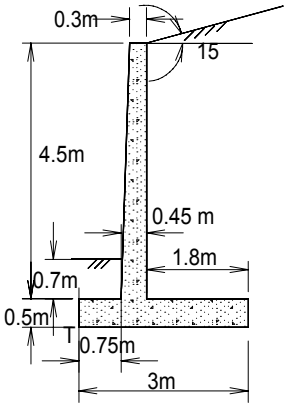
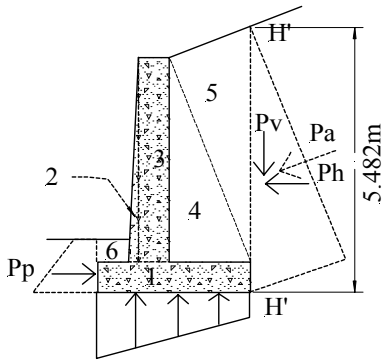
## Example 1

Check the retaining wall safety for overturning, sliding, and bearing capacity. Stem: top = 0.30 m, bottom = 0.45 m, length = 4.5 m. Base: thickness = 0.5 m, length = 3 m, front projection = 0.75 m, footing's bottom 1.2 m below ground, $\gamma_{conc} = 23.58$ kN/m$^3$. For underlying soil and soil in front of the wall use $\phi = 22°$, c = 50 kPa, and $\gamma = 19.3$ kN/m$^3$. Backfill $\phi = 30°$, c = 0, $\delta = 0.67\phi$, slope = 15°, and $\gamma = 18.5$ kN/m$^3$.

## Solution




Use 1m length of wall. Consider vertical plane HH'.
HH' = 5+1.8 tan 15 = 5.482 m




## Active forces

[1]$K_a = 0.373$

$$P_a = 18.5 \times 5.482^2 \frac{0.373}{2} = 103.7 \text{ kN}$$

$P_h = 103.7 \times \cos 15 = 100.2$ kN
$P_v = 103.7 \times \sin 15 = 26.8$ kN
Passive resistance
$K_p = 2.2, \quad \sqrt{K_p} = 1.48$
$P_p = 19.3 \times 1.2^2 \times 2.2 \div 2 + 2 \times 50 \times 1.2 \times 1.48 = 208.5$kN
Overturning

[1] *See tables in the book*

Resisting moments

| no | force kN | arm m | $M_R$ about C |
|---|---|---|---|
| 1 | 0.5×3×23.58=35.37 | 1.5 | 53.06 |
| 2 | 0.15×4.5×23.58×0.5=7.96 | 0.75+0.15×2/3 | 6.76 |
| 3 | 0.3×4.5×23.58 = 31.83 | 0.75+0.15+0.15 | 33.42 |
| 4 | 1.8×4.5×18.5×0.5 = 74.93 | 1.2+0.6 | 134.9 |
| 5 | 1.8×4.982×18.5×0.5 = 82.95 | 1.2+1.2 | 199 |
| 6 | 0.7×0.75×18.5 = 9.71 | 0.75/2 | 3.64 |
| $P_v$ | 26.83 | 3 | 80.49 |
| ΣV | 269.6 | $\Sigma M_R$ | 511.3 |

## Overturning moment

$M_0 = 100.2 \times 5.482 \div 3 = 183$ kN-m

FS = 511.3/183 = 2.8

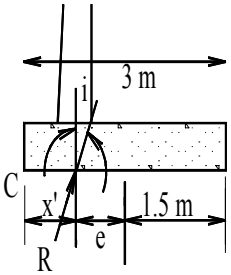
## Sliding resistance

$$FS = \frac{\text{horizontal resisting forces}}{\text{horizontal driving forces}} = \frac{\Sigma F_R}{\Sigma F_d} \geq 1.5$$

$\Sigma F_R = 269.6 \tan(22 \times 2/3) + 50 \times 3 + 208.5 = 429.0$

$$FS = \frac{429.0}{100.2} = 4.28 \geq 1.5$$ This includes passive resistance

## Base reaction




$$i = \tan^{-1}\frac{100.2}{269.6} = 20.38°$$

$$R = \sqrt{269.6^2 + 100.2^2} = 287.6 \text{ kN}$$

Take moment about [2] toe

$269.6 \times x' =$ [3] $\Sigma M_R - \Sigma M_o = 511.3 - 183 = 328.3$ kN-m

x' = 1.22 m

## Bearing capacity

e = 3/2 - 1.22 = 0.28 m

---

[2] *Note horizontal component of R has no moment about toe.*

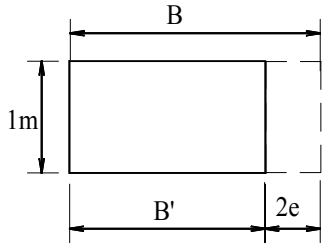
[3] *Net moment about toe*

[4] $q = \frac{\sum V}{A}\left(1 \pm \frac{6e}{B}\right)$

$$q_{max} = \frac{269.59}{1\times 3}\left(1 + \frac{6\times 0.28}{3}\right) = 140.2 \text{kPa}$$

$q_{min}$ = 35.5 kPa

B' = 3 - 2×0.28 = 2.44 m




$q_{ult} = cN_cF_{cs}\,F_{cd}\,F_{ci} + qN_qF_{qs}F_{qd}F_{qi} + 0.5\gamma BN_\gamma F_{\gamma s}F_{\gamma d}F_{\gamma i}$

For continuous footings shape factors = 1

$$F_{cd} = 1 + 0.4\frac{1.2}{3} = 1.16$$

$$F_{qd} = 1 + 2\tan 22(1 - \sin 22)^2\frac{1.2}{3} = 1.13$$

$F_{\gamma d} = 1$

$$F_{qi} = F_{ci} = \left(1 - \frac{20.37}{90}\right)^2 = 0.6$$

$$F_{\gamma i} = \left(1 - \frac{20.37}{22}\right)^2 = 0.01$$

$N_c$ = 16.88, $N_q$ = 7.82, $N_\gamma$ = 7.13

$q_{ult}$ = 50×16.88×1.16×0.6+1.2×18.5×7.82×1.13×0.6 + 0.5×19.3×2.44×7.13×0.01 = 706.7 kPa

$q_0$ (on reduced area) = 269.59/1×2.44 = 110.5 kPa

FS = 706.7/110.5= 6.4

FS against $q_{max}$ = 706.7/ 140.2 = 5

[4] *e≤B/6, else there will be tension on the base, which is not recommended*

## Semi-empirical Method

For wall heights 20' or less.

1. Determine H' as shown in [5]Figures.
2. Select the appropriate backfill soil type. If not known use type 5.
3. Pressure on wall is assumed to vary linearly with depth
4. $P_h = 0.5\ K_h H'^2$ $P_v = 0.5\ K_v H'^2$
5. For soil type 5 reduce H' by 4' to compute horizontal and vertical pressures. Resultant is assumed to act still at H'/3 above the base.
6. If wall is designed before backfill material is selected use the most unsuitable material or give alternate design.

## Walls on soft compressible layers

Wall settlement will reverse the direction of friction, and Pa will increase. For soils 1, 2, 3 and 5 multiply, Pa, by 1.5.

## Example 2

Use empirical method to determine active and passive forces for Example 1. Assume backfill Type 1

## Solution

$K_h = 5.5kPa$ $K_v = 1.5kPa$

$P_h = 0.5 \times 5.2 \times 5.482^2 = 78.14kPa$ (101.15kPa)

$P_v = 0.5 \times 1.5 \times 5.482^2 = 25.60kPa$ (26.83kPa)

[5] *7.4*