f_y}$	$A_s = 0.12\ in^2$
Use spacing of reinforcement	$spacing := 18 \cdot in$	
Area of steel provided	$A_s := \frac{A_b \cdot b}{spacing}$	$A_s = 0.21\ in^2$
Reinforcement ratio	$\rho := \frac{A_s}{b \cdot d}$	$\rho = 0.0006$
Check for min reinforcement	$Check_reinf := \begin{cases} \text{"Okay"} & \text{if } \rho \ge \rho_{min} \vee \frac{4\rho}{3} \le \rho_{max} \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	Check_reinf = "Okay"	
Shear capacity of concrete	$\phi V_c := \phi_v \cdot 2\sqrt{f'_c \cdot psi} \cdot b \cdot d$	$\phi V_c = 29819$ lbf
Check shear in heel slab	$Check_shear := \begin{cases} \text{"Okay"} & \text{if } \phi V_c \ge V_u \\ \text{"NG"} & \text{otherwise} \end{cases}$	
	Check_shear = "Okay"	

Title : Sols Wash Flood Walls Job # 046308-400
Dsgnr: J. Lobo Date: 9:00AM, 5 SEP 06
Description : Ret. wall analysis of walls for no-flood condition

Scope :

Code Ref: ACI 318-02, 1997 UBC, 2003 IBC, 2003 NFPA 5000

Cantilevered Retaining Wall Design

Description 12.0 ft wall with 6.0 ft of retained soil

Criteria

Retained Height	=	7.00 ft
Wall height above soil	=	5.00 ft
Slope Behind Wall	=	0.00 : 1
Height of Soil over Toe	=	12.00 in
Soil Density	=	120.00 pcf
Wind on Stem	=	0.0 psf

Soil Data

Allow Soil Bearing	=	2,000.0 psf
Coulomb Soil Pressure calculation		
Soil Friction Angle	=	31.0 deg
Active Pressure:Ka*Gamma=		33.5
Passive Pressure:Kp*Gamma		374.9
Footing||Soil Friction	=	0.350
Soil height to ignore for passive pressure	=	0.00 in

Footing Strengths & Dimensions

f'c =	3,000 psi	Fy =	60,000 psi	
Min. As %		=	0.0000	
Toe Width		=	5.75 ft	
Heel Width		=	7.50	
Total Footing Width		=	13.25	
Footing Thickness		=	30.00 in	
Key Width		=	0.00 in	
Key Depth		=	0.00 in	
Key Distance from Toe		=	0.00 ft	
Cover @ Top =	3.00 in	@ Btm.=	3.00 in	

Design Summary

Total Bearing Load	=	12,709 lbs	
...resultant ecc.	=	9.82 in	
Soil Pressure @ Toe	=	604 psf	OK
Soil Pressure @ Heel	=	1,314 psf	OK
Allowable	=	2,000 psf	
Soil Pressure Less Than Allowable			
ACI Factored @ Toe	=	845 psf	
ACI Factored @ Heel	=	1,840 psf	
Footing Shear @ Toe	=	3.2 psi	OK
Footing Shear @ Heel	=	2.3 psi	OK
Allowable	=	93.1 psi	
Wall Stability Ratios			
Overturning	=	20.77	OK
Sliding	=	4.46	OK
Sliding Calcs (Vertical Component NOT Used)			
Lateral Sliding Force	=	1,511.0 lbs	
less 100% Passive Force	= -	2,296.2 lbs	
less 100% Friction Force	= -	4,448.1 lbs	
Added Force Req'd	=	0.0 lbs	OK
....for 1.5 : 1 Stability	=	0.0 lbs	OK

Footing Design Results

		Toe	Heel
Factored Pressure	=	845	1,840 psf
Mu' : Upward	=	0	36,167 ft-#
Mu' : Downward	=	0	37,800 ft-#
Mu: Design	=	3,245	1,633 ft-#
Actual 1-Way Shear	=	3.18	2.33 psi
Allow 1-Way Shear	=	93.11	93.11 psi
Toe Reinforcing	=	None Spec'd	
Heel Reinforcing	=	None Spec'd	
Key Reinforcing	=	None Spec'd	

Stem Construction

Top Stem

			Stem OK
Design height		ft =	0.00
Wall Material Above "Ht"		=	Concrete
Thickness		=	10.00
Rebar Size		=	# 4
Rebar Spacing		=	18.00
Rebar Placed at		=	Edge
Design Data			
fb/FB + fa/Fa		=	0.687
Total Force @ Section	lbs	=	1,366.2
Moment....Actual	ft-#	=	3,244.8
Moment.....Allowable		=	4,721.3
Shear.....Actual	psi	=	14.2
Shear.....Allowable	psi	=	93.1
Bar Develop ABOVE Ht.	in	=	17.09
Bar Lap/Hook BELOW Ht.	in	=	6.00
Wall Weight		=	120.8
Rebar Depth 'd'	in	=	8.00
Masonry Data			
f'm	psi	=	
Fs	psi	=	
Solid Grouting		=	
Special Inspection		=	
Modular Ratio 'n'		=	
Short Term Factor		=	
Equiv. Solid Thick.		=	
Masonry Block Type = Normal Weight			
Concrete Data			
f'c	psi	=	3,000.0
Fy	psi	=	60,000.0

Other Acceptable Sizes & Spacings

Toe: Not req'd, Mu < S * Fr
Heel: Not req'd, Mu < S * Fr
Key: No key defined

Rev: 580000
User: KW-0605765, Ver 5.8.0, 1-Dec-2003
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Cantilevered Retaining Wall Design

Description 12.0 ft wall with 6.0 ft of retained soil

Summary of Overturning & Resisting Forces & Moments

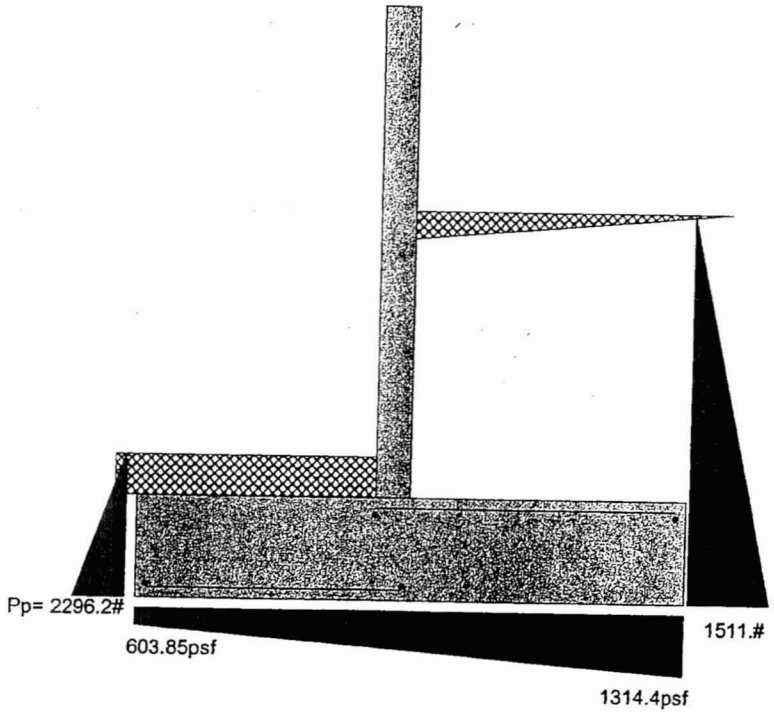
Item		.....OVERTURNING..... Force lbs	Distance ft	Moment ft-#
Heel Active Pressure	=	1,511.0	3.17	4,785.0
Toe Active Pressure	=			
Surcharge Over Toe	=			
Adjacent Footing Load	=			
Added Lateral Load	=			
Load @ Stem Above Soil	=			
SeismicLoad	=			
Total	=	1,511.0	**O.T.M.** =	4,785.0

Resisting/Overturning Ratio = **20.77**

Vertical Loads used for Soil Pressure = 12,708.7 lbs

Vertical component of active pressure NOT used for soil pressure

		.....RESISTING..... Force lbs	Distance ft	Moment ft-#
Soil Over Heel	=	5,600.0	9.92	55,533.3
Sloped Soil Over Heel	=			
Surcharge Over Heel	=			
Adjacent Footing Load	=			
Axial Dead Load on Stem	=		0.00	
Soil Over Toe	=	690.0	2.88	1,983.8
Surcharge Over Toe	=			
Stem Weight(s)	=	1,450.0	6.17	8,941.7
Earth @ Stem Transitions	=			
Footing Weight	=	4,968.7	6.63	32,917.8
Key Weight	=			
Vert. Component	=			
Total	=	12,708.7 lbs	**R.M.=**	99,376.5


Pp= 2296.2#
603.85psf
1511.#
1314.4psf

4.0 CONCRETE DROP STRUCTURE DESIGN

DROP STRUCTURE DESIGN

NOTES

1. MATERIAL STRENGTHS AND ALLOWABLE STRESSES

A. CONCRETE:

CONCRETE FOR DROP STRUCTURE SHALL CONFORM TO THE REQUIREMENTS OF ADOT CLASS 'S'

$f'_c = 3{,}000$ PSI

$f_c = 1{,}400$ PSI

B. REINFORCING STEEL:

REINFORCING STEEL SHALL CONFORM TO THE REQUIREMENTS OF ASTM A615 AND BE FURNISHED AS GRADE 60

$F_y = 60{,}000$ PSI

$f_s = 24{,}000$ PSI

2. DESIGN REFERENCES:

A. USACOE ENGINEERING MANUAL (EM) 1110-2-2007; "STRUCTURAL DESIGN OF CONCRETE LINED FLOOD CONTROL CHANNELS", 30 APRIL 1995

B. USACOE EM 1110-2-2502; "RETAINING AND FLOOD WALLS"

3. DESIGN METHODOLOGY:

DROP STRUCTURE SHALL BE DESIGNED USING THE WORKING STRESS METHOD.

DROP STRUCTURE DESIGN

NOTES

4. DEFINE LOADS

A. EARTH PRESSURE - NO EARTH PRESSURE LOADS ARE ASSUMED TO ACT

B. HYDROSTATIC PRESSURE - HYDROSTATIC LOAD IN INVERSE PROPORTION TO THE CALCULATED ENERGY GRADE LINE WILL BE APPLIED TO THE SLAB.

C. EARTHQUAKE FORCES - WICKENBURG IS A LOW SEISMIC ZONE. EQ LOADS WILL NOT GOVERN — REF. A P 2-4

D. WIND FORCES - WIND LOADS ON SLABS CAN BE IGNORED — REF. A P 2-4

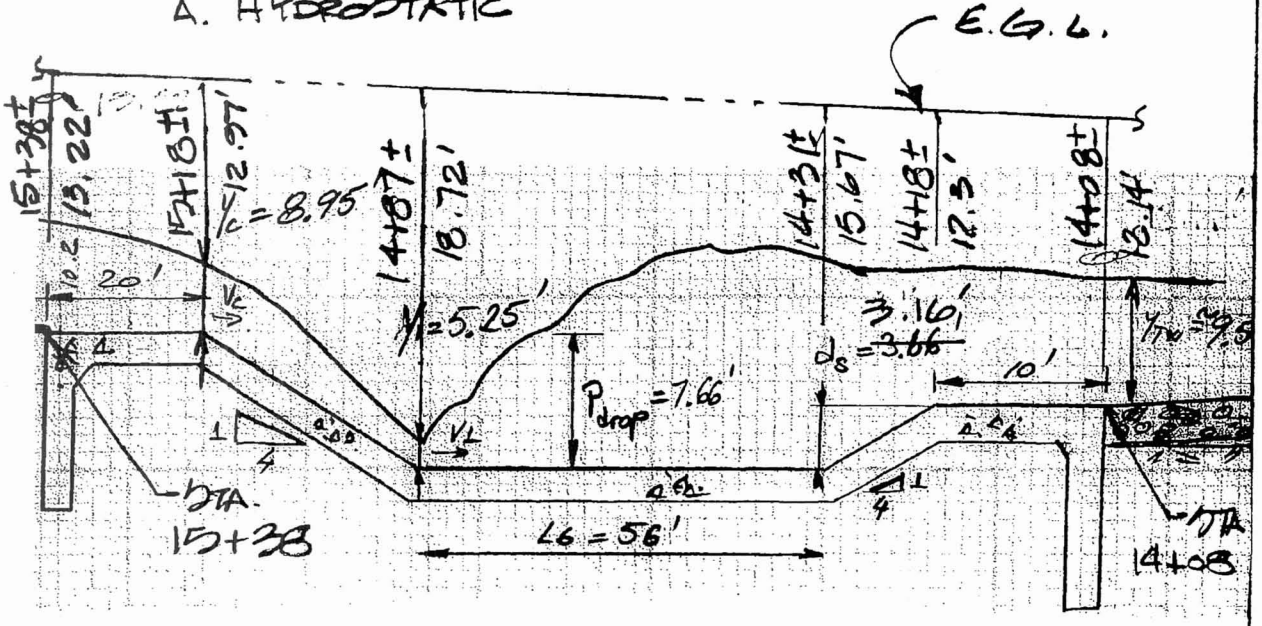
E. SURCHARGE - WHEEL LOADS AND/OR SURCHARGE LOADS SHALL BE APPLIED TO THE SLAB BASED ON THE NEED TO BACKFILL SAND IN THE STRUCTURE AFTER FLOOD EVENTS. USE AS REBAR CHECK — PER REF B

F. SELF WEIGHT - THE SELF WEIGHT OF THE SLAB WILL BE INCLUDED IN THE LOAD CALCULATION

Drop Structure Design

5. Determination of Loads

A. Hydrostatic



Notes

based on flow data provided by EEC

100-Sols 10-Hass

River Sta	Min Ch El ft	W.S. Elev ft	E.G. Elev ft	E.G. Slope	Vel Chnl ft/s	Flow Area sq.ft.	Top Width ft
26+30.00	2051.44	2061.3	2062.94	0.002589	10.28	1462.83	159.00
25+10.00	2051.16	2061.24	2062.48	0.001801	8.94	1683.10	174.02
23+55.00	2050	2060.26	2062.08	0.002863	10.82	1390.55	153.72
20+76.00	2047.1	2059.77	2061.31	0.001966	9.96	1509.84	138.00
19+76.00	2046.8	2059.31	2060.75	0.001814	9.64	1559.92	141.50
16+58.00	2046.5	2058.14	2060.05	0.002341	11.17	1380.95	138.00
16+18.00	2046.4	2057.93	2059.94	0.002872	11.38	1321.88	133.59
15+78.00	2046.4	2057.12	2059.74	0.004189	12.99	1158.26	126.16
15+38.00	2046.3	2056.51	2059.52	0.005065	13.92	1080.76	120.00
15+18.00	2046.3	2055.25	2059.27	0.010347	16.10	934.55	115.72
15+03.00	2042.47	2048.22	2058.39	0.04115	25.59	588.04	104.00
14+87.00	2038.64	2044.5	2057.36	0.054963	28.78	522.74	102.00
14+73.00	2038.64	2052.87	2054.53	0.002405	10.33	1456.35	112.00
14+59.00	2038.64	2052.83	2054.49	0.002431	10.37	1451.32	112.00
14+45.00	2038.64	2053.01	2054.37	0.001911	9.37	1605.47	120.00
14+31.00	2038.64	2053.08	2054.31	0.001724	8.90	1691.32	124.00
14+18.00	2041.8	2051.23	2054.1	0.00654	13.61	1105.25	123.00
14+08.00	2041.8	2051.43	2053.94	0.004083	12.72	1182.42	127.49
13+50.00	2041.8	2052.05	2053.43	0.002198	9.44	1593.60	173.99
13+00.00	2041.8	2052.25	2053.22	0.001418	7.94	1895.09	194.99
12+50.00	2041.6	2052.36	2053.09	0.000976	6.86	2192.97	213.49
12+00.00	2041.4	2052.42	2053.01	0.000728	6.15	2446.85	225.99
11+60.00	2041	2052.47	2052.95	0.000556	5.53	2720.16	241.00

Legend

Drop Structure

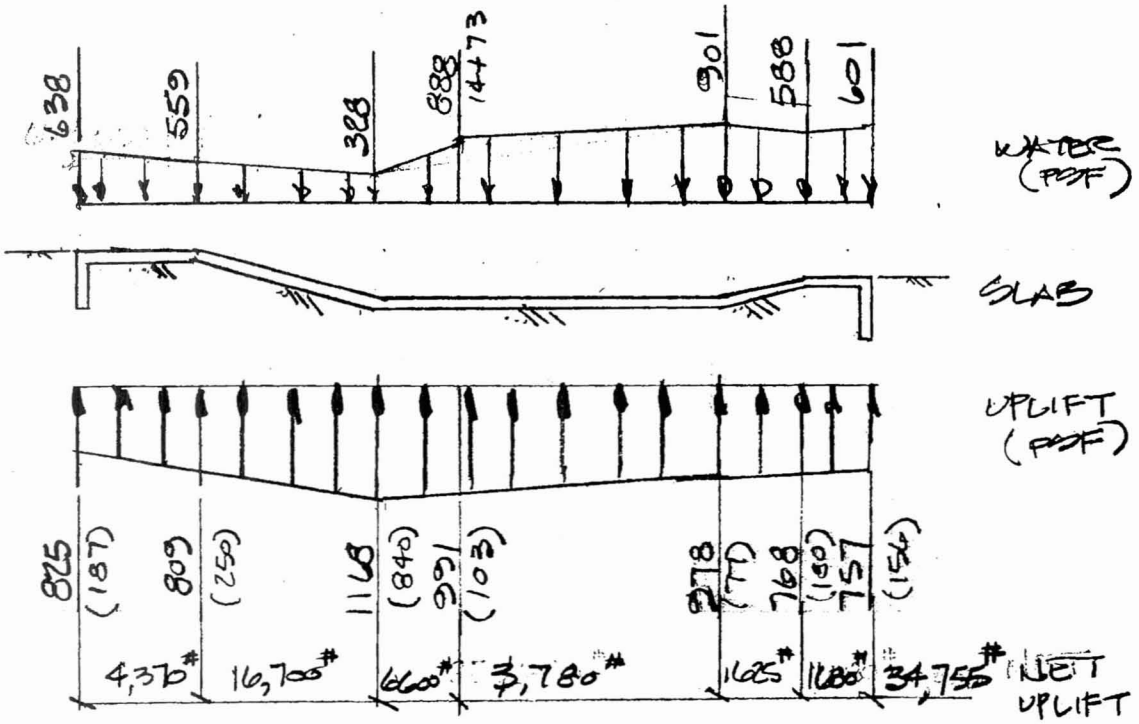
DROP STRUCTURE DESIGN

NOTES

5. DETERMINATION OF LOADS

A. HYDROSTATIC (CONT'D)

ASSUME FILL NOT PRESENT



UPLIFT = EGL

PER 1' STRIP

i) DETERMINE SLAB THICKNESS NEEDED TO BALANCE UPLIFT CONDITION:

> TOTAL SLAB LENGTH = 190'

INCLUDES 10' TOE DOWN

$$> \frac{34,755^{\#}}{(190')(150^{\#}/FT^2)} = 1.54' = 1'-6\tfrac{1}{2}''$$

→ USE 1'-6"

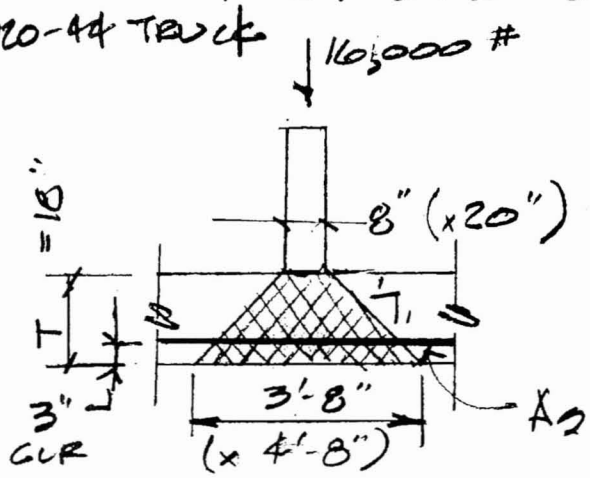
DROP STRUCTURE DESIGN

NOTES

5. DETERMINATION OF LOADS

B. SURCHARGE DUE TO LIVE LOAD

> CONSIDER POINT LOAD DUE TO HS20-44 TRUCK



ASSUME SLAB SETTLES EVENLY

> DISTRIBUTED LOAD AT FLEXURAL STEEL

$$\frac{16{,}000^{\#}}{(3.16)(4.16)} \cong 1220 \text{ PSF}$$

> DESIGN MOMENT:

$$M_D = \frac{1.22(4.67)^2}{8} = 3.32 \text{ K-FT}$$

ASSUME SIMPLY SUPPORTED

NO OTHER LOADS ARE APPLICABLE OR WILL GOVERN

DROP STRUCTURE DESIGN

NOTES

6. SLAB DESIGN

TRY #5 @ 18 O.C. E.W.

$A_s = 0.21 \text{ in}^2/\text{ft}$

$d = 18'' - 3'' \text{ cr} - 0.625/2'' = 14.69 \text{ in}$

$\rho = \frac{A_s}{bd} = \frac{0.21}{(12)(14.69)} = 0.00119$

$\eta = \frac{29{,}000}{57(3000)^{1/2}} = 9.28 \; ; \; \rho\eta = 0.011$

$k = \sqrt{2(0.011) + (0.011)^2} - 0.011 = 0.137$

$j = 1 - k/3 = 0.95$

$M_s = 0.21(24)(0.95)(14.69/12) = 5.9^{k\text{-}ft}$ ok

$M_c = (0.5)(1.4)(0.137)(0.95)(1)(14.69)^2$

$= 19.6^{k\text{-}ft}$ ok

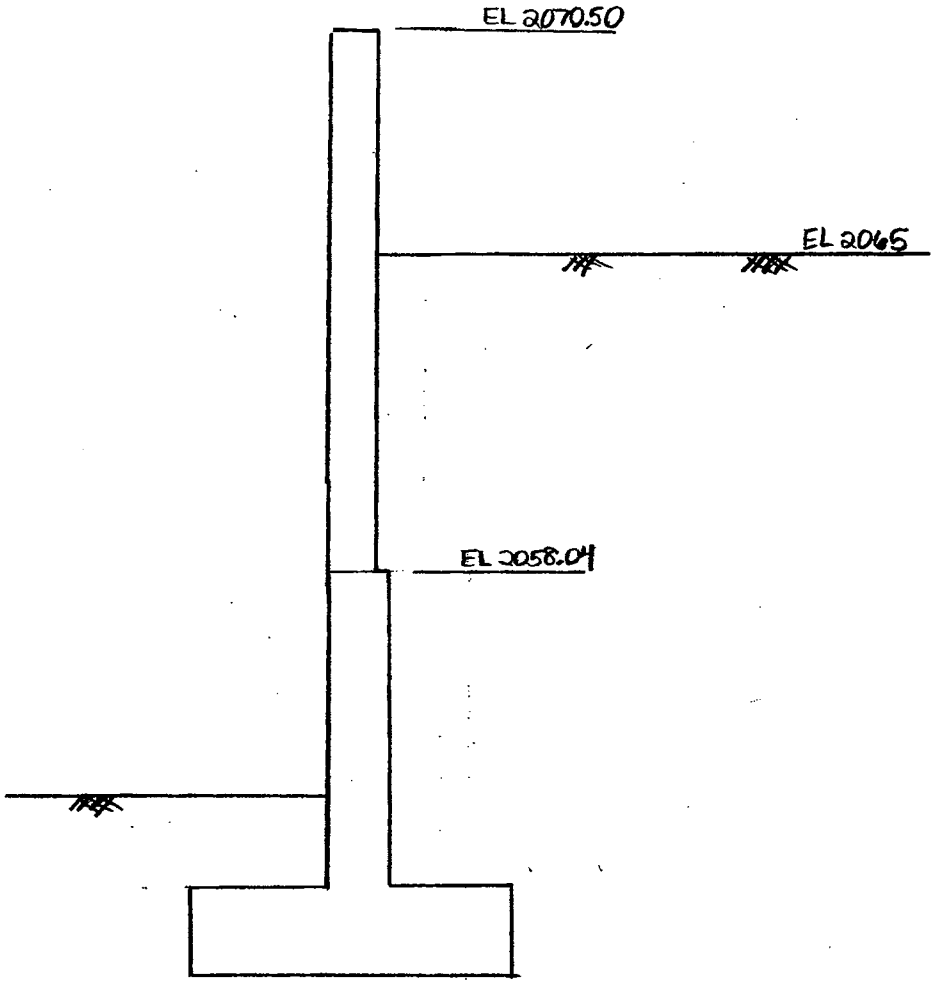
→ USE #5 @ 18" O.C.

5.0 MODIFICATIONS TO TEGNER STREET BRIDGE DESIGN

MODIFICATIONS TO TEGNER STREET BRIDGE
NORTHWEST WING WALL

NW Wing Wall

Load Case #1 - Backfill w/ no water in wash



$K_a = 0.271$
$\gamma = 120$ pcf

$P_a = \frac{1}{2}(120 \text{ pcf})(0.271)(6.96')^2 = 788 \text{ lb/ft}$

$M = (788 \text{ lb/ft})(\frac{1}{3})(6.96') = 1828 \text{ lb}\cdot\text{ft/ft}$

$V = 788 \text{ lb/ft}$

Req'd Steel = #5 @ 12" ⇒ See Next Sheet

NW Wing Wall Extension

Load Case #1

Design Information

f'_c =	3000	psi
f_c =	1200	psi
f_y =	60000	psi
f_s =	24000	psi
n =	9.00	
K =	0.31	
j = 1- k/3 =	0.90	
R_{ideal} =	166.94	psi
ρ_{ideal} =	0.0078	

Dimensional Data

Beam Depth =	10.00	in
d =	7	in
Design moment =	1.83	k-ft/ft
Design shear =	0.79	k/ft

DESIGN CALCULATIONS

approx. A_s req'd = $\frac{M}{f_s * j * d}$ = 0.146 in^2/ft

try # 5 bars at 12 in c/c

A_s = 0.310 in^2/ft **OK**

ρ = 0.004

R = 37.35 <= R_{ideal} = 166.94 psi **OK**

(AASHTO 8.17.1.1)

$M_n >= 1.2*M_{cr}$

$1.2*M_{cr} = f_r*I_g/y_t$

= 98590.0604 lb -in

= 8.22 k-ft/ft

M_n = ?

locate NA : 6 x^2

2.79 x

-19.53

x = N.A. = 1.59 in from compression face

f_t= 1200 $\frac{5.41}{1.59}$ = 4094.40 psi

but can't be more than

$$\frac{24000}{9} = 2666.67 \text{ psi}$$

therefore M_n = 4.01 < M_{cr} = 8.22 k-ft/ft

$$A_s \text{ min} = \frac{1.2M_{cr}}{f_s*j*d} = 0.655 \text{ in}^2/\text{ft}$$

(AASHTO 8.17.1.2)

A_s min = (1.33)A_s req.

= 0.194 in^2/ft

Therefore: A_s min = 0.194 in^2/ft **OK**

CHECK EXTREME FIBER STRESSES

$$f_s = \frac{12*M}{A_s*(d-x/3)} = 10.95 \text{ ksi} <= 24.00 \text{ ksi}$$ **OK**

$$f_c = \frac{f_s*x}{9*(d-x)} = 0.36 \text{ ksi} <= 1.20 \text{ ksi}$$ **OK**

USE # 5 BARS @ 12 in c/c

CHECK SHEAR STRESSES

(AASHTO 8.15.5.1) V_{design} = 9.40 psi

V = 0.79 k/ft

M = 1.83 k-in/ft

(AASHTO 8.15.5.2.1) $V_{allowable}$ = 53.35 psi

(AASHTO 8.19) .5$V_{all.}$ > V_{design}

26.68 >= 9.40 **OK**

THEREFORE NO SHEAR REINFORCEMENT IS NECESSARY

TEMPERATURE AND SHRINKAGE STEEL

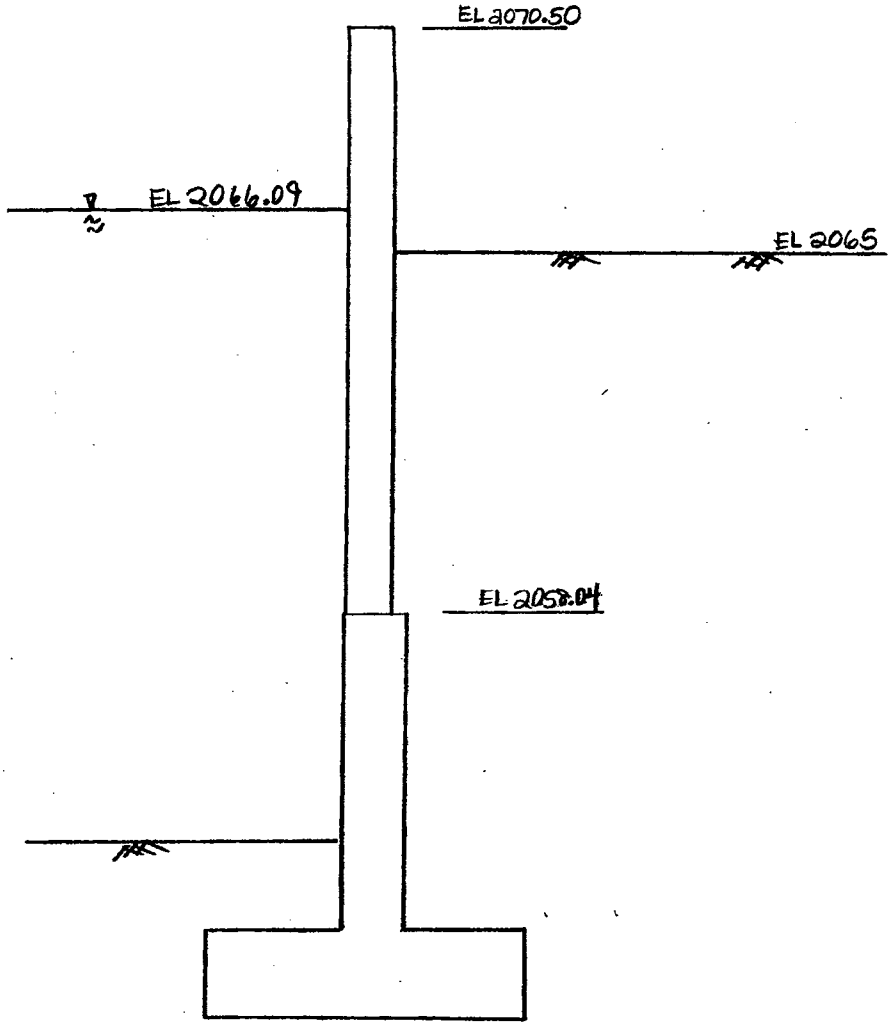
Use #4 @ 18 in in both faces in both directions

Gannett Fleming

SUBJECT Sols Wash
NW Wing Wall
BY BAG DATE 8/29/06 CHKD. BY DATE

SHEET NO. OF
JOB NO.

Load Case #2 - Backfill w/ 100 yr water in wash



$P_{water} = \frac{1}{2}(624\ pcf)(8.05')^2 = 2022\ lb/ft$

$M = (788\ lb/ft)(\frac{1}{3})(6.96') - (2022\ lb/ft)(\frac{1}{3})(8.05') = 3598\ lb\text{-}ft/ft$

$V = 788\ lb/ft - 2022\ lb/ft = 1234\ lb/ft$

Req'd Steel = #6 @ 12" ⇒ See Next sheet

NW Wing Wall Extension

Load Case #2

Design Information

f'_c =	3000	psi
f_c =	1200	psi
f_y =	60000	psi
f_s =	24000	psi
n =	9.00	
K =	0.31	
j = 1- k/3 =	0.90	
R_{ideal} =	166.94	psi
ρ_{ideal} =	0.0078	

Dimensional Data

Beam Depth =	10.00	in
d =	7	in
Design moment =	3.60	k-ft/ft
Design shear =	1.23	k/ft

DESIGN CALCULATIONS

approx. A_s req'd = $\frac{M}{f_s * j * d}$ = 0.287 in^2/ft

try # 6 bars at 12 in c/c

A_s = 0.440 in^2/ft **OK**

ρ = 0.005

R = 73.47 <= R_{ideal} = 166.94 psi **OK**

(AASHTO 8.17.1.1)

$M_n >= 1.2*M_{cr}$

$1.2*M_{cr} = f_r*I_g/y_t$

= 98590.0604 lb -in

= 8.22 k-ft/ft

M_n = ?

locate NA :

$6x^2$

$3.96x$

-27.72

x = N.A. = 1.84 in from compression face

f_t= $1200 \frac{5.16}{1.84}$ = 3353.82 psi

but can't be more than

$$\frac{24000}{9} = 2666.67 \text{ psi}$$

therefore M_n = 5.62 < M_{cr} = 8.22 k-ft/ft

$$A_s \text{ min} = \frac{1.2M_{cr}}{f_s*j*d} = 0.655 \text{ in}^2/\text{ft}$$

(AASHTO 8.17.1.2)

A_s min = (1.33)A_s req.
= 0.381 in^2/ft

Therefore: A_s min = 0.381 in^2/ft **OK**

CHECK EXTREME FIBER STRESSES

$$f_s = \frac{12*M}{A_s*(d-x/3)} = 15.38 \text{ ksi} <= 24.00 \text{ ksi}$$ **OK**

$$f_c = \frac{f_s*x}{9*(d-x)} = 0.61 \text{ ksi} <= 1.20 \text{ ksi}$$ **OK**

USE # 6 BARS @ 12 in c/c

CHECK SHEAR STRESSES

(AASHTO 8.15.5.1) Vdesign = 14.64 psi
V = 1.23 k/ft
M = 3.60 k-in/ft
(AASHTO 8.15.5.2.1) Vallowable = 55.06 psi

(AASHTO 8.19) .5Vall. > Vdesign
27.53 >= 14.64 **OK**

THEREFORE NO SHEAR REINFORCEMENT IS NECESSARY

TEMPERATURE AND SHRINKAGE STEEL

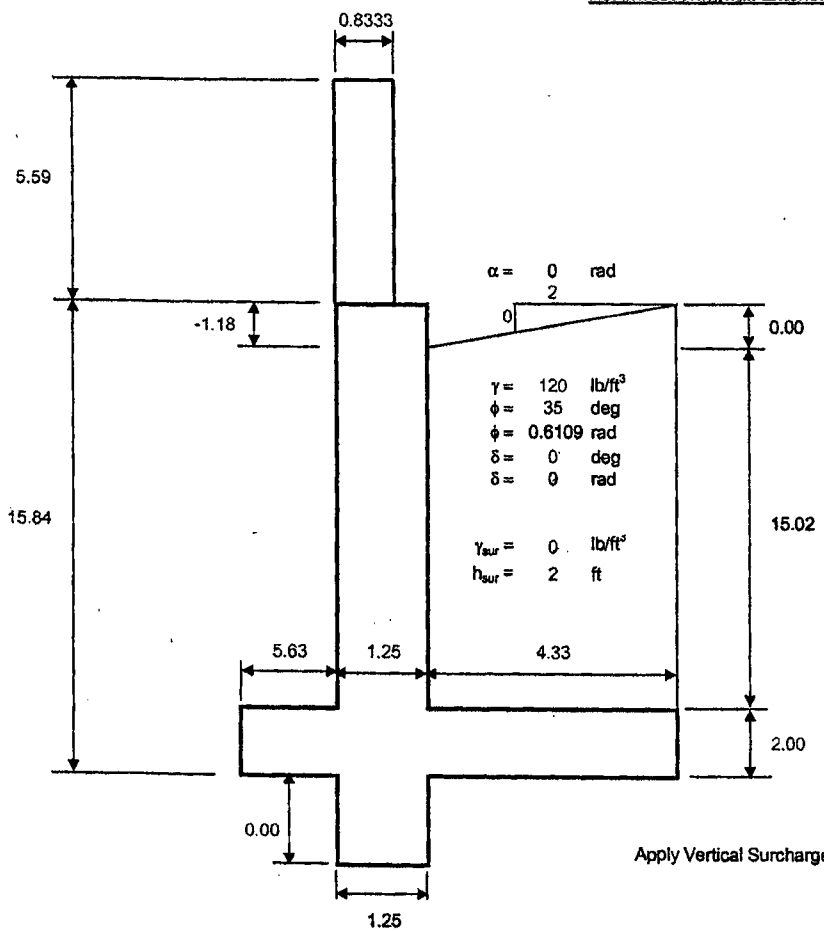
Use #4 @ 18 in in both faces in both directions

INPUT

Items to be inputted are RED
Results are BLUE

Northwest Wingwall Extension

Check stability of wing wall with new stem extension and new backfill.



σ_{allow} =	2	ksf

	Bar #	Spacing (in)	Moment	Shear
Rear Dowel =	7	6	OK	OK
Main Stem =	7	6	0.59	ft above key
Top Footing =	6	12	OK	OK
Bottom Footing =	6	12	NO GOOD	OK

Sliding =	OK
Overturning =	OK
Heel Bearing =	OK
Toe Bearing =	OK
Uplift =	OK

Apply Vertical Surcharge Pressure? n (y or n)

Notes: This spreadsheet uses Coulomb analysis
This spreadsheet is only valid for walls with plumb stems (β=90°)
For level backfill, enter "0" for the vertical component (cell F6)
Enter "0" for γ_{sur} to analyze without a surcharge load

Be sure to check development lengths and lap lengths.
Passive pressure is applied to the footing and the base key, but only if a base key is used.

8.

LOADS

Eqn 5.20 "Das"

K_a = 0.271
γ = 120 lb/ft^3
$K_a*\gamma$ = 0.033 k/ft^3

} Active Earth Pressure

Eqn 5.20 "Das"

K_a = 0.271
γ_{sur} = 0 lb/ft^3
Therefore $K_a*\gamma_{sur}$ = 0.000 k/ft^3

} Surcharge Pressure

Eqn 5.28 "Das"

K_p = 3.690
γ = 120 lb/ft^3
$K_p*\gamma$ = 0.443 k/ft^3

} Passive Pressure

$P_p = 1/2*\gamma*K_p*(H_{footer} + H_{key})^2$ = 0.000 k/ft
$P_a = 1/2*\gamma*K_a*H^2$ = 4.710 k/ft
P_{av} = 0.000 k/ft
P_{ah} = 4.710 k/ft

$q_{toe\ conc}$ = 0.3 k/ft^2
$q_{heel\ conc}$ = 0.3 k/ft^2
$W_{stem\ conc}$ = 2.97 k/ft
$W_{extension\ concrete}$ = 0.70 k/ft
$q_{soil\ right}$ = 1.80 k/ft^2
$q_{soil\ left}$ = 1.80 k/ft^2
$q_{vert\ surcharge}$ = 0.00 k/ft^2

Section	Y Force (k/ft)	X Force (k/ft)	Mom Arm (ft)	Neg Mom (k ft/ft)	Pos Mom (k-ft/ft)
Stem	2.970		6.260		18.591903
Toe	1.690		2.81745		4.763
Heel	1.298		9.049		11.746
Soil (main)	7.799		9.049		70.572
Soil (slope)	0.000		9.770		0.000
Base Key	0.000		6.260		0.000
Extension	0.699		6.052		4.228
Vertical Surcharge	0.000		9.049		0.000
Horizontal Surcharge		0.000	-8.510	0.000	
P_{av}	0.000		11.212		0.000
P_{ah}		4.710	-5.673	-26.722	
[Total]	14.457	4.710		26.722	109.902

Sliding						
Resisting Force	$F_R = \Sigma F_y * \tan\phi + P_p =$	10.123	k/ft			
Driving Force	$F_D = \Sigma F_x =$	4.710	k/ft			
Factor of Safety	$FS_S = F_R/F_D =$	2.149	>=	1.5		OK
Overturning						
Resisting Mom	$M_R = \Sigma M_{pos} =$	109.902	k-ft/ft			
Driving Mom	$M_D = \Sigma M_{neg} =$	26.722	k-ft/ft			
Factor of Safety	$FS_O = M_R/M_D =$	4.113	>=	2		OK
Bearing						
	$\sigma_{allow} =$	2	k/ft^2			
	$e =$	-0.148	ft			
	$q_{heel} = \Sigma Fy/D*(1-6e/D) =$	1.391	k/ft^2	<=	σ_{allow}	OK
	$q_{toe} = \Sigma Fy/D*(1+6e/D) =$	1.187	k/ft^2	<=	σ_{allow}	OK
Uplift						
	$q_{heel} =$	1.391	k/ft^2	>=	0	OK

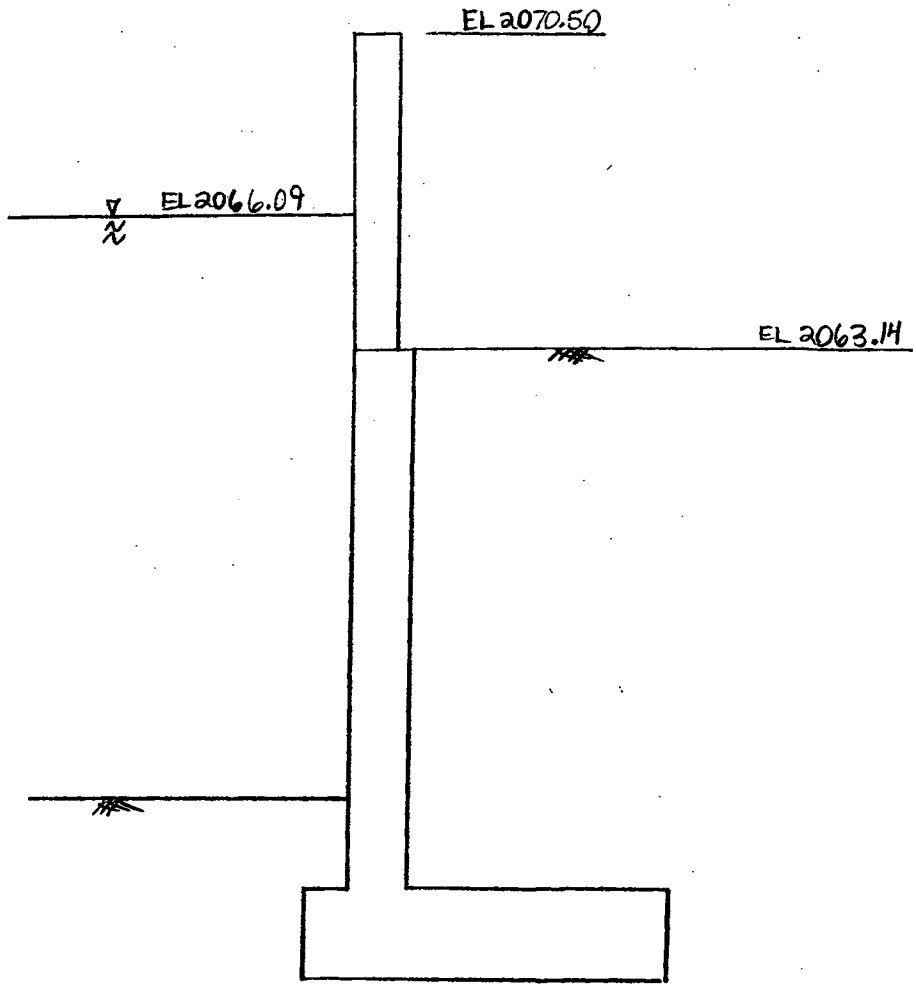
MODIFICATIONS TO TEGNER STREET BRIDGE SOUTHWEST HEADWALL

SW Headwall

Load Case #1 - Backfill w/ no water in wash

- No backfill is proposed behind SW Headwall

Load Case #2 - 100 yr water in wash



$P_{water} = \frac{1}{2}(62.4\,pcf)(2.95')^2 = 272\ lb/ft$

$M = (272\ lb/ft)(\frac{1}{3})(2.95') = 267\ lb\cdot ft/ft$

$V = 272\ lb/ft$

Req'd Steel = #5 @ 12" ⇒ See Next Sheet

SW Headwall Extension

Design Information

f'_c =	3000	psi
f_c =	1200	psi
f_y =	60000	psi
f_s =	24000	psi
n =	9.00	
K =	0.31	
j = 1- k/3 =	0.90	
R_{ideal} =	166.94	psi
ρ_{ideal} =	0.0078	

Dimensional Data

Beam Depth =	10.00	in
d =	7	in
Design moment =	0.27	k-ft/ft
Design shear =	0.27	k/ft

DESIGN CALCULATIONS

$$\text{approx. } A_s \text{ req'd} = \frac{M}{f_s * j * d} = 0.021 \text{ in}^2/\text{ft}$$

try # 5 bars at 12 in c/c

A_s = 0.310 in^2/ft **OK**

ρ = 0.004

R = 5.43 <= R_{ideal} = 166.94 psi **OK**

(AASHTO 8.17.1.1)

$M_n >= 1.2*M_{cr}$

$1.2*M_{cr} = f_r*I_g/y_t$

= 98590.0604 lb -in

= 8.22 k-ft/ft

M_n = ?

locate NA :

6 x^2

2.79 x

-19.53

x = N.A. = 1.59 in from compression face

$$f_t = 1200 \frac{5.41}{1.59} = 4094.40 \text{ psi}$$

but can't be more than

$$\frac{24000}{9} = \quad 2666.67 \text{ psi}$$

therefore M_n = 4.01 < M_{cr} = 8.22 k-ft/ft

$$A_s \text{ min} = \frac{1.2M_{cr}}{f_s{}^*j{}^*d} = 0.655 \text{ in}^2\text{/ft}$$

(AASHTO 8.17.1.2)

A_s min = (1.33)A_s req.

= 0.028 in^2/ft

Therefore: A_s min = 0.028 in^2/ft **OK**

CHECK EXTREME FIBER STRESSES

$$f_s = \frac{12^*M}{A_s{}^*(d-x/3)} = 1.59 \text{ ksi} \quad <= \quad 24.00 \text{ ksi}$$ **OK**

$$f_c = \frac{f_s{}^*x}{9^*(d-x)} = 0.05 \text{ ksi} \quad <= \quad 1.20 \text{ ksi}$$ **OK**

USE # 5 BARS @ 12 in c/c

CHECK SHEAR STRESSES

(AASHTO 8.15.5.1) Vdesign = 3.23 psi

V = 0.27 k/ft

M = 0.27 k-in/ft

(AASHTO 8.15.5.2.1) Vallowable = 53.35 psi

(AASHTO 8.19) .5Vall. > Vdesign

26.68 >= 3.23 **OK**

THEREFORE NO SHEAR REINFORCEMENT IS NECESSARY

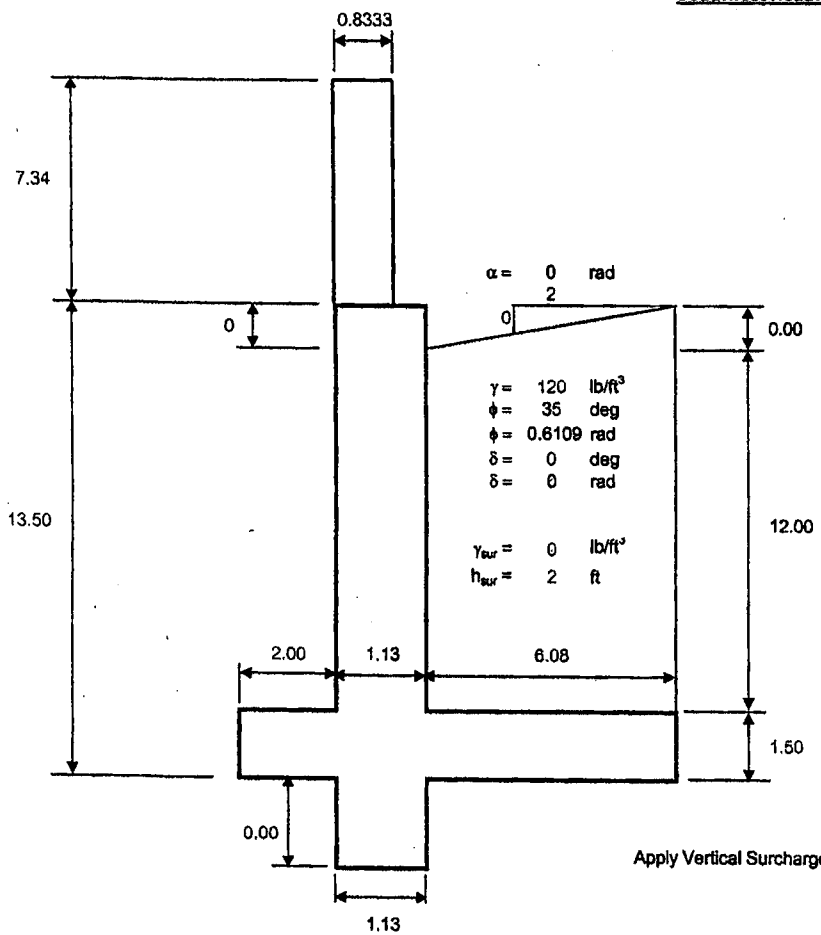
TEMPERATURE AND SHRINKAGE STEEL

Use #4 @ 18 in in both faces in both directions

INPUT

Items to be inputted are RED
Results are BLUE

Southwest Headwall Extension



σ_{allow} =	2	ksf

	Bar #	Spacing (in)	Moment	Shear
Rear Dowel =	7	12	NO GOOD	OK
Main Stem =	7	12	0.59	ft above key
Top Footing =	7	12	OK	OK
Bottom Footing =	9	12	OK	OK

Sliding =	OK
Overturning =	OK
Heel Bearing =	OK
Toe Bearing =	OK
Uplift =	OK

Apply Vertical Surcharge Pressure? n (y or n)

Notes: This spreadsheet uses Coulomb analysis
This spreadsheet is only valid for walls with plumb stems (β=90°)
For level backfill, enter "0" for the vertical component (cell F6)
Enter "0" for γ_{sur} to analyze without a surcharge load

Be sure to check development lengths and lap lengths.
Passive pressure is applied to the footing and the base key, but only if a base key is used.

4b

LOADS

Eqn 5.20 "Das" K_a = 0.271

γ = 120 lb/ft^3 } Active Earth Pressure

Therefore $K_a*\gamma$ = 0.033 k/ft^3

Eqn 5.20 "Das" K_a = 0.271

γ_{sur} = 0 lb/ft^3 } Surcharge Pressure

Therefore $K_a*\gamma_{sur}$ = 0.000 k/ft^3

Eqn 5.28 "Das" K_p = 3.690

γ = 120 lb/ft^3 } Passive Pressure

$K_p*\gamma$ = 0.443 k/ft^3

$P_p = 1/2*\gamma*K_p*(H_{footer} + H_{key})^2$ = 0.000 k/ft

$P_a = 1/2*\gamma*K_a*H^2$ = 2.963 k/ft

P_{av} = 0.000 k/ft

P_{ah} = 2.963 k/ft

$q_{toe\ conc}$ = 0.225 k/ft^2

$q_{heel\ conc}$ = 0.225 k/ft^2

$W_{stem\ conc}$ = 2.28 k/ft

$W_{extension\ concrete}$ = 0.92 k/ft

$q_{soil\ right}$ = 1.44 k/ft^2

$q_{soil\ left}$ = 1.44 k/ft^2

$q_{vert\ surcharge}$ = 0.00 k/ft^2

Section	Y Force (k/ft)	X Force (k/ft)	Mom Arm (ft)	Neg Mom (k ft/ft)	Pos Mom (k-ft/ft)
Stem	2.278		2.563		5.8376953
Toe	0.450		1		0.450
Heel	1.369		6.167		8.440
Soil (main)	8.760		6.167		54.016
Soil (slope)	0.000		7.180		0.000
Base Key	0.000		2.563		0.000
Extension	0.917		2.417		2.217
Vertical Surcharge	0.000		6.167		0.000
Horizontal Surcharge		0.000	-6.750	0.000	
P_{av}	0.000		9.208		0.000
P_{ah}		2.963	-4.500	-13.335	
Total	13.774	2.963		13.335	70.960

Sliding						
Resisting Force	$F_R = \Sigma F_y * \tan\phi + P_p =$	9.645	k/ft			
Driving Force	$F_D = \Sigma F_x =$	2.963	k/ft			
Factor of Safety	$FS_S = F_R/F_D =$	3.255	>=	1.5		OK
Overturning						
Resisting Mom	$M_R = \Sigma M_{pos} =$	70.960	k-ft/ft			
Driving Mom	$M_D = \Sigma M_{neg} =$	13.335	k-ft/ft			
Factor of Safety	$FS_O = M_R/M_D =$	5.321	>=	2		OK
Bearing						
	$\sigma_{allow} =$	2	k/ft^2			
	$e =$	0.420	ft			
	$q_{heel} = \Sigma Fy/D*(1-6e/D) =$	1.086	k/ft^2	<=	σ_{allow}	OK
	$q_{toe} = \Sigma Fy/D*(1+6e/D) =$	1.905	k/ft^2	<=	σ_{allow}	OK
Uplift						
	$q_{heel} =$	1.086	k/ft^2	>=	0	OK

In order to make this headwall pass the bearing pressure check, the toe must be increased from 9½" to 2'-0" in length. However, since the debris fin footing will be dowelled into this headwall footing, the toe will essentially be extended. Therefore, bearing is OK.

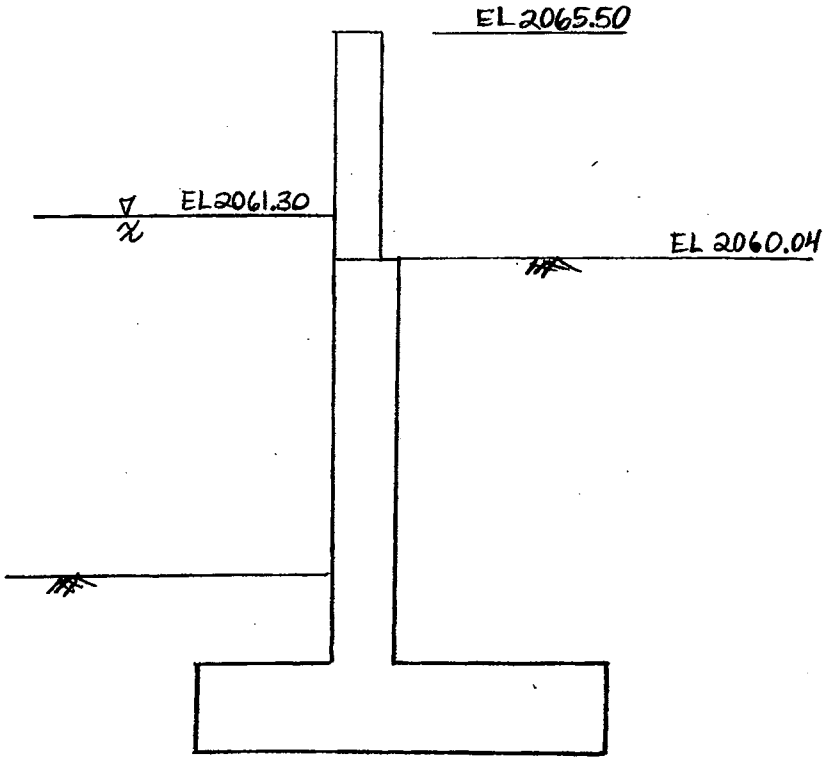
MODIFICATIONS TO TEGNER STREET BRIDGE

SOUTHEAST WING WALL

SE Wing Wall

Load Case #1 - Backfill w/ no water in wash
- No backfill is proposed behind SE Wing Wall

Load Case #2 - 100 yr water in wash



$P_{water} = \frac{1}{2}(62.4\,pcf)(1.24')^2 = 48\ lb/ft$

$M = (48\ lb/ft)(\frac{1}{3})(1.24') = 20\ lb\cdot ft/f$

$V = 48\ lb/ft$

Req'd Steel = #5's @ 12"

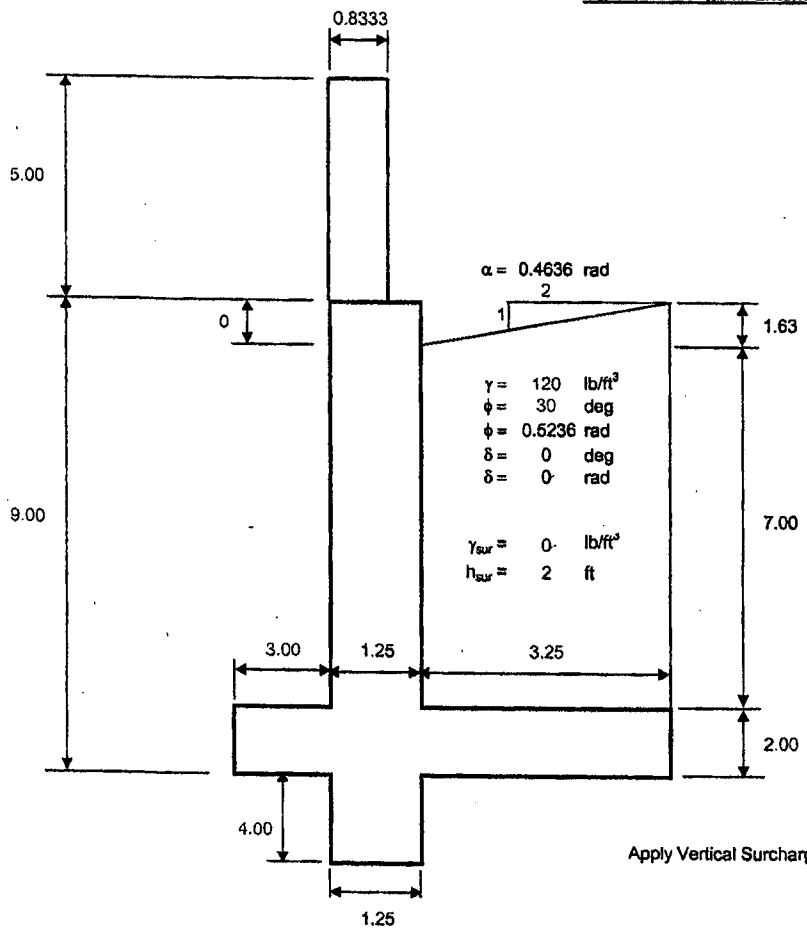
Forces are lower than those on the SW Headwall, so same steel will work

INPUT

Items to be inputted are RED
Results are BLUE

Southeast Wingwall Extension - At End

* Extend existing toe from 1'-6" to 3'-0" to achieve stability.



σ_{allow} =	2	ksf

	Bar #	Spacing (in)	Moment	Shear
Rear Dowel =	7	6	OK	OK
Main Stem =	7	6	0.59	ft above key
Top Footing =	6	12	OK	OK
Bottom Footing =	6	12	OK	OK

Sliding =	OK
Overturning =	OK
Heel Bearing =	OK
Toe Bearing =	OK
Uplift =	OK

Apply Vertical Surcharge Pressure? n (y or n)

Notes: This spreadsheet uses Coulomb analysis
This spreadsheet is only valid for walls with plumb stems (β=90°)
For level backfill, enter "0" for the vertical component (cell F6)
Enter "0" for γ_{sur} to analyze without a surcharge load

Be sure to check development lengths and lap lengths.
Passive pressure is applied to the footing and the base key, but only if a base key is used.

LOADS

Eqn 5.20 "Das"	K_a =	0.536		Active Earth Pressure
	γ =	120	lb/ft^3	
Therefore	$K_a*\gamma$ =	0.064	k/ft^3	
Eqn 5.20 "Das"	K_a =	0.536		Surcharge Pressure
	γ_{sur} =	0	lb/ft^3	
Therefore	$K_a*\gamma_{sur}$ =	0.000	k/ft^3	
Eqn 5.28 "Das"	K_p =	3.000		Passive Pressure
	γ =	120	lb/ft^3	
	$K_p*\gamma$ =	0.360	k/ft^3	

$P_p = 1/2*\gamma*K_p*(H_{footer} + H_{key})^2$ =	6.480	k/ft
$P_a = 1/2*\gamma*K_a*H^2$ =	3.630	k/ft
P_{av} =	0.000	k/ft
P_{ah} =	3.630	k/ft
$q_{toe\ conc}$ =	0.3	k/ft^2
$q_{heel\ conc}$ =	0.3	k/ft^2
$W_{stem\ conc}$ =	1.69	k/ft
$W_{extension\ concrete}$ =	0.62	k/ft
$q_{soil\ right}$ =	1.04	k/ft^2
$q_{soil\ left}$ =	0.84	k/ft^2
$q_{vert\ surcharge}$ =	0.00	k/ft^2

Section	Y Force (k/ft)	X Force (k/ft)	Mom Arm (ft)	Neg Mom (k ft/ft)	Pos Mom (k-ft/ft)
Stem	1.688		3.625		6.1171875
Toe	0.900		1.5		1.350
Heel	0.975		5.875		5.728
Soil (main)	2.730		5.875		16.039
Soil (slope)	0.317		6.417		2.033
Base Key	0.750		3.625		2.719
Extension	0.625		3.417		2.135
Vertical Surcharge	0.000		5.875		0.000
Horizontal Surcharge		0.000	-5.313	0.000	
P_{av}	0.000		7.500		0.000
P_{ah}		3.630	-3.542	-12.856	
Total	7.984	3.630		12.856	36.121

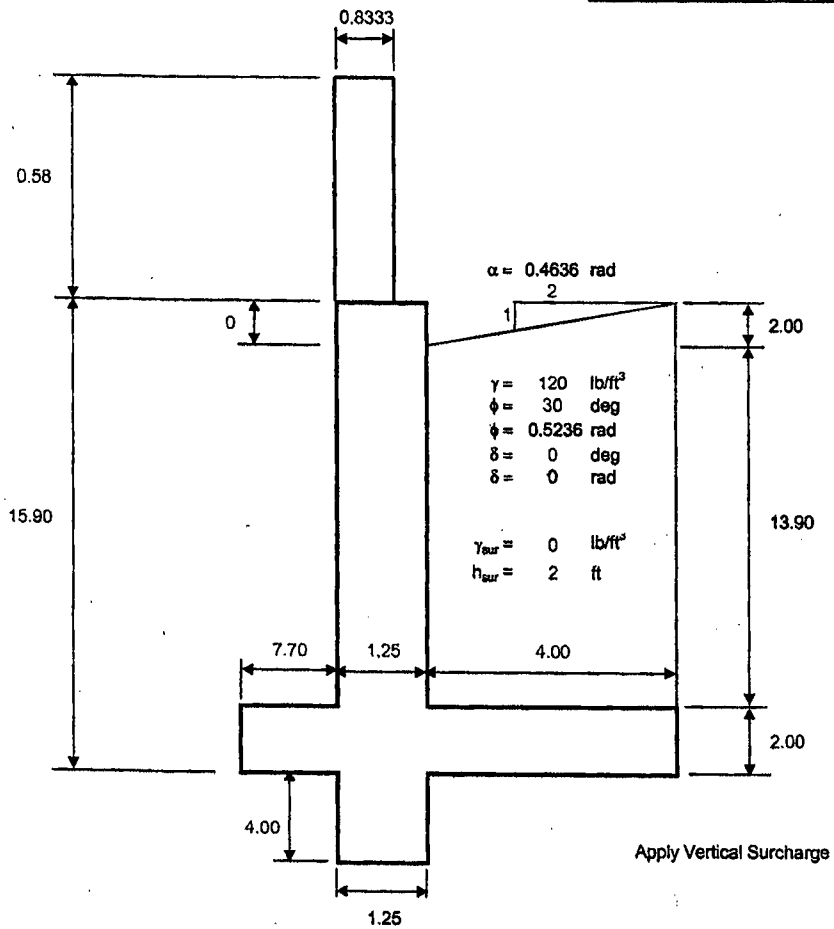
Sliding						
Resisting Force	$F_R = \Sigma F_y * \tan\phi + P_p =$	11.090	k/ft			
Driving Force	$F_D = \Sigma F_x =$	3.630	k/ft			
Factor of Safety	$FS_S = F_R/F_D =$	3.055	>=	1.5		OK
Overturning						
Resisting Mom	$M_R = \Sigma M_{pos} =$	36.121	k-ft/ft			
Driving Mom	$M_D = \Sigma M_{neg} =$	12.856	k-ft/ft			
Factor of Safety	$FS_O = M_R/M_D =$	2.810	>=	2		OK
Bearing						
	$\sigma_{allow} =$	2	k/ft^2			
	$e =$	0.836	ft			
	$q_{heel} = \Sigma Fy/D*(1-6e/D) =$	0.353	k/ft^2	<=	σ_{allow}	OK
	$q_{toe} = \Sigma Fy/D*(1+6e/D) =$	1.777	k/ft^2	<=	σ_{allow}	OK
Uplift						
	$q_{heel} =$	0.353	k/ft^2	>=	0	OK

INPUT

Items to be inputted are RED
Results are BLUE

Southeast Wingwall Extension – At Abutment

* Extend existing toe from 5.7' to 7.7' to achieve stability



σ_{allow} =	2	ksf

	Bar #	Spacing (in)	Moment	Shear
Rear Dowel =	7	6	NO GOOD	NO GOOD
Main Stem =	7	6	1.29	ft above key
Top Footing =	6	12	NO GOOD	OK
Bottom Footing =	6	12	NO GOOD	OK

Sliding =	NO GOOD
Overturning =	OK
Heel Bearing =	OK
Toe Bearing =	OK
Uplift =	OK

Apply Vertical Surcharge Pressure? n (y or n)

Notes: This spreadsheet uses Coulomb analysis
This spreadsheet is only valid for walls with plumb stems (β=90°)
For level backfill, enter "0" for the vertical component (cell F6)
Enter "0" for γ_{sur} to analyze without a surcharge load

Be sure to check development lengths and lap lengths.
Passive pressure is applied to the footing and the base key, but only if a base key is used.

LOADS

Eqn 5.20 "Das" K_a = 0.536

γ = 120 lb/ft^3

Therefore $K_a*\gamma$ = 0.064 k/ft^3

} Active Earth Pressure

Eqn 5.20 "Das" K_a = 0.536

γ_{sur} = 0 lb/ft^3

Therefore $K_a*\gamma_{sur}$ = 0.000 k/ft^3

} Surcharge Pressure

Eqn 5.28 "Das" K_p = 3.000

γ = 120 lb/ft^3

$K_p*\gamma$ = 0.360 k/ft^3

} Passive Pressure

$P_p = 1/2*\gamma*K_p*(H_{footer} + H_{key})^2$ = 6.480 k/ft

$P_a = 1/2*\gamma*K_a*H^2$ = 10.302 k/ft

P_{av} = 0.000 k/ft

P_{ah} = 10.302 k/ft

$q_{toe\ conc}$ = 0.3 k/ft^2

$q_{heel\ conc}$ = 0.3 k/ft^2

$W_{stem\ conc}$ = 2.98 k/ft

$W_{extension\ concrete}$ = 0.07 k/ft

$q_{soil\ right}$ = 1.91 k/ft^2

$q_{soil\ left}$ = 1.67 k/ft^2

$q_{vert\ surcharge}$ = 0.00 k/ft^2

Section	Y Force (k/ft)	X Force (k/ft)	Mom Arm (ft)	Neg Mom (k ft/ft)	Pos Mom (k-ft/ft)
Stem	2.981		8.325		24.818906
Toe	2.310		3.85		8.894
Heel	1.200		10.950		13.140
Soil (main)	6.672		10.950		73.058
Soil (slope)	0.480		11.617		5.576
Base Key	0.750		8.325		6.244
Extension	0.072		8.117		0.588
Vertical Surcharge	0.000		10.950		0.000
Horizontal Surcharge		0.000	-8.950	0.000	
P_{av}	0.000		12.950		0.000
P_{ah}		10.302	-5.967	-61.471	
Total	14.466	10.302		61.471	132.319

Sliding						
Resisting Force	$F_R = \Sigma F_y * \tan\phi + P_p =$	14.832	k/ft			
Driving Force	$F_D = \Sigma F_x =$	10.302	k/ft			
Factor of Safety	$FS_S = F_R/F_D =$	1.440		<	1.5	NO GOOD
Overturning						
Resisting Mom	$M_R = \Sigma M_{pos} =$	132.319	k-ft/ft			
Driving Mom	$M_D = \Sigma M_{neg} =$	61.471	k-ft/ft			
Factor of Safety	$FS_O = M_R/M_D =$	2.153		>=	2	OK
Bearing						
	$\sigma_{allow} =$	2	k/ft^2			
	$e =$	1.577	ft			
	$q_{heel} = \Sigma Fy/D*(1-6e/D) =$	0.301	k/ft^2	<=	σ_{allow}	OK
	$q_{toe} = \Sigma Fy/D*(1+6e/D) =$	1.933	k/ft^2	<=	σ_{allow}	OK
Uplift						
	$q_{heel} =$	0.301	k/ft^2	>=	0	OK

The Sliding Factor of Safety is slightly below the allowable. However the wing wall is integral with the abutment in this area, so it cannot slide.

Bearing Capacity Analysis

US Army Corps of Engineers EM 1110-2-2502
Engineering and Design of Retaining and Flood Walls

Assume NO Cohesion

$$Q = B' \left[\left(\cancel{\xi_{cd}\xi_{ci}\xi_{ct}\xi_{cg}cN_c}\right) + \left(\xi_{qd}\xi_{qi}\xi_{qt}\xi_{qg}q_oN_q\right) + 1/2\left(\xi_{\gamma d}\xi_{\gamma i}\xi_{\gamma t}\xi_{\gamma g}B'\gamma N_\gamma\right) \right]$$

Width of Base = B =	7.50	ft			
Eccentricity = e =	0.836	ft			
B' = B - 2e =	5.83	ft			
Unit Weight of Soil = γ =	120	pcf			
Embedment of Footing = D =	3.00	ft			
q_o =	360	psf			
Friction Angle = ϕ =	30	deg	=	0.524	radians
δ =	0	deg	=	0.000	radians
α =	0	deg	=	0.000	radians
β =	0	deg	=	0.000	radians

Bearing Capacity Factors:

$$N_q = [e^{(\pi \tan\phi)}] \tan^2(45+\phi/2)$$
$$= 18.40$$
$$N\gamma = (N_q-1)\tan(1.4\phi)$$
$$= 15.67$$

Embedment Factors:

$$\xi_{qd} = 1 + 0.1(D/B')\tan(45+\phi/2)$$
$$= 1.09$$
$$\xi_{\gamma d} = \xi_{qd}$$
$$= 1.09$$

Inclination Factors:

$$\xi_{qi} = (1-\delta°/90°)^2$$
$$= 1.00$$
$$\xi_{\gamma i} = (1-\delta°/\phi)^2$$
$$= 1.00$$

Base Tilt Factors:

$$\xi_{qt} = (1-\alpha\tan\phi)^2$$
$$= 1.00$$
$$\xi_{\gamma t} = \xi_{qt}$$
$$= 1.00$$

Ground Slope Factors:

$$\xi_{qg} = (1-\tan\beta)^2$$
$$= 1.00$$
$$\xi_{\gamma g} = \xi_{qg}$$
$$= 1.00$$

$Q =$ 76826.49 lb

$FS =$ 3

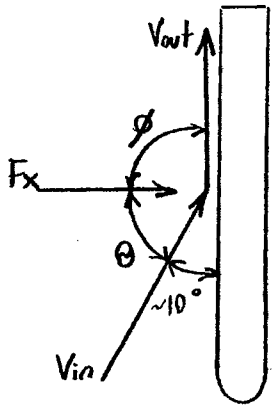
$Q_{allow} =$ 25609 lb

$Q_{actual} =$ 7984 lb **OK**

MODIFICATIONS TO TEGNER STREET BRIDGE DEBRIS FINS

Debris Fin Loading

Using water Jet Equation:



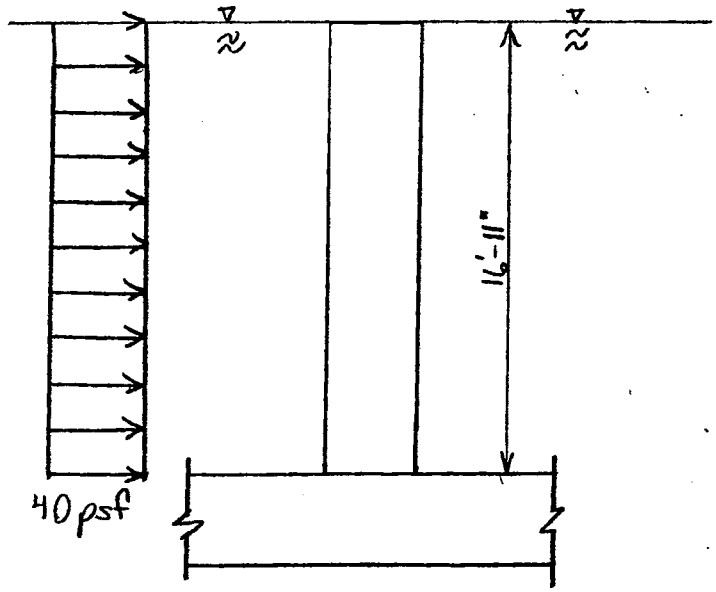
$$F_x = \frac{waV^2}{g}(\cos\theta + \cos\phi)$$

$w = 62.4\ lb/ft^3$
$g = 32.2\ ft/s^2$
$\theta = 80°$
$\phi = 90°$
$V = 10.9\ ft/s$

$$\frac{F_x}{a} = \frac{wV^2}{g}(\cos\theta + \cos\phi)$$

$$= \frac{(62.4\ lb/ft^3)(10.9\ ft/s)^2}{(32.2\ ft/s^2)}(\cos 80° + \cos 90°) = 39.98\ lb/ft^2$$

$$= 40\ psf$$



$M_{max} = (40\ psf)(16.92')(\frac{1}{2})(16.92')/1000$

$= 5.73\ k\cdot ft/ft$

$V_{max} = (40\ psf)(16.92')/1000$

$= 0.68\ k/ft$

Using AASHTO Stream Pressure Equation:

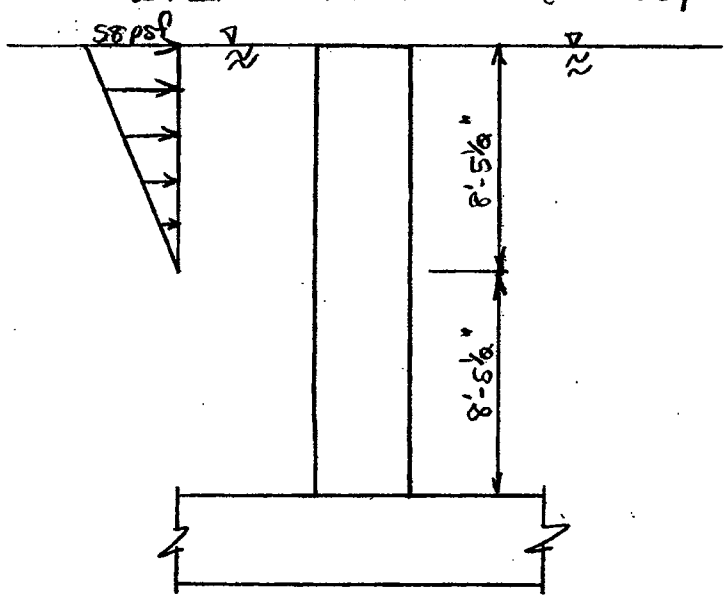
$P_{avg} = K(V_{avg})^2$

K = 1.4 for all piers subject to debris build-up
V_{avg} = 10.9 ft/s

$P_{avg} = (1.4)(10.9\ ft/s)^2 = 166.33\ lb/ft^2$

$P_{max} = 2P_{avg} = (2)(166.33\ lb/ft^2) = 332.66\ lb/ft^2$

$P_{max}\perp = P_{max}\sin 10° = (332.66\ psf)\sin 10° = 57.77\ psf$



$M_{max} = \frac{1}{2}(8.46')(58\ psf)(16.92' - \frac{1}{3}(8.46'))$

$= 3.46\ k\text{-}ft/ft$

$V_{max} = \frac{1}{2}(8.46')(58\ psf)$

$= 0.25\ k/ft$

Use worst case:

$M_{max} = 5.73\ k\text{-}ft/ft \Rightarrow 6.0\ k\text{-}ft/ft$

$V_{max} = 0.68\ k/ft \Rightarrow 1.0\ k/ft$

See Spreadsheet for calculations

Use #6's @ 12"

Debris Fins

Design Information

f'_c =	3000	psi
f_c =	1200	psi
f_y =	60000	psi
f_s =	24000	psi
n =	9.00	
K =	0.31	
j = 1- k/3 =	0.90	
R_{ideal} =	166.94	psi
ρ_{ideal} =	0.0078	

Dimensional Data

Beam Depth =	15.00	in
d =	12	in
Design moment =	6.00	k-ft/ft
Design shear =	1.00	k/ft

DESIGN CALCULATIONS

$$\text{approx. } A_s \text{ req'd} = \frac{M}{f_s * j * d} = 0.279 \text{ in}^2/\text{ft}$$

try # 6 bars at 12 in c/c

A_s = 0.440 in^2/ft **OK**

ρ = 0.003

R = 41.67 <= R_{ideal} = 166.94 psi **OK**

(AASHTO 8.17.1.1)

$M_n >= 1.2*M_{cr}$

$1.2*M_{cr} = f_r*I_g/y_t$

= 221827.636 lb -in

= 18.49 k-ft/ft

M_n = ?

locate NA : $6x^2$

$3.96x$

-47.52

x = N.A. = 2.50 in from compression face

$$f_t = 1200 \frac{9.50}{2.50} = 4551.88 \text{ psi}$$

but can't be more than

$$\frac{24000}{9} = 2666.67 \text{ psi}$$

therefore M_n = 9.83 < M_{cr} = 18.49 k-ft/ft

$$A_s \text{ min} = \frac{1.2M_{cr}}{f_s{}^*j^*d} = 0.859 \text{ in}^2\text{/ft}$$

(AASHTO 8.17.1.2)

A_s min = (1.33)A_s req.

= 0.371 in^2/ft

Therefore: A_s min = 0.371 in^2/ft **OK**

CHECK EXTREME FIBER STRESSES

$$f_s = \frac{12^*M}{A_s{}^*(d-x/3)} = 14.66 \text{ ksi} <= 24.00 \text{ ksi}$$ **OK**

$$f_c = \frac{f_s{}^*x}{9^*(d-x)} = 0.43 \text{ ksi} <= 1.20 \text{ ksi}$$ **OK**

USE # 6 BARS @ 12 in c/c

CHECK SHEAR STRESSES

(AASHTO 8.15.5.1) Vdesign = 6.94 psi

V = 1.00 k/ft

M = 6.00 k-in/ft

(AASHTO 8.15.5.2.1) Vallowable = 52.66 psi

(AASHTO 8.19) .5Vall. > Vdesign

26.33 >= 6.94 **OK**

THEREFORE NO SHEAR REINFORCEMENT IS NECESSARY

TEMPERATURE AND SHRINKAGE STEEL

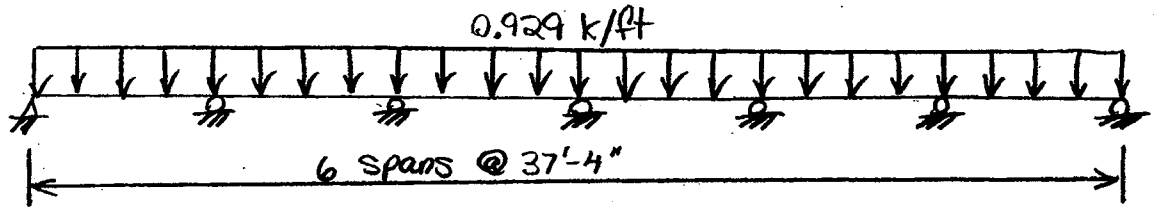
Use #4 @ 12 in in both faces in both directions

MODIFICATIONS TO TEGNER STREET BRIDGE PARAPET FLOODWALL

Design floodwall as a continuous beam

Self weight is the only load

$DL = (10")(7.43')(150\ lb/ft^3)/12 = 928.75\ lb/ft$



Max Pos Moment $= 0.078 wL^2 = (0.078)(0.929\ k/ft)(37.33')^2$

$= 100.98\ k\cdot ft$

Max Neg Moment $= 0.106\ wL^2 = (0.106)(0.929\ k/ft)(37.33')^2$

$= 137.23\ k\cdot ft$

Max Shear $= (63/104)\ wL = (63/104)(0.929\ k/ft)(37.33')$

$= 21.01\ k$

See spreadsheet for calculations

Use 4 #6's in the top and 2 #6's in the bottom

Floodwall

DESIGN INFORMATION

f'_c =	3000	psi
f_c =	1200	psi
f_y =	60000	psi
f_s =	24000	psi
n =	9.00	
K =	0.31	
j = 1- k/3 =	0.90	
R_{ideal} =	166.94	psi
ρ_{ideal} =	0.0078	

Dimensional Data

Beam Depth =	89.16	in
Beam Width =	10.00	in
d =	84.50	in
design moment =	137.23	k-ft
design shear =	21.01	k

DESIGN CALCULATIONS

$$\text{approx. } A_s \text{ req'd} = \frac{M}{f_s * j * d} = 0.906 \text{ in}^2$$

try 4 # 6 bars

A_s = 1.760 in^2 **OK**

ρ = 0.002

R = 23.06 <= R_{ideal} = 166.94 psi **OK**

(AASHTO 8.17.1.1)

$M_n >= 1.2*M_{cr}$

$1.2*M_{cr} = f_r*I_g/y_t$

= 6531185.31 lb -in

= 544.27 k-ft

M_n = ?

locate NA : $5x^2$

$15.84x$

-1338.48

x = N.A. = 14.85 in from compression face

$f_t = 1200 \frac{69.65}{14.85} = 5626.48$ psi

but can't be more than

$\frac{24000}{9} = 2666.67$ psi

therefore $M_n = 280.01 < M_{cr} = 544.27$ k-ft

$A_s \min = \frac{1.2M_{cr}}{f_s{}^*j^*d} = 3.592$ in^2

(AASHTO 8.17.1.2)

$A_s \min = (1.33)A_s$ req.

$= 1.205$ in^2

Therefore: $A_s \min = 1.205$ in^2 **OK**

CHECK EXTREME FIBER STRESSES

$f_s = \frac{12^*M}{A_s{}^*(d-x/3)} = 11.76$ ksi <= 24.00 ksi **OK**

$f_c = \frac{f_s{}^*x}{9^*(d-x)} = 0.28$ ksi <= 1.20 ksi **OK**

CHECK SHEAR STRESSES

(AASHTO 8.15.5.1) Vdesign = 24.86 psi

(AASHTO 8.15.5.2.1) Vallowable = 52.03 psi

1/2*Vallowable >= Vdesign

26.02 >= 24.86 **OK**

Floodwall

DESIGN INFORMATION

f'_c =	3000	psi
f_c =	1200	psi
f_y =	60000	psi
f_s =	24000	psi
n =	9.00	
K =	0.31	
j = 1- k/3 =	0.90	
R_{ideal} =	166.94	psi
ρ_{ideal} =	0.0078	

Dimensional Data

Beam Depth =	89.16	in
Beam Width =	10.00	in
d =	86.00	in
design moment =	100.98	k-ft
design shear =	21.01	k

DESIGN CALCULATIONS

$$\text{approx. } A_s \text{ req'd} = \frac{M}{f_s * j * d} = 0.655 \text{ in}^2$$

try 2 # 6 bars

A_s = 0.880 in^2 **OK**

ρ = 0.001

R = 16.38 <= R_{ideal} = 166.94 psi **OK**

(AASHTO 8.17.1.1)

$M_n >= 1.2*M_{cr}$

$1.2*M_{cr} = f_r*I_g/y_t$

= 6531185.31 lb -in

= 544.27 k-ft

M_n = ?

locate NA : $5x^2$

$7.92x$

-681.12

x = N.A. = 10.91 in from compression face

$f_t = 1200 \frac{75.09}{10.91} = 8262.38$ psi

but can't be more than

$\frac{24000}{9} = 2666.67$ psi

therefore $M_n = 144.96 < M_{cr} = 544.27$ k-ft

$A_s \text{ min} = \frac{1.2M_{cr}}{f_s*j*d} = 3.529 \text{ in}^2$

(AASHTO 8.17.1.2)

$A_s \text{ min} = (1.33)A_s \text{ req.}$

$= 0.871 \text{ in}^2$

Therefore: $A_s \text{ min} = 0.871 \text{ in}^2$ **OK**

CHECK EXTREME FIBER STRESSES

$f_s = \frac{12*M}{A_s*(d-x/3)} = 16.72$ ksi <= 24.00 ksi **OK**

$f_c = \frac{f_s*x}{9*(d-x)} = 0.27$ ksi <= 1.20 ksi **OK**

CHECK SHEAR STRESSES

(AASHTO 8.15.5.1) Vdesign = 24.43 psi

(AASHTO 8.15.5.2.1) Vallowable = 52.03 psi

1/2*Vallowable >= Vdesign

26.02 >= 24.43 **OK**

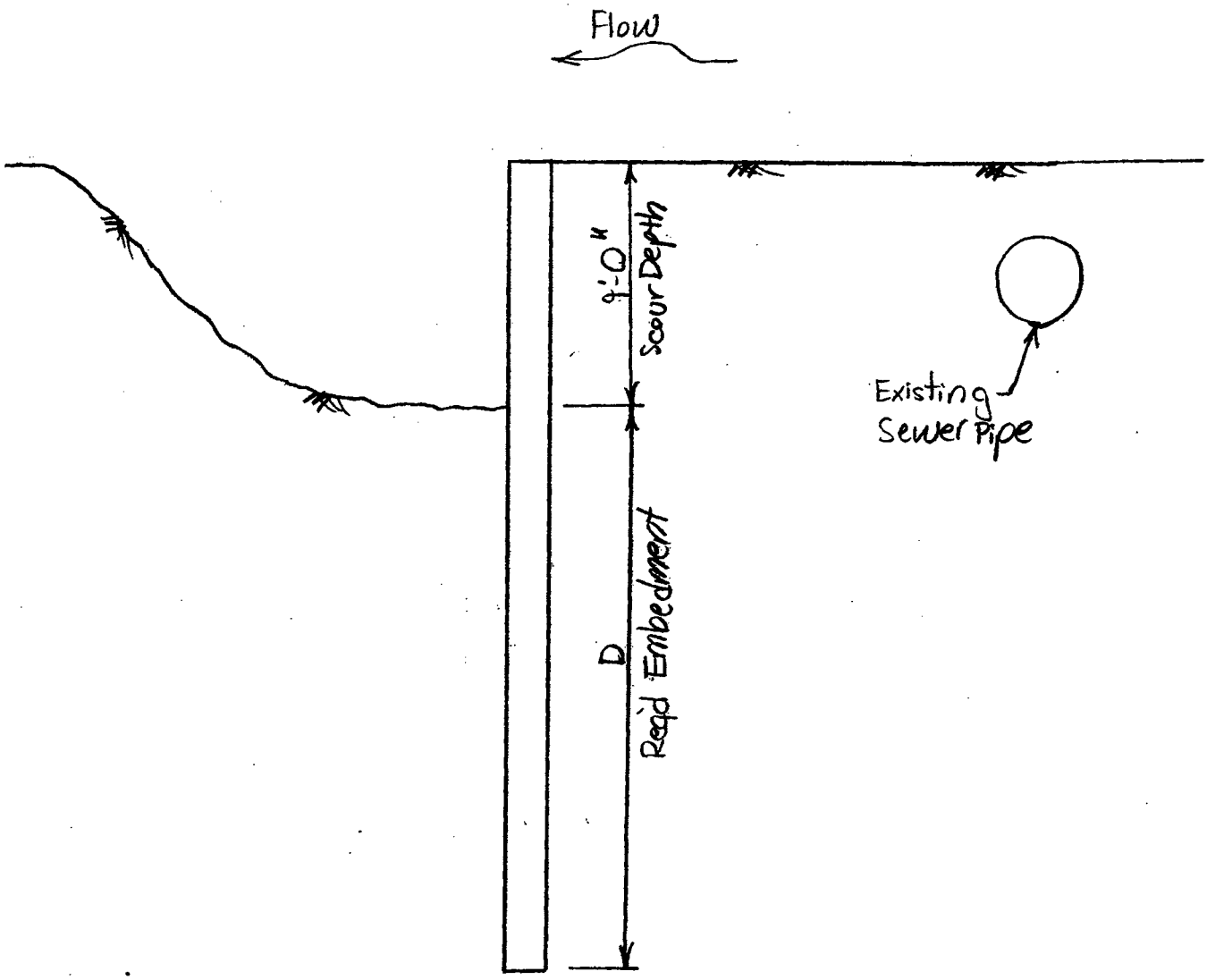
Gannett Fleming

SUBJECT Sols Wash
Sheet Pile Wall

BY BAG DATE 8/22/06 CHKD. BY DATE

SHEET NO. OF

JOB NO.



PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 22-AUGUST-2006 TIME: 10:16:24

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****************
*  INPUT DATA  *
****************

 I.--HEADING
'Cantilever Sheet Pile Grade Control Structure @ 18" VCP Sewer

II.--CONTROL
   CANTILEVER WALL DESIGN
   FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
   FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

III.--WALL DATA
   ELEVATION AT TOP OF WALL    = 2054.50 FT.

IV.--SURFACE POINT DATA

     IV.A.--RIGHTSIDE
        DIST. FROM     ELEVATION
        WALL (FT)        (FT)
           100.00      2054.50

     IV.B.--LEFTSIDE
        DIST. FROM     ELEVATION
        WALL (FT)        (FT)
           100.00      2045.50

 V.--SOIL LAYER DATA

     V.A.--RIGHTSIDE
        LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
        LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

              ANGLE OF        ANGLE OF                        <-SAFETY->
 SAT.   MOIST INTERNAL  COH-    WALL    ADH-    <--BOTTOM-->  <-FACTOR->
WGHT.   WGHT. FRICTION  ESION  FRICTION ESION   ELEV.  SLOPE  ACT. PASS.
(PCF)   (PCF)   (DEG)   (PSF)   (DEG)   (PSF)   (FT)  (FT/FT)
118.00 103.00   31.00    0.00   14.00    0.00                  DEF  DEF

     V.B.--LEFTSIDE
        LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
        LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

              ANGLE OF        ANGLE OF                        <-SAFETY->
 SAT.   MOIST INTERNAL  COH-    WALL    ADH-    <--BOTTOM-->  <-FACTOR->
WGHT.   WGHT. FRICTION  ESION  FRICTION ESION   ELEV.  SLOPE  ACT. PASS.
(PCF)   (PCF)   (DEG)   (PSF)   (DEG)   (PSF)   (FT)  (FT/FT)
118.00 103.00   31.00    0.00   14.00    0.00                  DEF  DEF

VI.--WATER DATA
   UNIT WEIGHT          = 62.40 (PCF)
   RIGHTSIDE ELEVATION  = 2054.50 (FT)
   LEFTSIDE ELEVATION   = 2045.50 (FT)
   SEEPAGE ELEVATION    = 2045.50 (FT)
   SEEPAGE GRADIENT     = AUTOMATIC

VII.--VERTICAL SURCHARGE LOADS

   VII.A.--VERTICAL LINE LOADS
        NONE

   VII.B.--VERTICAL UNIFORM LOADS
             LEFTSIDE     RIGHTSIDE
               (PSF)        (PSF)
               0.00        250.00
```


120

Sewer

VII.C.--VERTICAL STRIP LOADS
NONE

VII.D.--VERTICAL RAMP LOADS
NONE

VII.E.--VERTICAL TRIANGULAR LOADS
NONE

VII.F.--VERTICAL VARIABLE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 22-AUGUST-2006 TIME: 10:16:26

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**************************
*   SOIL PRESSURES FOR   *
* CANTILEVER WALL DESIGN *
**************************
```

I.--HEADING
'Cantilever Sheet Pile Grade Control Structure @ 18" VCP Sewer

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

SOIL PRESSURES ARE REPORTED FOR A SEEPAGE GRADIENT = 0.0001
AND MAY CHANGE WITH AUTOMATIC ADJUSTMENT OF THE GRADIENT.

		<---LEFTSIDE--->		<------NET------> (SOIL + WATER)		<--RIGHTSIDE--->	
ELEV. (FT)	NET WATER (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
2054.5	0.0	0.0	0.0	70.6	1224.2	70.6	1224.2
2053.5	62.4	0.0	0.0	148.7	1558.9	86.3	1496.5
2052.5	124.8	0.0	0.0	226.8	1893.5	102.0	1768.7
2051.5	187.2	0.0	0.0	305.0	2228.2	117.8	2041.0
2050.5	249.6	0.0	0.0	383.1	2562.9	133.5	2313.3
2049.5	312.0	0.0	0.0	461.2	2897.5	149.2	2585.5
2048.5	374.4	0.0	0.0	539.3	3232.2	164.9	2857.8
2047.5	436.8	0.0	0.0	617.4	3566.9	180.6	3130.1
2046.5	499.2	0.0	0.0	695.5	3901.5	196.3	3402.3
2045.5	561.6	0.0	0.0	773.6	4236.2	212.0	3674.6
2044.5	561.6	272.2	15.7	517.1	4492.8	227.7	3946.9
2043.5	561.6	544.5	31.4	260.5	4749.3	243.4	4219.2
2042.5	561.6	816.7	47.1	4.0	5005.9	259.1	4491.5
2042.5	561.6	820.9	47.4	0.0	5009.9	259.4	4495.7
2041.5	561.6	1088.9	62.8	-252.5	5262.5	274.8	4763.8
2040.5	561.5	1361.2	78.5	-509.1	5519.1	290.6	5036.1
2039.5	561.5	1633.4	94.2	-765.6	5775.7	306.3	5308.4
2038.5	561.5	1905.6	109.9	-1022.2	6032.2	322.0	5580.7
2037.5	561.5	2177.9	125.7	-1278.7	6288.8	337.7	5853.0

Sewer

2036.5	561.5	2450.1	141.4	-1535.2	6545.4	353.4	6125.3
2035.5	561.5	2722.3	157.1	-1791.8	6802.0	369.1	6397.5
2034.5	561.5	2994.6	172.8	-2048.3	7058.5	384.8	6669.8
2033.5	561.5	3266.8	188.5	-2304.8	7315.1	400.5	6942.1
2032.5	561.4	3539.0	204.2	-2561.4	7571.7	416.2	7214.4
2031.5	561.4	3811.3	219.9	-2817.9	7828.3	431.9	7486.7
2030.5	561.4	4083.5	235.6	-3074.4	8084.8	447.7	7759.0
2029.5	561.4	4355.7	251.3	-3331.0	8341.4	463.4	8031.3
2028.5	561.4	4628.0	267.0	-3587.5	8598.0	479.1	8303.6
2027.5	561.4	4900.2	282.7	-3844.1	8854.6	494.8	8575.9
2026.5	561.4	5172.5	298.4	-4100.6	9111.1	510.5	8848.2
2025.5	561.4	5444.7	314.1	-4357.1	9367.7	526.2	9120.5
2024.5	561.3	5716.9	329.8	-4613.7	9624.3	541.9	9392.8
2023.5	561.3	5989.2	345.5	-4870.2	9880.9	557.6	9665.1
2022.5	561.3	6261.4	361.2	-5126.7	10137.5	573.3	9937.4
2021.5	561.3	6533.6	377.0	-5383.3	10394.0	589.0	10209.7
2020.5	561.3	6805.9	392.7	-5639.8	10650.6	604.8	10482.0
2019.5	561.3	7078.1	408.4	-5896.4	10907.2	620.5	10754.3
2018.5	561.3	7350.3	424.1	-6152.9	11163.8	636.2	11026.6
2017.5	561.3	7622.6	439.8	-6409.4	11420.3	651.9	11298.9
2016.5	561.2	7894.8	455.5	-6666.0	11676.9	667.6	11571.2
2015.5	561.2	8167.0	471.2	-6922.5	11933.5	683.3	11843.5
2014.5	561.2	8439.3	486.9	-7179.0	12190.1	699.0	12115.8

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 22-AUGUST-2006 TIME: 10:16:27

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****************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'Cantilever Sheet Pile Grade Control Structure @ 18" VCP Sewer

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

```
WALL BOTTOM ELEV. (FT)      :     2026.28
      PENETRATION (FT)      :       19.22

MAX. BEND. MOMENT (LB-FT)   :  5.4414E+04
      AT ELEVATION (FT)     :     2034.76

MAX. SCALED DEFL. (LB-IN^3):  2.1926E+10
      AT ELEVATION (FT)     :     2054.50

SEEPAGE GRADIENT            :     0.2348
```

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF
ELASTICITY IN PSI TIMES PILE MOMENT
OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
IN INCHES.

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 22-AUGUST-2006 TIME: 10:16:27

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*****************************
* COMPLETE OF RESULTS FOR   *
*  CANTILEVER WALL DESIGN   *
*****************************
```

I.--HEADING
'Cantilever Sheet Pile Grade Control Structure @ 18" VCP Sewer

II.--RESULTS0. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
2054.50	0.0000E+00	0.	2.1926E+10	70.63
2053.50	4.8333E+01	110.	2.0707E+10	148.74
2052.50	2.4541E+02	297.	1.9487E+10	226.85
2051.50	6.6932E+02	563.	1.8268E+10	304.96
2050.50	1.3982E+03	907.	1.7050E+10	383.06
2049.50	2.5101E+03	1330.	1.5835E+10	461.17
2048.50	4.0832E+03	1830.	1.4624E+10	539.28
2047.50	6.1956E+03	2408.	1.3420E+10	617.39
2046.50	8.9254E+03	3065.	1.2227E+10	695.50
2045.50	1.2351E+04	3799.	1.1050E+10	773.60
2044.50	1.6502E+04	4468.	9.8937E+09	563.62
2043.50	2.1216E+04	4926.	8.7663E+09	353.64
2042.50	2.6284E+04	5175.	7.6755E+09	143.66
2041.82	2.9847E+04	5224.	6.9549E+09	0.00
2041.50	3.1496E+04	5214.	6.6302E+09	-66.32
2040.50	3.6641E+04	5042.	5.6394E+09	-276.30
2039.50	4.1511E+04	4661.	4.7118E+09	-486.28
2038.50	4.5894E+04	4070.	3.8558E+09	-696.26
2037.50	4.9580E+04	3269.	3.0791E+09	-906.24
2036.50	5.2361E+04	2257.	2.3879E+09	-1116.22
2035.50	5.4025E+04	1036.	1.7870E+09	-1326.20
2034.50	5.4363E+04	-395.	1.2793E+09	-1536.18
2033.50	5.3165E+04	-2036.	8.6531E+08	-1746.16
2032.50	5.0220E+04	-3887.	5.4293E+08	-1956.14
2031.50	4.5320E+04	-5949.	3.0706E+08	-2166.12
2030.50	3.8253E+04	-8220.	1.4918E+08	-2376.10
2029.50	2.8811E+04	-10701.	5.7067E+07	-2586.08
2029.30	2.6604E+04	-11226.	4.5102E+07	-2628.34
2028.50	1.7156E+04	-11985.	1.4383E+07	726.69
2027.50	6.2348E+03	-9158.	1.4509E+06	4927.20
2026.50	2.4050E+02	-2131.	1.7331E+03	9127.71
2026.33	1.4789E+01	-540.	6.4917E+00	9832.64
2026.28	0.0000E+00	0.	0.0000E+00	10060.51

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

ELEVATION (FT)	WATER PRESSURE (PSF)	<----------SOIL PRESSURES----------> <----LEFTSIDE-----> PASSIVE (PSF)	ACTIVE (PSF)	<---RIGHTSIDE----> ACTIVE (PSF)	PASSIVE (PSF)
2054.50	0.	0.	0.	71.	1224.
2053.50	62.	0.	0.	86.	1496.
2052.50	125.	0.	0.	102.	1769.
2051.50	187.	0.	0.	118.	2041.
2050.50	250.	0.	0.	133.	2313.

			Sewer		
2049.50	312.	0.	0.	149.	2586.
2048.50	374.	0.	0.	165.	2858.
2047.50	437.	0.	0.	181.	3130.
2046.50	499.	0.	0.	196.	3402.
2045.50	562.	0.	0.	212.	3675.
2044.50	532.	201.	12.	232.	4019.
2043.50	503.	401.	23.	252.	4363.
2042.50	474.	602.	35.	272.	4707.
2041.82	454.	739.	43.	285.	4942.
2041.50	444.	802.	46.	291.	5051.
2040.50	415.	1003.	58.	311.	5395.
2039.50	386.	1203.	69.	331.	5739.
2038.50	357.	1404.	81.	351.	6083.
2037.50	327.	1604.	93.	371.	6427.
2036.50	298.	1805.	104.	391.	6771.
2035.50	269.	2005.	116.	410.	7115.
2034.50	239.	2206.	127.	430.	7459.
2033.50	210.	2406.	139.	450.	7803.
2032.50	181.	2607.	150.	470.	8147.
2031.50	151.	2807.	162.	490.	8491.
2030.50	122.	3008.	174.	510.	8835.
2029.50	93.	3208.	185.	530.	9179.
2029.30	64.	3249.	187.	534.	9248.
2028.50	34.	3409.	197.	549.	9523.
2027.50	5.	3610.	208.	569.	9867.
2026.50	0.	3810.	220.	589.	10211.
2026.33	0.	3844.	222.	592.	10268.
2026.28	0.	4070.	235.	606.	10495.
2024.50	0.	4343.	251.	621.	10767.

Assume Nucor - Yamato Steel Sheet Piling

Grade A572 - Grade 50

$F_y = 50$ ksi

$f_b = (0.5)(50 \text{ ksi}) = 25$ ksi
$f_v = (0.33)(50 \text{ ksi}) = 16.5$ ksi

$M_{max} = 54.4$ k·ft
$V_{max} = 12.0$ k
$\Delta_{max} = 2.19 \times 10^{10}$ lb·in³

$$S_{min} = \frac{M_{max}}{f_b} = \frac{(54.4 \text{ k·ft})(12''/\text{ft})}{25 \text{ ksi}} = 26.1 \text{ in}^3/\text{ft}$$

$$A_{v,min} = \frac{V_{max}}{f_v} = \frac{12.0 \text{ k}}{16.5 \text{ ksi}} = 0.73 \text{ in}^2/\text{ft}$$

Use PZ27
$S = 30.2$ in³/ft
$A = 8.1$ in²/ft
$I = 188,188$ in⁴/ft

$$\Delta = \frac{2.19 \times 10^{10} \text{ lb·in}^3}{(29{,}000{,}000 \text{ psi})(188{,}188 \text{ in}^4)} = 0.004''$$

Req'd Embedment = 19.22'

Use (1.2)(19.22') = 23'

→ Bottom of sheeting = EL 2054.5 - 9' - 23' = 2022.5

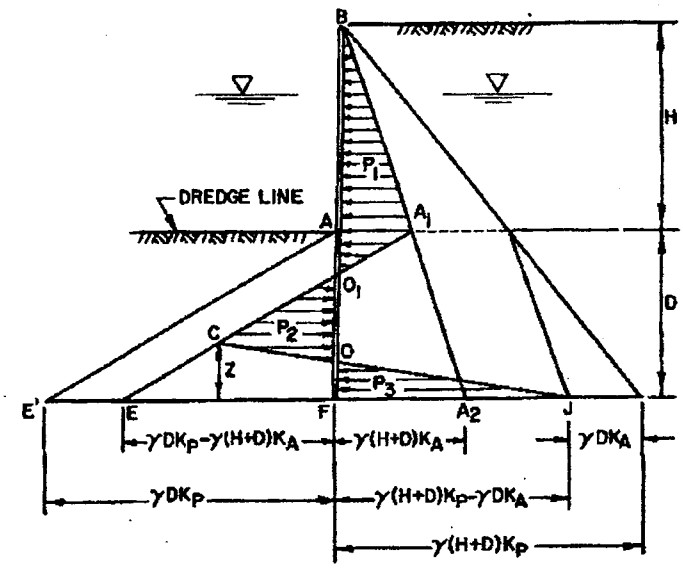
→ To keep particle velocity in sewer pipe below 1.0 in/s, install sheeting 20' away using a vibratory hammer.

TABLE 1
Ultimate Friction Factors and Adhesion for Dissimilar Materials

Interface Materials	Friction factor, tan [delta]	Friction angle [delta] degrees
Mass concrete on the following foundation materials:		
Clean sound rock	0.70	35
Clean gravel, gravel-sand mixtures, coarse sand	0.55 to 0.60	29 to 31
Clean fine to medium sand, silty medium to coarse sand, silty or clayey gravel	0.45 to 0.55	24 to 29
Clean fine sand, silty or clayey fine to medium sand	0.35 to 0.45	19 to 24
Fine sandy silt, nonplastic silt	0.30 to 0.35	17 to 19
Very stiff and hard residual or preconsolidated clay	0.40 to 0.50	22 to 26
Medium stiff and stiff clay and silty clay	0.30 to 0.35	17 to 19
(Masonry on foundation materials has same friction factors.)		
Steel sheet piles against the following soils:		
Clean gravel, gravel-sand mixtures, well-graded rock fill with spalls	0.40	22
Clean sand, silty sand-gravel mixture, single size hard rock fill	0.30	17
Silty sand, gravel or sand mixed with silt or clay	0.25	14
Fine sandy silt, nonplastic silt	0.20	11
Formed concrete or concrete sheet piling against the following soils:		
Clean gravel, gravel-sand mixture, well-graded rock fill with spalls	0.40 to 0.50	22 to 26
Clean sand, silty sand-gravel mixture, single size hard rock fill	0.30 to 0.40	17 to 22
Silty sand, gravel or sand mixed with silt or clay	0.30	17
Fine sandy silt, nonplastic silt	0.25	14
Various structural materials:		
Masonry on masonry, igneous and metamorphic rocks:		
Dressed soft rock on dressed soft rock	0.70	35
Dressed hard rock on dressed soft rock	0.65	33
Dressed hard rock on dressed hard rock	0.55	29
Masonry on wood (cross grain)	0.50	26
Steel on steel at sheet pile interlocks	0.30	17

Interface Materials (Cohesion)	Adhesion c+a, (psf)
Very soft cohesive soil (0 - 250 psf)	0 - 250
Soft cohesive soil (250 - 500 psf)	250 - 500
Medium stiff cohesive soil (500 - 1000 psf)	500 - 750
Stiff cohesive soil (1000 - 2000 psf)	750 - 950
Very stiff cohesive soil (2000 - 4000 psf)	950 - 1,300

NOTE: WATER LEVELS CAN BE DIFFERENT ON OPPOSITE SIDES DUE TO PUMPING, TIDAL FLUCTUATIONS AND OTHER REASONS.



1. Assume a trial depth of penetration, D. This may be estimated from the following approximate correlation.

Standard Penetration Resistance, N Blows/foot	Depth of Penetration*
0 - 4	2.0H
5 - 10	1.5H
11 - 30	1.25H
31 - 50	1.0H
+50	0.75H

* H = height of piling above dredge line

2. Determine the active and passive lateral pressure using appropriate coefficients of lateral earth pressure. If the Coulomb method is used, it should be used conservatively for the passive pressure.
3. Satisfy the requirements of static equilibrium: the sum of the forces in the horizontal direction must be zero and the sum of the moments about any point must be zero. The sum of the horizontal forces may be written in terms of pressure areas:

$$\Delta(\overrightarrow{EA_1A_2}) - \Delta(\overleftarrow{FBA_2}) - \Delta(\overleftarrow{ECJ}) = 0$$

Solve the above equation for the distance, Z. For a uniform granular soil,

$$Z = \frac{K_P\ D^2 - K_A\ (H+D)^2}{(K_P - K_A)\ (H+2D)}$$

FIGURE 23
Analysis for Cantilever Wall

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+))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))).
*4.  Take moments about point F.  If sum of moments is other than zero      *
*    readjust D and repeat calculations until sum of moments around F is    *
*    zero.                                                                   *
*                                                                            *
*5.  Compute maximum moment at point of zero shear.                          *
*                                                                            *
*6.  Increase D by 20% - 40% to result in approximate factory of safety of  *
*    1.5 to 2.                                                               *
.))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))-
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FIGURE 23 (continued)
Analysis for Cantilever Wall

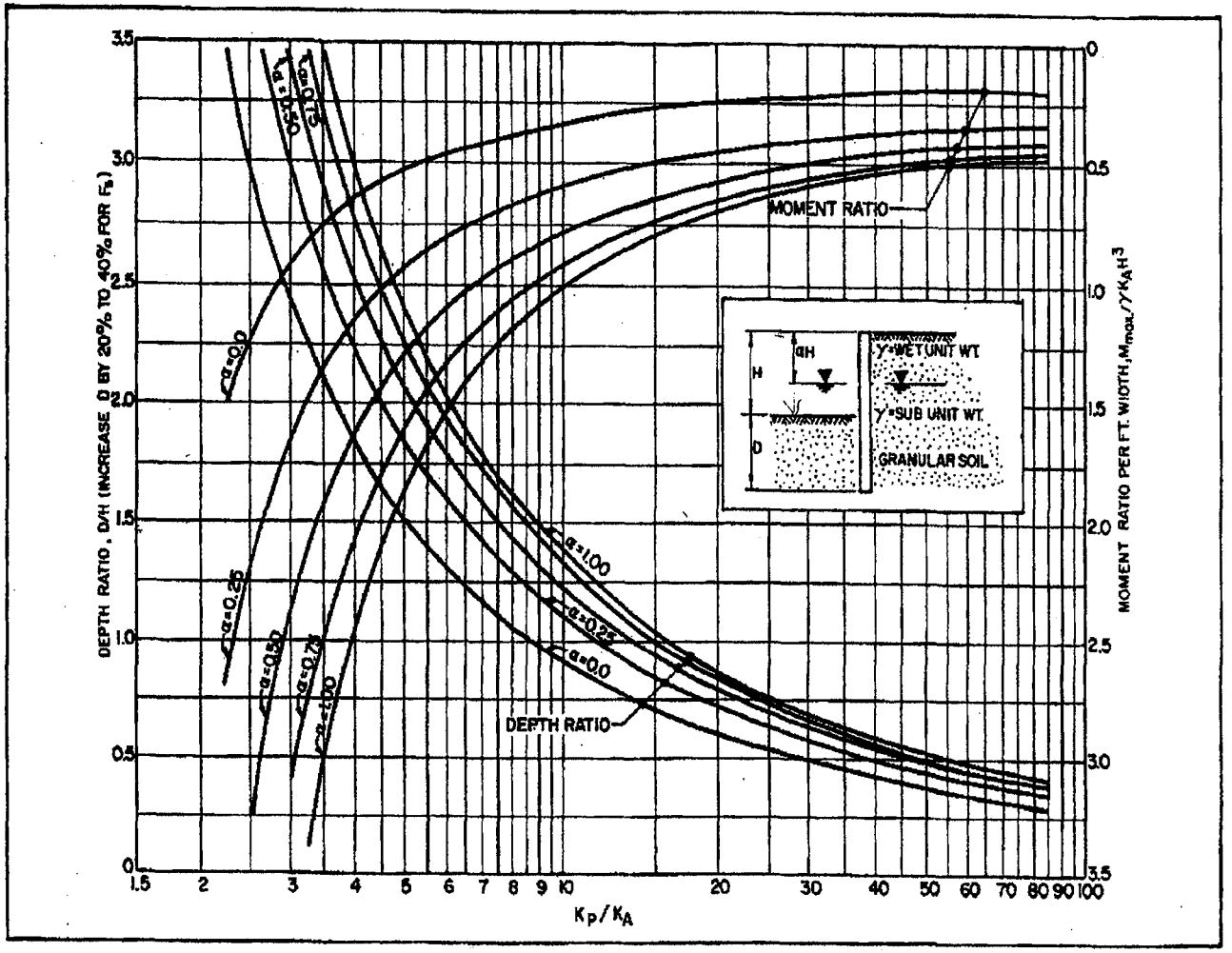

FIGURE 24
Cantilever Steel Sheet Pile Wall in Homogeneous Granular Soil

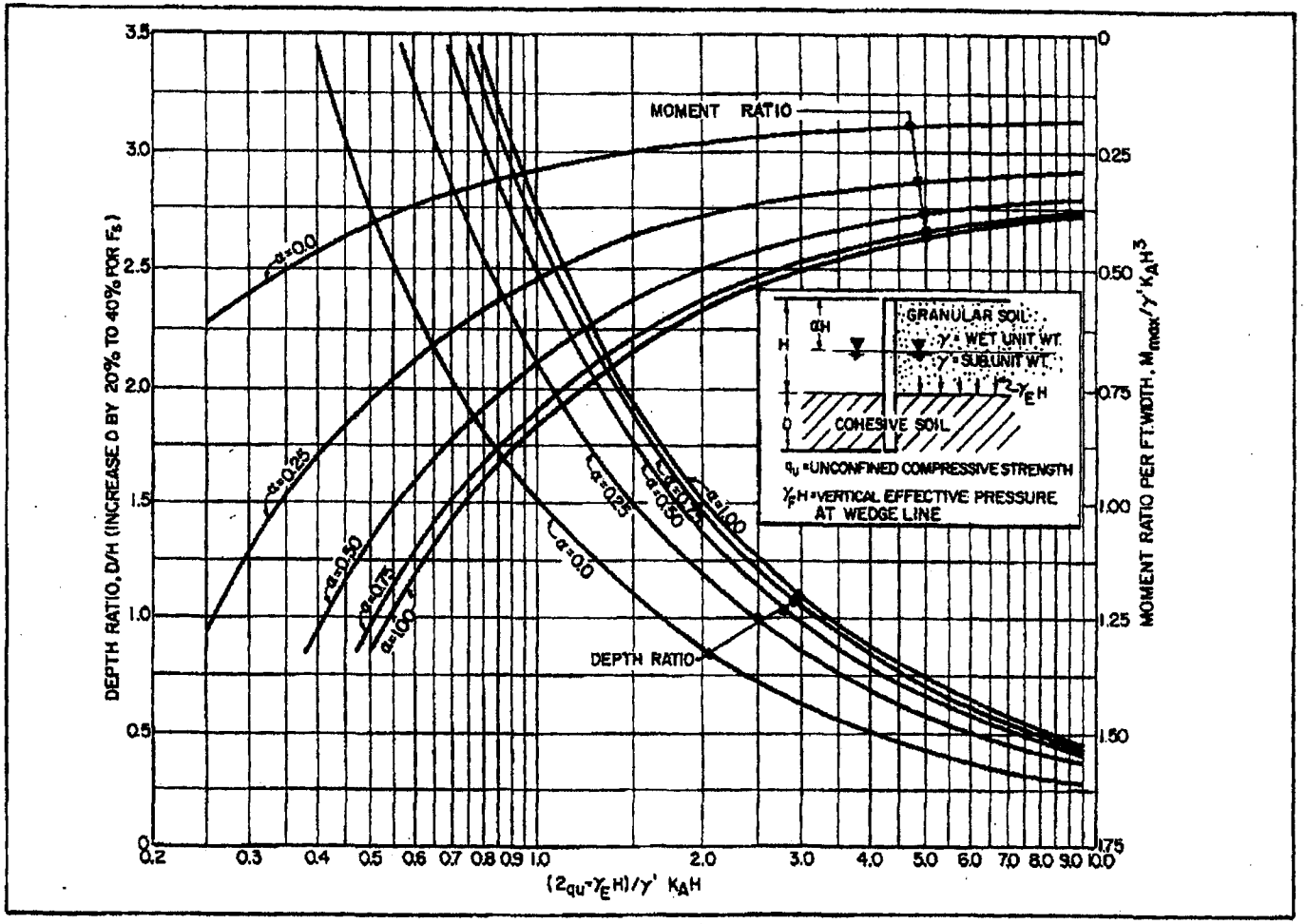

FIGURE 25
Cantilever Steel Sheet Pile Wall in Cohesive Soil with Granular Backfill

EXAMPLE

Backfill: $\phi = 30°$ Underlying Cohesive Stratum: $C = 750$ psf
$\gamma = 120$ pcf $\gamma' \approx 60$ psf
$\gamma' = 60$ pcf

Depth H to mud line = 20 ft

Depth to water = 5 ft

$\alpha = 5/20 = 0.25$

Wall friction = 0.3 (Table 1)

$K_A = 0.31$ (Figure 5)

$\gamma_E H = 120 \times 5 + 15 \times 60 = 1{,}500$ psf

$q_u = 2C = 1{,}500$ psf

USING FIGURE 25:

$$\frac{2q_u - \gamma_E H}{\gamma' K_A H} = \frac{3000-1500}{60 \times 0.31 \times 20} = 4.03$$

Depth ratio, $\frac{D}{H} = 0.69$

D calculated = 0.69 x 20 = 13.8 ft

D design = 13.8 x 1.3 = 17.9 ft

Moment ratio = 0.33

$M_{max} = 0.33 \times 60 \times 0.31 \times (20)^3 = 49{,}104$ ft-lb/ft of wall

FIGURE 25 (continued)
Cantilever Steel Sheet Pile Wall in Cohesive Soil with Granular Backfill

JOURNAL OF THE
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ENGINEERING DIVISION

Construction Vibrations: State-of-the-Art[a]

By John F. Wiss,[1] F. ASCE

Introduction

Vibrations produced during construction operations become of concern when they can be felt. They may be sufficiently intense to annoy the recipients or they may have detrimental effects on structures or equipment. This presentation will consider the sources of construction vibrations, the transmitting medium and the effects upon the receivers of the vibration. Instrumentation and criteria will be analyzed, as well as the need for further research.

Sources of Construction Vibration

Construction vibrations are of three different types: (1) Transient or impact vibration; (2) steady-state or continuous; and (3) pseudo-steady-state vibrations. All are shown in Fig. 1. Examples of transient construction vibrations are those that occur from blasting with explosives, impact pile driving, demolition, and wrecking balls. Steady-state vibrations may be generated by vibratory pile drivers, large pumps as used in jacking underground pipes, and compressors. Pseudo steady-state vibrations are so called because they are of a random nature or a series of impact vibrations that are at short enough intervals to approach essentially a steady-state condition. Examples of these are jackhammers, pavement breakers, trucks, bulldozers, cranes, and scrapers.

[a]Presented at the April 14–18, 1980, ASCE Convention and Exposition, held at Portland, Oreg.

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Effect of Source Energy

The magnitude of the vibration at a fixed distance from a source is a function of the energy at the source. This relationship may be established by increasing the energy at the source and determining the rate at which the vibration increases.

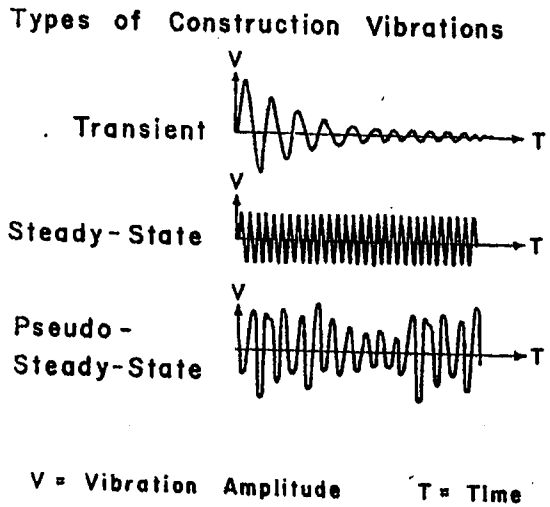

FIG. 1.—Construction Vibration Waveforms

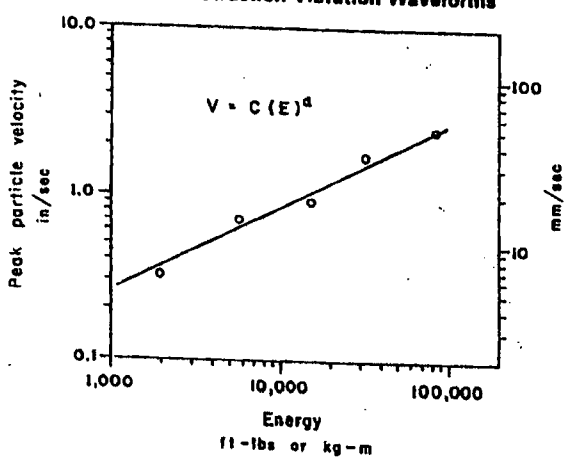

FIG. 2.—Typical Form: Peak Particle Velocity Versus Energy

The form of typical data (Fig. 2) can be approximated by a straight line on a log-log plot. A regression analysis will define the slope of this line. Increasing the energy can be accomplished by dropping a wrecking ball of a known weight from increasing heights. The energy in foot-pounds is the product of the weight and drop height.

Although the vibration magnitude may be expressed as particle displacement, velocity, or acceleration, it has been found by most investigators (9,22,31) that the peak particle velocity is most useful as concerns damage and human evaluation of transient vibration. The relationship between the peak particle velocity and energy may be expressed as

$$V = C(E)^{\alpha} \quad \text{(1)}$$

in which V = peak particle velocity, in inches per second; C = intercept, in inches per second (value of vibration amplitude at E = 1 ft-lb); E = impact

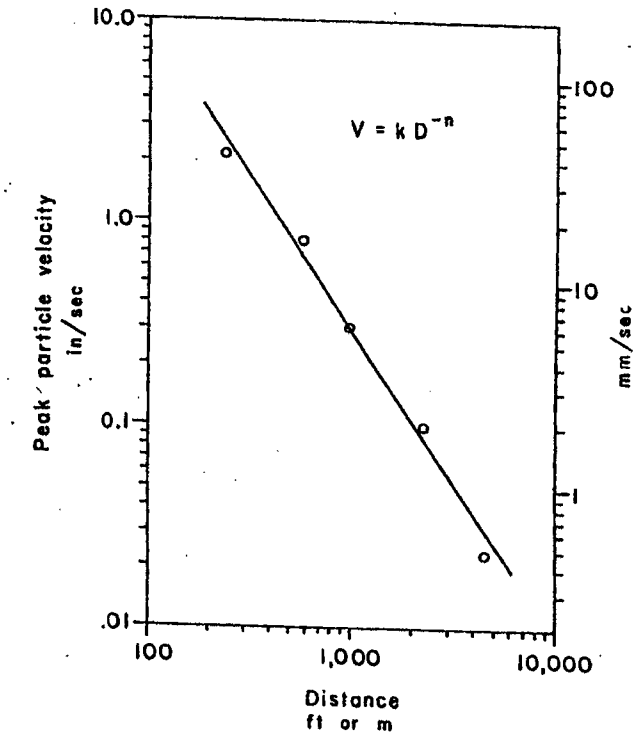

FIG. 3.—Typical Form: Peak Particle Velocity Versus Distance

energy, in foot-pounds; and α = slope, rate of increase. The value of α has been found generally to be one half.

Effect of Transmitting Media

In any investigation of ground vibration, it is necessary to determine the distance propagation equation or the rate of attenuation of the vibration. This dissipation of energy with distance varies from site to site and can be determined by recording the vibration simultaneously from several distances, preferably

133

straight line. A regression analysis of these data can be used with a propagation equation (see Fig. 3) of the form

$$V = kD^{-n} \quad \ldots\ldots (2)$$

in which V = peak particle velocity, in inches per second; k = intercept, in inches per second (value of vibration amplitude at D = 1 ft); D = distance, in feet; and n = slope, attenuation rate.

Combined Effect of Distance and Energy

It is convenient to express the peak particle velocity in terms of both distance and energy in a single expression. This may be done by the use of a scaled-distance propagation equation of the following form (see Fig. 4):

$$V = K\left(\frac{D}{\sqrt{E}}\right)^{-n} \quad \ldots\ldots (3)$$

in which V = peak particle velocity, in inches per second; K = intercept, in inches per second [value of vibration amplitude at $D/\sqrt{E}$ = 1 (ft/lb)$^{1/2}$];

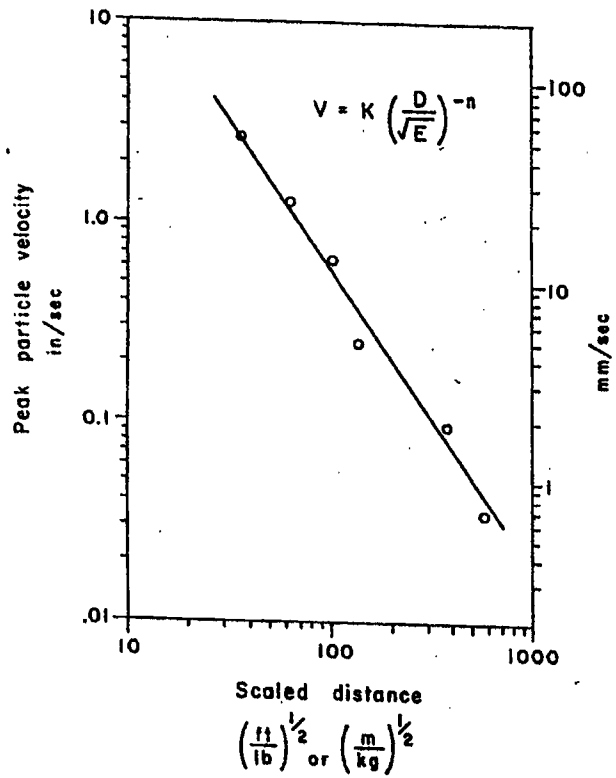

FIG. 4.—Typical Form: Peak Particle Velocity Versus Scaled Distance

D = distance, in feet; E = energy in foot-pounds for impacts or charge weight per delay for explosives-pounds; n = slope or attenuation rate; and $D/\sqrt{E}$ = scaled distance. The value of n in this expression generally lies between 1.0 and 2.0 with a relatively common value of 1.5.

Construction Vibration Intensities

Typical intensities of vibration from the operation of construction equipment are presented graphically in Fig. 5. All of the data used to prepare Fig. 5

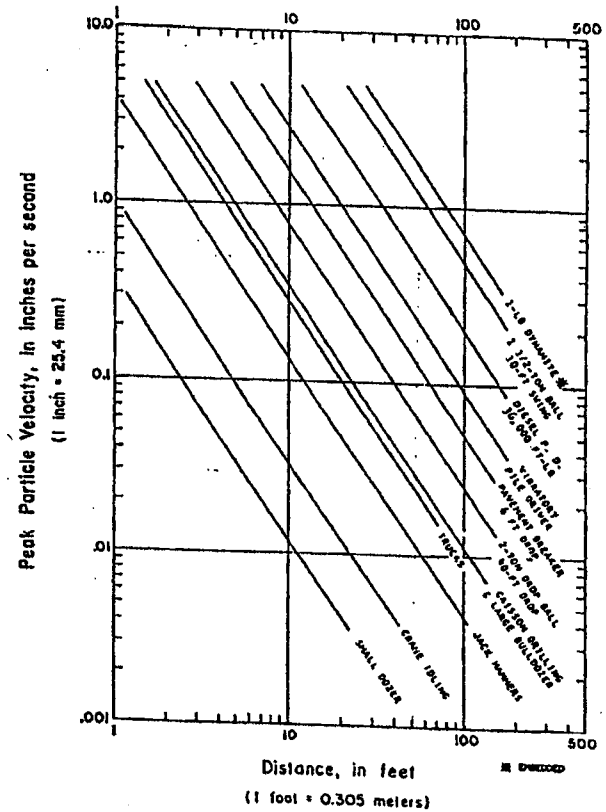

FIG. 5.—Relative Intensities of Construction Vibrations

were obtained by field measurements during actual construction operations (29). The vibration intensities reported in this figure are based on data recorded on the surface of the earth or in residential or relatively small commercial buildings. The response of more massive or subsurface structures may be different, depending on frequency of input and natural frequency of the structure.

It is of interest to note that the intensities involved in these construction activities are spread over a range of three orders of magnitude. It should be

134

recognized that this graph represents approximate values, but does illustrate the relative intensities of the several sources. The lines shown are for a particular set of soil conditions. The locations and slopes of lines for other conditions may be different.

Vibration Instruments

One of the early instruments used in the 1930s to indicate the intensity of impulse vibrations was the falling-pin seismometer. It consisted of 1/4-in. (6.4-mm) round pins of different lengths 4 in.–15 in. (10 cm–38 cm) which were placed on end on a level glass plate. Tubes of different lengths were bundled together so that individual pins could topple without knocking down adjacent pins. It was determined by its inventor that transient vibrations which "knocked over" the 10-in. pin (25.4 cm) or shorter, were capable of causing damage to a residential structure. More sophisticated instruments in the same era required the use of a "darkroom" tent in which a modified earthquake seismograph was used with a light beam drum recorder.

In the 1940s, one of the first "portable" instruments developed was a Leet three-component displacement seismograph which utilized a system of spring-suspended masses and light beams. When the light beams were deflected, multiple reflections magnified the motion, resulting in a recording on light-sensitive film of displacement versus time. This system was enclosed in an aluminum box and required 110v 60-cycle current for its operation; it weighed 70 lbs (31.8 kg). In the same period, a Knobel accelerograph which recorded particle acceleration versus time was developed. This was a self-contained battery-operated unit that recorded in three mutually perpendicular directions. Ten years later (1950), smaller battery-operated displacement recorders were available for field use. These generally had a magnification of 50 and weighed approximately 35 lbs (15.9 kg).

Vibration recording instruments in common use since 1960 utilize coils as suspended weights on soft springs with a magnetic core attached to the frame of the instrument. The voltage generated when the frame vibrates is a function of the particle velocity of the vibration. By means of light beam galvanometers, a recording of particle velocity versus time is obtained; several sensitivity levels can be selected. The more sophisticated instruments automatically trigger and identify the time and date of the event. A relatively inexpensive strip chart recorder which gives a bar graph of the maximum vibration is also available for long-term monitoring, as are magnetic tape analog equipment and digital recorders.

Criteria for Limiting Vibrations

Vibrations from construction operations are important primarily because of their potential to cause complaints or damage to a variety of structures, or both, above and below ground. They may also cause damage to building contents such as china collections, exhibits in museums, or more commonly, TV sets or glasses. Vibrations have resulted in complaints that they are disturbing to people in the enjoyment of their homes or interference with the performance of their jobs.

The most frequent complaints are from the owners of structures (particularly residential) who claim that damage has been done to their interior walls or exterior walls and foundations, or both. It is probably for this reason that most attention has been focused on residential-type construction. Investigators on this continent and abroad have suggested criteria for limiting such vibration. Some are simple, some are quite complex. The United States Bureau of Mines (USBM) (22) and Edwards and Northwood (9) recommended safe levels of 2.0 ips (50.8 mm/s) for residential structures (see Fig. 6). One investigator (4) classifies buildings in four categories based on their age and condition, and recommends criteria (Table 1) that range from 0.5 ips–4.0 ips (12 mm/s–100 mm/s), the former for old residential structures in very poor condition, the

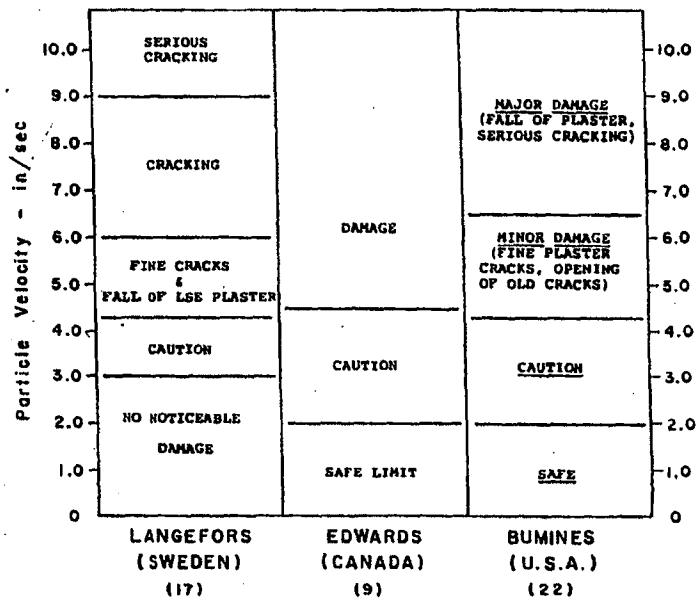

FIG. 6.—Comparison of Damage Criteria: Residential-Type Structures

latter for structures of substantial construction. Another investigator (6) recommends criteria that take into account whether the building is ancient or modern, specific construction details, and degree of distress for both ancient and modern buildings, type of building, type of soil, the cumulative effect of vibration, and an "importance factor." The latter ranges from light industrial to sensitive, ancient, historical buildings, on a scale of 1–10.

The new Swiss standard for vibration (32) differentiates between machines, traffic, and blasting, categorizing all buildings in four classes. For each class of building, permissible levels vary with frequency, as shown in Table 2. The Swiss criteria are more restrictive than the criteria for Langefors (17), Edwards and Northwood (9), and the United States Bureau of Mines (22).

To relate construction vibrations to damage criteria, Fig. 7 is presented. Fig.

135

TABLE 1.—Criteria Recommended by Chae (4)

Class (1)	Peak particle velocity, in inches per second (2)	Peak particle velocity, in millimeters per second (3)
I[a]	4	100
II[b]	2	50
III[c]	1	25
IV[d]	0.5	12

[a]Structures of substantial construction.
[b]Relatively new residential structures in sound condition.
[c]Relatively old residential structures in poor condition.
[d]Old residential structures in very poor condition.
Note: If structure is subjected to repeated blasting, or if blasting is done without instrumentation, lower category by one.

TABLE 2.—New Swiss Standard for Vibrations in Buildings (32)

Building class (1)	Vibration source (2)	Range of frequency, in hertz (3)	Peak particle velocity, in millimeters per second (4)	Peak particle velocity, in inches per second (5)
I[a]	Machines, traffic	10–30	12	(0.5)
		30–60	12–18	(0.5–0.7)
	Blasting	10–60	30	(1.2)
		60–90	30–40	(1.2–1.6)
II[b]	Machines, traffic	10–30	8	(0.3)
		30–60	8–12	(0.3–0.5)
	Blasting	10–60	18	(0.7)
		60–90	18–25	(0.7–1.0)
III[c]	Machines, traffic	10–30	5	(0.2)
		30–60	5–8	(0.2–0.3)
	Blasting	10–60	12	(0.5)
		60–90	12–18	(0.5–0.7)
IV[d]	Machines, traffic	10–30	3	(0.12)
		30–60	3–5	(0.12–0.2)
	Blasting	10–60	8	(0.3)
		60–90	8–12	(0.3–0.5)

[a]Buildings in steel or reinforced concrete, like factories, retaining walls, bridges, steel towers, open channels; underground chambers and tunnels with and without concrete alignment.
[b]Buildings with foundation walls and floors in concrete, walls in concrete or masonry; stone masonry retaining walls; underground chambers and tunnels with masonry alignments; conduits in loose material.
[c]Buildings as mentioned previously but with wooden ceilings and walls in masonry.
[d]Construction very sensitive to vibrations; objects of historic interest.

136

7 is the same as Fig. 5, previously presented, but has superimposed upon it the levels of vibration intensities which generally are considered by investigators in the United States to be thresholds of possible damage for both commercial buildings and for residential-type structures. These are 4.0 ips for commercial buildings and 2.0 ips for residential structures. It should be recognized that some of the sources are transient (impulsive) vibrations, others represent steady-state, and others are pseudo-steady-state vibrations. For purposes of

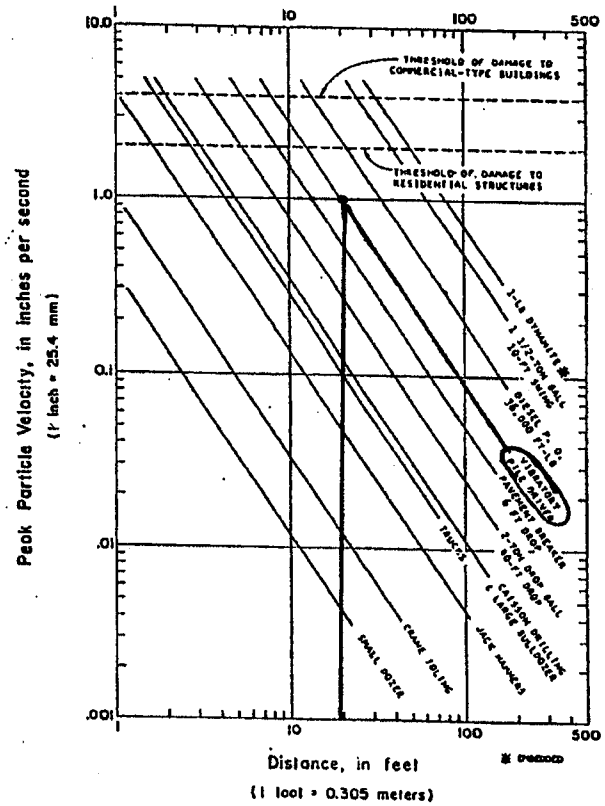

FIG. 7.—Construction Vibration Intensities Related to Damage Criteria

this presentation, they have been lumped together. It is emphasized that these are "threshold" values which generally must be exceeded before damage is likely to occur.

It is generally acknowledged that the ratio of the frequency of the vibrations transmitted to the natural frequency of the structure is an important parameter. The closer this ratio is to unity, the greater the response of the structure, therefore the lower should be the criteria. Since residences have natural frequencies in the range of 4 Hz–10 Hz, lower criteria have been suggested

lower frequency ground vibration than for higher frequency vibration.

Several investigators (7,20,21) have been and are working on the response spectrum. By this method, the amplitude of the vibrations induced in a structure is a function of the natural frequency and damping characteristics of the structure and the frequency composition and magnitude of the ground motion.

Published criteria for underground utilities are not available. Such utilities include tile or concrete drainpipe, sewer and water mains, and pipelines. In our experience, particle velocities of 3 ips have not damaged pipes and mains. Further, high pressure pipelines have withstood 10 ips–20 ips without experiencing any distress, as apparent from dynamic strain gage measurements.

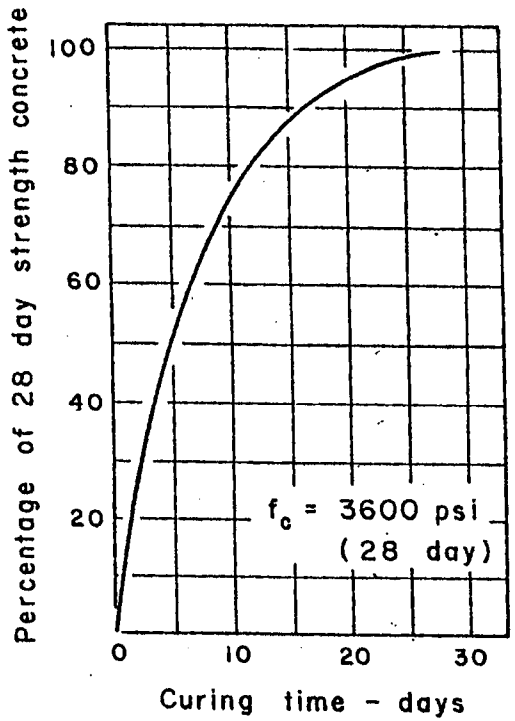

FIG. 8.—Strength of Concrete Versus Curing Time

Another problem that frequently arises on construction jobs is the safe level of transient vibration in the vicinity of young concrete. The primary sources of such are pile driving and excavation blasts. With young concrete, we are dealing with a material which increases in strength with time, thus, so must the criteria. The writer (27) considers the concrete to be essentially at full strength after 28 days, Ontario Hydro (unpublished) 90 days. A decision must then be made as to the particle velocity that full-strength concrete can withstand. The writer (27) says 5 ips, Atkins and Dixon (1) 4 ips, Ontario Hydro (unpublished) 3 ips. Because stress level is proportional to particle velocity, the criteria can be established when it is known how the concrete attains strength with time

(see Fig. 8), e.g., when the concrete attains 10% of its strength, the permissil level for vibration would be 0.5 ips, 0.4 ips, or 0.3 ips. When it attains 50 strength, the permissible level would be 2.5 ips, 2.0 ips, or 1.5 ips.

The effects of transient vibrations upon soils is another area that is of conce to engineers. Some work has been done on the effect of steady-state vibratio on soils (24). Little, if any, quantitative information is available on the effec of short-duration transient vibrations on soils. At best, the literature (5) stat that cohesive soils are least affected, e.g., compacted, by vibration, whi cohesionless soils are most sensitive to vibration.

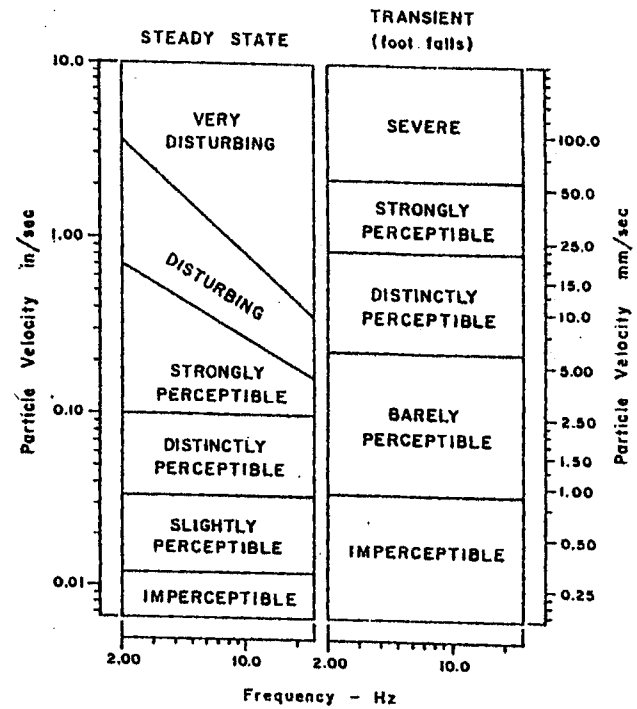

FIG. 9.—Comparison of Human Response to Steady State (23) and Transient Vibrations (28)

Information is available on the effect of cyclic loading on various materials. These have been experimentally determined for complete reversals of stress of several magnitudes and for partial reversals of stress. The studies have involved repetitious or steady-state reversals. There is no information on repeated transient loading. The difference is that in a transient, the peak stress occurs but once or twice with the remaining cycles being of reduced magnitudes. As far as is known, there is virtually no published information on fatigue studies of any kind on plaster or masonry materials used in building construction.

An investigation into the fatigue of plain concrete (15) reveals that the fatigue strength for a life of 10,000,000 cycles is roughly about 50% of static strength

for large-amplitude stress cycles, and approximately 85% for smaller cyclic stress amplitudes. Reinforced concrete exhibits a practical fatigue limit in the vicinity of 1,000,000 cycles and an endurance limit in excess of 20 ksi (1,409 kg/sq cm).

Human Response to Vibration

Regardless of the "safe" criteria that apply to transient vibration, it is rare that the criteria can be reached before complaints or claims are filed. The human body is an excellent detector of vibration, but a poor measuring device.

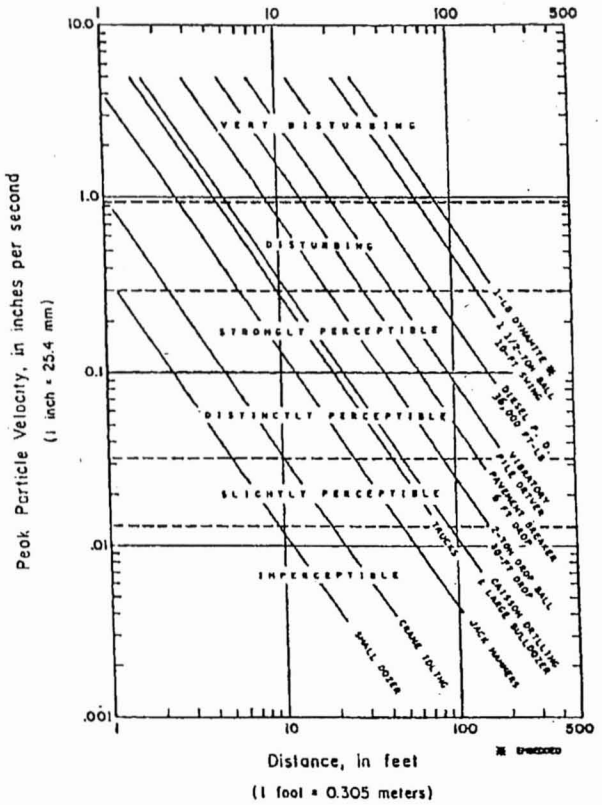

FIG. 10.—Construction Vibration Intensities Related to Human Evaluation of Vibrations (23)

Considerable work has been done on the human evaluation of steady-state vibrations (14,23), but very little has been done on transient vibrations. The only study found on transient vibrations (28) was concerned with impact vibrations which simulated footfalls while walking across a floor. The waveform is sufficiently similar to those resulting from impact pile driving or from single-hole blasts that the criteria would apply. Multidelay blasts do not have a waveform

that is similar to the footfall vibrations. The human evaluation of the transient vibration study compared to those ratings reported from steady-state vibration studies is shown in Fig. 9.

To relate construction vibrations to human response to steady-state vibrations, Fig. 10 is presented. Fig. 10 is the same as Fig. 5 previously presented but has superimposed upon it the normal subjective evaluation of the vibration intensity. It is apparent by comparison of Figs. 7 and 10 that the vibration intensities which are subjectively classified as "disturbing" or "very disturbing" are well below the intensities required to cause damage. Levels in the "disturbing" range may result in complaints or claims of damage.

Needed Research

It is considered that the instrumentation needed to measure and document vibration during construction operations is presently available. Although expensive, competition will bring the costs down.

The development of "practical," yet not overly conservative criteria is needed. This specifically applies to residences, buildings (both low-rise and high-rise), and other structures, as well as underground utilities. Those currently in use are either too simple or too complex. The criteria should be based on available and future controlled tests and not by arbitrary evaluations.

Studies to evaluate the criteria to be used for young concrete can be made in the field or in the laboratory by simulating transient vibrations on a hydraulic shaker. The effects of transient vibration on soils can be studied in the field with laboratory tests providing support information.

The effect of fatigue on common building materials, particularly plaster and masonry, should be investigated. This should be done for both continuous stress reversals, as well as transients. It is acknowledged that, when dealing with transients, the problem is more complex. When dealing with continuous reversals, only the frequency, amplitude, and time are parameters. With transients, there are the additional parameters of damping, duration of individual pulses, rate of occurrence, and complex waveforms.

Human response to transient vibration is being studied in a research program entitled "Human Response to Blast and Noise and Ground and Structure Vibrations," presently underway by a contractor for the United States Bureau of Mines. This is a 2-yr program which consists of attitude surveys and field and laboratory tests. It should provide meaningful results to the construction industry, even though the blasts investigated in the USBM program will be at surface coal mines and quarries.

Summary and Conclusions

The generation and propagation of vibrations due to construction have been considered. The relative intensity of the vibration produced by many construction operations and equipment are identified, based on more than a quarter century of field tests. Instruments suitable for the measurement of these vibrations have been described. The large differences in current damage criteria are revealed. Research is needed on the effects of vibration, both transient and steady-state, on young concrete, soils, and underground utilities. Fatigue data on building

materials for both transient and steady-state vibrations are needed. Additional research is needed in the human response to transient vibrations.

The state of the art has come a long way in the last 50 yr. With sufficient funding, all of the required research can be done; priorities will be established by the need. Hopefully, it will not take the next 50 yr for the required research.

Appendix I.—References

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Appendix II.—Notation

The following symbols are used in this paper:

D = distance, in feet (meters);
E = energy in foot-pounds (kilogram-meter) or explosive, in pounds (kilograms);
V = peak particle velocity, in inches per second (millimeters per second);
C, k, K = coefficients; and
α, n = exponents.

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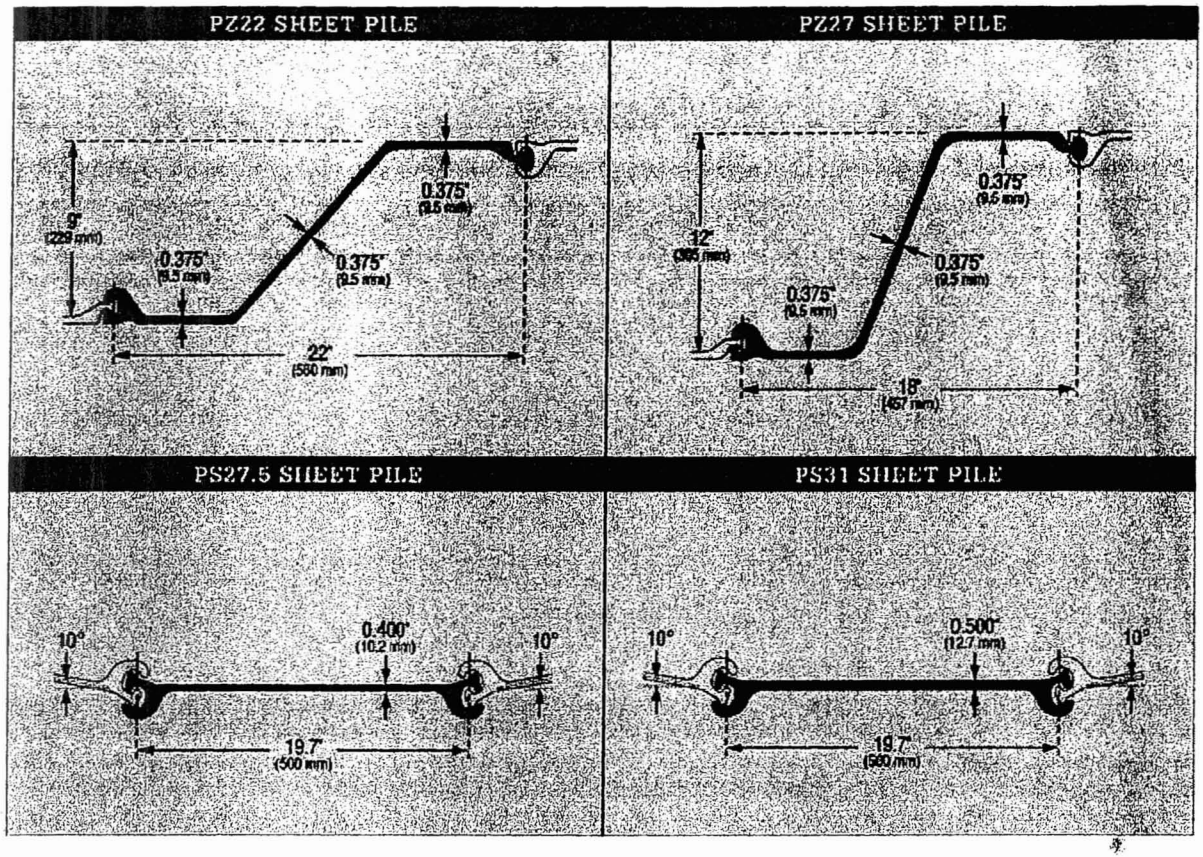
Section Designation	Area		Width		Height		Weight (Mass) Per Single		Weight (Mass) Per Wall		Moment of Inertia		Section Modulus Per Single		Section Modulus Per Wall		Surface Area Total Area		Surface Area Nominal Area*	
	in²	cm²	in	mm	in	mm	lb/ft	kg/m²	lb/ft²	kg/m²	in⁴	cm⁴	in³	cm³	in³/ft	cm³/m	ft²/ft	m²/m	ft²/ft	m²/m
PZ22	11.9	76.6	22.0	559	9.0	228.6	40.3	60.1	22.0	107	151	6301	32.5	532	17.7	952	4.92	1.50	4.48	1.37
PZ27	12.1	78.2	18.0	457	12.0	304.8	40.5	61.3	27.5	134	282	11734	45.3	742	30.2	1622	4.93	1.50	4.48	1.37
PS27.5	13.4	86.6	19.7	500	—	—	45.1	67.9	27.8	136	5.02	209	3.19	52.2	1.94	104	4.58	1.40	3.88	1.18
PS31	15.2	98.2	19.7	500	—	—	50.9	77.0	31.5	154	5.51	229	3.35	55.0	2.04	110	4.58	1.40	3.87	1.18

*Note: Nominal coating area excludes socket interior and ball of interlock.



To Top

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PO Box 5198 3101 New Haven Avenue Fort Wayne, IN 46803 P:800-348-1890 F:260-422-2040

7.0 STABILITY CHECK OF EXISTING TEGNER STREET BRIDGE

WEIGHT OF EXISTING STRUCTURE:

1. WEIGHT OF BOTTOM SLAB:

LENGTH = 80314.98 − 80089.21 = 225.77'

WIDTH = 94'

THK. = 2.0'

TREATING AS A PERFECT PARALLELOGRAM,

WT = 150 pcf × 225.77 × 94' × 2' = 6367 ᵏ

WT. OF CUT OFF WALL

LENGTH ~ 2 × 225.77 = 451.5'

WIDTH = 1.0'

DEPTH = 4.0' (TYP.)

WT = 150 pcf × 451.5' × 1.0' × 4.0' = 271 ᵏ

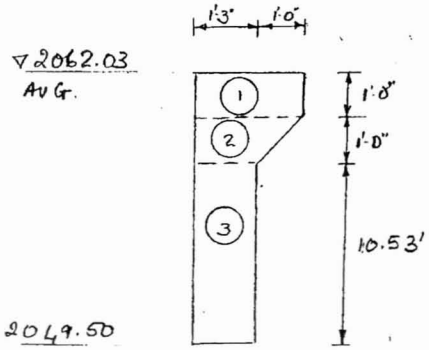
IGNORE ADDITL. WT. OF SLAB BENEATH EACH WING

2. WEIGHT OF ABUTMENTS:

ABUT 1 LENGTH = 129'-11½"

ABUT 2 LENGTH = 131'-0½"

TOTAL LENGTH = 260.08'



A1 = 2.25 ft²

A2 = 1.75 ft²

A3 = 13.16 ft²

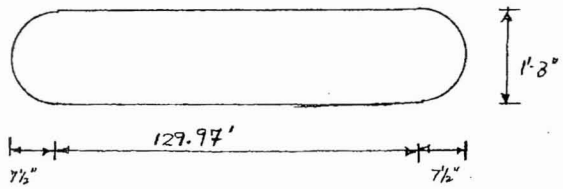
A = 17.16 ft²

WT = 0.15 kcf × 260.08' × 17.16 ft² = 669.4ᵏ ~ 669ᵏ

3. WEIGHT OF PIERS.

LENGTH = 2 (5" + 64'-11 5/16" + 3") = 131.22'
WIDTH = 1'-3"
HT = AVG. OF (12'-0 7/8" + 13'-0") = 12.54'

} INCLUDES ROUND ENDS.



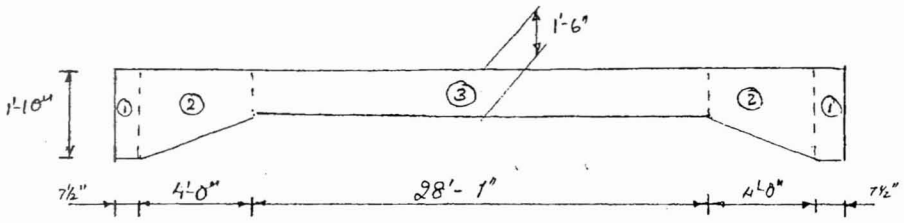
C/S AREA = $\pi \left(\frac{7\frac{1}{2}}{12}\right)^2$ + 129.97' × 1'-3" = 163.69 ft²

WT = 150pcf × 12.54' × 163.69 ft² = 307.9ᵏ EA.

TOTAL WT = 5 × 307.9ᵏ = 1539.50ᵏ.

5 PIERS, SIM.

4 WEIGHT OF DECK SLAB:



A1 = 2 (7½" × 1'-10") = 2.29 ft²
A2 = 2 ($\frac{1'-10" + 1'-6"}{2}$ × 4'-0") = 13.33 ft²

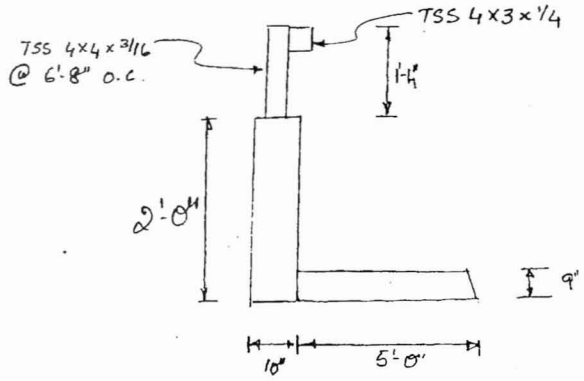
A3 = 28'-1" × 1'-6" = 42.13 ft³

A = 57.75 ft².

WIDTH = 92'-0"
NO. OF SPANS = 6

WT = 6 × 150pcf × 92.0' × 57.75 ft² = 4781.5ᵏ

5. WEIGHT OF CURB AND BARRIER:



WT. OF CURB = 150pcf × 5'-0" × 9" = 562.5 plf

WT. OF BARRIER = 150pcf × 2'-0" × 10" = 250.1 plf.

WT. OF RAILING = 10.5 plf + $\frac{9.40 \text{ plf} \times 1'\text{-}4'}{6'\text{-}8''}$ = 12.38 plf. POSTS @ 6'-8" O.C.

WT = 8.25 plf FOR EA. BARRIER.

TOTAL LENGTH = 2 × 225'-9¼" = 451.54'

TOTAL WT = 372.47^k ~ 372^k

$\boxed{\text{WEIGHT OF BRIDGE} = 14000^k}$

VEL. OF FLOW THROUGH BRIDGE = 10.9 ft/s

WATER SURFACE ELEV U/S OF BRIDGE = 2066.21'

DECK ELEV = 2064.32'
THK. OF SLAB = 1'-4"

∴ ELEV. OF DECK SOFFIT = 2064.32 − 1'-4" = 2062.99' i.e. WATER SURF. ABOVE STR.

BOTTOM OF CHANNEL = 2049.50'

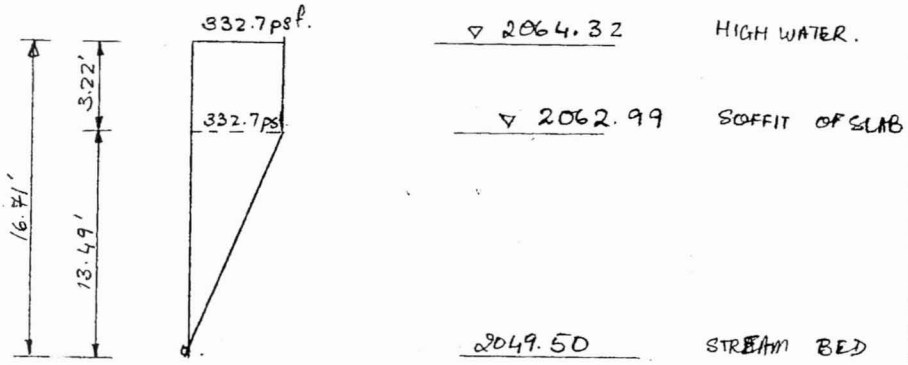
DEPTH OF WATER = 16.71'

PER AASHTO CL. 3.18.1.1, AVG. WATER PRES

$P_{avg} = k(V_{avg})^2$ k = 1.4 FOR DRIFT BUILD-UP CONDITIONS

$= 1.4(10.9)^2 = 166.3$ psf.

$P_{max} = 2 \times P_{avg} = 332.7$ psf @ TOP OF OPENING.



WIDTH OF PIER = 1'-3"

SKEW ANGLE OF BRIDGE PIERS = 45°.

ASSUME FLOW IS SKEWED 10° W.R.T. PIERS.

LENGTH OF PIER ~ 131.25'.

WIDTH OF PIER OBSTRUCTING FLOW = 131.25' (Tan 45 - Tan 35)
= 39.34'

HT. OF PIERS = 12.54'

AREA OF PIER OBSTRUCTING FLOW = 12.54' × (39.34' + 1.25')
= 509 ft²

HOR. FORCE DUE TO FLOW = FORCE ON PIER + FORCE ON SUPER.

FORCE ON PIER = $\left(\frac{1}{2} \times 0.33 \text{ ksf} \times 509 \text{ ft}^2\right) \times 7$ = 588^k.

5 PIERS + 2 ABUT. ACTUALLY NO FORCE ON ABUTS.

FORCE ON SUPER STR. = 0.33 ksf × 3.22' × 226'-9½"

= 242.45^k

FORCE DUE TO FLOW = 588 + 242.45 ~ 831^k

UPLIFT FORCE

HEAD CAUSING UPLIFT ON SUPER STR = 3.22'.
UPLIFT PRES = 3.22' × 62.4 pcf = 201 psf

UPLIFT FORCE ~ 201 psf × 92' × 226.79' = 4192^k

NET WT. OF STR = 14000^k - 4192^k = 9808^k

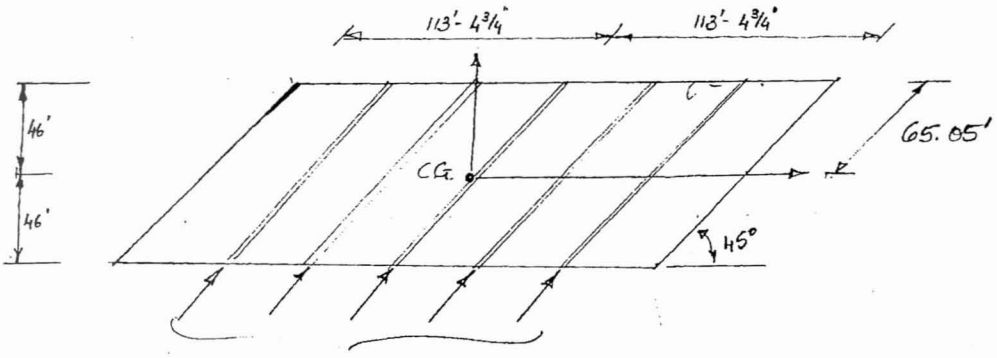
BRIDGE DOES NOT FLOAT.

ASSUME COEFF OF FRICTION = 0.25 BETN CONC & SOIL

HOR. RESISTING FORCE = 0.25 × 9808^k = 2452^k.

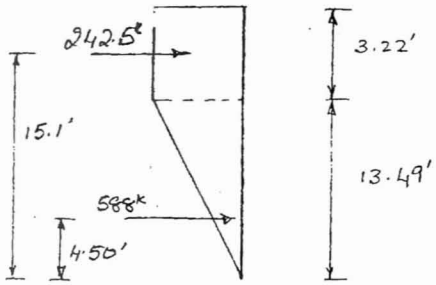
FSS = $\frac{2452^k}{831}$ = 2.95 > 1.50

OKAY IN SLIDING SAFET



STREAM FLOW FORCES

SINCE THE STRUCTURE IS A REGULAR PARALLELOGRAM WITH MASS REGULARLY DISTRIBUTED, CG COINCIDES WITH THE GEOMETRIC CENTER IN PLAN.



OVERTURNING MOMENT

$M_o = 588^k \times 4.50' + 242.5^k \times 15.1'$

$= 6308'^k$

RESTORING MOMENT DUE TO NET WEIGHT

$M_R = 9808^k \times 65.05' = 638010$

(UPLIFT & WT. ACT THROUGH SAME POINT)

FACTOR OF SAFETY $FS_o = \dfrac{638010^k}{6308'^k} = 101 > 1.50$

OKAY.

STRESSES BENEATH FOUNDATION:

NET MOMT $M_{NET} = 638010 - 6308 = 631702'^k$

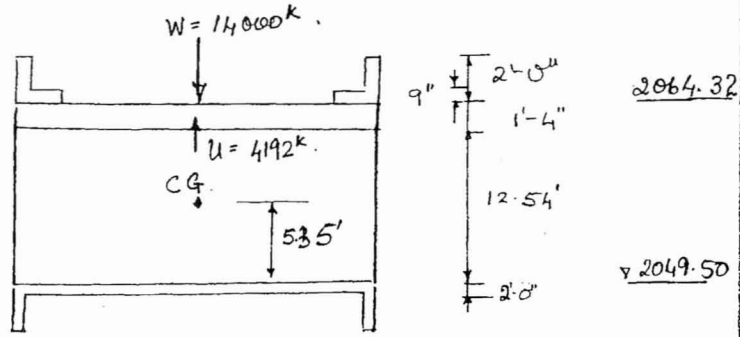
LOCATION OF RESULTANT $x \dfrac{631702}{9808} = 64.41'$

ECCENTRICITY $e = 65.05' - 64.41' = 0.64' < 21.68'$

FORCE IN MIDDLE THIRD - NO TENSION

IHR

CG. OF STRUCTURE.



COMPONENT.	WEIGHT.	LA. w.r.t. SLAB.	MOMT.
BASE SLAB	6367^k	-1.0'	-6367
CUT OFF WALLS	271^k	-4.0'	-1084
ABUTS.	669^k	6.27'	4194.6
PIERS	1539.50^k	6.27'	9652.7
DECK SLAB	4781.50^k	13.37'	63928.7
BARRIER.	372^k	15.04'	5594.9
	14000^k		74949.9

71715.38

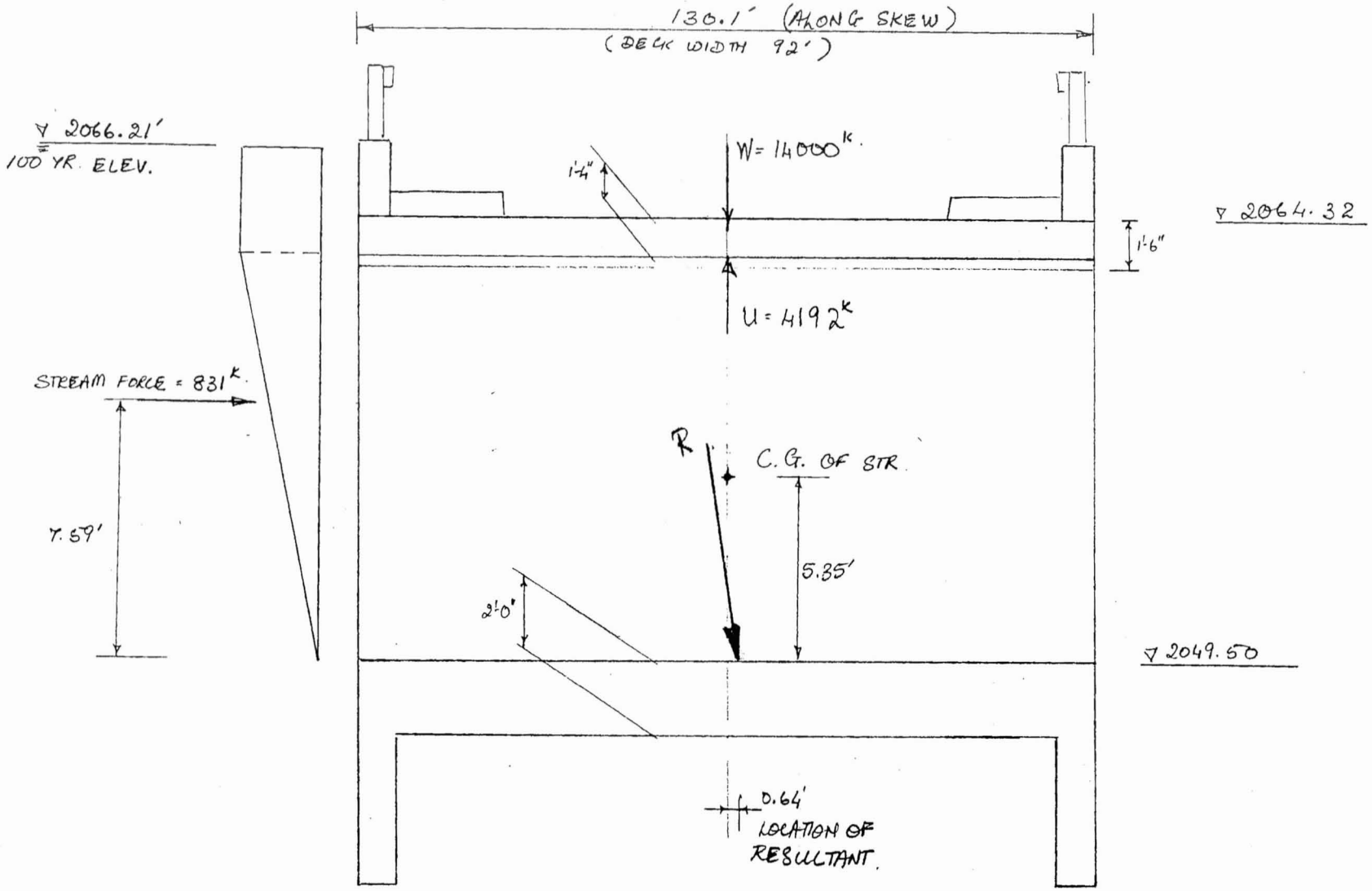
$$CG = \frac{74949.9}{14000} = 5.35'$$ ABOVE TOP OF BASE SLAB

Gannett Fleming

SUBJECT SOLS WASH BRIDGE
FORCES ON STR.

BY JAC DATE 9/17/06 CHKD. BY DATE

SHEET NO. 8 OF
JOB NO. 46308.400



FS - SLIDING. = 2.95
FS - OVERTURN. = 101.

150

8.0 TRACTIVE FORCE ANALYSIS

Tractive Force Analysis

Input Variables:

γ_w = 62.4 pcf

γ_s = 165 pcf

C* = 0.10

Legend:

Drop Structure

Tegner St. Bridge

Equations:

$\tau_b = \gamma_w * d * I_f$

$\tau_m = 0.75 * \tau_b$

$d_{50bed} = \tau_b / [C^*(\gamma_s - \gamma_w)]$

$d_{50slope} = \tau_m / \{[1-(\sin^2\theta/\sin^2\phi)]^{1/2})C^*(\gamma_s - \gamma_w)\}$

where, θ = bank slope in degrees

ϕ = friction angle of bank material in degrees

Analysis for 100 year Sols Wash / 10 year Hassayampa

											on bed / in wall		on 3:1 slope		on 2.5:1 slope	
Channel Designation	Station	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Avg Water Depth, d	Avg Bed Slope, I_f	Shear Stress on bed, τ_b	Shear Stress on bank, τ_m	d_{50}	d_{50}	d_{50}	d_{50}	d_{50}	d_{50}
			(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft/ft)	(psf)	(psf)	(ft)	(in)	(ft)	(in)	(ft)	(in)
Sols Wash Main	576	100-Sols 10-Hass	15045	2039.57	2046.06	12.17	6.49	0.004356	1.764006	1.323004	0.2	2.1	0.1	1.8	0.2	1.9
Sols Wash Main	739	100-Sols 10-Hass	15045	2040.28	2047.78	11.38	7.00	0.006503	2.838698	2.129024	0.3	3.3	0.2	2.8	0.3	3.0
Sols Wash Main	882	100-Sols 10-Hass	15045	2041.21	2048.57	14.74	7.43	0.001043	0.483645	0.362734	0.0	0.6	0.0	0.5	0.0	0.5
Sols Wash Main	1160	100-Sols 10-Hass	15045	2041.5	2052.51	5.77	9.19	0.002500	1.432860	1.074645	0.1	1.7	0.1	1.4	0.1	1.5
Sols Wash Main	1200	100-Sols 10-Hass	15045	2041.6	2052.48	6.23	10.95	0.002000	1.365936	1.024452	0.1	1.6	0.1	1.4	0.1	1.5
Sols Wash Main	1250	100-Sols 10-Hass	15045	2041.7	2052.43	6.88	10.80	0.002000	1.348464	1.011348	0.1	1.6	0.1	1.4	0.1	1.4
Sols Wash Main	1300	100-Sols 10-Hass	15045	2041.8	2052.33	7.87	10.63	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1350	100-Sols 10-Hass	15045	2041.8	2052.14	9.35	10.43	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1408	100-Sols 10-Hass	15045	2041.8	2051.53	12.58	10.04	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1416	100-Sols 10-Hass	15045	2041.8	2051.24	13.44	9.64	0.014000	8.429440	6.322080	14.2	170.0	12.2	146.3	13.0	155.8
Sols Wash Main	1431	100-Sols 10-Hass	15045	2036.64	2049.12	13.67	12.01	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1445	100-Sols 10-Hass	15045	2036.64	2053.06	9.84	14.44	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1459	100-Sols 10-Hass	15045	2036.64	2052.67	10.33	14.02	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1473	100-Sols 10-Hass	15045	2036.64	2052.01	10.7	14.25	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1487	100-Sols 10-Hass	15045	2036.64	2054.5	9.78	10.06	0.239025	150.348905	112.766179	14.7	175.6	12.5	150.5	13.3	160.0
Sols Wash Main	1503	100-Sols 10-Hass	15045	2042.47	2048.22	25.58	5.80	0.255053	92.485904	69.364428	9.0	108.2	7.7	92.6	8.2	98.5
Sols Wash Main	1518	100-Sols 10-Hass	15045	2046.3	2055.25	16.1	7.35	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1538	100-Sols 10-Hass	15045	2046.3	2056.51	13.92	9.58	0.002500	1.494480	1.120860	0.1	1.7	0.1	1.5	0.1	1.6
Sols Wash Main	1578	100-Sols 10-Hass	15045	2046.4	2057.12	12.99	10.47	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1618	100-Sols 10-Hass	15045	2046.4	2057.93	11.38	11.12	0.002500	1.735500	1.301625	0.2	2.0	0.1	1.7	0.2	1.8
Sols Wash Main	1658	100-Sols 10-Hass	15045	2046.5	2058.28	10.75	11.66	0.000943	0.686106	0.514579	0.1	0.8	0.1	0.7	0.1	0.7
Sols Wash Main	1976	100-Sols 10-Hass	15045	2046.8	2059.34	9.62	12.16	0.003000	2.276352	1.707264	0.2	2.7	0.2	2.3	0.2	2.4
Sols Wash Main	2076	100-Sols 10-Hass	15045	2047.1	2059.79	9.94	12.62	0.010394	8.182116	6.136587	0.8	9.6	0.7	8.2	0.7	8.7
Sols Wash Main	2355	100-Sols 10-Hass	15045	2050	2060.28	10.79	11.49	0.007484	5.363421	4.022566	0.5	6.3	0.4	5.4	0.5	5.7
Sols Wash Main	2510	100-Sols 10-Hass	15045	2051.16	2061.26	8.93	10.19	0.002333	1.483664	1.112748	0.1	1.7	0.1	1.5	0.1	1.6
Sols Wash Main	2630	100-Sols 10-Hass	15045	2051.44	2061.31	10.27	9.99	0.007882	4.911210	3.683408	0.5	5.7	0.4	4.9	0.4	5.2
Sols Wash Main	2800	100-Sols 10-Hass	15045	2052.78	2066.1	7.8	11.59	0.004000	2.894112	2.170584	0.3	3.4	0.2	2.9	0.3	3.1
Sols Wash Main	2825	100-Sols 10-Hass	15045	2052.88	2066.26	7.37	13.35	0.016000	13.328640	9.996480	1.3	15.6	1.1	13.3	1.2	14.2
Sols Wash Main	2920	100-Sols 10-Hass	15045	2054.4	2066.19	8.36	12.59	0.008000	6.282432	4.711824	0.6	7.3	0.5	6.3	0.6	6.7
Sols Wash Main	3020	100-Sols 10-Hass	15045	2055.2	2066.36	8.21	11.48	0.008000	5.728320	4.296240	0.6	6.7	0.5	5.7	0.5	6.1
Sols Wash Main	3120	100-Sols 10-Hass	14459	2056	2066.78	7.05	10.97	0.007077	4.844352	3.633264	0.5	5.7	0.4	4.9	0.4	5.2
Sols Wash Main	3250	100-Sols 10-Hass	14459	2056.92	2067.01	6.61	10.44	0.007867	5.122333	3.841750	0.5	6.0	0.4	5.1	0.5	5.5
Sols Wash Main	3400	100-Sols 10-Hass	14459	2058.1	2067	7.86	9.50	0.008333	4.937400	3.703050	0.5	5.8	0.4	4.9	0.4	5.3
Sols Wash Main	3580	100-Sols 10-Hass	14459	2059.6	2067.04	9.75	8.17	0.008333	4.248400	3.186300	0.4	5.0	0.4	4.3	0.4	4.5
Sols Wash Main	3700	100-Sols 10-Hass	14459	2060.6	2067.62	9.08	7.23	0.008000	3.609216	2.706912	0.4	4.2	0.3	3.6	0.3	3.8
Sols Wash Main	3850	100-Sols 10-Hass	14459	2061.8	2068.46	7.31	6.84	0.008889	3.793920	2.845440	0.4	4.4	0.3	3.8	0.3	4.0
Sols Wash Main	3985	100-Sols 10-Hass	14459	2063	2068.79	7.08	6.22	0.008372	3.252056	2.439042	0.3	3.8	0.3	3.3	0.3	3.5
Sols Wash Main	4200	100-Sols 10-Hass	14459	2064.8	2069.08	9.55	5.03	0.009150	2.874784	2.156088	0.3	3.4	0.2	2.9	0.3	3.1
Sols Wash Main	4400	100-Sols 10-Hass	14459	2066.63	2069.44	13.23	3.54									

Channel Designation	Station	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Avg Water Depth, d (ft)	Avg Bed Slope, i_f (ft/ft)	Shear Stress on bed, τ_b (psf)	Shear Stress on bank, τ_m (psf)	d_{50} (ft)	d_{50} (in)	d_{50} (ft)	d_{50} (in)	d_{50} (ft)	d_{50} (in)

Input Variables:

γ_w = 62.4 pcf

γ_s = 165 pcf

C* = 0.10

Legend:

Drop Structure
Tegner St. Bridge

Equations:

$\tau_b = \gamma_w * d * i_f$

$\tau_m = 0.75 * \tau_b$

$d_{50bed} = \tau_b / [C^*(\gamma_s - \gamma_w)]$

$d_{50slope} = \tau_m / \{[1-(\sin^2\theta/\sin^2\phi)]^{1/2})C^*(\gamma_s - \gamma_w)\}$

where, θ = bank slope in degrees

ϕ = friction angle of bank material in degrees

Analysis for 10 year Sols Wash / 100 year Hassayampa

Channel Designation	Station	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Avg Water Depth, d (ft)	Avg Bed Slope, i_f (ft/ft)	Shear Stress on bed, τ_b (psf)	Shear Stress on bank, τ_m (psf)	on bed / in wall d_{50} (ft)	on bed / in wall d_{50} (in)	on 3:1 slope d_{50} (ft)	on 3:1 slope d_{50} (in)	on 2.5:1 slope d_{50} (ft)	on 2.5:1 slope d_{50} (in)
Sols Wash Main	576	10-Sols 100-Hass	7019	2039.57	2054.17	1.97	14.60	0.004356	3.968334	2.976250	0.4	4.6	0.3	4.0	0.4	4.2
Sols Wash Main	739	10-Sols 100-Hass	7019	2040.28	2054.17	2.25	14.25	0.006503	5.780880	4.335660	0.6	6.8	0.5	5.8	0.5	6.2
Sols Wash Main	882	10-Sols 100-Hass	7019	2041.21	2054.16	3.16	13.42	0.001043	0.873555	0.655166	0.1	1.0	0.1	0.9	0.1	0.9
Sols Wash Main	1160	10-Sols 100-Hass	7019	2041.5	2054.29	2.31	12.87	0.002500	2.007720	1.505790	0.2	2.3	0.2	2.0	0.2	2.1
Sols Wash Main	1200	10-Sols 100-Hass	7019	2041.6	2054.29	2.49	12.74	0.002000	1.589952	1.192464	0.2	1.9	0.1	1.6	0.1	1.7
Sols Wash Main	1250	10-Sols 100-Hass	7019	2041.7	2054.28	2.72	12.64	0.002000	1.576848	1.182636	0.2	1.8	0.1	1.6	0.1	1.7
Sols Wash Main	1300	10-Sols 100-Hass	7019	2041.8	2054.26	3.07	12.52	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1350	10-Sols 100-Hass	7019	2041.8	2054.24	3.55	12.45	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1408	10-Sols 100-Hass	7019	2041.8	2054.17	4.58	12.41	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1418	10-Sols 100-Hass	7019	2041.8	2054.16	4.71	12.37	0.000000	0.000000	0.000000	18.4	219.3	15.6	187.7	16.6	199.6
Sols Wash Main	1431	10-Sols 100-Hass	7019	2038.84	2054.3	3.61	15.01	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1445	10-Sols 100-Hass	7019	2038.84	2054.29	3.62	15.64	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1459	10-Sols 100-Hass	7019	2038.84	2054.28	4.35	15.64	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1473	10-Sols 100-Hass	7019	2038.84	2054.27	4.35	15.63	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1487	10-Sols 100-Hass	7019	2038.84	2054.26	4.49	15.63	0.250375	233.190625	175.042969	22.7	273.0	19.5	233.7	20.7	248.5
Sols Wash Main	1503	10-Sols 100-Hass	7019	2042.47	2054.18	5.61	13.66	0.233352	217.562384	163.171788	21.2	254.5	18.2	217.9	19.3	231.6
Sols Wash Main	1518	10-Sols 100-Hass	7019	2046.3	2053.85	8.42	9.47	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1538	10-Sols 100-Hass	7019	2046.3	2053.62	9.44	7.29	0.002500	1.136460	0.852345	0.1	1.3	0.1	1.1	0.1	1.2
Sols Wash Main	1578	10-Sols 100-Hass	7019	2046.4	2053.89	8.95	7.40	0.000000	0.000000	0.000000	0.0	0.0	0.0	0.0	0.0	0.0
Sols Wash Main	1618	10-Sols 100-Hass	7019	2046.4	2054.18	8.3	7.63	0.002500	1.191060	0.893295	0.1	1.4	0.1	1.2	0.1	1.3
Sols Wash Main	1658	10-Sols 100-Hass	7019	2046.5	2054.36	7.99	7.82	0.000943	0.460347	0.345260	0.0	0.5	0.0	0.5	0.0	0.5
Sols Wash Main	1976	10-Sols 100-Hass	7019	2046.8	2055.17	7.08	8.12	0.003000	1.519128	1.139346	0.1	1.8	0.1	1.5	0.1	1.6
Sols Wash Main	2076	10-Sols 100-Hass	7019	2047.1	2055.57	7.34	8.42	0.010394	5.461230	4.095923	0.5	6.4	0.5	5.5	0.5	5.8
Sols Wash Main	2355	10-Sols 100-Hass	7019	2050	2055.92	9.16	7.20	0.007484	3.360019	2.520014	0.3	3.9	0.3	3.4	0.3	3.6
Sols Wash Main	2510	10-Sols 100-Hass	7019	2051.16	2056.86	7.46	5.81	0.002333	0.845936	0.634452	0.1	1.0	0.1	0.8	0.1	0.9
Sols Wash Main	2630	10-Sols 100-Hass	7019	2051.44	2057.05	8.92	5.66	0.007882	2.781462	2.086096	0.3	3.3	0.2	2.8	0.2	3.0
Sols Wash Main	2800	10-Sols 100-Hass	7019	2052.78	2060.24	6.83	6.53	0.004000	1.631136	1.223352	0.2	1.9	0.1	1.6	0.1	1.7
Sols Wash Main	2825	10-Sols 100-Hass	7019	2052.88	2060.34	6.62	7.46	0.016000	7.448064	5.586048	0.7	8.7	0.6	7.5	0.7	7.9

Channel Designation	Station	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Vel Chnl (ft/s)	Avg Water Depth, d (ft)	Avg Bed Slope, i_f (ft/ft)	Shear Stress on bed, τ_b (psf)	Shear Stress on bank, τ_m (psf)	d_{50} (ft)	d_{50} (in)	d_{50} (ft)	d_{50} (in)	d_{50} (ft)	d_{50} (in)
Sols Wash Main	2920	10-Sols 100-Hass	7019	2054.4	2060.3	8.05	6.68	0.008000	3.334656	2.500992	0.3	3.9	0.3	3.3	0.3	3.5
Sols Wash Main	3020	10-Sols 100-Hass	7019	2055.2	2060.56	8.2	5.63	0.008000	2.810496	2.107872	0.3	3.3	0.2	2.8	0.2	3.0
Sols Wash Main	3120	10-Sols 100-Hass	7019	2056	2060.99	7.81	5.17	0.007077	2.285280	1.713960	0.2	2.7	0.2	2.3	0.2	2.4
Sols Wash Main	3250	10-Sols 100-Hass	7019	2056.92	2061.49	7.53	4.78	0.007867	2.346406	1.759805	0.2	2.7	0.2	2.3	0.2	2.5
Sols Wash Main	3400	10-Sols 100-Hass	7019	2058.1	2061.79	9.79	4.13	0.008333	2.147600	1.610700	0.2	2.5	0.2	2.2	0.2	2.3
Sols Wash Main	3580	10-Sols 100-Hass	7019	2059.6	2063.14	10.35	3.62	0.008333	1.879800	1.409850	0.2	2.2	0.2	1.9	0.2	2.0
Sols Wash Main	3700	10-Sols 100-Hass	7019	2060.6	2064.6	8.13	3.77	0.008000	1.881984	1.411488	0.2	2.2	0.2	1.9	0.2	2.0
Sols Wash Main	3850	10-Sols 100-Hass	7019	2061.8	2065.59	6.34	3.89	0.008889	2.160427	1.620320	0.2	2.5	0.2	2.2	0.2	2.3
Sols Wash Main	3985	10-Sols 100-Hass	7019	2063	2066.02	6.86	3.40	0.008372	1.778835	1.334127	0.2	2.1	0.1	1.8	0.2	1.9
Sols Wash Main	4200	10-Sols 100-Hass	7019	2064.8	2067.27	8.51	2.74	0.009150	1.567285	1.175464	0.2	1.8	0.1	1.6	0.1	1.7
Sols Wash Main	4400	10-Sols 100-Hass	7019	2066.63	2068.26	11.81	2.05									

Tractive Force Analysis

Input Variables:

γ_w = 62.4 pcf

C^* = 0.10

γ_s = 165 pcf

Equations:

$\tau_b = \gamma_w * d * i_f$

$\tau_m = 0.75 * \tau_b$

$d_{50bed} = \tau_b / [C^*(\gamma_s - \gamma_w)]$

$d_{50slope} = \tau_m / \{[1-(\sin^2\theta/\sin^2\phi)]^{1/2} C^*(\gamma_s - \gamma_w)\}$

where, θ = bank slope in degrees

ϕ = friction angle of bank material in degrees

Analysis for 100 year Sols Wash / 10 year Hassayampa

Channel Designation	Station	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Avg Water Depth, d	Avg. Bed Slope, i_f	Shear Stress on bed, τ_b	Shear Stress on bank, τ_m	on bed / in wall		on 3:1 slope		on 2.5:1 slope	
											d_{50}	d_{50}	d_{50}	d_{50}	d_{50}	d_{50}
			(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft/ft)	(psf)	(psf)	(ft)	(in)	(ft)	(in)	(ft)	(in)
Sols Wash North	4600	100-Sols 10-Hass	8413	2068	2072.92	11.52	4.92	0.007000	2.149056	1.611792	0.2	2.5	0.2	2.2	0.2	2.3
Sols Wash North	4800	100-Sols 10-Hass	8413	2069.4	2075.09	8.25	5.31	0.007000	2.317224	1.737918	0.2	2.7	0.2	2.3	0.2	2.5
Sols Wash North	5000	100-Sols 10-Hass	8413	2070.8	2075.74	9.16	5.31	0.006000	1.989936	1.492452	0.2	2.3	0.2	2.0	0.2	2.1
Sols Wash North	5200	100-Sols 10-Hass	8413	2072	2075.53	14.12	4.23	0.007500	1.981980	1.486485	0.2	2.3	0.2	2.0	0.2	2.1
Sols Wash North	5400	100-Sols 10-Hass	8413	2073.5	2078.86	11.98	4.45	0.007500	2.080260	1.560195	0.2	2.4	0.2	2.1	0.2	2.2
Sols Wash North	5600	100-Sols 10-Hass	8413	2075	2080.1	14.05	5.23	0.010000	3.263520	2.447640	0.3	3.8	0.3	3.3	0.3	3.5
Sols Wash North	5800	100-Sols 10-Hass	8413	2077	2082.67	12.7	5.38	0.010000	3.360240	2.520180	0.3	3.9	0.3	3.4	0.3	3.6
Sols Wash North	6000	100-Sols 10-Hass	8413	2079	2083.82	13.88	5.25	0.010000	3.272880	2.454660	0.3	3.8	0.3	3.3	0.3	3.5
Sols Wash North	6200	100-Sols 10-Hass	8413	2081	2087.19	11.00	5.51									

Tractive Force Analysis

Input Variables:

γ_w = 62.4 pcf

C^* = 0.10

γ_s = 165 pcf

Equations:

$\tau_b = \gamma_w * d * I_f$

$\tau_m = 0.75 * \tau_b$

$d_{50bed} = \tau_b / [C^*(\gamma_s - \gamma_w)]$

$d_{50slope} = \tau_m / \{[1-(\sin^2\theta/\sin^2\phi)]^{1/2} C^*(\gamma_s - \gamma_w)\}$

where, θ = bank slope in degrees

ϕ = friction angle of bank material in degrees

Analysis for 10 year Sols Wash / 100 year Hassayampa

Channel Designation	Station	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Avg Water Depth, d	Avg. Bed Slope, i_f	Shear Stress on bed, τ_b	Shear Stress on bank, τ_m	on bed / in wall		on 3:1 slope		on 2.5:1 slope	
											d_{50}	d_{50}	d_{50}	d_{50}	d_{50}	d_{50}
			(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft/ft)	(psf)	(psf)	(ft)	(in)	(ft)	(in)	(ft)	(in)
Sols Wash North	4600	10-Sols 100-Hass	2129	2068	2070.61	6.14	2.61	0.007000	1.140048	0.855036	0.1	1.3	0.1	1.1	0.1	1.2
Sols Wash North	4800	10-Sols 100-Hass	2129	2069.4	2071.91	5.24	2.56	0.007000	1.118208	0.838656	0.1	1.3	0.1	1.1	0.1	1.2
Sols Wash North	5000	10-Sols 100-Hass	2129	2070.8	2072.8	6.17	2.25	0.006000	0.844272	0.633204	0.1	1.0	0.1	0.8	0.1	0.9
Sols Wash North	5200	10-Sols 100-Hass	2129	2072	2074.13	6.4	2.07	0.007500	0.966420	0.724815	0.1	1.1	0.1	1.0	0.1	1.0
Sols Wash North	5400	10-Sols 100-Hass	2129	2073.5	2075.86	8.03	2.25	0.007500	1.050660	0.787995	0.1	1.2	0.1	1.1	0.1	1.1
Sols Wash North	5600	10-Sols 100-Hass	2129	2075	2077.75	7.4	2.56	0.010000	1.594320	1.195740	0.2	1.9	0.1	1.6	0.1	1.7
Sols Wash North	5800	10-Sols 100-Hass	2129	2077	2079.36	8.44	2.56	0.010000	1.594320	1.195740	0.2	1.9	0.1	1.6	0.1	1.7
Sols Wash North	6000	10-Sols 100-Hass	2129	2079	2080.97	9.6	2.16	0.010000	1.350960	1.013220	0.1	1.6	0.1	1.4	0.1	1.4
Sols Wash North	6200	10-Sols 100-Hass	2129	2081	2084.12	8.14	2.54									

Tractive Force Analysis

Input Variables:

γ_w = 62.4 pcf

C^* = 0.10

γ_s = 165 pcf

Equations:

$\tau_b = \gamma_w * d * i_f$

$\tau_m = 0.75 * \tau_b$

$d_{50bed} = \tau_b / [C^*(\gamma_s - \gamma_w)]$

$d_{50slope} = \tau_m / \{[1-(\sin^2\theta/\sin^2\phi)]^{1/2})C^*(\gamma_s-\gamma_w)\}$

where, θ = bank slope in degrees

ϕ = friction angle of bank material in degrees

Analysis for 100 year Sols Wash / 10 year Hassayampa

Channel Designation	Station	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Avg Water Depth, d	Avg. Bed Slope, i_f	Shear Stress on bed, τ_b	Shear Stress on bank, τ_m	on bed / in wall		on 3:1 slope		on 2.5:1 slope	
											d_{50}	d_{50}	d_{50}	d_{50}	d_{50}	d_{50}
			(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft/ft)	(psf)	(psf)	(ft)	(in)	(ft)	(in)	(ft)	(in)
Sols Wash South	4600	100-Sols 10-Hass	6000	2068	2072.71	11.38	4.71	0.008000	2.351232	1.763424	0.2	2.7	0.2	2.4	0.2	2.5
Sols Wash South	4800	100-Sols 10-Hass	6000	2069.6	2074.47	11.26	4.79	0.007000	2.092272	1.569204	0.2	2.4	0.2	2.1	0.2	2.2
Sols Wash South	5000	100-Sols 10-Hass	6000	2071	2076.14	10.77	5.00	0.010000	3.123120	2.342340	0.3	3.7	0.3	3.1	0.3	3.3
Sols Wash South	5200	100-Sols 10-Hass	6000	2073	2077.68	12.24	4.91	0.006667	2.042560	1.531920	0.2	2.4	0.2	2.0	0.2	2.2
Sols Wash South	5500	100-Sols 10-Hass	6000	2075	2080.43	12.91	5.05									

Tractive Force Analysis

Input Variables:

γ_w = 62.4 pcf

C^* = 0.10

γ_s = 165 pcf

Equations:

$\tau_b = \gamma_w * d * i_f$

$\tau_m = 0.75 * \tau_b$

$d_{50bed} = \tau_b / [C^*(\gamma_s - \gamma_w)]$

$d_{50slope} = \tau_m / \{[1-(\sin^2\theta/\sin^2\phi)]^{1/2})C^*(\gamma_s-\gamma_w)\}$

where, θ = bank slope in degrees

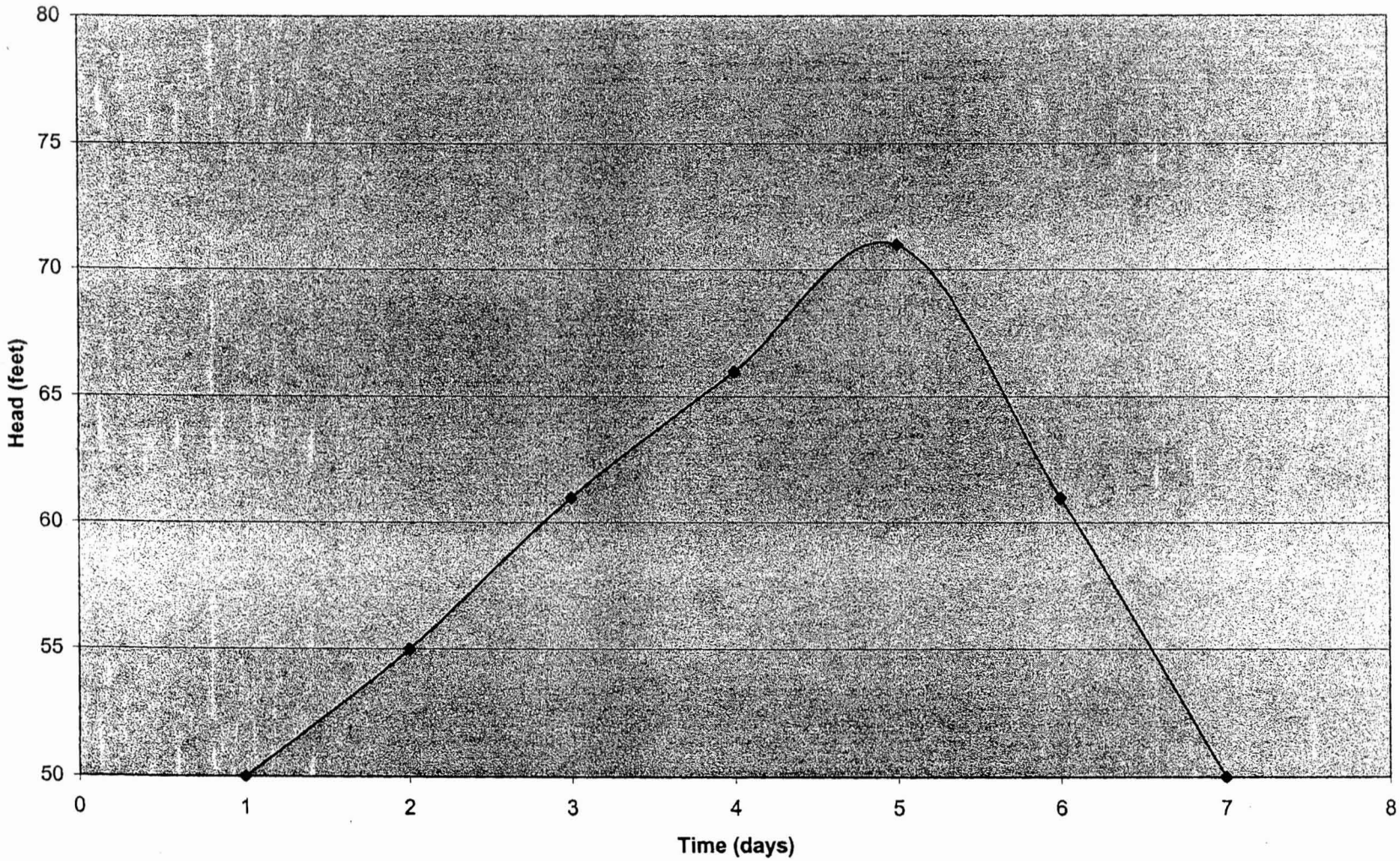
ϕ = friction angle of bank material in degrees

Analysis for 10 year Sols Wash / 100 year Hassayampa

Channel Designation	Station	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Avg Water Depth, d	Avg. Bed Slope, i_f	Shear Stress on bed, τ_b	Shear Stress on bank, τ_m	on bed / in wall		on 3:1 slope		on 2.5:1 slope	
											d_{50}	d_{50}	d_{50}	d_{50}	d_{50}	d_{50}
			(cfs)	(ft)	(ft)	(ft/s)	(ft)	(ft/ft)	(psf)	(psf)	(ft)	(in)	(ft)	(in)	(ft)	(in)
Sols Wash South	4600	10-Sols 100-Hass	4890	2068	2072.18	10.69	4.18	0.008000	2.086656	1.564992	0.2	2.4	0.2	2.1	0.2	2.2
Sols Wash South	4800	10-Sols 100-Hass	4890	2069.6	2074.02	10.26	4.30	0.007000	1.878240	1.408680	0.2	2.2	0.2	1.9	0.2	2.0
Sols Wash South	5000	10-Sols 100-Hass	4890	2071	2075.52	10.12	4.47	0.010000	2.789280	2.091960	0.3	3.3	0.2	2.8	0.2	3.0
Sols Wash South	5200	10-Sols 100-Hass	4890	2073	2077.19	11.25	4.36	0.006667	1.811680	1.358760	0.2	2.1	0.2	1.8	0.2	1.9
Sols Wash South	5500	10-Sols 100-Hass	4890	2075	2079.89	12	4.54									

9.0 SEEPAGE ANALYSIS AND GLOBAL STABILITY FOR LEVEE

Sols Wash Seepage Analysis Head vs. Time

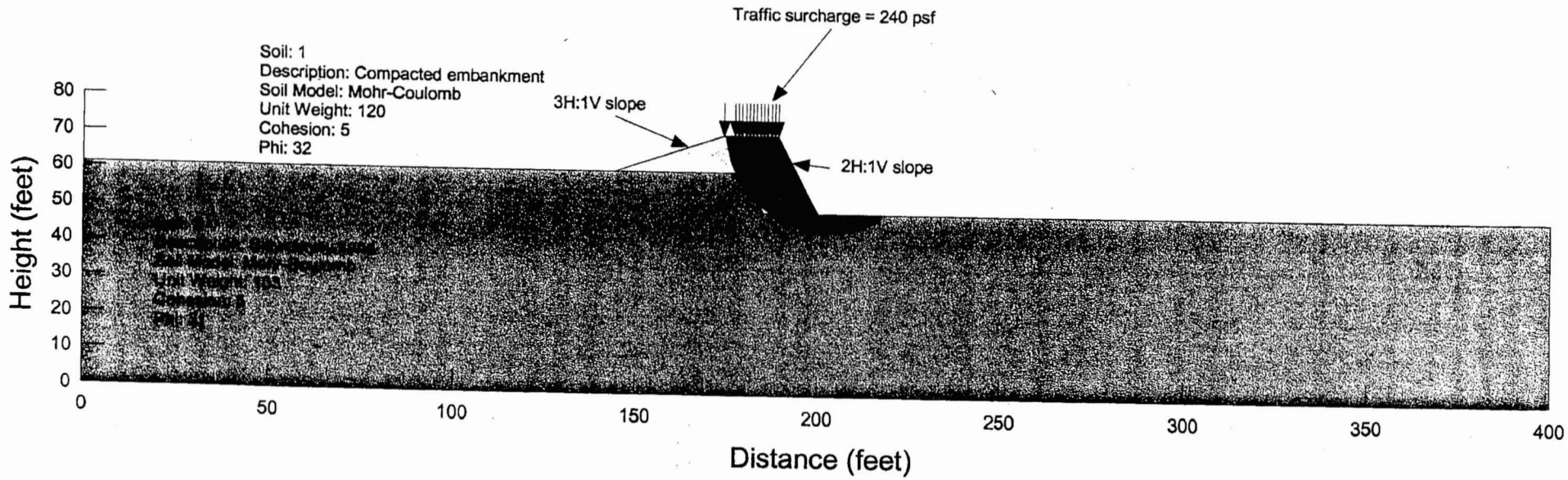


158

Description: Sols Wash Section 212+50 SB
Analysis Method: Morgenstern-Price
P.W.P. Option: (none)

Factor of safety = 1.3

End of Construction

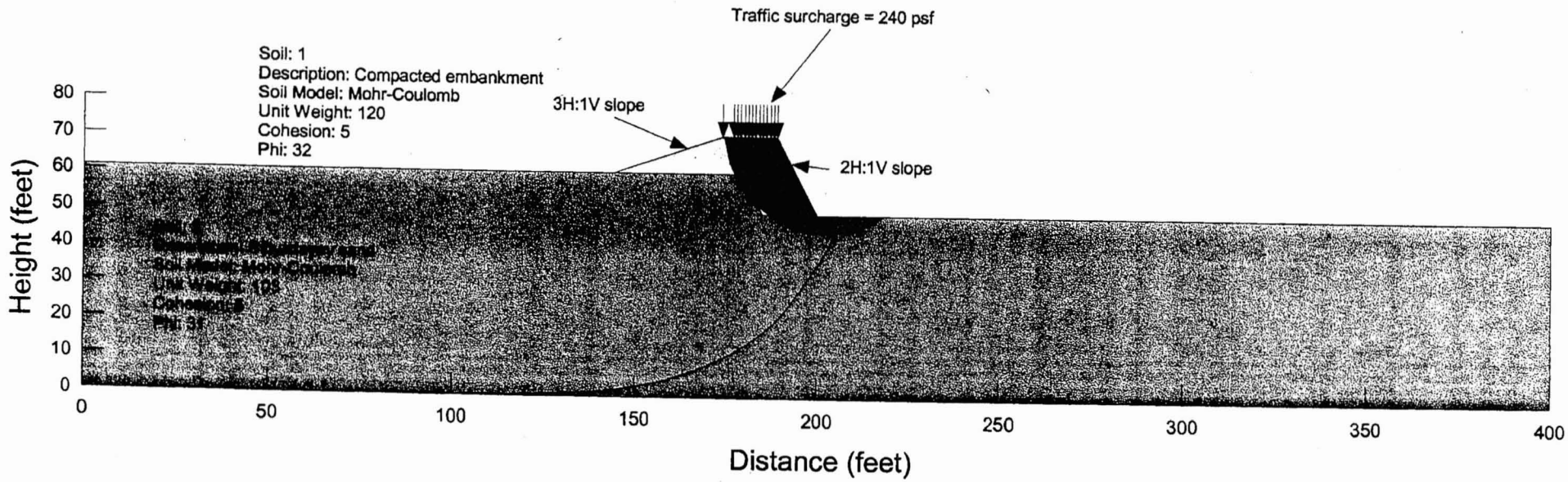


160

Description: Sols Wash Section 212+50 SB
Analysis Method: Morgenstern-Price
P.W.P. Option: SEEP/W Heads

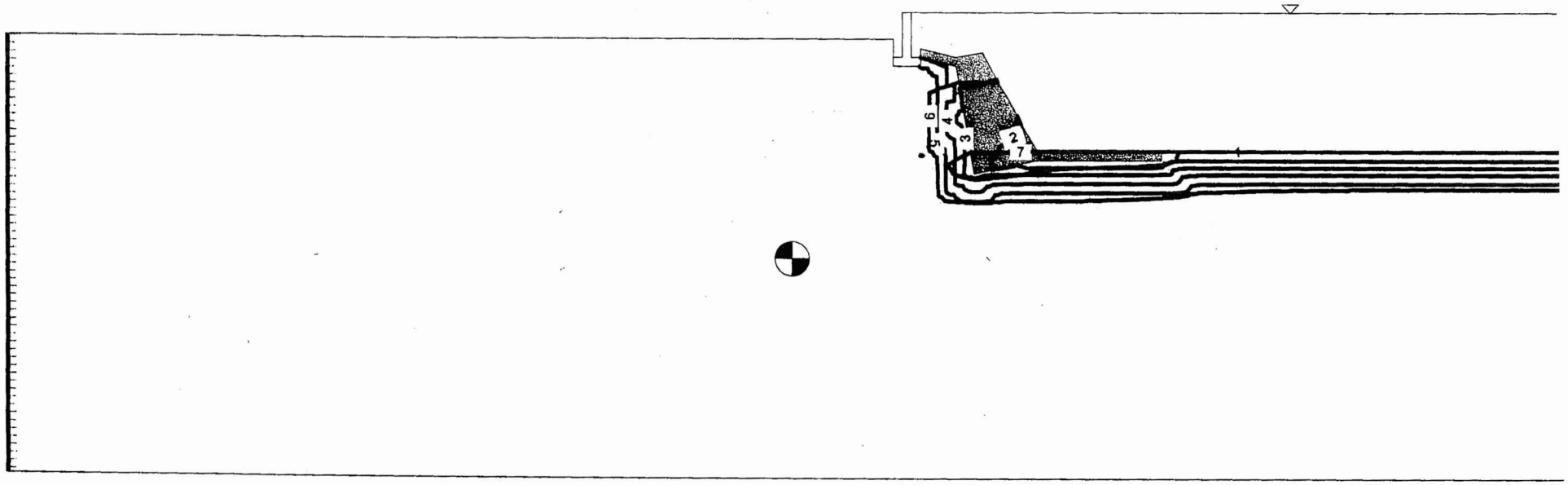
Factor of safety = 1.3

Rapid drawdown

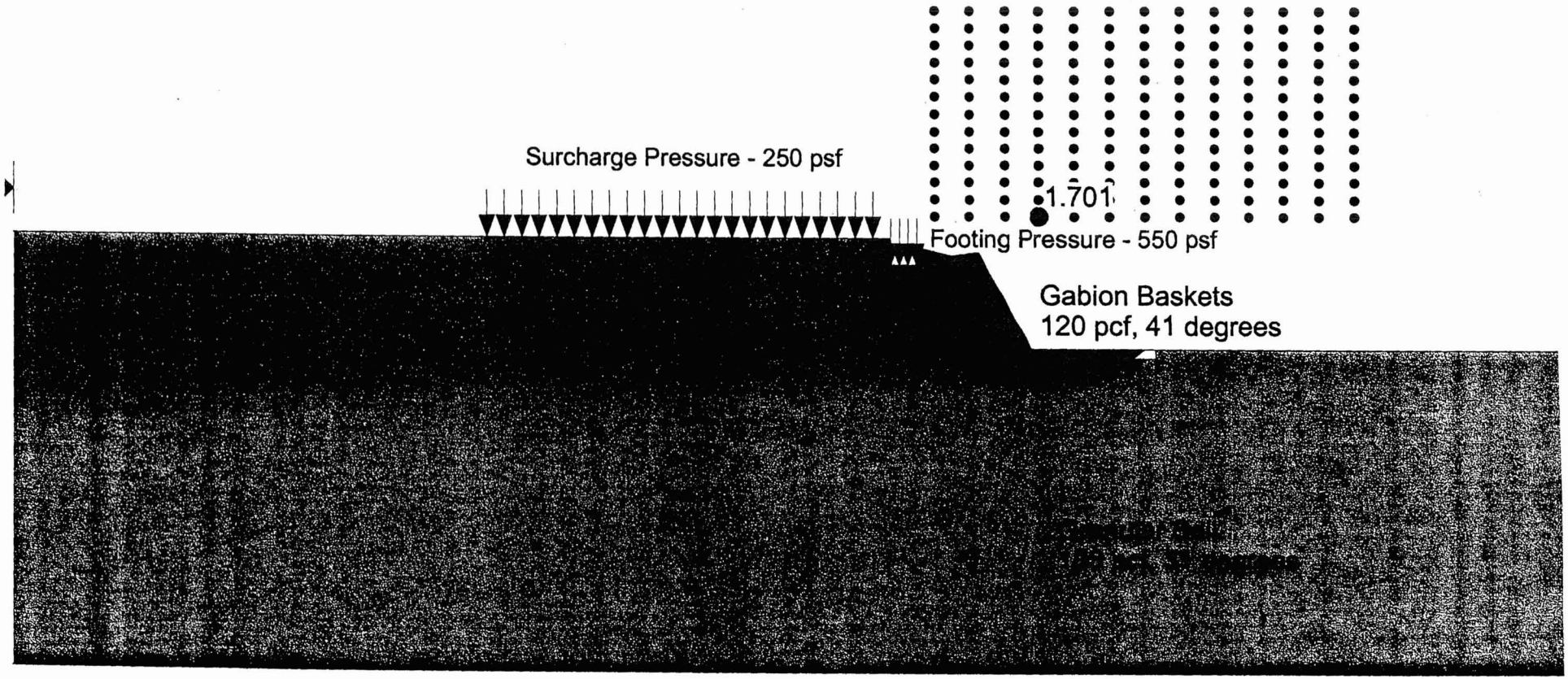


10.0 SEEPAGE ANALYSIS AND GLOBAL STABILITY FOR TYPE B FLOODWALLS

Sols Wash
Seepage Analysis @ Station 133+60
Type B Wall

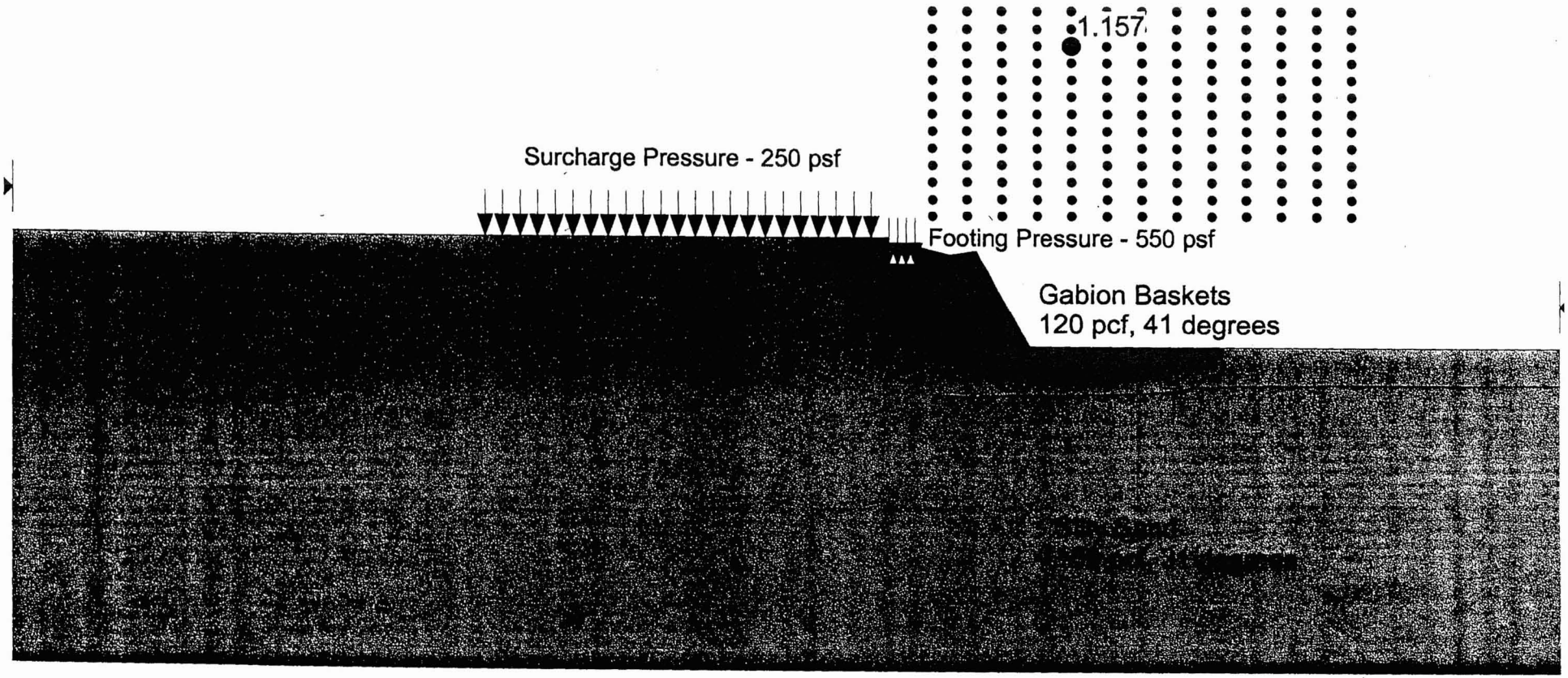


Sol's Wash - Stationing 133+60
Dry Condition



164

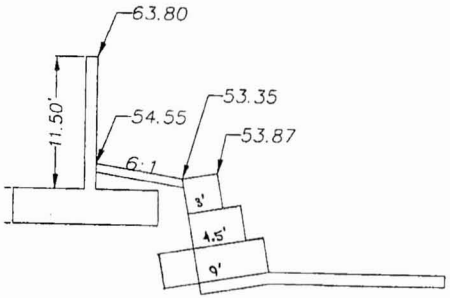
Sol's Wash - Stationing 133+60
Rapid Drawdown Condition
HWL = Top of Wall



165

11.0 GLOBAL STABILITY OF GABION WALLS

121+30

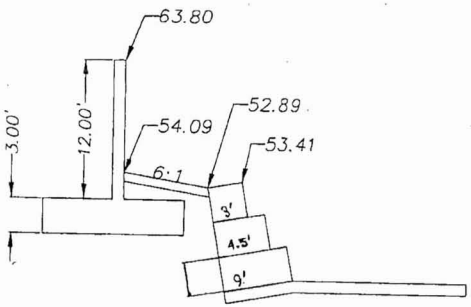


BAR SCALE

0 5 10 20

Scale 1" = 10'

120+70

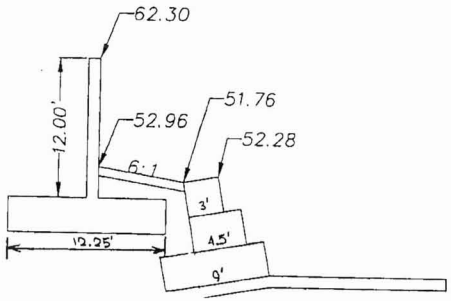


BAR SCALE

0 5 10 20

Scale 1" = 10'

116+20



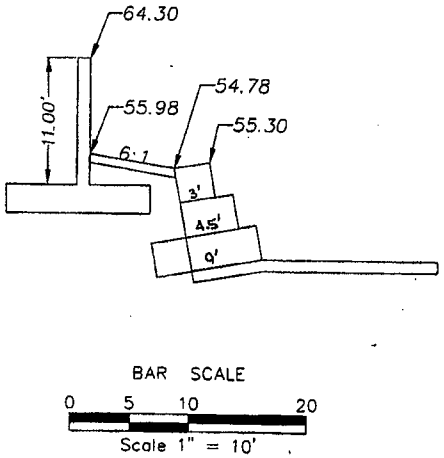
BAR SCALE

0 5 10 20

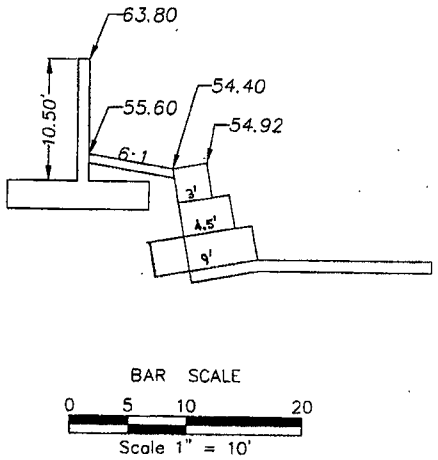
Scale 1" = 10'

167

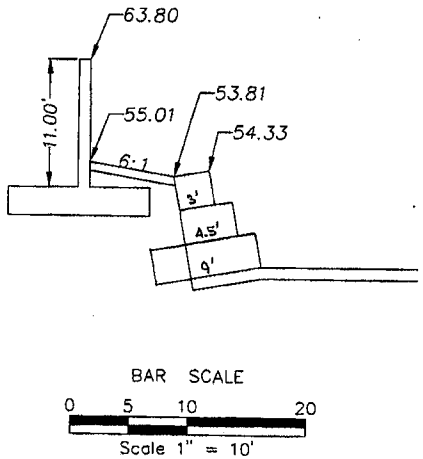
123+40



122+80

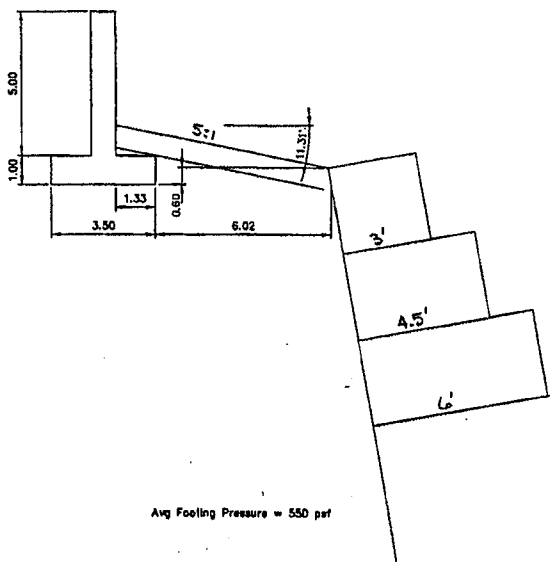


121+90



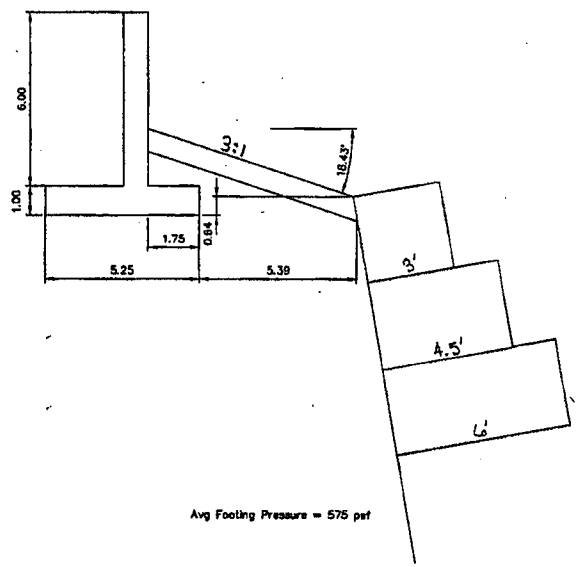
168

STA 139+00



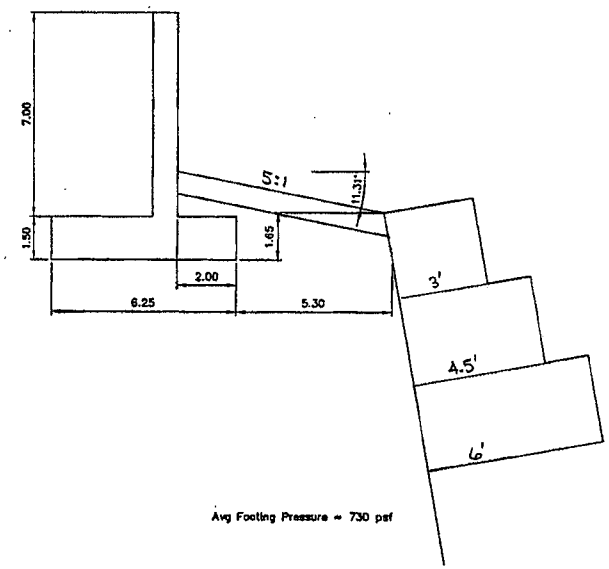
Avg Footing Pressure = 550 psf

STA 137+80



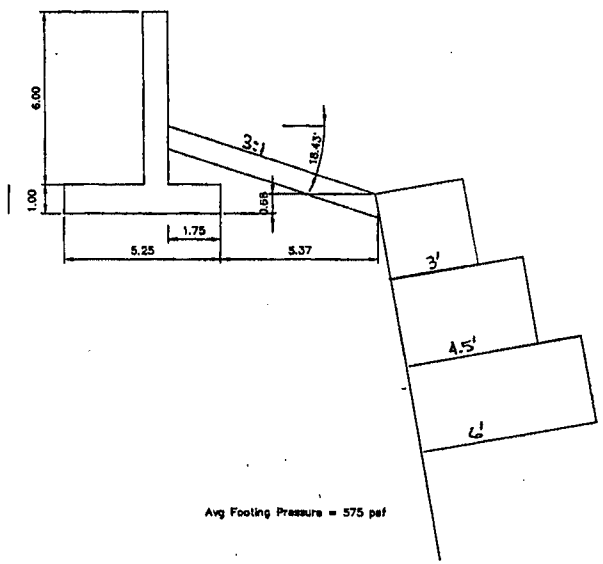
Avg Footing Pressure = 575 psf

STA 137+20



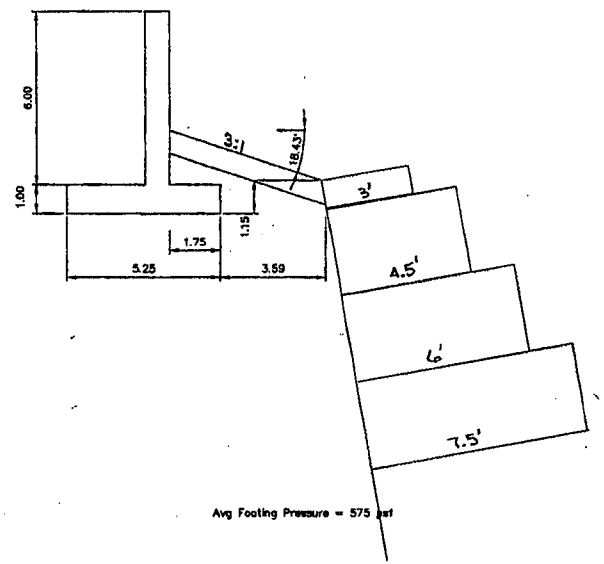
Avg Footing Pressure = 730 psf

STA 136+60



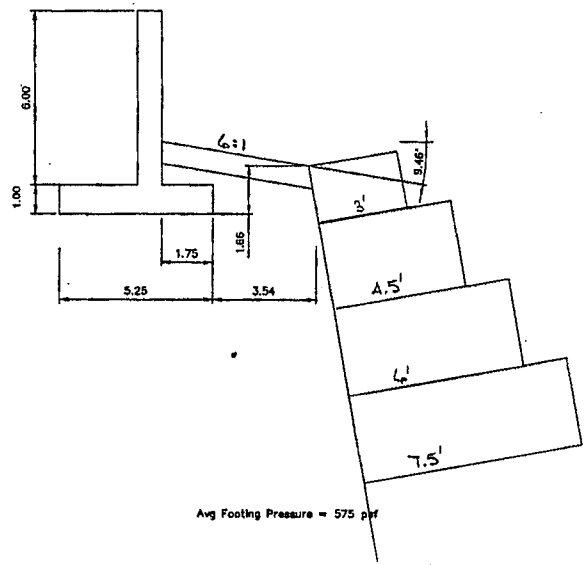
Avg Footing Pressure = 575 psf

STA 136+30



Avg Footing Pressure = 575 psf

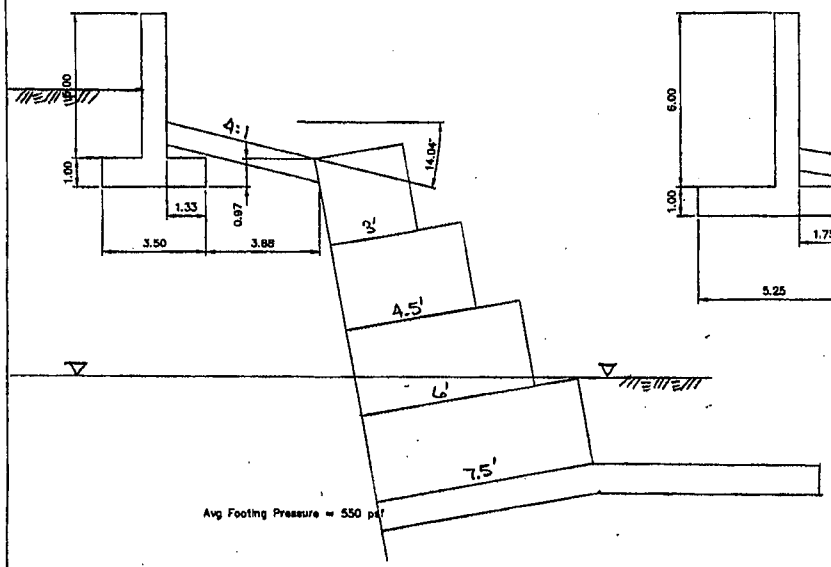
STA 135+70



Avg Footing Pressure = 575 psf

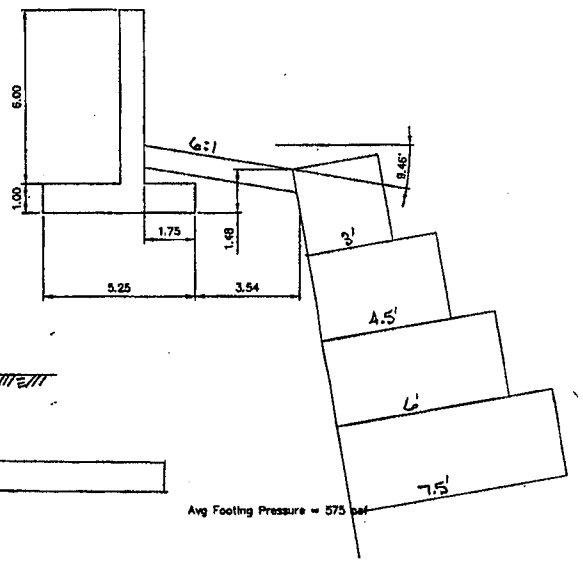
UL1

STA 133+60



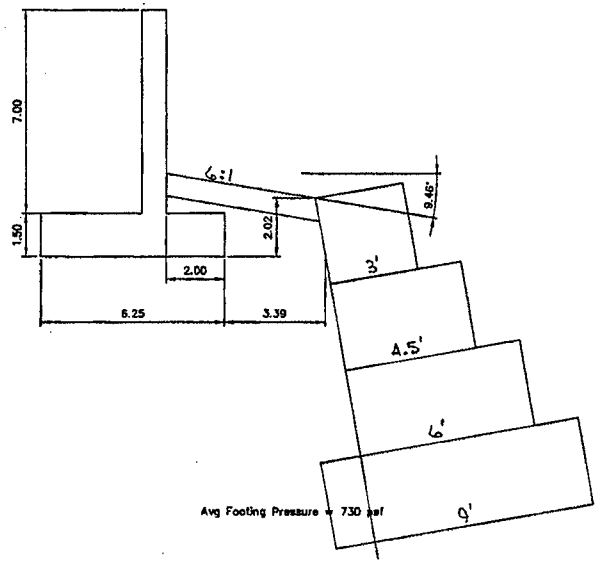
Avg Footing Pressure = 550 psf

STA 133+00



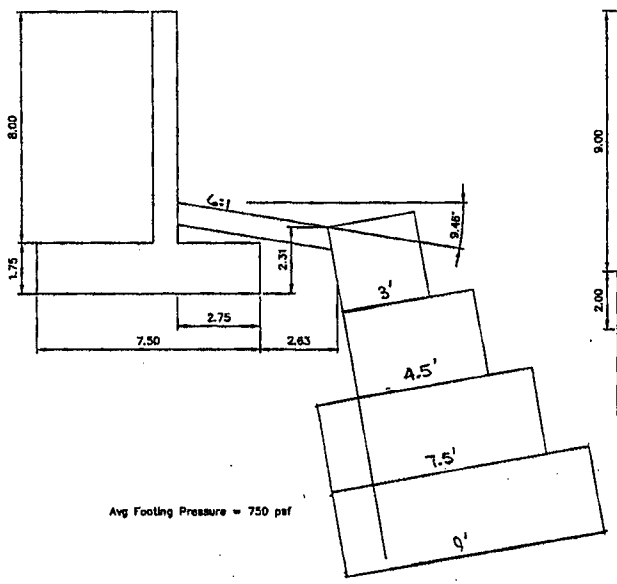
Avg Footing Pressure = 575 psf

STA 131+80



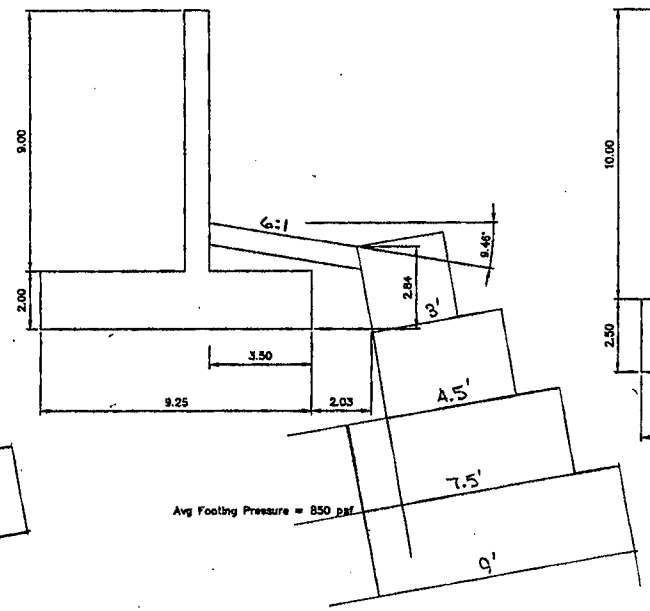
Avg Footing Pressure = 730 psf

STA 130+60



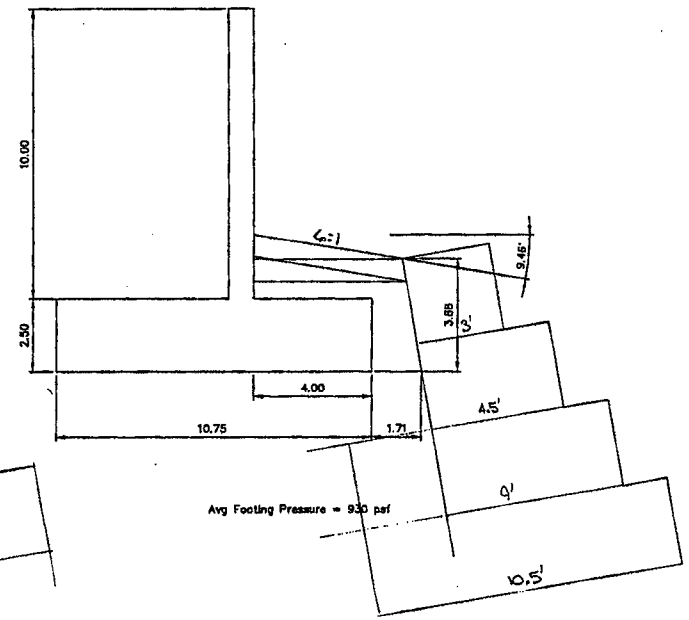
Avg Footing Pressure = 750 psf

STA 129+70.0



Avg Footing Pressure = 850 psf

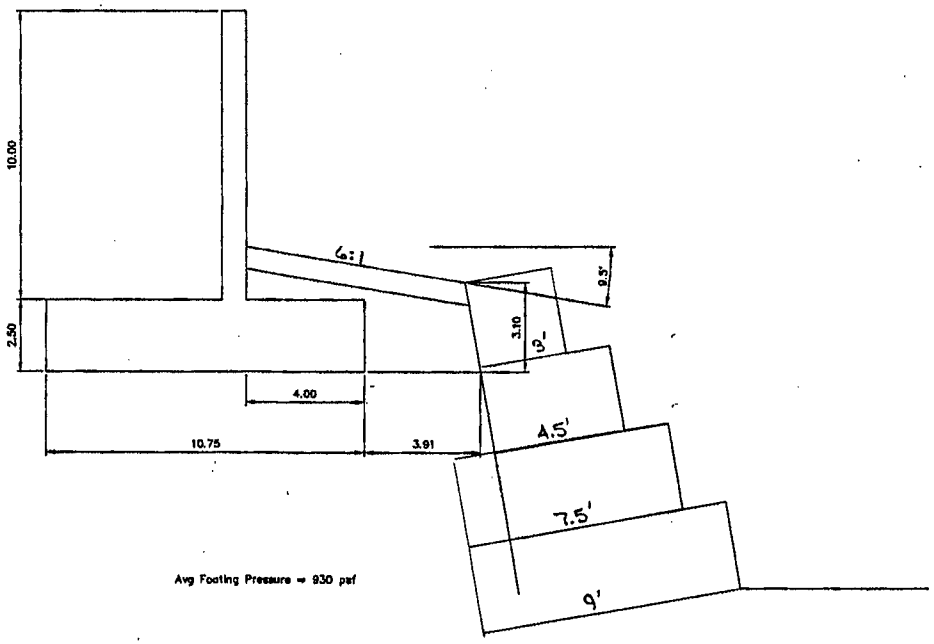
STA 129+13.29



Avg Footing Pressure = 930 psf

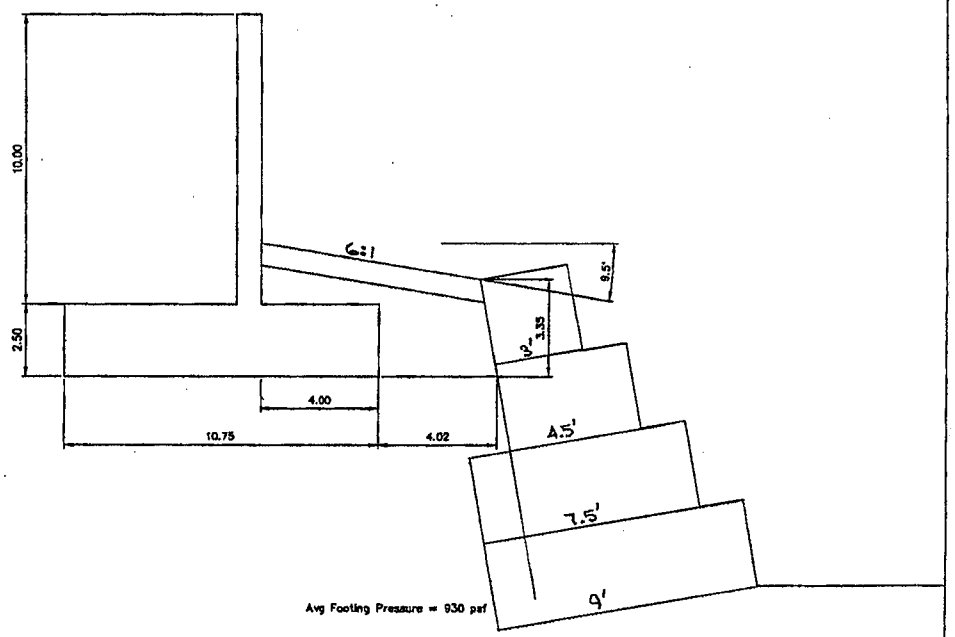
7

217+20



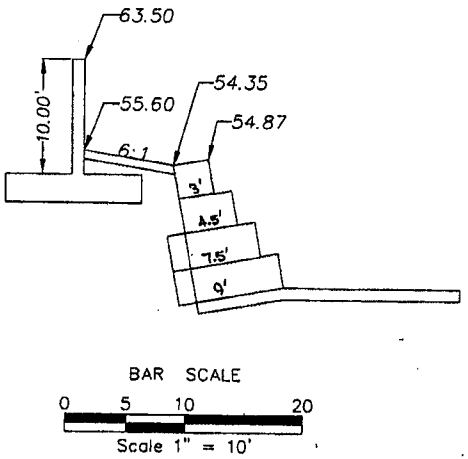
Avg Footing Pressure = 930 psf

219+50

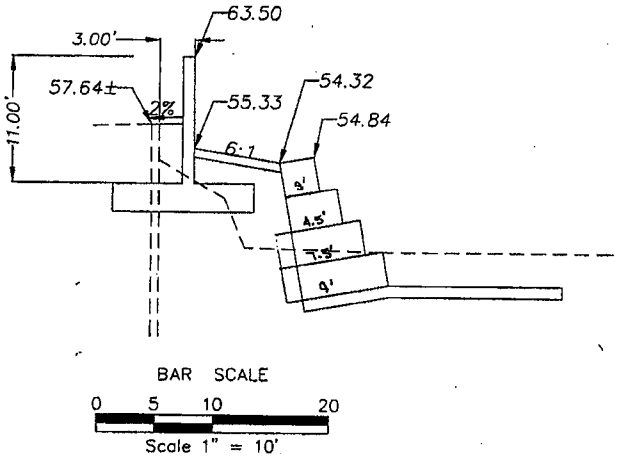


Avg Footing Pressure = 930 psf

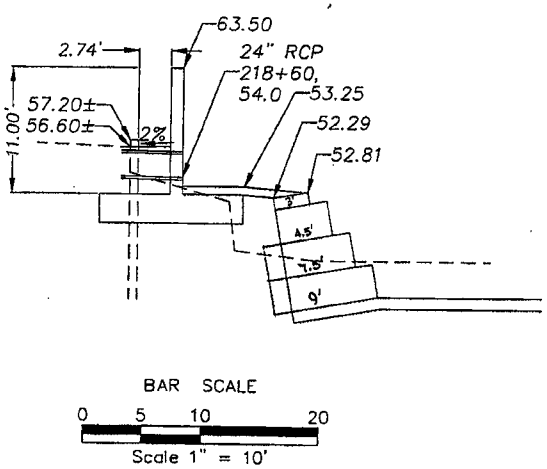
219+50



219+19

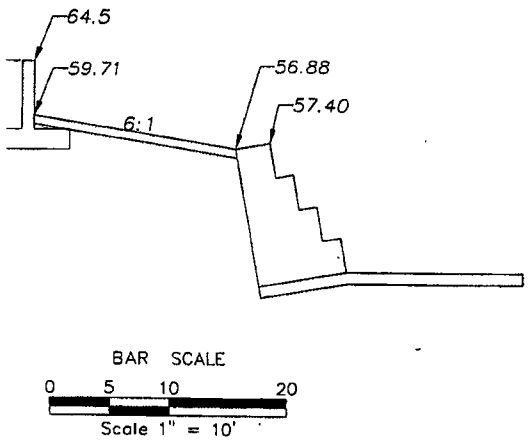


218+56

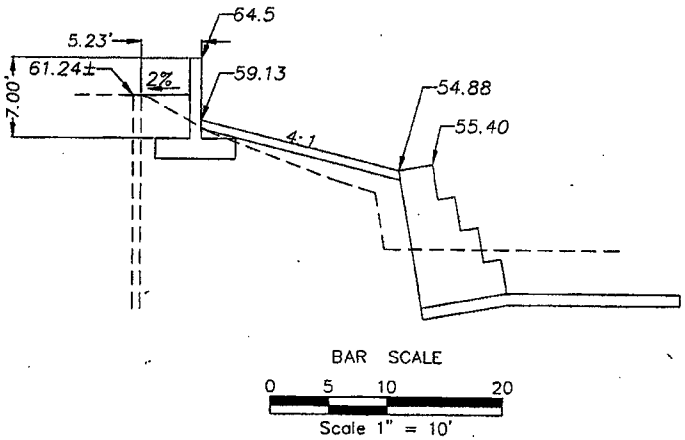


174

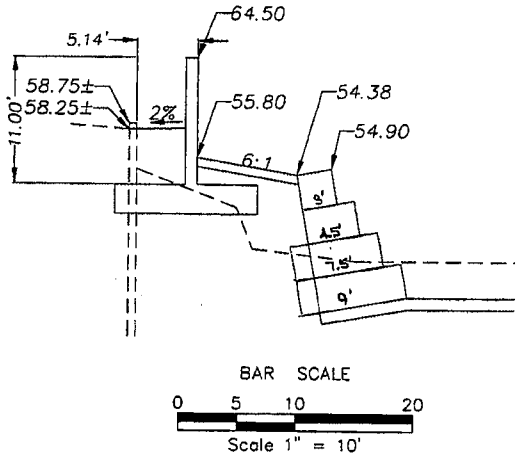
222+90



221+30

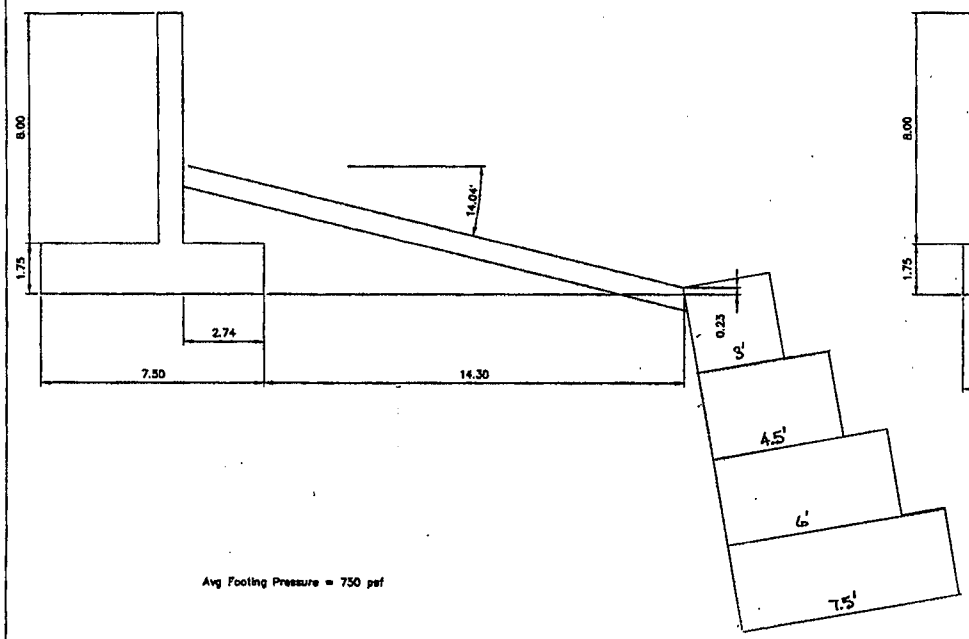


219+80



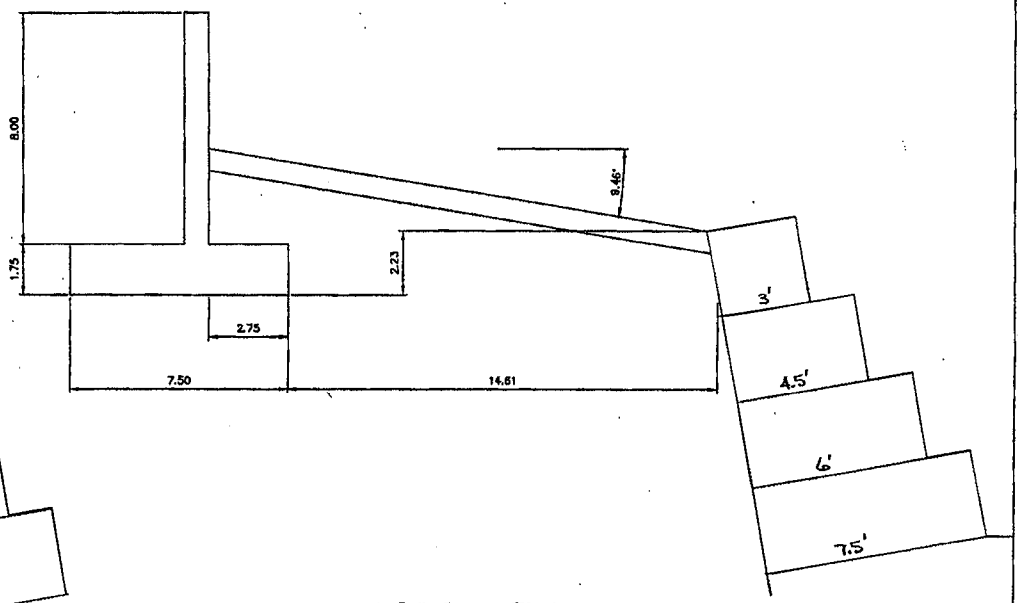
175

221+30



Avg Footing Pressure = 750 psf

222+90



Avg Footing Pressure = 750 psf

Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash Sheet No:_____ Of _____
Job Number: 046308 Des. By:_____ Date:_____
Location: Wickenburg, AZ Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 120+70 - Full Wall Height

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

9	is H, height of the gabion wall (ft)
9	is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
12.25	is a', the width of the floodwall footing (ft)
2.15	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
4.1	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
4.9	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.96	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_t/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	17	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
9.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.055	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
1	3.0	9.0	27.0	3.24	4.69	15.20
2	3.0	4.5	13.5	1.62	7.43	12.03
3	3.0	3.0	9.0	1.08	8.69	9.38
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	9.0	Total Area	49.5		Total Mom.	36.62

is M_{rg}, resisting mom.

TRUE means that the sum of the gabions entered equals H entered above.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 120+70 - Full Wall Height

TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

5.94 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
6.16 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.14 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.22 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.11 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr}hH_1Ka$ (k/ft of wall)
2.48 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 23.69 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 71.21 is θ_2, or $\tan^{-1}[(a'+b')/H']$
3.60 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

2.13 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
2.77 is z', moment arm for footing surcharge load (ft) — 3896.77 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
306.51 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

10.23 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
36.62 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
2.09 is M_{rw}, resisting moment from vertical component of F_e (k-ft/ft of wall)
38.71 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{rw}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.5 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
3.8 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

Maximum Applied Bearing Pressure

1.50 is B/6
-0.12 is e, the eccentricity, $B/2 - (M_r-M_o)/R$ (ft)
TRUE means that e < B/6, which is required
8.76 is B', or B effective, B - 2|e| (ft)
0.70 is σ_v, or R / B' (ksf)

Allowable Bearing Capacity

0.965 is s_γ, or $1 - 0.4(B'/L)$
1.919 is n, or $(2+B'/L) / (1+B'/L)$
0.559 is i_γ, or $(1 - F_H/R)^{(n+1)}$
0.790 is $b_\gamma = b_q$, or $(1-\theta\tan\phi_f)^2$
32.71 is N_γ, an internal friction angle factor from AASHTO Table 4.4.7.1A
24.64 is N_q, a bearing capacity factor from AASHTO Table 4.4.7.1A
1.06 is s_q, or $1+(B'/L)\tan\phi_f$
0.68 is i_q, or $(1 - F_H/R)^n$
5.04 is q_{ult}, or $0.5\gamma_{fw}B'N_\gamma s_\gamma b_\gamma i_\gamma + \gamma_{Df}D_fN_qs_qb_qi_q$ (ksf)
1.68 is q_{all}, or q_{ult} / SF (ksf)

Note: q_{all} must be > or = σ_v

TRUE q_{all} is > or = σ_v

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 120+70 - Level 2

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

6	is H, height of the gabion wall (ft)
4.5	is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
12.25	is a', the width of the floodwall footing (ft)
2.15	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
4.1	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
1.9	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.96	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_t/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	8	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.0 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
6.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.063	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
2	3.0	4.5	13.5	1.62	2.48	4.01
3	3.0	3.0	9.0	1.08	3.74	4.03
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	6.0	Total Area	22.5		Total Mom.	8.05

8.05 is M_{rg}, resisting mom.

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Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 120+70 - Level 2

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

2.70	is V_1, or γ_g(Total Area) (k/ft of wall)
0.00	is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
2.80	is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.50	is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.10	is F_{eV}, or $Sin(\delta-\theta)F_e$ (k/ft of wall)
0.49	is F_{eH}, or $Cos(\delta-\theta)F_e$ (k/ft of wall)
0.00	is F_{tr}, or $\gamma_t h H_1 Ka$ (k/ft of wall)
0.69	is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 48.53 is θ_1, or $Tan^{-1}(b'/H')$
0.00	is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 82.48 is θ_2, or $Tan^{-1}[(a'+b')/H']$
1.18	is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$
0.69	is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
1.21	is z', moment arm for footing surcharge load (ft) — 1558.61 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
	191.68 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

1.82	is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
8.05	is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00	is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.47	is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
8.52	is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.1 is the Safety Factor Against Sliding, $RTan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
4.7 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 120+70 - Level 3

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

3 is H, height of the gabion wall (ft)
3 is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
12.25 is a', the width of the floodwall footing (ft)
2.15 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
4.1 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
0 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.96 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
9.46 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	5	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
3.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.112 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.070 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
3	3.0	3.0	9.0	1.08	1.74	1.88
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	3.0	Total Area	9.0		Total Mom:	1.88

is M_{rg}, resisting mom.

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 120+70 - Level 3

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

1.08 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
1.10 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.13 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.02 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.12 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr}hH_1Ka$ (k/ft of wall)
0.00 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 0.00 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 0.00 is θ_2, or $\tan^{-1}[(a'+b')/H']$
0.12 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

0.00 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
0.00 is z', moment arm for footing surcharge load (ft) — 18662.40 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
416.03 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

0.12 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
1.88 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.08 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
1.95 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
7.8 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
15.8 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+13.29 - Full Wall Height

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

12	is H, height of the gabion wall (ft)
10.5	is B, the base width of the gabion wall (ft) — 0.9 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
10.75	is a', the width of the floodwall footing (ft)
1.71	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
3.88	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
8.12	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.93	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
0	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	20	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.4 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
12.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.21	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.110 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$

0.048 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$

0.054 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
1	3.0	10.5	31.5	3.78	5.43	20.53
2	3.0	7.5	22.5	2.7	7.43	20.06
3	3.0	4.5	13.5	1.62	9.43	15.27
4	3.0	3.0	9.0	1.08	10.69	11.54
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	12.0	Total Area	76.5		Total Mom.	67.40

67.40 is M_{rg}, resisting mom.

TRUE means that the sum of the gabions entered equals H entered above.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+13.29 - Full Wall Height

TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

9.18 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
9.54 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.81 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.36 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.78 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_b hH_1Ka$ (k/ft of wall)
3.78 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall)
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall)
5.56 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

11.89 is θ_1, or $\tan^{-1}(b'/H')$
56.91 is θ_2, or $\tan^{-1}[(a'+b')/H']$

4.19 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
3.93 is z', moment arm for footing surcharge load (ft)

5137.54 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
228.39 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

21.97 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
67.40 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
3.92 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
71.32 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.5 is the Safety Factor Against Sliding, $R\tan\phi_{mbr}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
3.2 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

Maximum Applied Bearing Pressure
1.75 is B/6
0.07 is e, the eccentricity, $B/2 - (M_r-M_o)/R$ (ft)
TRUE means that e < B/6, which is required
10.35 is B', or B effective, B - 2|e| (ft)
0.92 is σ_v, or R / B' (ksf)

Allowable Bearing Capacity
0.959 is s_γ, or $1 - 0.4(B'/L)$
1.906 is n, or $(2+B'/L) / (1+B'/L)$
0.549 is i_γ, or $(1 - F_H/R)^{(n+1)}$
0.791 is $b_\gamma = b_q$, or $(1-\theta\tan\phi_f)^2$
32.35 is N_γ, an internal friction angle factor from AASHTO Table 4.4.7.1A
24.43 is N_q, a bearing capacity factor from AASHTO Table 4.4.7.1A
1.07 is s_q, or $1+(B'/L)\tan\phi_f$
0.67 is i_q, or $(1 - F_H/R)^n$
5.43 is q_{ult}, or $0.5\gamma_{fw}B'N_\gamma s_\gamma b_\gamma i_\gamma + \gamma_{Df}D_fN_qs_qb_qi_q$ (ksf)
1.81 is q_{all}, or q_{ult} / SF (ksf)

Note: q_{all} must be > or = σ_v

TRUE q_{all} is > or = σ_v

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+13.29 - Level 2

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

9	is H, height of the gabion wall (ft)
9	is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
10.75	is a', the width of the floodwall footing (ft)
1.71	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
3.88	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
5.12	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.93	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
0	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	17	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
9.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.21	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.055	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
2	3.0	9.0	27.0	3.24	4.69	15.20
3	3.0	4.5	13.5	1.62	7.43	12.03
4	3.0	3.0	9.0	1.08	8.69	9.38
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	9.0	Total Area	49.5		Total Mom.	36.62

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+13.29 - Level 2

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

5.94 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
6.14 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.02 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.20 is F_{eV}, or $Sin(\delta-\theta)F_e$ (k/ft of wall)
1.00 is F_{eH}, or $Cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_b hH_1Ka$ (k/ft of wall)
2.60 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) 18.47 is θ_1, or $Tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) 67.66 is θ_2, or $Tan^{-1}[(a'+b')/H']$
3.60 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

2.35 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
2.77 is z', moment arm for footing surcharge load (ft) 3468.09 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
209.17 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

10.21 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
36.62 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
1.88 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
38.50 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.5 is the Safety Factor Against Sliding, $RTan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
3.8 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash Sheet No:_____ Of _____
Job Number: 046308 Des. By:_____ Date:_____
Location: Wickenburg, AZ Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+13.29 - Level 3

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

6	is H, height of the gabion wall (ft)
4.5	is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
10.75	is a', the width of the floodwall footing (ft)
1.71	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
3.88	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
2.12	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.65	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
0	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	8	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.0 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
6.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.21	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$

0.049 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$

0.063 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
3	3.0	4.5	13.5	1.62	2.48	4.01
4	3.0	3.0	9.0	1.08	3.74	4.03
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	6.0	Total Area	22.5		Total Mom.	8.05

8.05 is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+13.29 - Level 3

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

2.70 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
2.79 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.45 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.09 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.44 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr}hH_1Ka$ (k/ft of wall)
0.63 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 38.89 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 80.34 is θ_2, or $\tan^{-1}[(a'+b')/H']$
1.08 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

0.81 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
1.31 is z', moment arm for footing surcharge load (ft) — 1499.12 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
149.45 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

1.72 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
8.05 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.42 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
8.47 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.2 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
4.9 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+13.29 - Level 4

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

3 is H, height of the gabion wall (ft)
3 is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
10.75 is a', the width of the floodwall footing (ft)
1.71 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
3.88 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
0 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.93 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
0 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	5	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
3.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.21 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.112 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.070 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
4	3.0	3.0	9.0	1.08	1.74	1.88
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	3.0	Total Area	9.0		Total Mom.	1.88

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+13.29 - Level 4

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

1.08 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
1.10 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.11 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.02 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.11 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_t h H_1 Ka$ (k/ft of wall)
0.00 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 0.00 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 0.00 is θ_2, or $\tan^{-1}[(a'+b')/H']$
0.11 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

0.00 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
0.00 is z', moment arm for footing surcharge load (ft) — 13972.64 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
263.17 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

0.11 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
1.88 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.07 is M_{re}, resisting moment from vertical component of F_e (k-ft/ft of wall)
1.95 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{re}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
8.6 is the Safety Factor Against Sliding, $R\tan\phi_{mlr}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
17.5 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash Sheet No:_____ Of _____
Job Number: 046308 Des. By:_____ Date:_____
Location: Wickenburg, AZ Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+70 - Full Wall Height

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

12	is H, height of the gabion wall (ft)
9	is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
9.25	is a', the width of the floodwall footing (ft)
2.03	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.84	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
9.16	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.85	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_t/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	17	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
12.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.055	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
1	3.0	9.0	27.0	3.24	4.69	15.20
2	3.0	7.5	22.5	2.7	5.95	16.07
3	3.0	4.5	13.5	1.62	7.95	12.88
4	3.0	3.0	9.0	1.08	9.21	9.95
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	12.0	Total Area	72.0		Total Mom.	54.10

54.10 is M_{rg}, resisting mom.

TRUE means that the sum of the gabions entered equals H entered above.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+70 - Full Wall Height

TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

8.64	is V_1, or γ_g(Total Area) (k/ft of wall)
0.00	is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
9.04	is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
2.02	is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.40	is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.98	is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00	is F_{tr}, or $\gamma_s hH_1Ka$ (k/ft of wall)
3.32	is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall)
0.00	is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall)
5.30	is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

12.50 is θ_1, or $\tan^{-1}(b'/H')$
50.92 is θ_2, or $\tan^{-1}[(a'+b')/H']$

4.87	is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
4.29	is z', moment arm for footing surcharge load (ft)

4972.29 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
319.39 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

22.19	is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}z')+F_{hp}(W/3)$ (k-ft/ft of wall)
54.10	is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00	is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
3.78	is M_{rs}, resisting moment from vertical component of F_e (k-ft/ft of wall)
57.88	is M_r, total resisting moment $M_{rg}+M_{rs}+M_{rs}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5

1.5 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$

TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0

2.6 is the Safety Factor Against Overturning, M_r / M_o

TRUE means that the Safety Factor is OK

Maximum Applied Bearing Pressure

1.50 is B/6

0.55 is e, the eccentricity, $B/2 - (M_r-M_o)/R$ (ft)

TRUE means that e < B/6, which is required

7.90 is B', or B effective, B - 2|e| (ft)

1.14 is σ_v, or R / B' (ksf)

Allowable Bearing Capacity

0.968	is s_γ, or $1 - 0.4(B'/L)$
1.927	is n, or $(2+B'/L) / (1+B'/L)$
0.485	is i_γ, or $(1 - F_H/R)^{(n+1)}$
0.790	is $b_\gamma = b_q$, or $(1-\theta\tan\phi_f)^2$
32.71	is N_γ, an internal friction angle factor from AASHTO Table 4.4.7.1A
24.64	is N_q, a bearing capacity factor from AASHTO Table 4.4.7.1A
1.05	is s_q, or $1+(B'/L)\tan\phi_f$
0.62	is i_q, or $(1 - F_H/R)^n$
4.16	is q_{ult}, or $0.5\gamma_w B'N_\gamma s_\gamma b_\gamma i_\gamma + \gamma_{Df}D_fN_qs_qb_qi_q$ (ksf)
1.39	is q_{all}, or q_{ult} / SF (ksf)

Note: q_{all} must be > or = σ_v

TRUE q_{all} is > or = σ_v

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+70 - Level 2

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

9	is H, height of the gabion wall (ft)
9	is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
9.25	is a', the width of the floodwall footing (ft)
2.03	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.84	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
6.16	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.85	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_t/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	17	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
9.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.055	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
2	3.0	9.0	27.0	3.24	4.69	15.20
3	3.0	4.5	13.5	1.62	7.43	12.03
4	3.0	3.0	9.0	1.08	8.69	9.38
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	9.0	Total Area	49.5		Total Mom.	36.62

is M_{rg}, resisting mom.

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Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+70 - Level 2

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

5.94 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
6.16 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.14 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.22 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.11 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_b h H_1 Ka$ (k/ft of wall)
2.51 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 18.24 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 61.36 is θ_2, or $\tan^{-1}[(a'+b')/H']$
3.62 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

2.92 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
3.24 is z', moment arm for footing surcharge load (ft) — 3643.97 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
295.72 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

11.46 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
36.62 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
2.09 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
38.71 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.5 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
3.4 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+70 - Level 3

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

6 is H, height of the gabion wall (ft)
6 is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
9.25 is a', the width of the floodwall footing (ft)
2.03 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.84 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
3.16 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.85 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_b, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
9.46 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	11	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.8 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
6.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.059 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
3	3.0	6.0	18.0	2.16	3.21	6.94
4	3.0	3.0	9.0	1.08	5.21	5.63
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	6.0	Total Area	27.0		Total Mom.	12.57

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+70 - Level 3

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

3.24 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
3.34 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.50 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.10 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.49 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr}hH_1Ka$ (k/ft of wall)
1.24 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 32.72 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 74.35 is θ_2, or $\tan^{-1}[(a'+b')/H']$
1.74 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

1.27 is $H'-z'$, or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
1.89 is z', moment arm for footing surcharge load (ft) — 1991.25 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
236.06 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

3.33 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
12.57 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.62 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
13.19 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.7 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
4.0 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+70 - Level 4

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

3	is H, height of the gabion wall (ft)
3	is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
9.25	is a', the width of the floodwall footing (ft)
2.03	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.84	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
0.16	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.85	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_h, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	5	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
3.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.112	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.070	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft^2)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
4	3.0	3.0	9.0	1.08	1.74	1.88
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	3.0	Total Area	9.0		Total Mom.	1.88

is M_{rg}, resisting mom.

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Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 129+70 - Level 4

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

1.08 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
1.10 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.13 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.02 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.12 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr}hH_1Ka$ (k/ft of wall)
0.01 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 85.49 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 89.19 is θ_2, or $\tan^{-1}[(a'+b')/H']$
0.13 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

0.06 is $H'-z'$, or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
0.10 is z', moment arm for footing surcharge load (ft) — 103.40 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
18.57 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

0.12 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
1.88 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.08 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
1.95 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
7.4 is the Safety Factor Against Sliding, $R\tan\phi_{mb}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
15.7 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash Sheet No:_____ Of _____
Job Number: 046308 Des. By:_____ Date:_____
Location: Wickenburg, AZ Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 130+60 - Full Wall Height

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

12 is H, height of the gabion wall (ft)
9 is B, the base width of the gabion wall (ft) [0.8] is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
7.5 is a', the width of the floodwall footing (ft)
2.63 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.31 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
9.69 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.75 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
9.46 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	17	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
12.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.055 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
1	3.0	9.0	27.0	3.24	4.69	15.20
2	3.0	7.5	22.5	2.7	5.95	16.07
3	3.0	4.5	13.5	1.62	7.95	12.88
4	3.0	3.0	9.0	1.08	9.21	9.95
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	12.0	Total Area	72.0		Total Mom.	54.10

is M_{rg}, resisting mom.

TRUE means that the sum of the gabions entered equals H entered above.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 130+60 - Full Wall Height

TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

8.64 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
9.04 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
2.02 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.40 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.98 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_b hH_1Ka$ (k/ft of wall)
2.51 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 15.19 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 46.27 is θ_2, or $\tan^{-1}[(a'+b')/H']$
4.49 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

5.17 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
4.52 is z', moment arm for footing surcharge load (ft) — 4487.26 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
517.49 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

19.27 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}z')+F_{hp}(W/3)$ (k-ft/ft of wall)
54.10 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
3.78 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
57.88 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.7 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
3.0 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

Maximum Applied Bearing Pressure
1.50 is B/6
0.23 is e, the eccentricity, $B/2 - (M_r-M_o)/R$ (ft)
TRUE means that e < B/6, which is required
8.55 is B', or B effective, B - 2|e| (ft)
1.06 is σ_v, or R / B' (ksf)

Allowable Bearing Capacity
0.966 is s_γ, or 1 - 0.4(B'/L)
1.921 is n, or (2+B'/L) / (1+B'/L)
0.486 is i_γ, or $(1 - F_H/R)^{(n+1)}$
0.790 is $b_\gamma = b_q$, or $(1-\theta\tan\phi_f)^2$
32.71 is N_γ, an internal friction angle factor from AASHTO Table 4.4.7.1A
24.64 is N_q, a bearing capacity factor from AASHTO Table 4.4.7.1A
1.05 is s_q, or $1+(B'/L)\tan\phi_f$
0.62 is i_q, or $(1 - F_H/R)^n$
4.38 is q_{ult}, or $0.5\gamma_{fw}B'N_\gamma s_\gamma b_\gamma i_\gamma + \gamma_{Df}D_fN_q s_q b_q i_q$ (ksf)
1.46 is q_{all}, or q_{ult} / SF (ksf)

Note: q_{all} must be > or = σ_v

TRUE q_{all} is > or = σ_v

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 130+60 - Level 2

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

9	is H, height of the gabion wall (ft)
7.5	is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
7.5	is a', the width of the floodwall footing (ft)
2.63	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.31	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
6.69	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.75	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	14	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.6 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
9.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{0f}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.057	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
2	3.0	7.5	22.5	2.7	3.95	10.67
3	3.0	4.5	13.5	1.62	5.95	9.64
4	3.0	3.0	9.0	1.08	7.21	7.79
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	9.0	Total Area	45.0		Total Mom.	28.10

28.10 is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 130+60 - Level 2

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

5.40 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
5.62 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.14 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.22 is F_{eV}, or $\mathrm{Sin}(\delta-\theta)F_e$ (k/ft of wall)
1.11 is F_{eH}, or $\mathrm{Cos}(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr}hH_1Ka$ (k/ft of wall)
1.96 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 21.46 is θ_1, or $\mathrm{Tan}^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 56.56 is θ_2, or $\mathrm{Tan}^{-1}[(a'+b')/H']$
3.07 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

3.17 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
3.52 is z', moment arm for footing surcharge load (ft) — 3431.65 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
474.08 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

10.23 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
28.10 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
1.76 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
29.86 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.6 is the Safety Factor Against Sliding, $R\mathrm{Tan}\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
2.9 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 130+60 - Level 3

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

6	is H, height of the gabion wall (ft)
4.5	is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
7.5	is a', the width of the floodwall footing (ft)
2.63	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.31	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
3.69	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.75	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	8	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.0 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
6.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.063	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
3	3.0	4.5	13.5	1.62	2.48	4.01
4	3.0	3.0	9.0	1.08	3.74	4.03
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	6.0	Total Area	22.5		Total Mom.	8.05

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 130+60 - Level 3

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

2.70 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
2.80 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.50 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.10 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.49 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_h h H_1 Ka$ (k/ft of wall)
1.06 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 35.48 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 69.99 is θ_2, or $\tan^{-1}[(a'+b')/H']$
1.56 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

1.49 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
2.20 is z', moment arm for footing surcharge load (ft) — 2053.87 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
377.12 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

3.33 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}z')+F_{hp}(W/3)$ (k-ft/ft of wall)
8.05 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.47 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
8.52 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.6 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
2.6 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 130+60 - Level 4

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

3 is H, height of the gabion wall (ft)
3 is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
7.5 is a', the width of the floodwall footing (ft)
2.63 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.31 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
0.69 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.75 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
9.46 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	5	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
3.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.112 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.070 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
4	3.0	3.0	9.0	1.08	1.74	1.88
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	3.0	Total Area	9.0		Total Mom.	1.88

is M_{rg}, resisting mom.

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Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 130+60 - Level 4

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

1.08 is V_1, or γ_b(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
1.10 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.13 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.02 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.12 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_b hH_1Ka$ (k/ft of wall)
0.06 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 75.30 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 86.10 is θ_2, or $\tan^{-1}[(a'+b')/H']$
0.19 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

0.23 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
0.46 is z', moment arm for footing surcharge load (ft) — 399.86 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
101.68 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

0.15 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}z')+F_{hp}(W/3)$ (k-ft/ft of wall)
1.88 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.08 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
1.95 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
5.2 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
12.9 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash Sheet No:_____ Of _____
Job Number: 046308 Des. By:_____ Date:_____
Location: Wickenburg, AZ Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 131+80 - Full Wall Height

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

12	is H, height of the gabion wall (ft)
9	is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
6.25	is a', the width of the floodwall footing (ft)
3.39	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.02	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
9.98	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.73	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	17	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
12.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.055	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
1	3.0	9.0	27.0	3.24	4.69	15.20
2	3.0	6.0	18.0	2.16	6.69	14.45
3	3.0	4.5	13.5	1.62	7.95	12.88
4	3.0	3.0	9.0	1.08	9.21	9.95
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	12.0	Total Area	67.5		Total Mom.	52.48

is M_{rg}, resisting mom.

TRUE means that the sum of the gabions entered equals H entered above.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 131+80 - Full Wall Height

TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

8.10	is V_1, or γ_g(Total Area) (k/ft of wall)
0.00	is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
8.50	is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
2.02	is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.40	is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.98	is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00	is F_{tr}, or $\gamma_b hH_1Ka$ (k/ft of wall)
2.04	is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 18.76 is θ_1, or $\tan^{-1}(b'/H')$
0.00	is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 44.01 is θ_2, or $\tan^{-1}[(a'+b')/H']$
4.02	is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$
5.23	is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
4.75	is z', moment arm for footing surcharge load (ft) — 4274.09 is R_{fs}, or $(a'+b')^2(90-\theta_2)$; 818.68 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

17.63	is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
52.48	is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00	is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
3.78	is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
56.26	is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5

1.8 is the Safety Factor Against Sliding, $R\tan\phi_{mb}/F_H$

TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0

3.2 is the Safety Factor Against Overturning, M_r / M_o

TRUE means that the Safety Factor is OK

Maximum Applied Bearing Pressure

1.50 is B/6

-0.05 is e, the eccentricity, $B/2 - (M_r-M_o)/R$ (ft)

TRUE means that e < B/6, which is required

8.91 is B', or B effective, B - 2|e| (ft)

0.95 is σ_v, or R / B' (ksf)

Allowable Bearing Capacity

0.964	is s_γ, or $1 - 0.4(B'/L)$
1.918	is n, or $(2+B'/L) / (1+B'/L)$
0.461	is i_γ, or $(1 - F_H/R)^{(n+1)}$
0.790	is $b_\gamma = b_q$, or $(1-\theta\tan\phi_f)^2$
32.71	is N_γ, an internal friction angle factor from AASHTO Table 4.4.7.1A
24.64	is N_q, a bearing capacity factor from AASHTO Table 4.4.7.1A
1.06	is s_q, or $1+(B'/L)\tan\phi_f$
0.60	is i_q, or $(1 - F_H/R)^n$
4.30	is q_{ult}, or $0.5\gamma_{fw}B'N_\gamma s_\gamma b_\gamma i_\gamma + \gamma_{bf}D_fN_qs_qb_qi_q$ (ksf)
1.43	is q_{all}, or q_{ult} / SF (ksf)

Note: q_{all} must be > or = σ_v

TRUE q_{all} is > or = σ_v

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Job Name: FCDMC - Sols Wash Sheet No:_____ Of _____
Job Number: 046308 Des. By:_____ Date:_____
Location: Wickenburg, AZ Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 131+80 - Level 2

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

9	is H, height of the gabion wall (ft)
6	is B, the base width of the gabion wall (ft) — 0.7 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
6.25	is a', the width of the floodwall footing (ft)
3.39	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.02	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
6.98	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.73	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	11	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.8 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
9.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.059	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
2	3.0	6.0	18.0	2.16	3.21	6.94
3	3.0	4.5	13.5	1.62	4.47	7.25
4	3.0	3.0	9.0	1.08	5.73	6.19
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	9.0	Total Area	40.5		Total Mom.	20.39

is M_{rg}, resisting mom.

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Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 131+80 - Level 2

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

4.86 is V_1, or γ_0(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
5.08 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.14 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.22 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.11 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_b hH_1Ka$ (k/ft of wall)
1.60 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 25.90 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 54.09 is θ_2, or $\tan^{-1}[(a'+b')/H']$
2.71 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

3.23 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
3.75 is z', moment arm for footing surcharge load (ft) — 3336.83 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
736.59 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

9.32 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
20.39 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
1.43 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
21.82 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.6 Is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
2.3 Is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 131+80 - Level 3

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

6 is H, height of the gabion wall (ft)
4.5 is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
6.25 is a', the width of the floodwall footing (ft)
3.39 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.02 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
3.98 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.73 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
9.46 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	8	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.0 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
6.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.063 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
3	3.0	4.5	13.5	1.62	2.48	4.01
4	3.0	3.0	9.0	1.08	3.74	4.03
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	6.0	Total Area	22.5		Total Mom.	8.05

8.05 is M_{rg}, resisting mom.

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ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 131+80 - Level 3

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

2.70 is V_1, or γ_0(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
2.80 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.50 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.10 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.49 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_b h H_1 Ka$ (k/ft of wall)
0.88 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 40.42 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 67.57 is θ_2, or $\tan^{-1}[(a'+b')/H']$
1.37 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

1.57 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
2.41 is z', moment arm for footing surcharge load (ft) — 2084.78 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
569.74 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

3.10 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
8.05 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.47 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
8.52 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.8 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
2.8 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 131+80 - Level 4

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

3 is H, height of the gabion wall (ft)
3 is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
6.25 is a', the width of the floodwall footing (ft)
3.39 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.02 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
0.98 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.73 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
9.46 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	5	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
3.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.112 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.070 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
4	3.0	3.0	9.0	1.08	1.74	1.88
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	3.0	Total Area	9.0		Total Mom.	1.88

1.88 is M_{rg}, resisting mom.

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Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 131+80 - Level 4

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

1.08 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
1.10 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.13 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.02 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.12 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr}hH_1Ka$ (k/ft of wall)
0.08 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 73.88 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 84.20 is θ_2, or $\tan^{-1}[(a'+b')/H']$
0.21 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

0.33 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
0.65 is z', moment arm for footing surcharge load (ft) — 539.43 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
185.30 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

0.18 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
1.88 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.08 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
1.95 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
4.7 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
11.1 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+00 - Full Wall Height

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

12	is H, height of the gabion wall (ft)
7.5	is B, the base width of the gabion wall (ft) — 0.6 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
5.25	is a', the width of the floodwall footing (ft)
3.54	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
1.48	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
10.52	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.58	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	14	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.6 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
12.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$

0.048 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$

0.057 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
1	3.0	7.5	22.5	2.7	3.95	10.67
2	3.0	6.0	18.0	2.16	5.21	11.26
3	3.0	4.5	13.5	1.62	6.47	10.49
4	3.0	3.0	9.0	1.08	7.73	8.35
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	12.0	Total Area	63.0		Total Mom.	40.77

is M_{rp}, resisting mom.

TRUE means that the sum of the gabions entered equals H entered above.

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash Sheet No:_____ Of _____
Job Number: 046308 Des. By:_____ Date:_____
Location: Wickenburg, AZ Ck'd By:_____ Date:_____

Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+00 - Full Wall Height

TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

7.56 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
7.96 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
2.02 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.40 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.98 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_b hH_1Ka$ (k/ft of wall)
1.44 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) 18.60 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) 39.88 is θ_2, or $\tan^{-1}[(a'+b')/H']$
3.42 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

5.68 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
4.84 is z', moment arm for footing surcharge load (ft) 3872.44 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
894.78 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

14.90 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
40.77 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
3.20 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
43.97 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.0 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
2.9 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

Maximum Applied Bearing Pressure
1.25 is B/6
0.10 is e, the eccentricity, $B/2 - (M_r-M_o)/R$ (ft)
TRUE means that e < B/6, which is required
7.31 is B', or B effective, B - 2|e| (ft)
1.09 is σ_v, or R / B' (ksf)

Allowable Bearing Capacity
0.971 is s_γ, or $1 - 0.4(B'/L)$
1.932 is n, or $(2+B'/L) / (1+B'/L)$
0.432 is i_γ, or $(1 - F_H/R)^{(n+1)}$
0.789 is $b_\gamma = b_q$, or $(1-\theta\tan\phi_f)^2$
33.20 is N_γ, an internal friction angle factor from AASHTO Table 4.4.7.1A
24.93 is N_q, a bearing capacity factor from AASHTO Table 4.4.7.1A
1.05 is s_q, or $1+(B'/L)\tan\phi_f$
0.58 is i_q, or $(1 - F_H/R)^n$
3.69 is q_{ult}, or $0.5\gamma_w B'N_\gamma s_\gamma b_\gamma i_\gamma + \gamma_D D_f N_q s_q b_q i_q$ (ksf)
1.23 is q_{all}, or q_{ult} / SF (ksf)

Note: q_{all} must be > or = σ_v

TRUE q_{all} is > or = σ_v

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+00 - Level 2

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

9 is H, height of the gabion wall (ft)
6 is B, the base width of the gabion wall (ft) — 0.7 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
5.25 is a', the width of the floodwall footing (ft)
3.54 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
1.48 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
7.52 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.58 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_b, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
9.46 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	11	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.8 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
9.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.059 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
2	3.0	6.0	18.0	2.16	3.21	6.94
3	3.0	4.5	13.5	1.62	4.47	7.25
4	3.0	3.0	9.0	1.08	5.73	6.19
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	9.0	Total Area	40.5		Total Mom.	20.39

20.39 is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+00 - Level 2

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

4.86 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
5.08 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.14 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.22 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.11 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_s hH_1Ka$ (k/ft of wall)
1.17 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 25.21 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 49.45 is θ_2, or $\tan^{-1}[(a'+b')/H']$
2.29 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

3.60 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
3.92 is z', moment arm for footing surcharge load (ft) — 3132.87 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
811.94 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

7.95 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
20.39 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
1.43 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
21.82 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.9 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
2.7 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+00 - Level 3

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

6 is H, height of the gabion wall (ft)
4.5 is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
5.25 is a', the width of the floodwall footing (ft)
3.54 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
1.48 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
4.52 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.58 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
9.46 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	8	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.0 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
6.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.063 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
3	3.0	4.5	13.5	1.62	2.48	4.01
4	3.0	3.0	9.0	1.08	3.74	4.03
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	6.0	Total Area	22.5		Total Mom.	8.05

is M_{rg}, resisting mom.

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21

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+00 - Level 3

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

2.70 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
2.80 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.50 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.10 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.49 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr}hH_1Ka$ (k/ft of wall)
0.72 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 38.07 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 62.79 is θ_2, or $\tan^{-1}[(a'+b')/H']$
1.21 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

1.85 is $H'-z'$, or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
2.67 is z', moment arm for footing surcharge load (ft) — 2102.60 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
650.80 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

2.91 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
8.05 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.47 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
8.52 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.0 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
2.9 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+00 - Level 4

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

3	is H, height of the gabion wall (ft)
3	is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
5.25	is a', the width of the floodwall footing (ft)
3.54	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
1.48	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
1.52	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.58	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	5	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
3.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{bf}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.112	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.070	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
4	3.0	3.0	9.0	1.08	1.74	1.88
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	3.0	Total Area	9.0		Total Mom.	1.88

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+00 - Level 4

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

1.08 is V_1, or γ_0(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
1.10 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.13 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.02 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.12 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_b h H_1 Ka$ (k/ft of wall)
0.13 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 66.76 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 80.19 is θ_2, or $\tan^{-1}[(a'+b')/H']$
0.26 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

0.53 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
0.99 is z', moment arm for footing surcharge load (ft) — 758.02 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
291.20 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

0.25 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
1.88 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.08 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
1.95 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
3.8 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
7.7 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+60 - Full Wall Height

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

12	is H, height of the gabion wall (ft)
7.5	is B, the base width of the gabion wall (ft) — 0.6 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
3.5	is a', the width of the floodwall footing (ft)
3.88	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
0.97	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
11.03	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.55	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
14.04	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	14	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.6 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
12.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.25	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.057	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
1	3.0	7.5	22.5	2.7	3.95	10.67
2	3.0	6.0	18.0	2.16	5.21	11.26
3	3.0	4.5	13.5	1.62	6.47	10.49
4	3.0	3.0	9.0	1.08	7.73	8.35
			0.0	0	0.00	-0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	12.0	Total Area	63.0		Total Mom.	40.77

40.77 is M_{rg}, resisting mom.

TRUE means that the sum of the gabions entered equals H entered above.

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+60 - Full Wall Height

TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

7.56 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
7.98 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
2.16 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.42 is F_{eV}, or $\mathrm{Sin}(\delta-\theta)F_e$ (k/ft of wall)
2.11 is F_{eH}, or $\mathrm{Cos}(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_t hH_1Ka$ (k/ft of wall)
0.97 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall)
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall)
3.09 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

19.38 is θ_1, or $\mathrm{Tan}^{-1}(b'/H')$
33.79 is θ_2, or $\mathrm{Tan}^{-1}[(a'+b')/H']$

6.19 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
4.84 is z', moment arm for footing surcharge load (ft)

3061.67 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
1063.14 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

13.16 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
40.77 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
3.41 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
44.19 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.2 is the Safety Factor Against Sliding, $R\mathrm{Tan}\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
3.4 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

Maximum Applied Bearing Pressure
1.25 is B/6
-0.14 is e, the eccentricity, $B/2 - (M_r-M_o)/R$ (ft)
TRUE means that e < B/6, which is required
7.23 is B', or B effective, B - 2|e| (ft)
1.10 is σ_v, or R / B' (ksf)

Allowable Bearing Capacity
0.971 is s_γ, or $1 - 0.4(B'/L)$
1.933 is n, or $(2+B'/L) / (1+B'/L)$
0.406 is i_γ, or $(1 - F_H/R)^{(n+1)}$
0.789 is $b_\gamma = b_q$, or $(1-\theta\mathrm{Tan}\phi_f)^2$
33.20 is N_γ, an internal friction angle factor from AASHTO Table 4.4.7.1A
24.93 is N_q, a bearing capacity factor from AASHTO Table 4.4.7.1A
1.05 is s_q, or $1+(B'/L)\mathrm{Tan}\phi_f$
0.55 is i_q, or $(1 - F_H/R)^n$
3.47 is q_{ult}, or $0.5\gamma_{fw}B'N_\gamma s_\gamma b_\gamma i_\gamma + \gamma_{Df}D_fN_qs_qb_qi_q$ (ksf)
1.16 is q_{all}, or q_{ult} / SF (ksf)

Note: q_{all} must be > or = σ_v

TRUE q_{all} is > or = σ_v

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sois Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+60 - Level 2

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

9	is H, height of the gabion wall (ft)
6	is B, the base width of the gabion wall (ft) — 0.7 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
3.5	is a', the width of the floodwall footing (ft)
3.88	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
0.97	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
8.03	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.55	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_t/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
14.04	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	11	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.8 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
9.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.25	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/(\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.059	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
2	3.0	6.0	18.0	2.16	3.21	6.94
3	3.0	4.5	13.5	1.62	4.47	7.25
4	3.0	3.0	9.0	1.08	5.73	6.19
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	9.0	Total Area	40.5		Total Mom.	20.39

20.39 is M_{rg}, resisting mom.

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Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+60 - Level 2

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

4.86 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
5.10 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.21 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.24 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.19 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr}hH_1Ka$ (k/ft of wall)
0.82 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 25.79 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 42.58 is θ_2, or $\tan^{-1}[(a'+b')/H']$
2.01 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

4.00 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
4.03 is z', moment arm for footing surcharge load (ft) — 2582.45 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
966.65 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

6.89 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
20.39 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
1.53 is M_{rs}, resisting moment from vertical component of F_e (k-ft/ft of wall)
21.91 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{rs}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.2 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
3.2 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash Sheet No:_____ Of _____
Job Number: 046308 Des. By:_____ Date:_____
Location: Wickenburg, AZ Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+60 - Level 3

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

6 is H, height of the gabion wall (ft)
4.5 is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
3.5 is a', the width of the floodwall footing (ft)
3.88 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
0.97 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
5.03 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.55 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
14.04 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	8	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.0 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
6.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.25 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.063 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
3	3.0	4.5	13.5	1.62	2.48	4.01
4	3.0	3.0	9.0	1.08	3.74	4.03
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	6.0	Total Area	22.5		Total Mom.	8.05

is M_{rg}, resisting mom.

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Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+60 - Level 3

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

2.70 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
2.81 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.54 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.11 is F_{eV}, or $\mathrm{Sin}(\delta-\theta)F_e$ (k/ft of wall)
0.53 is F_{eH}, or $\mathrm{Cos}(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr} h H_1 Ka$ (k/ft of wall)
0.56 is F_{hw}, or $q_{hw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 37.65 is θ_1, or $\mathrm{Tan}^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 55.72 is θ_2, or $\mathrm{Tan}^{-1}[(a'+b')/H']$
1.08 is F_H, or $F_{eH}+F_{tr}+F_{hw}+F_{hp}$

2.13 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
2.90 is z', moment arm for footing surcharge load (ft) — 1866.89 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
788.16 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

2.67 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{hw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
8.05 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.50 is M_{re}, resisting moment from vertical component of F_e (k-ft/ft of wall)
8.55 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{re}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.2 is the Safety Factor Against Sliding, $R\mathrm{Tan}\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
3.2 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+60 - Level 4

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

3 is H, height of the gabion wall (ft)
3 is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
3.5 is a', the width of the floodwall footing (ft)
3.88 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
0.97 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
2.03 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.55 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
14.04 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	5	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
3.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.25 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.112 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.070 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
4	3.0	3.0	9.0	1.08	1.74	1.88
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	3.0	Total Area	9.0		Total Mom.	1.88

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 133+60 - Level 4

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

1.08 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
1.11 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.13 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.03 is F_{eV}, or $\mathrm{Sin}(\delta-\theta)F_e$ (k/ft of wall)
0.13 is F_{eH}, or $\mathrm{Cos}(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_b hH_1Ka$ (k/ft of wall)
0.15 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 62.38 is θ_1, or $\mathrm{Tan}^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 74.62 is θ_2, or $\mathrm{Tan}^{-1}[(a'+b')/H']$
0.28 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

0.72 is $H'-z'$, or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
1.31 is z', moment arm for footing surcharge load (ft) — 837.65 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
415.78 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

0.33 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
1.88 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.08 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
1.96 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
3.4 is the Safety Factor Against Sliding, $R\mathrm{Tan}\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
5.9 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash Sheet No:_____ Of _____
Job Number: 046308 Des. By:_____ Date:_____
Location: Wickenburg, AZ Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 136+30 - Full Wall Height

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

10	is H, height of the gabion wall (ft)
7.5	is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
5.25	is a', the width of the floodwall footing (ft)
3.59	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
1.15	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
8.85	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.58	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
18.43	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	14	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.6 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
10.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)

0.27 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$

0.048 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$

0.057 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
1	3.0	7.5	22.5	2.7	3.95	10.67
2	3.0	6.0	18.0	2.16	5.21	11.26
3	3.0	4.5	13.5	1.62	6.47	10.49
4	1.0	3.0	3.0	0.36	7.56	2.72
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	10.0	Total Area	57.0		Total Mom.	35.14

35.14 is M_{rg}, resisting mom.

TRUE means that the sum of the gabions entered equals H entered above.

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 136+30 - Full Wall Height

TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

6.84 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
7.16 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.62 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.32 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.59 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_b h H_1 Ka$ (k/ft of wall)
1.31 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 22.08 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 44.97 is θ_2, or $\tan^{-1}[(a'+b')/H']$
2.89 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

4.47 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
4.38 is z', moment arm for footing surcharge load (ft) — 3519.08 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
875.36 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

11.01 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
35.14 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
2.53 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
37.67 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.2 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
3.4 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

Maximum Applied Bearing Pressure

1.25 is B/6
0.03 is e, the eccentricity, $B/2 - (M_r-M_o)/R$ (ft)
TRUE means that e < B/6, which is required
7.45 is B', or B effective, B - 2|e| (ft)
0.96 is σ_v, or R / B' (ksf)

Allowable Bearing Capacity

0.970 is s_γ, or 1 - 0.4(B'/L)
1.931 is n, or (2+B'/L) / (1+B'/L)
0.480 is i_γ, or $(1 - F_H/R)^{(n+1)}$
0.789 is $b_\gamma = b_q$, or $(1-\theta\tan\phi_f)^2$
33.20 is N_γ, an internal friction angle factor from AASHTO Table 4.4.7.1A
24.93 is N_q, a bearing capacity factor from AASHTO Table 4.4.7.1A
1.05 is s_q, or $1+(B'/L)\tan\phi_f$
0.62 is i_q, or $(1 - F_H/R)^n$
4.09 is q_{ult}, or $0.5\gamma_w B'N_\gamma s_\gamma b_\gamma i_\gamma + \gamma_{Df}D_fN_q s_q b_q i_q$ (ksf)
1.36 is q_{all}, or q_{ult} / SF (ksf)

Note: q_{all} must be > or = σ_v

TRUE q_{all} is > or = σ_v

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 136+30 - Level 2

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

7	is H, height of the gabion wall (ft)
6	is B, the base width of the gabion wall (ft) — 0.9 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
5.25	is a', the width of the floodwall footing (ft)
3.59	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
1.15	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
5.85	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.58	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
18.43	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	11	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.8 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
7.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.27	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.059	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
2	3.0	6.0	18.0	2.16	3.21	6.94
3	3.0	4.5	13.5	1.62	4.47	7.25
4	1.0	3.0	3.0	0.36	5.56	2.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	7.0	Total Area	34.5		Total Mom.	16.19

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 136+30 - Level 2

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

4.14 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
4.30 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.79 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.16 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.78 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr} h H_1 Ka$ (k/ft of wall)
0.94 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 31.54 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 56.50 is θ_2, or $\tan^{-1}[(a'+b')/H']$
1.72 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

2.57 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
3.28 is z', moment arm for footing surcharge load (ft) — 2617.50 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
753.48 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

4.90 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
16.19 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.98 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
17.18 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.2 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
3.5 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 136+30 - Level 3

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

4	is H, height of the gabion wall (ft)
4.5	is B, the base width of the gabion wall (ft) — 1.1 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
5.25	is a', the width of the floodwall footing (ft)
3.59	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
1.15	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
2.85	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.58	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
18.43	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	8	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.0 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
4.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.27	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.063	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k-ft)
3	3.0	4.5	13.5	1.62	2.48	4.01
4	1.0	3.0	3.0	0.36	3.56	1.28
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	4.0	Total Area	16.5		Total Mom.	5.29

5.29 is M_{rg}, resisting mom.

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Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 136+30 - Level 3

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

1.98 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
2.03 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.26 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.05 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.25 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr} h H_1 Ka$ (k/ft of wall)
0.38 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 51.55 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 72.13 is θ_2, or $\tan^{-1}[(a'+b')/H']$
0.63 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

1.05 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
1.80 is z', moment arm for footing surcharge load (ft) — 1396.40 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
495.48 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

1.02 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
5.29 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.24 is M_{re}, resisting moment from vertical component of F_e (k-ft/ft of wall)
5.53 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{re}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.8 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
5.4 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 136+30 - Level 4

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

1	is H, height of the gabion wall (ft)
3	is B, the base width of the gabion wall (ft) — 3.0 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
5.25	is a', the width of the floodwall footing (ft)
3.59	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
1.15	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
0	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.58	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
18.43	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	5	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
1.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.27	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.112	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.070	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
4	1.0	3.0	3.0	0.36	1.56	0.56
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	1.0	Total Area	3.0		Total Mom.	0.56

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 136+30 - Level 4

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

0.36 is V_1, or γ_0(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
0.36 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.02 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.00 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.02 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_b hH_1Ka$ (k/ft of wall)
0.00 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 0.00 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 0.00 is θ_2, or $\tan^{-1}[(a'+b')/H']$
0.02 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

0.00 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
0.00 is z', moment arm for footing surcharge load (ft) — 7033.10 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
1159.93 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

0.01 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
0.56 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.01 is M_{re}, resisting moment from vertical component of F_e (k-ft/ft of wall)
0.57 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{re}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
19.9 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
108.2 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of_____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 137+20 - Full Wall Height

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

9	is H, height of the gabion wall (ft)
6	is B, the base width of the gabion wall (ft) — 0.7 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
6.25	is a', the width of the floodwall footing (ft)
5.3	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
1.7	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
7.3	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.73	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
8	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_h, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
11.3	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	11	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.8 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
9.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.24	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.059	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
1	3.0	6.0	18.0	2.16	3.21	6.94
2	3.0	4.5	13.5	1.62	4.47	7.25
3	3.0	3.0	9.0	1.08	5.73	6.19
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	9.0	Total Area	40.5		Total Mom.	20.39

is M_{rg}, resisting mom.

TRUE means that the sum of the gabions entered equals H entered above.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 137+20 - Full Wall Height

TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

4.86 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
5.09 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.16 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.23 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.14 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_b h H_1 Ka$ (k/ft of wall)
1.29 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 35.98 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 57.71 is θ_2, or $\tan^{-1}[(a'+b')/H']$
2.43 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

3.09 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
4.21 is z', moment arm for footing surcharge load (ft) — 4308.14 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
1517.40 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

8.84 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
20.39 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
1.47 is M_{rs}, resisting moment from vertical component of F_e (k-ft/ft of wall)
21.85 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{rs}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.8 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
2.5 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

Maximum Applied Bearing Pressure

1.00 is B/6
0.44 is e, the eccentricity, $B/2 - (M_r-M_o)/R$ (ft)
TRUE means that e < B/6, which is required
5.12 is B', or B effective, B - 2|e| (ft)
0.99 is σ_v, or R / B' (ksf)

Allowable Bearing Capacity

0.980 is s_γ, or $1 - 0.4(B'/L)$
1.951 is n, or $(2+B'/L) / (1+B'/L)$
0.472 is i_γ, or $(1 - F_H/R)^{(n+1)}$
0.788 is $b_\gamma = b_q$, or $(1-\theta\tan\phi_f)^2$
33.95 is N_γ, an internal friction angle factor from AASHTO Table 4.4.7.1A
25.36 is N_q, a bearing capacity factor from AASHTO Table 4.4.7.1A
1.03 is s_q, or $1+(B'/L)\tan\phi_f$
0.61 is i_q, or $(1 - F_H/R)^n$
3.37 is q_{ult}, or $0.5\gamma_{fw}B'N_\gamma s_\gamma b_\gamma i_\gamma + \gamma_{Df}D_fN_q s_q b_q i_q$ (ksf)
1.12 is q_{all}, or q_{ult} / SF (ksf)

Note: q_{all} must be > or = σ_v

TRUE q_{all} is > or = σ_v

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 137+20 - Level 2

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

6	is H, height of the gabion wall (ft)
4.5	is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
6.25	is a', the width of the floodwall footing (ft)
5.3	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
1.7	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
4.3	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.73	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
8	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
11.3	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	8	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.0 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
6.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.24	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.063	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
2	3.0	4.5	13.5	1.62	2.48	4.01
3	3.0	3.0	9.0	1.08	3.74	4.03
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	6.0	Total Area	22.5		Total Mom.	8.05

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 137+20 - Level 2

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

2.70 is V_1, or γ_0(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
2.80 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.52 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.10 is F_{eV}, or $Sin(\delta-\theta)F_e$ (k/ft of wall)
0.51 is F_{eH}, or $Cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr}hH_1Ka$ (k/ft of wall)
0.65 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 50.95 is θ_1, or $Tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 69.58 is θ_2, or $Tan^{-1}[(a'+b')/H']$
1.16 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

1.61 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
2.69 is z', moment arm for footing surcharge load (ft) — 2724.08 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
1097.00 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

2.77 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
8.05 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.48 is M_{rs}, resisting moment from vertical component of F_e (k-ft/ft of wall)
8.53 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{rs}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.1 is the Safety Factor Against Sliding, $RTan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
3.1 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash Sheet No:_____ Of _____
Job Number: 046308 Des. By:_____ Date:_____
Location: Wickenburg, AZ Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 137+20 - Level 3

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

3	is H, height of the gabion wall (ft)
3	is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
6.25	is a', the width of the floodwall footing (ft)
5.3	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
1.7	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
1.3	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.73	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
8	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
11.3	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	5	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
3.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.24	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.112	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.070	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
3	3.0	3.0	9.0	1.08	1.74	1.88
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	3.0	Total Area	9.0		Total Mom.	1.88

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 137+20 - Level 3

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

1.08 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
1.11 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.13 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.03 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.13 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_w h H_1 Ka$ (k/ft of wall)
0.08 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 76.22 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 83.58 is θ_2, or $\tan^{-1}[(a'+b')/H']$
0.20 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

0.44 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
0.86 is z', moment arm for footing surcharge load (ft) — 856.69 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
387.13 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

0.19 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
1.88 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.08 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
1.96 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
4.7 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
10.1 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash Sheet No:_____ Of _____
Job Number: 046308 Des. By:_____ Date:_____
Location: Wickenburg, AZ Ck'd By:_____ Date:_____

Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 137+80 - Full Wall Height

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

9	is H, height of the gabion wall (ft)
6	is B, the base width of the gabion wall (ft) — 0.7 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
5.25	is a', the width of the floodwall footing (ft)
5.39	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
0.7	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
8.3	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.58	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
8	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
18.43	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	11	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.8 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
9.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.27	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.059	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
1	3.0	6.0	18.0	2.16	3.21	6.94
2	3.0	4.5	13.5	1.62	4.47	7.25
3	3.0	3.0	9.0	1.08	5.73	6.19
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	9.0	Total Area	40.5		Total Mom.	20.39

is M_{rp}, resisting mom.

TRUE means that the sum of the gabions entered equals H entered above.

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Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 137+80 - Full Wall Height

TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

4.86 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
5.12 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.31 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.26 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.29 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_r h H_1 Ka$ (k/ft of wall)
1.02 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 33.00 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 52.04 is θ_2, or $\tan^{-1}[(a'+b')/H']$
2.30 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

3.69 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
4.61 is z', moment arm for footing surcharge load (ft) — 4297.09 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
1655.98 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

8.55 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
20.39 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
1.65 is M_{rz}, resisting moment from vertical component of F_e (k-ft/ft of wall)
22.04 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{rz}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.9 is the Safety Factor Against Sliding, $R\tan\phi_{mbr}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
2.6 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

Maximum Applied Bearing Pressure
1.00 is B/6
0.36 is e, the eccentricity, $B/2 - (M_r-M_o)/R$ (ft)
TRUE means that e < B/6, which is required
5.27 is B', or B effective, B - 2|e| (ft)
0.97 is σ_v, or R / B' (ksf)

Allowable Bearing Capacity
0.979 is s_γ, or 1 - 0.4(B'/L)
1.950 is n, or (2+B'/L) / (1+B'/L)
0.426 is i_γ, or $(1 - F_H/R)^{(n+1)}$
0.788 is $b_\gamma = b_q$, or $(1-\theta\tan\phi_f)^2$
33.95 is N_γ, an internal friction angle factor from AASHTO Table 4.4.7.1A
25.36 is N_q, a bearing capacity factor from AASHTO Table 4.4.7.1A
1.03 is s_q, or $1+(B'/L)\tan\phi_f$
0.57 is i_q, or $(1 - F_H/R)^n$
3.14 is q_{ult}, or $0.5\gamma_w B'N_\gamma s_\gamma b_\gamma i_\gamma + \gamma_{Df}D_fN_qs_qb_qi_q$ (ksf)
1.05 is q_{all}, or q_{ult} / SF (ksf)

Note: q_{all} must be > or = σ_v

TRUE q_{all} is > or = σ_v

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 137+80 - Level 2

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

6	is H, height of the gabion wall (ft)
4.5	is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
5.25	is a', the width of the floodwall footing (ft)
5.39	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
0.7	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
5.3	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.58	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
8	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
18.43	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	8	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.0 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
6.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_G, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_G, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.27	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.063	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft^2)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
2	3.0	4.5	13.5	1.62	2.48	4.01
3	3.0	3.0	9.0	1.08	3.74	4.03
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	6.0	Total Area	22.5		Total Mom.	8.05

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 137+80 - Level 2

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

2.70 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
2.81 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.58 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.11 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.57 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr}hH_1Ka$ (k/ft of wall)
0.62 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 45.48 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 63.52 is θ_2, or $\tan^{-1}[(a'+b')/H']$
1.19 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

2.07 is $H'-z'$, or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
3.23 is z', moment arm for footing surcharge load (ft) — 2997.66 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
1293.33 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

3.13 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
8.05 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.55 is M_{rs}, resisting moment from vertical component of F_e (k-ft/ft of wall)
8.59 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{rs}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.1 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
2.7 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 137+80 - Level 3

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

3	is H, height of the gabion wall (ft)
3	is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
5.25	is a', the width of the floodwall footing (ft)
5.39	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
0.7	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
2.3	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.58	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
8	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
18.43	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	5	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
3.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.27	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.112	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.070	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
3	3.0	3.0	9.0	1.08	1.74	1.88
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	3.0	Total Area	9.0		Total Mom.	1.88

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 137+80 - Level 3

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

1.08 is V_1, or γ_0(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
1.11 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.15 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.03 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.14 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr}hH_1Ka$ (k/ft of wall)
0.16 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 66.89 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 77.80 is θ_2, or $\tan^{-1}[(a'+b')/H']$
0.30 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

0.80 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
1.50 is z', moment arm for footing surcharge load (ft) — 1380.90 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
671.36 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

0.39 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
1.88 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.09 is M_{re}, resisting moment from vertical component of F_e (k-ft/ft of wall)
1.97 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{re}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
3.2 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
5.1 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 217+20 - Full Wall Height

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

12 is H, height of the gabion wall (ft)
9 is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
10.75 is a', the width of the floodwall footing (ft)
3.91 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
3.1 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
8.9 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.93 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
8 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
9.46 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	17	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
12.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{DS}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.055 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
1	3.0	9.0	27.0	3.24	4.69	15.20
2	3.0	7.5	22.5	2.7	5.95	16.07
3	3.0	4.5	13.5	1.62	7.95	12.88
4	3.0	3.0	9.0	1.08	9.21	9.95
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	12.0	Total Area	72.0		Total Mom.	54.10

54.10 is M_{rg}, resisting mom.

TRUE means that the sum of the gabions entered equals H entered above.

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Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 217+20 - Full Wall Height

TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

8.64 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
9.04 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
2.02 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.40 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.98 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_s hH_1Ka$ (k/ft of wall)
3.22 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 23.72 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 58.74 is θ_2, or $\tan^{-1}[(a'+b')/H']$
5.20 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

4.09 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
4.81 is z', moment arm for footing surcharge load (ft) — 6718.63 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
1013.34 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

23.40 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
54.10 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
3.78 is M_{rs}, resisting moment from vertical component of F_e (k-ft/ft of wall)
57.88 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{rs}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.5 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
2.5 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

Maximum Applied Bearing Pressure
1.50 is B/6
0.68 is e, the eccentricity, $B/2 - (M_r-M_o)/R$ (ft)
TRUE means that e < B/6, which is required
7.83 is B', or B effective, B - 2|e| (ft)
1.18 is σ_v, or R / B' (ksf)

Allowable Bearing Capacity
0.969 is s_γ, or 1 - 0.4(B'/L)
1.929 is n, or (2+B'/L) / (1+B'/L)
0.485 is i_γ, or $(1 - F_H/R)^{(n+1)}$
0.790 is $b_\gamma = b_q$, or $(1-\theta\tan\phi_f)^2$
32.71 is N_γ, an internal friction angle factor from AASHTO Table 4.4.7.1A
24.64 is N_q, a bearing capacity factor from AASHTO Table 4.4.7.1A
1.05 is s_q, or $1+(B'/L)\tan\phi_f$
0.62 is i_q, or $(1 - F_H/R)^n$
4.07 is q_{ult}, or $0.5\gamma_{fw}B'N_\gamma s_\gamma b_\gamma i_\gamma + \gamma_{Df}D_fN_qs_qb_qi_q$ (ksf)
1.36 is q_{all}, or q_{ult} / SF (ksf)

Note: q_{all} must be > or = σ_v

TRUE q_{all} is > or = σ_v

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 217+20 - Level 2

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

9 is H, height of the gabion wall (ft)
7.5 is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
10.75 is a', the width of the floodwall footing (ft)
3.91 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
3.1 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
5.9 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.93 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
8 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
9.46 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	14	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.6 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
9.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.057 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
2	3.0	7.5	22.5	2.7	3.95	10.67
3	3.0	4.5	13.5	1.62	5.95	9.64
4	3.0	3.0	9.0	1.08	7.21	7.79
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	9.0	Total Area	45.0		Total Mom.	28.10

28.10 is M_{rg}, resisting mom.

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Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 217+20 - Level 2

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

5.40 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
5.62 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.14 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.22 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.11 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr}hH_1Ka$ (k/ft of wall)
2.11 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 33.53 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 68.08 is θ_2, or $\tan^{-1}[(a'+b')/H']$
3.22 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

2.43 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
3.47 is z', moment arm for footing surcharge load (ft) — 4711.51 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
863.27 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

10.66 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
28.10 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
1.76 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
29.86 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.5 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
2.8 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash Sheet No:_____ Of _____
Job Number: 046308 Des. By:_____ Date:_____
Location: Wickenburg, AZ Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 217+20 - Level 3

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

6	is H, height of the gabion wall (ft)
4.5	is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
10.75	is a', the width of the floodwall footing (ft)
3.91	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
3.1	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
2.9	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.93	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
8	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	8	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.0 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
6.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.063	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
3	3.0	4.5	13.5	1.62	2.48	4.01
4	3.0	3.0	9.0	1.08	3.74	4.03
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	6.0	Total Area	22.5		Total Mom.	8.05

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 217+20 - Level 3

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

2.70 is V_1, or γ_0(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
2.80 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.50 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.10 is F_{eV}, or $\mathrm{Sin}(\delta-\theta)F_e$ (k/ft of wall)
0.49 is F_{eH}, or $\mathrm{Cos}(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr} h H_1 Ka$ (k/ft of wall)
0.76 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) 53.44 is θ_1, or $\mathrm{Tan}^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) 78.81 is θ_2, or $\mathrm{Tan}^{-1}[(a'+b')/H']$
1.26 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

1.05 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
1.85 is z', moment arm for footing surcharge load (ft) 2404.83 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
558.99 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

2.40 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
8.05 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.47 is M_{re}, resisting moment from vertical component of F_e (k-ft/ft of wall)
8.52 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{re}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.9 is the Safety Factor Against Sliding, $R\mathrm{Tan}\phi_{mbr}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
3.5 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 217+20 - Level 4

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

3 is H, height of the gabion wall (ft)
3 is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
10.75 is a', the width of the floodwall footing (ft)
3.91 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
3.1 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
0 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.93 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
8 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_{ts}, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
14.04 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	5	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
3.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.25 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.112 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.070 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
4	3.0	3.0	9.0	1.08	1.74	1.88
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	3.0	Total Area	9.0		Total Mom.	1.88

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 217+20 - Level 4

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

1.08 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
1.11 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.13 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.03 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.13 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_s hH_1Ka$ (k/ft of wall)
0.00 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 0.00 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 0.00 is θ_2, or $\tan^{-1}[(a'+b')/H']$
0.13 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

0.00 is $H'-z'$, or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
0.00 is z', moment arm for footing surcharge load (ft) — 19342.40 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
1375.93 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

0.13 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
1.88 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.08 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
1.96 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
7.3 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
14.8 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 219+19 - Full Wall Height

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

12 is H, height of the gabion wall (ft)
9 is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
11.75 is a', the width of the floodwall footing (ft)
3 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
4 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
8 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.97 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_{fr}, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
0 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	17	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
12.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.21 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.055 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
1	3.0	9.0	27.0	3.24	4.69	15.20
2	3.0	7.5	22.5	2.7	5.95	16.07
3	3.0	4.5	13.5	1.62	7.95	12.88
4	3.0	3.0	9.0	1.08	9.21	9.95
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	12.0	Total Area	72.0		Total Mom.	54.10

54.10 is M_{rg}, resisting mom.

TRUE means that the sum of the gabions entered equals H entered above.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 219+19 - Full Wall Height

TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

8.64	is V_1, or γ_g(Total Area) (k/ft of wall)
0.00	is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
9.00	is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.81	is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.36	is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.78	is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00	is F_{tr}, or $\gamma_b hH_1Ka$ (k/ft of wall)
3.53	is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall)
0.00	is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall)
5.31	is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$
20.56	is θ_1, or $\tan^{-1}(b'/H')$
61.53	is θ_2, or $\tan^{-1}[(a'+b')/H']$
3.72	is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
4.28	is z', moment arm for footing surcharge load (ft)
6194.92	is R_{fs}, or $(a'+b')^2(90-\theta_2)$
625.00	is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

22.23	is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
54.10	is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00	is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
3.40	is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
57.49	is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5

1.5 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$

TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0

2.6 is the Safety Factor Against Overturning, M_r / M_o

TRUE means that the Safety Factor is OK

Maximum Applied Bearing Pressure

1.50	is B/6
0.58	is e, the eccentricity, $B/2 - (M_r-M_o)/R$ (ft)
TRUE	means that e < B/6, which is required
7.84	is B', or B effective, B - 2|e| (ft)
1.15	is σ_v, or R / B' (ksf)

Allowable Bearing Capacity

0.969	is s_γ, or $1 - 0.4(B'/L)$
1.927	is n, or $(2+B'/L) / (1+B'/L)$
0.525	is i_γ, or $(1 - F_H/R)^{(n+1)}$
0.790	is $b_\gamma = b_q$, or $(1-\theta\tan\phi_f)^2$
32.71	is N_γ, an internal friction angle factor from AASHTO Table 4.4.7.1A
24.64	is N_q, a bearing capacity factor from AASHTO Table 4.4.7.1A
1.05	is s_q, or $1+(B'/L)\tan\phi_f$
0.65	is i_q, or $(1 - F_H/R)^n$
4.44	is q_{ult}, or $0.5\gamma_w B'N_\gamma s_\gamma b_\gamma i_\gamma + \gamma_D D_f N_q s_q b_q i_q$ (ksf)
1.48	is q_{all}, or q_{ult} / SF (ksf)

Note: q_{all} must be > or = σ_v

TRUE q_{all} is > or = σ_v

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 219+19 - Level 2

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

9 is H, height of the gabion wall (ft)
7.5 is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
11.75 is a', the width of the floodwall footing (ft)
3 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
4 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
5 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.97 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
9.46 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	14	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.6 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
9.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.057 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
2	3.0	7.5	22.5	2.7	3.95	10.67
3	3.0	4.5	13.5	1.62	5.95	9.64
4	3.0	3.0	9.0	1.08	7.21	7.79
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	9.0	Total Area	45.0		Total Mom.	28.10

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 219+19 - Level 2

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

5.40 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
5.62 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.14 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.22 is F_{eV}, or $Sin(\delta-\theta)F_e$ (k/ft of wall)
1.11 is F_{eH}, or $Cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_b hH_1Ka$ (k/ft of wall)
2.17 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 30.96 is θ_1, or $Tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 71.27 is θ_2, or $Tan^{-1}[(a'+b')/H']$
3.29 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

2.06 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
2.94 is z', moment arm for footing surcharge load (ft) — 4074.03 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
531.33 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

9.72 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
28.10 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
1.76 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
29.86 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
1.5 is the Safety Factor Against Sliding, $RTan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
3.1 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 219+19 - Level 3

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

6 is H, height of the gabion wall (ft)
4.5 is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3 is B_T, the top width of the gabion wall (ft)
3 is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
11.75 is a', the width of the floodwall footing (ft)
3 is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
4 is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
2 is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.97 is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1 is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125 is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2 is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0 is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0 is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1 is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100 is L, the length of the wall (ft)
9.46 is β, the backslope angle (deg)
10 is θ, the wall tilt angle (deg)
21.3 is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3 is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed
ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers
γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	8	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.0 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0 is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
6.0 is H_1, the height from bottom of footing to finished ground
0.0 is H_2, the height from top of wall to finished ground at back face of wall
1 is D_f, the gabion wall footing embedment (ft)
0.120 is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120 is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41 is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120 is γ_b, unit weight of the backfill soils (kcf)
32 is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23 is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.063 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
3	3.0	4.5	13.5	1.62	2.48	4.01
4	3.0	3.0	9.0	1.08	3.74	4.03
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	6.0	Total Area	22.5		Total Mom.	8.05

is M_{rg}, resisting mom.

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 219+19 - Level 3

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

2.70 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
2.80 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.50 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.10 is F_{eV}, or $Sin(\delta-\theta)F_e$ (k/ft of wall)
0.49 is F_{eH}, or $Cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_t h H_1 Ka$ (k/ft of wall)
0.56 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 56.31 is θ_1, or $Tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 82.28 is θ_2, or $Tan^{-1}[(a'+b')/H']$
1.05 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

0.71 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
1.29 is z', moment arm for footing surcharge load (ft) — 1679.98 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
303.21 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

1.71 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
8.05 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.47 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
8.52 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.3 is the Safety Factor Against Sliding, $RTan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
5.0 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 219+19 - Level 4

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

3	is H, height of the gabion wall (ft)
3	is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
11.75	is a', the width of the floodwall footing (ft)
3	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
4	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
0	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.97	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
6.1	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	5	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
3.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.112 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$

0.049 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$

0.070 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
3	3.0	3.0	9.0	1.08	1.74	1.88
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	3.0	Total Area	9.0		Total Mom.	1.88

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 219+19 - Level 4

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

1.08 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
1.10 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.13 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.02 is F_{eV}, or $\mathrm{Sin}(\delta-\theta)F_e$ (k/ft of wall)
0.12 is F_{eH}, or $\mathrm{Cos}(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr} h H_1 Ka$ (k/ft of wall)
0.00 is F_{hw}, or $q_{hw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 0.00 is θ_1, or $\mathrm{Tan}^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 0.00 is θ_2, or $\mathrm{Tan}^{-1}[(a'+b')/H']$
0.12 is F_H, or $F_{eH}+F_{tr}+F_{hw}+F_{hp}$

0.00 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
0.00 is z', moment arm for footing surcharge load (ft) — 19580.63 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
810.00 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

0.12 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{hw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
1.88 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.08 is M_{re}, resisting moment from vertical component of F_e (k-ft/ft of wall)
1.95 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{re}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
7.8 is the Safety Factor Against Sliding, $R\mathrm{Tan}\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
15.8 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 221+30 - Full Wall Height

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

12	is H, height of the gabion wall (ft)
7.5	is B, the base width of the gabion wall (ft) — 0.6 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
7.5	is a', the width of the floodwall footing (ft)
14.3	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
0.23	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
11.77	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.75	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
18	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
14.04	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	14	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.6 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
12.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.25	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.057	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
1	3.0	7.5	22.5	2.7	3.95	10.67
2	3.0	6.0	18.0	2.16	5.21	11.26
3	3.0	4.5	13.5	1.62	6.47	10.49
4	3.0	3.0	9.0	1.08	7.73	8.35
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	12.0	Total Area	63.0		Total Mom.	40.77

40.77 is M_{rg}, resisting mom.

TRUE means that the sum of the gabions entered equals H entered above.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 221+30 - Full Wall Height

TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

7.56	is V_1, or γ_g(Total Area) (k/ft of wall)
0.00	is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
7.98	is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
2.16	is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.42	is F_{eV}, or $Sin(\delta-\theta)F_e$ (k/ft of wall)
2.11	is F_{eH}, or $Cos(\delta-\theta)F_e$ (k/ft of wall)
0.00	is F_{tr}, or $\gamma_b h H_1 Ka$ (k/ft of wall)
1.09	is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall)
0.00	is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall)
3.20	is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$
50.54	is θ_1, or $Tan^{-1}(b'/H')$
61.64	is θ_2, or $Tan^{-1}[(a'+b')/H']$
4.53	is $H'-z'$, or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
7.24	is z', moment arm for footing surcharge load (ft)
13480.17	is R_{fs}, or $(a'+b')^2(90-\theta_2)$
8068.56	is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

16.33	is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
40.77	is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00	is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
3.41	is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
44.19	is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5

2.2 is the Safety Factor Against Sliding, $RTan\phi_{min}/F_H$

TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0

2.7 is the Safety Factor Against Overturning, M_r / M_o

TRUE means that the Safety Factor is OK

Maximum Applied Bearing Pressure

1.25 is B/6

0.26 is e, the eccentricity, $B/2 - (M_r-M_o)/R$ (ft)

TRUE means that e < B/6, which is required

6.98 is B', or B effective, B - 2|e| (ft)

1.14 is σ_v, or R / B' (ksf)

Allowable Bearing Capacity

0.972	is s_γ, or $1 - 0.4(B'/L)$
1.935	is n, or $(2+B'/L) / (1+B'/L)$
0.405	is i_γ, or $(1 - F_H/R)^{(n+1)}$
0.789	is $b_\gamma = b_q$, or $(1-\theta Tan\phi_f)^2$
33.20	is N_γ, an internal friction angle factor from AASHTO Table 4.4.7.1A
24.93	is N_q, a bearing capacity factor from AASHTO Table 4.4.7.1A
1.04	is s_q, or $1+(B'/L)Tan\phi_f$
0.55	is i_q, or $(1 - F_H/R)^n$
3.40	is q_{ult}, or $0.5\gamma_{fw}B'N_\gamma s_\gamma b_\gamma i_\gamma + \gamma_{Df}D_fN_q s_q b_q i_q$ (ksf)
1.13	is q_{all}, or q_{ult} / SF (ksf)

Note: q_{all} must be > or = σ_v

FALSE q_{all} is > or = σ_v

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 221+30 - Level 2

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

4.86 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
5.10 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.21 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.24 is F_{eV}, or $\mathrm{Sin}(\delta-\theta)F_e$ (k/ft of wall)
1.19 is F_{eH}, or $\mathrm{Cos}(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr}hH_1Ka$ (k/ft of wall)
0.70 is F_{hw}, or $q_{hw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 58.48 is θ_1, or $\mathrm{Tan}^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 68.09 is θ_2, or $\mathrm{Tan}^{-1}[(a'+b')/H']$
1.89 is F_H, or $F_{eH}+F_{tr}+F_{hw}+F_{hp}$

3.20 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
5.57 is z', moment arm for footing surcharge load (ft) — 10414.70 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
6445.57 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

7.48 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{hw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
20.39 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
1.53 is M_{rs}, resisting moment from vertical component of F_e (k-ft/ft of wall)
21.91 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{rs}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.3 is the Safety Factor Against Sliding, $R\mathrm{Tan}\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
2.9 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash Sheet No:_____ Of _____
Job Number: 046308 Des. By:_____ Date:_____
Location: Wickenburg, AZ Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 221+30 - Level 3

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

6	is H, height of the gabion wall (ft)
4.5	is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
7.5	is a', the width of the floodwall footing (ft)
14.3	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
0.23	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
5.77	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.75	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
18	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_t/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
14.04	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	8	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.0 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
6.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.25	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.063	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
3	3.0	4.5	13.5	1.62	2.48	4.01
4	3.0	3.0	9.0	1.08	3.74	4.03
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	6.0	Total Area	22.5		Total Mom.	8.05

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 221+30 - Level 3

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

2.70 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
2.81 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.54 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.11 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.53 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_t hH_1Ka$ (k/ft of wall)
0.34 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 68.03 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 75.17 is θ_2, or $\tan^{-1}[(a'+b')/H']$
0.87 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

2.01 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
3.76 is z', moment arm for footing surcharge load (ft) — 7045.45 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
4493.44 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

2.35 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
8.05 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.50 is M_{re}, resisting moment from vertical component of F_e (k-ft/ft of wall)
8.55 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{re}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.8 is the Safety Factor Against Sliding, $R\tan\phi_{mio}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
3.6 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash Sheet No:_____ Of _____
Job Number: 046308 Des. By:_____ Date:_____
Location: Wickenburg, AZ Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 221+30 - Level 4

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

3	is H, height of the gabion wall (ft)
3	is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
7.5	is a', the width of the floodwall footing (ft)
14.3	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
0.23	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
2.77	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.75	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
18	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{ts}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
14.04	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	5	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
3.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.25	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.112	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.070	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
4	3.0	3.0	9.0	1.08	1.74	1.88
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	3.0	Total Area	9.0		Total Mom.	1.88

is M_{rg}, resisting mom.

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Gabion Wall Design In Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 221+30 - Level 4

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

1.08 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
1.11 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.13 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.03 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.13 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_h h H_1 Ka$ (k/ft of wall)
0.09 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 79.04 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 82.76 is θ_2, or $\tan^{-1}[(a'+b')/H']$
0.22 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

0.94 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
1.83 is z', moment arm for footing surcharge load (ft) — 3441.42 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
2241.78 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

0.29 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
1.88 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.08 is M_{re}, resisting moment from vertical component of F_e (k-ft/ft of wall)
1.96 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{re}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
4.4 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
6.8 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 222+90 - Full Wall Height

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

12	is H, height of the gabion wall (ft)
7.5	is B, the base width of the gabion wall (ft) — 0.6 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
7.5	is a', the width of the floodwall footing (ft)
14.61	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.23	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
9.77	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.75	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
18	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{ts}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	14	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.6 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
12.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111 is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$

0.048 is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$

0.057 is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
1	3.0	7.5	22.5	2.7	3.95	10.67
2	3.0	6.0	18.0	2.16	5.21	11.26
3	3.0	4.5	13.5	1.62	6.47	10.49
4	3.0	3.0	9.0	1.08	7.73	8.35
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	12.0	Total Area	63.0		Total Mom.	40.77

40.77 is M_{rg}, resisting mom.

TRUE means that the sum of the gabions entered equals H entered above.

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 222+90 - Full Wall Height

TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

7.56	is V_1, or γ_0(Total Area) (k/ft of wall)	
0.00	is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)	
7.96	is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)	
2.02	is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)	
0.40	is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)	
1.98	is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)	
0.00	is F_{tr}, or $\gamma_b hH_1Ka$ (k/ft of wall)	
0.81	is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall)	56.23 is θ_1, or $\tan^{-1}(b'/H')$
0.00	is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall)	66.16 is θ_2, or $\tan^{-1}[(a'+b')/H']$
2.79	is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$	
3.61	is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)	
6.16	is z', moment arm for footing surcharge load (ft)	11654.11 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
		7208.58 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

12.90	is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
40.77	is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00	is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
3.20	is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
43.97	is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5

2.5 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$

TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0

3.4 is the Safety Factor Against Overturning, M_r / M_o

TRUE means that the Safety Factor is OK

Maximum Applied Bearing Pressure

1.25 is B/6

-0.16 is e, the eccentricity, $B/2 - (M_r-M_o)/R$ (ft)

TRUE means that e < B/6, which is required

7.19 is B', or B effective, B - 2|e| (ft)

1.11 is σ_v, or R / B' (ksf)

Allowable Bearing Capacity

0.971	is s_γ, or $1 - 0.4(B'/L)$
1.933	is n, or $(2+B'/L) / (1+B'/L)$
0.432	is i_γ, or $(1 - F_H/R)^{(n+1)}$
0.789	is $b_\gamma = b_q$, or $(1-\theta\tan\phi_f)^2$
33.20	is N_γ, an internal friction angle factor from AASHTO Table 4.4.7.1A
24.93	is N_q, a bearing capacity factor from AASHTO Table 4.4.7.1A
1.05	is s_q, or $1+(B'/L)\tan\phi_f$
0.58	is i_q, or $(1 - F_H/R)^n$
3.66	is q_{ult}, or $0.5\gamma_w B'N_\gamma s_\gamma b_\gamma i_\gamma + \gamma_{Df}D_fN_qs_qb_qi_q$ (ksf)
1.22	is q_{all}, or q_{ult} / SF (ksf)

Note: q_{all} must be > or = σ_v

TRUE q_{all} is > or = σ_v

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 222+90 - Level 2

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

9	is H, height of the gabion wall (ft)
6	is B, the base width of the gabion wall (ft) — 0.7 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
7.5	is a', the width of the floodwall footing (ft)
14.61	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.23	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
6.77	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.75	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
18	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	11	is D_2 to be used (ft)	0	is D_3 to be used (ft)

32.8 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
9.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.048	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.059	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
2	3.0	6.0	18.0	2.16	3.21	6.94
3	3.0	4.5	13.5	1.62	4.47	7.25
4	3.0	3.0	9.0	1.08	5.73	6.19
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	9.0	Total Area	40.5		Total Mom.	20.39

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 222+90 - Level 2

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

4.86 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
5.08 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
1.14 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.22 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
1.11 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_b hH_1Ka$ (k/ft of wall)
0.44 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) 65.14 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) 72.98 is θ_2, or $\tan^{-1}[(a'+b')/H']$
1.56 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

2.38 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
4.39 is z', moment arm for footing surcharge load (ft) 8322.41 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
5306.87 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

5.28 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
20.39 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
1.43 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
21.82 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
2.8 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
4.1 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 222+90 - Level 3

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

6	is H, height of the gabion wall (ft)
4.5	is B, the base width of the gabion wall (ft) — 0.8 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
7.5	is a', the width of the floodwall footing (ft)
14.61	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.23	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
3.77	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.75	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
18	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	8	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.0 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
6.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_G, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_G, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.111	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.063	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
3	3.0	4.5	13.5	1.62	2.48	4.01
4	3.0	3.0	9.0	1.08	3.74	4.03
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	6.0	Total Area	22.5		Total Mom.	8.05

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 222+90 - Level 3

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

2.70 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
2.80 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.50 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.10 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.49 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_{tr}hH_1Ka$ (k/ft of wall)
0.15 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 75.53 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 80.32 is θ_2, or $\tan^{-1}[(a'+b')/H']$
0.65 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

1.28 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
2.49 is z', moment arm for footing surcharge load (ft) — 4730.38 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
3088.46 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

1.36 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}z')+F_{hp}(W/3)$ (k-ft/ft of wall)
8.05 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.47 is M_{re}, resisting moment from vertical component of F_e (k-ft/ft of wall)
8.52 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{re}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
3.8 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
6.2 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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Gannett Fleming ENGINEERS AND PLANNERS

Job Name: FCDMC - Sols Wash
Job Number: 046308
Location: Wickenburg, AZ

Sheet No:_____ Of _____
Des. By:_____ Date:_____
Ck'd By:_____ Date:_____

Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 222+90 - Level 4

Reference: AASHTO, Standard Specifications for Highway Bridges, 17th Ed., 2002

Variables

3	is H, height of the gabion wall (ft)
3	is B, the base width of the gabion wall (ft) — 1.0 is the B/H ratio
3	is B_T, the top width of the gabion wall (ft)
3	is X, the distance from the front of the top basket to the toe of the slope above wall(ft)
7.5	is a', the width of the floodwall footing (ft)
14.61	is b', the distance from the gabion wall backface to the nearest edge of the floodwall footing (ft)
2.23	is d', the distance from the top of the gabion wall to the bottom of the floodwall footing (ft)
0.77	is H', the height from the floodwall footing to the bottom of the gabion wall (ft)
0.75	is q_{fw}, the equivalent uniform bearing pressure of the floodwall (ksf)
18	is c', the distance from the gabion wall backface to the nearest edge of the traffic surcharge (ft)
0.125	is γ_{tr}, unit weight to be used in traffic surcharge calculation (kcf)
2	is h, the depth of soil to reflect traffic surcharge (ft)

Traffic surcharge is within $H_1/2$? **FALSE**

0	is W, the height of water behind the wall for determining hydrostatic pressure (ft)
100.0	is Z_r, the vertical distance from bottom of gabion wall footing to top of rock (ft)
1	is Z_w, the depth to water table below bottom of gabion wall footing (ft)
100	is L, the length of the wall (ft)
9.46	is β, the backslope angle (deg)
10	is θ, the wall tilt angle (deg)
21.3	is δ, the angle of wall friction (deg) - Note: Typically 2/3(ϕ_b).
3	is SF, the Bearing Capacity Safety Factor for calculating q_{all}

D_1, D_2, and D_3 are depths of soil layers to be analyzed

ϕ_1, ϕ_2, and ϕ_3 are the respective internal friction angles of the layers

γ_1, γ_2, and γ_3 are the respective unit weights of the layers

1	is D_1 actual (ft)	99	is D_2 actual (ft)	0	is D_3 actual (ft)
41	is ϕ_1 (deg)	32	is ϕ_2 (deg)	0	is ϕ_3 (deg)
0.120	is γ_1 (kcf)	0.11	is γ_2 (kcf)	0	is γ_3 (kcf)
1	is D_1 to be used (ft)	5	is D_2 to be used (ft)	0	is D_3 to be used (ft)

33.5 is ϕ_f, the weighted internal friction angle of the foundation soils (deg)

$$\phi_f = (D_1\phi_1+D_2\phi_2+D_3\phi_3) / (D_1 + D_2 + D_3)$$

41.0	is ϕ_{min}, the minimum internal friction angle used for sliding (deg)
3.0	is H_1, the height from bottom of footing to finished ground
0.0	is H_2, the height from top of wall to finished ground at back face of wall
1	is D_f, the gabion wall footing embedment (ft)
0.120	is γ_{Df}, unit weight of soil above the bottom of footing (kcf)
0.120	is γ_g, unit weight of the gabion fill (kcf) - Note: Based on 30% porosity.
41	is ϕ_g, the internal friction angle of the gabion fill (deg)
0.120	is γ_b, unit weight of the backfill soils (kcf)
32	is ϕ_b, the internal friction angle of the backfill soils (deg)
0.23	is Ka (sloped backslope)

$$Ka = \cos^2(\phi_b+\theta)/\{\cos^2\theta\cos(\theta-\delta)[1+[\sin(\phi_b+\delta)\sin(\phi_b-\beta)/\cos(\theta-\delta)\cos(\theta+\beta)]^{1/2}]^2\}$$

0.112	is γ_f, the weighted unit weight of foundation soils (kcf) $\gamma_f = (\gamma_1D_1+\gamma_2D_2+\gamma_3D_3)/(D_1+D_2+D_3)$
0.049	is γ'_f, the effective unit weight of foundation soils (kcf) $\gamma'_f = \gamma_f - 0.0624$
0.070	is γ_{fw}, the weighted unit weight of the foundation soils affected by depth of water below the footing (kcf) IF: Z_w<B use $\gamma_{fw} = \gamma'_f+(Z_w/B)(\gamma_f-\gamma'_f)$

Select Gabion Sizes - Note: From bottom to top of wall.

Row #	Height (ft)	Width (ft)	Area (ft²)	Weight (k)	Mom. Arm (ft)	Moment (k ft)
4	3.0	3.0	9.0	1.08	1.74	1.88
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
			0.0	0	0.00	0.00
Total Ht.	3.0	Total Area	9.0		Total Mom.	1.88

is M_{rg}, resisting mom.

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Gabion Wall Design in Drained Conditions, Coulomb Theory, Level Front - Sloping Backfill
Station 222+90 - Level 4

TRUE means that the sum of the gabions entered equals H entered above.
TRUE means that the width of the bottom row of gabions entered equals B entered above.

Loads

1.08 is V_1, or γ_g(Total Area) (k/ft of wall)
0.00 is V_2, or $\gamma_b(H_2B_T/2)$ (k/ft of wall)
1.10 is R, or $V_1 + V_2 + F_{eV}$ (k/ft of wall)
0.13 is F_e, or $0.5\gamma_b H_1^2 Ka$ (k/ft of wall)
0.02 is F_{eV}, or $\sin(\delta-\theta)F_e$ (k/ft of wall)
0.12 is F_{eH}, or $\cos(\delta-\theta)F_e$ (k/ft of wall)
0.00 is F_{tr}, or $\gamma_s h H_1 Ka$ (k/ft of wall)
0.01 is F_{fw}, or $q_{fw}/90[H'(\theta_2-\theta_1)]$ (k/ft of wall) — 86.98 is θ_1, or $\tan^{-1}(b'/H')$
0.00 is F_{hp}, or $0.5\gamma_w W^2$ (k/ft of wall) — 88.01 is θ_2, or $\tan^{-1}[(a'+b')/H']$
0.13 is F_H, or $F_{eH}+F_{tr}+F_{fw}+F_{hp}$

0.27 is H'-z', or $[H'^2(\theta_2-\theta_1)-(R_{fs}-Q_{fs})-57.30a'H']/[2H'(\theta_2-\theta_1)]$ (ft)
0.50 is z', moment arm for footing surcharge load (ft) — 975.05 is R_{fs}, or $(a'+b')^2(90-\theta_2)$
643.96 is Q_{fs}, or $b'^2(90-\theta_1)$

Moments

0.13 is M_o, overturning moment or $F_{eH}(H_1/3)+F_{tr}(H_1/2)+F_{fw}(z')+F_{hp}(W/3)$ (k-ft/ft of wall)
1.88 is M_{rg}, resisting moment from gabions (k-ft/ft of wall)
0.00 is M_{rs}, resisting moment from soil wedge above gabions (k-ft/ft of wall)
0.08 is M_{ra}, resisting moment from vertical component of F_e (k-ft/ft of wall)
1.95 is M_r, total resisting moment $M_{rg}+M_{rs}+M_{ra}$ (k-ft/ft of wall)

Safety Factor For Sliding FS > or = 1.5
7.4 is the Safety Factor Against Sliding, $R\tan\phi_{min}/F_H$
TRUE means that the Safety Factor is OK

Safety Factor For Overturning FS > or = 2.0
15.4 is the Safety Factor Against Overturning, M_r / M_o
TRUE means that the Safety Factor is OK

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12.0 SETTLEMENT ANALYSIS FOR TYPE A FLOODWALLS

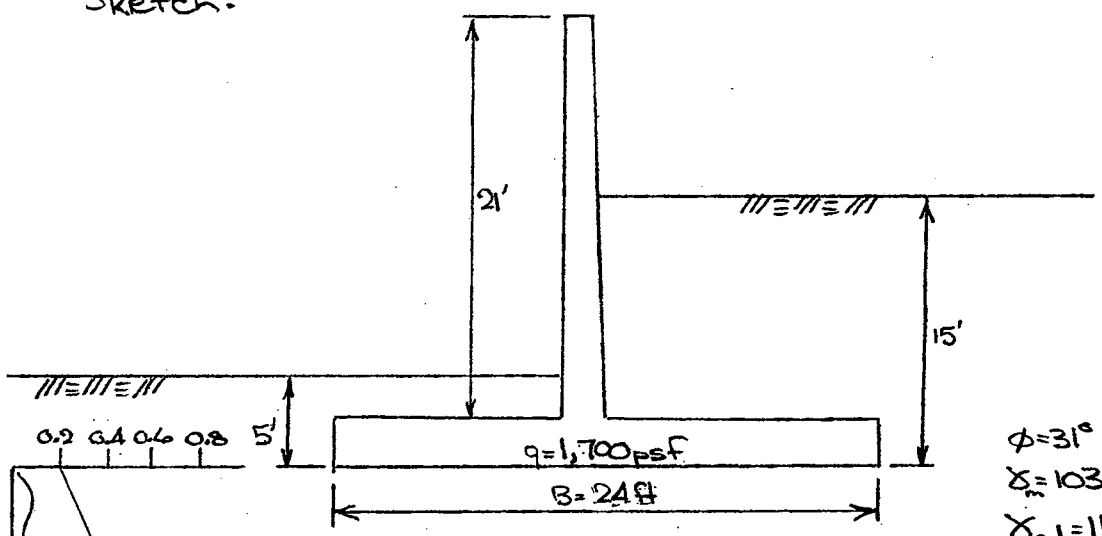
Estimate settlement of Type A Floodwall @ Station 227+50 SB:

Note that this section is critical w.r.t. footing size & pressure.

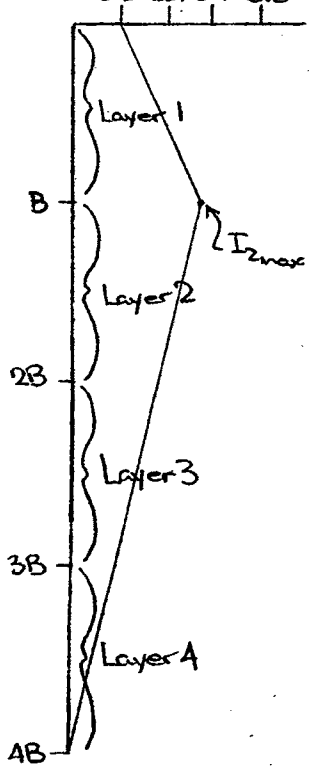
References: USACE, Settlement Analysis, EM 1110-1-1904, 1990.

Bowles, Foundation Analysis & Design, 4th Ed., 1988.

Sketch:



$\phi = 31°$
$\gamma_m = 103$ pcf
$\gamma_{sat} = 118$ pcf
$E_s = 400$ ksf



$$\Delta p = 1{,}700\text{ psf} - [5'(103\text{ pcf})] = 1{,}185\text{ psf}$$

$$I_{z max} = 0.5 + 0.1\left[\frac{\Delta p}{\sigma'_{vp}}\right]^{1/2}$$

$$= 0.5 + 0.1\left[\frac{1{,}185\text{ psf}}{103\text{ pcf}(29\text{ ft})}\right]^{1/2}$$

$$= 0.56 (@ B)$$

At $B/2 \Rightarrow I_z = 0.2 + (0.56 - 0.2)/2 = 0.38$

At $2B \Rightarrow I_z = 0.56 - (0.56/3) = 0.37$

At $3B \Rightarrow I_z = 0.56 - 2(0.56/3) = 0.19$

Layer	Δz (ft)	z_{cl} (ft)	E_s (ksf)	I_z	$\frac{I_z \Delta z}{E_s}$ (ft/ksf)
1	24	12	400	0.38	2.28×10^{-2}
2	24	36	400	0.47	2.82×10^{-2}
3	24	60	400	0.28	1.68×10^{-2}
4	24	84	400	0.10	0.60×10^{-2}
					$\Sigma = 7.38 \times 10^{-2}$

$$C_1 = 1 - 0.5\left(\frac{p_o}{\Delta p}\right) \geq 0.5 \Rightarrow C_1 = 1 - 0.5\left(\frac{5\text{ ft} \times 103\text{ pcf}}{1{,}185\text{ psf}}\right) = 0.78$$

$$C_2 = 1 + 0.2\log_{10}\left(\frac{t}{0.1}\right) \Rightarrow \text{Assume } t = 1\text{ year} \therefore C_2 = 1.2$$

$$\rho = C_1 C_2 \Delta p \Sigma \frac{I_z \Delta z}{E_s}$$

$$= 0.78(1.2)(1.185\text{ ksf})(0.0738)(12\text{ in/ft})$$

$$= \underline{\underline{0.98\text{ in}}}$$

<u>Note</u>: Consolidation settlement not an issue due to unsaturated soil conditions. Additionally, most settlement will occur during construction of the wall.

Bowles, Fnd. Analysis & Design, 4th Ed., 1988

TABLE 2-7 Typical range of values for the static stress-strain modulus E_s for selected soils

Field values depend on stress history, water content, density, etc.

Soil	E_s ksf	E_s Mpa
Clay		
Very soft	50–250	2–15
Soft	100–500	5–25
Medium	300–1000	15–50
Hard	1000–2000	50–100
Sandy	500–5000	25–250
Glacial till		
Loose	200–3200	10–150
Dense	3000–15 000	150–720
Very dense	10 000–30 000	500–1440
Loess	300–1200	15–60
Sand		
Silty	150–450	5–20
Loose	200–500	10–25
Dense	1000–1700	50–81
Sand and gravel		
Loose	1000–3000	50–150
Dense	2000–4000	100–200
Shale	3000–300 000	150–5000
Silt	40–400	2–20

Use E_s = 400 ksf

axis being
here is only

is a lateral
r than 0.5
ms—during
asticity does
lastic over
makes the
works with
value.
from the
determinate
difficulty in
erials are
number of

The *modulus of subgrade reaction* k_s is defined as the ratio of stress to deformation as shown on Fig. 2-37*c*. The units of k_s are the same as unit weight.

The shear modulus G' (and may be subscripted) is defined as the ratio of shear stress to shear strain. It is related to E_s and μ as

$$G'_s = \frac{s}{\epsilon_s} = \frac{E_s}{2(1+\mu)} \qquad (b)$$

The shearing strain ϵ_s is the change in right angle at any corner of an element as in Fig. 2-37*b* such that

$$\epsilon_s = \text{angle } BCD - \text{angle } B'C'D' \qquad (c)$$

Another concept occasionally used is the volumetric strain, defined as

$$\epsilon_v = \frac{\Delta V}{V} = \epsilon_1 + \epsilon_2 + \epsilon_3 \qquad (d)$$

286

13.0 SETTLEMENT ANALYSIS FOR TYPE B FLOODWALLS

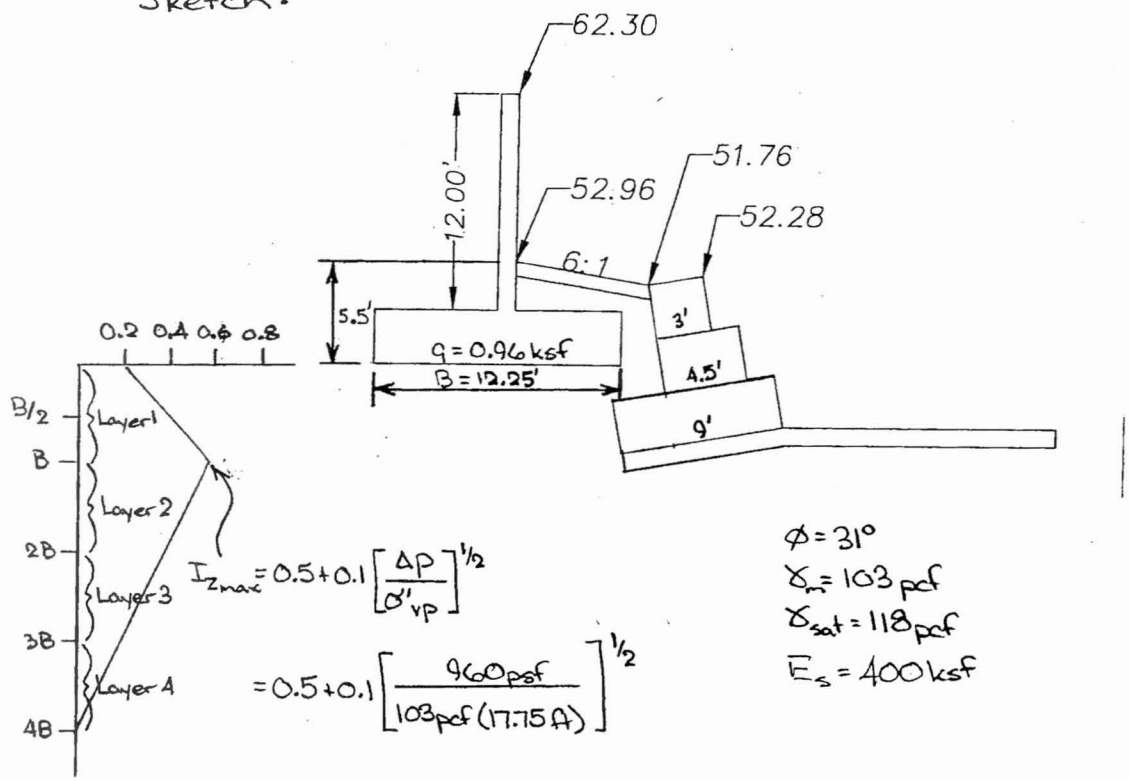
Estimate settlement of floodwall @ Station 120+70 NB:

Note that this setion is critical w.r.t. footing size & pressure.

References: USACE, Settlement Analysis, EM 1110-1-1904, 1990.

Bowles, Foundation Analysis & Design, 4th Ed., 1988.

Sketch:



$$I_{z_{max}} = 0.5 + 0.1\left[\frac{\Delta p}{\sigma'_{vp}}\right]^{1/2}$$

$$= 0.5 + 0.1\left[\frac{960\,psf}{103\,pcf\,(17.75\,ft)}\right]^{1/2}$$

$$= 0.57 \text{ (@ B)}$$

$\phi = 31°$
$\gamma_m = 103$ pcf
$\gamma_{sat} = 118$ pcf
$E_s = 400$ ksf

At $B/2 \Rightarrow I_z = 0.2 + (0.57 - 0.2)/2 = 0.39$

At $2B \Rightarrow I_z = 0.57 - (0.57/3) = 0.38$

At $3B \Rightarrow I_z = 0.57 - 2(0.57/3) = 0.19$

Layer	ΔZ (ft)	Z_d (ft)	E_s (ksf)	I_z	$\frac{I_z \Delta Z}{E_s}$ $(\frac{ft}{ksf})$
1	12.25	6.13	400	0.39	1.19×10^{-2}
2	12.25	18.38	400	0.48	1.47×10^{-2}
3	12.25	30.60	400	0.29	0.89×10^{-2}
4	12.25	42.88	400	0.10	0.31×10^{-2}
					$\Sigma = 3.86 \times 10^{-2}$

$$C_1 = 1 - 0.5\left(\frac{p_o}{\Delta p}\right) \geq 0.5 \Rightarrow C_1 = 1 - 0.5\left(\frac{5.5ft \times 103pcf}{960psf}\right) = 0.70$$

$$C_2 = 1 + 0.2\log_{10}\left(\frac{t}{0.1}\right) \Rightarrow \text{Assume } t = 1.0_{yr} \therefore C_2 = 1.2$$

$$\rho = C_1 C_2 \Delta p \Sigma \frac{I_z \Delta Z}{E_s}$$

Conservative

$$= 0.70(1.20)(0.96ksf)(0.0386)(12in/ft)$$

$$= \underline{\underline{0.37in.}}$$

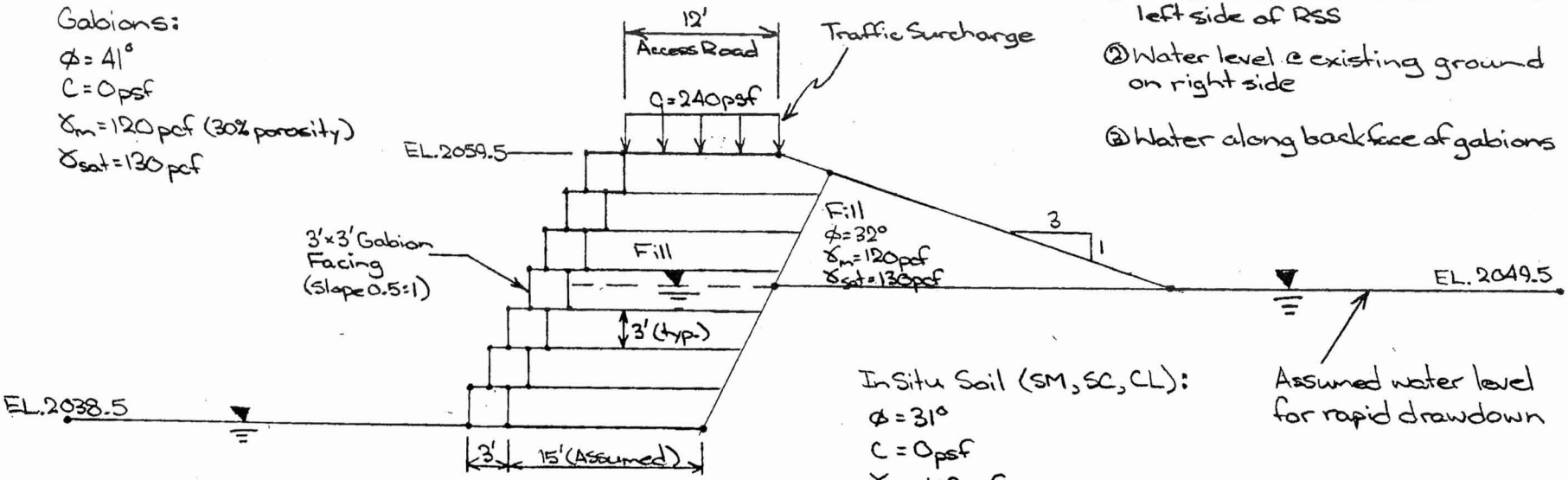
<u>Note</u>: Consolidation settlement not an issue due to unsaturated soil conditions. Additionally, most settlement will occur during construction of the wall.

14.0 REINFORCED SOIL SLOPE DESIGN

MCFCD - Sols Wash RSS Levee - Station 212+50 SB

Gabions:
$\phi = 41°$
$C = 0$ psf
$\gamma_m = 120$ pcf (30% porosity)
$\gamma_{sat} = 130$ pcf

Assumptions:
① Water level @ wash bottom on left side of RSS
② Water level @ existing ground on right side
③ Water along backface of gabions



In Situ Soil (SM, SC, CL):
$\phi = 31°$
$C = 0$ psf
$\gamma_m = 103$ pcf
$\gamma_{sat} = 118$ pcf

Note: Based on the seepage analysis the water table shown here is a conservative assumption for the rapid drawdown case.

Scale 1" = 12'

Gannett Fleming

SUBJECT MCFCD - Sols Wash RSS @ Station 212+50 SB
BY FDN DATE 8/06 CHKD. BY DATE
SHEET NO. 1 OF 1
JOB NO. 046308.300

291

MCFCD - Sols Wash RSS Levee -Sta. 212+50

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PROJECT IDENTIFICATION

Title: MCFCD - Sols Wash RSS Levee -Sta. 212+50
Project Number: -
Client:
Designer: Dave Checked: GC 09/06
Station Number: 212+50 SB

Description:
→ Analysis for dry/normal condition. ←

Company's information:

Name: Gannett Fleming Inc.
Street: 207 Senate Avenue
Camp Hill, PA 17011
Telephone #: 717 763 7211
Fax #: 717 303 0346
E-Mail:

Original file path and name: N:\433\Personal\DRS\MCFCD\MCFCD1.MSE
Original date and time of creating this file: Thu Mar 16 13:24:33 2006

PROGRAM MODE: ANALYSIS of a Complex Slope using GEOSYNTHETIC as reinforcing material.

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292

INPUT DATA (EXCLUDING REINFORCEMENT LAYOUT)

SOIL DATA

Soil Layer #:	Unit weight, γ [lb/ft ^{3}]	Internal angle of friction, ϕ [deg.]	Cohesion, c [lb/ft ^{2}]
....1.....Fill (RSS & Backfill).....	120.0	32.0	0.0
....2.....In-situ (sm, sc, cl).....	103.0	31.0	0.0

REINFORCEMENT

Reinforcement Type #	Geosynthetic Designated Name	Ultimate Strength, Tult [lb/ft]	Reduction Factor for Installation Damage, RFid	Reduction Factor for Durability, RFd	Reduction Factor for Creep, RFc	Coverage Ratio, Rc
1	Geosynthetic type #1	6000.00	3.00	1.50	1.50	1.00

Assumed

Interaction Parameters Type #	Geosynthetic Designated Name	== Direct Sliding == Cds-phi	Cds-c	==== Pullout ==== Ci	Alpha
1	Geosynthetic type #1	0.80	0.00	0.80	0.80

Relative Orientation of Reinforcement Force, ROR = 0.00. Assigned Factor of Safety to resist pullout, Fs-po = 1.50

WATER

Water is not present

SEISMICITY

Not Applicable

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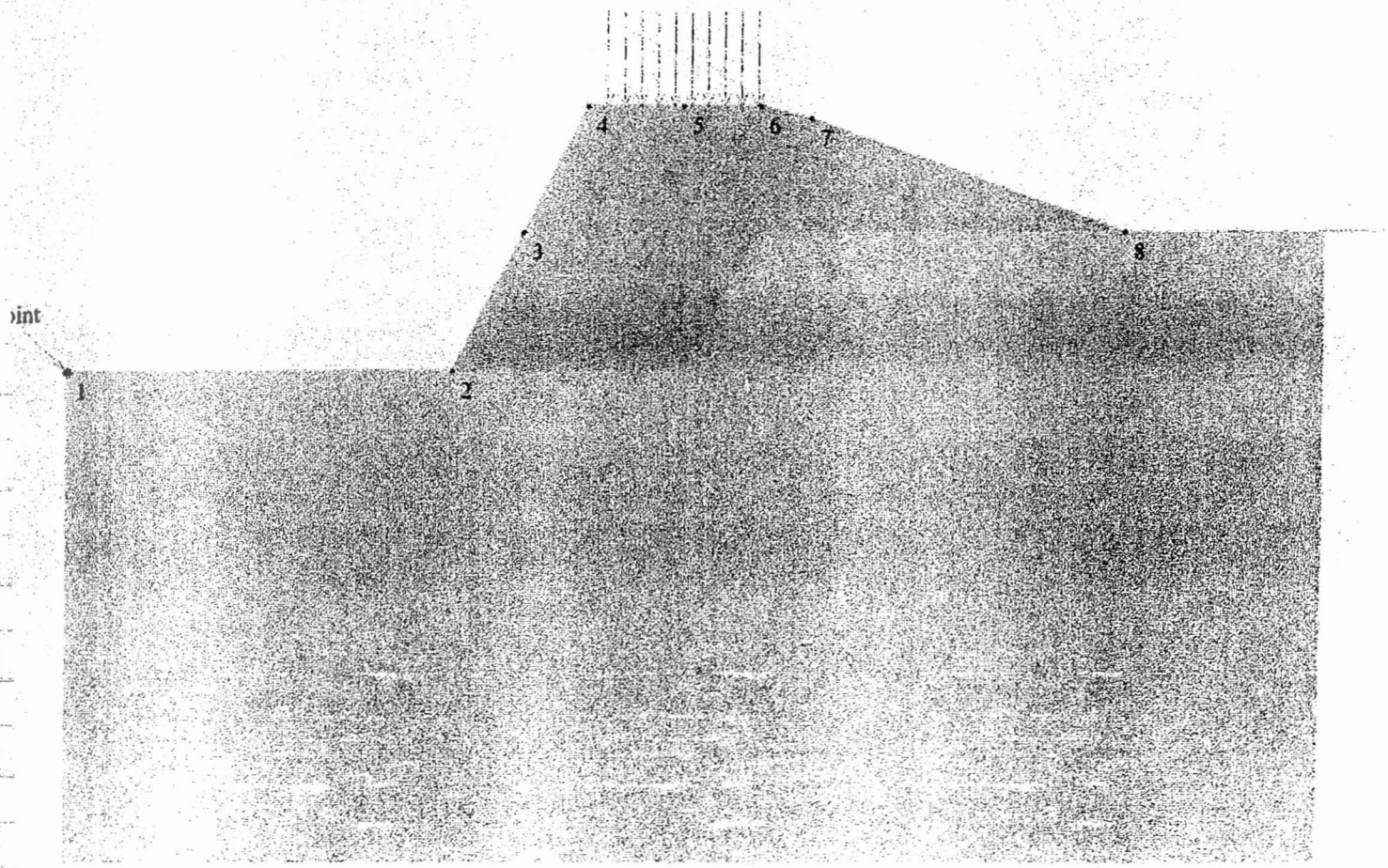
DRAWING OF SPECIFIED GEOMETRY - COMPLEX - Elaborate Input

-- Problem geometry is defined along sections selected by user at x ordinates.
-- Y1 represents the Y ordinates of soil surface. Y2 represent the ordinates of the end of soil layer 1 and start of soil layer 2, and so on.

GEOMETRY
Soil profile contains 2 layers (see details in next page)

UNIFORM SURCHARGE
Load Q1 = 240.00 [lb/ft²] inclined from verical at 0.00 degrees, starts at X1s = 12.80 and ends at X1e = 16.46 [ft].
Surcharge load, Q2.....None
Surcharge load, Q3.....None

STRIP LOAD
.....None.....



SCALE:

0 2 4 6[ft]

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294

TABULATED DETAILS OF SPECIFIED GEOMETRY

Soil profile contains 2 layers. Coordinates in [ft.]

#	X	Y1	Y2
1	0.00	38.50	38.50
2	30.00	38.50	38.50
3	35.50	49.50	38.50
4	40.50	59.50	38.50
5	48.00	59.50	38.50
6	54.00	59.50	49.50
7	58.00	58.50	49.50
8	82.50	49.50	49.50
9	110.00	49.50	49.50

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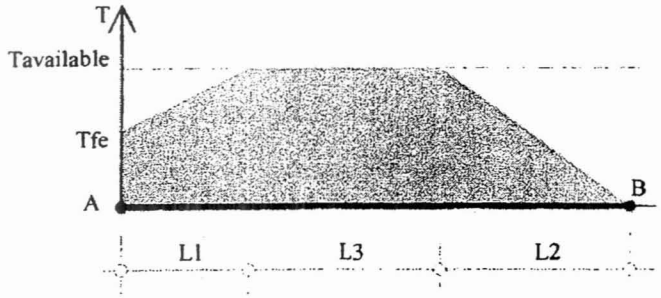
295

DISTRIBUTION OF AVAILABLE STRENGTH ALONG EACH REINFORCEMENT LAYER



A = Front-end of reinforcement (at face of slope)
B = Rear-end of reinforcement
AB = L1 + L2 + L3 = Embedded length of reinforcement

Tavailable = Long-term strength of reinforcement
Tfe = Available front-end strength (e.g., connection to facing)

L1 = Front-end 'pullout' length
L2 = Rear-end pullout length
Tavailable prevails along L3

$\frac{T_{ULT}}{(RF)_{TOTAL}} = T_A$

Factor of safety on resistance to pullout on either end of reinforcement, Fs-po = 1.50

Reinforcement Layer #	Designated Name	Height Relative to Toe [ft]	L [ft]	L1 [ft]	L2 [ft]	L3 [ft]	Tfe [lb/ft]	Tavailable [lb/ft]
1	Geosynthetic type #1	0.00	15.00	0.00	0.69	14.31	888.89	888.89
2	Geosynthetic type #1	1.50	15.00	0.00	0.72	14.28	888.89	888.89
3	Geosynthetic type #1	3.00	15.00	0.00	0.79	14.21	888.89	888.89
4	Geosynthetic type #1	4.50	15.00	0.00	0.85	14.15	888.89	888.89
5	Geosynthetic type #1	6.00	15.00	0.00	0.95	14.05	888.89	888.89
6	Geosynthetic type #1	7.50	15.00	0.00	1.05	13.95	888.89	888.89
7	Geosynthetic type #1	9.00	15.00	0.00	1.18	13.82	888.89	888.89
8	Geosynthetic type #1	10.50	15.00	0.00	1.35	13.65	888.89	888.89
9	Geosynthetic type #1	12.00	15.00	0.00	1.57	13.43	888.89	888.89
10	Geosynthetic type #1	13.50	15.00	0.00	1.87	13.13	888.89	888.89
11	Geosynthetic type #1	15.00	15.00	0.00	2.33	12.67	888.89	888.89
12	Geosynthetic type #1	16.50	15.00	0.00	3.12	11.88	888.89	888.89
13	Geosynthetic type #1	18.00	15.00	0.00	4.66	10.34	888.89	888.89
14	Geosynthetic type #1	19.50	15.00	0.00	9.32	5.68	888.89	888.89

(1.5 ft spacing
15 ft length (Note: 20 ft length req'd for sudden drawdown condition)

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RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each entry point (considering all specified exit points)

Entry Point #	Entry Point (X, Y) [ft]		Exit Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	42.00	59.50	30.15	38.98	18.03	59.67	23.97	7.73	
2	42.98	59.50	30.08	38.87	19.89	59.59	23.09	3.69	
3	43.96	59.50	29.97	38.78	21.09	59.86	22.88	2.71	
4	44.94	59.50	30.11	38.77	22.82	59.66	22.13	2.19	
5	45.92	59.50	29.96	38.68	23.98	59.80	21.95	1.97	
6	46.90	59.50	30.06	38.67	25.13	59.87	21.77	1.84	
7	47.88	59.51	29.89	38.58	26.71	59.52	21.18	1.75	
8	48.86	59.50	29.97	38.57	27.42	59.86	21.45	1.73	
9	49.84	59.50	29.75	38.52	28.54	59.79	21.30	1.72	
10	50.82	59.50	15.33	38.71	26.93	59.59	23.89	1.69	
11	51.80	59.50	14.75	38.65	27.27	59.75	24.53	1.61	
12	52.78	59.50	14.59	38.75	27.84	59.88	24.94	1.43	
13	53.76	59.50	16.05	38.73	29.12	59.62	24.64	1.34	
14	54.74	59.32	18.16	38.73	30.38	59.81	24.36	1.32	
15	55.72	59.07	16.06	38.71	29.30	61.72	26.55	1.32	OK
16	56.70	58.83	16.33	38.56	29.91	61.85	26.96	1.32	
17	57.68	58.58	16.82	38.67	30.21	63.07	27.83	1.33	
18	58.66	58.26	14.06	38.62	28.75	65.71	30.82	1.34	
19	59.63	57.90	14.93	38.53	29.03	67.27	32.01	1.36	
20	60.61	57.54	14.59	38.72	30.00	66.72	31.96	1.38	
21	61.59	57.18	13.82	38.74	29.69	68.73	33.93	1.40	
22	62.57	56.82	12.82	38.52	28.94	71.47	36.69	1.43	
23	63.55	56.46	12.08	38.53	28.63	73.86	39.02	1.47	
24	64.53	56.10	10.57	38.56	27.89	77.07	42.22	1.50	
25	65.51	55.74	9.07	38.59	27.14	80.57	45.70	1.54	
26	66.49	55.38	8.34	38.59	26.82	83.68	48.73	1.59	
27	67.47	55.02	6.86	38.61	26.07	87.80	52.81	1.64	
28	68.45	54.66	6.90	38.59	26.16	90.74	55.59	1.70	
29	69.43	54.30	6.19	38.58	25.80	94.76	59.50	1.76	
30	70.41	53.94	6.26	38.55	25.85	98.28	62.86	1.82	
31	71.39	53.58	6.34	38.53	25.88	102.14	66.55	1.89	
32	72.37	53.22	5.68	38.51	25.46	107.36	71.63	1.97	
33	73.35	52.86	2.21	38.70	24.89	110.55	75.34	2.05	
34	74.33	52.50	2.76	38.53	25.47	112.47	77.35	2.13	
35	75.31	52.14	2.10	38.51	25.08	118.49	83.22	2.22	
36	76.29	51.78	1.16	38.58	25.28	121.67	86.53	2.31	
37	77.27	51.42	-0.03	38.51	25.67	122.47	87.80	2.41	
38	78.25	51.06	-0.46	38.65	26.86	121.16	86.92	2.51	
39	79.23	50.70	-0.65	38.71	27.51	123.17	89.03	2.62	
40	80.20	50.34	-0.27	38.59	28.68	121.79	88.09	2.73	
41	81.18	49.98	-0.45	38.66	29.35	123.73	90.14	2.85	
42	82.16	49.62	-0.62	38.73	30.49	122.28	89.15	2.97	
43	83.14	49.50	-0.47	38.67	31.02	123.73	90.70	3.07	
44	84.12	49.50	-0.32	38.61	31.01	128.55	95.24	3.16	
45	85.10	49.50	-0.17	38.56	31.45	129.85	96.61	3.24	
46	86.08	49.50	-0.02	38.51	31.40	135.13	101.60	3.33	
47	87.06	49.50	-0.73	38.74	31.84	136.50	103.05	3.42	
48	88.04	49.50	-0.58	38.69	32.29	137.88	104.50	3.51	
49	89.02	49.50	-0.43	38.64	32.74	139.26	105.95	3.61	
50	90.00	49.50	-0.29	38.59	32.63	145.22	111.60	3.70	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-entry' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

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RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each exit point (considering all specified entry points)

Exit Point #	Exit Point (X, Y) [ft]		Entry Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	-0.61	38.89	59.63	57.90	21.68	73.20	40.92	1.53	
2	0.15	38.86	59.63	57.90	22.10	72.72	40.36	1.51	
3	1.01	38.74	60.61	57.54	22.40	74.82	41.94	1.50	
4	1.67	38.80	59.63	57.90	22.93	71.77	39.24	1.49	
5	2.54	38.69	59.63	57.90	23.07	72.14	39.24	1.48	
6	3.30	38.67	59.63	57.90	23.49	71.65	38.67	1.46	
7	4.05	38.64	59.63	57.90	23.91	71.16	38.11	1.45	
8	4.82	38.61	58.66	58.26	24.17	69.18	36.17	1.44	
9	5.58	38.59	58.66	58.26	24.59	68.72	35.63	1.43	
10	6.33	38.56	58.66	58.26	25.02	68.26	35.09	1.42	
11	7.09	38.53	58.66	58.26	25.45	67.80	34.55	1.41	
12	7.85	38.50	57.68	58.58	25.72	66.01	32.80	1.40	
13	8.17	38.75	58.66	58.26	26.04	67.57	33.92	1.39	
14	8.94	38.72	57.68	58.58	26.33	65.77	32.16	1.38	
15	9.70	38.69	57.68	58.58	26.77	65.33	31.64	1.37	
16	10.46	38.66	57.68	58.58	27.20	64.89	31.12	1.36	
17	11.22	38.64	56.70	58.83	27.51	63.26	29.52	1.35	
18	12.07	38.54	57.68	58.58	27.83	64.60	30.45	1.35	
19	12.74	38.58	55.72	59.07	28.26	61.34	27.55	1.34	
20	13.10	38.80	56.70	58.83	28.59	62.54	28.35	1.33	
21	13.87	38.78	55.72	59.07	28.92	61.03	26.87	1.33	
22	14.72	38.67	56.70	58.83	29.25	62.21	27.66	1.33	
23	15.48	38.65	55.72	59.07	29.59	60.70	26.18	1.32	
24	16.06	38.71	55.72	59.07	29.30	61.72	26.55	1.32	OK
25	16.75	38.74	55.72	59.07	30.27	60.34	25.48	1.32	
26	17.72	38.59	55.72	59.07	30.73	59.93	25.00	1.32	
27	18.16	38.73	54.74	59.32	30.38	59.81	24.36	1.32	
28	19.13	38.58	54.74	59.32	30.61	59.80	24.13	1.33	
29	19.70	38.65	55.72	59.07	30.90	60.86	24.88	1.33	
30	20.65	38.53	54.74	59.32	31.34	59.35	23.40	1.33	
31	21.26	38.59	55.72	59.08	32.38	59.10	23.33	1.35	
32	21.80	38.65	55.72	59.07	31.86	60.32	23.89	1.36	
33	22.80	38.52	55.72	59.07	32.10	60.27	23.65	1.36	
34	23.39	38.58	55.72	59.07	32.34	60.20	23.40	1.38	
35	23.99	38.62	55.72	59.07	32.58	60.12	23.16	1.39	
36	24.97	38.51	54.74	59.32	32.30	59.71	22.44	1.41	
37	25.61	38.53	55.72	59.07	32.22	61.18	23.59	1.42	
38	26.25	38.55	55.72	59.07	32.47	61.04	23.33	1.44	
39	26.90	38.56	55.72	59.07	32.72	60.88	23.06	1.45	
40	27.57	38.56	56.70	58.83	32.52	62.50	24.45	1.47	
41	28.24	38.57	55.72	59.07	32.93	60.94	22.86	1.49	
42	29.74	38.50	56.70	58.83	29.29	67.15	28.65	1.40	
43	30.00	38.50	57.68	58.58	30.50	66.93	28.43	1.50	
44	30.47	39.93	57.68	58.58	31.20	68.03	28.11	1.59	
45	31.15	41.39	57.68	58.58	34.02	66.02	24.80	1.69	
46	31.83	42.82	57.68	58.58	34.71	67.18	24.52	1.81	
47	32.78	44.23	57.68	58.58	37.31	65.15	21.40	1.95	
48	33.47	45.67	56.70	58.83	37.99	64.77	19.63	2.12	
49	34.23	47.09	57.68	58.58	40.27	64.44	18.37	2.32	
50	34.75	48.59	57.68	58.58	40.93	65.71	18.20	2.57	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-exit' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

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CRITICAL RESULTS OF ROTATIONAL AND TRANSLATIONAL STABILITY ANALYSES

Rotational (Circular Arc; Bishop) Stability Analysis

Minimum Factor of Safety = 1.32

Critical Circle: Xc = 29.30[ft], Yc = 61.72[ft], R = 26.55[ft]. (Number of slices used = 53)

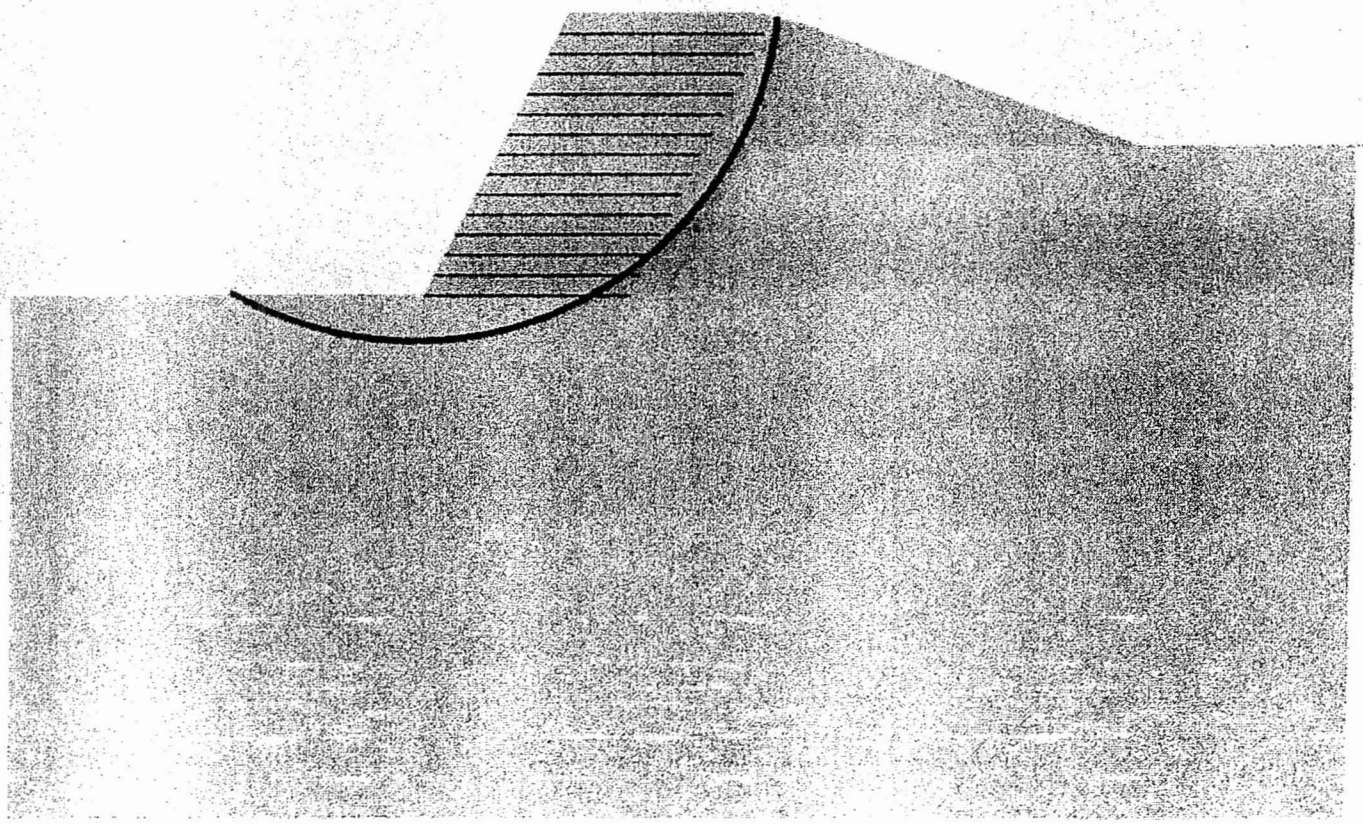
Translational (2-Part Wedge; Spencer), Direct Sliding, Stability Analysis

NOT CONDUCTED

Three-Part Wedge Stability Analysis

NOT CONDUCTED

REINFORCEMENT LAYOUT: DRAWING



SCALE:

0 2 4 6[ft]

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REINFORCEMENT LAYOUT: TABULATED DATA & QUANTITIES

Layer #	Reinf. Type #	Geosynthetic Designated Name	Height Relative to Toe [ft]	Embedded Length [ft]	Covergae Ratio, Rc	(X, Y) front [ft]		(X, Y) rear [ft]	
1	1	Geosynthetic type #1	0.00	15.00	1.00	30.00	126.31	45.00	126.31
2	1	Geosynthetic type #1	1.50	15.00	1.00	30.75	127.81	45.75	127.81
3	1	Geosynthetic type #1	3.00	15.00	1.00	31.50	129.31	46.50	129.31
4	1	Geosynthetic type #1	4.50	15.00	1.00	32.25	130.81	47.25	130.81
5	1	Geosynthetic type #1	6.00	15.00	1.00	33.00	132.31	48.00	132.31
6	1	Geosynthetic type #1	7.50	15.00	1.00	33.75	133.81	48.75	133.81
7	1	Geosynthetic type #1	9.00	15.00	1.00	34.50	135.31	49.50	135.31
8	1	Geosynthetic type #1	10.50	15.00	1.00	35.25	136.81	50.25	136.81
9	1	Geosynthetic type #1	12.00	15.00	1.00	36.00	138.31	51.00	138.31
10	1	Geosynthetic type #1	13.50	15.00	1.00	36.75	139.81	51.75	139.81
11	1	Geosynthetic type #1	15.00	15.00	1.00	37.50	141.31	52.50	141.31
12	1	Geosynthetic type #1	16.50	15.00	1.00	38.25	142.81	53.25	142.81
13	1	Geosynthetic type #1	18.00	15.00	1.00	39.00	144.31	54.00	144.31
14	1	Geosynthetic type #1	19.50	15.00	1.00	39.75	145.81	54.75	145.81

QUANTITIES

Reinf. Type #	Designated Name	Coverage Ratio	Area of reinforcemnt [ft²] / length of slope [ft]
1	Geosynthetic type #1	1.00	210.00

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300

CRITICAL RESULTS OF ROTATIONAL AND TRANSLATIONAL STABILITY ANALYSES

Rotational (Circular Arc; Bishop) Stability Analysis

Minimum Factor of Safety = 1.32

Critical Circle: Xc = 29.30[ft], Yc = 61.72[ft], R = 26.55[ft]. (Number of slices used = 53)

Translational (2-Part Wedge; Spencer), Direct Sliding, Stability Analysis

Minimum Factor of Safety = 1.32

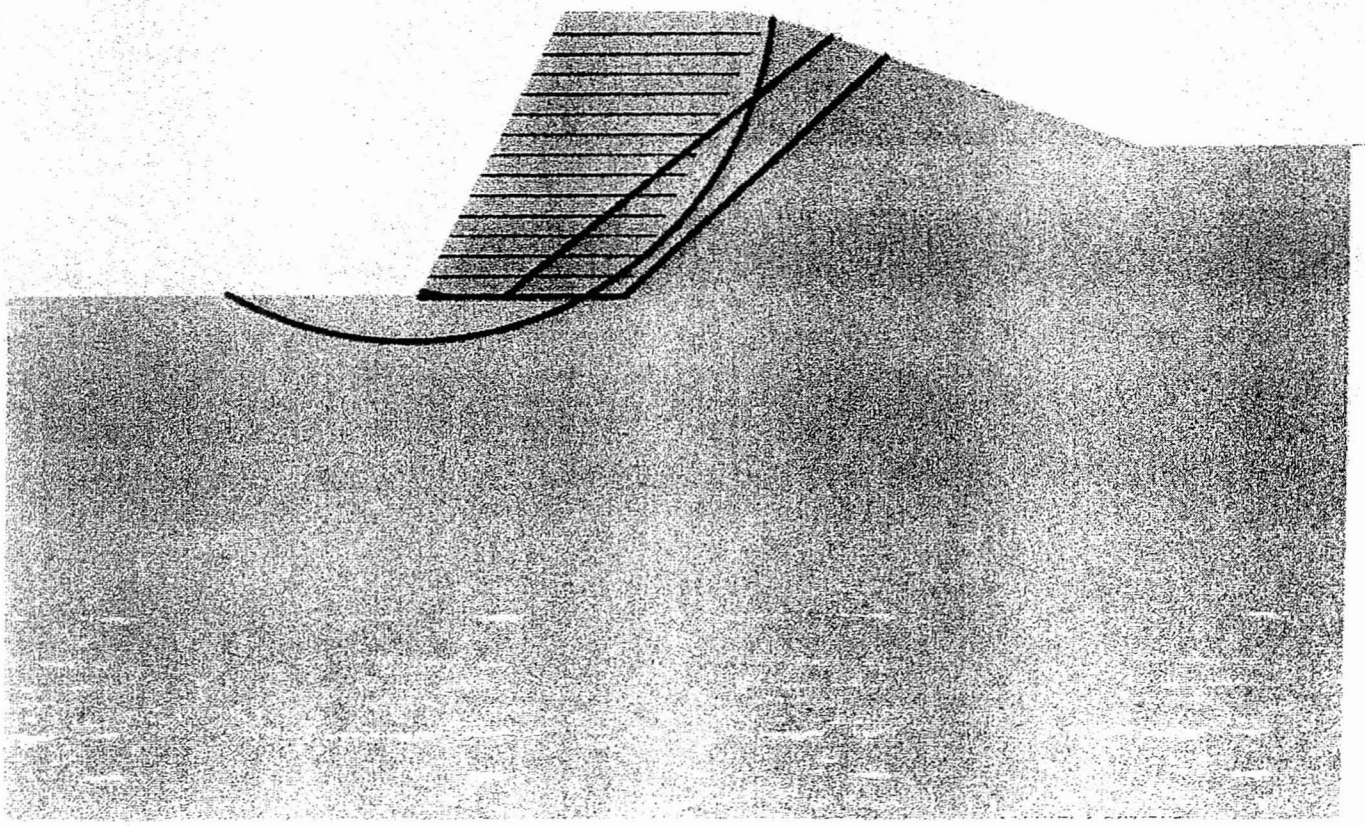
Critical Two-Part Wedge: (Xa = 30.00, Ya = 38.50) [ft]
(Xb = 36.26, Yb = 38.50) [ft]
(Xc = 60.03, Yc = 57.75) [ft]
(Number of slices used = 30)
Interslice resultant force inclination = 35.17 [degrees]

Three-Part Wedge Stability Analysis

Minimum Factor of Safety = 1.82

Critical Three-Part Wedge: (X2 = 30.21, Y2 = 38.91) [ft]
(X-left = 32.00, Y-left = 38.50) [ft]
(X-right = 45.00, Y-right = 38.50) [ft]
(X1 = 64.06, Y1 = 56.27) [ft]
(Number of slices used = 45)
Interslice resultant force inclination = 26.89 [degrees]

REINFORCEMENT LAYOUT: DRAWING



SCALE:

0 2 4 6[ft]

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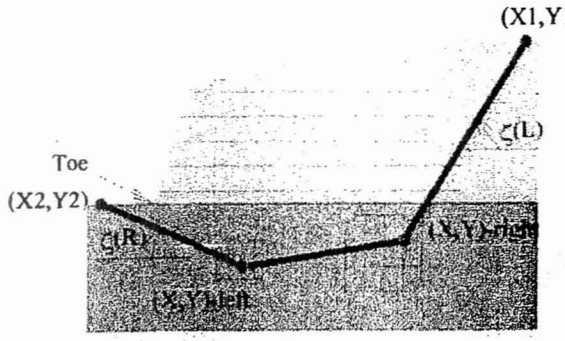
RESULTS OF 3-PART WEDGE ANALYSIS



Results in the table below represent the critical slip surface composed of a three-part wedge and identified by the specified points (X-left, Y-left) and (X-right, Y-right) and angles Zeta(L) and Zeta(R). ReSSA finds the (X,Y) coordinates, as well as the angles Zeta, based on user-specified search domain. The trace of the critical three-part wedge is fully defined by four points: (X1, Y1), (X-left, Y-left), (X-right, Y-right), (X2, Y2).

Critical 3-part wedge (Automatic search):

(X2, Y2) [ft]	Zeta(L) [degrees]	(X-left, Y-left) [ft]	(X-right, Y-right) [ft]	Zeta(R) [degrees]	(X1, Y1) [ft]	Fs
(30.21, 38.91)	13.00	(32.00, 38.50)	(45.00, 38.50)	43.00	(64.06, 56.27)	1.817

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MCFCD - Sols Wash RSS Levee -Sta. 212+50

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PROJECT IDENTIFICATION

Title: MCFCD - Sols Wash RSS Levee -Sta. 212+50
Project Number: -
Client:
Designer: Dave Checked: GC 09/06
Station Number: 212+50 SB

Description:
Analysis for 100-year flood drawdown condition.

Company's information:

Name: Gannett Fleming Inc.
Street: 207 Senate Avenue
Camp Hill, PA 17011
Telephone #: 717 763 7211
Fax #: 717 303 0346
E-Mail:

Original file path and name: N:\433\Personal\DRS\MCFCD\MCFCD2.MSE
Original date and time of creating this file: Thu Mar 16 13:24:33 2006

PROGRAM MODE: ANALYSIS of a Complex Slope using GEOSYNTHETIC as reinforcing material.

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303

INPUT DATA (EXCLUDING REINFORCEMENT LAYOUT)

SOIL DATA

========== Soil Layer #: ==========	Unit weight, γ [lb/ft ³]	Internal angle of friction, ϕ [deg.]	Cohesion, c [lb/ft ²]
....1.....Fill (RSS & Backfill).....	130.0	32.0	0.0
....2.....In-situ (sm, sc, cl).....	118.0	31.0	0.0

REINFORCEMENT

Reinforcement Type #	Geosynthetic Designated Name	Ultimate Strength, Tult [lb/ft]	Reduction Factor for Installation Damage, RFid	Reduction Factor for Durability, RFd	Reduction Factor for Creep, RFc	Coverage Ratio, Rc
1	Geosynthetic type #1	6000.00	3.00	1.50	1.50	1.00

Interaction Parameters Type #	Geosynthetic Designated Name	== Direct Sliding == Cds-phi	Cds-c	==== Pullout ==== Ci	Alpha
1	Geosynthetic type #1	0.80	0.00	0.80	0.80

Relative Orientation of Reinforcement Force, ROR = 0.00. Assigned Factor of Safety to resist pullout, Fs-po = 1.50

WATER

Unit weight of water = 62.45 [lb/ft ³]
Water pressure is defined by phreatic surface in Effective Stress Analysis.

SEISMICITY

Not Applicable

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DRAWING OF SPECIFIED GEOMETRY - COMPLEX - Elaborate Input

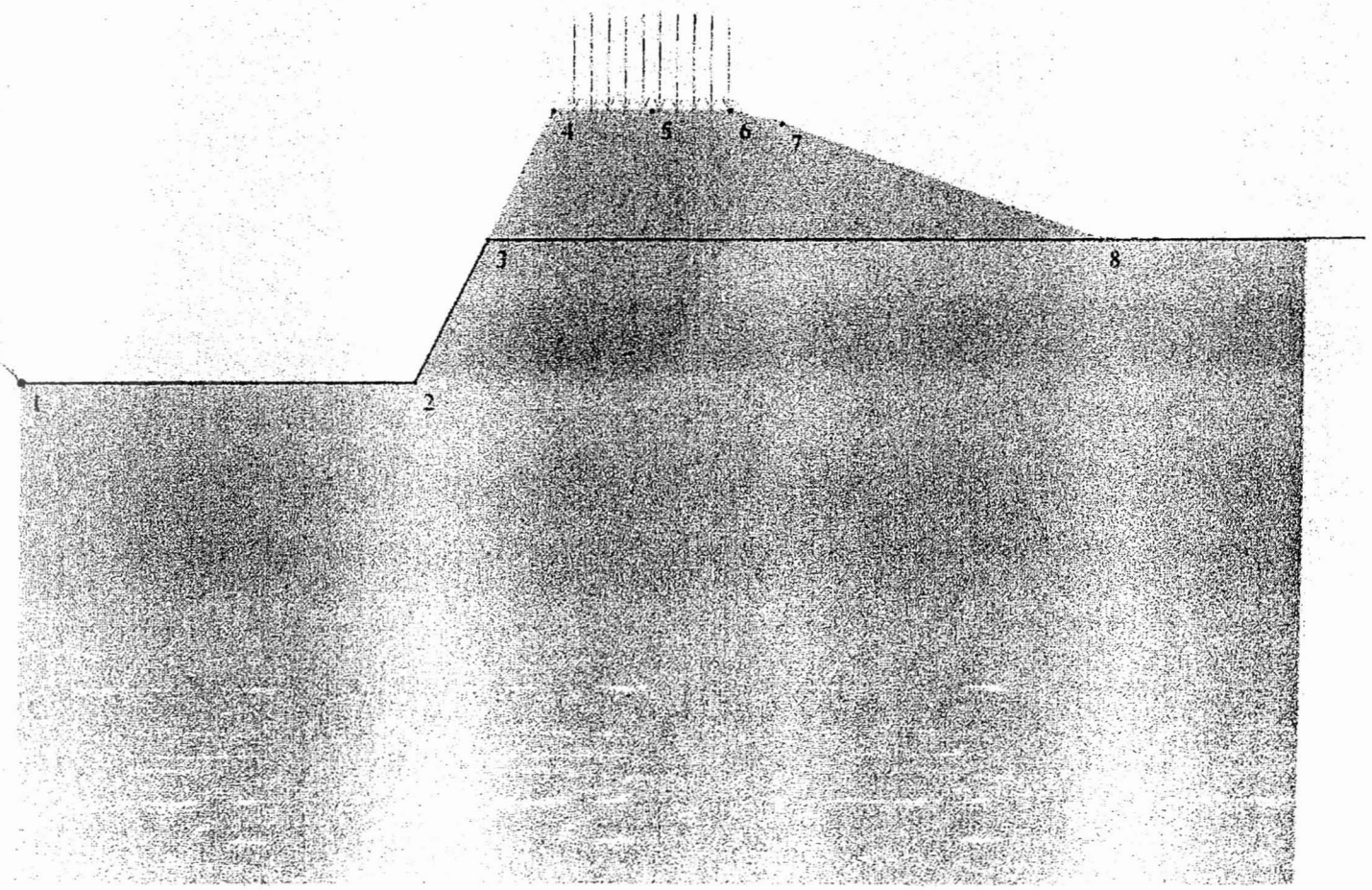
-- Problem geometry is defined along sections selected by user at x ordinates.
-- Y1 represents the Y ordinates of soil surface. Y2 represent the ordinates of the end of soil layer 1 and start of soil layer 2, and so on.
-- Yw represents the Y ordinates of phreatic surface.

GEOMETRY
Soil profile contains 2 layers (see details in next page)

WATER GEOMETRY
Phreatic line was specified.

UNIFORM SURCHARGE
Load Q1 = 240.00 [lb/ft²] inclined from verical at 0.00 degrees, starts at X1s = 12.80 and ends at X1e = 16.46 [ft].
Surcharge load, Q2.....None
Surcharge load, Q3.....None

STRIP LOAD
.....None.....



SCALE:

0 2 4 6[ft]

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305

TABULATED DETAILS OF SPECIFIED GEOMETRY

Soil profile contains 2 layers. Coordinates in [ft.]
Water was described by phreatic line. Y values are tabulated in the right most column.

#	X	Y1	Y2	Yw (phreatic)
1	0.00	38.50	38.50	38.50
2	30.00	38.50	38.50	38.50
3	35.50	49.50	38.50	49.50
4	40.50	59.50	38.50	49.50
5	48.00	59.50	38.50	49.50
6	54.00	59.50	49.50	49.50
7	58.00	58.50	49.50	49.50
8	82.50	49.50	49.50	49.50
9	110.00	49.50	49.50	49.50

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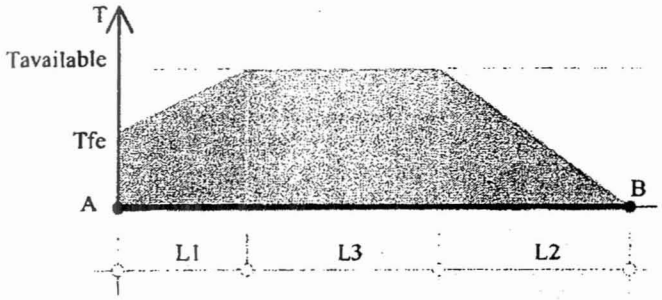
306

DISTRIBUTION OF AVAILABLE STRENGTH ALONG EACH REINFORCEMENT LAYER



A = Front-end of reinforcement (at face of slope)
B = Rear-end of reinforcement
AB = L1 + L2 + L3 = Embedded length of reinforcement

Tavailable = Long-term strength of reinforcement
Tfe = Available front-end strength (e.g., connection to facing)

L1 = Front-end 'pullout' length
L2 = Rear-end pullout length
Tavailable prevails along L3

Factor of safety on resistance to pullout on either end of reinforcement, Fs-po = 1.50

Reinforcement Layer #	Designated Name	Height Relative to Toe [ft]	L [ft]	L1 [ft]	L2 [ft]	L3 [ft]	Tfe [lb/ft]	Tavailable [lb/ft]
1	Geosynthetic type #1	0.00	20.00	0.00	0.89	19.11	888.89	888.89
2	Geosynthetic type #1	1.50	20.00	0.00	0.92	19.08	888.89	888.89
3	Geosynthetic type #1	3.00	20.00	0.00	0.98	19.02	888.89	888.89
4	Geosynthetic type #1	4.50	20.00	0.00	1.02	18.98	888.89	888.89
5	Geosynthetic type #1	6.00	20.00	0.00	1.08	18.92	888.89	888.89
6	Geosynthetic type #1	7.50	20.00	0.00	1.15	18.85	888.89	888.89
7	Geosynthetic type #1	9.00	20.00	0.00	1.25	18.75	888.89	888.89
8	Geosynthetic type #1	10.50	20.00	0.00	1.35	18.65	888.89	888.89
9	Geosynthetic type #1	12.00	20.00	0.00	1.48	18.52	888.89	888.89
10	Geosynthetic type #1	13.50	20.00	0.00	1.84	18.16	888.89	888.89
11	Geosynthetic type #1	15.00	20.00	0.00	2.40	17.60	888.89	888.89
12	Geosynthetic type #1	16.50	20.00	0.00	3.35	16.65	888.89	888.89
13	Geosynthetic type #1	18.00	15.00	0.00	4.30	10.70	888.89	888.89
14	Geosynthetic type #1	19.50	15.00	0.00	8.60	6.40	888.89	888.89

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RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each entry point (considering all specified exit points)

Entry Point #	Entry Point (X, Y) [ft]		Exit Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	42.00	59.50	30.15	38.98	18.03	59.67	23.97	4.60	
2	42.98	59.50	30.08	38.87	19.89	59.59	23.09	2.54	
3	43.96	59.50	29.97	38.78	21.09	59.86	22.88	1.94	
4	44.94	59.50	30.11	38.77	22.82	59.66	22.13	1.59	
5	45.92	59.50	29.96	38.68	23.98	59.80	21.95	1.45	
6	46.90	59.50	30.06	38.67	25.13	59.87	21.77	1.36	
7	47.88	59.51	10.35	38.72	23.35	59.53	24.53	1.27	
8	48.86	59.50	10.65	38.54	23.93	59.64	24.93	1.23	
9	49.84	59.50	11.34	38.55	24.73	59.79	25.11	1.21	
10	50.82	59.50	12.80	38.54	26.01	59.54	24.81	1.18	
11	51.80	59.50	11.81	38.73	26.37	59.59	25.43	1.18	
12	52.78	59.50	12.13	38.51	26.95	59.65	25.82	1.18	
13	53.76	59.50	12.82	38.52	27.77	59.79	25.99	1.19	
14	54.74	59.32	11.90	38.68	27.92	60.21	26.84	1.20	
15	55.72	59.07	11.13	38.71	27.61	61.61	28.22	1.22	
16	56.70	58.83	8.36	38.71	28.30	58.93	28.40	1.16	
17	57.68	58.58	11.84	38.78	30.40	58.77	27.28	1.09	
18	58.66	58.26	10.96	38.90	29.94	60.57	28.80	1.09	
19	59.63	57.90	10.67	38.53	29.72	61.97	30.19	1.09	OK
20	60.61	57.54	11.01	38.82	30.11	63.29	31.04	1.09	
21	61.59	57.18	10.68	38.52	30.35	63.64	31.90	1.09	
22	62.57	56.82	7.49	38.78	28.92	66.45	35.00	1.10	
23	63.55	56.46	7.55	38.72	28.91	68.56	36.70	1.12	
24	64.53	56.10	8.37	38.63	29.29	70.40	38.04	1.13	
25	65.51	55.74	5.33	38.74	27.87	73.96	41.82	1.15	
26	66.49	55.38	6.18	38.64	28.22	76.25	43.59	1.18	
27	67.47	55.02	3.14	38.74	26.82	80.43	47.94	1.21	
28	68.45	54.66	4.78	38.61	27.52	82.71	49.61	1.24	
29	69.43	54.30	2.51	38.67	26.51	86.99	53.95	1.28	
30	70.41	53.94	1.76	38.68	26.30	90.31	57.17	1.32	
31	71.39	53.58	1.01	38.69	26.09	93.90	60.64	1.36	
32	72.37	53.22	-0.09	38.54	26.24	94.76	62.08	1.41	
33	73.35	52.86	-0.23	38.61	26.82	96.01	63.46	1.45	
34	74.33	52.50	-0.53	38.76	27.76	95.42	63.33	1.50	
35	75.31	52.14	-0.68	38.84	28.36	96.64	64.69	1.55	
36	76.29	51.78	-0.09	38.54	28.96	97.88	66.07	1.60	
37	77.27	51.42	-0.37	38.69	29.90	97.18	65.86	1.66	
38	78.25	51.06	-0.29	38.65	30.52	98.39	67.22	1.71	
39	79.23	50.70	-0.16	38.58	31.14	99.61	68.59	1.77	
40	80.20	50.34	-0.02	38.51	32.63	95.02	65.26	1.83	
41	81.18	49.98	-0.68	38.87	32.70	100.01	69.66	1.90	
42	82.16	49.62	-0.56	38.80	33.34	101.21	71.03	1.96	
43	83.14	49.50	-0.42	38.73	33.87	102.20	72.15	2.02	
44	84.12	49.50	-0.28	38.65	34.34	103.08	73.14	2.07	
45	85.10	49.50	-0.14	38.57	34.80	103.95	74.13	2.12	
46	86.08	49.50	-0.82	38.92	34.97	107.14	77.03	2.18	
47	87.06	49.50	-0.68	38.85	35.44	108.05	78.06	2.23	
48	88.04	49.50	-0.54	38.78	35.90	108.96	79.08	2.28	
49	89.02	49.50	-0.41	38.71	36.37	109.88	80.11	2.34	
50	90.00	49.50	-0.27	38.63	36.52	113.38	83.31	2.39	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-entry' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

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RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

Critical circles for each exit point (considering all specified entry points)

Exit Point #	Exit Point (X, Y) [ft]		Entry Point (X, Y) [ft]		Critical Circle (Xc, Yc, R) [ft]			Fs	STATUS
1	-0.38	38.81	62.57	56.82	24.95	69.31	39.64	1.15	
2	0.38	38.78	62.57	56.82	25.35	68.92	39.14	1.14	
3	1.31	38.59	61.59	57.18	25.03	68.71	38.34	1.13	
4	2.06	38.56	61.59	57.18	25.44	68.31	37.83	1.13	
5	2.82	38.53	61.59	57.18	25.84	67.92	37.33	1.12	
6	3.57	38.50	61.59	57.18	26.25	67.52	36.83	1.12	
7	3.78	38.92	60.61	57.54	26.43	65.84	35.18	1.11	
8	4.54	38.88	60.61	57.54	26.84	65.46	34.70	1.11	
9	5.29	38.85	60.61	57.54	27.24	65.09	34.21	1.10	
10	6.05	38.81	60.61	57.54	27.66	64.71	33.73	1.10	
11	6.88	38.71	60.61	57.54	27.84	64.99	33.61	1.10	
12	7.63	38.68	60.61	57.54	28.25	64.60	33.13	1.09	
13	8.41	38.63	59.63	57.90	28.46	63.06	31.60	1.09	
14	9.17	38.60	59.63	57.90	28.88	62.69	31.13	1.09	
15	9.92	38.56	59.63	57.90	29.30	62.33	30.66	1.09	
16	10.67	38.53	59.63	57.90	29.72	61.97	30.19	1.09	OK
17	10.96	38.90	58.66	58.26	29.94	60.57	28.80	1.09	
18	11.87	38.74	58.66	58.26	30.37	60.22	28.35	1.09	
19	12.78	38.57	58.66	58.26	30.58	60.38	28.16	1.09	
20	13.22	38.79	58.66	58.26	31.01	60.03	27.71	1.09	
21	14.16	38.60	58.66	58.26	31.44	59.68	27.25	1.09	
22	14.61	38.81	58.66	58.26	31.65	59.81	27.05	1.09	
23	15.55	38.63	58.66	58.26	32.09	59.46	26.59	1.10	
24	16.02	38.81	58.66	58.26	32.31	59.57	26.38	1.10	
25	16.97	38.63	58.66	58.26	32.75	59.21	25.93	1.11	
26	17.46	38.79	58.66	58.26	32.97	59.30	25.71	1.12	
27	18.42	38.61	58.66	58.26	33.41	58.93	25.25	1.13	
28	18.93	38.76	58.66	58.26	33.86	58.56	24.80	1.14	
29	19.90	38.57	58.66	58.26	34.09	58.62	24.57	1.15	
30	20.43	38.70	58.66	58.26	34.32	58.68	24.34	1.16	
31	21.40	38.52	58.66	58.26	34.78	58.29	23.88	1.18	
32	21.95	38.62	58.66	58.26	34.56	59.17	24.11	1.19	
33	22.51	38.71	58.66	58.26	34.80	59.18	23.88	1.21	
34	23.51	38.54	58.66	58.26	35.03	59.18	23.64	1.23	
35	24.09	38.61	58.66	58.26	35.51	58.75	23.15	1.25	
36	24.69	38.67	58.66	58.26	35.75	58.72	22.91	1.27	
37	25.71	38.50	58.66	58.26	36.00	58.69	22.66	1.30	
38	26.32	38.55	58.66	58.26	36.25	58.64	22.41	1.32	
39	26.95	38.58	58.66	58.26	36.00	59.38	22.68	1.35	
40	27.60	38.59	59.63	57.90	35.72	61.34	24.16	1.38	
41	28.26	38.61	59.63	57.90	36.24	60.78	23.57	1.41	
42	29.97	38.57	48.86	59.50	27.42	59.86	21.45	1.29	
43	29.72	38.48	49.84	59.50	28.51	59.78	21.33	1.44	
44	30.70	39.93	49.84	59.50	30.02	59.73	19.82	1.56	
45	31.38	41.36	49.84	59.50	31.43	59.77	18.41	1.70	
46	32.03	42.79	48.86	59.50	32.14	59.50	16.72	1.86	
47	32.83	44.22	49.84	59.51	34.46	59.51	15.38	2.07	
48	33.42	45.66	48.86	59.50	34.80	59.65	14.06	2.32	
49	34.11	47.10	48.86	59.51	36.26	59.52	12.60	2.65	
50	34.98	48.50	53.76	59.50	36.92	66.73	18.33	3.05	

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-exit' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

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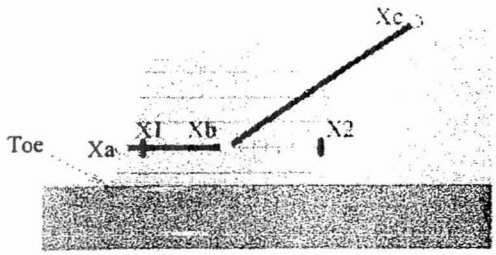
RESULTS OF TRANSLATIONAL ANALYSIS



Results in the table below represent critical two-part wedges identified between specified starting (X1) and ending (X2) search points. Wedges along all reinforcement layers and at elevation zero are reported. The critical two-part wedge, one for each predetermined elevation, is defined by Xa, Xb and Xc where Xa is the front end of the passive wedge (slope face), Xb is where the passive wedge ends and the active one starts, and Xc is the X-ordinate at which the active wedge starts.

Critical two-part wedge along each interface:

Interface	Height Relative to Toe [ft]	(Xa, Ya) [ft]		(Xb, Yb) [ft]		(Xc, Yc) [ft]		Fs	STATUS
At toe elevation	0.00	0.00	38.50	0.00	38.50	N/A	N/A	N/A	No convergence
Reinf. Layer #1	0.00	30.00	38.50	38.26	38.50	51.89	59.50	1.15	OK
Reinf. Layer #2	1.50	30.75	40.00	35.08	40.00	53.91	59.50	1.23	OK
Reinf. Layer #3	3.00	31.50	41.50	35.78	41.50	54.85	59.29	1.28	OK
Reinf. Layer #4	4.50	32.25	43.00	36.58	43.00	53.66	59.50	1.34	OK
Reinf. Layer #5	6.00	33.00	44.50	37.28	44.50	50.32	59.50	1.42	OK
Reinf. Layer #6	7.50	33.75	46.00	38.08	46.00	50.23	59.50	1.48	OK
Reinf. Layer #7	9.00	34.50	47.50	38.78	47.50	51.20	59.50	1.66	OK
Reinf. Layer #8	10.50	35.25	49.00	39.58	49.00	50.84	59.50	1.81	OK
Reinf. Layer #9	12.00	36.00	50.50	40.28	50.50	50.27	59.50	1.97	OK
Reinf. Layer #10	13.50	36.75	52.00	41.08	52.00	49.71	59.50	2.16	OK
Reinf. Layer #11	15.00	37.50	53.50	41.78	53.50	48.93	59.50	2.39	OK
Reinf. Layer #12	16.50	38.25	55.00	42.58	55.00	46.35	59.50	2.48	OK
Reinf. Layer #13	18.00	39.00	56.50	42.28	56.50	43.94	59.50	2.92	OK
Reinf. Layer #14	19.50	39.75	58.00	43.08	58.00	43.98	59.50	3.88	OK

Note: In the 'Status' column, OK means the critical two part-wedge was identified within the specified search domain. 'Minimum on Edge' means the critical result corresponds to a minimum on the edge of the search domain; i.e., either on X1 or X2 or the internally preset limits on Xc.

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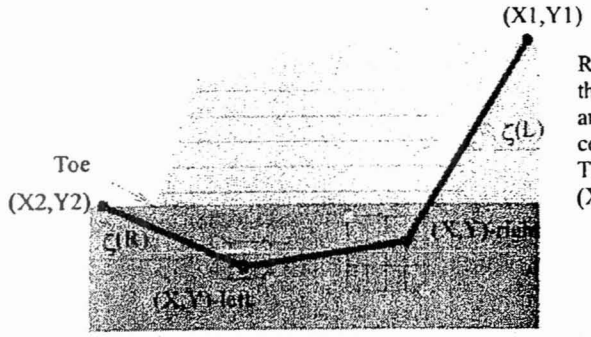
310

RESULTS OF 3-PART WEDGE ANALYSIS



Results in the table below represent the critical slip surface composed of a three-part wedge and identified by the specified points (X-left, Y-left) and (X-right, Y-right) and angles Zeta(L) and Zeta(R). ReSSA finds the (X,Y) coordinates, as well as the angles Zeta, based on user-specified search domain. The trace of the critical three-part wedge is fully defined by four points: (X1, Y1), (X-left, Y-left), (X-right, Y-right), (X2, Y2).

Critical 3-part wedge (Automatic search):

(X2, Y2) [ft]	Zeta(L) [degrees]	(X-left, Y-left) [ft]	(X-right, Y-right) [ft]	Zeta(R) [degrees]	(X1, Y1) [ft]	Fs
(30.21, 38.91)	13.00	(32.00, 38.50)	(45.00, 38.50)	39.00	(66.05, 55.54)	1.573

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CRITICAL RESULTS OF ROTATIONAL AND TRANSLATIONAL STABILITY ANALYSES

Rotational (Circular Arc; Bishop) Stability Analysis

Minimum Factor of Safety = 1.09

Critical Circle: Xc = 29.72[ft], Yc = 61.97[ft], R = 30.19[ft]. (Number of slices used = 55)

Translational (2-Part Wedge; Spencer), Direct Sliding, Stability Analysis

Minimum Factor of Safety = 1.15

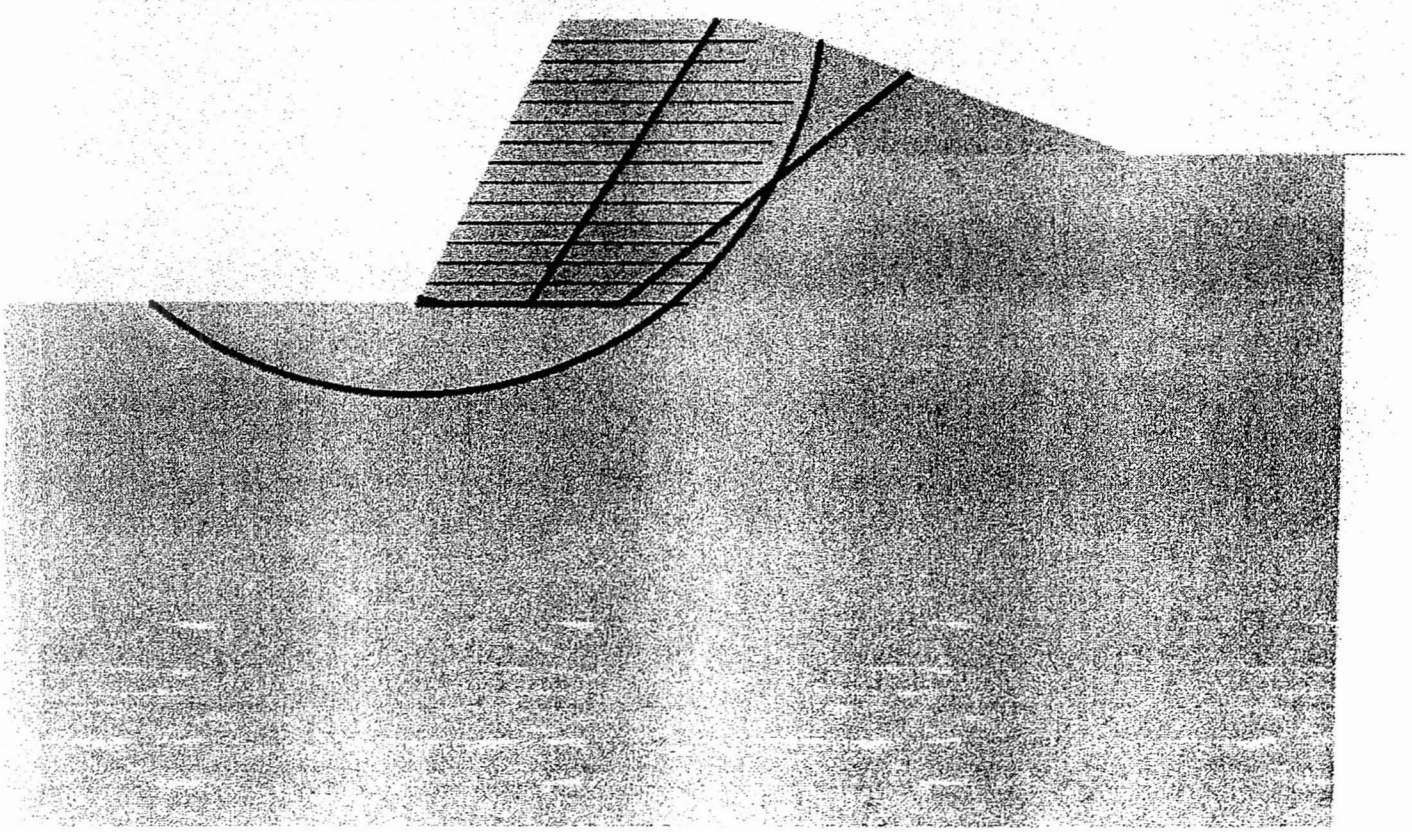
Critical Two-Part Wedge: (Xa = 30.00, Ya = 38.50) [ft]
(Xb = 38.26, Yb = 38.50) [ft]
(Xc = 51.89, Yc = 59.50) [ft]
(Number of slices used = 30)
Interslice resultant force inclination = 18.01 [degrees]

Three-Part Wedge Stability Analysis

Minimum Factor of Safety = 1.57

Critical Three-Part Wedge: (X2 = 30.21, Y2 = 38.91) [ft]
(X-left = 32.00, Y-left = 38.50) [ft]
(X-right = 45.00, Y-right = 38.50) [ft]
(X1 = 66.05, Y1 = 55.54) [ft]
(Number of slices used = 45)
Interslice resultant force inclination = 24.43 [degrees]

REINFORCEMENT LAYOUT: DRAWING



SCALE:

0 2 4 6[ft]

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312

REINFORCEMENT LAYOUT: TABULATED DATA & QUANTITIES

Layer #	Reinf. Type #	Geosynthetic Designated Name	Height Relative to Toe [ft]	Embedded Length [ft]	Covergae Ratio, Rc	(X, Y) front [ft]		(X, Y) rear [ft]	
1	1	Geosynthetic type #1	0.00	20.00	1.00	30.00	126.31	50.00	126.31
2	1	Geosynthetic type #1	1.50	20.00	1.00	30.75	127.81	50.75	127.81
3	1	Geosynthetic type #1	3.00	20.00	1.00	31.50	129.31	51.50	129.31
4	1	Geosynthetic type #1	4.50	20.00	1.00	32.25	130.81	52.25	130.81
5	1	Geosynthetic type #1	6.00	20.00	1.00	33.00	132.31	53.00	132.31
6	1	Geosynthetic type #1	7.50	20.00	1.00	33.75	133.81	53.75	133.81
7	1	Geosynthetic type #1	9.00	20.00	1.00	34.50	135.31	54.50	135.31
8	1	Geosynthetic type #1	10.50	20.00	1.00	35.25	136.81	55.25	136.81
9	1	Geosynthetic type #1	12.00	20.00	1.00	36.00	138.31	56.00	138.31
10	1	Geosynthetic type #1	13.50	20.00	1.00	36.75	139.81	56.75	139.81
11	1	Geosynthetic type #1	15.00	20.00	1.00	37.50	141.31	57.50	141.31
12	1	Geosynthetic type #1	16.50	20.00	1.00	38.25	142.81	58.25	142.81
13	1	Geosynthetic type #1	18.00	15.00	1.00	39.00	144.31	54.00	144.31
14	1	Geosynthetic type #1	19.50	15.00	1.00	39.75	145.81	54.75	145.81

QUANTITIES

Reinf. Type #	Designated Name	Coverage Ratio	Area of reinforcemnt [ft²] / length of slope [ft]
1	Geosynthetic type #1	1.00	270.00

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313

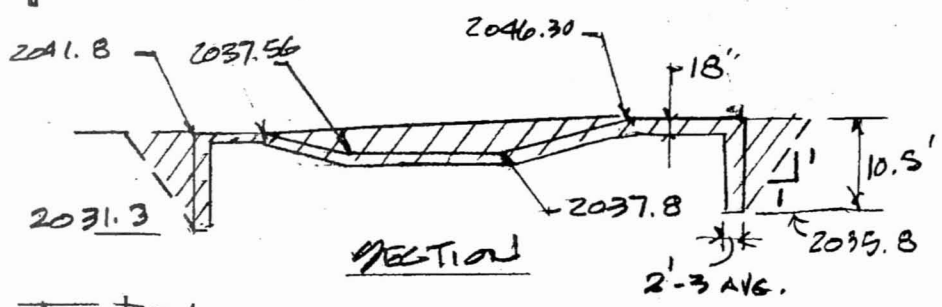
15.0 QUANTITIES AND COSTS

QUANTITIES

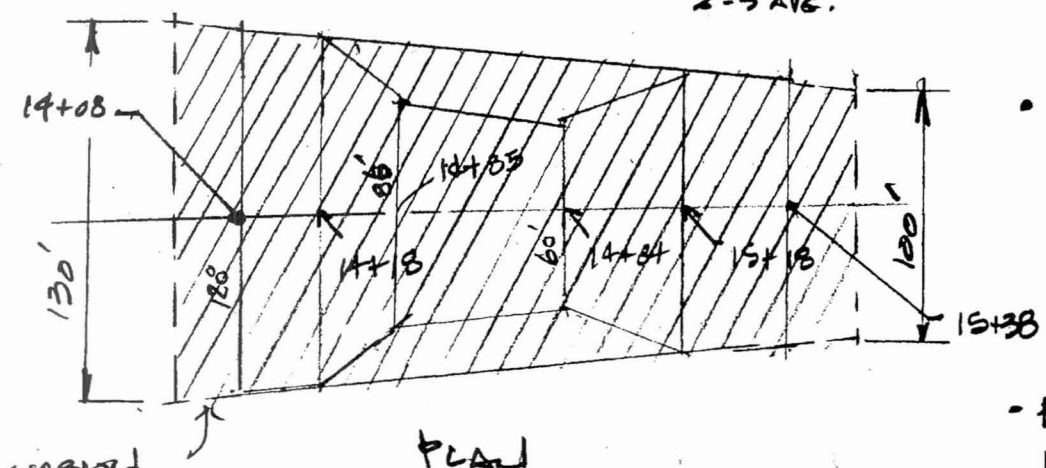
ITEM	DESCRIPTION	PAY UNIT
503-11	CONCRETE DROP STRUCTURE	LUMP SUM

THE WORK UNDER THIS ITEM INCLUDES EXCAVATION, BACKFILL CONCRETE, REINFORCING STEEL, INSTALLATION OF GABION BASKETS AND BACKFILL OF NATIVE MATERIAL

→ EXCAVATION:



SECTION



PLAN

- TOE DOWN:

$\left(\frac{2.25+10.75}{2}\right)100/27 = 28$ CY

$+ \left(\frac{2.25+10.75}{2}\right)130/27 = 36$ CY

- FLAT SECTIONS

$1.5(128)(10)/27 = 62$ CY

$1.5(100)(20)/27 = 111$ CY

- BOWL

$100\left(\frac{80+107}{2}\right)\left(\frac{4.84+8.5}{2}\right)/27 = 2{,}206$ CY

TOTAL = 2,443

→ USE 2,500 CY

QUANTITIES

ITEM	DESCRIPTION	PAY UNIT
305-11	CONCRETE DROP STRUCTURE	LUMP SUM

→ STRUCTURE BACKFILL

ASSUME 4" OF COARSE AGGREGATE BELOW SLAB AS VAPOR BARRIER

$(8+17+50+34+18)\left(\frac{100+128}{2}\right)(0.33)/27 = 177$ CY

→ USE 180 CY

→ CONCRETE

- TOE DOWNS

$2(2.25)(9)(114)/27 = 171$ CY

↑ AVG

- SLABS (16 NORE DRAIN HOLES)

$(1968 + 2712 + 2(1500) + 1698 + 1317)(1.5)/27 = 595$

↑ FLOOR SECTIONAL AREAS (10,705 SF)

→ USE 600 CY

→ REINFORCING STEEL

- #5 @ 18" o.c. E.W. TOP . . . PER 2.25 SF AREA THERE IS $4(1.5)(1.043\#/FT) = 6.258\#$

↑ FT

$10,705(6.258) = 66,992\#$; USE 75,000#

→ BACKFILL WITH NATIVE MATERIAL

= 2,200 CY

→ GAMMALS : 9 EA

Gannett Fleming

SUBJECT SAND WASH QUANTITIES

BY JAG DATE CHKD. BY DATE

SHEET NO. OF

JOB NO. 046308

3 of 3

QUANTITIES

ITEM	DESCRIPTION	PAY UNIT
305-11	CONC. DROP STRUCTURE	LUMP SUM

SUM INDIVIDUAL QUANTITIES TO DETERMINE LUMP SUM COST:

> EXCAVATION	2,500	($30)	=	$75,000
> STR. BACKFILL	180	($40)	=	$7,200
> CONCRETE	600	($500)	=	$300,000
> REINF. STEEL	75,000	($1.50)	=	$112,500
> NATIVE BACKFILL	2,200	($10)	=	$22,000
> GABIONS	9	($1,000)	=	$9,000

$525,700

→ USE $525,000

Gannett Fleming

SUBJECT Sols wash Quantities
BY BAG DATE 8/29/06 CHKD. BY DATE
SHEET NO. OF
JOB NO.

NW Wing Wall

Excavation

No Excavation req'd to extend NW wing wall

Concrete

Stem = $[\frac{1}{2}(36.5')(12.46' + 5.59')(10''/12) + (4.5')(5.59')(10''/12)]/27$

= 13.0 CY

Reinforcement

#6 Dowels = (2)(3.83')(1.502 lb/ft)(41')(12"/12") = 472 lb

#6 Vert = (2)(1')(1.502 lb/ft)(356 ft²) = 1069 lb

#4 Horiz = (2)(1')(0.668 lb/ft)(12"/18")(356 ft²) = 317 lb

Total = 1858 lb

Dowels

(2)(41')(12"/12") = 82 EA

Gannett Fleming

SUBJECT Sols Wash Quantities
BY BAG DATE 8/29/06 CHKD. BY DATE
SHEET NO. OF
JOB NO.

SW Headwall

Excavation

No Excavation req'd to extend the SW Headwall

Concrete

Stem = (35')(7.36')(10"/12")/27 = 7.9 CY

Reinforcement

#5 Dowels = (2)(3.5')(1.043 lb/ft)(35')(12"/12") = 256 lb

#5 Vert = (2)(7.36')(1.043 lb/ft)(35')(12"/12") = 537 lb

#4 Horiz = (2)(35')(0.668 lb/ft)(7.36')(12"/18") = 229 lb

Total = 1022 lb

Dowels

(2)(35')(12"/12") = 70 EA

Gannett Fleming

SUBJECT Sols wash Quantities
BY BAG DATE 8/29/06 CHKD. BY DATE
SHEET NO. OF
JOB NO.

SE Wing wall

Excavation

$(35')(3.5')(3')/27 = \underline{13.6\ CY}$

Concrete

Stem $= [\frac{1}{2}(13.4')(5.46' + 3') + (13.1')(3') + (4.5')(3')](10''/12)/27$

$= 3.4\ CY$

Footing Extension $= (32')(2')(2')/27 = 4.7\ CY$

Total $= \underline{8.1\ CY}$

Reinforcement

Stem:

#5 Dowels $= (2)(3.5')(1.043\ lb/ft)(13.4')(12''/12'')$

$+ (2)(4.33')(1.043\ lb/ft)(17.6')(12''/12'') = 256\ lb$

#5 Vert $= (2)(1')(1.043\ lb/ft)(57\ ft^2) = 119\ lb$

#4 Horiz $= (2)(1')(0.668\ lb/ft)(57\ ft^2 + 53\ ft^2)(12''/18'') = 98\ lb$

Footing Extension:

#6 Dowels $= (2)(3.75')(1.502\ lb/ft)(32')(12''/12'') = 360\ lb$

#5 Horiz $= (6)(32')(1.043\ lb/ft) = 200\ lb$

Total $= \underline{1033\ lb}$

Gannett Fleming

SUBJECT Sols Wash Quantities
BY BAG DATE 8/29/06 CHKD. BY DATE
SHEET NO. OF
JOB NO.

SE Wing Wall Cont'd

Dowels

(2)(13.4'+17.6')(12"/12") + (2)(32')(12"/12") = 126 EA

Removal of Portions of Existing Structures

Stem = [½(13.1')(2.4')(1') + (4.5')(2.4')(1')]/27 = 1.0 CY

Gannett Fleming

SUBJECT Sols Wash Quantities
BY BAG DATE 8/29/06 CHKD. BY DATE
SHEET NO. OF
JOB NO.

NE Wing Wall

Removal of Portions of Existing Structures

Footing = [(7')(13')(2') + (13')(4')(1')]/27 = 8.7 CY

Stem = [½(12.25')(5.5' + 13.9') + (0.75')(13.9')](1')/27 = 4.8 CY

Total = 13.5 CY

Total Cost = (13.5 CY)($300/CY) = $4050 ⇒ $5000

Debris Fins

Excavation

Footing = [(5376 ft²)(3') + (6')(4')(240')]/27 = 811 CY

Concrete

Stem = (364 ft²)(1.25')(5 Fins)/27 = 84.3 CY

Footing = [(5104 ft²)(2') + (6')(1')(240')]/27 = 431.4 CY

Total = 515.7 CY

Reinforcement

Stem:

#6 Vert = (2)(1')(1.502 lb/ft)(12"/12")(364 ft²)(5 Fins)
+ (2)(3.5')(1.502 lb/ft)(12"/12")(31.83')(5 Fins) = 7141 lb

#5 Horiz = (2)(1')(1.043 lb/ft)(12"/12")(364 ft²)(5 Fins) = 3797 lb

#5 ⌒ = (6')(1.043 lb/ft)(34')(12"/12")(5 Fins) = 1064 lb

#5 • = (34')(1.043 lb/ft)(5 Fins) = 177 lb

Footing:

#6 Horiz = (2)(1')(1.502 lb/ft)(5104 ft²) = 15,332 lb

#5 Horiz = (2)(1')(1.043 lb/ft)(5104 ft²) = 10,647 lb

#4 Horiz in Toe Down = (2)(240')(0.668 lb/ft)(6')(12"/18") = 1283 lb

Gannett Fleming

SUBJECT Sols Wash Quantities

BY BAG DATE 8/29/06 CHKD. BY DATE

SHEET NO. OF

JOB NO.

#4 Γ = (2)(8.75')(0.668 lb/ft)(240')(12"/18") = 1870 lb

#6 Dowels = (4')(1.502 lb/ft)(293')(12"/12") = 1760 lb

Total = 43,071 lb

Dowels

(293')(12"/12") = 293 EA

Gannett Fleming

SUBJECT Sols Wash Quantities
BY BAG DATE 8/29/06 CHKD. BY DATE
SHEET NO. OF
JOB NO.

Parapet Floodwall

Concrete

(223')(10"/12)(7')/27 = 48.2 CY

Reinforcement

#6's = (6)(223')(1.502 lb/ft) = 2010 lb

#4's = (12)(223')(0.668 lb/ft) = 1788 lb

#5 ⊡ Bars = (2)(9')(1.043 lb/ft)(223')(12"/24") = 2093 lb

#6's at NW Wing Wall = (14)(5.5')(1.502 lb/ft) = 116 lb

#6 Dowels at NW Wing Wall = (4)(4.25')(1.502 lb/ft) = 26 lb

Total = 6033 lb

Dowels

4 EA

EEC Summary

Modifications To Tegner Street Bridge

NW Wing wall:

Area = ½(36.5')(12.46' + 5.59') + (4.5')(5.59') = 355 SF

Cost = (13.0 CY)($500) + (1858 lb)($1.50) + (82)($10) = $10,107

SW Headwall:

Area = (35')(7.36') = 258 SF

Cost = (7.9 CY)($500) + (1022 lb)($1.50) + (70)($10)

= $6,183

SE Wing wall:

Area = ½(13.4')(5.46' + 3') + (13.1')(3') + (4.5')(3') = 110 SF

Cost = (13.6 CY)($30) + (8.1 CY)($500) + (1033 lb)($1.50)

+ (126)($10) = $7,268

NE Wing Wall Removal:

Cost = $5,000

Debris Fins

Cost = (811 CY)($30) + (515.7 CY)($500) + (43,071 lb)($1.50)

+ (293)($10) = $349,717

Gannett Fleming

SUBJECT Sols Wash Quantities
BY BAG DATE 8/31/06 CHKD. BY DATE
SHEET NO. OF
JOB NO.

Parapet Floodwall:

Cost = (48.2 CY)($500) + (60331b)($1.50) + (4)($10)

= $33,190

Total Cost = $10,107 + $6,183 + $7,268 + $5,000

+ $349,717 + $33,190 = $411,465

= $410,000 LS

Gannett Fleming

SUBJECT Sols Wash Sheet Pile Wall
BY BAG DATE 8/23/06 CHKD. BY DATE
SHEET NO. OF
JOB NO.

Sheet Pile Wall For Sewer Line Protection

Steel Sheet Piling

Assume PZ27 is used

Total Projected Area = (42')(32') = 1344 ft²

Weight = (1344 ft²)(27.5 lb/ft²) = 36,960 lb = 37,000 lb

Cost = (37,000 lb)($3.00/lb) = $111,000 = $110,000

Epoxy Coating or Galvanizing

Area = (42')(12') = 504 ft²

Cost = (504 ft²)($5/ft²) = $2520 = $2500

3000 psi Concrete

Cap: (2')(2')(40.5')/27 = 6.0 CY

Over Footing: (2')(3.3')(9.5')/27 = 2.1 CY

Total = 6.0 CY + 2.1 CY = 8.1 CY = 8 CY

Cost = (8 CY)($500/CY) = $4000

Reinforcement

Π Bars: (6')(1.043 lb/ft)(50')(12"/12") = 312.9 lb

• Bars: [(7)(50') + (2)(9.5')](1.043 lb/ft) = 384.9 lb

Dowels: (2)(6')(1.043 lb/ft)(9.5')(12"/12") = 118.9 lb

Total Weight = 312.9 lb + 384.9 lb + 118.9 lb = 816.7 lb = 820 lb

Cost = (820 lb)($1.50/lb) = $1230 = $1250

Total Cost = $117,750 = $120,000 LS