APPENDIX

APPENDIX 1: DESIGN EXAMPLE

No. 1; Stability Analysis of Embankment

No. 2; Design of Side Ditch

No. 3; Design of Retaining Wall With Anchoring

No. 4; Design of Retaining
(Trial Method With Wedge Shape)

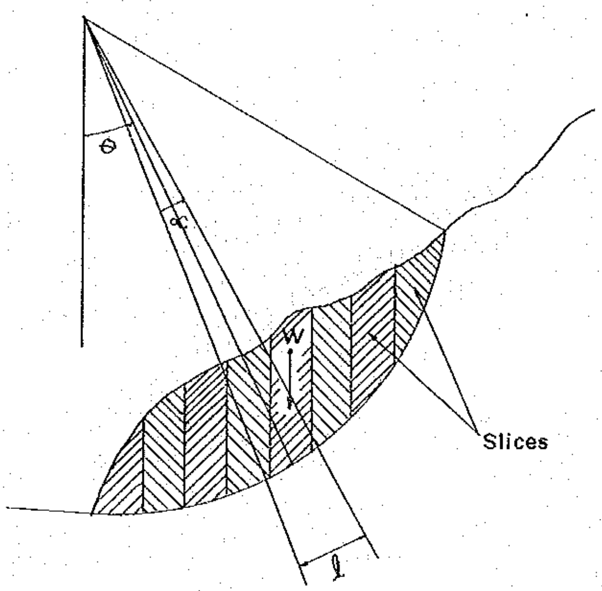
No. 5; Design of Catch Fence

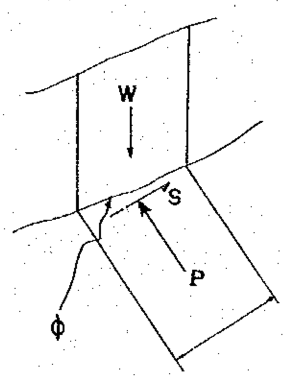
APPENDIX 1:

DESIGN EXAMPLE NO.1; STABILITY ANALYSIS OF EMBANKMENT

I. METHODOLOGY:

According to this method, a mass on the sliding plane is divided into several slices with appropriate width, the shearing forces and resisting forces of slices are totalled, and then the factor of safety is determined from the ratio between them, for which the equation (A) can be used. Normally, the number of slices is greater than 6 to 7.





$$Fs = \frac{\Sigma \{c.\ell + (W \cos \theta - u.\ell) - \tan \phi\}}{\Sigma W \sin \theta} \quad ---- (A)$$

Where shearing strength is given by:

$$S = c + (\delta . \mu) \tan \phi$$

Fs = Factor of Safety

δ = Normal stress (t/m^2)

P = Normal reaction acting to the bottom plane of slice (t/m)

W = Weight of slice (t/m)

ℓ = Length of arc of sliding plane cut by each slice (m)

C = Cohesion (t/m^2)

$\emptyset$ = Internal friction angle of soil (degree)

μ = Pore water pressure (t/m^2)

R = Radius of circle (m)

θ = Refer to figure (degree)

$$P = W. \cos\theta$$

$$\delta = P/\ell = W/\ell \ . \ \cos\theta$$

Total resisting shearing force along the surface of sliding

$$S = \Sigma(\ell . s) = \Sigma\left[\ell . \left\{ c + (\delta - \mu) \tan\phi\right\}\right]$$

$$= \Sigma\left\{c . \ell + (W. \cos\theta - \mu\ell) \tan\emptyset\right\}$$

Total acting moment:

$$Ma = R . \sin\theta \times W = R . W \sin\theta$$

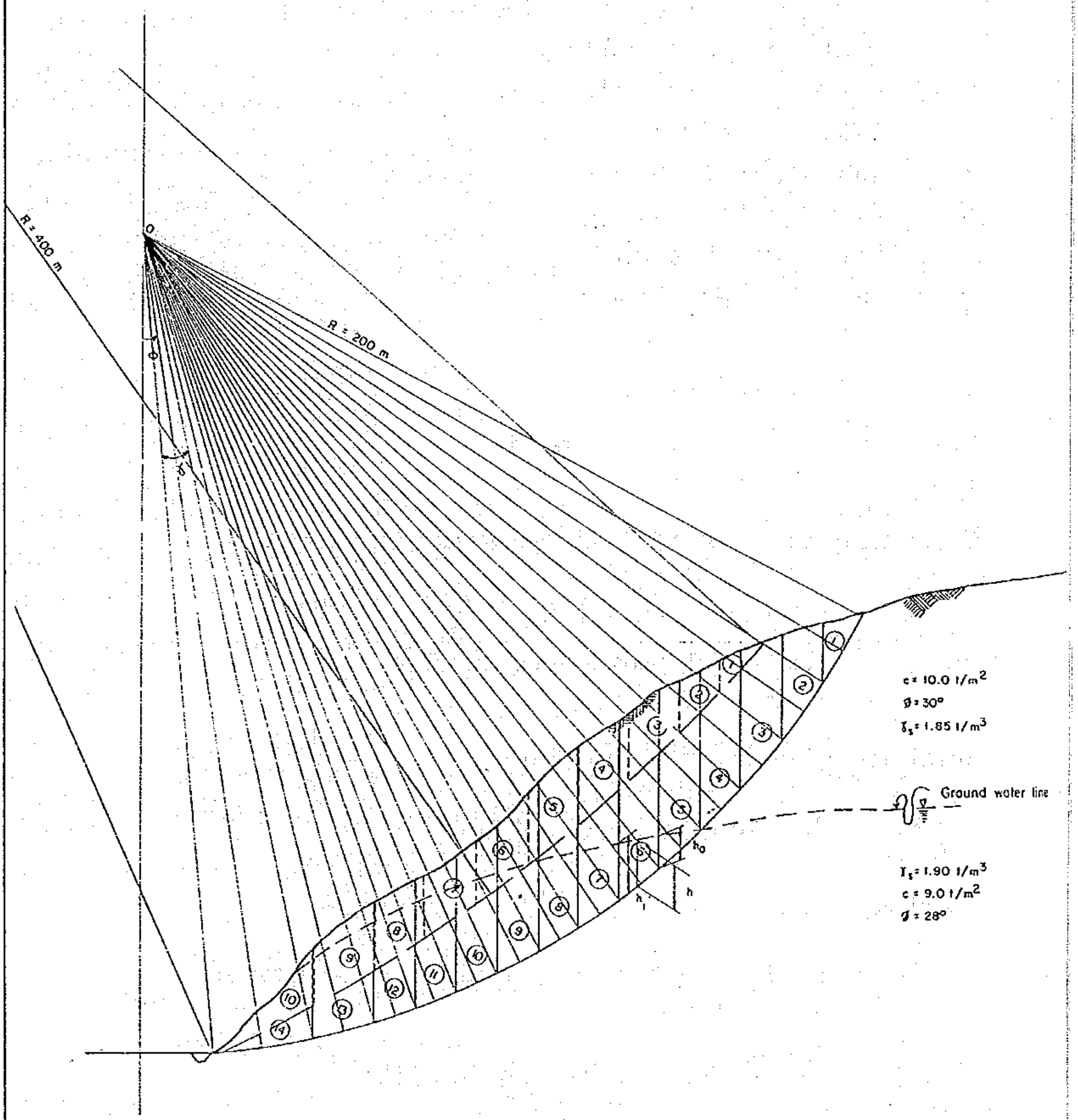
Total resisting moment:

$$Mr = S . R = R \times \Sigma\left\{ c . \ell + (W \cos\theta - \mu\ell) \tan\emptyset\right\}$$

$$\therefore \ Fs = \frac{R \times \Sigma\left\{ c . \ell + (W \cos\theta - \mu\ell) \tan\emptyset\right\}}{\Sigma R \ W \sin\theta}$$

$$= \frac{\Sigma\left\{c . \ell + W \cos\theta - u . \ell) \tan\emptyset\right\}}{\Sigma W \sin\theta} \quad ------ (A)$$

Case - 1 R = 200 m

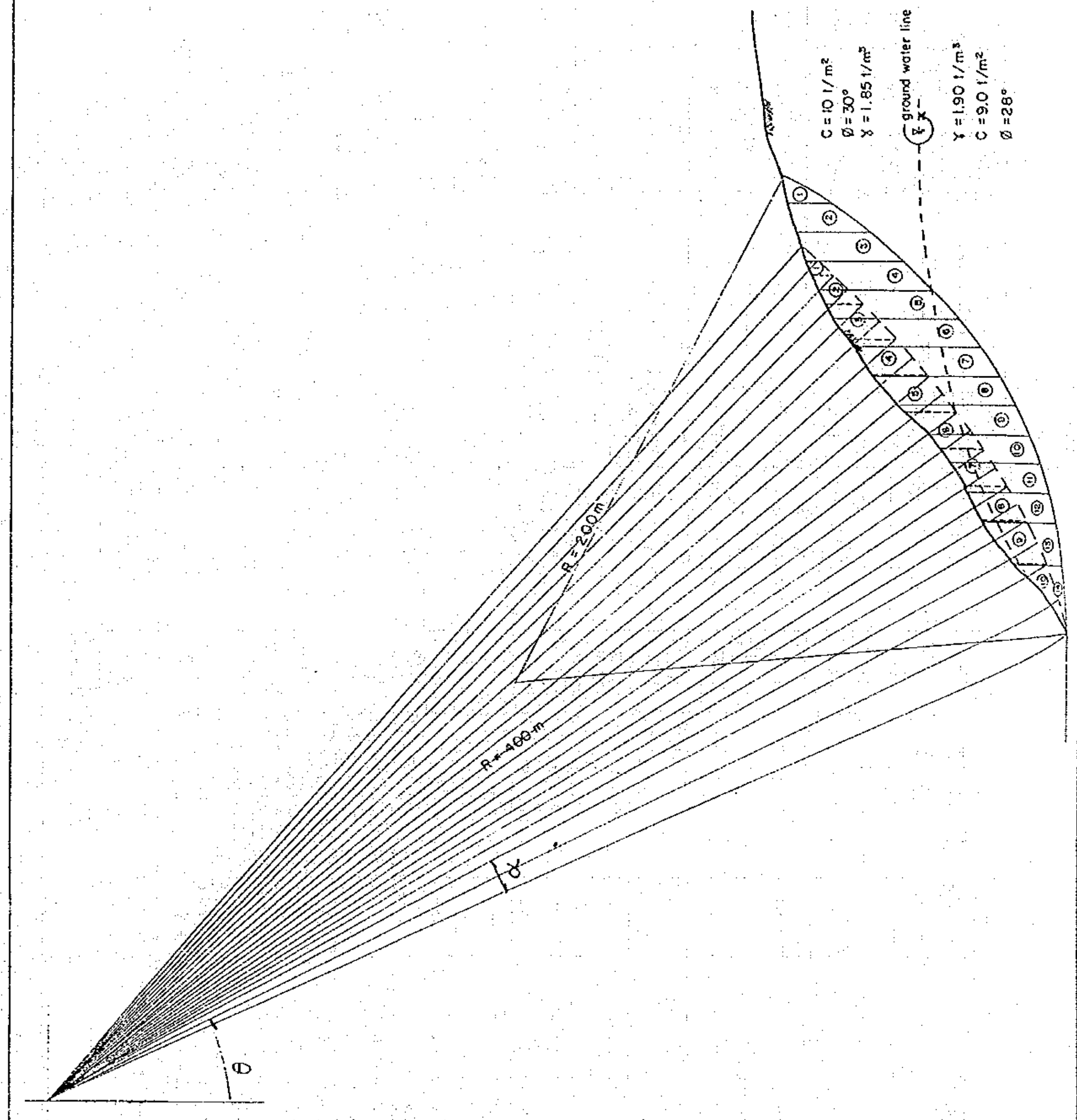


R = 400 m
R = 200 m
O
θ
δ
c = 10.0 t/m²
φ = 30°
γs = 1.85 t/m³
Ground water line
γs = 1.90 t/m³
c = 9.0 t/m²
φ = 28°

R = 200 M

Slice No.	(1) Area of Trapezium A (m^2)	(2) Unit Weight of Soil γ (t/m^3)	(3) Weight of Slices W = γ.A (t/m)	(4) θ (degree)	(5) cos θ	(6) sin θ	(7) W cos θ	(8) u.ℓ (t/m)	(9) W cos θ − u.ℓ	(10) (W cos θ − u.ℓ) × tan θ	(11) W sin θ	(12) α	(13) ℓ(m) = $\frac{\alpha}{360}(2\pi r)$	(14) c.ℓ (t/m)
1	1/2 (10)(15) = 75	1.85	138.75	59.5	0.5075	0.8616	70.415	—	70.415	40.654	119.547	5.5	19.199	191.99
2	$\left(\frac{10+26}{2}\right)$ 10 = 180	1.85	333.00	54.5	0.5807	0.8141	193.373	—	193.373	111.646	271.095	5.0	17.453	174.53
3	$\left(\frac{26+34}{2}\right)$ 10 = 300	1.85	555.00	49.5	0.6494	0.7604	360.417	—	360.417	208.086	422.022	4.5	15.708	157.08
4	$\left(\frac{34+40}{2}\right)$ 10 = 370	1.85	684.50	45.5	0.7009	0.7132	479.766	—	479.766	276.993	488.185	4.0	13.963	139.963
5	$\left(\frac{40+44}{2}\right)$ 10 − 52.361 = 367.639 1/2 (13.963) 7.5 = 52.361	1.85 1.90	660.132 99.486	41.5	0.7489	0.6626	583.856	$\left(\frac{0+7.5}{2}\right)$ ℓ = 52.361	531.495	282.601	516.575	4.0	13.963	125.667
6	$\left(\frac{44+44}{2}\right)$ 10 − 107.50 = 332.50 $\left(\frac{7.5+14}{2}\right)$ 10 = 107.50	1.85 1.90	615.125 204.250	37.5	0.7933	0.6087	650.010	$\left(\frac{7.5+14}{2}\right)$ ℓ = 131.333	518.677	275.785	496.753	3.5	12.217	109.953
7	$\left(\frac{44+54}{2}\right)$ 10 − 165.00 = 325.00 $\left(\frac{14+19}{2}\right)$ 10 = 165.00	1.85 1.90	601.250 313.50	34	0.8290	0.5592	758.327	$\left(\frac{14+19}{2}\right)$ ℓ = 201.581	556.746	296.027	511.528	3.5	12.217	109.953
8	$\left(\frac{54+42}{2}\right)$ 10 − 205.00 = 275.00 $\left(\frac{19+22}{2}\right)$ 10 = 205.00	1.85 1.90	506.75 389.50	31	0.8571	0.5150	769.89	$\left(\frac{19+22}{2}\right)$ ℓ = 250.448	519.442	276.192	462.598	3.5	12.217	109.953
9	$\left(\frac{42+36}{2}\right)$ 10 − 230.00 = 160.00 $\left(\frac{22+24}{2}\right)$ 10 = 230.00	1.85 1.90	296.00 437.00	27.5	0.8870	0.4617	650.171	$\left(\frac{22+24}{2}\right)$ ℓ = 240.856	409.315	217.636	338.426	3.0	10.472	94.248
10	$\left(\frac{36+33}{2}\right)$ 10 − 250.00 = 95.00 $\left(\frac{24+26}{2}\right)$ 10 = 250.00	1.85 1.90	175.75 475.00	24.5	0.9099	0.4146	592.117	$\left(\frac{24+26}{2}\right)$ ℓ = 261.80	330.317	175.633	269.801	3.0	10.472	94.248
11	$\left(\frac{33+31}{2}\right)$ 10 − 260.00 = 60.00 $\left(\frac{26+26}{2}\right)$ 10 = 260.00	1.85 1.90	111.00 494.00	21.5	0.9304	0.3665	562.892	$\left(\frac{26+26}{2}\right)$ ℓ = 272.272	290.620	154.525	221.733	3.0	10.472	94.248
12	$\left(\frac{31+29}{2}\right)$ 10 − 250.00 = 50.00 $\left(\frac{26+24}{2}\right)$ 10 = 250.00	1.85 1.90	92.50 475.00	18	0.9510	0.3090	539.692	$\left(\frac{26+24}{2}\right)$ ℓ = 305.425	234.267	124.562	175.357	3.5	12.217	109.953
13	$\left(\frac{29+21}{2}\right)$ 15 − 322.50 = 52.50 $\left(\frac{24+19}{2}\right)$ 10 = 322.50	1.85 1.90	97.125 512.75	14.5	0.9681	0.2503	687.23	$\left(\frac{24+19}{2}\right)$ ℓ = 300.205	367.025	205.785	177.682	4.0	13.963	125.667
14	1/2 (26.18)21 − 246.71 = 26.18 1/2 (26.18) (19) = 246.71	1.85 1.90	48.433 472.549	8.5	0.9890	0.1478	515.251	$\left(\frac{19+0}{2}\right)$ ℓ = 248.71	266.541	141.722	77.001	7.5	26.18	235.62
			$Fs = \frac{1873.073 + 2787.845}{4550.303} = 1.024$							2787.845	4550.303			1873.073

Case - 2 R = 400 m,


C = 10 t/m²
Ø = 30°
γ = 1.85 t/m³
ground water line
γ = 1.90 t/m³
C = 9.0 t/m²
Ø = 28°
R = 200 m
R = 400 m
α
θ

r = 400 M

Slice No.	(1) Area of Tropezium A (m²)	(2) Unit Weight γ (t/m³)	(3) Weight of Slices W = γ.A (t/m)	(4) θ (degree)	(5) cos θ	(6) sin θ	(7) W cos θ	(8) U . ℓ (t/m)	(9) W cos θ − U . ℓ	(10) (W cos θ − U.ℓ) x tan θ	(11) W sin θ	(12) α	(13) ℓ (m) = $\frac{\alpha}{360}(2\pi r)$	(14) C.ℓ (t/m)
1	1/2 (8) (11) = 44.00	1.85	81.40	48	0.6691	0.7431	54.464	—	54.464	31.444	60.4883	2.0	13.963	139.63
2	$\left(\frac{8+13}{2}\right)$10 = 105.00	1.85	194.25	46	0.6946	0.7193	134.926	—	134.926	77.899	139.724	2.25	15.708	157.08
3	$\left(\frac{13+16}{2}\right)$12.50 = 181.25	1.85	335.31	43.50	0.7254	0.6883	243.233	—	243.233	140.431	230.7938	2.25	15.706	157.08
4	$\left(\frac{16+19}{2}\right)$12.50 = 216.75	1.85	404.68	41.25	0.7518	0.6593	304.238	—	304.238	175.652	266.8055	2.50	17.453	174.53
5	$\left(\frac{19+18}{2}\right)$12.50 = 231.25	1.85	427.81	38.75	0.7798	0.6259	333.606	—	333.606	192.607	267.7662	2.25	15.706	157.08
6	$\left(\frac{18+10}{2}\right)$12.50 = 175.00 1/2 (6) (12.50) = 37.50	1.85 1.90	323.75 71.25	36.50	0.8038	0.5948	317.501	$\left(\frac{6}{2}\right)$ℓ = 47.124	270.377	143.762	234.946	2.25	15.708	141.372
7	$\left(\frac{10+6}{2}\right)$12.50 = 100.00 $\left(\frac{6+9}{2}\right)$12.50 = 93.75	1.85 1.90	185.00 178.125	34.25	0.8266	0.5628	300.159	$\left(\frac{6+9}{2}\right)$ℓ = 117.81	182.349	96.956	204.3667	2.25	15.706	141.372
8	$\left(\frac{6+5}{2}\right)$12.50 = 68.75 $\left(\frac{9+12}{2}\right)$12.50 = 131.25	1.85 1.90	127.187 249.375	32.25	0.8457	0.5336	318.458	$\left(\frac{9+12}{2}\right)$ℓ = 164.934	153.524	81.630	200.9335	2.25	15.708	141.372
9	$\left(\frac{5+1}{2}\right)$15.00 = 45.00 $\left(\frac{12+12}{2}\right)$15.00 = 180.00	1.85 1.90	83.25 342.00	30	0.8660	0.5000	366.266	$\left(\frac{12+12}{2}\right)$ℓ = 209.436	156.79	84.430	212.625	2.50	17.453	157.077
10	1/2 (1) (5) = 2.50 1/2 (24.43) 12 = 146.58	1.85 1.90	4.625 278.502	26.75	0.8929	0.4501	252.804	$\left(\frac{12}{2}\right)$ℓ = 157.08	95.724	50.897	127.4354	3.75	26.18	235.62
										1075.708	1945.884			1602.213

$$Fs = \frac{1602.213 + 1075.708}{1945.884} = 1.376$$

APPENDIX 1:

DESIGN EXAMPLE NO. 2; DESIGN OF SIDE DITCH

(1) Required cross sectional area of side ditch

$$Q = A \cdot V$$

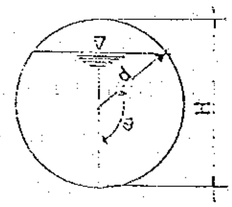
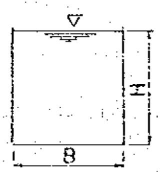
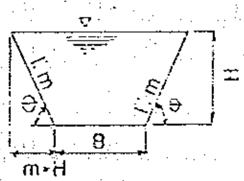
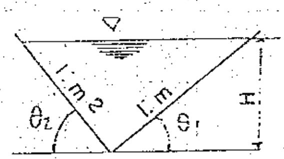
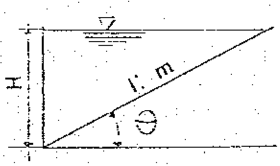
Q ; Discharge of side ditch
A ; Cross-sectional area of side ditch
V ; Mean velocity of stream

$$V = \frac{1}{n} \cdot R^{2/3} \cdot i^{1/2}$$

n ; Coefficient of roughness
i ; Surface slope of water
R ; Hydraulic radius $(= \frac{A}{P})$
A ; Area of running water
P ; Wetted perimeter

Drainage Type		n (Coefficient of Roughness)
Earth and Travel	Earth	0.02 ~ 0.025
	Sand and gravel	0.025 ~ 0.04
	Rock	0.025 ~ 0.035
Cast-in-Place	Cement mortar	0.01 ~ 0.013
	Concrete	0.013 ~ 0.018
	Stone pitching	0.015 ~ 0.03
Fabricated	Concrete pipe	0.012 ~ 0.016

Characteristics of each Cross Section

	Cross Section	Area of Running Water	Hydraulic Radius
Circle	 H=d (1-cos Ø)	$d^2\left(\varphi - \frac{1}{2}\sin 2\varphi\right)$ (d : radian)	$\frac{\varphi}{2}\left(1 - \frac{\sin 2\varphi}{2\varphi}\right)$ (φ : radian)
Rectangle		B . H	$\frac{B \,.\, H}{2H + B}$
Trapezoid		H (B + m.H) or H (B + H cot θ)	$\frac{H\,(B + m.H)}{B + 2H\sqrt{1 + m^2}}$ $\frac{H\,(B + H\cot\theta)}{B + 2H\operatorname{cosec}\theta}$
Triangle		$\frac{H^2}{2}(m_1 + m_2)$ or $\frac{H^2}{2}(\cot\theta_1 + \cot\theta_2)$	$\frac{H}{2} \cdot \frac{m_1 + m_2}{\sqrt{1+m_1^2} + \sqrt{1+m_2^2}}$ or $\frac{H}{2} \cdot \frac{\sin(\theta_1 + \theta_2)}{\sin\theta_1 + \sin\theta_2}$
		$\frac{m.\,H^2}{2}$ or $\frac{H^2 \,.\, \cot\theta}{2}$	$\frac{H}{2} \cdot \frac{m}{1 + \sqrt{1+m^2}}$ or $\frac{H}{2} \cdot \frac{\cos\theta}{1 + \sin\theta}$

(2.) Determination of run-off

$$Q = \frac{1}{3.6} \times C \times I \times A$$

Q ; Run-off m^3/sec
C ; Coefficient of run-off
I ; Rainfall intensity mm/hour
A ; Drainage area (km^2)

Table of Coefficient of Run-off

Type of Surface		Coefficient of Run-off
Roadway surface	Paved	0.70 ~ 0.95
	Unpaved	0.30 ~ 0.70
Shoulder or Slope surface	Fine materials	0.40 ~ 0.65
	Coarse materials	0.10 ~ 0.30
	Hard rock	0.70 ~ 0.85
	Soft rock	0.50 ~ 0.75
Sod on Sandy soil	Gradient 0~2%	0.05 ~ 0.10
	" 2~7%	0.10 ~ 0.15
	" more than 7%	0.15 ~ 0.20
Sod on Clayey soil	Gradient 0~2%	0.13 ~ 0.17
	" 2~7%	0.18 ~ 0.22
	" more than 7%	0.25 ~ 0.35

Example - I

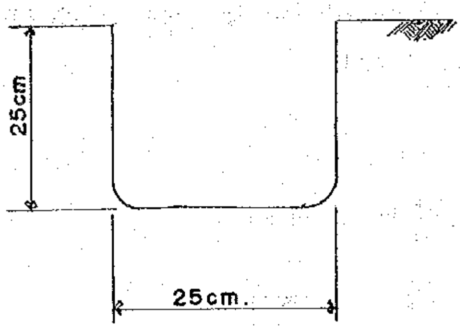
Design Condition

- Rainfall intensity curve

$$I = \frac{4725}{t + 45} \text{ mm/hour}$$

t ; duration of rainfall (minute)

- Gradient $i = 1/300$
- Cross section of Concrete - U - type ditch

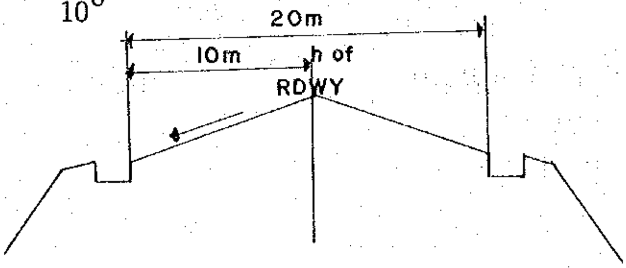


- Coefficient of run-off $C = 0.95$ (paved)
- Rainfall intensity at $t = 10$ minutes

$$I = \frac{4725}{10 + 45} = 85.9 \text{ mm/hour}$$

- L ; spacing of vertical ditch
- Drainage area (catchment area)

$$A = \frac{1}{10^6} \times 10^{\text{meters}} \times L^{\text{meters}}$$



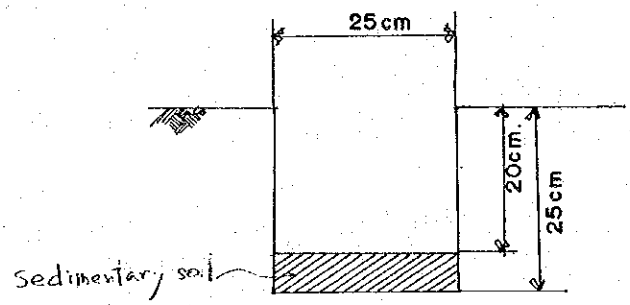
$$\therefore \quad Q = \frac{1}{3.6} \times C \times I \times A$$

$$= \frac{1}{3.6} \times 0.95 \times 85.9 \times 10 \times L \times \frac{1}{10^6} = 0.00027\ L$$

. Allowable discharge of side ditch will be obtained by the following formula

$$Qc = A \times \frac{1}{n} R^{2/3} . i^{1/2}$$

Sedimentary soil will be considered in side ditch at 20 per cent of running water area



$$Qc = 0.25^m \times 0.20^m \times \frac{1}{0.015} \times \left(\left(\frac{0.20 \times 0.25}{2 \times 0.20 + 0.25}\right)\right)^{2/3} \times \left(\left(\frac{1}{300}\right)\right)^{1/2}$$

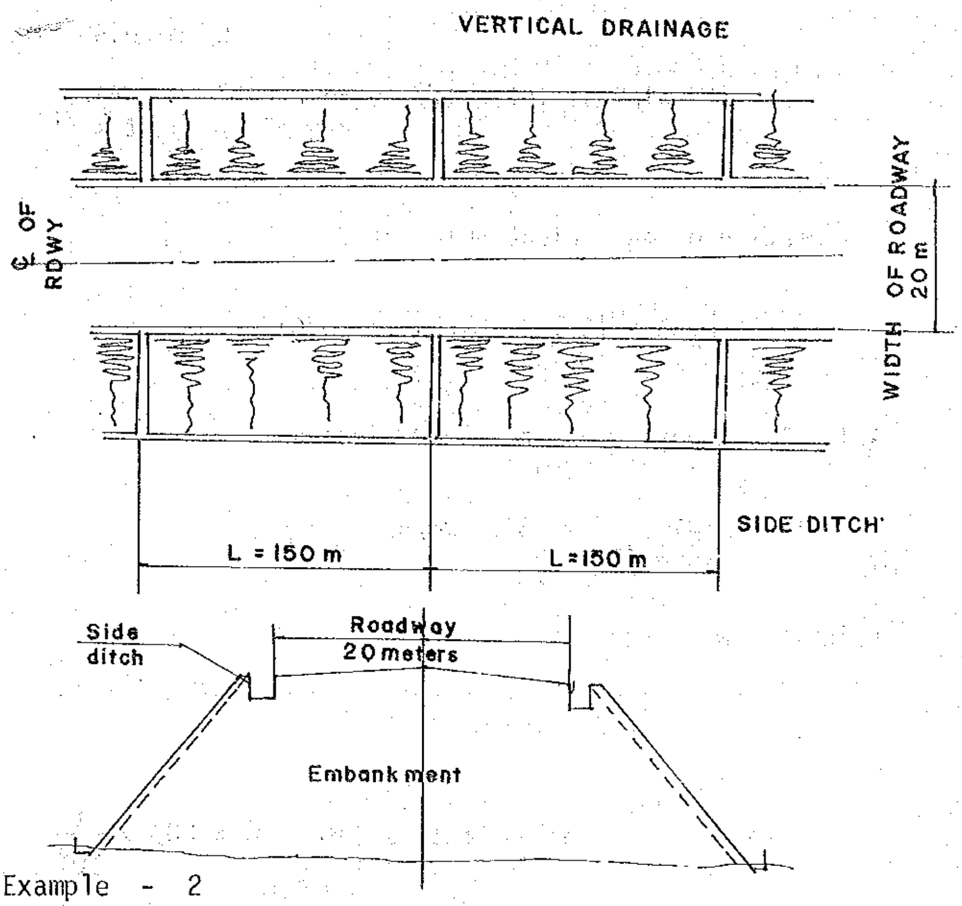
$$= 0.0348$$

$Q < Qc$ is required

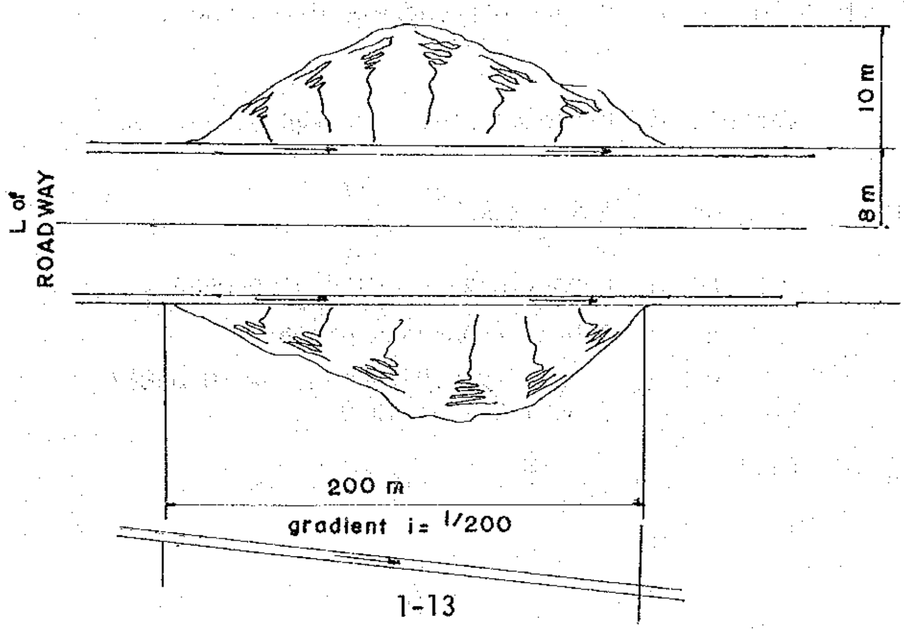
$0.00027\ L < 0.034b$

$\therefore\ L < 153.2^m$

Therefore, the spacing of vertical ditch shall be placed at 150 meter interval on this road section.



Example - 2



Design Condition

- Coefficient of run-off $C = 0.35$ for cut slope

  $C = 0.95$ for roadway

- Rainfall intensity curve $I = \frac{4725}{t + 45}$

- Computation of equivalent value of C

$$C = \frac{0.35 \times 10 + 0.95 \times 8}{10 + 8} = 0.617$$

- Rainfall intensity at $t = 10$ minutes

$$I = \frac{4725}{10 + 45} = 85.9 \text{ mm/hour}$$

- Calculation of run-off

$$Q = \frac{1}{3.6} \times C \times I \times A$$

$$= \frac{1}{3.6} \times 0.617 \times 85.9 \times (10 + 8) \times 200 \times \frac{1}{10^6}$$

$$= 0.053 \text{ m}^3\text{/sec} = 53 \ \ell\text{/sec}$$

If 0.30 x 0.36 U-Type of concrete ditch used;

Capable discharge of side ditch Qc ;

Qc ; $A \times \frac{1}{n} \times R^{2/3} \cdot i^{1/2}$

(80%)

A ; $0.30 \times 0.36 \times 0.8 = 0.0864$

n ; 0.013 (concrete ditch)

R ; $\frac{0.30 \times 0.8 \times 0.36}{0.30 + 2 \times 0.8 \times 0.36} = 0.09863$

$i \ ; \ \frac{1}{200}$

$$\therefore \quad Qc \doteqdot 0.0864 \times \frac{1}{0.013} \times 0.09863^{2/3} \times \frac{1}{200}^{1/2}$$

$$= 0.100 \ m^3/sec > Q = 0.053 \ M^3/sec \quad 0.K$$

too much but still 0.K

If 0.30 x 0.30 U-Type concrete ditch used;

$$A = 0.3 \times 0.3 \times 0.8 = 0.072 \ m^2$$

$$R = \frac{0.30 \times 0.8 \times 0.30}{0.30 + 2 \times 0.8 \times 0.30} = 0.0923$$

$$Qc = 0.072 \times \frac{1}{0.013} \times 0.0923^{2/3} \times \left(\left(\frac{1}{200}\right)\right)^{1/2}$$

$$= 0.080 \ m^3/sec > Q = 0.053 \ m^3/sec \quad 0.K$$

If 0.24 x 0.3 U-Type concrete ditch used;

$$A = 0.24 \times 0.8 \times 0.30 = 0.0576$$

$$R = \frac{0.24 \times 0.8 \times 0.30}{0.24 + 2 \times 0.8 \times 0.30} = 0.080$$

$$Qc = 0.056 \times \frac{1}{.013} \times 0.0800^{2/3} \times \left(\left(\frac{1}{200}\right)\right)^{1/2}$$

$$= 0.058 \ m^3/sec > Q = 0.053 \ m^3/sec \quad 0.K$$

If 0.24 x 0.24 U-Type concrete ditch used;

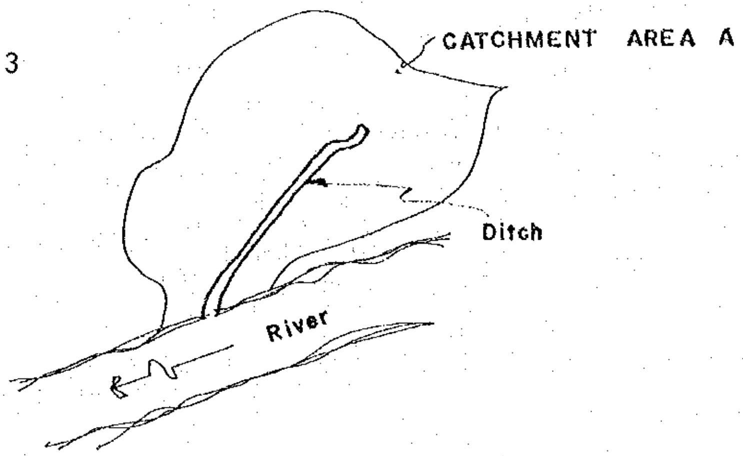
$$A = 0.24 \times 0.8 \times 0.24 = 0.0461$$

$$R = \frac{0.24 \times 0.8 \times 0.24}{0.24 + 2 \times 0.8 \times 0.24} = 0.07385$$

$$Qc = 0.0461 \times \frac{1}{0.013} \times 0.07385^{2/3} \times \left(\left(\frac{1}{200}\right)\right)^{1/2}$$

$$= 0.044 \ m^3/sec < Q = 0.053 \ m^3/sec \quad \text{Not } 0.K$$

Example - 3



L : Length of Ditch = 1.5 km

i ; Surface slope of water along ditch

(= 1/200)

Design Condition

$A = 3.0\ km^2$

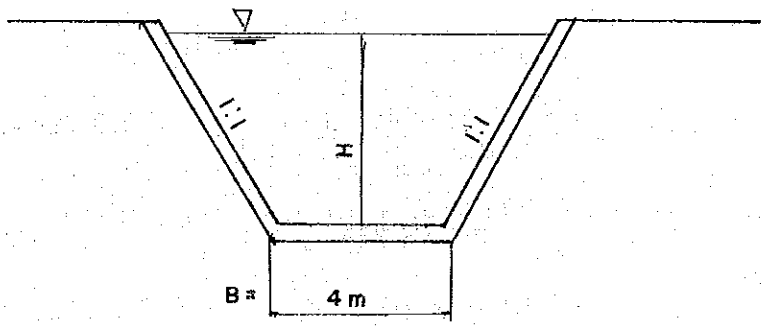
$L = 1.5\ km$

$t = 20 + \frac{L}{V}$ (minutes)

v = Mean velocity of water stream

n = 0.025 (coefficient of roughness)

Cross section of Ditch is indicated below:



. Capable discharge of running water in Ditch

$$Q_c = A \cdot V$$

$$V = \frac{1}{n} \times R^{2/3} \cdot i^{1/2}$$

$$A = H \times (B + H)$$

$$R = \frac{H \times (B + H)}{B + 2\sqrt{2} \times H}$$

If $H = 2.5$ m

$$A = 2.5 \times (4.0 + 2.5) = 16.25 \text{ m}^2$$

$$R = \frac{16.25}{4 + 2 \times \sqrt{2} \times 2.5} = 1.468 \text{ m}$$

$$V = \frac{1}{0.025} \times 1.468^{2/3} \times \left(\frac{1}{200}\right)^{1/2} = 3.65 \text{ m/sec}$$

$$\therefore Q_c = 16.25 \times 3.65 \text{ m/sec} = 59.4 \text{ m}^3\text{/sec}$$

. Duration of rainfall

$$t = 20 + \frac{L}{V}$$

$$= 20 + \frac{1.5 \times 10^3}{3.65 \times 60} = 26.85 \text{ minutes}$$

. Rainfall intensity

$$I = \frac{8625}{t + 55} = \frac{8625}{26.85 + 55} = 105.4 \text{ mm/hour}$$

. Coefficient of run-off

$$C = 0.527 \quad \text{(given value)}$$

$$\therefore Q = \frac{1}{3.6} \times C \times I \times A$$

$$= \frac{1}{3.6} \times 0.527 \times 105.4 \times 3.0$$

$$= 46.3 \text{ m}^3\text{/sec} \qquad Q_c = 59.4 \text{ m}^3\text{/sec} \qquad \text{O.K}$$

If $H = 2.2$ meter

$$A = 2.2 \times (4.0 + 2.2) = 13.64\ m^2$$

$$R = \frac{13.64}{4.0 + 2.\sqrt{2} \times 2.2} = 1.334\ m$$

$$v = \frac{1}{0.025} \times 1.334^{2/3} \times \left(\left(\frac{1}{200}\right)\right)^{1/2}$$

$$= 3.428\ m/sec$$

$$Qc = 13.64 \times 3.428 = 46.8\ m^3/sec$$

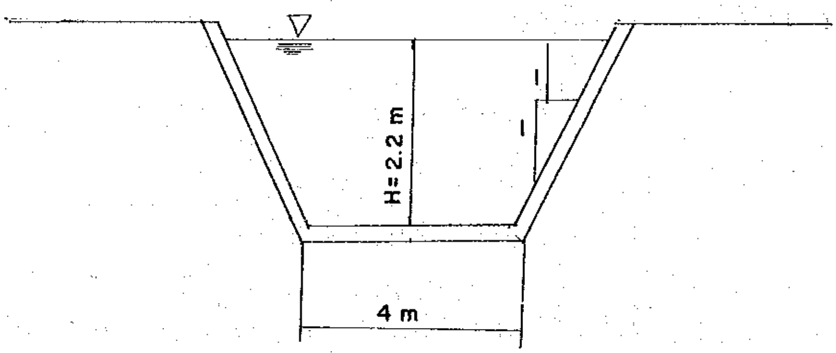
$$t = 20 + \frac{1500}{3.428 \times 60} = 27.29\ \text{minutes}$$

$$I = \frac{8625}{27.29 + 55} = 104.8\ \text{mm/hour}$$

$$Q = \frac{1}{3.6} \times 0.527 \times 104.8 \times 3.0 = 46.0\ m^3/hour < Qc$$

$$Qc = 46.6\ m^3/hour \quad O.K$$

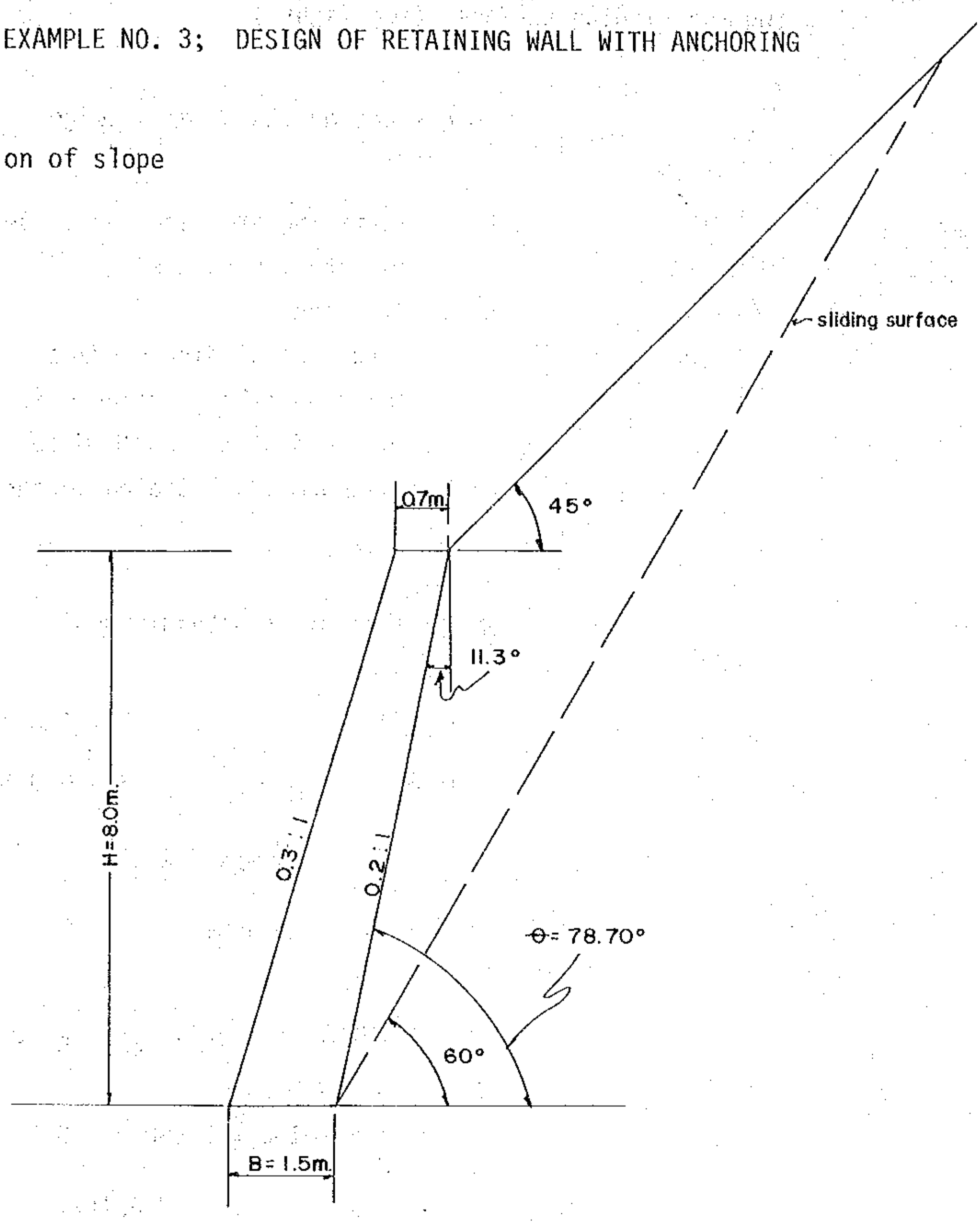
Therefore, Used Ditch shall be illustrated as the figure shown below.



APPENDIX 1:

DESIGN EXAMPLE NO. 3; DESIGN OF RETAINING WALL WITH ANCHORING

1) Dimension of slope

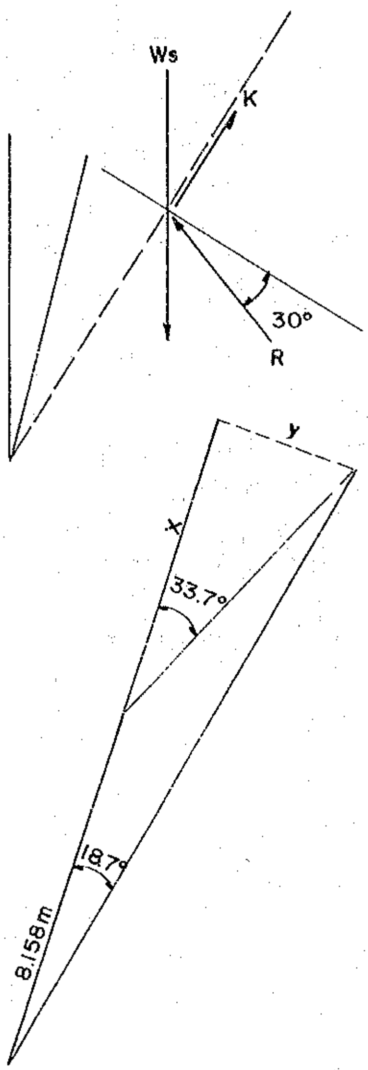


2) Characteristics of soil (or rock)

Unit weight γ = 1.8 t/m^3

Angle of internal friction ϕ = 30°

We assumed that the safety factor of stability is equal to 1.0 along the sliding surface (see figure)



Forces act on the sliding wedge

k ; Resisting shearing force due to cohesion (= c x ℓ)

C ; Cohesion

; Length of sliding surface

R ; Reaction (the reaction R is inclined at the angle Ø to the normal to sliding surface)

W_s = Weight of sliding wedge

$\tan 33.7° = \frac{Y}{X}$ $\quad Y = 0.667\,X$

$\tan 18.7° = \frac{Y}{8.158 + X}$ $\quad Y = 0.338\,(8.158+X)$

$\therefore \quad X = \frac{0.338 \times 8.158}{0.667 - 0.338} = 8.38/^{m}$

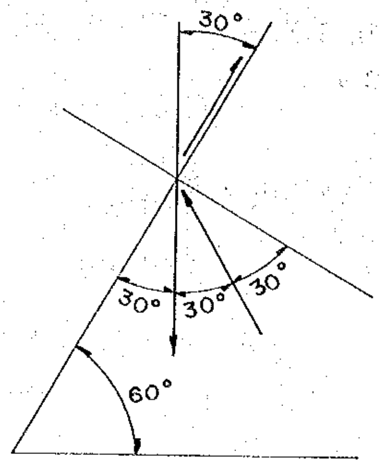
$Y = 5.590m$

$\ell = (8.158 + 8.381)\ \frac{1}{\cos 18.7°} = 17.461^{m}$

$Ws = A \times \gamma$

$= \frac{1}{2} \times 8.158 \times 5.590 \times 1.8 = 41.043t/m$

$K = c \times \ell = c \times 17.461t/m$



$W_s = R\cos 30° + K.\cos 30°$

$R\sin 30° = K\sin 30°$

$R = K$

$K = R = W/(2x\cos 30°) = \frac{41.043}{2 \times \cos 30°}$

$= 23.696 t/m$

$K = 23.696 t/m = c \times 17.461$

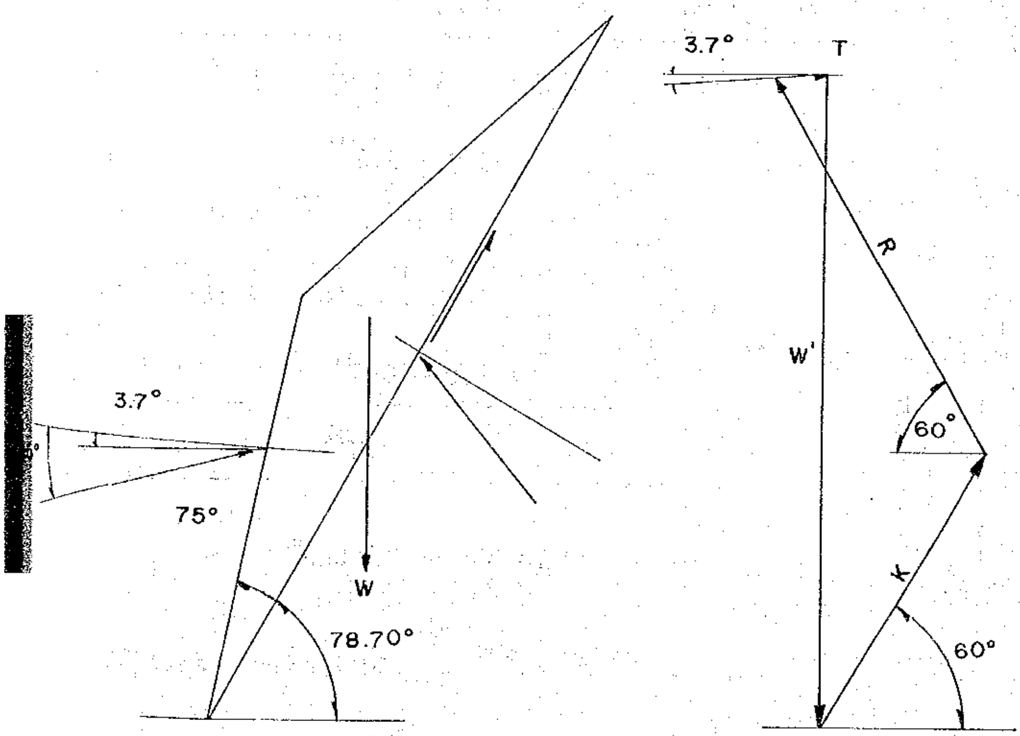
$C = 1.357\ (t/m^2)$

3) Computation of earth pressure

Proposed safety factor $S_{pf} = 1.5$

$W' = S_{pf} \times W_s = 1.5 \times 41.043 t/m = 61.565 t/m$

$K = c \times \ell = 1.375 \times 17.461 = 23.696 t/m$



$$W' = K \sin 60° + R \sin 60° + T \sin 3.7°$$
$$K \cdot \cos 60° = R \cos 60° - T \cos 3.7°$$

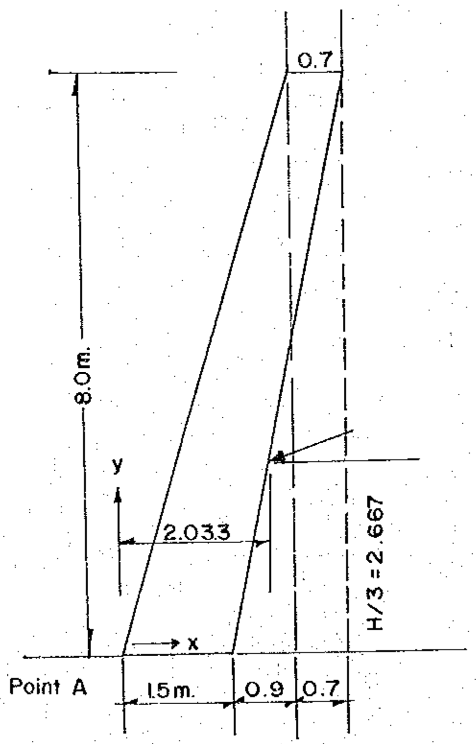
$$61.565 = 23.696 \times \sin 60° + R \sin 60° + T \sin 3.7°$$
$$23.696 \times \cos 60° = R \cos 60° - T \cos 3.7°$$

$$41.044 = 0.866 R + 0.0645T$$
$$11.848 = 0.5 R - 0.998T$$
$$R = 23.696 + 1.996T$$

$$41.044 = 0.866 (23.696 + 1.996T) + 0.0645T$$
$$1.793 T. = 20.523 \quad T = 11.45^{t}$$

4) Stability check of retaining wall

a) Computation of self-weight



No		Area	χ	A_χ
(1)	◺	$\frac{1}{2} \times (1.5 + 0.9) \times 8.0 = 9.6^{m2}$	1.6^{m}	15.360
(2)	▯	$0.7 \times 8.0 = 5.6^{m2}$	2.75	15.400
(3)	◺	$\frac{1}{2} \times (0.9 + 0.7) \times 8.0 = -6.4^{m}$	2.567	-16.429
Σ		8.8^{m2}		14.331

$$\bar{x} = \frac{14.331}{8.8} = 1.629^{m}$$

$$W = 8.8^{m2} \times 2.403t/m^3 = 21.146t/m$$

b) Resultant forces at point A

i) Earth pressure

Horizontal (←) $T_H = T \times \cos 3.7 = 11.45 \times \cos 3.7 = 11.426 t/m$

Vertical (↓) $T_V = T \times \sin 3.7 = 11.45 \times \sin 3.7 = 0.739 t/m$

ii) Concrete weight

$$W = 21.146^t$$

iii) Resultant forces

	V	X	V.x	H	Y	H. Y
Earth pressure	0.739	2.033	11.502	11.426	2.667	30.473
Concrete weight	21.146	1.629	34.447			
Σ	21.885		35.949	11.426		30.473

$V = 21.885^t$

$H = 11.426^t$

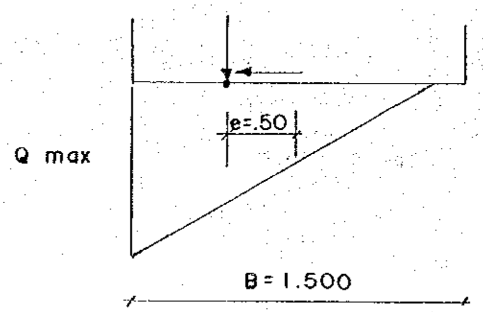
$M = V_X - H_Y = 35.949 - 30.473 = 5.476^{t.m}$

$e = M/V = 0.250^m$

c) Stability check

for overturning (within middle third)

$$e_o = \frac{B}{2} - e = \frac{1.5}{2} - 0.250 = 0.500^m \geqq \frac{B}{6} = 0.25$$



for soil reaction

$$Q_{max} = \frac{2 \times V}{3 \times (\frac{B}{2} - e_o)}$$

$$= \frac{2 \times 21.885}{3 \times 0.250} = 58.36 \ t/m^2 \quad Q_a = 30t/m^2$$

Q_a ; Allowable bearing capacity

for sliding

$$S_f = \frac{Hr}{H}$$

S_f ; Safety factor (more than 1)

H_u ; Resistant horizontal force

H_u ; $\mu \cdot V + c \cdot B_0$

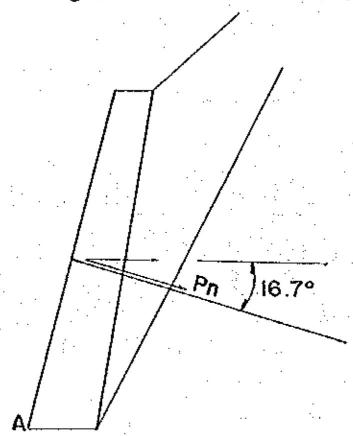
μ ; Coefficient of friction between concrete and rock (= 0.7)

C ; Cohesion of rock = $2.0t/m^2$

$$S_f = \frac{\mu \cdot V + C \cdot B_0}{H} = \frac{0.7 \times 21.885 + 2.0 \times 1.5}{11.426}$$

$$= 1.60 > 1.5$$

4) Stability check of retaining wall in case of anchoring



Required force due to anchor Pn

$$P_nH = Pn \cos 16.7° = 0.96\ Pn\ (ton)$$

$$P_nV = Pn \sin 16.7° = 0.29\ Pn\ (ton)$$

Resultant forces at point A

	V	X	V_X	H	Y	H_Y
Earth pressure	0.739	2.033	1.502	11.426	2.667	30.473
Concrete weight	21.146	1.629	34.447			
Anchor force	0.29Pn	1.20	0.348Pn	-0.96Pn	4.00	-3.840Pn
Σ	21.885 + 0.29Pn		35.949 + 0.348Pn	11.426 - 0.96Pn		30.473 - 3.840Pn

$$V = 21.885 + 0.2Pn$$
$$H = 11.426 - 0.96Pn$$
$$M = 35.949 + 0.34Pn - (30.473 - 3.840Pn)$$
$$= 5.476 + 4.188Pn$$

$$e_0 = \frac{B}{2} - e \leqq \frac{B}{6}$$

$$= \frac{1.5}{2} - \frac{M}{V} \leqq \frac{B}{6} = \frac{1.5}{6} = 0.250$$

Therefore

$$\frac{5.476 + 4.188Pn}{21.885 + 0.29Pn} \geqq 0.750 - 0.250 = 0.500$$

$$5.476 + 4.188Pn \geqq (21.885 + 0.29Pn)\ (0.500)$$
$$4.043Pn \geqq 5.467\ ton$$
$$Pn \geqq 1.35$$

Then Pn = 1.5 ton/m

Pn H = 1.5 x 0.96 = 1.440 ton

Pn V = 1.5 x 0.29 = 0.435 ton

Resultant force at point A

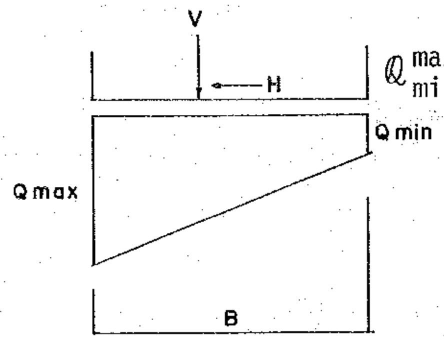
$$V = 21.885 + 0.29 \times 1.5 = 22.320 \text{ ton}$$
$$H = 11.426 - 0.96 \times 1.5 = 9.986 \text{ ton}$$
$$M = 5.476 + 4.188 \times 1.5 = 11.758 \text{ t.m}$$
$$e = M/V - 11.758/22.320 = 0.527 \text{ m}$$

. Stability check

overturning

$$e_o = \frac{B}{2} - e = \frac{1.50}{2} - 0.527 = 0.223 \leqq \frac{B}{6} = 0.250^{m}$$

Soil reaction



$$Q_{min}^{max} = \frac{V}{B} \pm \frac{6.V.e_o}{B^2}$$

$$= \frac{22.320}{1.5} \pm \frac{6 \times 22.320 \times 0.223}{1.52}$$

$$= 14.88 + 13.27 = \begin{cases} 28.15 \text{ t/m}^2 < Q_a = 30 \text{ t/m}^2 \\ 1.61 \text{ t/m}^2 \end{cases}$$

Sliding

$$S_f = \frac{U.V + C.B}{H}$$

$$= \frac{0.7 \times 22.320 + 2.0 \times 1.5}{9.986} = 1.87 > 1.5$$

Design of anchor material

. Required area of anchor material

(Note) Uncoated stress-relieved steel wire, and strand for prestressed concrete is usually used for anchor materials.

$$A_s \geqq \frac{Po}{pa}$$

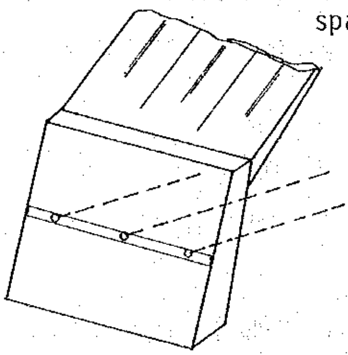
A_s ; Required area of anchor material (mm^2)

P_o ; Designed anchor force (kg)

σpa ; Allowable tension stress (kg/mm^2)

$P_o = 1.5^{ton}/m \times 3.0m = 4.5^{ton} = 4500^{kg}$

spacing of anchor 3.0 meters



$\sigma pa \leqq 0.60\ \sigma pu$ and $0.75\ \sigma py$

σpu ; Ultimate tension stress kg/mm^2

σpy ; Yield tension stress kg/mm^2

Composition	(mm^2) Area	(kg/m) Unit Weight	Tensile Stress (kg/mm^2)	(t/ea)	Yield Stress (kg/mm^2)	(t/ea)
Ø 5	19.64	0.154	165	3.25	145	2.85
Ø 7	38.48	0.302	155	5.95	135	5.20
Ø 8	50.27	0.395	150	7.55	130	6.55
T 9.3	51.61	0.405	175	9.05	150	7.70
T 10.8	69.68	0.546	175	12.20	150	10.40

$A_s \geqq \frac{Po}{Pa}$ $\quad 0.60 \times \sigma pu \times A_s \geqq Po = 4,500$ kg and

$0.75 \times \sigma py \times A_s \geqq Po = 4,500$ kg

$$\begin{cases} \sigma pu \cdot A_s \geqq 7{,}500 \\ \sigma py \cdot A_s \geqq 6{,}000 \end{cases}$$

Used Ø 8 steel wire

$\sigma pu \cdot A_s$ = 7,550kg/ea 7,500 kg O.K

$\sigma py \cdot A_s$ = 6,550kg/ea 6,000 kg O.K

. Allowable bond stress between steel wire (or stand) and concrete grout.

Designed Concrete Compression Strength at 28 days σck (kg/cm^2)

	180	240	300	more than 400
Steel wire	7	8	9	10
Strand	14	16	18	20

Source: Standard specification of Japan Civil Engineering Association

$$A_1 \geqq \frac{Po}{tab}$$

A_1 ; Required surface area of anchor (cm^2)

Po ; Designed anchor force (kg)

tab ; Allowable bond stress (kg/cm^2)

$$A_1 \geqq \frac{4{,}500kg}{8kg1cm^2} = 562.5cm^2$$

$$A_1 = \pi \times D \times \ell = 3.14 \times 0.8 \times \ell = 562.5cm^2$$

$$\ell = 223.8cm = 230cm = 2.3 \text{ meters}$$

Design of Anchorage

Diameter of Anchor hole	Applicable Soil
90 ～ 140 mm	clay, sand, silt
60 ～ 110 mm	sand and gravel, boulder, rock

. Ultimate tension force

$$T = \pi \cdot \ell a \cdot D \cdot tu$$

T ; Ultimate tension force in anchorage
D ; Diameter of anchor hole
ℓ ; Anchor length
tu ; Bond strength between concrete grout and soil (or rock)

Type of Soil or Rock			Recommended tu kg/cm2	Remarks
Rock		Hard rock	15 ～ 25	
		Soft rock	10 ～ 15	
		Weathered rock	6 ～ 10	
		Consolidated clay	6 ～ 12	Similar to adobe
Sand and Gravel	Standard Penetration Test	N = Value = 10	1.0 ～ 2.0 1.0 ～ 2.0	
		= 20	1.7 ～ 2.5	
		= 30	2.5 ～ 3.5	
		= 40	3.5 ～ 4.5	
		= 50	4.5 ～ 7.0	
Sand	Standard Penetration Test	N = Value = 10	1.0 ～ 1.4	
		= 20	1.8 ～ 2.2	
		= 30	2.3 ～ 2.7	
		= 40	2.9 ～ 3.5	
		= 80	3.0 ～ 4.0	
Cohesive Soil			1.0 x C	C; Cohesion of Soil

Used 80mm anchor hole

Type of rock ; weathered rock tu = 6 kg/cm^2

$\therefore$ T = π x ℓa x D x tu

= π x ℓa x 8^{cm} x 6 kg/cm^2

= 150.8 x ℓa kg

. Safety factor of anchoring

Permanent force ; F_s = 3.0

Tentative force ; F_s = 2.0 (Earthquake force, under construction)

$$Po \leqq \frac{T}{F_s}$$

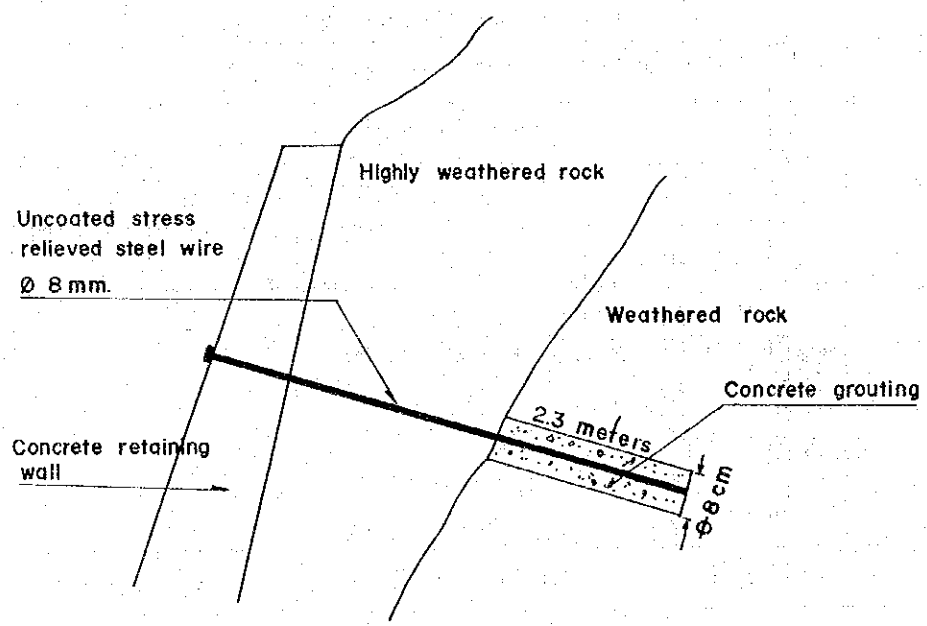
Po ; Designed anchor force = 4,500 kg

$$4{,}500 \quad \frac{150.8 \times \ell a}{3.0}$$

$\ell a \geqq$ 89.5cm = 1.0m < 2.3m = ℓ

ℓ ; required length of anchor based on the bond stress

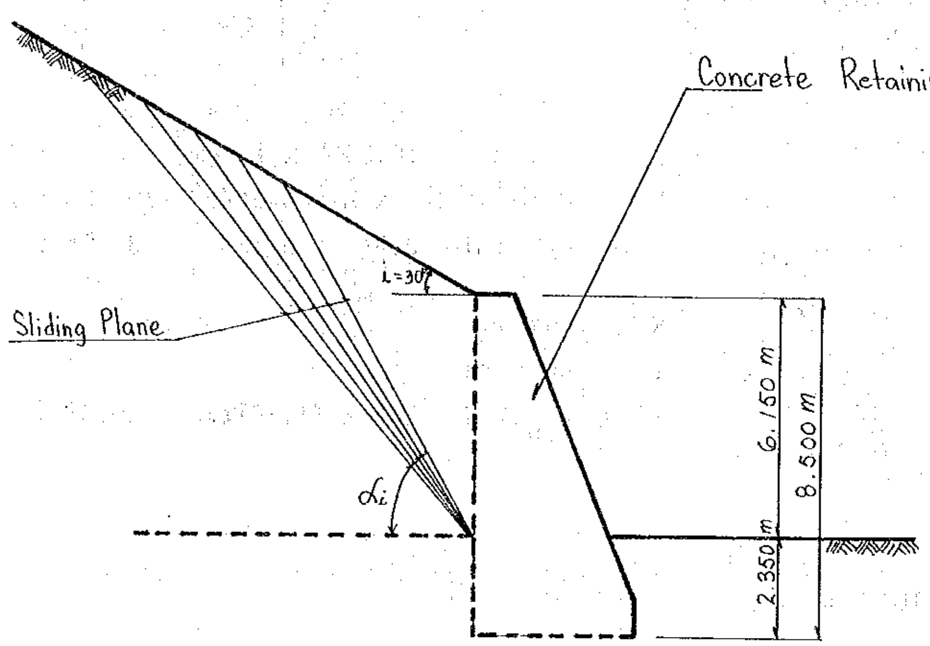
. <u>We will used 2.3 meters length of anchor</u>



APPENDIX 1:

DESIGN EXAMPLE NO. 4; DESIGN OF RETAINING WALL BY TRIAL METHOD WITH WEDGE SHAPE

1) Dimension of Slope

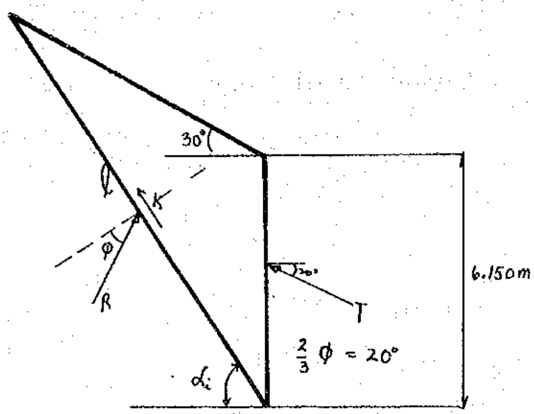


$$\alpha_i = \begin{cases} 60°, & 56° \\ 52°, & 48° \\ 44°, & \end{cases}$$

2) Characteristics of back soil

Unit Weight of Soil	γ	=	1.9 ton/m^3		
Internal Angle of Friction	ϕ	=	30°		
Cohesion	C	=	1.0 t/m^2		
Proposed Safety Factor	Fsp	=	1.3		
Friction between wall and soil	f	=	1/2 x C	=	0.5t/m^2
Angle of Reaction Force	δ	=	2/3 ϕ	=	20°

3) Computation of Earth Pressure



A ; Area of Wedge

ℓ ; Length of Sliding Plane

$W = A \times \gamma$

$K = C \times \ell$

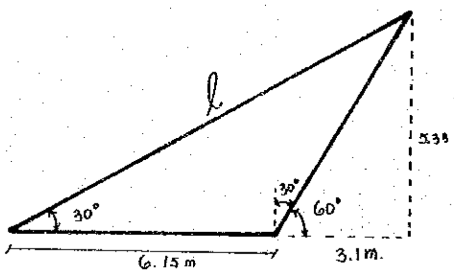
$S = c/2 \times H$

R = Unknown

T = Unknown

$W' = F_{sp} \times W$

i) $\alpha_i = 60°$



$W = A \times \gamma = 16.39m^2 \times 1.96m^3 = 31.141t/m$

$K = C \times \ell = C \times \ell = 1.0t/m^2 \times 10.68m = 10.68t/m$

$S = c/2 \times H = 0.5\frac{t}{m^2} \times 6.15m = 3.08t/m$

R = Unknown

T = Unknown

$W' = F_{sp} \times W = 1.3 \times 31.141t/m = 40.483t/m$

$A_\Delta = 16.390m^2$

$\text{Cos } 30^\circ = \dfrac{6.150 \times 3.100}{\ell}$

$\ell = \dfrac{6.150 \times 3.100}{\cos 20^\circ}$

$\ell = 10.680m.$

$\beta = 30 + 30 = 60°$

$W' = K \sin 60° + S + R \sin \beta + T \sin 20°$ ——————— (1)

$K \cos 60° + T \cos 20° = R \cos \beta$ ——————— (2)

From Equation (1)

$40.483 = 10.680 \sin 60^\circ + 3.080 + R \sin 60^\circ + T \sin 20^\circ$

$28.150 = R \sin 60^\circ + T \sin 20^\circ$

$$R \sin 60^\circ = 28.150 - T \sin 20^\circ$$

$$R = \frac{(28.150 - T \sin 20^\circ)}{\sin 60} \qquad \text{———— (3)}$$

In Equation (2)

$$10.680 \cos 60^\circ + T \cos 20^\circ = \frac{(28.150 - T \sin 20^\circ)}{\sin 60} \cos 60^\circ$$

$$5.340 + .940T = 16.250 - .197T$$

$$1.137T = 10.910$$

$$T = 9.60$$

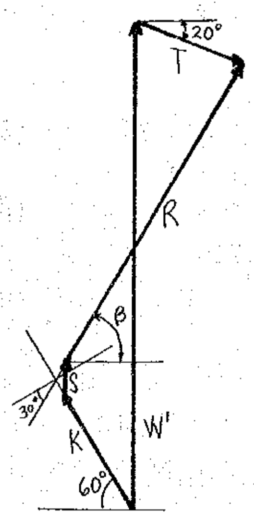
Substituting T in Equation (3)

$$R = \frac{28.150 - 9.600 \sin 20^\circ}{\sin 60^\circ}$$

$$= \frac{24.870}{\sin 60^\circ}$$

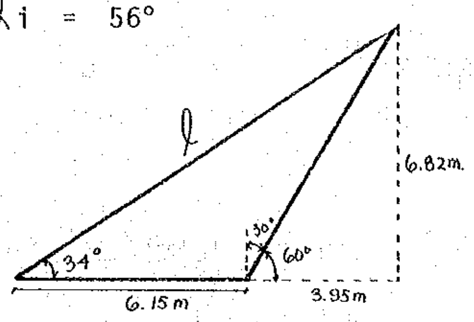
$$R = 28.720$$

VECTOR ANALYSIS



SCALE : 1/600 m.

ii) $\alpha i = 56°$



W = 20.97 x 1.9 = 39.843t/m
K = 1 x 12.18 = 12.18t/m
S = 0.5 x 6.15 = 3.08t/m
R = Unknown
T = Unknown
W' = 1.3 x 39.843 = 51.8t/m

$A_{\Delta} = 20.970m^2$

$\ell = \dfrac{6.150 \times 3.950}{\text{Cos } 34}$

$\ell = 12.183m$

$\beta = 30 + 34 = 64°$

$W' = K \sin 56° + S + R \sin \beta + T \sin 20°$ ——————— (1)

$K \cos 56° + T \cos 20° = R \cos \beta$ ——————— (2)

From Equation (1)

$51.800 = 12.180 \sin 56° + 3.080 + R \sin 64° + T \sin 20°$

$38.620 = R \sin 64° + T \sin 20°$

$R = \dfrac{(38.620 - T \sin 20°)}{\text{Sin } 64°}$ ——————— (3)

In Equation (2)

$12.180 \cos 56° + T \cos 20° = \dfrac{(38.620 - T \sin 20°)}{\text{Sin } 64°} \text{Cos } 64°$

$6.810 + .940T = 18.840 - .167T$

$1.110T = 12.030$

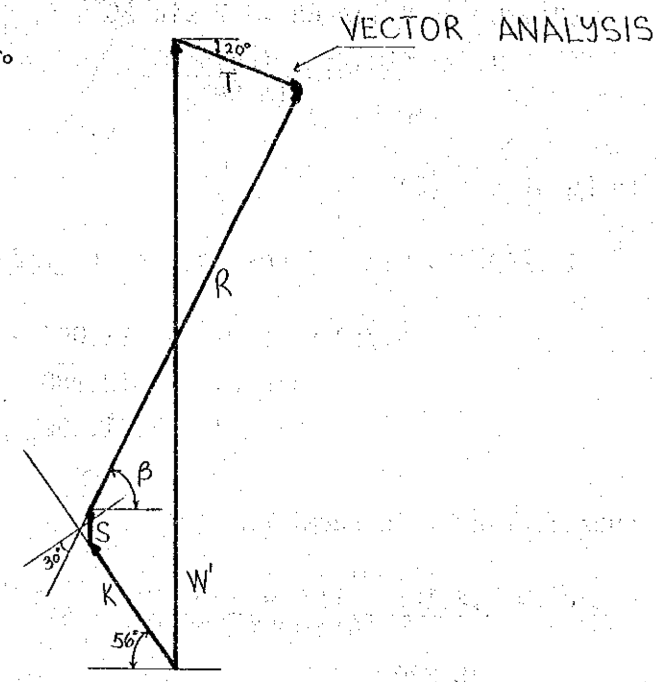
$T = 10.830$

Substituting T in Equation (3)

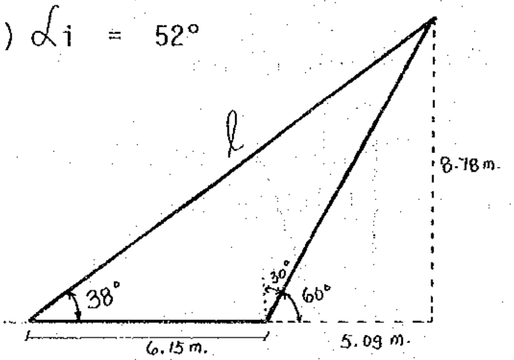
$$R = \frac{(38.620 - 10.830 \sin 20°)}{\sin 64°}$$

$$= \frac{34.920}{\sin 64°}$$

$$R = 38.850$$



iii) α_i = 52°



W = 26.9 x 1.9 = 51.110t/m
K = 1 x 14.26 = 14.260t/m
S = 0.5 x 6.15 = 3.080t/m
R = Unknown
T = Unknown
W' = 1.3 x 51.11 = 66.443t/m

$$A_\Delta = 26.900 m^2$$

$$\ell = \frac{6.150 \times 5.090}{\cos 38°}$$

$$\ell = 14.260 m$$

$$\beta = 30° + 38° = 68°$$

$$W' = K \sin 52° + S + R \sin \beta + T \sin 20° \quad \text{———} (1)$$

$$K \cos 52° + T \cos 20° = R \cos \beta \quad \text{———} (2)$$

From Equation (1)

$$66.443 = 14.260 \sin 52° + 3.080 + R \sin 68° + T \sin 20$$

$$52.125 = R \sin 68° + T \sin 20°$$

$$R = \frac{52.125 - T \sin 20°}{\text{Sin } 68°} \quad \text{------} (3)$$

In Equation (2)

$$14.260 \cos 52° + T \cos 20° = \frac{(52.125 - T \sin 20°)}{\text{Sin } 68°} \text{ Cos } 68°$$

$$8.780 + .940T = 21.060 - .138T$$

$$1.078T = 12.280$$

$$T = 11.390$$

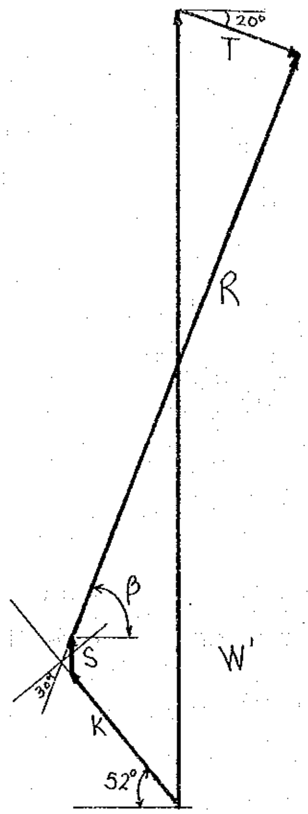
Substituting T in Equation (3)

$$R = \frac{52.125 - 11.390 \sin 20°}{\text{Sin } 68°}$$

$$= \frac{48.230}{\text{Sin } 68°}$$

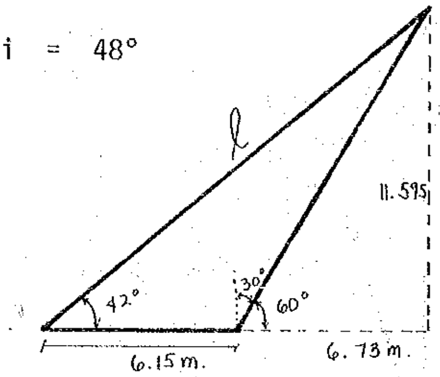
$$R = 52.020$$

VECTOR ANALYSIS



Scale : $\frac{1}{600}$ m

iv) α_i = 48°



W = 35.65 x 1.9 = 67.735t/m
K = 1.0 x 17.33 = 17.330t/m
S = 0.500 x 6.160 = 3.080t/m
R = Unknown
T = Unknown
W' = 1.3 x 67.735 = 88.055t/m

A_A = 35.650m^2

$\ell = \dfrac{6.150 \times 6.730}{\text{Cos } 47°}$

ℓ = 17.330m

β = 30° + 42° = 72°

W' = K sin 48° + S + R sin β + T sin 20° ——— (1)

K cos 48° + T cos 20° = R cos β ——— (2)

From Equation (1)

88.055 = 17.330 sin 48° + 3.080 + R sin 72° + T sin 20

72.100 = R sin 72° x T sin 20°

$R = \dfrac{(72.100 - T \sin 20°)}{\text{Sin } 72°}$ ——— (3)

In Equation (2)

$17.330 \cos 48° + T \cos 20° = \dfrac{(72.100 - T \sin 20°)}{\text{Sin } 72°} \text{ Cos } 72°$

11.600 + .940T = 23.430 - .110T

1.050T = 11.820

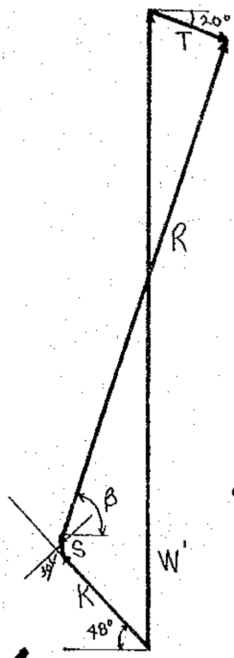
T = 11.260

Substituting T in Equation (3)

$$R = \frac{72.100 - 11.260 \sin 20^{\circ}}{\sin 72^{\circ}}$$

$$= \frac{68.250}{\sin 72^{\circ}}$$

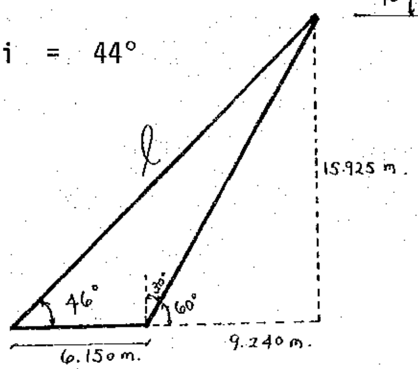
$$R = 71.760$$



VECTOR ANALYSIS

SCALE : $\frac{1}{1000}$ m

v) $\alpha i = 44^{\circ}$



W = 48.97 x 1.9 = 93.043t/m

K = 1 x 22.15 = 22.150t/m

S = 0.5 x 6.15 = 3.080t/m

R = Unknown

T = Unknown

W' = 1.3 x 93.043 = 120.956t/m

$A_{\Delta} = 48.970 m^2$

$$\ell = \frac{6.150 + 9.240}{\cos 46^{\circ}}$$

$\ell = 22.150$

$\beta = 30 + 46 = 76^{\circ}$

$W' = K \sin 44^{\circ} + S + R \sin \beta + T \sin 20^{\circ}$ ———— (1)

$K \cos 44^{\circ} + T \cos 20^{\circ} = R \cos \beta$ ———— (2)

From Equation (1)

$$120.956 = 22.150 \sin 44^\circ + 3.080 + R \sin 76^\circ + T \sin 20^\circ$$

$$102.490 = R \sin 76^\circ + T \sin 20^\circ$$

$$R = \frac{102.490 - T \sin 20^\circ}{\text{Sin } 76^\circ} \quad \text{———} \quad (3)$$

In Equation (2)

$$22.150 \cos 44^\circ + T \cos 20^\circ = \frac{(102.490 - T \sin 20^\circ)}{\text{Sin } 76^\circ} \text{ Cos } 76^\circ$$

$$15.930 + .94T = 25.550 - .085T$$

$$1.025T = 9.620$$

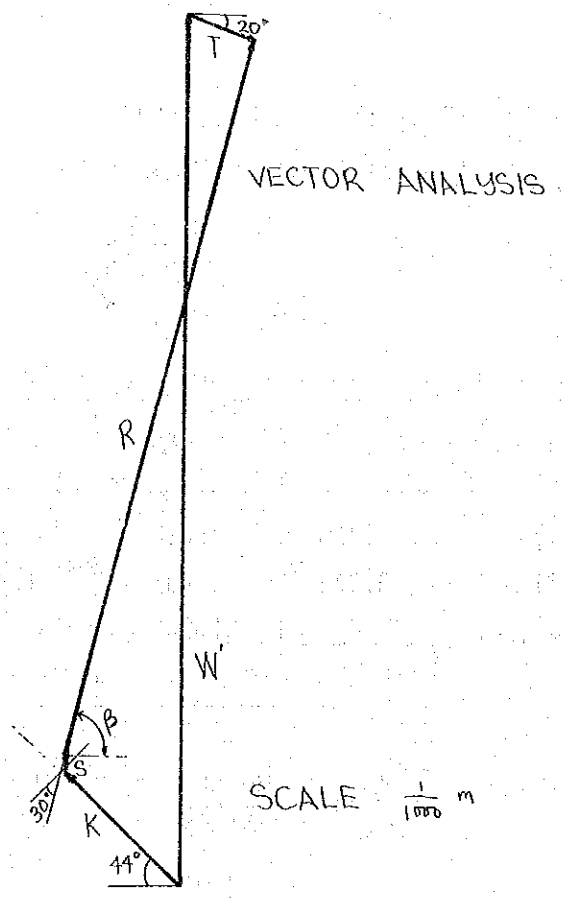
$$T = 9.390$$

Substituting in Equation (3)

$$R = \frac{102.490 - 9.39 \sin 20^\circ}{\text{Sin } 76^\circ}$$

$$= \frac{99.280}{\text{Sin.}76^\circ}$$

$$R = 102.320$$



.˙. Critical Earth Pressure

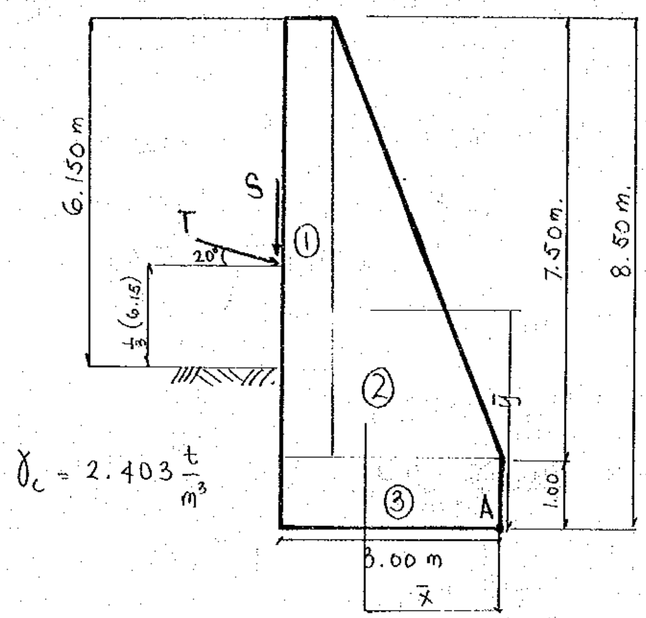
T = 11.39t/m

4) Computation of Resulting Forces at Point A

FIGURE:

T = 11.39t/m

S = 3.08t/m



Area:

A_1 = .5 x 7.5 = $3.750m^2$

A_2 = $\frac{1}{2}$ (2.5) (7.5) = $9.375m^2$

A_3 = 1 (3) = $3.000m^2$

ΣA = $16.125m^2$

Description	A (m^2)	X_o (m)	Y_o (m)	Ax_o (m^3)	Ay_o (m^3)
(1)	3.750	2.750	4.750	10.313	17.813
(2)	9.375	1.667	3.500	15.656	32.813
(3)	3.000	1.500	0.500	4.500	1.500
	Σ=16.125			Σ=30.469	Σ=52.126

$$\bar{X} = \frac{Ax_o}{\Sigma A} = \frac{30.469}{16.125} = 1.889m.$$

$$\bar{Y} = \frac{\Sigma A y_o}{\Sigma A} = \frac{52.126}{16.125} = 3.233m.$$

Consider 1m. strip:

Vertical Forces:

$V = \gamma_c \times A \times 1$

$V_1 = 2.403 \frac{t}{m^3} \times 3.75 m^2 \times 1m = 9.011t$

$V_2 = 2.403 \times 9.375 \times 1 = 22.528t$

$V_3 = 2.403 \times 3.000 \times 1 = 7.209t$

Concrete Weight, $V_T = V_1 + V_2 + V_3$

$V_T = 38.749t$

Earth Pressure, $S = 3.08t$

Earth Pressure, $T_Y = T \sin 20°$

$= 11.39 \sin 20°$

$T_Y = 3.896t$

Horizontal Forces:

Earth Pressure, $T_X = T \cos 20°$

$= 11.39 \cos 20°$

$T_X = 10.703t$

Description	V	X	Vx	H	Y	Hy
Earth Pressure, T	3.896	3.000	11.688	10.703	4.4	47.093
Earth Pressure, S	3.080	3.000	9.240	0	0	0
Concrete Weight	38.749	1.889	73.240	0	0	0
	Σ=45.725		Σ=94.168	Σ=10.703		Σ=47.093

$M_O = Vx - Hy$

$= 94.168 - 47.093$

$M_O = 47.075$ t-m.

Total Resulting Forces at Point A

$V = 45.725t$
$H = 10.703t$
$M = 47.075t\text{-}m.$

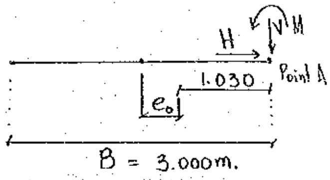
5) Stability Check of Retaining Wall

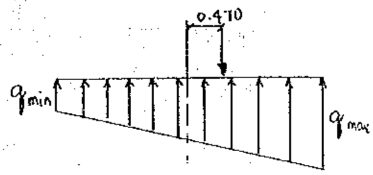
1) Bearing capacity of soil ; $q\,max \leq 30t/m^2$
2) Overturning ; resultant force with middle third
3) Sliding ; $SF > 1.5$

$$e = \frac{M}{V} = \frac{47.075}{45.725} = 1.030m.$$

$$e_o = \frac{B}{2} - e = 0.470 < \frac{B}{6} = 0.500$$

O.K.





$$q\,\frac{max}{min} = \frac{V}{A} \pm \frac{M_c}{I} \times Y$$

$$= \frac{V}{A} \pm \frac{6M_c}{B^2}$$

$$= \frac{45.725}{3.000} \pm \frac{6 \times 45.725 \times 0.470}{9}$$

$$= 15.242 \pm 14.327$$

$q\,max = 29.569t/m^2 < 30t/m^2$

$q\,min = 0.915t/m^2$

O.K.

$$S_f = \frac{H_R}{H} = \frac{V \times \mu}{H} \quad ; \mu = 0.6$$

$$= \frac{45.725 \times 0.6}{10.703}$$

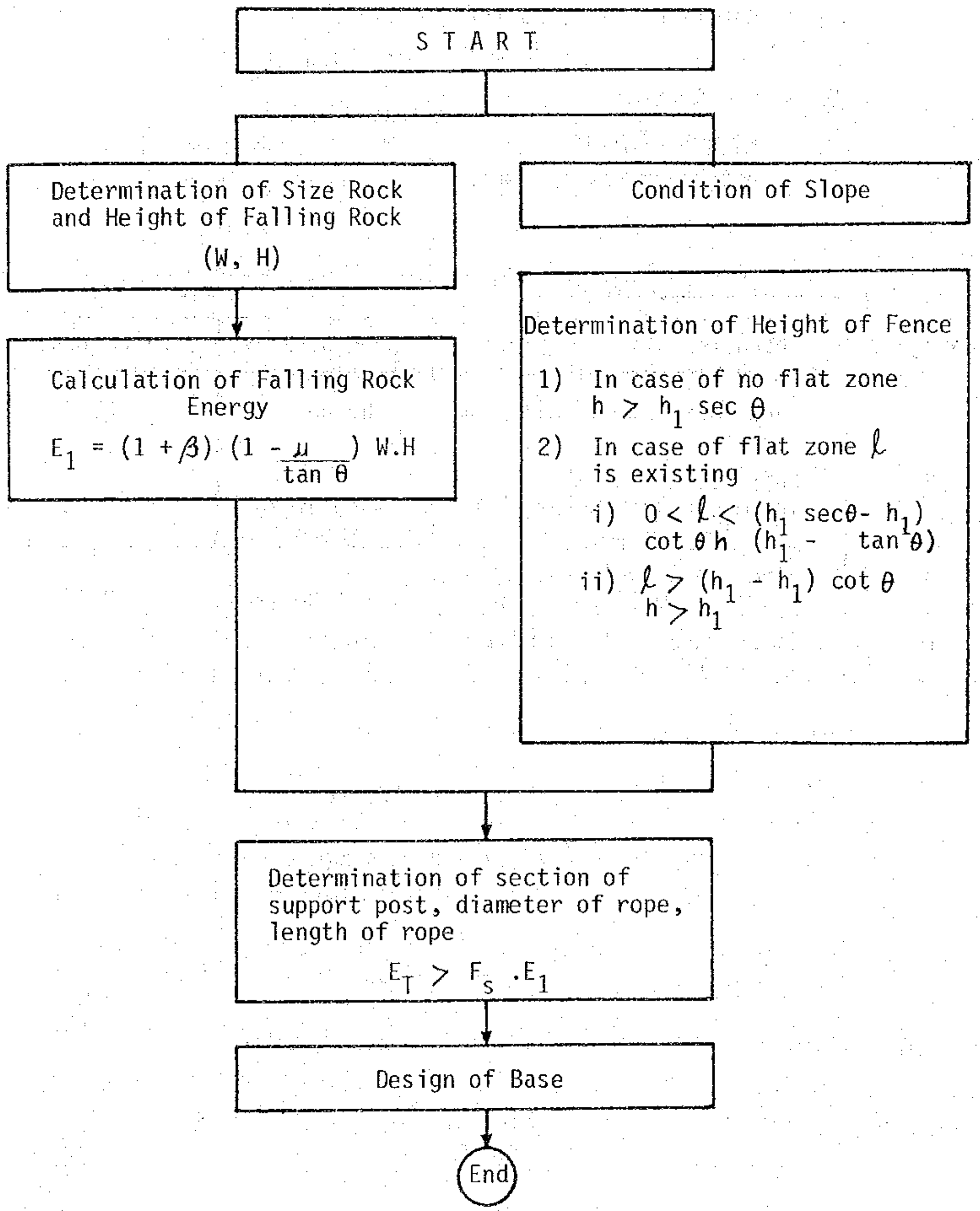
$$S_f = 2.56 > 1.5$$

O.K.

APPENDIX 1:

DESIGN EXAMPLE NO. 5; CATCH FENCE

1) Design Flow Chart



Computation of Falling Rock Energy

$$E_1 = (1 + \beta)\ (1 - \frac{\mu}{\tan})\ W.H$$

Wherein;

$$(1 + \beta)\ (1 - \frac{\mu}{\tan}) \leqq 1.0$$

E = Kinetic Energy
β = Rotation Energy Factor (= 0.1)
μ = Equivalent coefficient of friction
θ = Gradient of Slope
W = Weight of Rock
H = Height of Falling Rock

Value of μ

Category	Characteristics of Slope	Shape of Rock	μ to be designed
A	Hard Rock, small No tree	Round	0.05
B	Soft Rock, medium to large, No tree	Angular to round	0.15
C	Sand and Gravel, talus deposit, small to medium	No tree	0.25
D	Talus deposit (with boulder) medium to large	Angular	0.35

Computation of Energy absorbed by the Fence

1) Computation of Reaction "R"

$$\left(\frac{a}{2} + \frac{T_Y . L}{2 E_W . A}\right)\left(\cos \theta_1\right) = \frac{a}{2}$$

Characteristics of Wire Rope

Diameter	Cross Sectional Area, A (cm.^{2})	Yield Stress T_Y (tons)
Ø 18	1.29	12.0
Ø 16	1.01	9.0
Ø 14	0.78	7.5
Ø 12	0.59	5.3

E_W ; Young Modulus of Wire Rope = 1.0×10^6 kg/cm^2

L ; Length of Wire Rope = 60.0 meters

a ; Spacing of Supporting Post = 3.0 meters

$\therefore$; $\cos \theta_1 = \frac{a}{2} \Big/ \left(\frac{a}{2} + \frac{T_Y . L}{2 E_W . A}\right)$

Diameter	Ø 18	Ø 16	Ø 14	Ø 12
$\cos \theta_1$	0.843	0.849	0.839	0.848
θ_1	32.53°	31.93	33.00	32.04
R (ton)	12.904	9.519	8.169	5.623

$$R = 2 \times T_Y \times \sin \theta_1$$

$$\cos \theta_1 = \frac{a}{2} \Big/ \left(\frac{a}{2} + \frac{T_Y \cdot L}{2 E_W A} \right)$$

<u>for Ø 18 wire</u>

$$\cos \phi_1 = \frac{300}{2} \Big/ \left\{ \frac{300}{2} + \frac{(12000)\ (6000)}{2(1.0 \times 10^6)\ (1.29)} \right\}$$

$$\cos \theta_1 = 0.8431372$$

$$\theta_1 = 32.53°$$

$$R = 2\ T_Y \sin \phi_1 = 2\ (12{,}000) \sin 32.53 = 12{,}904.763 \text{ kg}$$

<u>for Ø 16 wire</u>

$$\cos \theta_1 = \frac{300}{2} \Big/ \left\{ \frac{300}{2} + \frac{(9000)\ (6000)}{2(1.0 \times 10^6)\ (1.01)} \right\}$$

$$\cos \theta_1 = .8487394$$

$$\theta_1 = 31.93°$$

$$R = 2\ (9000) \sin 31.93° = 9{,}518.6012 \text{ kg}$$

<u>for Ø 14 wire</u>

$$\cos \theta_1 = \frac{300}{2} \Big/ \left\{ \frac{300}{2} + \frac{(7500)\ (6000)}{2(1.0 \times 10^6)\ (0.78)} \right\}$$

$$\cos \theta_1 = 0.8387096$$

$$\theta_1 = 32.995885°$$

$$R = 2\ (7500) \sin 32.995885 = 8{,}168.682 \text{ kg}$$

for Ø 12 wire

$$\cos\theta_1 = \frac{300}{2} \Big/ \left\{\frac{300}{2} + \frac{(5300)\ (6000)}{2\ (1.0\times10^6)\ (0.59)}\right\}$$

$$\cos\theta_1 = .8477011$$

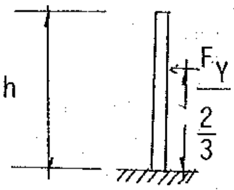
$$\theta_1 = 32.037493°$$

$$R = 2\cdot(5300)\ (\sin 32.037493) = 5{,}623.025 \text{ kg}$$

2) Computation of "F_Y"

$$F_y = \frac{\sigma_y \cdot Z}{h2}$$

3.0 = h

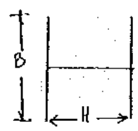


$\frac{2}{3} \cdot h = h2 = 2.0$ meters

h : Height of Fence = 3.0 meters

σ_y : Yield Point of H-steel = 2,400 $^{kg}/_{cm^2}$ (Material ; 5541)

Section Modulus of H-Steel



H x B (mm)	Section Modulus Z (cm^3)	F_Y (kg)
1) 150 x 75	88.8	1,065.
2) 175 x 90	139.	1,668
3) 200 x 100	184.	2,208
4) 250 x 125	324.	3,888
5) 200 x 200	472.	5,664
6) 300 x 200	771.	9,252
7) 250 x 250	867.	10,404
8) 300 x 300	1360.	16,320.

3) Comparison of "R" and "F_Y"

			F_Y							
			150x75 1.1	175x90 1.7	200x100 2.2	250x125 3.9	200x200 5.7	300x200 9.3	250x250 10.4	300x300 16.3
R	Ø 18	12.9	0	0	0	0	0	0	0	x
	Ø 16	9.5	0	0	0	0	0	0	x	x
	Ø 14	8.2	0	0	0	0	0	x	x	x
	Ø 12	5.6	0	0	0	0	x	x	x	x

Note;

0 ; $R > F_Y$

x ; $R < F_Y$

$$F_Y = \frac{\sigma_Y \cdot Z}{h_2}$$

1) $F_Y = \frac{(2400)\ (88.8)}{200\ cm} = 1065.6$ kg

2) $F_Y = \frac{(2400)\ (139)}{200} = 1668$ kg

3) $F_Y = \frac{(2400)\ (184)}{200} = 2208$ kg

4) $F_Y = \frac{(2400)\ (324)}{200} = 3888$ kg

5) $F_Y = \frac{(2400)\ (472)}{200} = 5664$ kg

6) $F_Y = \frac{(2400)\ (771)}{200} = 9252$ kg

7) $F_Y = \frac{(2400)\ (867)}{200} = 10404$ kg

8) $F_Y = \frac{(2400)\ (1360)}{200} = 16320$ kg

4) Computation of Absorption Energy

A) in case of $R > F_Y$

i) Absorption Energy by Wire Rope "E_R"

$$E_R = \frac{L}{E_W \cdot A} (T^2 - T_o^2) \qquad (1)$$

$$\left(\frac{a}{2} + \frac{T.\ L}{2\ E_W \cdot A}\right)\left(\sqrt{1 - \frac{F_Y^2}{4\ T^2}}\right) = \frac{a}{2} \qquad (2)$$

T_o ; initial stress of wire-rope = 500 kg

From Equation (2)

Diameter	Ø 18	Ø 16	Ø 14	Ø 12
T	6.3	4.7	2.9	2.25
From Equation	(1)			
E_R	1.8	1.3	.66	.49

Equation (2)

$$\left(a/2 + \frac{T.L}{2\ E_W A}\right)\left(\sqrt{1 - \frac{F_Y^2}{4\ T^2}}\right) = \frac{a}{2}$$

Ø 18

$$\left\{\frac{300}{2} + \frac{T\ 6000}{2\ (1.0 \times 10^6)\ (1.29)}\right\}^2 (47^2 - 5664^2) = 90{,}000T^2$$

$$T^4 + 127197.04T^3 - 8020212.77T^2 - 1.035T - 3.34 \times 10^{16} = 0$$

$f = 6320\text{kg} = 6.3$ ton

Ø 16

$$\left\{\frac{300}{2} + \frac{T\ 6000}{2\ (1.0 \times 10^6)}\ (1.01)\right\}^2 \ (4T^2 - 3888^2) = 90{,}000T^2$$

$$T^4 + 105839.21T^3 - 3778843.44T^2 - 3.808 \times 10^{11}T - 9.59 \times 10^{15} = 0$$

$f \approx 4699.5kg = 4.7$ ton

Ø 14

$$\left\{\frac{300}{2} + \frac{T\ 6000}{2\ (1.0 \times 10^6)}\ (.78)\right\}^2 \ (4T^2 - 2208^2) = 90{,}000T^2$$

$$T^4 + 77972.97T^3 - 1218817.5T^2 - 9.503 \times 10^{10}T - 1.85 \times 10^{15} = 0$$

$f \approx 2980.5kg = 2.9$ ton

Ø 12

$$\left\{\frac{300}{2} + \frac{T\ 6000}{2\ (1.0 \times 10^6)}\ (.59)\right\}^2 \ (4T^2 - 1668^2) = 90{,}000T^2$$

$$T^4 + 58994.20T^3 - 695551.26T^2 - 4.10 \times 10^{10}T - 6.05 \times 10^{14} = 0$$

$f = 2253.5kg = 2.25$ ton

ii) Absorption Energy by Supporting Post "E_p"

$$E_p = 0.54 \times h_2 \cdot F_Y$$

$$= 0.54 \times \frac{2}{3} \times 300 \times F_Y$$

Size of H-Steel	150 x 75	175 x 90	200 x 100	250 x 125	200 x 200	300 x 200	250 x 250	300 x 300
E_P	1.15	1.80	2.40	4.2	6.12	9.99	11.2	17.6

iii) Absorption Energy by Wire Mesh "E_N"

$$E_N = 2.5 \text{ t-m} \quad \text{(by the experiment)}$$

iv) Total Absorption Energy by the Fence

$$E_T = E_R + E_P + E_N$$

		E_P					
	150x75	175x90	200x100	250x125	200x200	300x300	250x250
E_R ø 18					10.42		
ø 16				8.00			X
ø 14			5.56			X	X
ø 12		4.79			X	X	X

$$E_N = 2.50 \text{ t.m}$$

B) In case of $R < F_Y$

i) Absorption Energy by Wire Rope

$$E_R = 2\,T_Y \,.\, L.S.$$

$$S = \frac{T_Y}{E_W \,.\, A} \qquad (\text{Max } S = 0.05)$$

Diameter	Ø 18	Ø 16	Ø 14	Ø 12
S	0.009	0.012	0.015	0.020
E_R	12.96	17.28	21.60	28.80

ii) Absorption Energy by Supporting Post

$$E_P = \frac{R^2 \cdot H_2^{\ 3}}{3\ E_H \cdot 1}$$

E_H ; Young Modulus of H-Steel (= 2.1 x 10^6 kg/cm^2)

I ; Inertia of H-Steel

Size of H-Steel	200 x 200	300 x 200	250 x 250	300 x 300
Inertia (1)	4720	11,300	10,800	20,400
E_P	.448	.187	.195	.103

iii) Absorption Energy of Wire Mesh

E_N = 2.50 t.m

iv) Total Absorption Energy of the Fence

$E_T = E_R + E_P + E_N$

		E_P		
	200 x 200	300 x 200	250 x 250	300 x 300
E_R Ø 18				15.536
Ø 16			19.975	
Ø 14		24.287		
Ø 12	31.75			

E_N = 2.5 t.m

C) Summary of Absorption Energy by the Fence

	150 x 75	175 x 90	200 x 100	250 x 125	200 x 200	300 x 200	250 x 250	300 x 300
Ø 18					10.42			25.563
Ø 16				8.00			19.975	
Ø 14			5.56			24.647		
Ø 12		4.79			31.75			

APPENDIX 2 STANDARD DRAWINGS

No. 1. Typical Cross Sections of Cut Slope and Embankment Slope

No. 2. Surface Drainage

No. 3. Subsurface Drainage

No. 4. Concrete Spraying

No. 5. Stone and Block Pitching

No. 6. Cast-in-Place Concrete Crib

No. 7. Sprayed Concrete Crib

No. 8. Wicker

No. 9. Gabion

No. 10. Anchoring

No. 11. Stone Masonry Retaining Wall

No. 12. Gravity Type Retaining Wall and Gabion Type Retaining Wall

No. 13. Supported Type Retaining Wall

No. 14. Catch Fill and Ditch

No. 15. Catch Wall

No. 16. Catch Fence

No. 17. Catch Wire Net

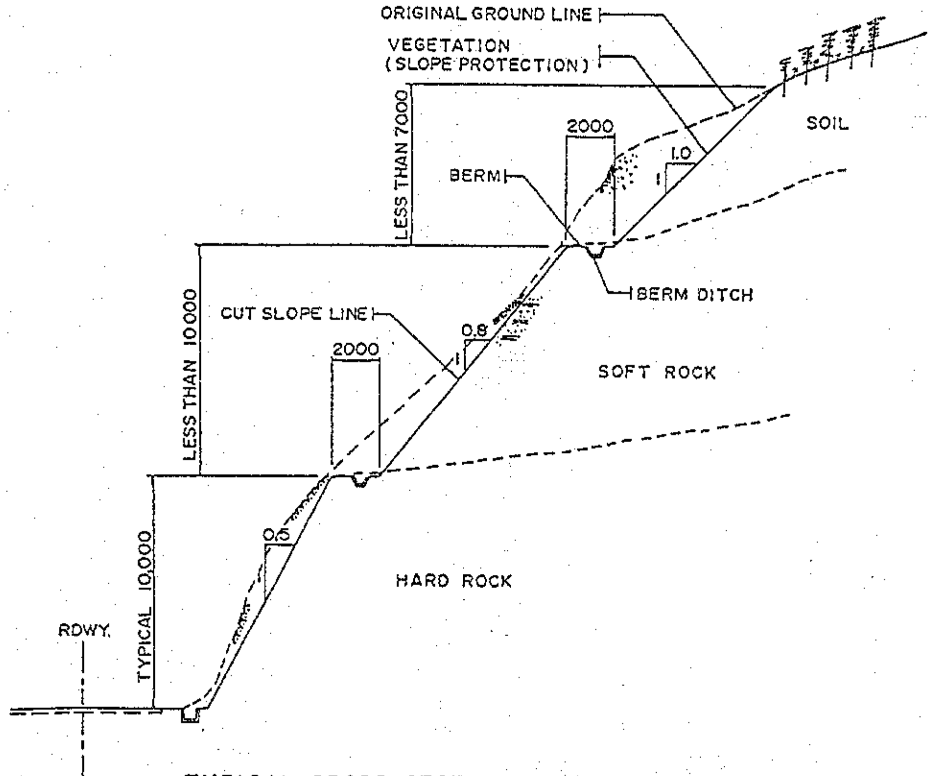
No. 18. Anchored Wire Net

No. 19. Rock Shed

No. 20. Stone Pitching Waterway and Foot Protection

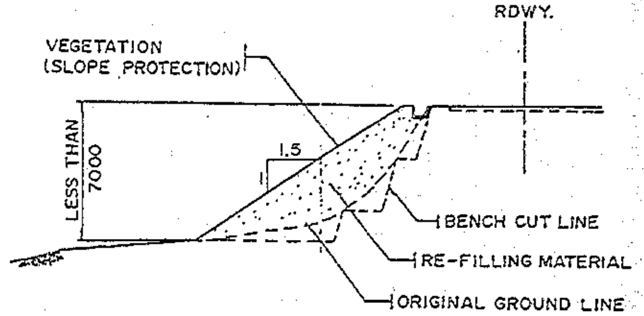
No. 21. Concrete Sabo Dam

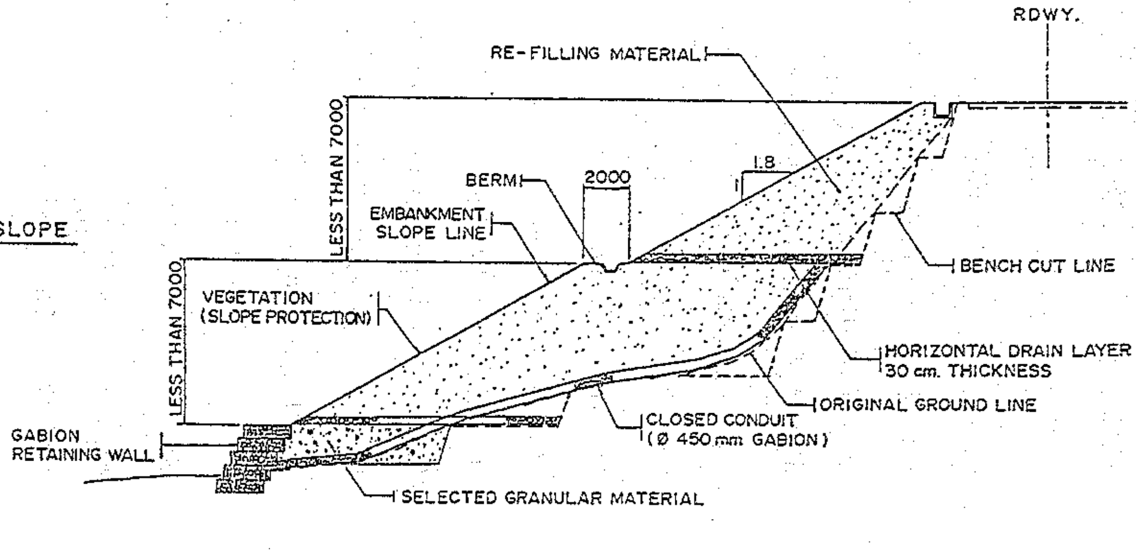
THE FEASIBILITY STUDY OF PHIL. ROAD DISASTER PREVENTION PROJECT		
SCALE	TYPICAL CROSS SECTIONS OF CUT SLOPE AND EMBANKMENT SLOPE	DRAWING NO. 1



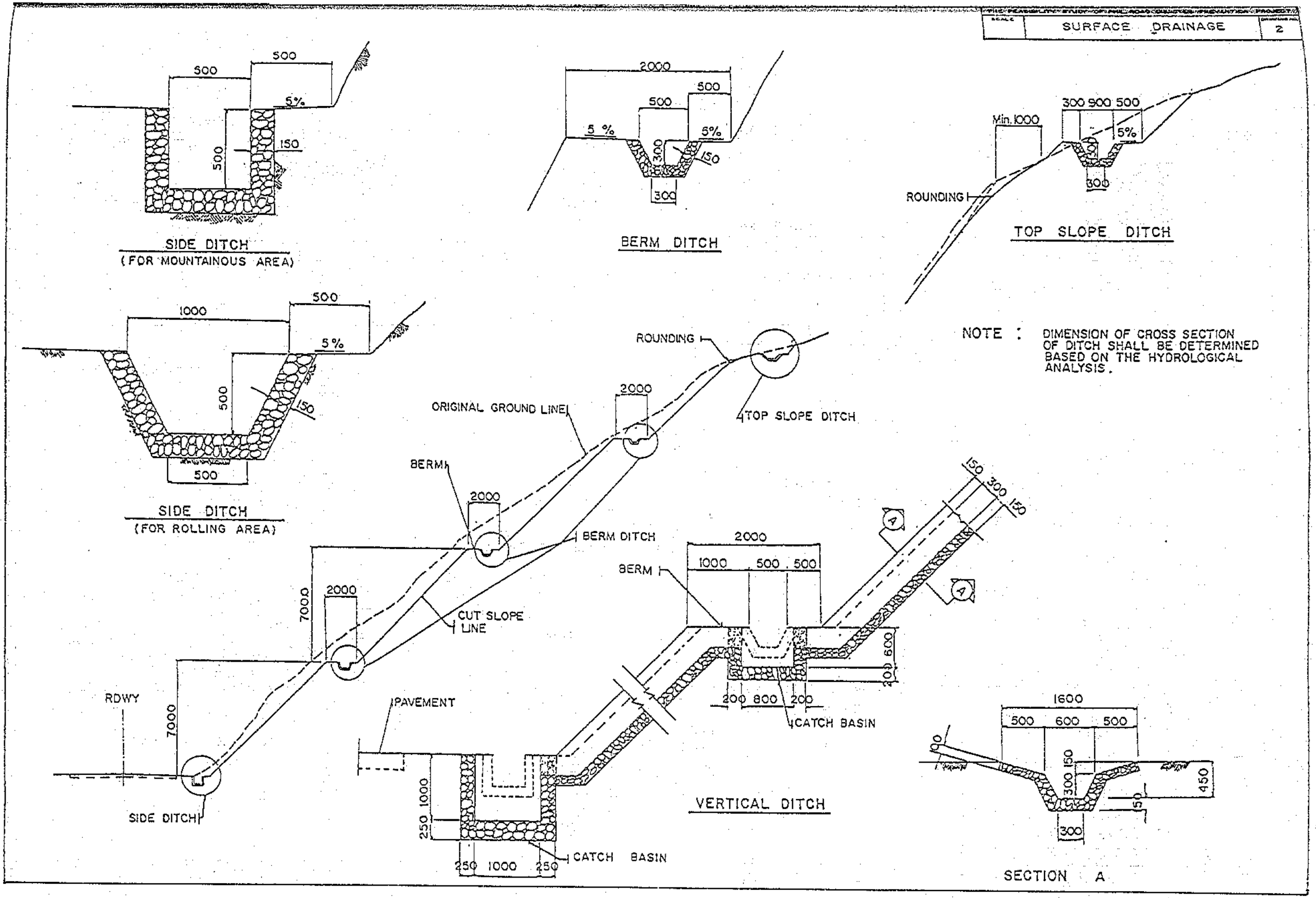
TYPICAL CROSS SECTION FOR CUT SLOPE

ITEM	KINDS OF ROCKS		
	SOIL	SOFT ROCK	HARD ROCK
GRADIENT	1.0 : 1	0.8 : 1	0.5 : 1
LOCATION OF BERM	EVERY 7.0 M	EVERY 10.0 M	—
WIDTH OF BERM	2.0 M	2.0 M	—

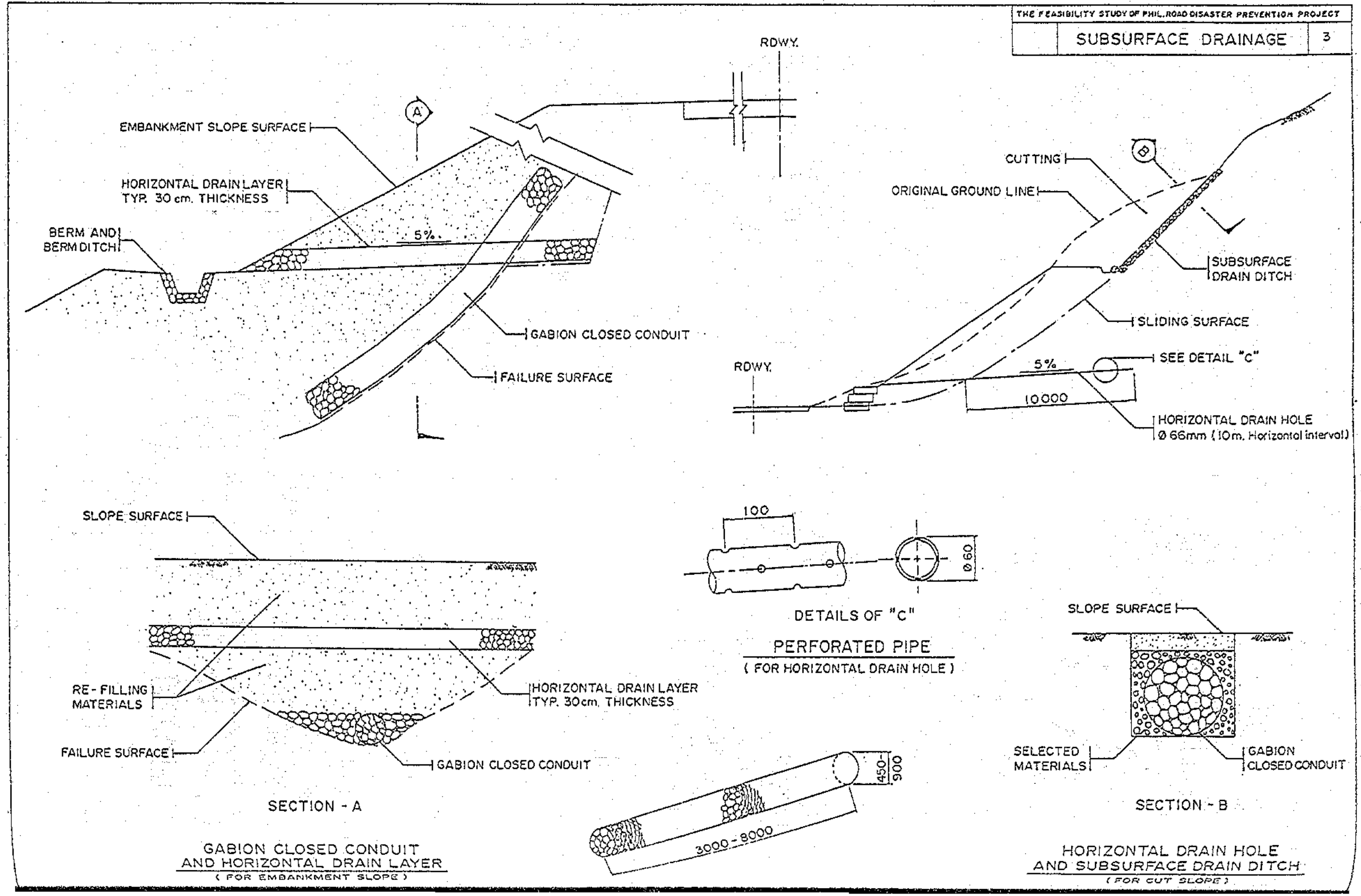




TYPICAL CROSS SECTION FOR EMBANKMENT SLOPE



SURFACE DRAINAGE
2
SIDE DITCH
(FOR MOUNTAINOUS AREA)
BERM DITCH
TOP SLOPE DITCH
Min.1000
ROUNDING
SIDE DITCH
(FOR ROLLING AREA)
ORIGINAL GROUND LINE
TOP SLOPE DITCH
BERM
BERM DITCH
CUT SLOPE LINE
RDWY
SIDE DITCH
PAVEMENT
CATCH BASIN
VERTICAL DITCH
SECTION A
NOTE : DIMENSION OF CROSS SECTION OF DITCH SHALL BE DETERMINED BASED ON THE HYDROLOGICAL ANALYSIS.

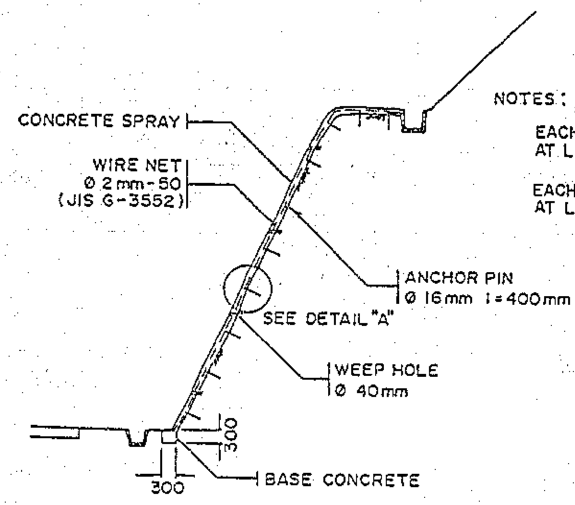

THE FEASIBILITY STUDY OF PHIL. ROAD DISASTER PREVENTION PROJECT
SUBSURFACE DRAINAGE
3
RDWY.
A
EMBANKMENT SLOPE SURFACE
HORIZONTAL DRAIN LAYER
TYP. 30 cm. THICKNESS
BERM AND
BERM DITCH
5%
GABION CLOSED CONDUIT
FAILURE SURFACE
B
CUTTING
ORIGINAL GROUND LINE
SUBSURFACE
DRAIN DITCH
SLIDING SURFACE
SEE DETAIL "C"
RDWY.
5%
10000
HORIZONTAL DRAIN HOLE
Ø 66mm (10m. Horizontal interval)
SLOPE SURFACE
RE-FILLING
MATERIALS
FAILURE SURFACE
HORIZONTAL DRAIN LAYER
TYP. 30cm. THICKNESS
GABION CLOSED CONDUIT
SECTION - A
GABION CLOSED CONDUIT
AND HORIZONTAL DRAIN LAYER
(FOR EMBANKMENT SLOPE)
100
Ø 60
DETAILS OF "C"
PERFORATED PIPE
(FOR HORIZONTAL DRAIN HOLE)
450-900
3000-8000
SLOPE SURFACE
SELECTED
MATERIALS
GABION
CLOSED CONDUIT
SECTION - B
HORIZONTAL DRAIN HOLE
AND SUBSURFACE DRAIN DITCH
(FOR CUT SLOPE)

THE FEASIBILITY STUDY OF PHIL. ROAD DISASTER PREVENTION PROJECT		
SCALE	CONCRETE SPRAYING	DRAWING NO. 4

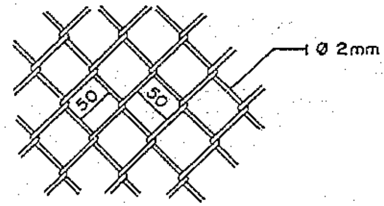
NOTES:

EACH ANCHOR PIN SHALL BE PLACED AT LEAST FOR EVERY 1 SQ. M.

EACH WEEP HOLE SHALL BE PLACED AT LEAST FOR EVERY 2 SQ. M.

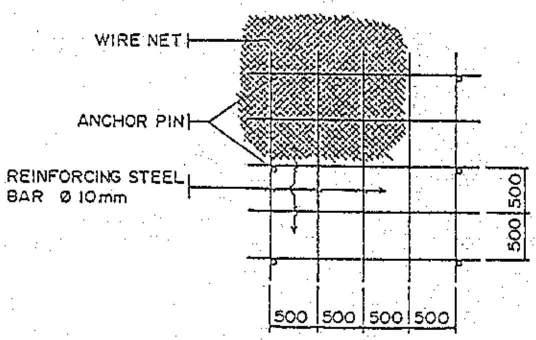


CONCRETE SPRAYING



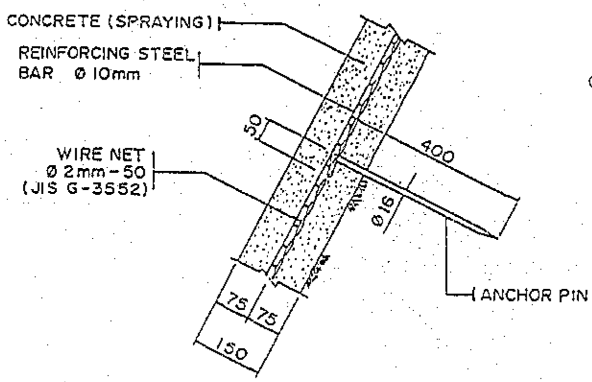
DETAILS OF WIRE NET

(Ø2mm-50) (JIS G-3552)



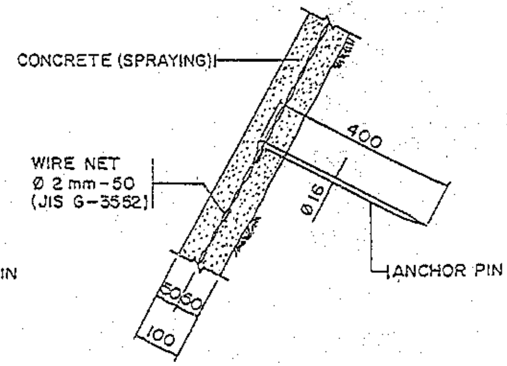
BAR ARRANGEMENT

THICKNESS 15cm.



DETAILS OF "A"

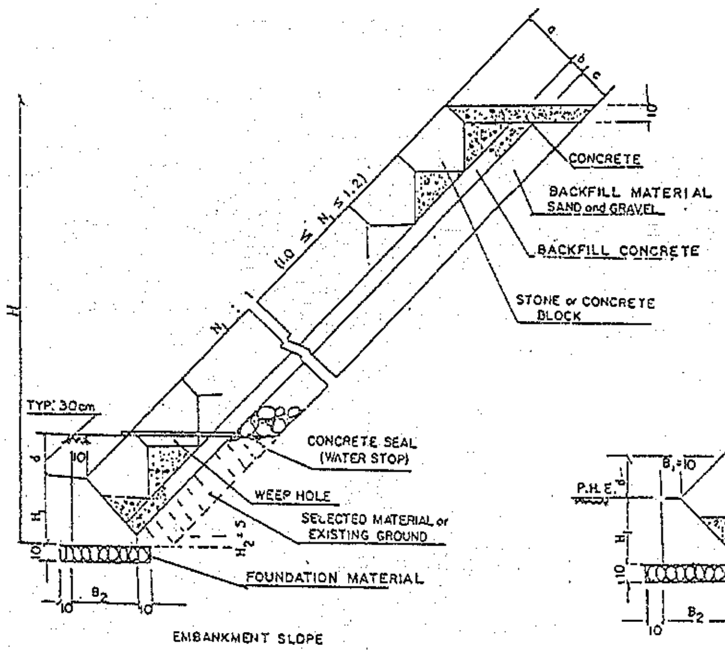
THICKNESS 15 cm.



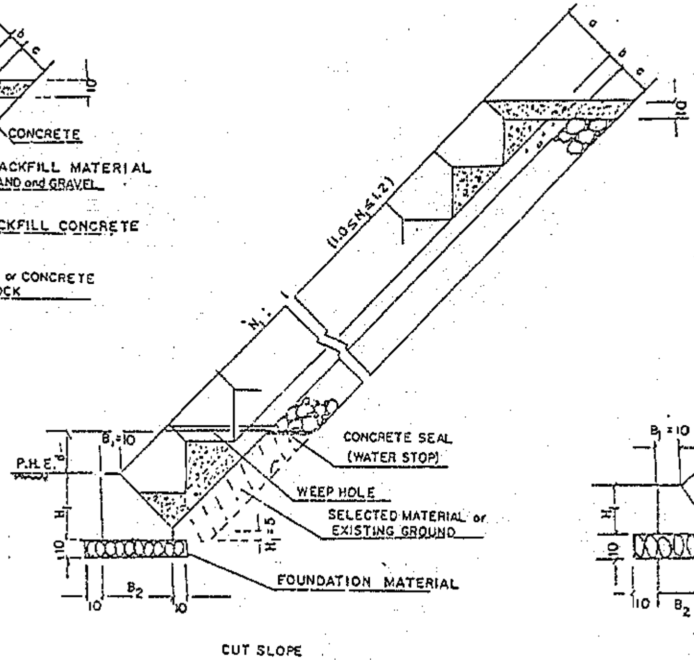
DETAILS OF "A"

THICKNESS 10 cm.

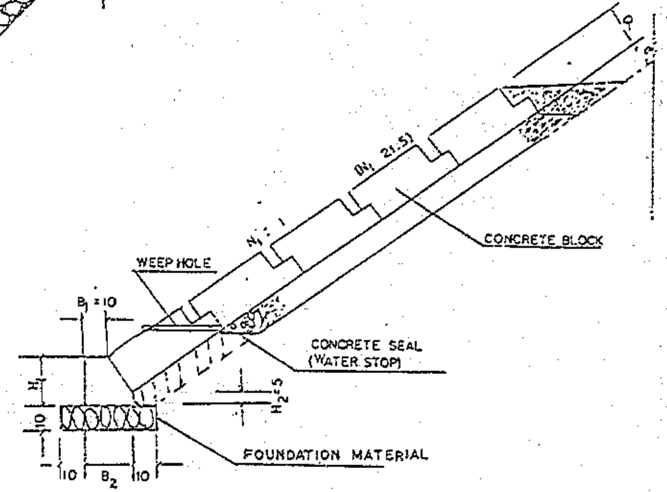
THE FEASIBILITY STUDY OF PHIL. ROAD DISASTER PREVENTION PROJECT		
SCALE	STONE and BLOCK PITCHING	DRAWING NO. 5



WET PITCHING
FOR EMBANKMENT SLOPE



WET PITCHING
FOR CUT SLOPE



DRY PITCHING
(NO BACKFILL CONCRETE)

DIMENSION OF WALL

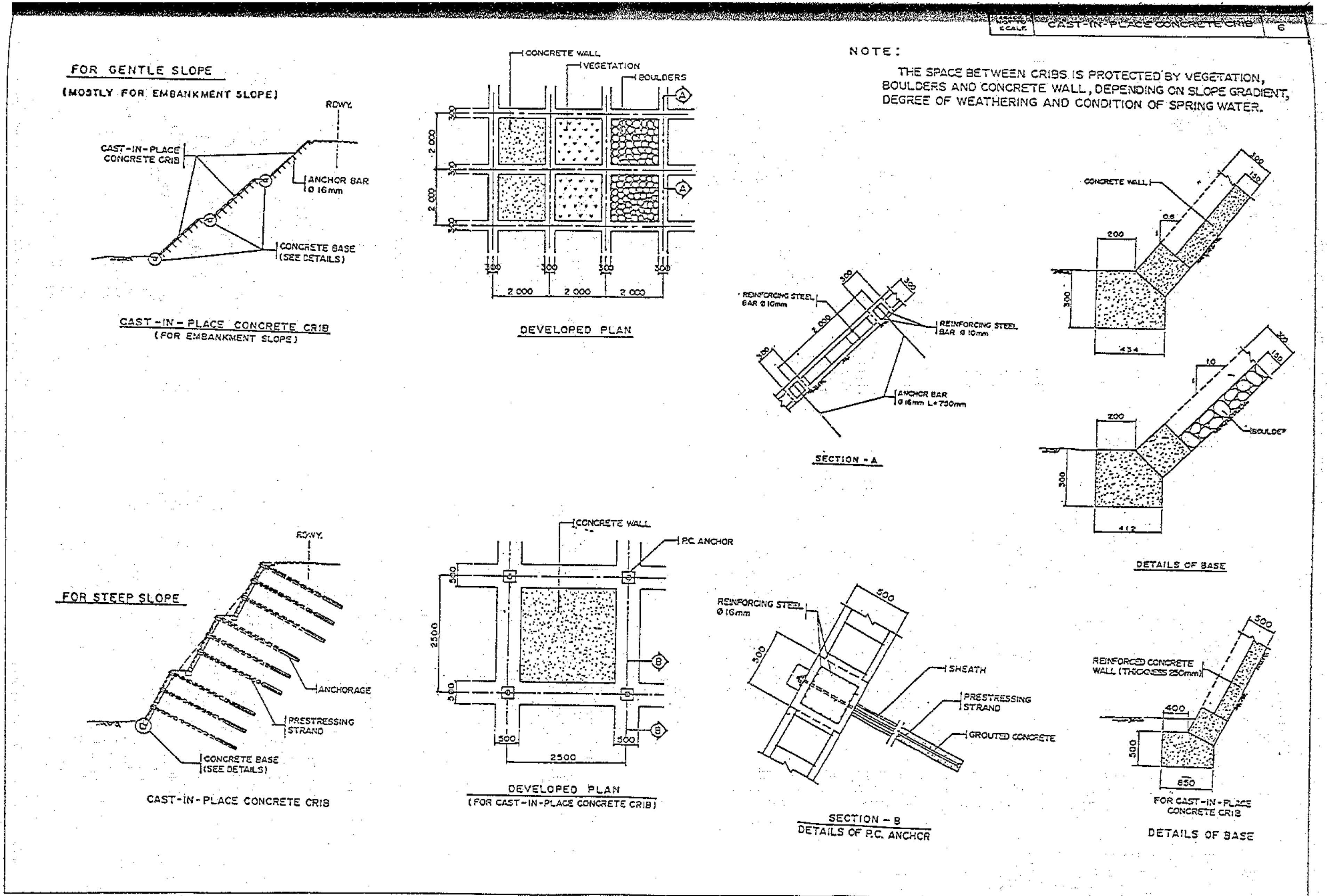
Unit; cm.

GRADIENT	WALL		BACKFILL CONCRETE	BACKFILL MATERIAL
N_1	STONE a	CONCRETE BLOCK a	b	c
1.0:1～1.5:1	35	35	10	20
1.5:1	25	12	0	10

DIMENSION OF BASE

Unit; cm.

	B_1	B_2	H_1	H_2
DRY PITCHING (b = 0 cm)	10	20	25	5
WET PITCHING (b= 10 cm)	10	40	45	5

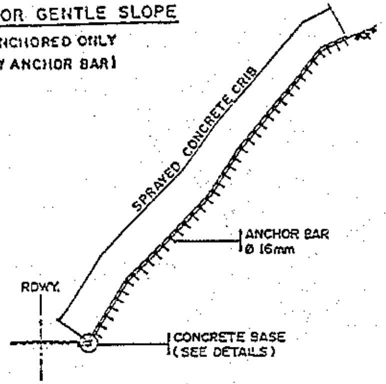

NOT TO SCALE
CAST-IN-PLACE CONCRETE CRIB
6
NOTE:
THE SPACE BETWEEN CRIBS IS PROTECTED BY VEGETATION, BOULDERS AND CONCRETE WALL, DEPENDING ON SLOPE GRADIENT, DEGREE OF WEATHERING AND CONDITION OF SPRING WATER.
FOR GENTLE SLOPE
(MOSTLY FOR EMBANKMENT SLOPE)
ROWY.
CAST-IN-PLACE CONCRETE CRIB
ANCHOR BAR Ø 16mm
CONCRETE BASE (SEE DETAILS)
CAST-IN-PLACE CONCRETE CRIB
(FOR EMBANKMENT SLOPE)
CONCRETE WALL
VEGETATION
BOULDERS
A
300
2 000
DEVELOPED PLAN
REINFORCING STEEL BAR Ø 10mm
ANCHOR BAR Ø 16mm L=750mm
SECTION - A
CONCRETE WALL
BOULDER
200
300
434
412
DETAILS OF BASE
FOR STEEP SLOPE
ANCHORAGE
PRESTRESSING STRAND
CONCRETE BASE (SEE DETAILS)
CAST-IN-PLACE CONCRETE CRIB
P.C. ANCHOR
B
500
2500
DEVELOPED PLAN
(FOR CAST-IN-PLACE CONCRETE CRIB)
REINFORCING STEEL Ø 16mm
SHEATH
GROUTED CONCRETE
SECTION - B
DETAILS OF P.C. ANCHOR
REINFORCED CONCRETE WALL (THICKNESS 250mm)
400
850
FOR CAST-IN-PLACE CONCRETE CRIB
DETAILS OF BASE

THE FEASIBILITY STUDY OF PHIL. ROAD DISASTER PREVENTION PROJECT		
SCALE NOT TO SCALE	SPRAYED CONCRETE CRIB	7.

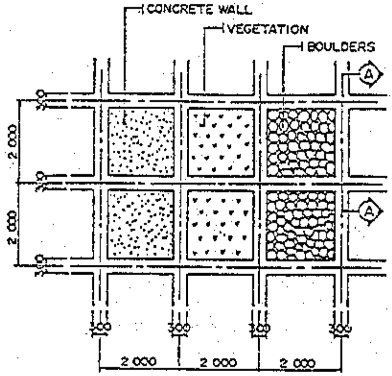
NOTE:

THE SPACE BETWEEN CRIBS IS PROTECTED BY VEGETATION, BOULDERS AND CONCRETE WALL, DEPENDING ON SLOPE GRADIENT, DEGREE OF WEATHERING AND CONDITION OF SPRING WATER.

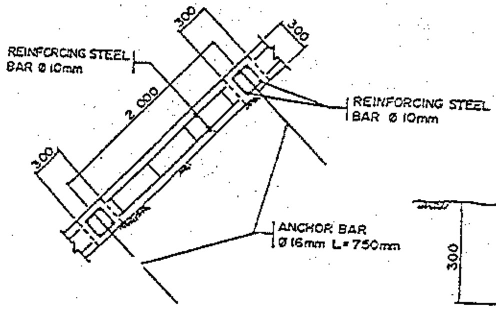
FOR GENTLE SLOPE
(ANCHORED ONLY BY ANCHOR BAR)



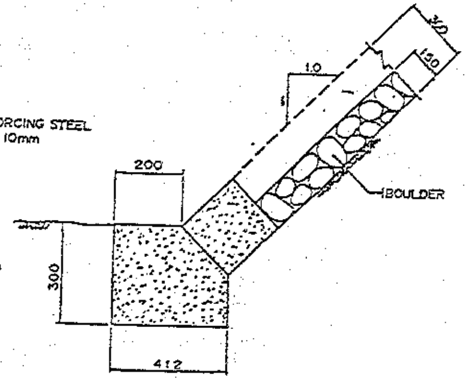
SPRAYED CONCRETE CRIB
(FOR CUT SLOPE)



DEVELOPED PLAN



SECTION - A

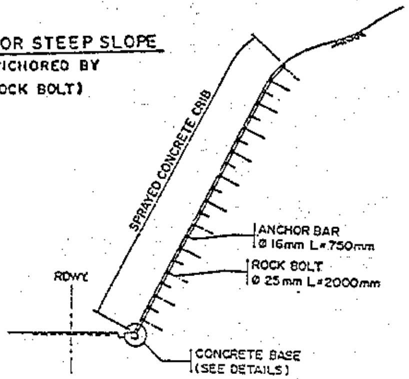


DETAILS OF BASE

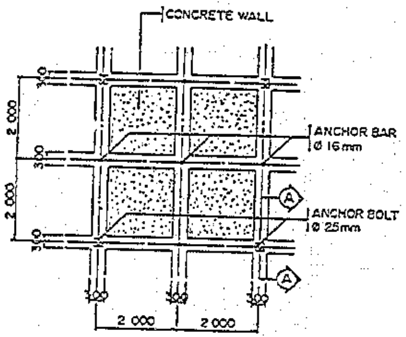
NOTE:

THE SPACE BETWEEN CRIBS IS PROTECTED BY CONCRETE WALL WHEN ANCHORING IS REQUIRED.

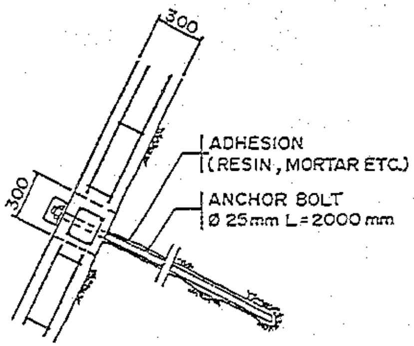
FOR STEEP SLOPE
(ANCHORED BY ROCK BOLT)



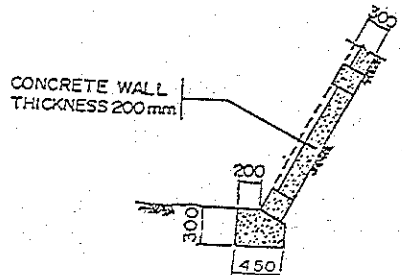
SPRAYED CONCRETE CRIB



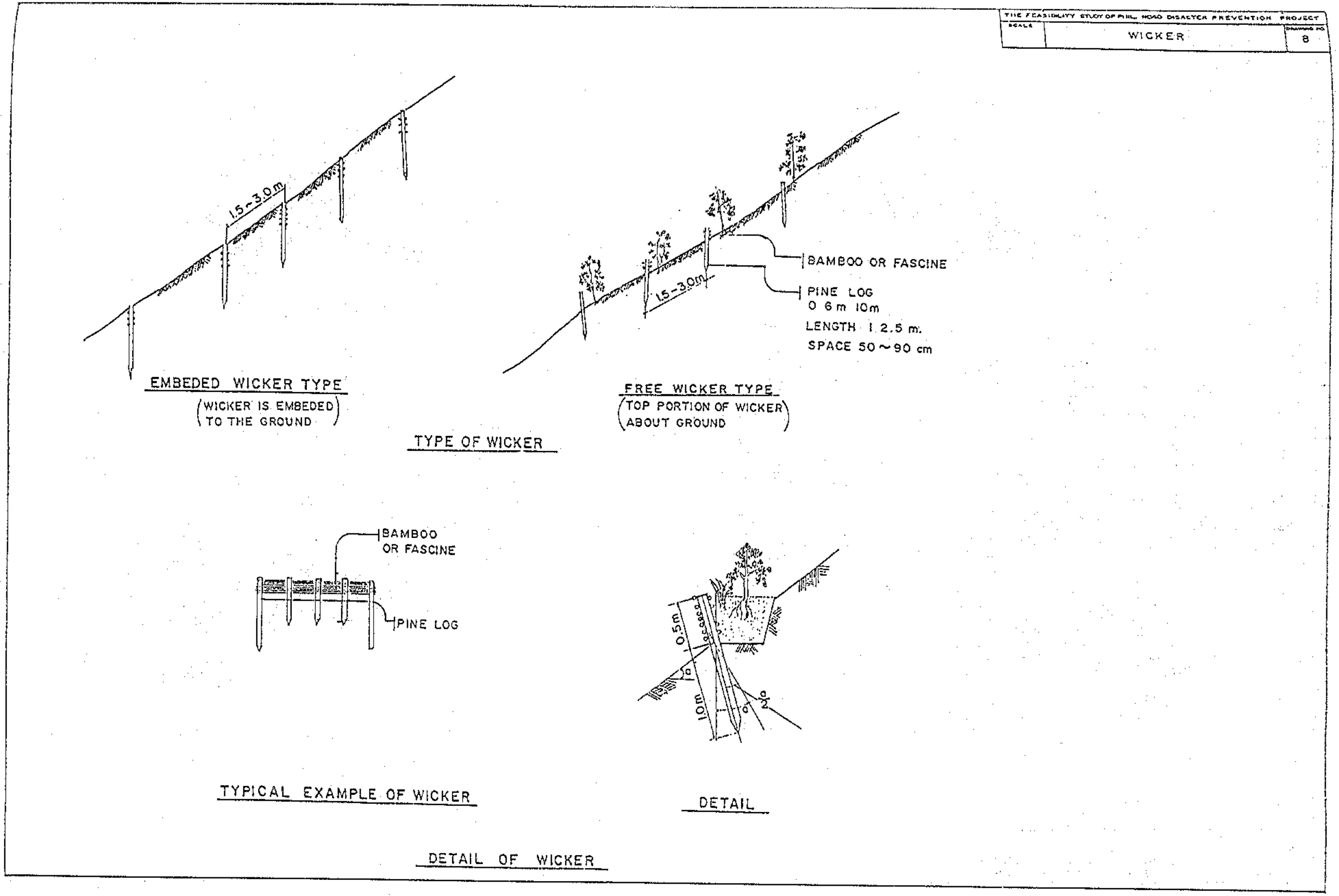
DEVELOPED PLAN
(FOR SPRAYED CONCRETE CRIB)



SECTION - A
DETAILS OF ROCK BOLT

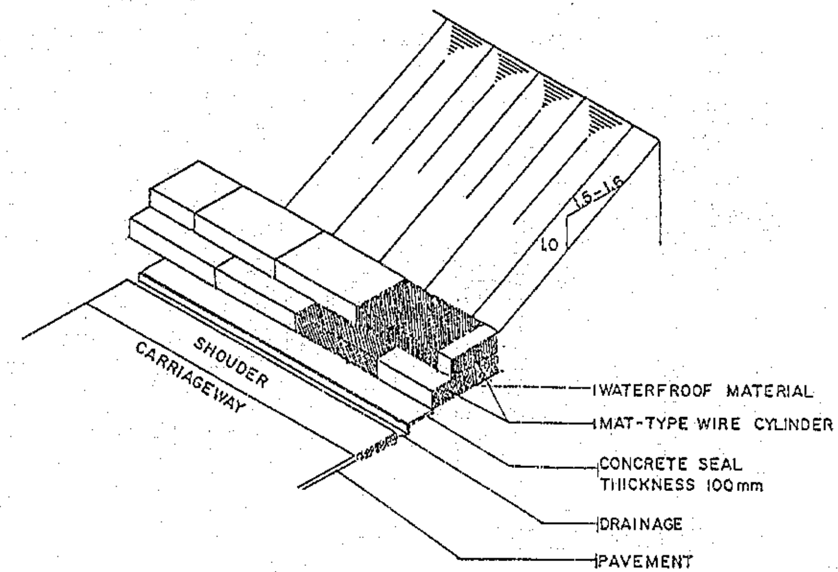


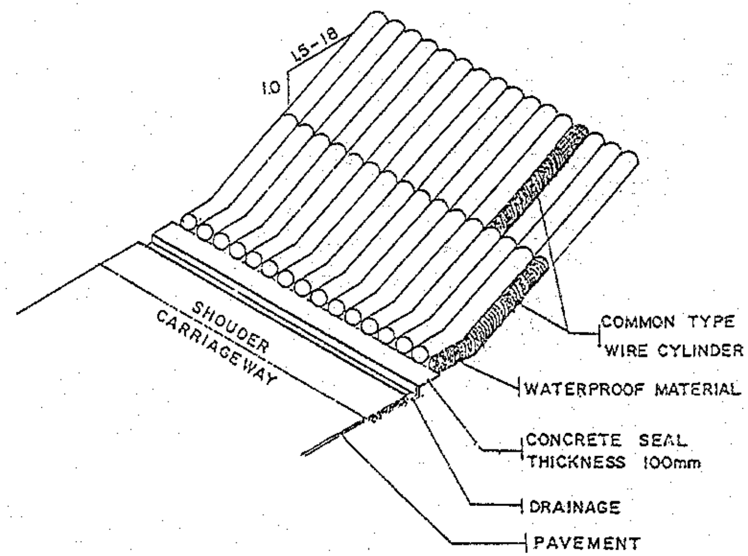
FOR SPRAYED CONCRETE CRIB

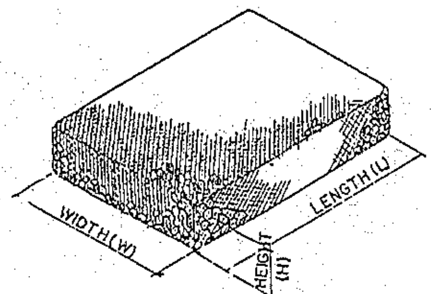

THE FEASIBILITY STUDY OF PHIL. ROAD DISASTER PREVENTION PROJECT
SCALE
WICKER
DRAWING NO.
8
1.5~3.0m
EMBEDED WICKER TYPE
(WICKER IS EMBEDED TO THE GROUND)
1.5~3.0m
BAMBOO OR FASCINE
PINE LOG
O 6m 10m
LENGTH 1 2.5 m.
SPACE 50~90 cm
FREE WICKER TYPE
(TOP PORTION OF WICKER ABOUT GROUND)
TYPE OF WICKER
BAMBOO
OR FASCINE
PINE LOG
0.5m
10m
TYPICAL EXAMPLE OF WICKER
DETAIL
DETAIL OF WICKER

THE FEASIBILITY STUDY OF PHIL. ROAD DISASTER PREVENTION PROJECT

SCALE		DRAWING NO.
	GABION	9

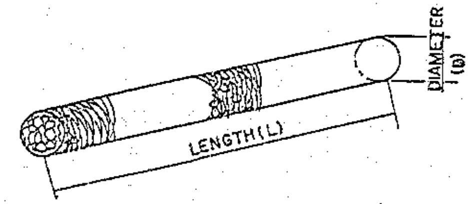






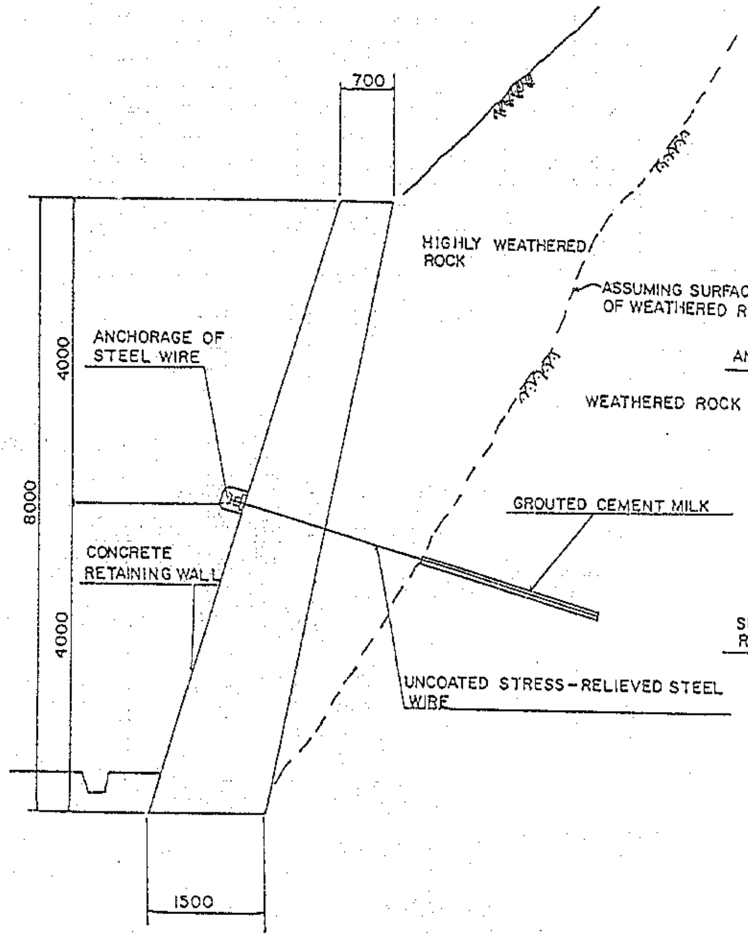
MAT-TYPE GABION

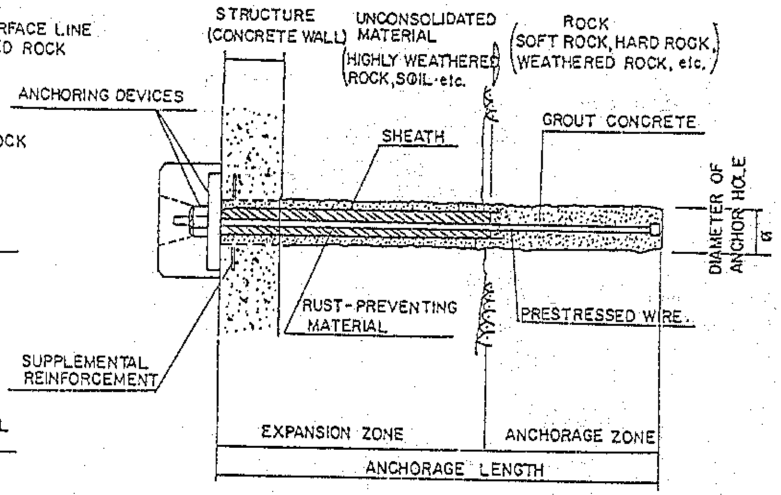
TYPE	H	W	L
1	40cm	120cm.	200cm
2	50cm	180cm	300cm.
3	[illegible]	[illegible]	[illegible]



COMMON TYPE GABION

TYPE	D	L
1	45cm	300cm.
2	60cm	500cm.
3	[illegible]	[illegible]

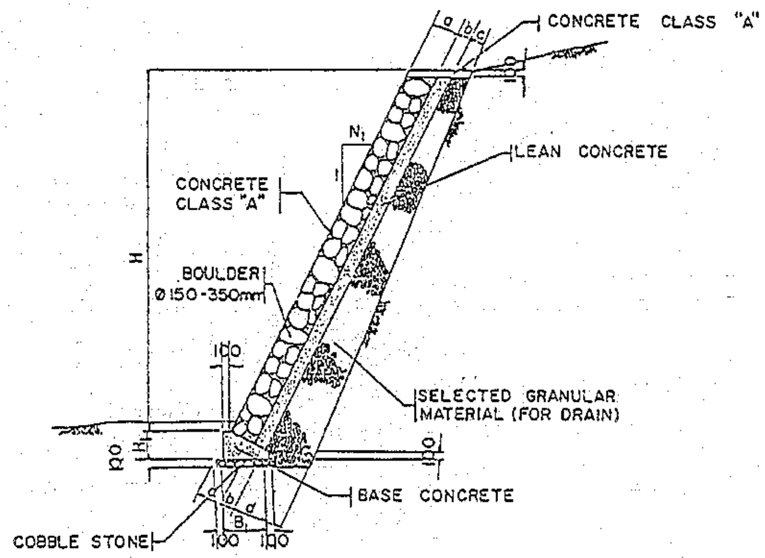




CONCEPTIONAL FIGURE OF PRESTRESSED ANCHORAGE SYSTEM

THE FEASIBILITY STUDY OF PHIL. ROAD DISASTER PREVENTION PROJECT

SCALE	STONE MASONRY RETAINING WALL	DRAWING NO. 11

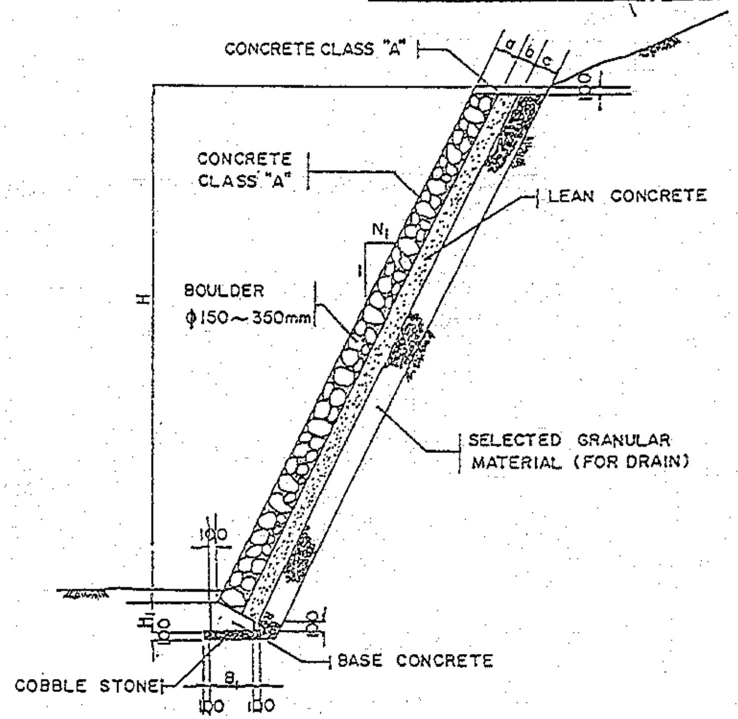


FOR EMBANKMENT SLOPE

H	N_1	a	b	c	d	B_1	H_1
1000	0.3	350	100	200	300	520	300
1500	0.3	350	100	200	340	520	300
2000	0.4	350	100	200	380	520	300
2500	0.4	350	100	200	420	520	300
3000	0.4	350	100	200	460	520	300
3500	0.5	350	150	200	500	550	350
4000	0.5	350	150	200	540	550	350
4500	0.5	300	150	200	580	550	350
5000	0.5	350	150	200	620	550	350

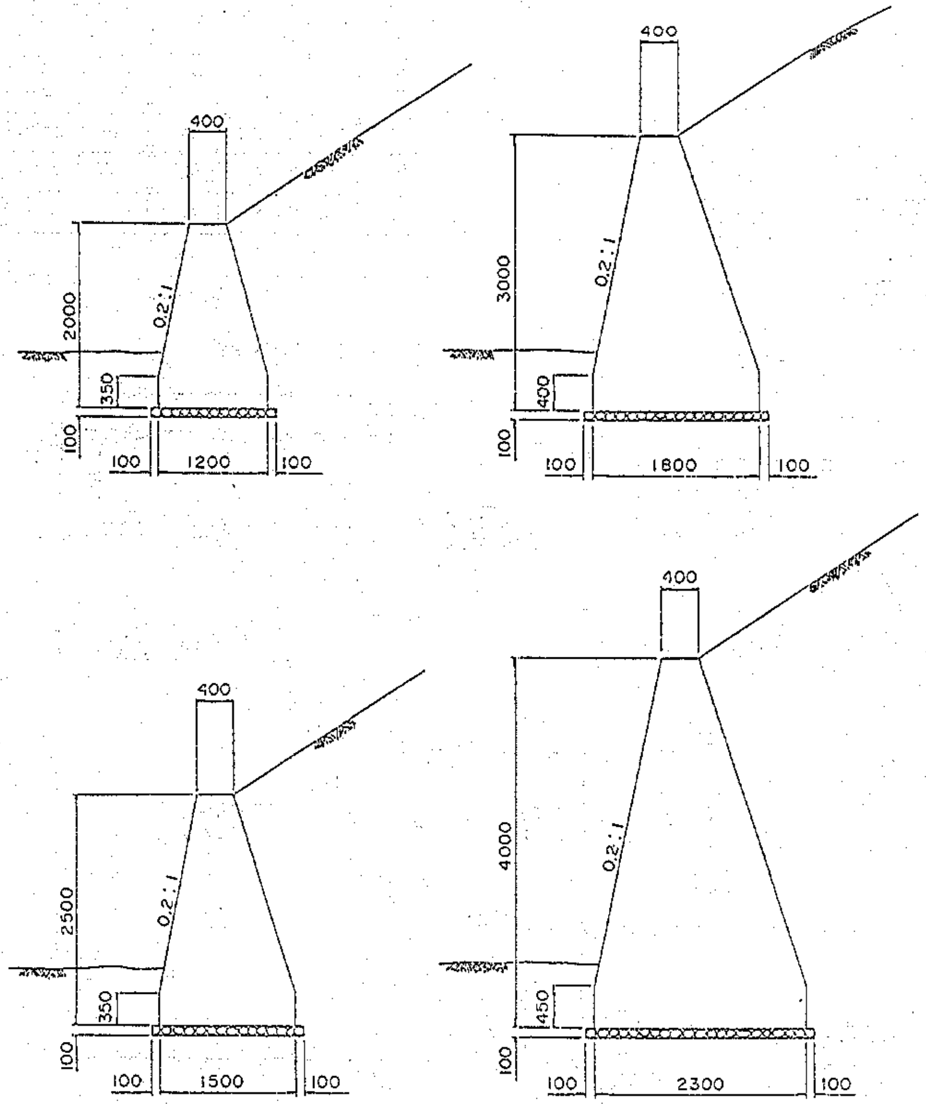
NOTE:

EACH WEEP HOLE SHALL BE PLACED AT LEAST FOR EVERY 2 SQ.M.

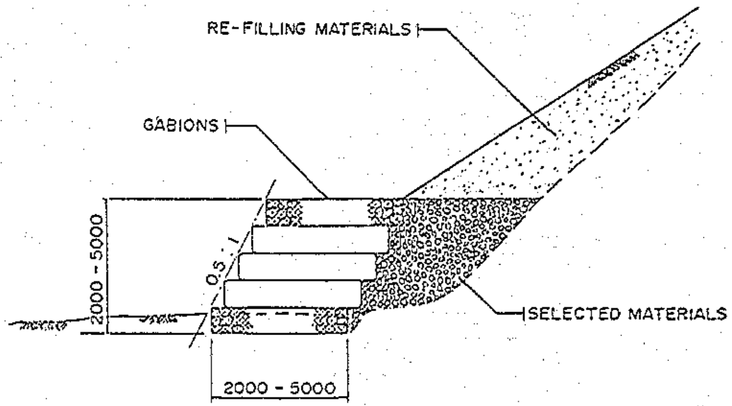


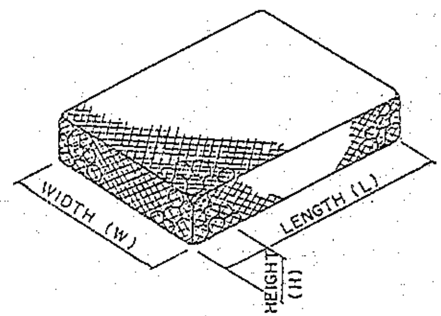
FOR CUT SLOPE

H	N_1	a	b	c	B_1	H_1
1000	0.3	250	50	300	520	300
2000	0.3	250	100	300	520	300
3000	0.3	250	100	300	520	300
4000	0.4	350	150	300	550	350
5000	0.4	350	150	300	550	350
6000	0.5	350	200	300	550	350
7000	0.5	350	200	300	550	350



GRAVITY TYPE RETAINING WALL





DIMENSION

W ; 1200 - 2000
L ; 2000 - 5000
H ; 400 - 600

GABION RETAINING WALL

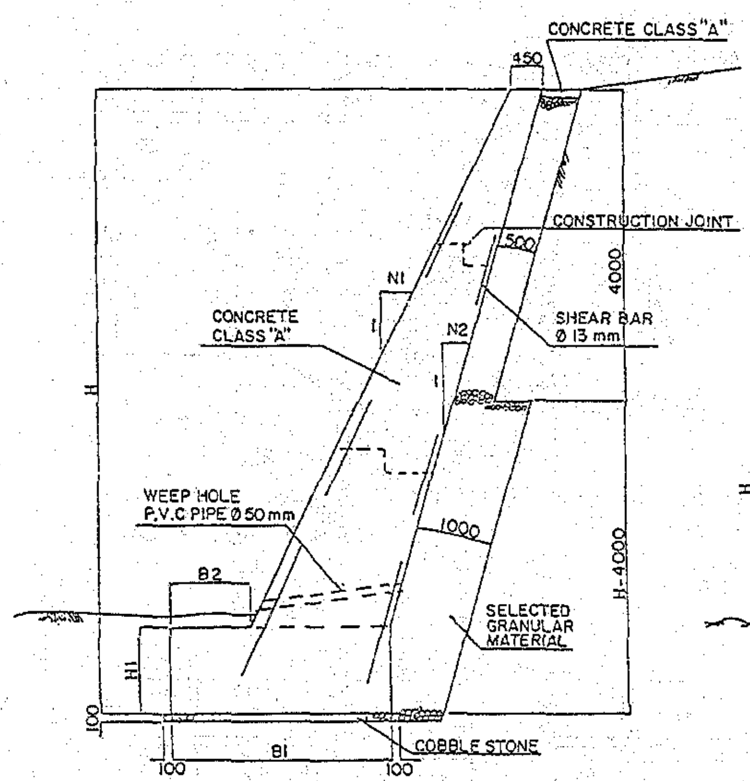
THE FEASIBILITY STUDY OF PHIL. ROAD DISASTER PREVENTION PROJECT

SCALE	SUPPORTED TYPE RETAINING WALL	DRAWING NO. 13

NOTES :

(1) EACH WEEP HOLES SHALL BE PROVIDED AT LEAST FOR EVERY 2.0 Sq.M.

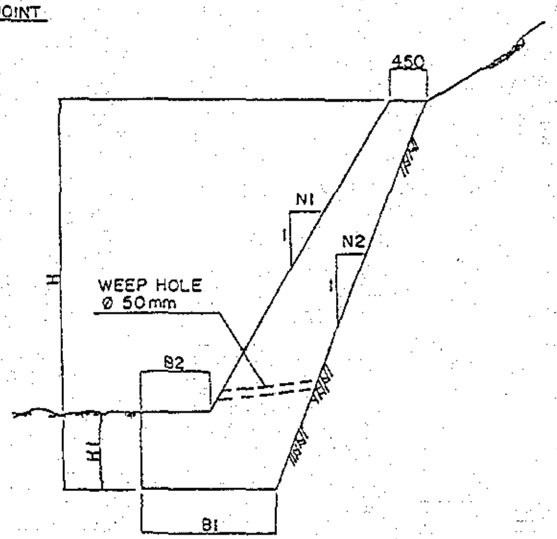
(2) SHEAR BARS SHALL BE PROVIDED AT EVERY CONSTRUCTION JOINT.



FOR EMBANKMENT SLOPE

DIMENSION TABLE

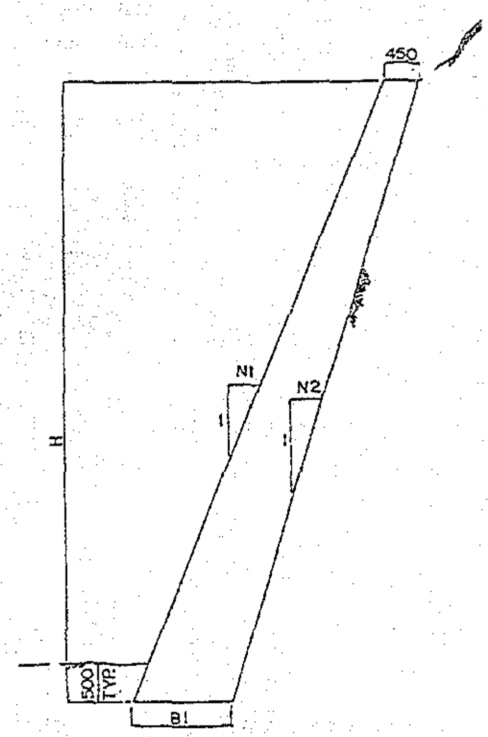
H	N1	N2	H1	B1	B2
3000	0.40	0.35	600	1100	530
4000	0.40	0.30	700	1400	620
5000	0.45	0.35	800	1600	730
6000	0.45	0.30	900	2050	840
7000	0.50	0.35	1000	2250	900
8000	0.50	0.30	1100	2850	1020



FOR CUT SLOPE (SOFT ROCK)

DIMENSION TABLE

H	N1	N2	H1	B1	B2
3000	0.6	0.4	800	1620	950
5000	0.6	0.4	1000	1750	900



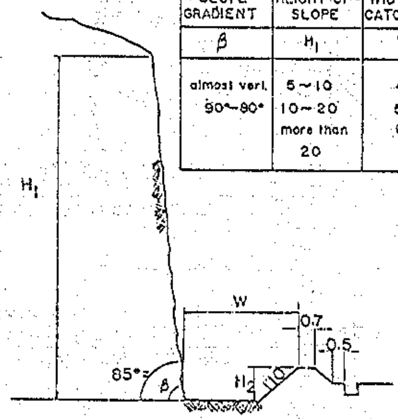
FOR CUT SLOPE (HARD ROCK)

DIMENSION TABLE

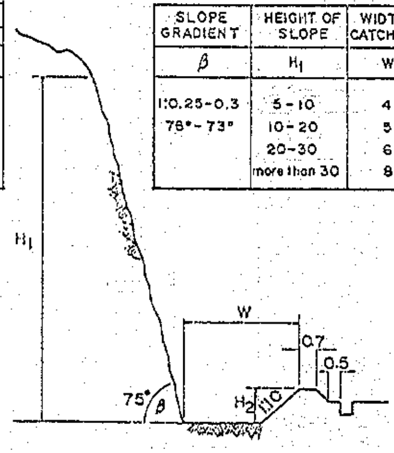
H	N1	N2	B1
3000	0.4	0.3	750
5000	0.4	0.3	950
8000	0.4	0.3	1250

THE FEASIBILITY STUDY OF PHIL. ROAD DISASTER PREVENTION PROJECT

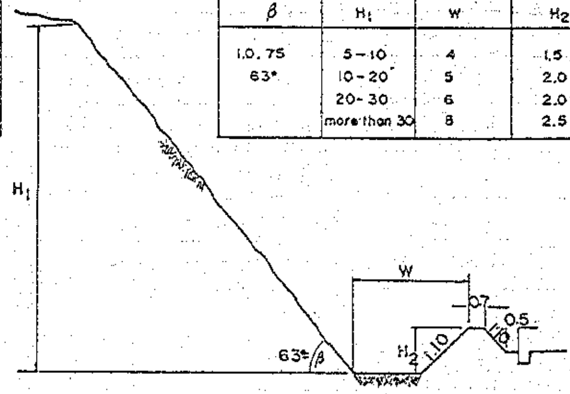
SCALE | CATCH FILL AND DITCH | DRAWING NO. 14



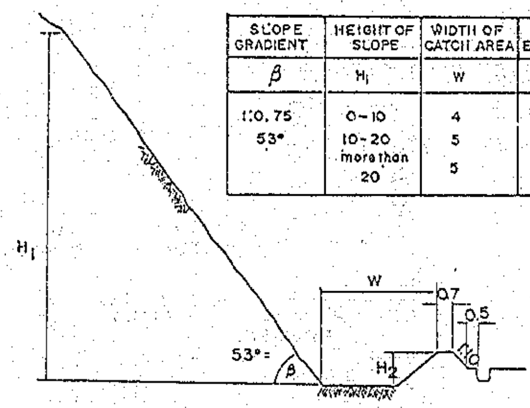
SLOPE GRADIENT	HEIGHT OF SLOPE	WIDTH OF CATCH AREA	HEIGHT OF EMBANKMENT
β	H_1	W	H_2
almost vert. 90°~80°	5~10	4	1.10
	10~20	5	1.5
	more than 20	8	1.50



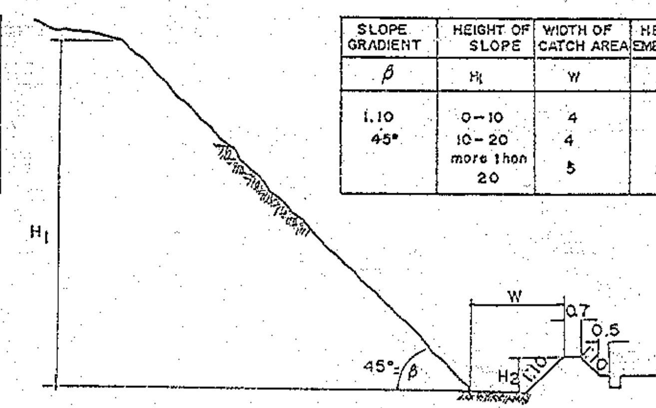
SLOPE GRADIENT	HEIGHT OF SLOPE	WIDTH OF CATCH AREA	HEIGHT OF EMBANKMENT
β	H_1	W	H_2
1:0.25-0.3 78°-73°	5-10	4	1.0
	10-20	5	1.5
	20-30	6	2.0
	more than 30	8	2.0



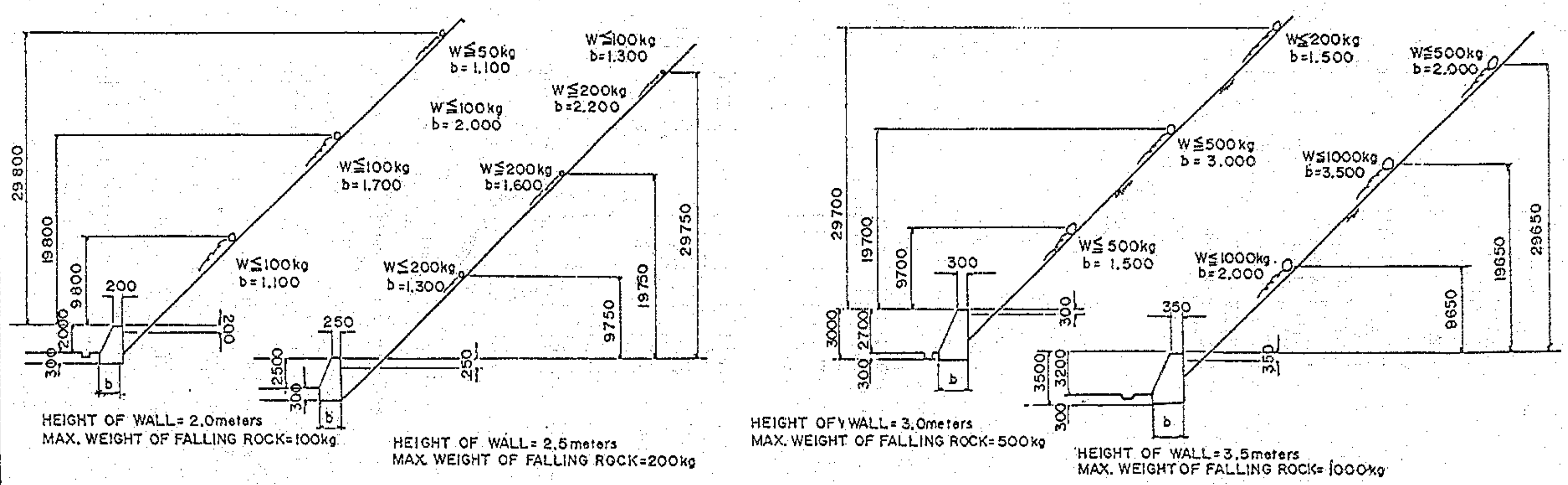
SLOPE GRADIENT	HEIGHT OF SLOPE	WIDTH OF CATCH AREA	HEIGHT OF EMBANKMENT
β	H_1	W	H_2
1:0.75 63°	5-10	4	1.5
	10-20	5	2.0
	20-30	6	2.0
	more than 30	8	2.5

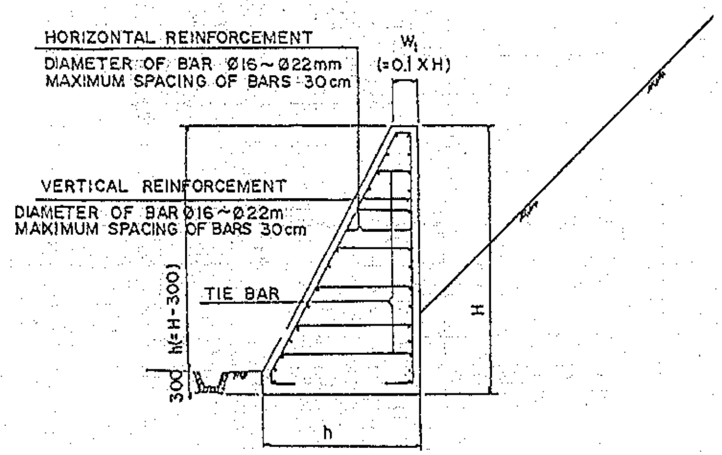


SLOPE GRADIENT	HEIGHT OF SLOPE	WIDTH OF CATCH AREA	HEIGHT OF EMBANKMENT
β	H_1	W	H_2
1:0.75 53°	0-10	4	1.0
	10-20	5	1.5
	more than 20	5	2.0



SLOPE GRADIENT	HEIGHT OF SLOPE	WIDTH OF CATCH AREA	HEIGHT OF EMBANKMENT
β	H_1	W	H_2
1:1.0 45°	0-10	4	1.0
	10-20	4	1.5
	more than 20	5	2.0



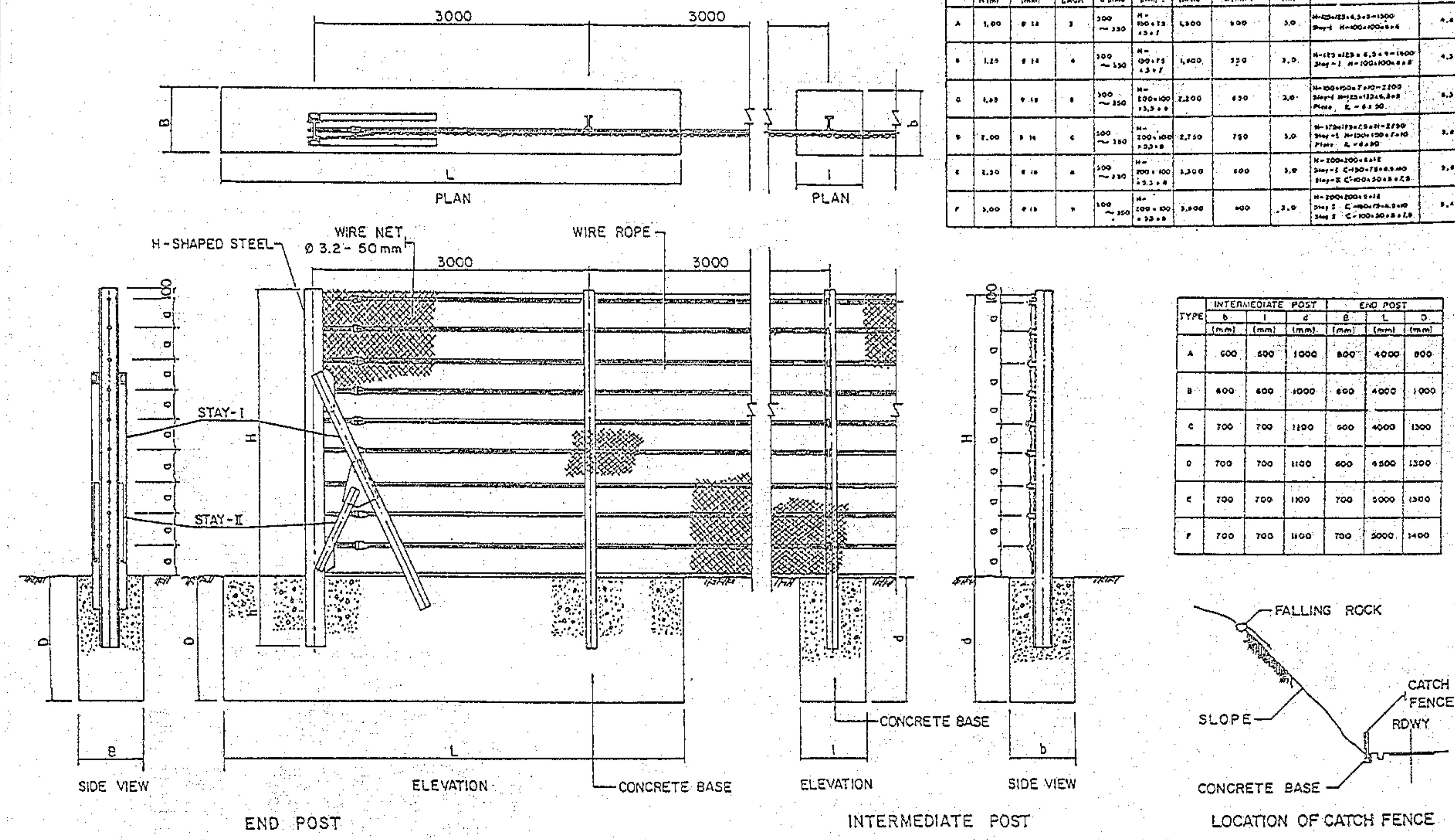


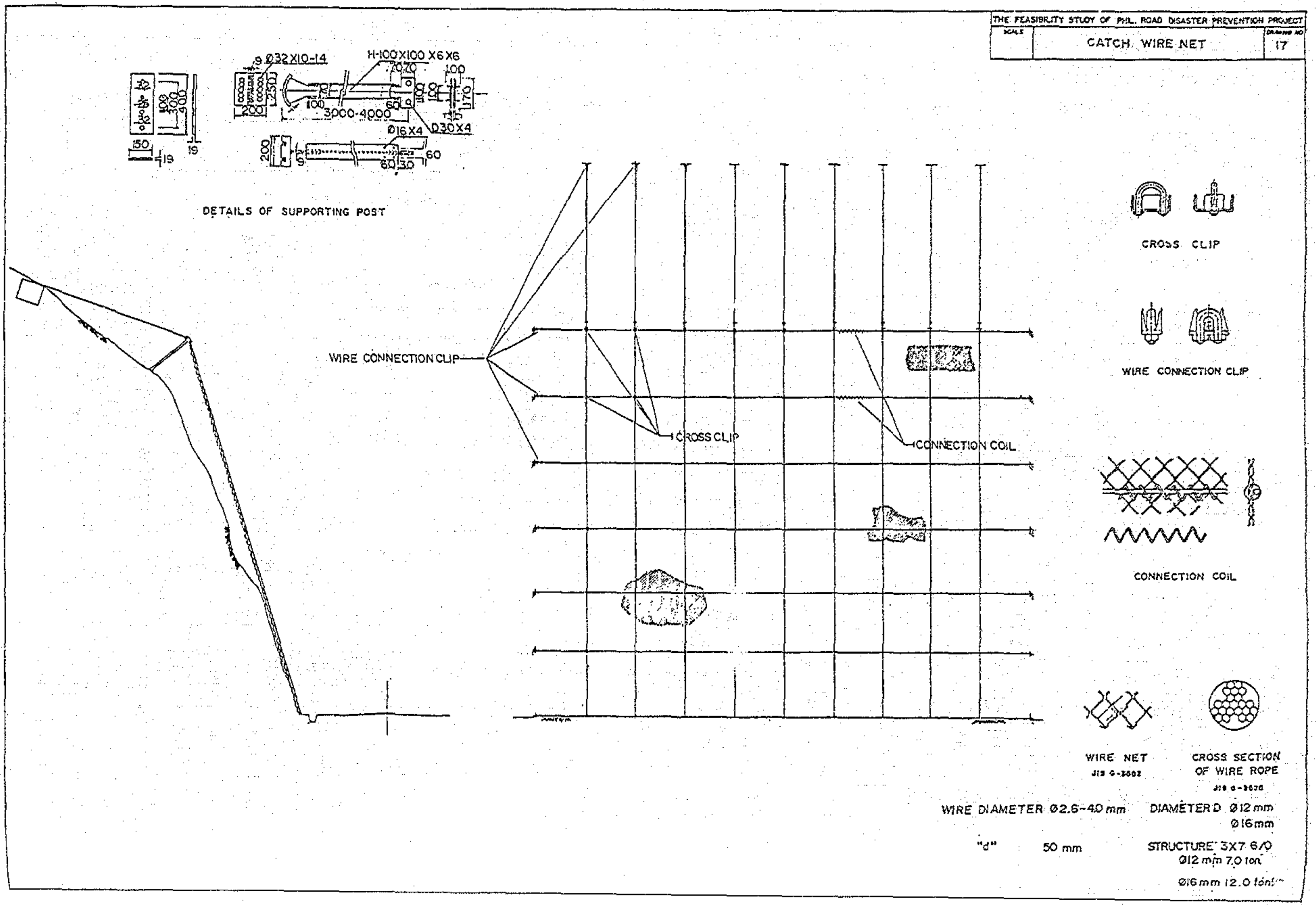
DIMENSION TABLE OF CATCH WALL

HEIGHT OF WALL (H)	WIDTH OF BASE (b)	WIDTH OF TOP OF WALL (W_1)	h	REMARKS
2000	1100	200	1700	W < 100kg, h < 10m / W < 50kg, h 30m
	1700			W < 100kg, h < 20m
	2000			W < 100kg, h < 30m
2500	1300	250	2200	W < 200kg, h < 10m / W < 100kg, h 30m
	1600			W < 200kg, h < 20m
	2200			W < 200kg, h < 30m
3000	1500	300	2700	W < 500kg, h < 10m / W < 200kg, h 30m
	3000			W < 500kg, h < 20m
3500	2000	350	3200	W < 1000kg, h < 10m / W < 500kg, h 30m
	3000			W < 1000kg, h < 20m

TYPE	HEIGHT H (m)	WIRE ROPE DIAMETER (mm)	WIRE ROPE NUMBER EACH	WIRE ROPE SPACING a (mm)	INTERMEDIATE SUPPORT POST SECTION (mm)	INTERMEDIATE SUPPORT POST LENGTH (mm)	INTERMEDIATE SUPPORT POST EMBEDMENT h (mm)	INTERMEDIATE SUPPORT POST SPACING (m)	END SUPPORT POST	ABSORPTION ENERGY BY FENCE (t-m)
A	1,00	ϕ 12	3	300 ~ 350	H = 150×75 ×5×7	1,500	500	3,0	H=125×125×6.5×9=1300 Stay-I H=100×100×6×8	4,4
B	1,25	ϕ 14	4	300 ~ 350	H = 150×75 ×5×7	1,800	550	3,0	H=125×125×6.5×9=1400 Stay-I H=100×100×6×8	4,3
C	1,50	ϕ 16	5	300 ~ 350	H = 200×100 ×5.5×8	2,200	650	3,0	H=150×150×7×10=2200 Stay-I H=125×125×6.5×9 Plate [illegible]	6,3
D	2,00	ϕ 16	6	300 ~ 350	H = 200×100 ×5.5×8	2,750	750	3,0	H=175×175×7.5×11=2750 Stay-I H=150×150×7×10 Plate [illegible]	3,6
E	2,50	ϕ 18	8	300 ~ 350	H = 200×100 ×5.5×8	3,300	600	3,0	H=200×200×8×12 Stay-I C-150×75×6.5×10 Stay-II C-100×50×5×7.5	9,6
F	3,00	ϕ 18	9	300 ~ 350	H = 200×100 ×5.5×8	3,800	800	3,0	H=200×200×8×12 Stay I C-150×75×6.5×10 Stay II C-100×50×5×7.5	9,4

TYPE	INTERMEDIATE POST b (mm)	INTERMEDIATE POST l (mm)	INTERMEDIATE POST d (mm)	END POST B (mm)	END POST L (mm)	END POST D (mm)
A	600	600	1000	800	4000	800
B	600	600	1000	600	4000	1000
C	700	700	1100	600	4000	1300
D	700	700	1100	600	4500	1300
E	700	700	1100	700	5000	1300
F	700	700	1100	700	5000	1400




THE FEASIBILITY STUDY OF PHIL. ROAD DISASTER PREVENTION PROJECT
SCALE
CATCH WIRE NET
DRAWING NO
17
DETAILS OF SUPPORTING POST
Ø32X10-14
H-100X100 X6X6
3000-4000
Ø16X4
Ø30X4
WIRE CONNECTION CLIP
CROSS CLIP
CONNECTION COIL
CROSS CLIP
WIRE CONNECTION CLIP
CONNECTION COIL
WIRE NET
CROSS SECTION OF WIRE ROPE
WIRE DIAMETER Ø2.6-4.0 mm
"d" 50 mm
DIAMETER D Ø12 mm
Ø16mm
STRUCTURE 3X7 6/0
Ø12 mm 7.0 ton
Ø16 mm 12.0 ton

THE FEASIBILITY STUDY OF PHIL. ROAD DISASTER PREVENTION PROJECT

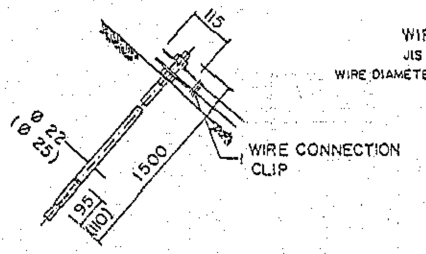
SCALE	ANCHOR WIRE NET	DRAWING NO. 18

DIMENSION TABLE OF ROCK NET

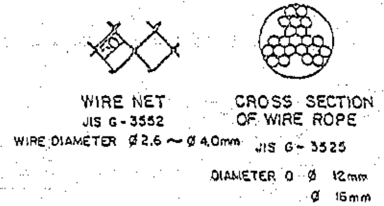
TYPE \ ITEM	WIRE NET	WIRE ROPE*1		CONDITION OF SLOPE AND ROCK			ANCHOR
	GALVANIZED WIRE NET	MAIN ROPE	SUB ROPE	MAXIMUM SLOPE LENGTH	MAXIMUM SLOPE GRADIENT	ALLOWABLE*2 WEIGHT OF ROCK	ROCK ANCHOR
1500	Ø 4.0mm x 50 x 50	Ø 16	Ø 12	50 m	0.5:1	1500 kg	Ø 25
1000	Ø 3.2mm x 50 x 50	Ø 16	Ø 12	70 m	0.5:1	1000 kg	Ø 25
500	Ø 2.6mm x 50 x 50	Ø 12	Ø 12	70 m	0.5:1	500 kg	Ø 22

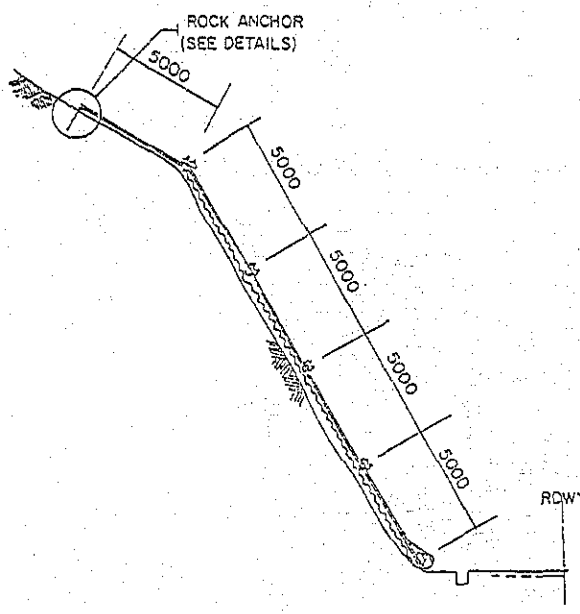
*1 JIS-G 3525 3x7 G/O TYPE
ULTIMATE TENSILE STRENGTH MORE THAN 7000 kg FOR Ø 12mm
MORE THAN 12000 kg FOR Ø 16mm

*2 UNIT ; PER 40 SQUARE METER (4m x 10m)

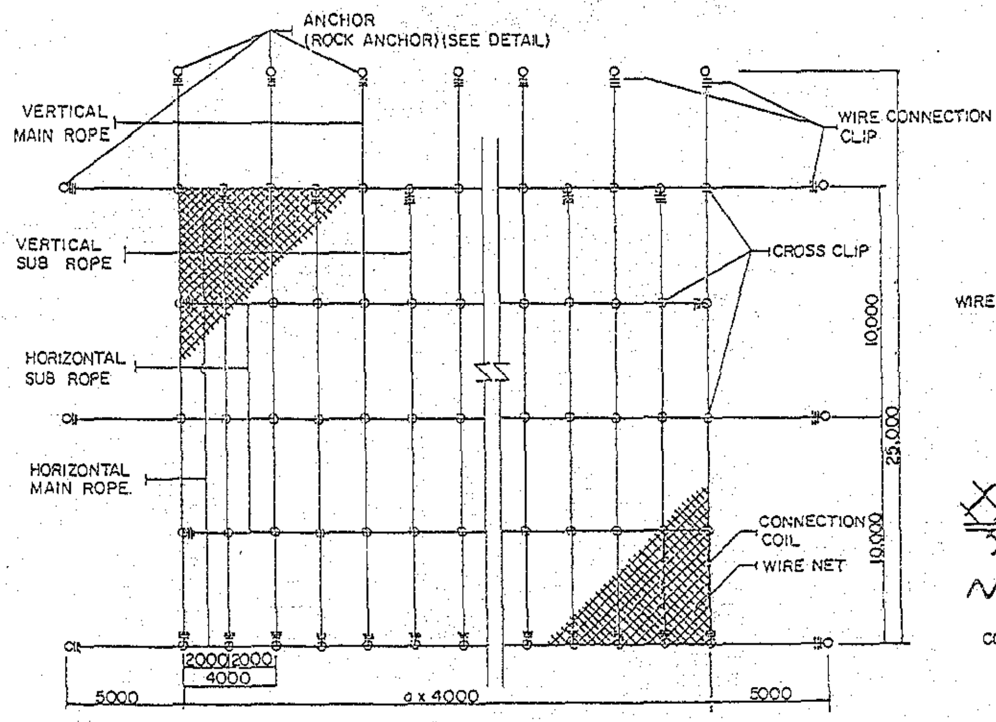


DETAILS OF ROCK ANCHOR

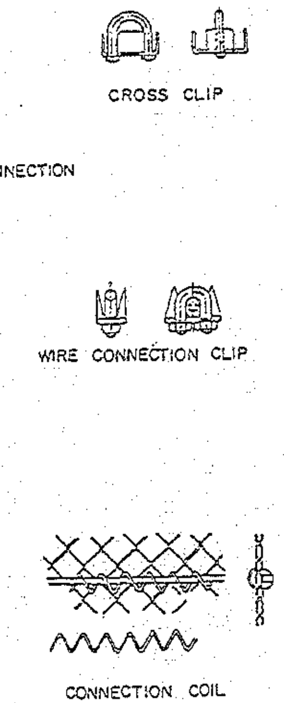




CROSS SECTION

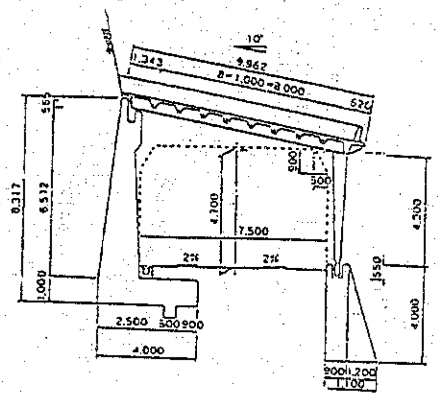


DEVELOPED PLAN

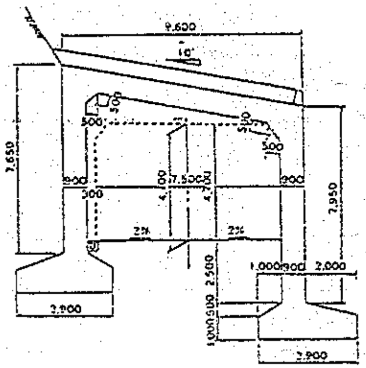


ANCHOR WIRE NET

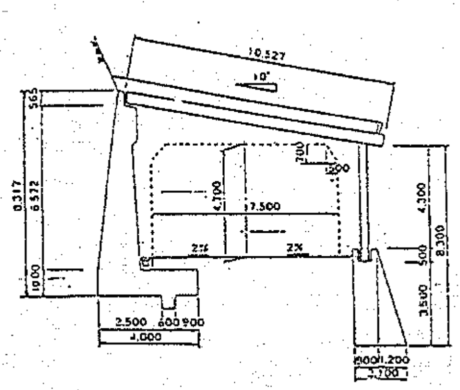
THE FEASIBILITY STUDY OF PHIL. ROAD DISASTER PREVENTION PROJECT		
SCALE	ROCH SHED	DRAWING NO. 19



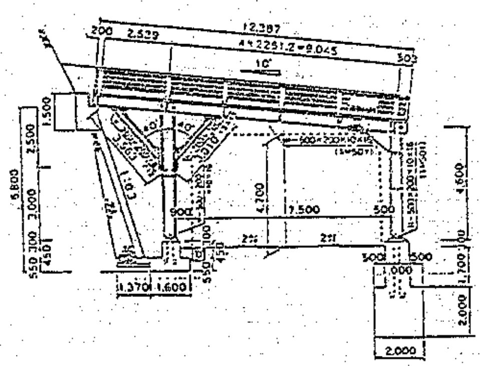
PRESTRESSED CONCRETE T-BEAM TYPE



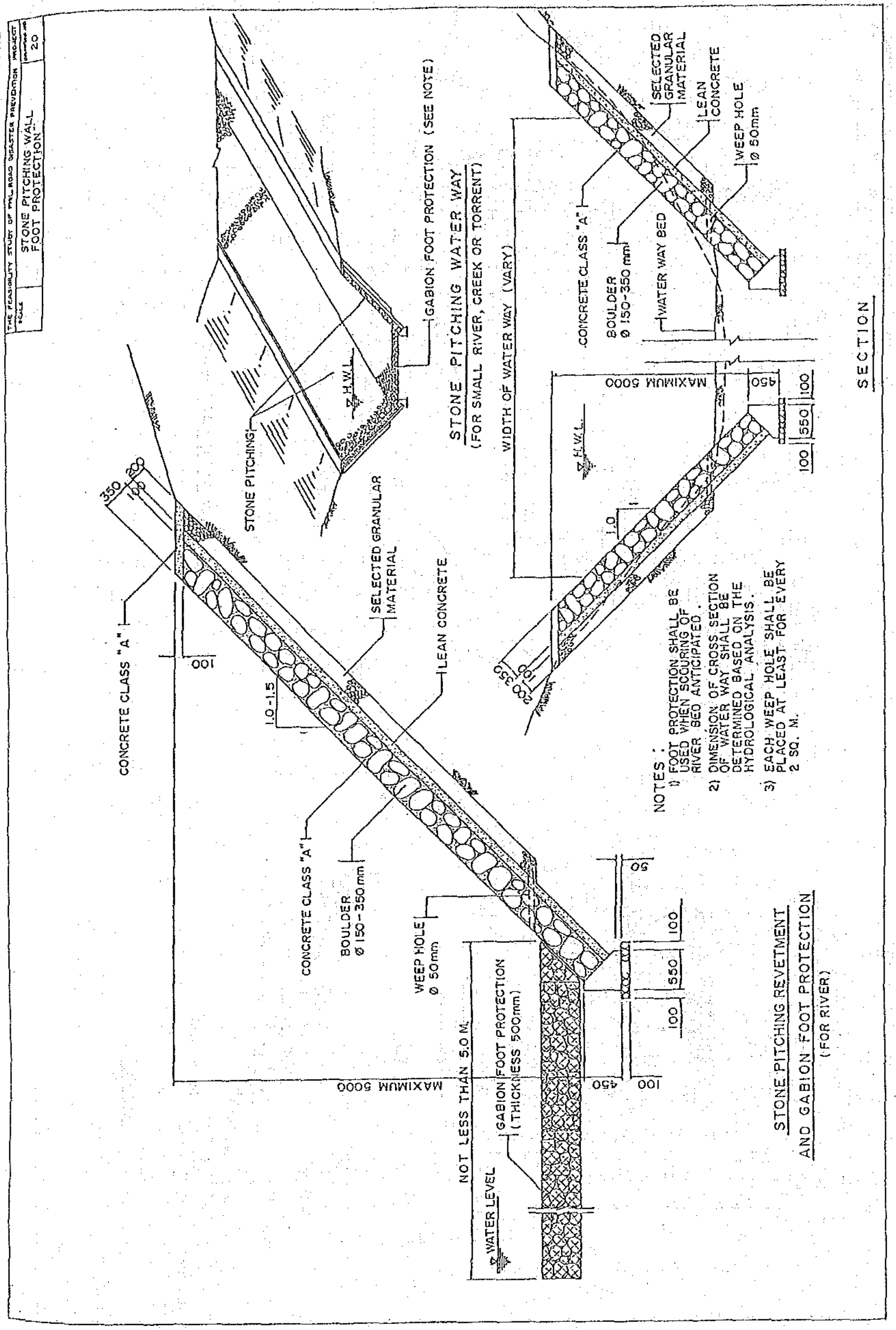
REINFORCED CONCRETE PORTAL TYPE



PRESTRESSED CONCRETE VOIDED SLAB TYPE



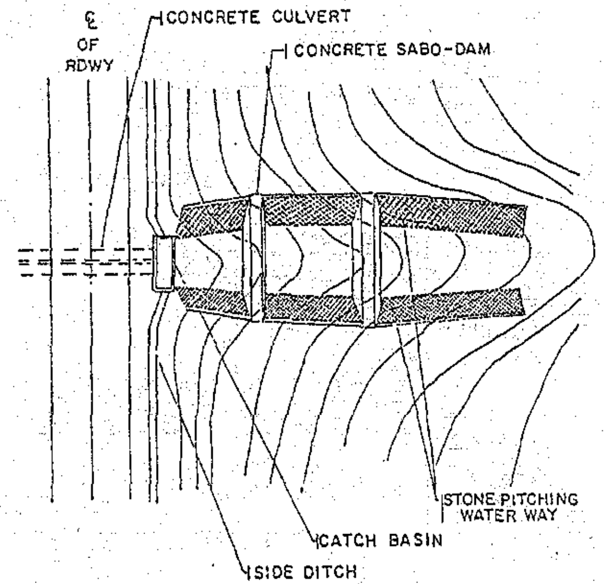
METAL TYPE


THE FEASIBILITY STUDY OF PHIL. ROAD DISASTER PREVENTION
STONE PITCHING WALL "FOOT PROTECTION"
20
STONE PITCHING
GABION FOOT PROTECTION (SEE NOTE)
H.W.L.
STONE PITCHING WATER WAY
(FOR SMALL RIVER, CREEK OR TORRENT)
WIDTH OF WATER WAY (VARY)
MAXIMUM 5000
CONCRETE CLASS "A"
BOULDER
Ø 150-350 mm
WATER WAY BED
SELECTED GRANULAR MATERIAL
LEAN CONCRETE
WEEP HOLE
Ø 50mm
1.0
350
200
100
450
550
SECTION
NOTES :
1) FOOT PROTECTION SHALL BE USED WHEN SCOURING OF RIVER BED ANTICIPATED.
2) DIMENSION OF CROSS SECTION OF WATER WAY SHALL BE DETERMINED BASED ON THE HYDROLOGICAL ANALYSIS.
3) EACH WEEP HOLE SHALL BE PLACED AT LEAST FOR EVERY 2 SQ. M.
CONCRETE CLASS "A"
SELECTED GRANULAR MATERIAL
LEAN CONCRETE
1.0-1.5
BOULDER
Ø 150-350 mm
WEEP HOLE
Ø 50mm
NOT LESS THAN 5.0 M.
GABION FOOT PROTECTION
(THICKNESS 500mm)
WATER LEVEL
MAXIMUM 5000
50
100
550
450
STONE PITCHING REVETMENT
AND GABION FOOT PROTECTION
(FOR RIVER)

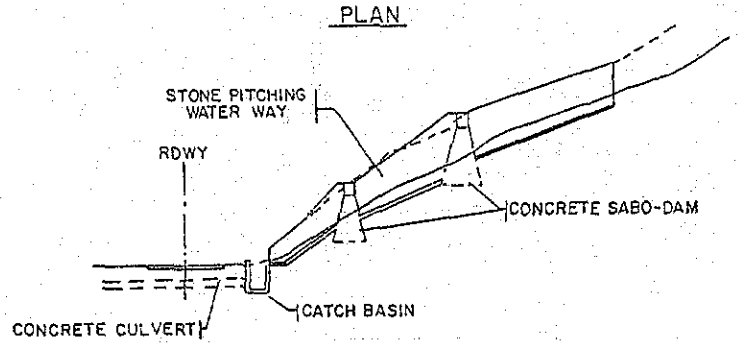
THE FEASILITY STUDY OF PHIL. ROAD DISASTER PREVENTION PROJECT

STUDY	CONCRETE SABO-DAM	DRAWING NO. 21

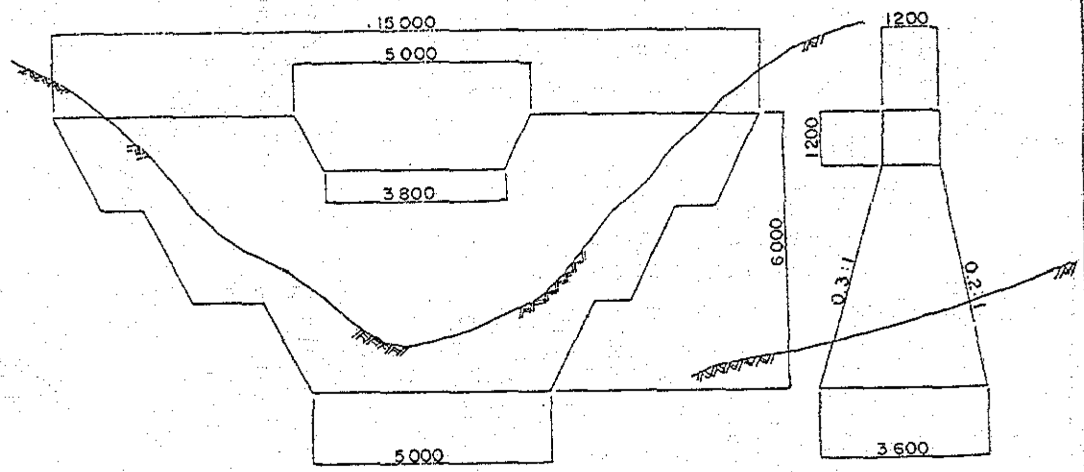
NOTE: DIMENSION OF CONCRETE SABO-DAM SHALL BE DETERMINED BASED ON THE HYDROLOGICAL ANALYSIS, TOPOGRAPHY AND GEOLOGY.



PLAN



ELEVATION



CONCRETE SABO-DAM

JICA