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Design of Cantilever Retaining Wall

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***Abstract*: The paper deals with the design and cost economics of a 4m high and 272m long earth fill retaining wall. The aim was to design cantilever retaining wall section and its costing for the horizontal backfill. For that actual parameters from Three Jewels, Pune site were considered. The retaining wall designed for section 1-1 with retaining height 3.35m (as per the geotechnical strata report). As part of consulting engineering firm, the purpose of retaining wall for the Three Jewels site was to maintain two different earth levels where the ground level changes abruptly due to sloppy area. This is constructed in between phase-II and Phase –III in future development.**

***Keywords*: Retaining wall, Active earth pressure, Passive earth pressure, Lateral pressure.**

1. Introduction

Retaining walls are usually built to hold the soil back to the retail soil unable to stand vertically by them. However, walls can also be constructed for aesthetic landscaping purposes. They are also provided to maintain the field at two different levels. Retaining walls shall be designed to withstand lateral earth and water pressure, effect of overload load, self-weight of wall. The following are the different types of retaining walls, depending on the size and the pressure resisting mode:

a) Gravity wall-masonry or plain concrete.
b) Cantilever retaining wall.
c) Counter fort retaining wall.
d) Buttress retaining wall.

The analysis and design of retaining walls includes the following subsequent:

1. Estimation of the primary dimensions of the wall, then these dimensions should be examined.
2. Exterior stability of walls (to check slippery, stability and bearing stability of retaining walls).
3. Main and secondary reinforcements for reinforced concrete retaining walls should be calculated.

2. Purpose of work

This paper shows the analysis and design of cantilever retaining wall. The design consists of two major stages: the first is an evaluation of the stability of the entire structure under service load, including overturning, sliding, and bearing failure modes, and the second is the design of individual components, such as under combined fact load, Stem, heel and toe for bending and shearing.

3. Design Requirement

The following information is required for retaining wall design:

1. Retained height of retaining wall – It is different for different section due to abrupt change in ground level.
2. From geotechnical report:
   - Allowable soil pressure – 40 ton/sq. Meter
   - Coefficient of friction – 0.5 as per the strata
   - Axial load on stem, surcharge load and wind load if applicable- horizontal backfill without surcharge load.
   - Soil density - for filling 1.8t/m^3 and for CWR 2.1t/m^3
   - Angle of repose -for filling$30^o$and for CWR42^o

4. Design and calculation of retaining wall

A. Design problem statement

Design of cantilever retaining wall for retaining height 3.35 (as per the section 1-1 in geotechnical strata report).

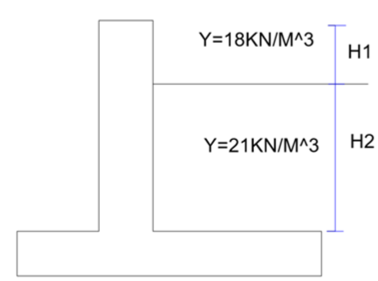
Given data: (as per the strata report)

1) SBC (Soil Bearing Capacity): 40 ton/sq. Meter
2) Section 1-1

Depth of layer	description	Density (t/m^3)	Angle of repose
0.00m-0.48m	Filling	1.8	30
0.48m-3.35m	CWR	2.1	42

3) Height above the ground level in section 1-1 / retaining height of retaining wall: 3.35m
4) Dry moist backfill with no surcharge
5) Coefficient of friction: 0.5
6) Materials:

Concrete –M25 fck=25mpa
Steel HYSD bar-Fe 500 fy= 500mpa

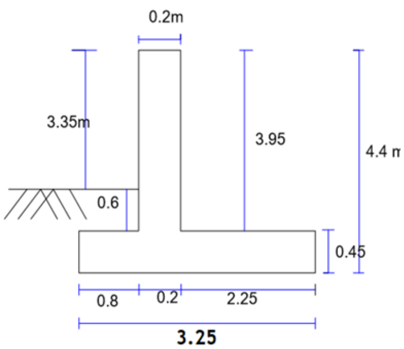


Step 1: Calculation of coefficient of active earth pressure.

(Rankine's lateral earth pressure theory)Ka=$\frac{1-sin\emptyset}{1+sin\emptyset}$ = 0.198

Step 2: Dimension of the retaining wall(provided)

1. Minimum depth of foundation: DF=1.05m.
2. Total depth of retaining wall 4.4m
3. Base width of slab = 0.6H to 0.8H =3250 mm
4. Toe projection = $\frac{B}{3}\ to\ \frac{B}{4}$=800 mm
5. Thickness of base slab = $\frac{H}{14}$ to $\frac{H}{12}$ =450mm
6. Top width of stem =200mm



Step 3: Design of stem

1. To find base width of stem

Ka1=0.33Ɣ1=18KN/M^3 ; Ka2=0.198Ɣ2=21KN/M^3

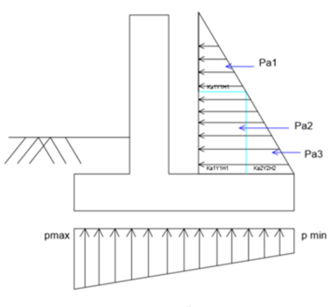
As per IS 1893(PART 3):2014 Clause no. 22.1.1

Pa1=0.68 KN;

Pa2=9.89 KN;

Pa3=25.03KN;

Pa= Pa1+Pa2+Pa3= 35.60KN



We used Fe 500 and M25: d = 148.03mm; Assume eff. Cover =50mm

Total width of base stem=200mm (provided); Height of stem =4.4-1.05=3.95m

Ast=$\frac{0.5fck}{fy}\left[1-\sqrt{1-\frac{4.6\,M_u}{fckbd^2}}\right]$*bd =1366.21$mm^2$

Spacing =$\frac{\frac{\Pi}{4}*dia^2}{Ast}*b$ =147.167mm< $3d$; Provide 16mm dia @150mm c/c

Ast actual =1340.41mm^2; Distribution Steel: 0.12% of Ag= 240mm^2; Spacing 209.3$mm(dia=8mm)<5d$

Hence, provide 8 mm dia @200mm c/c in horizontal direction at both back and front faces of stem. Gradually increase the spacing to 250mm and 350mm c/c towards the top of stem. For Fe500 M25; provide Development length LD= Dia*49=785mm.

Step 4: Stability computation

Total moment =Mo+Mr=72.87+303.55=375.44KN-m

Z=$\frac{\sum M}{\sum W}=1.656m$ Eccentricity=E= (z-$\frac{B}{2}$) =0.031< $\frac{B}{6}=0.54$

Pmax=$\frac{\sum w}{B}[1+\frac{6e}{B}]$=70.27 KN/$m^2$;

Pmin=$\frac{\sum w}{B}[1-\frac{6e}{B}]$=62.66KN/$m^2$

Step 5: Design of heel

Maximum BM in the heel slab @ b section

Total moment on heel =M1-M2=58.91KN-m; Ultimate moment =Mu=58.91*1.5=88.36KN-m ;Total load W=V= W1-W2= 38.4KN Vu=1.5*38.4 =57.6 KN

Ast=$\frac{0.5fck}{fy}\left[1-\sqrt{1-\frac{4.6\,M_u}{fckbd^2}}\right]$*bd=521.67$mm^2$

Spacing =$\frac{\frac{\Pi}{4}*dia^2}{Ast}*b=385mm(dia=16mm)<3d$

Provide minimum spacing of 300mm

Ast provided=670.20mm^2

Therefore, provide 16mm dia @300mm c/c at top of heel slab. As tension is on top side.

Distribution Steel: 0.12% of Ag=$\frac{0.12}{100}*1000*450=540mm^2$

Spacing =$\frac{\frac{\Pi}{4}*dia^2}{Ast}*b=209.44mm(dia=12mm)$

Provide 12mm dia @200c/c

Step 6: Design of toe slab

Maximum BM in the toe slab is computed at section c as,

S.No.	Description	Load	C.G @C	Moment
1	Upward earth pressure (dcko2)	54.70KN	0.4m	21.88KN-m
2	Upward earth pressure (o2ek)	0.756KN	0.53	0..4KN-m
	Total	W1=55.45KN		M1=22.28KN-m
3	Self-weight of toe slab	9KN	0.4	3.6KN-m
4	Soil above the toe slab neglected			
	Total	W2=9KN		M2= 3.6KN-m

Total moment on toe slab =M1-M2=18.68KN-m

Mu=28.02KN-m; Total load v= w1-w2= 46.45KN; Vu=69.67KN

Ast=$\frac{0.5fck}{fy}\left[1-\sqrt{1-\frac{4.6\,M_u}{fckbd^2}}\right]$*bd=162.43$mm^2$

Spacing =$\frac{\frac{\Pi}{4}*dia^2}{Ast}*b=990mm(dia=16mm)<3d=1200mm$

Provide 16 mm dia bar @300mm c/c at the bottom of toe slab

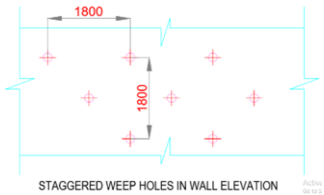
Ast provided =$\frac{\frac{\Pi}{4}*16^2}{300}$*1000=670.20$mm^2$

Distribution Steel: 0.12% of Ag=$\frac{0.12}{100}*1000*450=540mm^2$

Spacing= $\frac{\frac{\Pi}{4} * dia^2}{Ast} * b = 209.44mm\ (dia = 12mm) < 5d$

Provide 12mm dia @200c/c

Step 7: Design for drainage of water

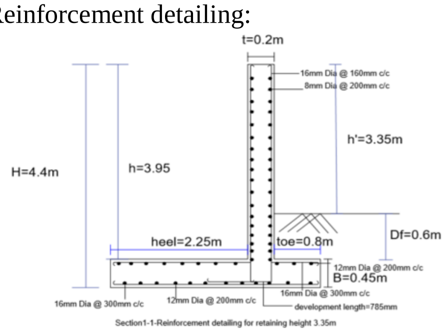


Pipe type: PVC; Provide Pipe diameter: 150mm; Assume weep holes spacing: 1800mm

Step 8: Stability checks

S.No.	Stability	Design FOS	As per is 456:2000
1	Stability against overturning	4.72	Should be greater than 1.4
2	stability against sliding	2.47	Should be greater than 1.4
3	Allowable settlement at ultimate bearing capacity	12mm	as per strata report

Step 9: Reinforcement detailing:



5. Result

Step	Description	Result obtained
1	Calculation of coefficient of active earth	Ka = 0.198
2	Provided dimension of the retaining wall	Minimum depth of foundation =1.05m. Total depth of retaining wall =4.4m Base width of slab =3250 mm Toe projection =800 mm Thickness of base slab =450mm Top width of stem =200mm
3	Design of stem	Main bar:16mm dia@160mm c/c Distribution bar: 8 mm dia@200mmc/c
4	stability computation	Pmax=70.27 KN/m^2 Pmin=62.66KN/m^2
5	Design of heel	Main bar: 16mm dia @300mm c/c Distribution steel:12mm dia @200c/c
6	Design of toe slab	Main bar: 16 mm dia bar @300mmc/c Distribution steel: 12mm dia @200c/c
7	Design for drainage of water	Provide PVC pipe of 150mm dia with 1.8m spacing (staggered pattern)
8	Stability checks	Stability against overturning = 4.72 stability against sliding = 2.47 Allowable settlement at ultimate bearing capacity = 12mm

6. Conclusion

Retaining wall is a structure which is used to retain earth from hill slopes. According to data from the site the soil bearing capacity was 40t/m^2 and the retaining height was 3.55 m. According to the results obtained, the structure may reduce the cost of construction as well as quantity of the backfill.

References

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