Design Of Shear Key

1.3 Design for Cantilever Retaining Wall For Toe Slab with shear key

Example 3

Design a Toe slab 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

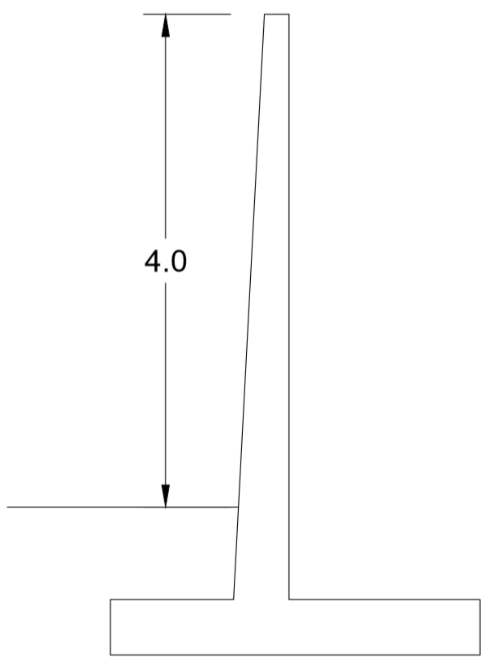


Fig.1.1 Cantilever retaining wall

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

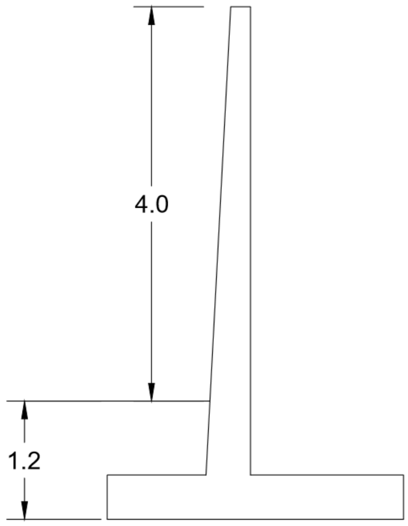


Fig.1.2 Cantilever retaining wall (Depth of foundation)

(b) Overall depth of wall = 4 + 1.2

‘H = 5.2m

= 5200mm

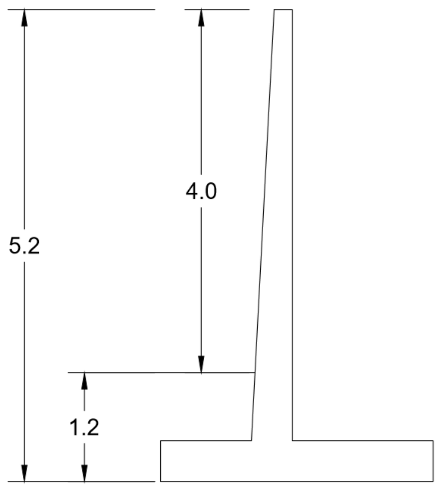


Fig.1.3 Cantilever retaining wall (Overall depth of wall)

(c) Thickness of base slab = H / 12

= 5200 / 12

= 433mm ~ 450mm

(d) Height of stem 'h' = 5200 - 450

= 4750mm

= 4.75m

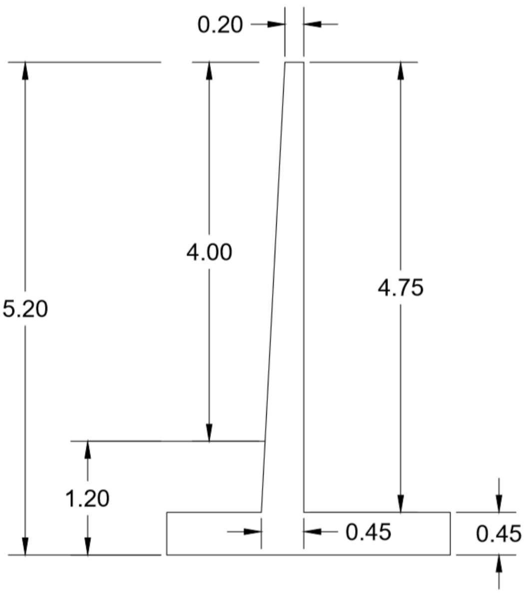


Fig.1.4 Cantilever retaining wall (Thickness of base slab)

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

= 2600 to 3120

= 3000mm

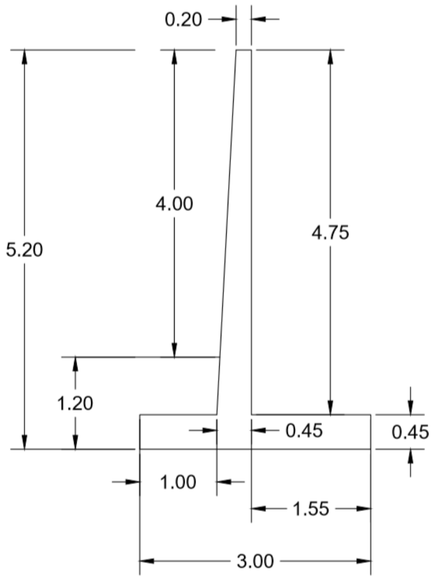


Fig.1.5 Cantilever retaining wall (Width of base slab)

Step 2: Stability calculation

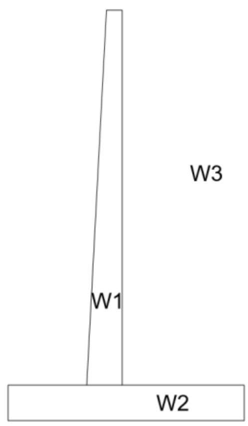


Fig.1.6 Cantilever retaining wall (Stability calculation)

(a) Find load

w1 $= (b \times d \times \gamma c) + (½ \times bh \times \gamma c)$

$= (0.2 \times 4.75 \times 24) + (½ \times 0.25 \times 4.75 \times 24)$

$= 22.80 + 14.25$

$= 37.05$ KN

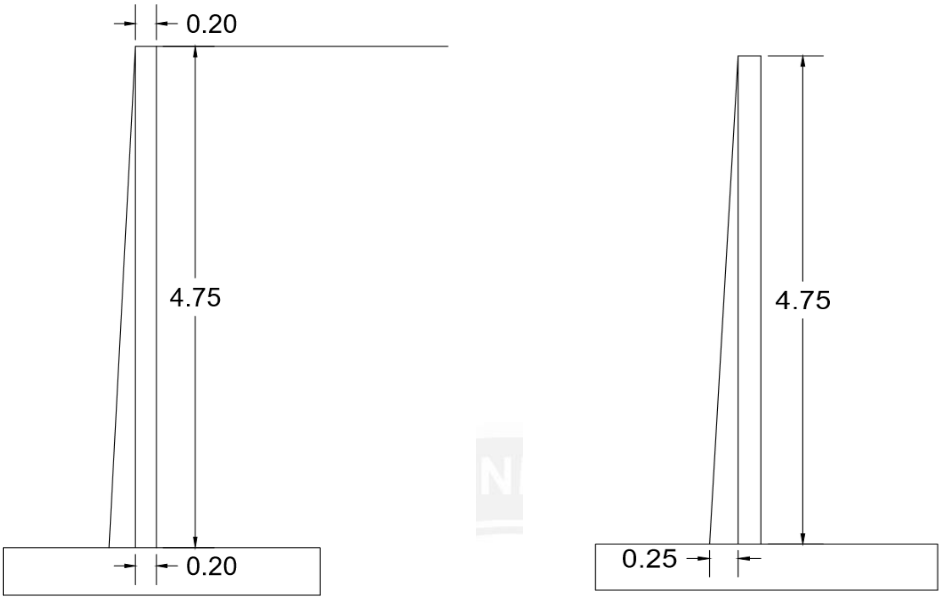


Fig.1.7 Cantilever retaining wall (Stability calculation)

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

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

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

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

$$= 80.78 \text{ KN/m}^2$$

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

$$= 53.85 \text{ KN/m}^2$$

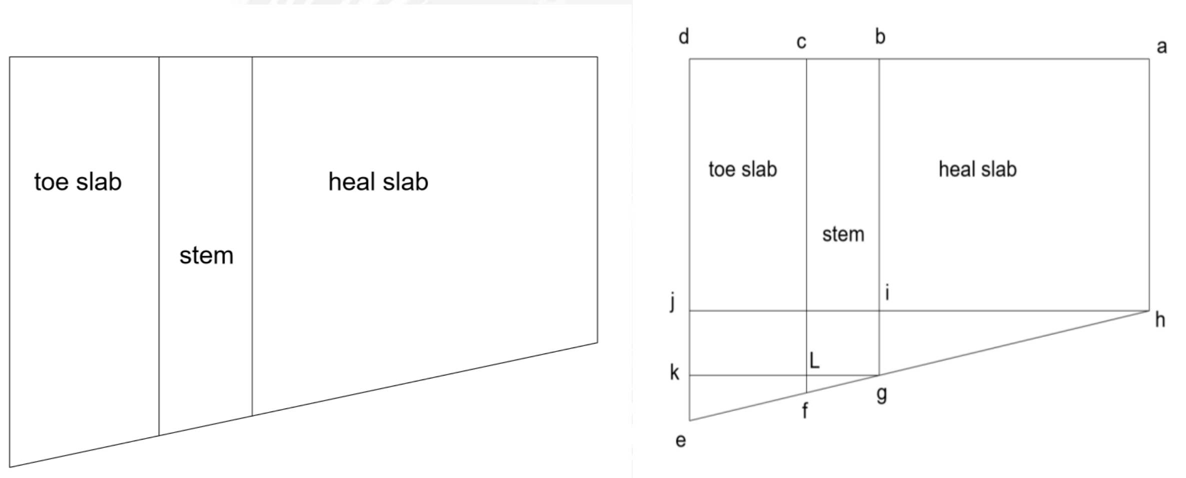


Fig.1.8 Cantilever retaining wall (Stability calculation Top view)

Step 3 : Design of Toe slab

(a) Find load (deductions)

Self weight of toe slab

$$\text{'Wd1'} = B \times D \times \gamma c$$

$$= 1 \times 0.45 \times 24$$

$$= 10.8 \text{ KN}$$

Self weight of soil over toe slab

'Wd2' $= b \times d \times \gamma s$

$= 1 \times 0.75 \times 18$

$= 13.50$ KN

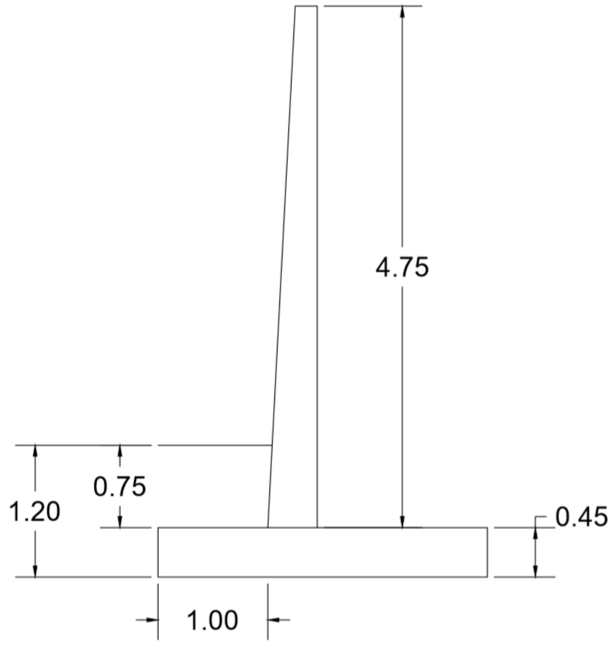


Fig.1.9 Cantilever retaining wall (Toe slab)

Moment deduction

Md1 = W1 x length

$= 10.8 \times 0.5$

= 5.40KNm

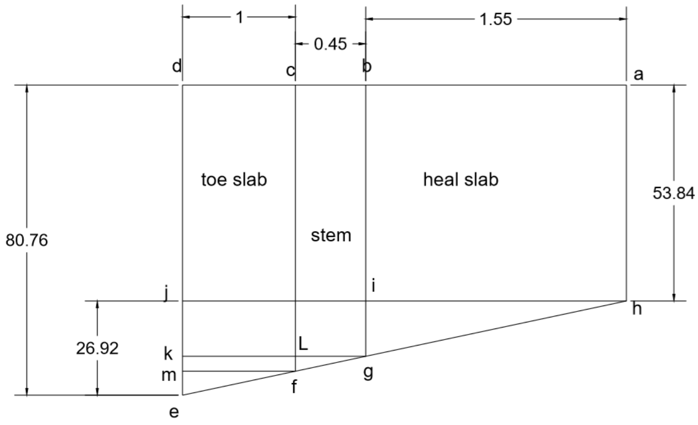
Md2 = 13.50 x 0. 5

= 6.75KNm

Md = M1 + M2

= 5.40 + 6.75

= 12.15KNm



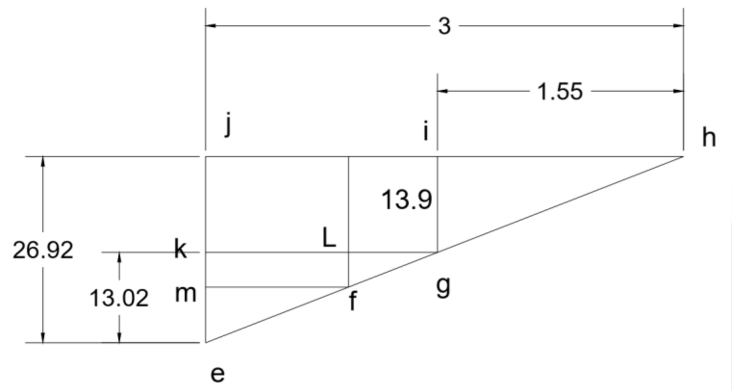


Fig.1.10 Cantilever retaining wall (Heal slab Top view)

(b) Upward pressure

(cdmf) 'W 1' = σmax (breadth) x d

= 1 x 71.78

= 71.78 KN

(mfe) 'W 2' = ½ b x h

= ½ x 1 x 8.98

= 4.49 KN

Moment

(cdmf) 'M 1' = W 1 x length

= 71.78 x 0.5

= 35.89 KNm

(mfe) 'Md 2' = W 2 x length (triangular)

= 4.49 x 0.33

= 1.496 KNm

M = M1 + M2

= 35.89 + 1.496

= 37.38KNm

Bending moment 'M' = M - Md

= 37.38 – 12.15

= 25.23 KNm

Factored moment 'Mu' = 25.23 x 1.5

= 37.85 KNm

(c) Find Ast

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

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37.85x10^6 = (0.87 x 415 x Ast x 400) [(1- 415 x Ast) /(1000 x 400 x 20)

37.85x10^6 = (144.42 x 10^3 Ast) [(1 – 5.187 x 10^-5 Ast)]

37.85x10^6 = (144.42 x 10^3 Ast) – (7.49 Ast^2)

37.85x10^6 - (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 = 37.85x10^6

x1 = 19015.96mm^2

x2 $= 265.7 mm^2$

Ast $= 265.7 mm^2$

Find spacing

Provide 12mm dia bars

Spacing $= 1000 \times [(\pi d^2 / 4) / Ast]$

$= 1000 \times [(\pi \times 12^2 / 4) / 265.7]$

$= 425.65 \sim 300mm$ (max)

Provide 12mm dia bars at 240mm c/c

Find distribution reinforcement

Ast (dist) $= (0.12 / 100) \times bD$

$= (0.12 / 100) \times 1000 \times 450$

$= 540 mm^2$

Provide 12mm dia bars

Spacing $= 1000 \times (\pi d^2 / 4) / Ast$

$= 1000 \times [(\pi \times 12^2 / 4) / 540]$

$= 209mm \sim 210mm$

Provide 12mm dia bars at 210mm c/c

Step 4 : Check for safety against sliding

P $= Ka \times \gamma (H^2 / 2)$

$= (1/3) \times 18 \times (5.2^2 / 2)$

$= 81.12 KN$

i.e Ka $= (1 - \sin Ø / 1 + \sin Ø)$

F.O.S against sliding $= (\mu W / P)$

= (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

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0.25 --- 0.36

0.50 --- 0.48

(0.36+0.48) /2 = 0.42

τc = 0.42 N/mm^2

$\tau c > \tau v$

Hence safe

Reinforcement detail

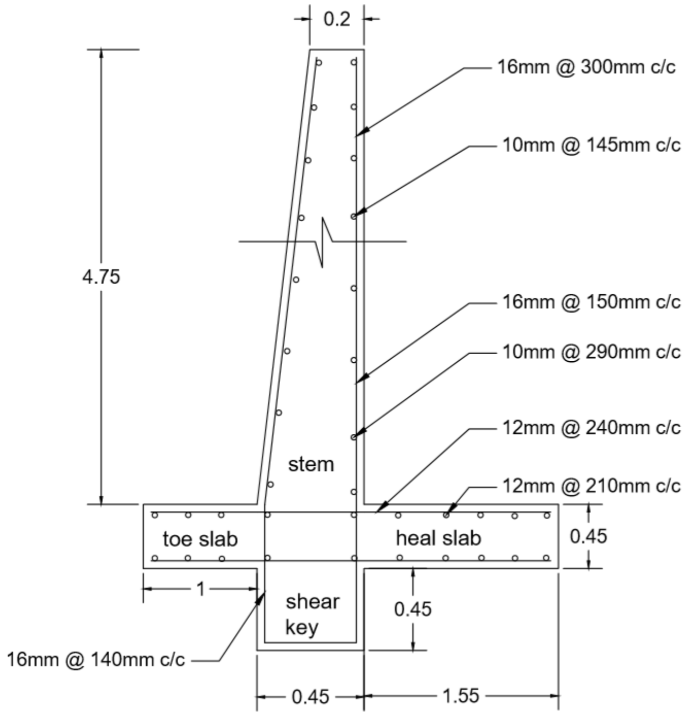

Fig.1.11 Cantilever retaining wall (Reinforcement details cross section)

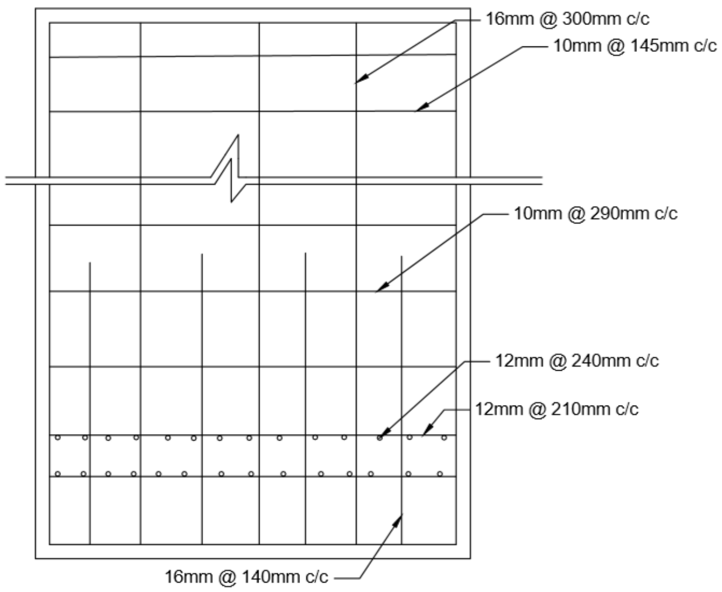

Fig.1.12 Cantilever retaining wall (Reinforcement details Longitudinal cross section)