Then flexural compressive stress, $f_{ubc}$

$= (49.1 \times 10^3)/(0.23 \times 10^6)$
$+ (3.085 \times 10^6)/(38.0 \times 10^6)$
$= 0.213 + 0.081$
$= +0.294$ N/mm$^2$

and flexural tensile stress, $f_{ubt}$

$= +0.213 - 0.081$
$= +0.132$ N/mm$^2$, i.e. compressive

Thus compressive stress covers the full width of the section, as shown in Figure 42.

The maximum stress is within the previously calculated allowable value.

*'Dead + superimposed'*
A check should also be made on the overall stability of the wall and the associated maximum axial compressive stresses.

*Design loads*

Dead + superimposed $= 1.4\,G_k + 1.60Q_k$

Roof dead load $= 1.4 \times 0.65 = 0.91$ kN/m$^2$

Roof superimposed load $= 1.6 \times 0.75 = 1.20$ kN/m$^2$

Self-weight of masonry per metre height
$= 1.4 \times 0.23 \times 20 = 6.44$ kN/m

Total design axial load (at base of wall)

| | | |
|---|---|---|
| roof dead load | $= 0.91 \times 40/2$ | $= 18.20$ |
| roof superimposed load | $= 1.20 \times 40/2$ | $= 24.00$ |
| self-weight of masonry | $= 6.44 \times 7.5$ | $= 48.30$ |
| | Total | $= 90.50$ kN/m |

Total design axial load (at midheight of wall)

| | | |
|---|---|---|
| roof dead + superimposed load | $= 18.2 + 24.0$ | $= 42.40$ |
| self-weight of masonry | $= 6.44 \times 3.75$ | $= 24.15$ |
| | Total | $= 66.55$ kN/m |

*Capacity reduction factor*
Eccentricity of loading, $e_x = 0$

Slenderness ratio, $SR$
= effective height/effective thickness
$= 0.75 \times 7.5/0.55$
$= 10.23$

Then, from BS 5628 : Part 1, Table 7 with $e_x = 0$ and $SR = 10.23$
$\beta = 0.965$ (by interpolation)

Therefore, design vertical load resistance
$= \beta \times \text{area} \times f_k/\gamma_m$
$= 0.965 \times 0.23 \times 6.4 \times 10^3/3.5$
$= 406$ kN/m

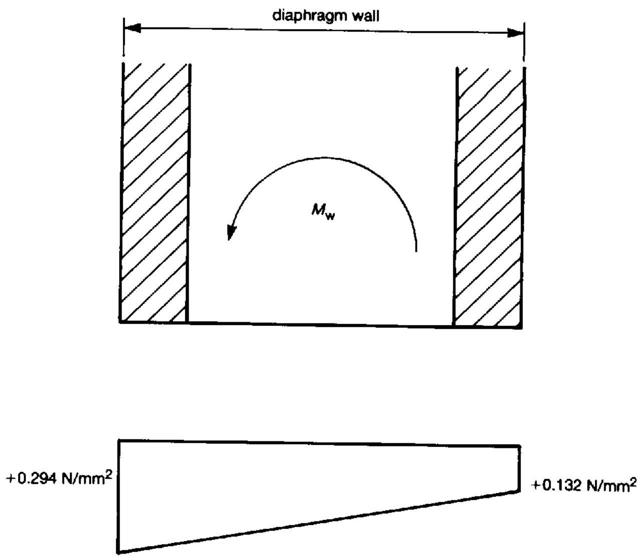


Figure 42: Stress distribution

This exceeds the total design axial load calculated at 66.35 kN/m and demonstrates that in practice it is usual for only the dead + wind load combination to be designed.

Maximum axial compressive stress (at base of wall)
$= (66.55 \times 10^3)/(0.23 \times 10^6)$
$= 0.288$ N/mm$^2$

Maximum allowable axial compressive stress (i.e. with no slenderness reduction)
$= 6.4/3.5$
$= 1.83$ N/mm$^2$

**Worked example 2: Retaining wall in unreinforced masonry (uncracked section)**
A retaining wall is required to support a non-cohesive granular fill to a height of 1.5 m. The surface of the fill is level as shown in Figure 43 and for this example there are no requirements for surcharge loading. A dpc consisting of two courses of slate bedded in mortar is to be used. The design stages are varied from the previous example to meet the special requirements of the problem.

***Stage 1. Calculate lateral loading, overturning moment and shear***
Lateral earth pressure $= K_a \rho h$

where $K_a$ is coefficient of active earth pressure and $\rho$ is bulk density of soil

Design lateral earth pressure $= \gamma_f K_a h$

$\gamma_f = 1.6$

$$K_a = \frac{1 - \sin\theta}{1 + \sin\theta} = 0.27$$

$\rho = 15$ kN/m$^3$

Consider 1 m length of wall

Design lateral earth pressure at base
$= 1.6 \times 0.27 \times 15 \times 1.5$
$= 9.72$ kN/m$^2$

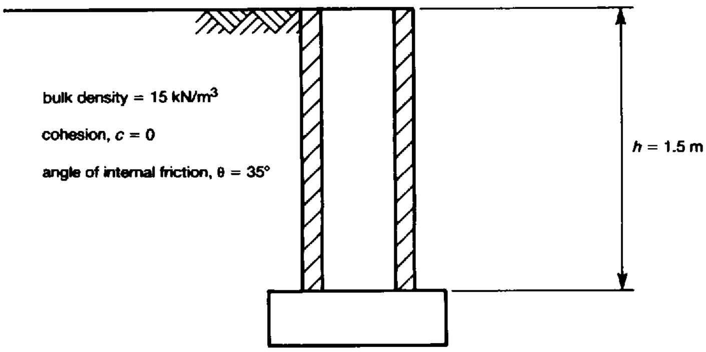


Figure 43: Worked Example 2 - retaining wall

Design shear at base, $V = 9.72 \times 1.5/2$
$= 7.29$ kN

Design moment at base, $M = 7.29 \times 1.5/3$
$= 3.65$ kNm

***Stage 2. Choose unit strength, unit size and mortar grade***

Assume solid concrete blocks are used with a material density of 20 kN/m$^3$ and a compressive strength of 7 N/mm$^2$. The face size of the blocks to be used is 440 x 215 x 100 mm. The blocks are laid in mortar designation (iii). The blocks are to be manufactured with special category control of manufacture. Materials testing and full time site supervision of workmanship will be undertaken.

***Stage 3. Calculate section modulus and select trial section***

A slate dpc is to be used. This must be mortar bedded and the construction will be fully supervised, enabling flexural tensile stress to be considered at the base.

From BS 5628, Table 3, the characteristic flexural strength ($f_{kx}$) of concrete blocks of 7 N/mm$^2$ in mortar designation (iii) with the plane of failure parallel to the bed joints is 0.25 N/mm$^2$.

From BS 5628, Table 4, the partial safety factor on material strength with 'special/special' quality control $\gamma_m = 2.5$.

Design flexural strength $= f_{kx}/\gamma_m = 0.25/2.5$
$= 0.1$ N/mm$^2$

Where tensile stress can be developed the stress diagram at the base will be as shown in Figure 44.

Stress due to the self-weight of the wall $P/A$
$= \gamma_f \rho h A/A$
$= 0.9 \times 20 \times 1.5 \times A \times 10^3/(A \times 10^6)$
$= 0.027$ N/mm$^2$

To ensure that the design flexural strength is not exceeded

$P/A - M/Z = f_{kx}/\gamma_m$

$Z$ required $= 3.65 \times 10^6/0.127$
$= 0.029 \times 10^9$
$= 29 \times 10^{-3}$ m$^3$ per m length

From Table 1, Section D provides the $Z$ required so this section will check.

***Stage 4. Check maximum rib spacing***

With the increased lateral loading on the flange in a retaining wall the ability of the flange to span between ribs generally governs the rib spacing.

At the base of the wall the lowest section of flange will span two ways (see Figure 45). This is taken into account to provide the maximum economy of design.

Design pressure at base
$= 9.72$ kN/m$^2$

Design pressure at 315 mm above base
$= 1.6 \times 0.27 \times 15 \times (1.5 - 0.315)$
$= 7.68$ kN/m$^2$

Average design pressure on triangular base
$= (9.72 + 7.68)/2$
$= 8.7$ kN/m$^2$

Total design load on triangle $= 8.7 \times 0.63 \times 0.315/2$
$= 0.86$ kN

Design moment at base $= 0.86 \times 0.315/3$
$= 0.09$ kNm

Design stress, $M/Z = 0.09 \times 10^6 \times 6/(630 \times 100^2)$
$= 0.086$ N/mm$^2$

Design flexural strength parallel to bed joint
$= f_{kx,par}/\gamma_m = 0.1$ N/mm$^2$

i.e. $M/Z = f_{kx,par}/\gamma_m$

Design bending moment on plane perpendicular to bed joint
$= \gamma_f W b_d^2/10$

Consider 1 m height of wall

Design loading, $\gamma_f W =$ design pressure $= 7.68$ kN/m

Design moment $= 7.68 \times 0.73^2/10$
$= 0.41$ kN/m height

Design stress perpendicular to bed joints
$M/Z = 0.41 \times 10^6 \times 6/(10^3 \times 100^2)$
$= 0.246$ N/mm$^2$

Design flexural strength perpendicular to bed joints
$= f_{kx}/\gamma_m$
$= 0.6/2.5$
$= 0.24$ N/mm$^2$

Acceptable, as the loading reduces with height.

***Stage 5. Check horizontal applied shear stress***

Horizontal design shear force, $V = 7.29$ kN per m length

Shear force per diaphragm $= 7.29 \times 0.73$
$= 5.32$ kN

Horizontal shear stress, $v_h = VA_z\bar{y}/IB_r$

$A_z$ (see Figure 40) $= (0.73 \times 0.1) + (0.1 \times 0.35)/2$
$= 0.0905$ m$^2$

$$\bar{y} = \frac{0.73 \times 0.1\,(0.35/2 + 0.1/2) \times (0.1 \times 0.35/2 \times 0.35/4)}{0.0905}$$
$= 0.198$ m

From Table 1, $I = 7.87 \times 10^{-3}$ m$^4$

$$v_h = \frac{5.32 \times 10^{-3} \times 0.0905 \times 10^6 \times 0.198 \times 10^{-3}}{7.87 \times 10^{-3} \times 10^{12} \times 100}$$
$= 0.121$ N/mm$^2$