HOLLINGSWORTH ASSOCIATES
Geotechnical/Environmental Engineers
2895 W. Oxford Ave. #4 Sheridan, Colorado 80110
303-781-5188/fax 303-781-5224

I. Purpose:

The purpose of the calculation is to determine the size of sheet pile required embedded 18 feet and cantilevered 11 feet.

Methods and Assumptions:

Sheet pile size was determined by the conventional method of cantilever sheet piling. Assumptions stated in body.

References:

1) Soil Mechanics, Lambe + Whitman, John Wiley & Sons Inc., 1969

2) NAVFAC DM-7.2

Conclusions:

Size of sheet pile required; $S = 11.81\ in^3$

Size of PZC12 sheet pile; $S = 52.0\ in^3 > 11.81\ in^3$

HOLLINGSWORTH ASSOCIATES
Geotechnical/Environmental Engineers
2895 W. Oxford Ave. #4 Sheridan, Colorado 80110
303-781-5188/fax 303-781-5224

II. Determining Active Pressure - See page 6 for drawing.

* Barrier wall will be in use for longer than one month; assume $c = 0$ and $\phi_w = 0$.

* Assume $\gamma = 110$ pcf, $\phi = 30^0$

Equation for Active Pressure of an inclined surface:

$$P_a = \left[\frac{\csc(\beta)\sin(\beta-\phi)}{\sqrt{\sin(\beta+\phi_w)} + \sqrt{\frac{\sin(\phi+\phi_w)\sin(\phi-i)}{\sin(\beta-i)}}} \right]^2 \gamma H$$

Where:

P_a = Active Pressure (PSF per foot of wall)
γ = Moist unit weight of soil (Pcf)
H = Height of exposed sheet pile (Ft.)
ϕ_w = Wall friction angle (degrees)
ϕ = Friction angle of soil (degrees)
i = Angle surface makes with the horizontal (degrees)
β = Angle sheet pile makes with the horizontal (degrees)

$\gamma = 110$ pcf $H = 11$ Ft. $\phi_w = 0$ $\phi = 30°$ $i \approx 10.1°$ $\beta = 90°$

$$P_a = \left[\frac{\csc(90^0)\sin(90°-30°)}{\sqrt{\sin(90°+0°)} + \sqrt{\frac{\sin(30°+0°)\sin(30°-10.1°)}{\sin(90^0-10.1^0)}}} \right]^2 (110\text{ pcf})(11\text{ Ft.})$$

$P_a = 452.75$ psf

HOLLINGSWORTH ASSOCIATES
Geotechnical/Environmental Engineers
2895 W. Oxford Ave. #4 Sheridan, Colorado 80110
303-781-5188/fax 303-781-5224

III. Determine maximum moment

A) Locate point of zero pressure (at distance x below Y):

$$Y = \frac{P_a}{\gamma(K_p - K_a)}$$

$P_a = 452.75$ psf
$\gamma = 110$ pcf
K_p = coefficient of passive pressure
K_a = coefficient of active pressure

From Table 13.1 on page 165 of Lambe and Whitman:

based on $\phi = 30°$: $K_a = 0.333$
$K_p = 3.00$

$$Y = \frac{452.75}{(110)(3.00 - 0.333)}$$

$$Y = 1.54 \text{ Ft.}$$

ΣP_a at a distance Y below the excavation

$$\Sigma P_a = \frac{(H+Y)(P_a)}{2}$$

$$\Sigma P_a = \frac{(11 + 1.54)(452.75)}{2}$$

$$\Sigma P_a = 2{,}838.74 \text{ lb.}$$

Plane of zero shear : $\Sigma P_a = \Sigma P_p$

$$\Sigma P_a = \frac{\gamma(K_p - K_a)x^2}{2}$$

HOLLINGSWORTH ASSOCIATES
Geotechnical/Environmental Engineers
2895 W. Oxford Ave. #4 Sheridan, Colorado 80110
303-781-5188/fax 303-781-5224

III.

$$2,838.74 = \frac{(110)(3.00-0.333)X^2}{2}$$

$$X = 4.4 \text{ Ft.}$$

B) Maximum moment

$$M_{max} = M_A$$

$$+\circlearrowleft M_A = \left(\frac{HP_a}{2}\right)\left(\frac{H}{3}+Y+X\right) + \left(\frac{YP_a}{2}\right)\left(\frac{2Y}{3}+X\right) - (\Sigma P_a)\left(\frac{X}{3}\right)$$

$$M_A = \left(\frac{(11)(452.75)}{2}\right)\left(\frac{11}{3}+1.54+4.4\right) + \left(\frac{(1.54)(452.75)}{2}\right)\left(\frac{2(1.54)}{3}+4.4\right)$$

$$- (2,838.74)\left(\frac{4.4}{3}\right)$$

$$M_A = 21,650.2 \text{ Ft-lb.}$$

HOLLINGSWORTH ASSOCIATES
Geotechnical/Environmental Engineers
2895 W. Oxford Ave. #4 Sheridan, Colorado 80110
303-781-5188/fax 303-781-5224

IV. Required section modulus

$$S_{min} = \frac{M_{max}}{f_b}$$

Where: S_{min} = section modulus per foot of wall ($In.^3$)
$M_{max.}$ = Maximum bending moment (In.-lbs.)
f_b = Allowable bending stress (psi)

* Assume f_b = 22,000 psi

$$M_{max} = M_A = (21,650.2 \text{ Ft-lb})\left(\frac{12 \text{ In.}}{1 \text{ Ft.}}\right) = 259,802.4 \text{ In.-lb.}$$

$$S_{min} = \frac{(259,802.4)}{(22,000)}$$

$$\left[S_{min} = 11.81 \text{ In}^3 \right]$$

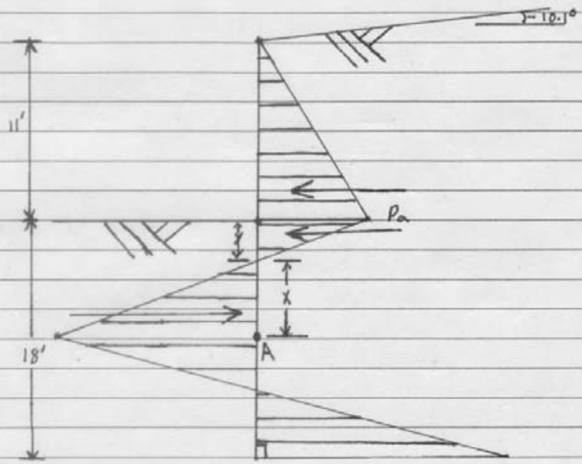
Job No: 07-14

Project: Trihydro - Cincinnati

HOLLINGSWORTH ASSOCIATES
Geotechnical/Environmental Engineers

2895 W. Oxford Ave. #4 Sheridan, Colorado 80110
303-781-5188/fax 303-781-5224

Date: 7/12/06



Job No: 07-14
Project: Trihydro-Cincinnati

HOLLINGSWORTH ASSOCIATES
Geotechnical/Environmental Engineers
2895 W. Oxford Ave. #4 Sheridan, Colorado 80110
303-781-5188/fax 303-781-5224

Date: 11/9/07
Page 1 of

I. Purpose:

The purpose of the calculations is to determine the size of the riprap required for the barrier wall protection.

II. Methods & Assumptions

Riprap size will be determined by three methods

(1) FHWA - HEC-11

(2) California Bank and Shore Rock Slope Protection Design

(3) Colorado State Spread Sheet

Input for flow depth and velocity was provided by HEC-RES runs from Trihydro

Max velocity = 11.15 ft/sec
max width = 1099.18 ft
max depth = 41 ft

Reach-1 Sta 48
500 yr flood

(1) FHWA - HEC11

EQ: 6 $D_{50} = 0.00594\, V_a^3 / \left((d_{avg})^{0.5} K_1^{1.5} \right)$

D_{50} = the median riprap particle size (m)
C = correction factor
V_a = avg velocity in main channel (m/s)
d_{avg} = depth in main flow channel
K_1 = constant
$= \left[1 - (\sin^2\theta / \sin^2\phi) \right]^{0.5}$
θ = bank angle
ϕ = riprap angle of repose

$C_{sg} = 2.12 / (S_s - 1)^{1.5}$
S_s = specific gravity of riprap
$C_{sf} = (SF/1.2)^{1.5}$

SF = stability factor

HOLLINGSWORTH ASSOCIATES
Geotechnical/Environmental Engineers
2895 W. Oxford Ave. #4 Sheridan, Colorado 80110
303-781-5188/fax 303-781-5224

$V_a = 11.15$ ft/sec
$= 3.4$ m/sec

$d_{avg} = 41$ ft
$= 12.5$ m

$K_1 = \left[1 - (\sin^2 26.6/\sin^2 40)\right]^{0.5}$ $\theta = 26.6°$
$\phi = 40°$

$K_1 = 0.717$

Using a specific gravity for riprap = 2.65 and a stability factor of 1.2 the correction factor is not needed for Eq. 6 (they are the values used in derivation of Eq. 6)

$\therefore\ D_{50} = 0.00594(3.4)^3/(12.5)^{0.5}\,0.717^{1.5}$

$D_{50} = 0.11$ meters

Gradation From Table 2 Rock Riprap

$1.5D_{50}$ to $1.7D_{50}$	100% smaller	0.19 m
$1.2D_{50}$ to $1.4D_{50}$	85	0.15 m
$1.0D_{50}$ to $1.4D_{50}$	50	0.11 m
$0.4D_{50}$ to $0.6D_{50}$	15	0.04 m

If use AASHTO Facing

100%	0.4 m
50	0.29 m
10	0.12 m

Thickness $= 2D_{50} = 2 \times 0.29$ m $= 0.58$ m $\approx$ 0.6 m
or $D_{100} = 0.4$ m

HOLLINGSWORTH ASSOCIATES
Geotechnical/Environmental Engineers
2895 W. Oxford Ave. #4 Sheridan, Colorado 80110
303-781-5188/fax 303-781-5224

(2) California Bank and Shore Rock Slope Protection Design

Equation 1

$$W = \frac{0.00002\, V^6\, SG}{(SG-1)^3 \sin^3 (r-a)}$$

W = theoretical minimum rock wt (lbs)
V = velocity (ft/sec)
SG = specific gravity = 2.65
r = 70 degrees
a = bank, slope 26.6°

$$W = \frac{0.00002\,(11.15)^6 (2.65)}{(2.65-1)^3 \sin^3 (70-26.6)}$$

W = 69.9 lbs

From Table 5-1 Appendix B - Gradation should be

<u>Facing</u> :

0-5 % retained	90 Kg
50-100 %	34 Kg
90-100 %	11 Kg

From Table 5-2 RSP Fabric Type A

Type A - Fabric: woven
Weight 135 gms/m^2
Grab tensile strength: 0.45 Kilonewtons
Elongation at break: 35 %
Toughess 15 Kilonewtons

(3) Colorado State Spread Sheet (attached)
d_{50} = 0.24 meters - method from River Mechanics

d_{50} is greater than other 2 methods ∴ but fits d_{50} and gradation for AASHTO Facing class

This spreadsheet is a process to assist with proper design of riprap for channel banks based on the she
enter the information in the green cells, Excel performs the calculations, and puts the results in the oran
user adjusts this value until the stability factor is equal or greater than one. So it is both an input and an
suggested to use the channel riprap design sheet first to determine the median particle size. Input this
gradation from the U.S. Army Corps of Engineers along with applicable ranges. It also determines whe

Step #1:

Straight Channel and River Bend Riprap Input Parameters			
W:	335	m	Channel width
h:	12.5	m	Flow depth
S:	0.000674	m/m	Slope gradient of river
θ_1:	35	degrees	Slope angle of river bank
G:	2.65		Specific gravity of the riprap
ϕ:	40	degrees	Natural angle of repose of the riprap
τ_{*c}:	0.047		Critical Shields parameter
γ:	9810	N/m^3	Specific weight of water

Straight Channel Riprap Design			
τ_0:	82.65	Pa	Shear stress applied on riprap particle
d_m:	0.240678	m	Effective riprap size for straight channels

For straight channe
nee

Optional Step #2:

River Bend Riprap Input Parameters			
R:	457	m	Radius of curvature of the river bend
d_s:	0.240678	m	Diameter or riprap particle to analyze (d_m from straight channel is a g
M:	1		M/N is the list to drag ratio. M=N may be a good appro
N:	1		

River Bend Riprap Design			
θ_0:	0.039	degrees	Slope angle of the river
n:	0.030		Manning's n
θ:	0.067	degrees	Geometrical parameter
a_θ:	0.819		Geometrical parameter
λ:	16.75	degrees	Streamline deviation angle, must be greater than or equal to 0
η_0:	0.45		Stability number
β:	16.09	degrees	Particle orientation angle
η_1:	0.35		Sidelsope stability number for the riprap
SF0:	0.82		Stability factor for λ > or = 0

Source of information is River Mechanicsby Dr. Pierre Julien, Cambridge University Press, 2002 pages
Programmed by Todd Rivas for CE 717 at Colorado State University 2003.

ear stress approach outlined in *River Mechanics (pages 240-243, 245-250)*. Users
ige cells. The only exception is the rirap particale size for river bends (purple). The
i output. (Hint: Use Goal Seek or Solver in Excel - look in the 'Tools' Menu). It is
into the gradation and filter design sheet. This last sheet provides a suggested
ther a filter is needed, as well as a gradation range for a filter.

els, this is all that is
ded.

iood start)
ximation

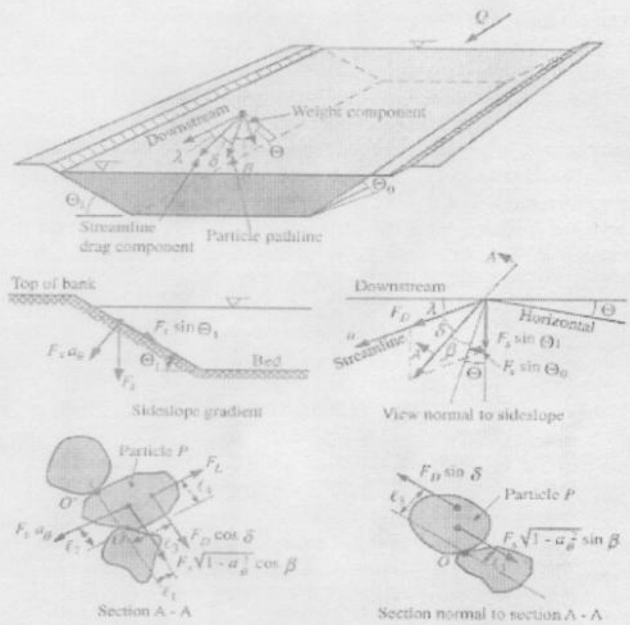


Figure 6.1. Particle-stability analysis.

Figure 6.1 in *River Mechanics. Particle stability analysis variables*

Warning: The river or river bank may be too steep for adequate results

158-162, 240-250.

SECTION 72
SLOPE PROTECTION

72-1 GENERAL

72-1.01 Description.—Slope protection consists of rock, concrete, concreted-rock or slope paving. The type of slope protection to be used will be designated in the Engineer's Estimate, the special provisions or shown on the plans. The slope protection shall be placed in conformance with these specifications, the special provisions, and the details and dimensions shown on the plans or directed by the Engineer.

72-2 ROCK SLOPE PROTECTION

72-2.01 Description.—This work shall consist of placing revetment type rock courses on the slopes.

The mass of the individual pieces of rock in each class shall be as indicated in the table in Section 72-2.02, "Materials," or as specified in the special provisions. The classes of rock slope protection will be designated in the Engineer's Estimate as 8T, 4T, 2T, 1T, 1/2T, 1/4T, Light, Facing, and No. 1, No. 2 or No. 3 Backing.

72-2.02 Materials.—The individual classes of rocks used in rock slope protection shall conform to the following, unless otherwise specified in the special provisions, or as shown on the plans.

GRADING OF ROCK SLOPE PROTECTION

PERCENTAGE LARGER THAN*

Rock Mass	*Method A Placement*					*Method B Placement*							
	Classes					*Classes*							
											Backing		
	8T	*4T*	*2T*	*1T*	*1/2T*	*1T*	*1/2T*	*1/4T*	*Light*	*Facing*	*No. 1*	*No. 2*	*No. 3*
14.5-Tonne	0-5	—	—	—	—	—	—	—	—	—	—	—	—
7.25-Tonne	50-100	0-5	—	—	—	—	—	—	—	—	—	—	—
3.6-Tonne	95-100	50-100	0-5	—	—	—	—	—	—	—	—	—	—
1.8-Tonne	—	95-100	50-100	0-5	—	0-5	—	—	—	—	—	—	—
900-kg	—	—	95-100	50-100	0-5	50-100	0-5	—	—	—	—	—	—
450-kg	—	—	—	95-100	50-100	—	50-100	0-5	—	—	—	—	—
220-kg	—	—	—	—	95-100	95-100	—	50-100	0-5	—	—	—	—
90-kg	—	—	—	—	—	—	95-100	—	50-100	0-5	0-5	—	—
34-kg	—	—	—	—	—	—	—	95-100	—	50-100	50-100	0-5	—
11-kg	—	—	—	—	—	—	—	—	95-100	90-100	90-100	25-75	0-5
2.2-kg	—	—	—	—	—	—	—	—	—	—	—	90-100	25-75
0.4-kg	—	—	—	—	—	—	—	—	—	—	—	—	90-100

* The amount of material smaller than the smallest rock mass listed in the table for any class of rock slope protection shall not exceed the percentage limit listed in the table determined on a mass basis. Compliance with the percentage limit shown in the table for all other rock masses of the individual pieces of any class of rock slope protection shall be determined by the ratio of the number of individual pieces larger than the specified rock mass compared to the total number of individual pieces larger than the smallest rock mass listed in the table for that class.

The material shall also conform to the following quality requirements: