REINFORCED CONCRETE CANTILEVER AND COUNTER FORT RETAINING WALL

1.1 Retaining wall

A retaining wall is a structure, designed and constructed to resist the lateral pressure of soil.

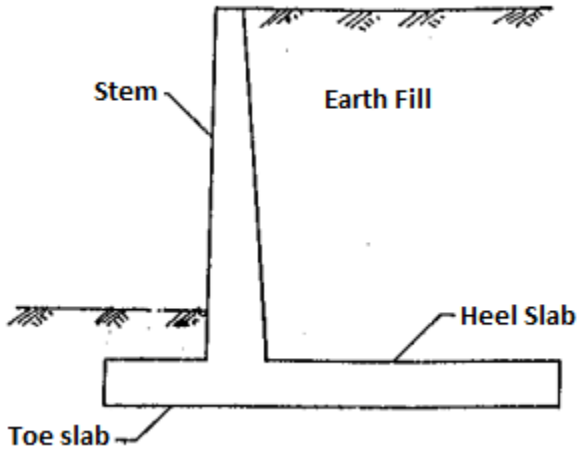

Fig.1.1 Cantilever retaining wall

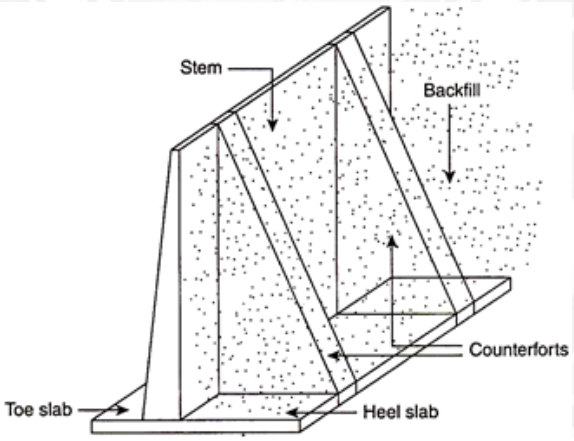

Fig.1.2 Counter fort retaining wall

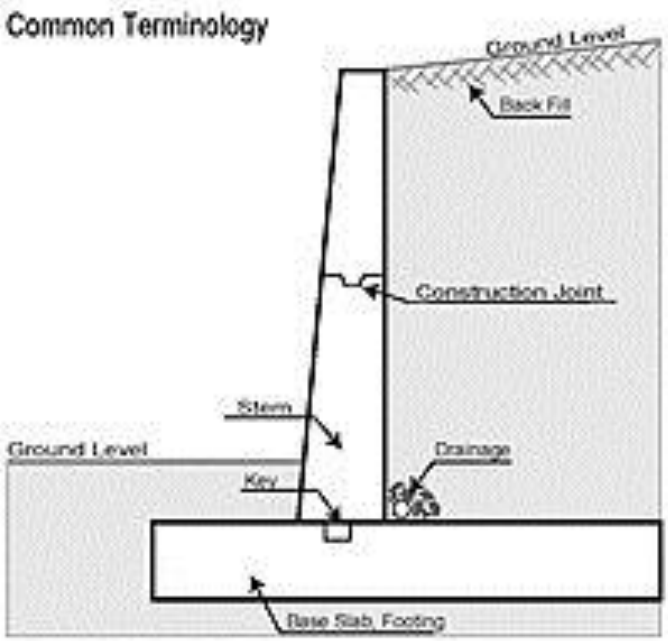

Fig.1.3 Cantilever retaining wall

1.2 Design for Cantilever Retaining wall For Stem

Example 1

Design a stem for cantilever retaining wall to retain an earth embankment with a horizontal top 4m above ground level. Density of earth = 18 KN/m^3. Angle of internal friction Ø = 30 degree. SBC of soil = 200 KN/m^2. Coefficient of friction between soil and concrete = 0.5. Adopt M20 grade concrete and Fe 415 HYSD bars.

Given data :

Density of earth	'γ'	= 18 KN/m^3
Angle of internal friction	'Ø'	= 30
SBC of soil	'q'	= 200 KN/m^2

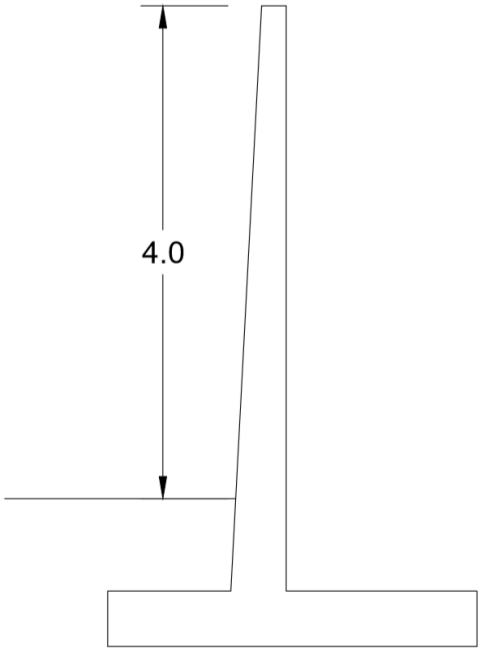

Fig.1.4 Cantilever retaining wall

Step 1: Dimensions of retaining wall

(a) Depth of foundation = q / γ (1- sin Ø / 1+ sin Ø)^2

= 200 / 18 (1- sin 30 / 1+ sin 30)^2

= 1.2m

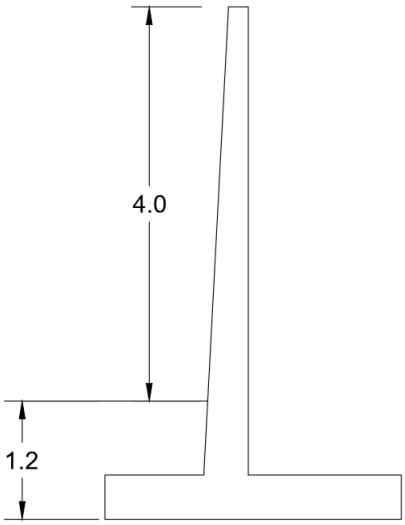

Fig.1.5 Cantilever retaining wall (Depth of foundation)

(b) Overall depth of wall = 4 + 1.2

‘H = 5.2m

= 5200mm

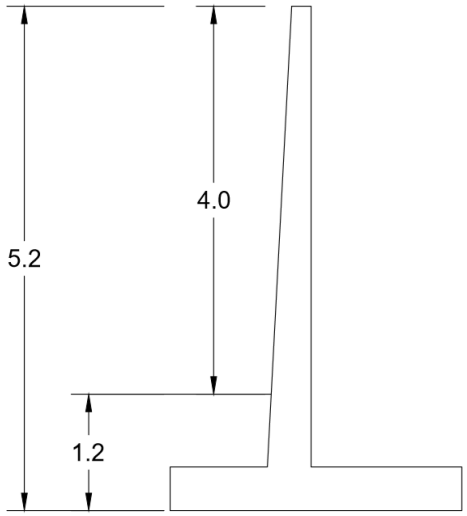

Fig.1.6 Cantilever retaining wall (Overall depth of wall)

(c) Thickness of base slab = H / 12

= 5200 / 12

= 433mm ~ 450mm

(d) Height of stem ‘h’ = 5200 - 450

= 4750mm

= 4.75m

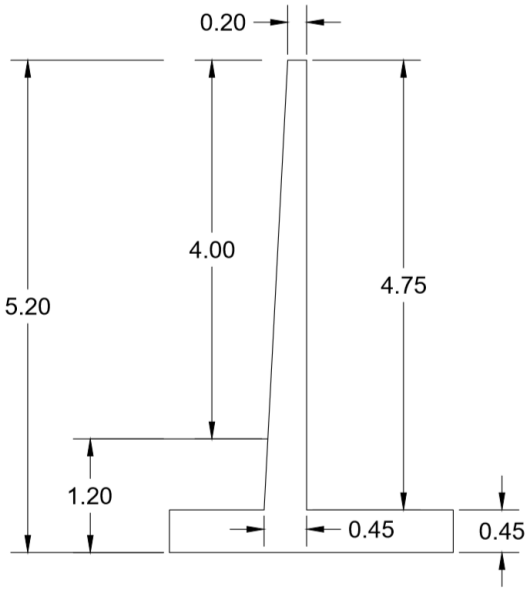

Fig.1.7 Cantilever retaining wall (Thickness of base slab)

(e) Width of base slab ‘b’ = 0.5H to 0.6H

= 2600 to 3120

= 3000mm

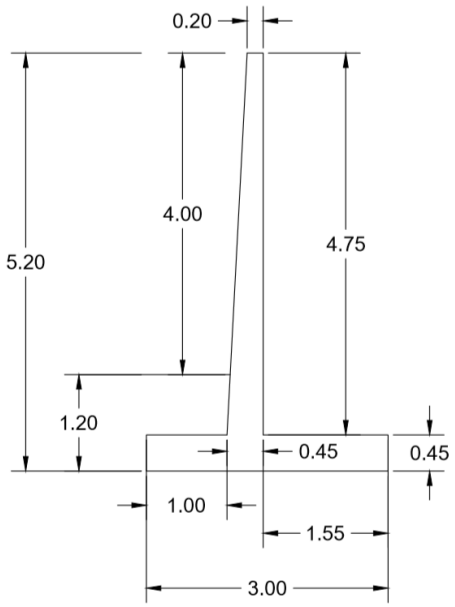

Fig.1.8 Cantilever retaining wall (Width of base slab)

Step 2 : Design of stem

(a) Max BM at base

‘M’ = Ka (γ h^3 / 6)

i.e Ka = (1- sin Ø / 1+ sin Ø)

= (1 / 3) (18 x 4.75^3 / 6)

= 107.2 KNm

Factored moment ‘Mu’ = 107.2 x 1.5

= 161 KNm

= 161 x 10^6 Nmm

(b) Effective depth required

$$d = \sqrt{\frac{Mu}{0.138 \times fck \times b}}$$

$$d = \sqrt{\frac{161 \times 10^6}{0.138 \times 20 \times 10^3}}$$

= 241.5 ~ 242mm

i.e b = 1000mm

= 10^3mm

fck = 20 N/mm^2

(b) Effective depth at base of stem

overall depth ‘D’ = 450mm

cover = 50mm

effective depth ‘d’ = D – 50

= 450 – 50

= 400mm

(c) Find Ast

Mu = (0.87 fy Ast d)[(1- Ast fy) / (b d fck)]

Page no. 96 , IS 456:2000

161 x 10^6 = (0.87 x 415 x Ast x 400) [(1- 415 x Ast) / (1000 x 400 x 20)

161 x 10^6 = (144.42 x 10^3 Ast) [(1 – 5.187 x 10^-5 Ast)]

161 x 10^6 = (144.42 x 10^3 Ast) – (7.49 Ast^2)

161 x 10^6 - (144.42 x 10^3 Ast) + (7.49 Ast^2) = 0

(using calculator) mode > Eqn > degree > 2

a = 7.49

b = -144.42 x 10^3

c = 161 x 10^6

x1 = 18093mm^2

x2 = 1188mm^2

Ast = 1188 mm^2

Find spacing

Provide 16mm dia bars

Spacing = 1000 x [(πd^2 / 4) / Ast]

= 1000 x [(π x 16^2 / 4) / 1188]

= 169.24 ~ 170mm

Provide 16mm dia bars at 170mm c/c

Find distribution reinforcement

Ast (dist) = (0.12 / 100) x bD

= (0.12 / 100) x 1000 x 450

= 540 mm^2

Provide 10mm dia bars

Spacing = 1000 x (πd^2 / 4) / Ast

= 1000 x [(π x 10^2 / 4) / 540]

= 145mm

Provide 10mm dia bars at 145mm c/c

Provide 10mm dia bars at 290mm c/c on both faces

Step 3: Stability calculation

Fig.1.8 Cantilever retaining wall (Stability calculation)

(a) Find load

w1 = (b x d x γc) + (½ x bh x γc)

= (0.2 x 4.75 x 24) + (½ x 0.25 x 4.75 x 24)

= 22.80 + 14.25

= 37.05 KN

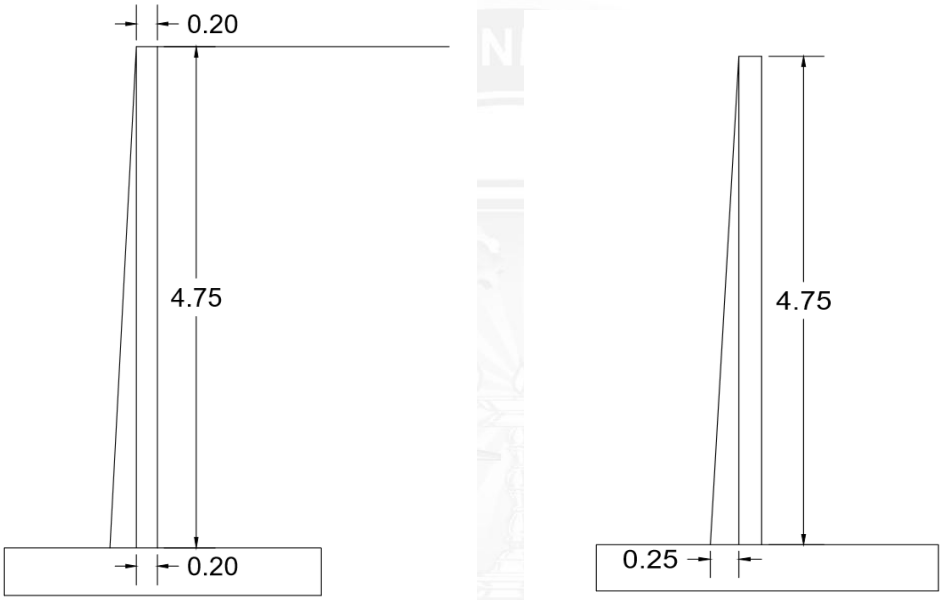

Fig.1.8 Cantilever retaining wall (Stability calculation)

w2 = b x d x γc

= 3 x 0.45 x 24

= 32.40 KN

w3 = b x d x γs

= 1.55 x 4.75 x 18

= 132.50 KN

Total load = w1 + w2 + w3

= 201.95 KN

(b)Find moment @ a

M1 = W1 x Length

= (22.80 x 1.65) + (14.25 x 1.83)

= 37.62 + 26.07

= 63.69 KNm

M2 = W2 x Length

= 32.40 x 1.5

= 48.60 KNm

M3 = W3 x Length

= 132.50 x 0.78

= 103.35 KNm

M4 = 107.2 KNm (Moment at base)

Total moment M = M1 + M2 + M3 + M4

=322.81 KNm

Point of application

Z = $\sum$M / $\sum$W

= 322.81 / 201.95

= 1.6m

Eccentricity

e = Z – b/2

= 1.6 – (3/2)

= 0.1m

i.e b = 3 (width of base slab)

$e < b/6$

$b/6 = 3/6$

$= 0.5$

$0.1 < 0.5$

Hence safe

Max and Min pressure at base

$\sigma = \sum W / b [1 \pm (6e / b)]$

$= 201.95/3 [1 \pm (6 \times 0.1 / 3)$

$\sigma max = 67.32 [1 + 0.2]$

$= 80.78$ KN/m^2

$\sigma min = 67.32 [1 - 0.2]$

$= 53.85$ KN/m^2

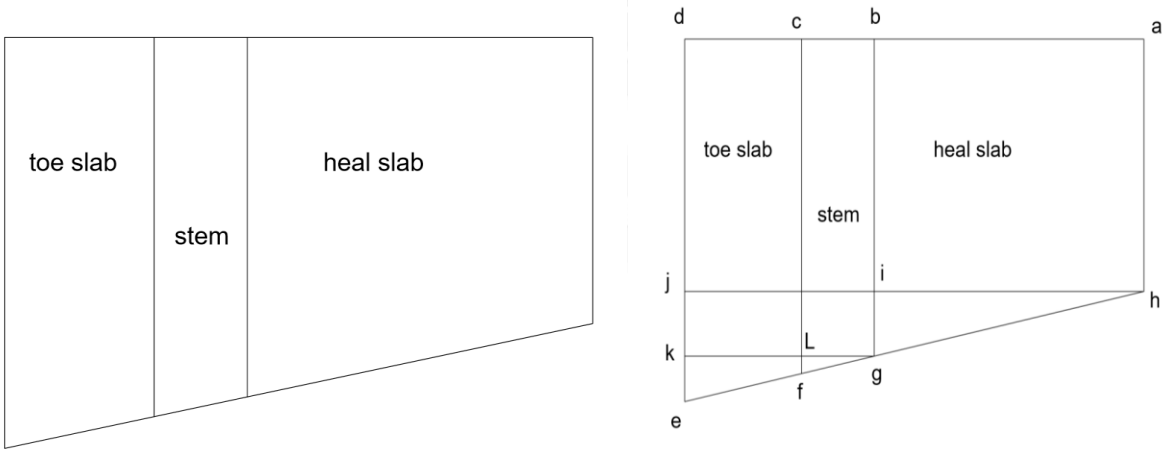

Fig.1.9 Cantilever retaining wall (Stability calculation Top view)

Step 4 : Check for safety against sliding

P = Ka x γ(H^2 / 2)

= (1/3) x 18 x (5.2^2 / 2)

= 81.12KN

i.e Ka = (1- sin Ø / 1+ sin Ø)

F.O.S against sliding = (μW / P)

= (0.5 x 201.95 / 81.12)

= 1.24 < 1.5

μ = 0.5 (given)

Since the wall is unsafe , so a shear key is to be designed below the stem

Step 5 : Design of shear key

Intensity of passive pressure in shear key front

Pp = KP x (σmax)pressure in shear key front

KP = (1+ sin Ø / 1- sin Ø)

= (1+sin 30 / 1- sin 30)

= 3

Pp = KP x (σmax)pressure in shear key front

= 3 x 71.78

= 215.34 KN/m^2

Passive force PF = PP x a

= 215.34 x 0.45

= 97KN

F.O.S against sliding =[(μW + PF) / P]

= {[(0.5 x 201.95) + 97] / 81.12}

= 2.4 > 1.5

Hence safe

Minimum % of reinforcement in shear key

Ast = (0.3/100) x bD

= 0.003 x 1000 x 450

= 1350mm^2

Provide 16mm dia bars

Spacing = 1000 x (πd^2 / 4) / Ast

= 1000 x [(π x 16^2 / 4) / 1350]

= 148.9mm ~ 150mm

Provide 16mm dia bars at 150mm c/c

Step 6 : Find shear stress

Shear force 'V' = 1.5P – μW

= (1.5 x 81.12) – (0.5 x 201.95)

= 20.7KN

Factored Shear force

'Vu' = 20.7 x 1.5

= 31.05KN

Shear stress ‘τv’ = Vu / bd

= 31.05 x 10^3 / (1000 x 400)

= 0.077 N/mm^2

Find τc

100Ast / bd = 100 x 1350/ (1000 x 400)

= 0.335 N/mm^2

Table 19, page no. 73 ,IS 456 2000

0.25 --- 0.36

0.50 --- 0.48

(0.36+0.48) /2 = 0.42

τc = 0.42 N/mm^2

τc > τv

Hence safe

Reinforcement detail

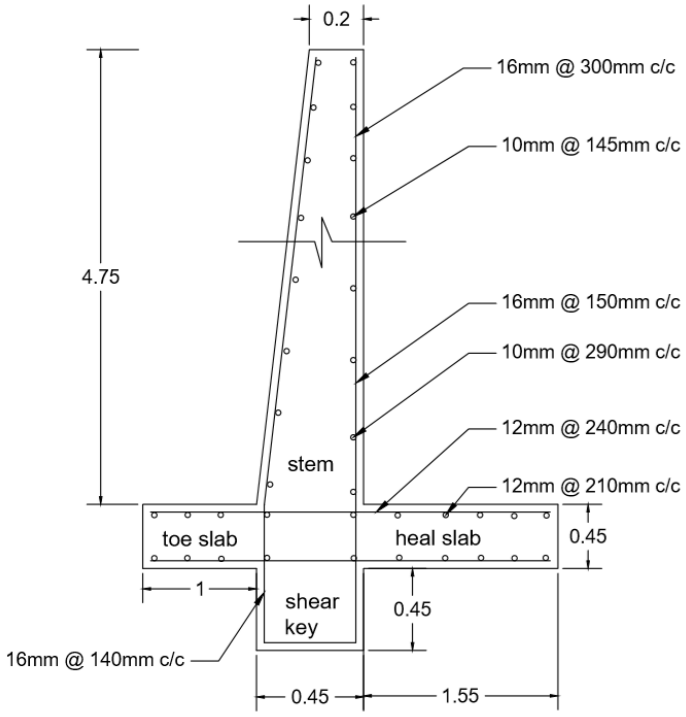

Fig.1.10 Cantilever retaining wall (Reinforcement details cross section)

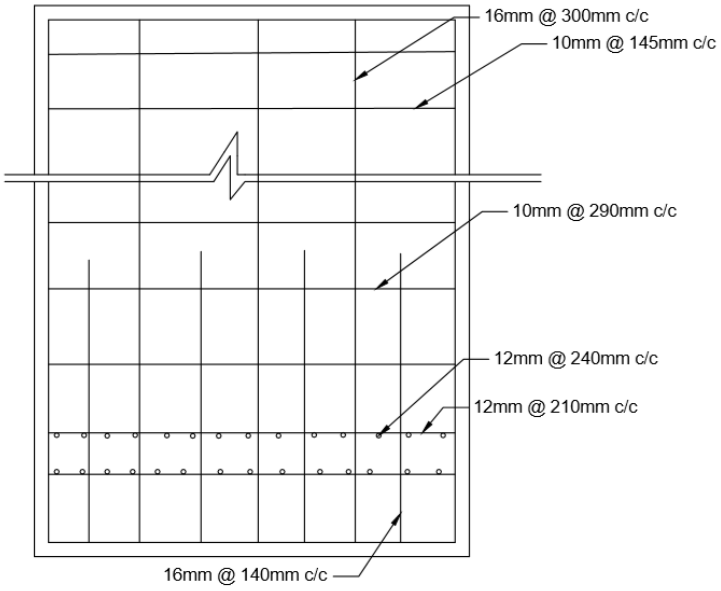

Fig.1.11 Cantilever retaining wall (Reinforcement details Longitudinal cross section)