DESIGN OF RETAINING WALL

INTRODUCTION:
This wall is designed for active earth pressure and live load surcharge pressure. The loads for the purpose of design are calculated per meter length of wall.

BASIC DESIGN:

Formation level = 100.72 m
Foundation level = 91.80 m
Height of the wall above the Ground Level = 7.42 m
Depth of foundation below Ground level = 1.50 m
Slope of surcharge is = 0.00 degree
Safe bearing capacity = 200.00 kN/m²

MATERIALS:

Grade of concrete = M 25
Permissible flexural compressive stress $\sigma_{cbc}$ = 8.333 N/mm²
modular ratio $m$ = 10 for roads, means of IS [280/3]

Neutral axis depth factor $n$ = $(1/(1+(200/(10*8.333))))$ = 0.294
Leverarm factor $j$ = $(1-0.294/3)$ = 0.902
Moment resistance factor $Q$ = $(0.5*0.294*0.902*8.333)$ = 1.105 N/mm²

Maximum shear stress = 1.90 N/mm² from code
Clear cover to the reinforcement = 50 mm
Clear cover to footing reinforcement = 75 mm
Density of concrete = 24 kN/mm³
Development length factor $L_d$ = 46 Ø
Grade of steel = Fe 415
Tension in flexure, shear or combined bending $\sigma_{st}$ = 200 N/mm²

Back Fill:

Angle of slope of the embankment or backfill $\beta$ = 0 degree
Angle of internal friction $\phi$ = 30 degree
Angle of internal friction soil to soil $\delta$ = 20 degree
Inclination of wall with respect to vertical $\alpha$ = 7 degree
Cohesion \( c = 0.000 \) kN/m²

Density of earth \( \gamma = 18.000 \) kN/m³

Density of water \( \gamma_W = 10.000 \) kN/m³

Coefficient of active earth pressure in horizontal direction

\[
Ka = \frac{\cos^2(\phi - \alpha)}{\cos^2\alpha \left[ 1 + \left( \frac{\sin(\phi + \delta) \cos(\phi - \beta)}{\cos(\alpha + \delta) \cos(\alpha - \beta)} \right)^2 \right]} = 0.307
\]

LOADS:

Active earth pressure at bottom of footing level \( = K_a \gamma h = 49.332 \) kN/m²

Due to live load surcharge \( = (0.307 \times 18 \times 1.2) = 6.637 \) kN/m²

Depth of potential tension crack due to cohesion "z" \( = 0.000 \) m - \( 2c/(\gamma(K_a)0.5) \)

Live load surcharge \( = 1.20 \) m of backfill

![Diagram of foundation loads and pressures](image-url)
**DESIGN OF STEM:** Top straight portion of the stem

Dry condition:

Force due to active earth pressure = \(0.5 \times 15.209 \times 2.75\) = 20.912 kN

Lever arm = \((0.42 \times 2.75)\) = 1.155 m

Bending moment = \((20.912 \times 1.155)\) = 24.154 kN.m

Force due to surcharge = \(6.637 \times 2.75\) = 18.251 kN

Lever arm = \((2.75 \times 0.5)\) = 1.375 m

Bending moment = \((18.251 \times 1.375)\) = 25.095 kN.m

Total Design BM = \((25.095 + 24.154)\) = 49.249 kN.m

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d, Required = \((\sqrt{(49.249 \times 1000000 / (1.105 \times 1000)})\) = 211.080 mm

d, Provided = \((0.3 \times 1000) - 50 - 16 - 8\) = 226.00 mm \(\text{SAFE}\)

Ast Required = \((49.249 \times 1000000 / ((200 \times 0.902 \times 226)))\) = 1208.00 mm²

Minimum steel required is = 0.12% = 360.00 mm²

Providing tor 16 @ 125 mm

Steel provided = 1608.50 mm² \(\text{SAFE}\)

**Base of the stem:**

Dry condition:

Force due to active earth pressure = \(0.5 \times 42.696 \times 7.72\) = 164.81 kN

Lever arm = \((0.42 \times 7.72)\) = 3.242 m

Bending moment = \((164.806 \times 3.242)\) = 534.37 kN.m

Force due to surcharge = \(6.637 \times 7.72\) = 51.235 kN

Lever arm = \((7.720 \times 0.5)\) = 3.860 m

Bending moment = \((51.235 \times 3.860)\) = 197.77 kN.m

Total Design BM = \((197.767 + 534.366)\) = 732.13 kN.m

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d, Required = \((\sqrt{(732.132 \times 1000000 / (1.105 \times 1000)))\) = 813.853 mm

d, Provided = \((1.2 \times 1000) - 50 - 25 - 12.5\) = 1112.50 mm \(\text{SAFE}\)

Ast Required = \((732.132 \times 1000000 / ((200 \times 0.902 \times 1112.5)))\) = 3648.1 mm²
Minimum steel required is $= 0.12\% = 1440.00 \text{ mm}^2$

Providing $tor 25 @ 125 \text{ mm} + tor 0 @ 125 \text{ mm}$

Steel provided $= 3926.991 \text{ mm}^2$ SAFE

CHECKING BASE PRESSURE:

For checking the base pressure all the loads acting on the base slab are calculated about TOE of the base slab. The load calculations are listed in following table.

Force and BM due to active earth pressure are considered as -ve for sign convention purpose.

<table>
<thead>
<tr>
<th>S.no.</th>
<th>Description</th>
<th>Load in KN</th>
<th>Load in kN</th>
<th>Lever arm in</th>
<th>BM in kN.m</th>
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<tbody>
<tr>
<td>1</td>
<td>Active earth pressure</td>
<td>220.02</td>
<td>3.75</td>
<td>-824.3</td>
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<tr>
<td>2</td>
<td>Liveload surcharge</td>
<td>59.20</td>
<td>4.46</td>
<td>-264.0</td>
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<td></td>
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<td></td>
<td>-1088.3</td>
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<tr>
<td>3</td>
<td>Vertical component due to Active earth pressure</td>
<td>105.28</td>
<td>2.900</td>
<td>305.33</td>
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<tr>
<td>4</td>
<td>Vertical comp. of live load surcharge</td>
<td>28.33</td>
<td>2.900</td>
<td>82.15</td>
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<tr>
<td>5</td>
<td>Earth weight</td>
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<tr>
<td>A</td>
<td></td>
<td>416.88</td>
<td>5.300</td>
<td>2209.46</td>
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<tr>
<td>B</td>
<td></td>
<td>44.55</td>
<td>3.350</td>
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<tr>
<td>C</td>
<td></td>
<td>2.24</td>
<td>0.967</td>
<td>2.16</td>
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<tr>
<td>D</td>
<td></td>
<td>18.90</td>
<td>5.800</td>
<td>109.62</td>
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<td></td>
<td>Wt. of earth on toe</td>
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<tr>
<td>E</td>
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<td>16.38</td>
<td>0.676</td>
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<tr>
<td>F</td>
<td></td>
<td>14.04</td>
<td>1.300</td>
<td>18.25</td>
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<td>6</td>
<td>Self weight of wall</td>
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<td>a</td>
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<td>55.58</td>
<td>2.750</td>
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<tr>
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<td>53.68</td>
<td>3.200</td>
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<tr>
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<tr>
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<tr>
<td>f</td>
<td></td>
<td>25.20</td>
<td>4.800</td>
<td>120.96</td>
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</tr>
</tbody>
</table>

Sum of $P = 904.66 \text{ kN}$ Net BM $= 2627.48 \text{ kN.m}$

Sum of $H = 279.221 \text{ kN}$

Self weight of wall $= 258.060 \text{ kN}$

Eccentricity $= e(=b/2 - M/V) = 0.496 \text{ m}$ SAFE

Check for base pressure

Maximum $(P/A + Pe/Z) = 191.216 \text{ kN/m}^2$ SAFE

Minimum $(P/A - Pe/Z) = 74.860 \text{ kN/m}^2$ SAFE
CHECK FOR STABILITY

Stability against Sliding

Total Vertical load = 904.659 kN
Total Horizontal load = 279.221 kN
\( \tan \phi = 0.577 \)
Factor of safety against sliding = 1.871 >1.5 SAFE

Stability against Overturning

Restoring moment \( RM = 3715.8 \) kN.m
Overturning moment is due to earth pressure \( OM = 1088.3 \) kN.m
Factor of safety against Overturning \( \frac{RM}{OM} = 3.414 \) >2 SAFE

DESIGN OF TOE SLAB:

BM due to base pressure = 596.2 kN.m
BM due to self weight of slab = 135.20 kN.m
BM due to weight of earth on toe = 46.64 kN.m
Total BM = 414.34 kN.m
Design BM acting on the Toe slab = 414.34 kNm
Effective depth required \( d_{req} = 612.25 \) mm
Providing overall depth as = 1200.0 mm
Effective depth provided = 1099.0 mm SAFE
Steel required = 2089.99 mm²
Minimum steel required is 0.12% = 1440.00 mm²
Providing \( tor 20 \) @ 100 mm C/C = 3141.59 mm² SAFE

Check for Shear:

Critical section at a distance (eff. depth) i.e. = 1099.00 mm from the face of the support:
Overall depth provided = 0.904 m
Effective depth = 819.12 mm
Due to base pressure = 267.740 kN
Due to self weight of slab = -25.291 kN
Total shear at c = 242.449 kN
BM due to base pressure = 205.76 kN.m  
BM due to self wt. of slab = 16.460 kN.m  
BM at c = -189.30 kN.m  
Design shear \( (V \pm M \tan \beta / d) \) = 186.078 kN  
Shear stress \( \tau = (V \pm M \tan \beta / d) / b d \)  
\[ \tau = 0.227 \quad \text{SAFE} \]  
100 As/bd = 0.286  
Permissible Shear stress in concrete with out shear steel = 0.244 N/mm²  
**Hence Shear Reinforcement is NOT required.**

**DESIGN OF HEEL SLAB**

BM due to base pressure = 413.87 kN.m  
BM due to self weight of slab = 79.200 kN.m  
BM due to weight of earth on Heel = 227.34 kN.m  
Total BM = 107.33 kN.m  
Design BM acting on the Heel slab = 107.33 kN.m  
Effective depth required \( d_{eq} \) = 311.61 mm  
Providing overall depth as = 1200.0 mm  
Effective depth provided = 1103.0 mm \( \text{SAFE} \)  
Steel required = 539.4 mm²  
Minimum steel required is 0.12% = 1440.00 mm²  
Providing tor 16 @ 125 mm C/C = 1608.495 mm² \( \text{SAFE} \)  

**Check for Shear:**

The slab is checked for shear at face of the support = 195.400 kN  
Tan of Angle between top and bottom edges of the heel slab = 0.233  
Design shear force considering the effect of slope of the slab = 172.695 kN  
Shear stress \( \tau = 0.157 \quad \text{N/mm}^2 \)  
100 As/bd = 0.146  
Permissible Shear stress in concrete with out shear steel = 0.188 N/mm²  
**Hence Shear Reinforcement is NOT required.**