

**CANTILEVER RETAINING WALL
12 CONWAY GROVE, CASTLE PARK, MERTHYR TYDFIL
TYPE 1 WALL
STRUCTURAL CALCULATIONS TO BS 8110**

Data:

Maximum height of wall = 2.0 m

Density of earth = 19 kN/m³ Well drained cohesionless.

Angle of shearing resistance $\Phi = 30^\circ$

horizontal component

$$k_a = \frac{1 - \sin \Phi}{1 + \sin \Phi}$$

$$k_a = \frac{1 - \sin 30}{1 + \sin 30} = 0.27$$

$$k_a = \frac{1 - 0.5}{1 + 0.5} = \frac{1}{3}$$

Co-efficient of friction between base and earth = 0.4

Safe ground bearing capacity = 100 kN/m²

Wall to be built of reinforced concrete 0.300 m thick = 24 kN/m³

Introduce free draining material to rear of wall.

Active pressure (p_a) = $k_a p_h = \frac{1}{3} \times 19 \times 3.000 = 19.000 \text{ kN/m}^2$

Allow for surcharge 10.0 kN / m²

SLIDING

Consider the forces acting on a 1m length of wall. Horizontal force on wall due to backfill.

$F_a = 0.5 p_a h = 0.5 \times 19.000 \times 2.00 = 19.00 \text{ kN}$ and

Weight of wall (W_{wall}) = $0.30 \times 2.00 \times 24 = 14.40 \text{ kN}$

Weight of base (W_{base}) = $0.30 \times 2.30 \times 24 = 16.56 \text{ kN}$

Weight of toe (W_{toe}) = $0.30 \times 0.50 \times 24 = 3.60 \text{ kN}$

Weight of soils1 (W_{soils1}) = $0.20 \times 1.50 \times 19 = 4.56 \text{ kN}$

Weight of soils2 (W_{soils2}) = $0.50 \times 2.00 \times 19 = 19.00 \text{ kN}$

Surcharge $10 \times 0.5 = 5.0 \text{ kN}$

Total vertical force (W_t) = 63.12 kN

Friction force (F_f) is

$$F_f = \mu W_t = 0.4 \times 63.12 = 25.25 \text{ kN}$$

Passive pressure force (F_p) = $\frac{1}{3} \times 0.8 \times 19 = 5.07 \text{ kN}$

Net horizontal pressure (F_n) = $19.0 - 5.07 \text{ kN} = 13.93 \text{ kN}$

Hence factor of safety against sliding is $F_f / F_n = 25.25 / 13.93 = 1.81 > 1.5 \therefore$ o.k.

OVERTURNING

Taking moments about point A (see above) sum of overturning moments (M over) is

$$\frac{F_a \times 2.0}{3} = \frac{19.00 \times 2.0}{3} = 12.67 \text{ kNm}$$

Sum of restoring moments (M res) is

$$M_{\text{res}} = W_{\text{wall}} \times 1.65 + W_{\text{base}} \times 1.15 + W_{\text{soil1}} \times 0.75 + W_{\text{soil2}} \times 2.05 + W_{\text{surcharge}} \times 2.05$$

$$= 14.40 \times 1.65 + 16.56 \times 1.15 + 4.56 \times 0.75 + 19.0 \times 2.05 + 5.0 \times 2.05$$

$$= 23.76 + 19.04 + 3.42 + 38.95 + 10.25$$

$$= 95.42$$

Factor of safety against overturning is

$$\frac{95.42}{12.67} = 7.53 > 2 \therefore \text{O.K.}$$

GROUND BEARING PRESSURE

Moment about centreline of base (M) is

$$M = \frac{F_a \times 2.00}{3} + W_{\text{soil1}} \times 0.40 - W_{\text{soil2}} \times 0.9 - W_{\text{wall}} \times 0.50 - W_{\text{surcharge}} \times 0.9$$

$$= \frac{19.00 \times 2.000}{3} + 4.56 \times 0.40 - 19.00 \times 0.90 - 14.40 \times 0.5 - 5 \times 0.9$$

$$= 12.67 + 1.82 - 17.10 - 7.2 - 4.5$$

$$= -14.31$$

$$N (Wt) = 63.12$$

$$\frac{M}{N} = \frac{-14.31}{63.12} = -0.226 < \frac{D}{6} = \frac{2.5}{6} = 0.416$$

Therefore the maximum ground pressure occurs at the heel which is given by

$$P_{\text{heel}} = \frac{63.12}{2} + \frac{4 \times 14.31}{2^2} = 31.56 + 14.31$$

$$= 45.87 \text{ kNm}^2 < \text{allowable } 100 \text{ kNm}^2$$

Ground Bearing pressure at the heel p heel is

$$P_{\text{heel}} = \frac{63.12}{2} + \frac{4 \times 14.31}{2^2} = 31.56 - 14.31$$

$$= 17.25 \text{ kNm}^2 < \text{allowable } 100 \text{ kNm}^2$$

BENDING REINFORCEMENT

Wall

Height of stem of wall = 2.0 m. Horizontal force on stem due to backfill F_s is

$$F_s = 0.5 k_a p h^2$$

$$= 0.5 \times \frac{1}{3} \times 19 \times 2.0^2$$

$$= 12.67$$

Design moment at base of wall M is

$$M = \frac{\gamma F_s h}{3} = \frac{1.4 \times 12.67 \times 2.0}{3} = 11.83 \text{ kNm}$$

Effective Depth

Assume diameter of main steel $\Phi = 20\text{mm}$

Hence effective depth d is

$$d = 300 - \text{cover} - (\Phi)/2 = 300 - 30 - 10 = 260$$

Ultimate moment of resistance

$$M_u = 0.156 \times f_{cu} \times b d^2 = 0.156 \times 30 \times 10^3 \times 260^2 \times 10^{-6} = 73.008$$

Since $M_u > M$ no compression reinforcement needed

Steel Area

$$K = \frac{M}{f_{cu} b d^2} = \frac{11.83 \times 10^6}{30 \times 10^3 \times 260^2} = 0.0077$$

$$z = d(0.55 + \sqrt{0.25 - K/0.9})$$

$$= 260(0.5 + \sqrt{0.25 - 0.0077/0.9}) = 260(0.5 + 0.518) = 264.91$$

$$A_s = \frac{M}{0.87 f_y z} = \frac{11.83 \times 10^6}{0.87 \times 500 \times 264.918} = 102.66$$

Apply additional factor of safety of 2.0 = 205.32

Hence from table 3.22 provide T12 at 200mm centres ($A_s = 566\text{mm}^2/\text{m}$) in rear face (RF) of wall.

Steel is also required in the front face (FF) of wall in order to prevent excessive cracking. This is therefore based on the minimum steel area i.e.

$$= 0.13\% b h = 0.13\% \times 10^3 \times 300 = 390 \text{ mm}^2 / \text{m}$$

Hence provide H12 at 200mm centres ($A_s = 566\text{mm}^2$)

Base

All loads factored by 1.4

Design moment about base of wall stem $M =$

$$\frac{1.4 \times 18.0 \times 2.1}{2} + \frac{1.4 \times 19.0 \times 2.1^2}{4} - \frac{1.4 \times 21.6 \times 2.1^2}{2}$$
$$= 26.46 + 29.33 - 66.68 = -10.889$$

Steel Area

Assume diameter of main steel $\Phi = 20\text{mm}$

Hence effective depth d is

$$d = 300 - \text{cover} - (\Phi)/2 = 300 - 30 - 10 = 260$$

$$K = \frac{M}{f_{cu} b d^2} = \frac{6.939 \times 10^6}{30 \times 10^3 \times 260^2} = 0.0063$$

$$z = d(0.55 + \sqrt{(0.25 - K)/(0.9)})$$

$$= 260 (0.5 + \sqrt{(0.25 - 0.0063 / 0.9)}) = 260 (0.5 + 0.493) = 238.32$$

$$A_s = \frac{M}{0.87 f_y z} = \frac{10.889 \times 10^6}{0.87 \times 500 \times 238.32} = 220.97$$

$$\text{Apply factor of safety of 2.0} = 441.95$$

Hence from Table 3.22, provide H12 at 200 mm centres ($A_s = 566 \text{ mm}^2/\text{m}$) at bottom (B) of base.

Distribution steel H12-200 H12-200 (B)

Toe Design moment at point B, M_B , is given by

$$M_B \text{ kNm} = \frac{162.4 \times 0.7^2}{2} - \frac{0.7 \times 384 \times 14 \times 0.7}{42} = 365$$

$$A_s = 365 \text{ mm}^2 / \text{m} < \text{minimum steel area} = 520 \text{ mm}^2 / \text{m}$$

Hence provide H12 at 200 mm centres ($A_s = 566 \text{ mm}^2 / \text{m}$), at top (T) of base and as distribution steel in base and stem of wall.

REINFORCEMENT DETAILS

The additional sketch and bending schedule provided shows the main reinforcement requirements for the retaining wall.

For reasons of buildability the actual reinforcement details may well be slightly different.