SRI VIDYA COLLEGE OF ENGINEERING & TECHNOLOGY

VIRUDHUNAGAR

QUESTION BANK WITH ANSWER

DEPARTMENT: CIVIL SEMESTER: 07

SUBJECT CODE /NAME: CE6601/DESIGN OF REINFORCED CONCRETE AND BRICK MASONDRY STRUCTURES

YEAR: III

UNIT I – RETAINING WALLS

Design of cantilever and counterfort retaining walls.

PART - A (2 marks)

1. What are the types of retaining walls? (AU Nov/Dec-2011)

- Gravity retaining wall
- Cantilever retaining wall
- Counterfort retaining wall
- Buttress retaining wall
- Basement or foundation wall

2. Name the two important stability aspects? (AU Nov/Dec-2011, 12, 13)(May/Jun-2012)

- Stability against
- overturning Stability
- against sliding Stability of foundation base

3. What is gravity retaining wall? (AU Nov/Dec-2012)

A gravity wall made of plain concrete or brick masonry. The stability of the wall is maintained by its weight.it is generally made up to a height of 3m of wall.

4. How the vertical stem of a counterfort retaining wall is designed? (AU May/Jun-2012)

The stem is designed as a continuous slab with span equal to the spacing of counterforts. The spacing of counterforts may vary from 2.5m to 4m.maximum load on stem is at its lowest portion due to maximum horizontal earth pressure.

Consider one meter height of vertical slab and design for maximum moments. The maximum negative moment at the end support may be taken as $wl^2/10$ and that at intermediate supports as $wl^2/12$, where l is the span and w is the earth pressure intensity at the lowest portion of vertical slab.

The reinforcement curtailed towards the top. The section is checked for shear and end anchorage.

5. What is the structural action between cantilever and counterfort type retaining wall? (AU May/Jun-2013)

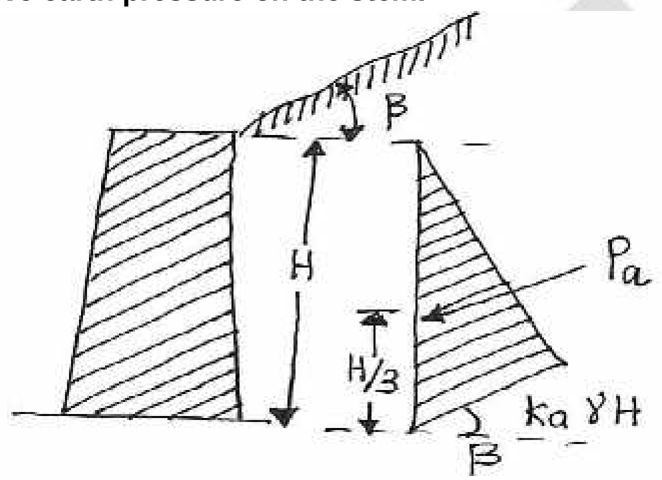
In cantilever retaining wall the pressure and other forces are withstand by the stem of the retaining wall and base slab.

In counterfort retaining wall is provided the height of retaining wall is more than 6m.the walls also provided perpendicular to stem wall. The counterfort act as support to stem and heel slab.

6. What is the function of weep hole in retaining wall construction? (AU May/Jun-2013)

- The weep hole is provided in the retaining wall for the purpose of water distribution through the hole from the back fill materials.
- The weep hole is act as drainage in the hilly side retaining walls due to the rain water.

7. A cantilever retaining wall supports an inclined backfill. Sketch the distribution of active earth pressure on the stem. (AU Nov/Dec-2011)



8. What is a Retaining wall?

Retaining walls are generally used to retain earth or such materials to maintain unequal levels on its two faces. The soil on the back face is at a higher level and is called back fill. Retaining walls are extensively used in the construction of basements below ground level, wing walls of bridge and to retain slopes in hilly terrain roads.

9. What are the forces acting on retaining wall?

- Self-weight of retaining wall
- Weight of soil above the foundation
- base Earth pressure on retaining wall
- Surcharge
- Soil reaction on the footing
- Frictional force on the footing due to sliding.

10. What are the disadvantages of gravity retaining walls?

Gravity walls of stone masonry were generally used in the earlier days to the height of the earth fill. The advent of reinforced concrete has resulted in thinner retaining walls.

11. What are the types of retaining walls?

Retaining wall can be classified structurally as

- Cantilever retaining wall
- Counter fort retaining wall

12. What is a cantilever retaining wall?

The most common and widely used retaining wall is of cantilever type. Vertical stem resisting earth pressure one side and the slab bends like a cantilever. The thickness of the vertical slab is large at the bottom and decreases towards the top in proportion to the varying soil pressure.

13. What is a counter fort retaining wall?

Counter fort retaining walls are used for large heights exceeding 5 mts of earth fill. In counterfort retaining wall the vertical stem is designed as a continuous slab spanning between the counterforts. Counter forts are designed as cantilever beams from the base slab.

14. What are the forces acting on a retaining wall?

Forces acting on a retaining wall are

- Lateral earth pressure due to the back fill
- Vertical forces including weight of soil, stem, heel, toe, and soil fill above the toe.
- The soil pressure developed to resist the earth pressure and other vertical forces acting on the heel and

15. Define Active Earth pressure.

If the soil exerts a push against the wall by virtue of its tendency to slip laterally and seek its natural slope (angle of repose) thus making the wall to move slightly away from the back filled soil mass. This kind of pressure is known active earth pressure.

16. Define Passive earth pressure.

The pressure or resistance which soil develops in response to movement of the structure towards it is called the Passive Earth Pressure.

17. What are the stability conditions should be checked for the retaining walls?

The stability of retaining walls should be checked against the following conditions The wall should be stable

(a) The wall should be stable against Overturning

(b) The wall should be stable against bearing capacity failure.

18. What is meant by backfill?

The material retained or supported by a retaining wall is called backfill.

19. What is meant by surcharge?

The position of the backfill lying above the horizontal plane at the elevation of the top of a wall is called the surcharge.

20. What is a gravity retaining wall?

A gravity retaining wall is the one in which the earth pressure exerted by the backfill is resisted by dead weight of the wall, which is either made of masonry or mass concrete.

21. What is meant by submerged backfill?

The sand fill behind the retaining wall saturated with water is called submerged backfill.

22. What is the function of counterforts in a retaining wall?

The stem of the counterfort retaining wall acts as a continuous slab supported on counterforts. The counterforts take reactions both from the stem as well as the heel slab. Since

the active earth pressure on stem acts outwards and net pressure heel slab acts downwards, the counterforts are subjected to tensile stresses along the outer face of the counterforts.

23. What is meant by back anchoring of retaining wall?

When the height of retaining wall is much more, it becomes uneconomical to provide counterforts. In order to reduce the section of stem etc. in the high retaining walls, the stem may be anchored at its back. The anchor practically takes all the earth pressure and B.M and S.F. in the stem are greatly reduced. When the wall is unsafe in sliding, shear key will have to be provided.

24. When is the design of shear key necessary?

When the wall is unsafe in sliding, shear key will have to be provided.

PART B (16 MARKS)

1. Design a cantilever retaining wall to retain earth embankment 4m height above ground level the density of earth is 18kN/m^3 and its angle of repose is 30 degrees. The embankment is horizontal at its top. The safe bearing capacity of the soil may be taken as 20018kN/m^2 and the co efficient of friction between soil and concrete is 0.5.adopt M20 grade concrete and Fe415 HYSD bars.

(AUC May/Jun-2012, 13) (AUC Nov/Dec-2011, 12, 13)

1. Data

Height of embankment above G.L.
=4M Density of soil=18kN/m^3
Angle of repose=30 degrees
S.B.C of soil=200kN/m^2
Coefficient of friction=0.5

Materials : M-20 grade concrete (f_{ck} = 20 N/mm^2)
Fe-415 HYSD bars (f_y = 415 N/mm^2)

2. *Dimensions of retaining wall*

$$\text{Minimum depth of foundation} = \left(\frac{p}{w}\right)\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

$$= \left(\frac{200}{18}\right)\left(\frac{1}{3}\right)^2 = 1.2 \text{ m}$$

Provide depth of foundation = 1.2 m
Overall depth of wall = H = (4 + 1.2) = 5.2 m
Thickness of base slab = (H/12) = (5200/12) = 433 mm
Adopt thickness of base slab = 450 mm
Thickness of stem at base = 450 mm
Height of stem = h = (5.2 − 0.45) = 4.75 m
Width of base slab = b = 0.5H to 0.6H
0.5H = 2.6 m
0.6H = 3.12 m ∴ Adopt b = 3 m
The overall dimensions of retaining wall is shown in Fig. 10.3.

3. *Design of stem*

Height of stem = h = 4.75 m
Maximum working moment in stem is :

$$M = C_p\left(\frac{w h^3}{6}\right)$$

where $$C_p = \left(\frac{1-\sin\phi}{1+\sin\phi}\right) = (1/3)$$

$$M = \left(\frac{1}{3} \times \frac{18 \times 4.75^3}{6}\right) = 107.17 \text{ kN m}$$

Factored bending moment = M_u = (1.5 × 107.17) = 161 kN.m
Limiting thickness of stem at base is :

$$d = \sqrt{\frac{M_u}{0.138 f_{ck} b}} = \sqrt{\frac{161 \times 10^6}{0.138 \times 20 \times 10^3}} = 242 \text{ mm}$$

Assumed thickness is more than the limiting value. Hence the section is under reinforced. Adopt effective depth of stem = d = 400 mm at bottom gradually tapering to 200 mm at top. Compute the parameter :

$$\left(\frac{M_u}{b \cdot d^2}\right) = \left(\frac{161 \times 10^6}{10^3 \times 400^2}\right) = 1.006$$

Refer Table 2 of SP : 16 design tables corresponding to f_{ck} = 20 N/mm^2 and read out the percentage of reinforcement as :

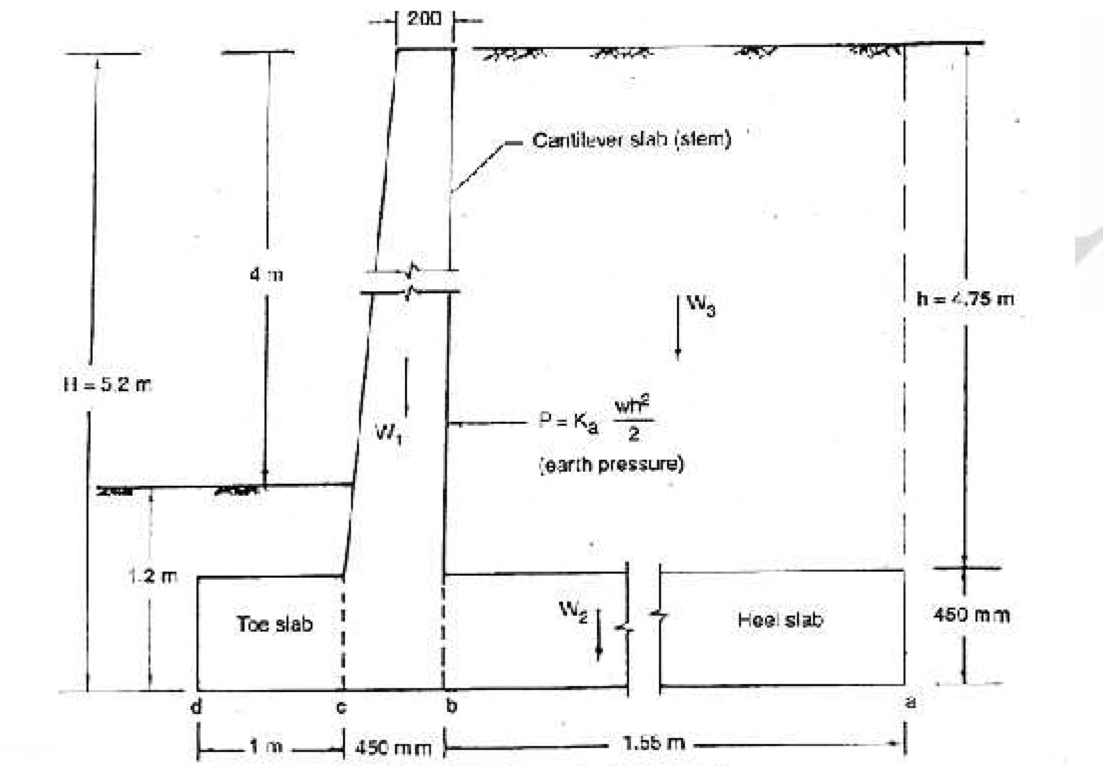


Fig. 10.3. Dimensions of retaining wall.

$$\therefore \quad A_{st} = \left(\frac{p_t\, b\, d}{100}\right) = \left(\frac{0.3 \times 10^3 \times 400}{100}\right) = 1200 \text{ mm}^2$$

Provide 16 mm diameter bars at 150 mm centres in the vertical direction at the bottom of the stem (A_{st} = 1341 mm^2) gradually increasing to 300 mm towards the top.
Distribution bars = (0.0012 × 1000 × 450) = 540 mm^2
Provide 10 mm diameter bars at 250 mm centres on both faces.

4. *Stability calculations (pressure distribution at base)*
Heel projection = (2 – 0.45) = 1.55 m
The overall dimensions of wall is shown in Fig. 10.3.
The stability computations for one metre run of wall is shown in Table 10.1.
Distance of point of application of resultant from end 'a' is :

$$Z = \left(\frac{327.45}{204.90}\right) = 1.6 \text{ m}$$

Eccentricity = $e = [Z - (b/2)] - [1.6 - (3/2)] = 0.1$ m
$(b/6) = (3/6) = 0.5 \quad \therefore\ e < (b/6)$

Table 10.1. Stability calculations for one metre run of wall

Loads	Magnitude of load (kN)	Distance from 'a' (m)	Moment (kN.m)
$W_1 = (0.2 \times 4.75 \times 25)$	23.80	1.65	39.27
$(0.5 \times 0.25 \times 4.75 \times 25)$	14.84	1.83	27.15
$W_2 = (3 \times 0.45 \times 25)$	33.75	1.50	50.62
$W_3 = (1.55 \times 4.75 \times 18)$	132.51	0.78	103.35
Moment due to earth pressure $= C_p\,(wh^3/6)$ $= (1/3)\,(18 \times 4.75^3)/6$			107.06
Total $\therefore\ \Sigma W = 204.90$			$M = 327.45$

Maximum and minimum pressure at base are computed as :

$$p_{\substack{max\\min}} = \left(\frac{204.90}{3}\right)\left(1 + \frac{(6 \times 0.1)}{3}\right)$$

Hence $p_{max} = 82.00\ kN/m^2$ and $p_{min} = 55\ kN/m^2$ (Refer Fig. 10.4)

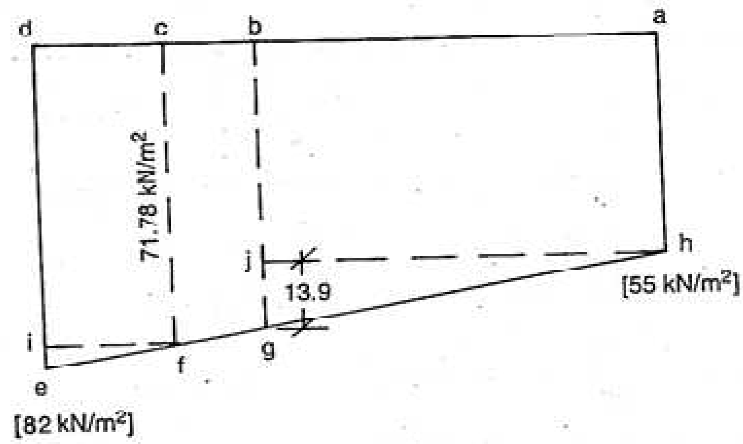


Fig. 10.4. Pressure distribution at base.

5. *Design of heel slab*

Moment computations are shown in Table 10.2.

Table 10.2. Moment computations

Loads	Magnitude of load (kN)	Distance from 'a' (m)	Moment (kN.m)
$W_3 = (1.55 \times 4.75 \times 18)$	132.50	0.775	102.68
Self weight of heel slab $(1.55 \times 0.45 \times 25)$	17.40	0.775	13.51
		Total	= 116.19
Deduct for upward pressure 'abih' (53.84×1.55)	83.45	0.775	64.67
Upward pressure 'ghi' $(0.5 \times 1.55 \times 13.9)$	10.77	0.516	5.55
		Total deduction	= 70.22
Maximum working bending moment in heel slab			= 46.00

Maximum design ultimate moment = $M_u = (1.5 \times 46) = 69$ kN.m

$$\left(\frac{M_u}{b\ d^2}\right) = \left(\frac{69 \times 10^6}{10^3 \times 400^2}\right) = 0.43$$

Refer Table 2 of SP : 16 and read out the percentage of reinforcement as $p_t = 0.121$.

$$\therefore \quad A_{st} = \left(\frac{p_t\, b\, d}{100}\right) = \left(\frac{0.121 \times 10^3 \times 400}{100}\right) = 484 \text{ mm}^2$$

Provide 12 mm diameter bars at 200 mm centres ($A_{st} = 565$ mm^2)

Distribution reinforcement = $(0.0012 \times 1000 \times 450) = 540$ mm^2

Provide 12 mm diameter bars at 200 mm centres ($A_{st} = 565$ mm^2).

6. *Design of toe slab*

The maximum bending moment in the toe slab is determined by taking moments of the forces about the point 'c'. The moment computations are shown in Table 10.3.

Table 10.3. Moment computations

Loads	Magnitude of load (kN)	Distance from 'a' (m)	Moment about 'c' (kN.m)
Upward pressure 'cdif' (71.78 × 1)	71.78	0.5	35.89
Upward pressure 'jfe' (0.5 × 1 × 8.98)	4.49	0.67	3.00
		Total	= 38.89
Deduct self weight of toe slab (1 × 10.45 × 25)	11.2	0.5	5.60
Dead weight of soil over toe slab (0.75 × 1 × 18)	13.5	0.5	6.75
		Total deduction	= 12.35
Maximum service load B.M. in toe slab			= 26.54

Maximum design ultimate moment = $M_u = (1.5 \times 26.54) = 39.81$ kN.m

Compute the parameter $(M_u/b\,d^2) = (39.81 \times 10^6) / (10^3 \times 400^2)$
$= 0.244$

Refer Table 2 of SP : 16 and read out the percentage steel as p_t is less than 0.12 per cent. Hence provide minimum reinforcement of 0.12 per cent.

$$A_{st} = 0.0012 \times 450 \times 1000) = 540 \text{ mm}^2$$

Provide 12 mm diameter bars at 200 mm centres ($A_{st} = 565$ mm^2)

7. *Check for safety against sliding*

Total horizontal earth pressure is :

$$P = K_a\left(\frac{w\,H^2}{2}\right) = \left[\frac{1}{3} \times 18 \times \frac{5.2^2}{2}\right] = 81.12 \text{ kN}$$

Assuming coefficient of friction $\mu = 0.5$

Maximum possible frictional force = $W = (0.5 \times 204.84) = 102.4$ kN

$\therefore$ Factor of safety against sliding = (102.84 / 81.12) = 1.26 < 1.5

Hence a shear key has to be designed.

8. *Design of shear key*

If p_p = intensity of passive pressure developed just in front of the shear key, the value of p_p is computed as :

$$p_p = K_p p$$

where $K_p = \left(\frac{1+\sin\phi}{1-\sin\phi}\right) = (1/K_a) = 3$

and $p = 72.8$ kN/m² (refer Fig. 10.3)

$\therefore$ $p_p = (3 \times 72.8) = 218.6$ kN/m²

If 'a' is the depth of shear key = 450 mm

Total passive force = $p_p = (p_p \, . \, a) = (218.6 \times 0.45) = 98.3$ kN

$\therefore$ Factor of safety against sliding is :

$$\text{F.S.} = \left[\frac{W + p_p}{p}\right] = \left[\frac{102.4 + 98.3}{81.12}\right] = 2.45 > 1.5$$

Hence the retaining wall is safe against failure due to sliding. The reinforcement in stem is extended up the shear key.

9. Check for shear stresses at junction of stem and base slab

Net working shear force = V = $(1.5\,p - mW)$

= $(1.5 \times 81.12) - 102.4$

= 19.28 kN

Factored shear force = V_u = $(1.5 \times 19.28) = 28.92$ kN

Nominal shear stress = τ_v = $(28.92 \times 10^3) / (1000 \times 400)$

= 0.072 N/mm²

$$\left(\frac{100\,A_{st}}{b\,d}\right) = \left(\frac{100 \times 1341}{1000 \times 400}\right) = 1.25$$

From Table 19 of IS : 456–2000, read out the permissible shear stress as :

$$\tau_c = 0.40 \text{ N/mm}^2 > \tau_v$$

Hence shear stresses are within safe permissible limits.

The reinforcement details in the retaining wall are shown in Fig. 10.5.

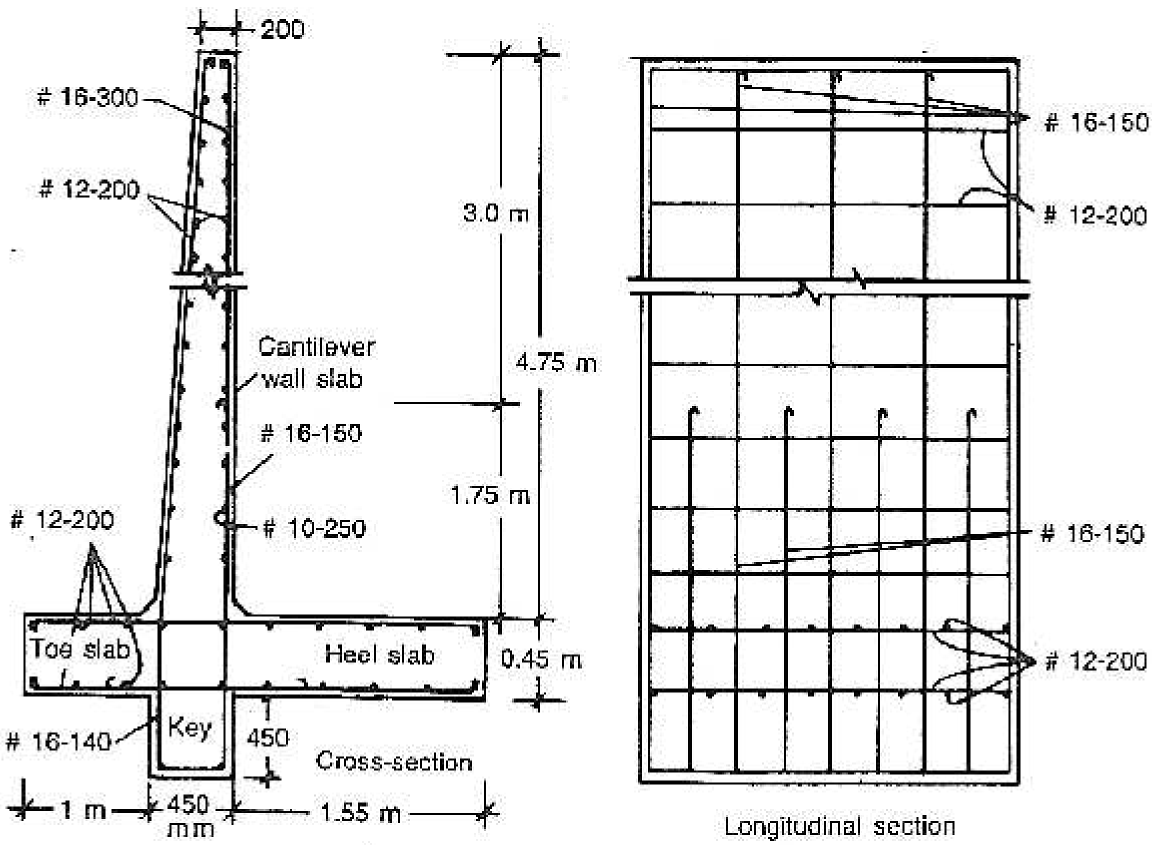


Fig. 10.5. Reinforcement details in retaining wall.

2. Design a counterfort type retaining wall to suit the following data:

Height of wall above ground level=6m
S.B.C. of soil at site=160kN/m^2
Angle of internal friction=33 degrees
Density of soils=16 kN/m^3
Spacings of counterforts=3m c/c
Materials=M20 grade concrete
Fe415 HYSD bars

Sketch the details of reinforcements in details in the wall. (AUC May/Jun-2012, 13)
(AUC Nov/Dec-2011, 12, 13)

1. *Dimensions of retaining wall*

$$\text{Minimum depth of foundation} = \frac{p}{w}\left(\frac{1 - \sin\phi}{1+\sin\phi}\right)^2$$

$$= \frac{160}{16}\left(\frac{1}{3}\right)^2 = 1.11 \text{ m}$$

Provide depth of foundation = 1.2 m

∴ Overall height of wall $H = (6 + 1.2) = 7.2$ m

Thickness of base slab $= 2\,LH$ cm

$= (2 \times 3 \times 7.2) = 43.2$ cm

Provide 450 mm thick base slab

Base width $= 0.6H$ to $0.7H$

$(0.6 \times 7.2) = 4.32$ m

$(0.7 \times 7.2) = 5.04$ m

Adopt base width $= 4.5$ m

Toe projection $= (1/4 \times 4.5) = 1.1$ m

2. *Design of stem*

Pressure intensity at base :

$$= wh\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$$

where $h = (7.2 \times 0.45) = 6.75$ m

∴ pressure intensity $= (16 \times 6.75 \times 1/3) = 36$ kN/m^2

$$\text{Maximum working moment} = \left(\frac{36 \times 3^2}{12}\right) = 27 \text{ kNm}$$

Factored moment $= M_u = (1.5 \times 27) = 40.5$ kNm

Effective depth required for balanced section is :

$$d = \sqrt{\frac{M_u}{(0.138 f_{ck}\, b)}} = \sqrt{\frac{40.5 \times 10^6}{(0.138 \times 20 \times 10^3)}} = 121 \text{ mm}$$

Assuming an under-reinforced section and to provide a suitable thickness to resist design shear at base of stem, adopt an overall thickness of 220 mm constant up to the top.

Effective depth $= d = 175$ mm

The reinforcement in the stem is computed using the relation :

$$(40.5 \times 10^6) = (0.87 \times 415\, A_{st} \times 175)\left[1 - \frac{415\, A_{st}}{(10^3 \times 175 \times 20)}\right]$$

Solving $A_{st} = 700$ mm^2

Provide 12 mm diameter bars at 150 mm c/c ($A_{st} = 754$ mm^2)

Distribution reinforcement $= 0.12$ per cent of section

$= (0.0012 \times 220 \times 1000)$

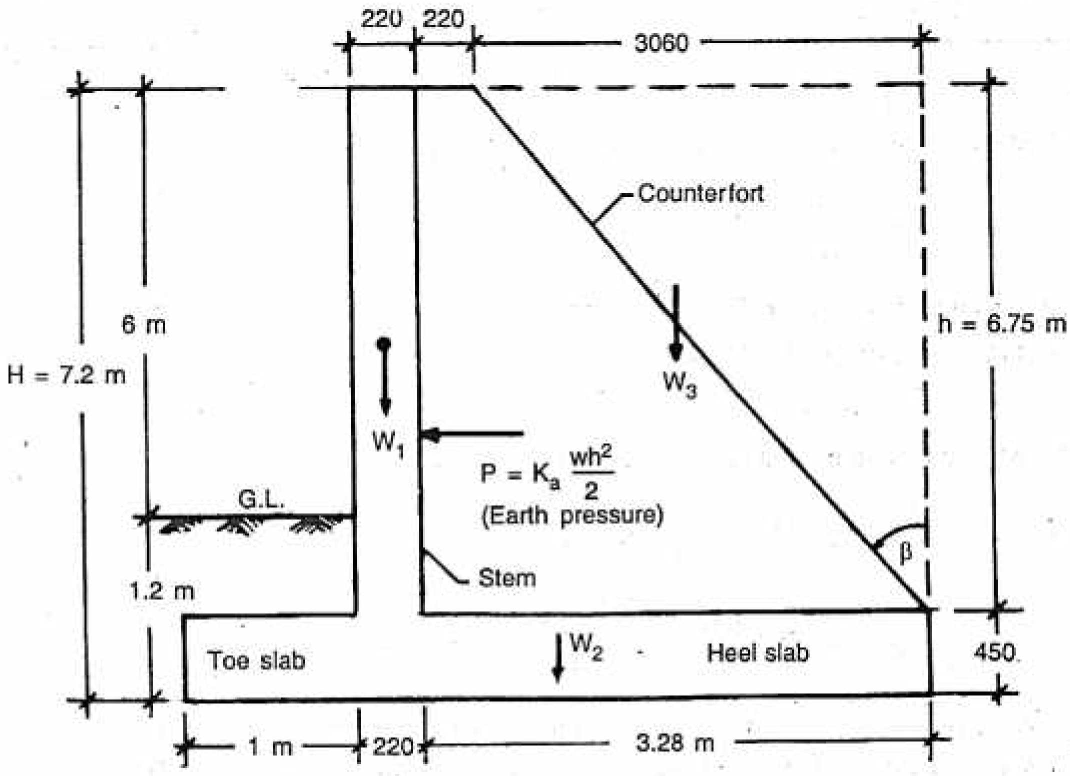
$= 264$ mm^2/m

Adopt 6 mm diameter bars at 200 mm c/c (A_{st} = 283 mm^2)

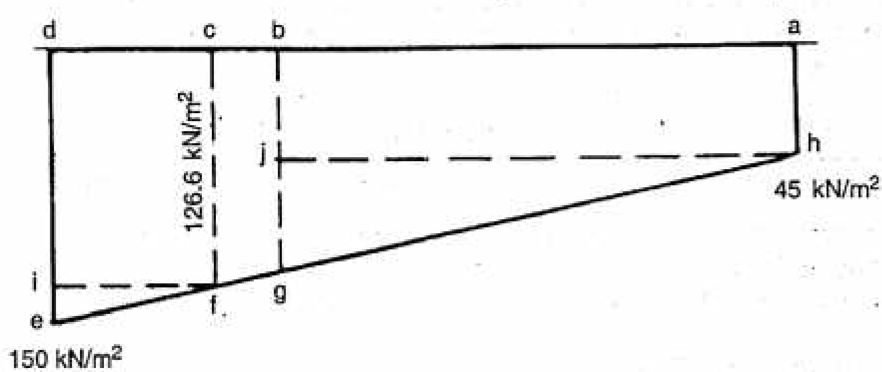
The dimensions of the various structural elements of the counterfort retaining wall are shown in Fig. 10.6(a).

3. *Stability calculations*

The pressure distribution at base is computed by calculating the various forces acting and taking moments of all the forces about the heel. The various forces acting and their moments about the heel point *a* are compiled in Table 10.4.



(a) Counterfort retaining wall (overall dimensions)



(b) Pressure distribution

Fig. 10.6. Counterfort retaining wall.

Table 10.4. Stability computations

Loads	Magnitude of load (kN)	Distance from 'a' (m)	Moment about c (kN.m)
$W_1 = (0.22 \times 6.75 \times 24)$	35.64	3.39	120.80
$W_2 = (0.45 \times 4.5 \times 24)$	48.60	2.25	109.35
$W_3 = (3.28 \times 6.75 \times 16)$	354.24	1.64	580.95
Moment of earth pressure $= K_a = \frac{wh^3}{6} = \left(\frac{1}{3} = \frac{16 \times 7.2^3}{6}\right)$			331.77
Total	ΣW = 438.49		ΣM = 1142.87

Distance of the point of application of the resultant from point *a* is :

$$z = \frac{\Sigma M}{\Sigma W} = \left(\frac{1142.87}{438.49}\right) = 2.66 \text{ m}$$

∴ Eccentricity $e = (z - b/2) = (2.66 - 4.5/2) = 0.41$ m

But $(h / 6) = (4.5 / 6) = 0.75$ m

∴ $e < (b / 6)$

∴ Maximum and minimum pressures at the base are given by :

$$\sigma_{max} = \frac{438.49}{4.5}\left(1 + \frac{6 \times 0.41}{4.5}\right) = 150 \text{ kN/m}^2$$

$$\sigma_{min} = \frac{438.49}{4.5}\left(1 - \frac{6 \times 0.41}{4.5}\right) = 45 \text{ kN/m}^2$$

The maximum intensity of pressure does not exceed the permissible value of 160 kN/m^2. The pressure distribution at the base of the retaining wall is shown in Fig. 10.6(b).

4. *Design of toe slab*

The maximum bending moment acting on the toe slab is calculated by considering moments of all the forces about the point *c*. The computations are shown in Table 10.5 for one metre length of the wall.

Table 10.5. Moment in toe slab

Loads	Magnitude of load (kN)	Distance from 'c' (m)	Moment about 'c' (kN.m)
Upward pressure 'cdif' (126.6 × 1)	126.6	0.5	63.30
Upward pressure 'efi' (0.5 × 1 × 23.4)	11.7	0.67	7.84
Total			71.14
Deduct self weight of toe slab (1 × 0.45 × 24)	10.8	0.5	5.40
Dead weight of soil over toe slab (0.75 × 1 × 16)	12.0	0.5	6.00
Total deduction			11.40

Maximum working moment in toe slab :

$$M = (71.14 - 11.4) = 59.74 \text{ kNm}$$

Factored moment = $M = (1.5 \times 59.74) = 89.61$ kNm
Effective depth of toe slab = 400 mm
Reinforcements in toe slab is computed using the relation :

$$(89.61 \times 10^6) = (0.87 \times 415\, A_{st} \times 400)\left[1 - \frac{415\, A_{st}}{(10^3 \times 400 \times 20)}\right]$$

Solving $A_{st} = 644 \text{ mm}^2$
Provide 12 mm diameter bars at 150 mm c/c ($A_{st} = 754 \text{ mm}^2$)
Distribution bars = $(0.0012 \times 100 \times 450) = 540 \text{ mm}^2$
Provide 10 mm diameter bars at 280 mm c/c on both faces ($A_{st} = 561 \text{ mm}^2$).

5. *Design of heel slab*

Considering 1 m wide strip of heel slab near heel end a, upward soil pressure = 45 kN/m²

Weight of soil on strip = (16 × 6.75)	=	108.00 kN/m²
Self weight of strip = (1 × 0.45 × 24)	=	10.80 kN/m²
Total	=	118.80 kN/m²
Deduct for downward pressure	=	−45.00 kN/m²
Net downward pressure	=	73.00 kN/m²

Spacing of counterforts = 3 m
∴ Maximum negative service BM at counterforts is :

$$M = \left(\frac{73.80 \times 3^2}{12}\right) = 55.35 \text{ kNm}$$

Factored moment = $M_u = (1.5 \times 55.35) = 83$ kNm
Reinforcements in heel slab is computed using the relation :

$$(83 \times 10^6) = (0.87 \times 415\, A_{st} \times 400)\left[1 - \frac{415\, A_{st}}{(1000 \times 175 \times 20)}\right]$$

Solving $A_{st} = 600 \text{ mm}^2$
Provide 12 mm diameter bars at 150 mm c/c ($A_{st} = 754 \text{ mm}^2$)
Distribution bars = 0.12 per cent of cross-section
= $(0.0012 \times 1000 \times 450) = 540 \text{ mm}^2$

Provide 10 mm diameter bars at 280 mm centres on both faces ($A_{st} = 561 \text{ mm}^2$)

6. *Design of counterforts*

Thickness provided at the top = (220 + 220) = 440 mm
Thickness of counterfort = 440 mm

Maximum working moment in counterfort is :

$$M = \left(K_a \times \frac{wh^3}{6} \times L\right) = \left(\frac{1}{3} \times \frac{16 \times 6.75^3}{6} \times 3\right) = 820.12 \text{ kNm}$$

Factored moment = M_u = (1.5 × 820.12) = 1230 kNm

Reinforcement at the bottom of counterfort is computed by using the relation :

$$(1230 \times 10^6) = (0.87 \times 415\, A_{st} \times 4400)\left[1 - \frac{415\, A_{st}}{(440 \times 4400 \times 20)}\right]$$

Solving A_{st} = 800 mm^2

But minimum reinforcement as per IS : 456–2000 code is given as :

$$A_s = \left(\frac{0.85\text{ b d}}{f_y}\right) = \left[\frac{(0.85 \times 440 \times 4400)}{415}\right]$$

$= 3965$ mm^2

Provide 5 bars of 32 mm diameter (A_{st} = 4020 mm^2)

7. *Curtailment of bars*

Let h_1 = depth at which 1 bar can be curtailed.

Then $$\left(\frac{5-1}{5}\right) = \left(\frac{h_1}{6.75^2}\right)$$

∴ h_1 = 6 m from top

Let h_2 = depth at which 2 bars can be curtailed.

Then $$\left(\frac{5-2}{5}\right) = \left(\frac{h_2}{6.75^2}\right)$$

∴ h_2 = 5.2 m from top

Let h_3 = depth at which 3 bars can be curtailed.

Then $$\left(\frac{5-3}{5}\right) = \left(\frac{h_3}{6.75^2}\right)$$

∴ h_3 = 4.2 m from top

The remaining two bars are taken right up to the top.

8. *Connection between counterfort and upright slab*

Consider the bottom 1 m height of upright slab.

Pressure on this strip = 36 kN/m^2

Total lateral pressure transferred to the counterfort for 1 m height = 36(3 – 0.44) = 91.8 kN

Factored force = (1.5 × 91.8) - 137.7 kN

$$\text{Steel required per metre height} = \left(\frac{137.7 \times 10^3}{0.87 \times 415}\right) = 381 \text{ mm}^2$$

Provide minimum reinforcement of 10 mm diameter bars in the form of horizontal links at 280 mm centres.

9. *Connection between counterfort and heel slab*

Tension transferred in 1 m width of counterfort near the heel end = 73.8 (3 – 0.44) = 189 kN

Factored force = (1.5 × 189) = 283.5 kN

$$\text{Steel required for 1 m width} = \left(\frac{283.5 \times 10^3}{0.87 \times 415}\right) = 785 \text{ mm}^2$$

Spacing of 10 mm diameter bars in the form of two-legged links

$$= \left(\frac{2 \times 78.5 \times 10^3}{0.87 \times 415}\right) = 785 \text{ mm}^2$$

Provide 10 mm diameter two-legged vertical links at 200 mm centres.

10. The details of reinforcements in the counterfort retaining wall are shown in Fig. 10.7.

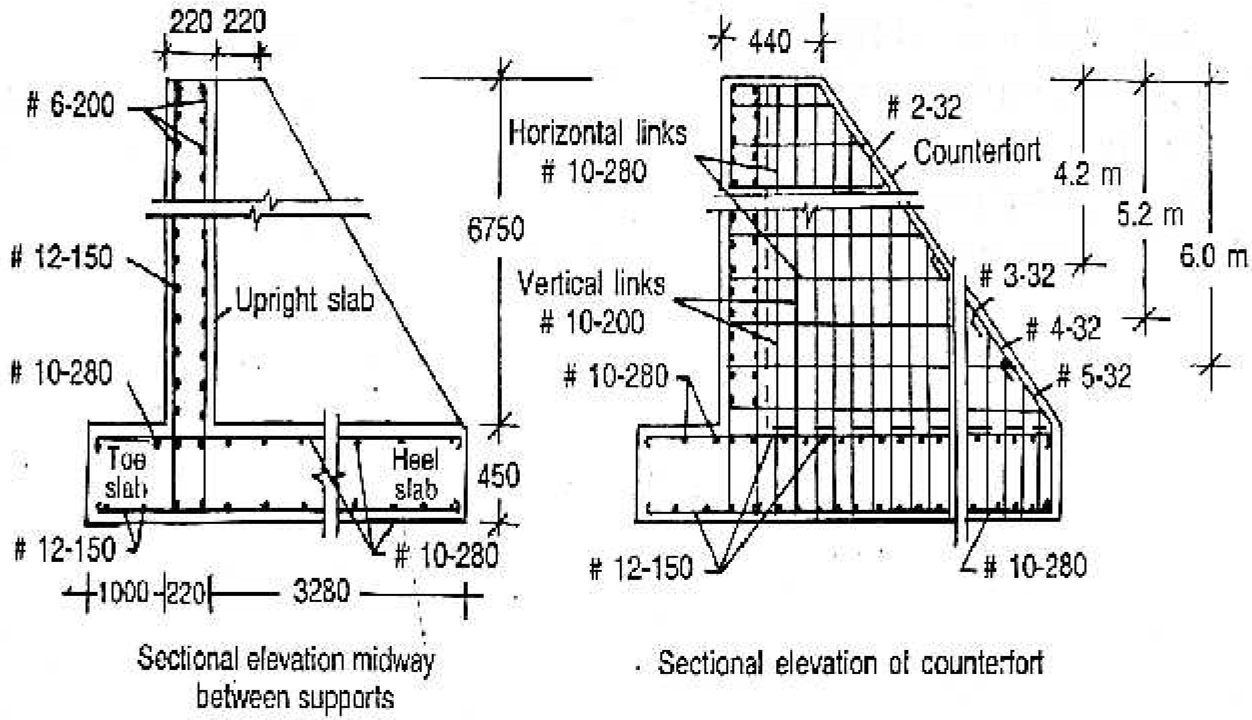


Fig. 10.7. Reinforcement details in counterfort retaining wall.

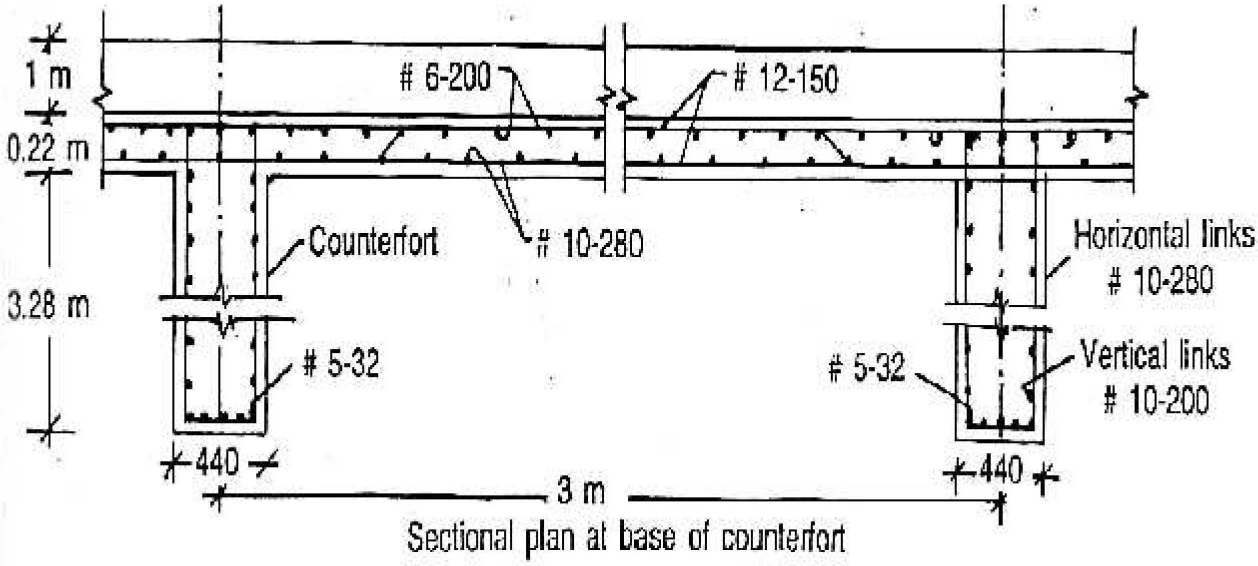


Fig. 10.7. Reinforcement details in counterfort retaining wall.