Masonry Design

Masonry construction uses modular units:

- Brickwork (kiln dried clay bricks) – mainly for facades;
- Blockwork (concrete blocks) – mainly for structural use;
- Stonework (eg. stone arch bridges - not covered here) – usually ornamental.

Its form of construction may be:

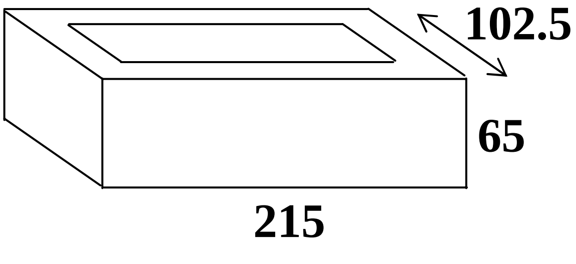
- Unreinforced – the usual case;
- Reinforced – very useful for garden walls and piers;
- Prestressed – unusual, see Peter Rice's Pavilion of the Future in Seville.

We will consider the structural design of unreinforced brick- and block-work.

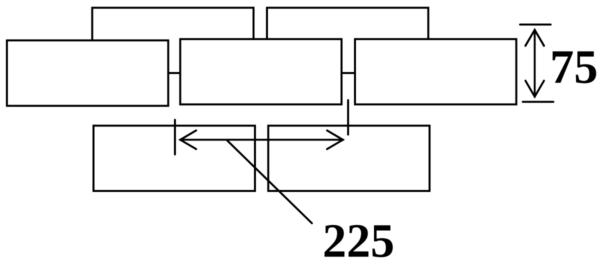
Bricks

Mostly governed by aesthetic requirements; not normally structural.

- made of clay and kiln dried (hence they expand with moisture);
- very light and strong.



Standard brick size



Format size

Brick Varieties

i. Common (for general building work)

ii. Facing - specially made for their appearance

iii. 'Engineering' - very dense and strong + defined absorption and strength limits

Blocks

The main structural element in masonry.

- Larger than bricks;
- Made from (lean) concrete - wet process (hence they shrink);
- Resistant to moisture.

A larger range of sizes is available, but it is usual in Ireland touse only the 215×100×440 solid block and the 215×215×440 hollow block.

'Work size' = size of block

'Co-ordinating size' = size of block + mortar (corresponds to format size in bricks).

Mortar joints are nominally 10 mm.

Movement joints

Used to allow for local effects of temperature and moisture content.

Material	**Spacing**
Clay bricks	On plan: up to 12 m c/c (6 m from corners); Vertically: 9 m or every 3 storeys if h > 12 m or 4 storeys
Concrete blocks	3 m – 7 m c/c

Masonry Design – Basis

Firstly, it is important to note that Irish masonry construction practice differs significantly from British practice and the Irish masonry design standard IS 325: Part 1: *Code of Practice for the Use of Masonry* is to be considered the superior design code and is recognized as such in the Irish Building Regulations, TGD A.

Partial Factors of Safety for design loads, γ_f, are:

a) Dead and imposed load

i) design dead load = 0.9 G_k or 1.4 G_k

ii) design imposed load = 1.6 Q_k

iii) design worst credible earth and water lateral load = 1.2 E_u

b) Dead and wind load

i) design dead load = 0.9 G_k or 1.4 G_k

ii) design wind load = 1.4 W_k

iii) design worst credible earth and water lateral load = 1.2 E_u

c) Dead, imposed and wind load

i) design dead load = 1.2 G_k

ii) design imposed load = 1.2 Q_k

iii) design wind load = 1.2 W_k

iv) design worst credible earth and water lateral load = 1.2 E_u

The partial factors of safety for material, γ_m, is given by the following:

Table 4. Partial safety factors for material strength, γ_m

		Category of construction control	
		Special	Normal
Category of manufacturing control of structural units	Special	2.5	3.1
	Normal	2.8	3.5

Characteristic Strength of Masonry, f_k

The characteristic strength is found from Table 2 of I.S. 325 – next two pages.

This table requires:

1. the shape factor for the unit as laid, given by:

$$\text{shape factor} = \frac{\text{height as laid}}{\text{thickness as laid}}$$

   The shape factors for usual cases are:

   a) Block on flat: (215×100×440) – **0.47**;

   b) Block on edge: (100×215×440) – **2.15**;

   c) Hollow block: (215×215×440) – **1.0**.

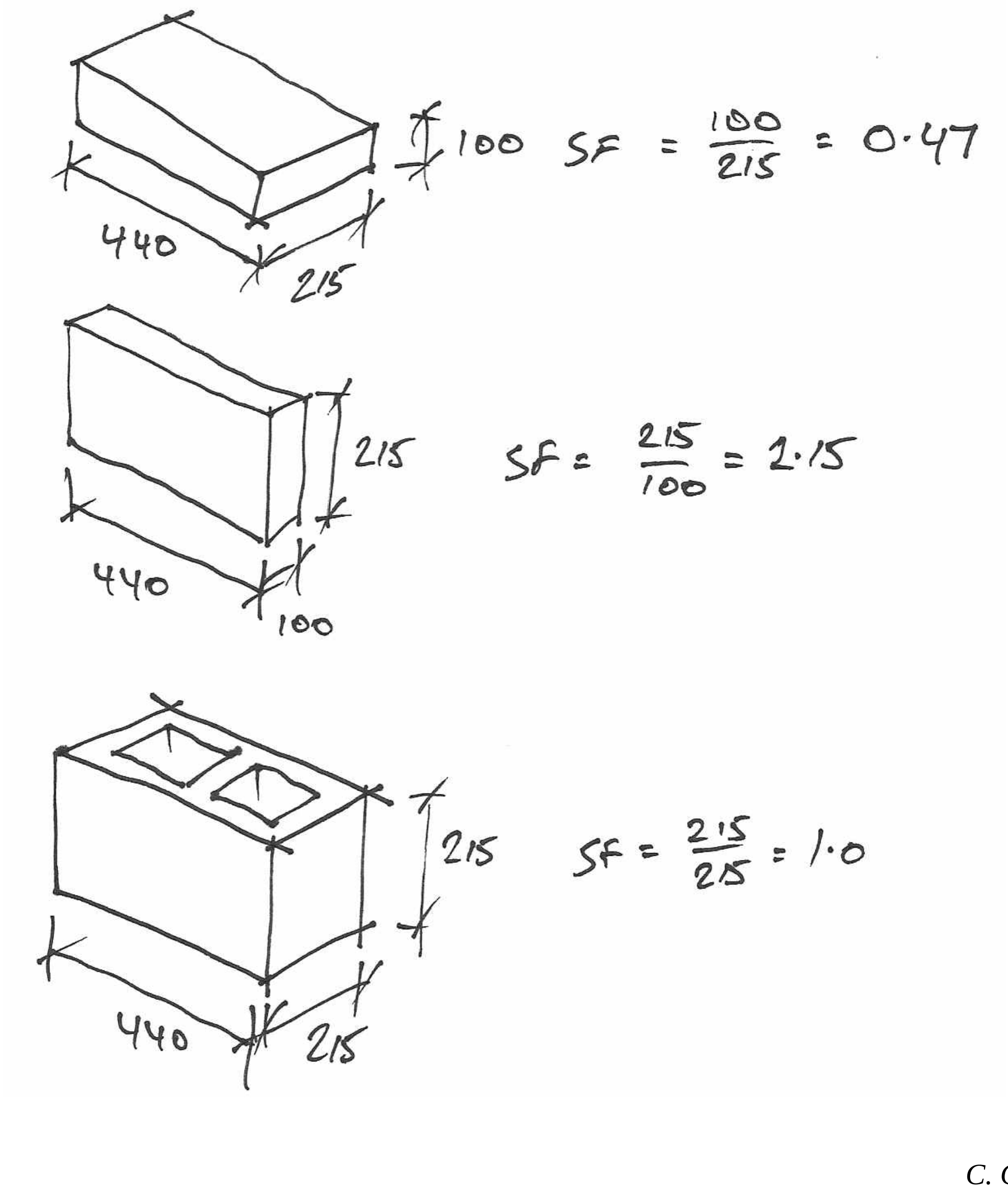


Table 2. Characteristic compressive strength of masonry, f_k, in MPa.

(a) Constructed with standard format bricks

Mortar designation	Compressive strength of brick determined as shown in relevant I.S. MPa								
	5	10	15	20	27.5	35	50	70	100
(i)	2.5	4.4	6.0	7.4	9.2	11.4	15.0	19.2	24.0
(ii)	2.5	4.2	5.3	6.4	7.9	9.4	12.2	15.1	18.2
(iii)	2.5	4.1	5.0	5.8	7.1	8.5	10.6	13.1	15.5
(iv)	2.2	3.5	4.4	5.2	6.2	7.3	9.0	10.8	12.7

(b) Constructed with hollow blocks having an aspect ratio of 1.0.

Mortar designation	Compressive strength of block determined on edge per I.S. 20 MPa					
	3.0	5.0	7.0	10	15	20
(i)	1.9	3.2	4.1	4.9	6.2	7.4
(ii)	1.9	3.2	3.9	4.6	5.5	6.4
(iii)	1.9	3.2	3.8	4.5	5.2	5.8
(iv)	1.9	2.8	3.4	3.9	4.6	5.2

(c) Constructed with hollow blocks having an aspect ratio of between 2.0 and 4.0.

Mortar designation	Compressive strength of block determined on edge per I.S. 20 MPa					
	3.0	5.0	7.0	10	15	20
(i)	3.0	5.0	5.7	6.1	6.8	7.5
(ii)	3.0	5.0	5.5	5.7	6.1	6.5
(iii)	3.0	5.0	5.4	5.5	5.7	5.9
(iv)	3.0	4.4	4.8	4.9	5.1	5.3

(d) Constructed with solid blocks having an aspect ratio of 1.0.

Mortar designation	Compressive strength of block determined on edge per I.S. 20 MPa					
	5	7	10	15	20	30 or greater
(i)	3.2	4.4	5.7	7.7	9.5	12.9
(ii)	3.2	4.1	5.4	6.8	8.2	10.8
(iii)	3.1	4.1	5.3	6.4	7.5	9.8
(iv)	2.8	3.6	4.5	5.7	6.7	8.5

(e) Constructed from solid concrete blocks having an aspect ratio of between 2.0 and 4.0.

Mortar designation	Compressive strength of block determined on edge per I.S. 20 MPa					
	5	7	10	15	20	30 or greater
(i)	5.0	6.8	8.8	12.0	14.8	20.2
(ii)	5.0	6.4	8.4	10.6	12.8	16.8
(iii)	5.0	6.4	8.2	10.0	11.6	15.2
(iv)	4.4	5.6	7.0	8.8	10.4	13.2

(f) Constructed from solid concrete blocks having an aspect ratio of between 0.4 and 0.5.

Mortar designation	Compressive strength of block determined on edge per I.S. 20 MPa					
	5	7	10	15	20	30 or greater
(i)	3.9	5.0	6.6	8.5	10.4	12.8
(ii)	3.7	4.6	5.8	7.3	8.7	10.6
(iii)	3.6	4.5	5.4	6.6	7.9	9.6
(iv)	3.1	3.9	4.8	5.9	6.9	8.2

2. The appropriate mortar designation: usually taken as (iii):

Table 1. Requirements for mortar

		Mortar designation	Type of mortar (proportion by volume)			Mean compressive strength at 28 days	
			Cement : lime : sand	Masonry cement : sand	Cement : sand with plasticizer	Preliminary (laboratory) tests	Site tests
↑ Increasing strength	Increasing ability to accommodate movement, e.g. due to settlement, temperature and moisture changes ↓					MPa	MPa
		(i)	1 : 0 to ¼ : 3	—	—	16.0	11.0
		(ii)	1 : ½ : 4 to 4½	1 : 2½ to 3½	1 : 3 to 4	6.5	4.5
		(iii)	1 : 1 : 5 to 6	1 : 4 to 5	1 : 5 to 6	3.6	2.5
		(iv)	1 : 2 : 8 to 9	1 : 5½ to 6½	1 : 7 to 8	1.5	1.0
Direction of change in properties is shown by the arrows			Increasing resistance to frost attack during construction → ← Improvement in bond and consequent resistance to rain penetration				

From these tables we derive a "quick-use" table for f_k in N/mm^2 assuming Mortar Designation (iii):

Designation (N/mm^2)	**Solid Block**		**Hollow Block (SF = 1.0)**
	On edge (SF = 2.15)	**On flat (SF = 0.47)**	
5 (grey)	5.0	3.6	3.2
10 (red)	8.2	5.4	4.5
15 (green)	10	6.6	5.2
20 (black)	11.6	7.9	5.8

The colours of the blocks are used to identify different strength blocks on site.

Masonry Design – Axial Capacity

The axial capacity is given by the equation:

$$N = \beta \cdot \frac{f_k t b}{\gamma_m}$$

- b is the length, normally taken per metre, so $b = 1000 \text{ mm}$;
- t is the thickness of the load-bearing leaf;
- f_k is the characteristic compressive strength of masonry.
- γ_m is the partial factor of safety for material:

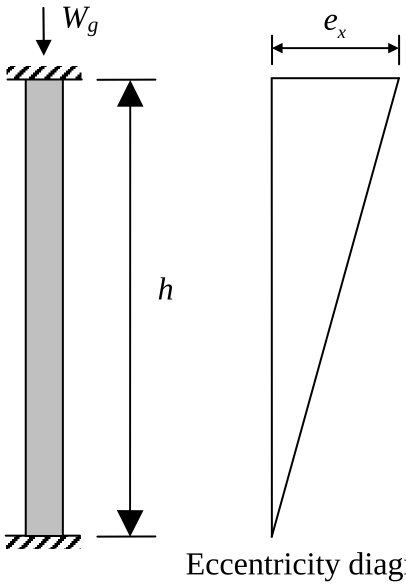
  Unless in exceptional circumstances, $\gamma_m = 3.5$.
- β is the capacity reduction factor:

$$\beta = 1.1\left[1 - 2 \cdot \frac{e_m}{t}\right]$$

  where $\frac{e_m}{t}$ is the maximum eccentricity ratio of the wall which is a function of
  - $\frac{e_x}{t}$ – the eccentricity ratio due to gravity loads;
  - $\frac{e_w}{t}$ – the eccentricity ratio due to wind/lateral loads;
  - $\frac{e_a}{t}$ – the additional eccentricity ratio due to slenderness effects.

The eccentricities are the most awkward inputs to calculate and are explained in the following.

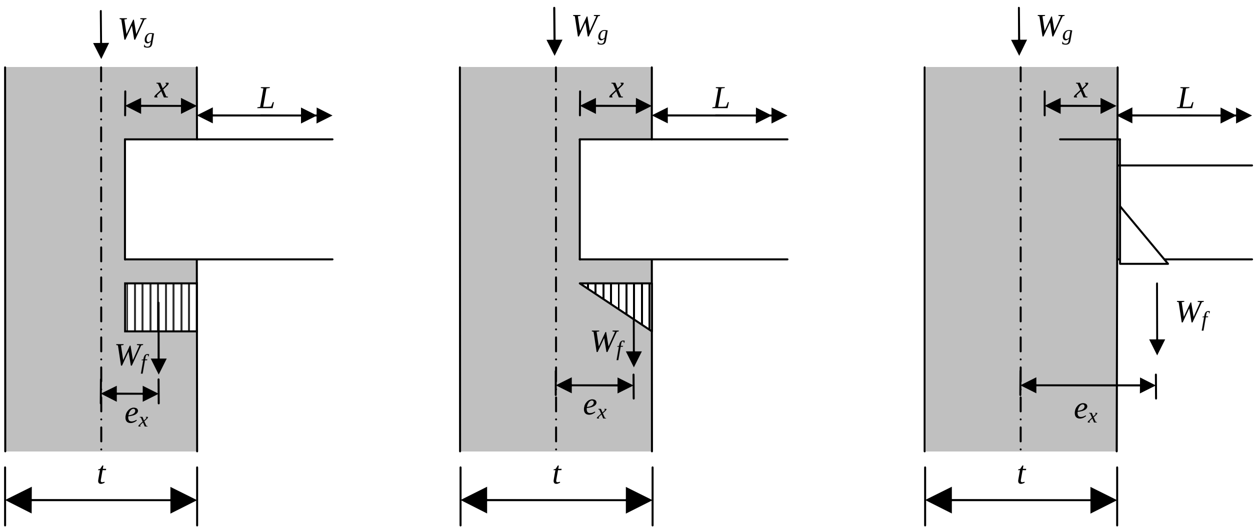
$\frac{e_x}{t}$ – Eccentricity due to gravity loads



Eccentricity diagram

Eccentricity of gravity loads depends on the way the load is delivered to the wall. We assume that the introduced eccentricity vanishes at the bottom, giving an eccentricity distribution diagram.

The different types of construction give different eccentricities as:



Case (a) Case (b) Case (c)

Case (a): Occurs if the floor is concrete and $\frac{L}{t} \leq 30$. The eccentricity is:

$$e_x = \frac{t}{2} - \frac{x}{2}$$

Case (b): Most cases besides (a) and (c); the eccentricity is:

$$e_x = \frac{t}{2} - \frac{x}{3}$$

Case (c): Joist hangers and the like; the eccentricity is taken as:

$$e_x = \frac{t}{2} + 25 \text{ mm}$$

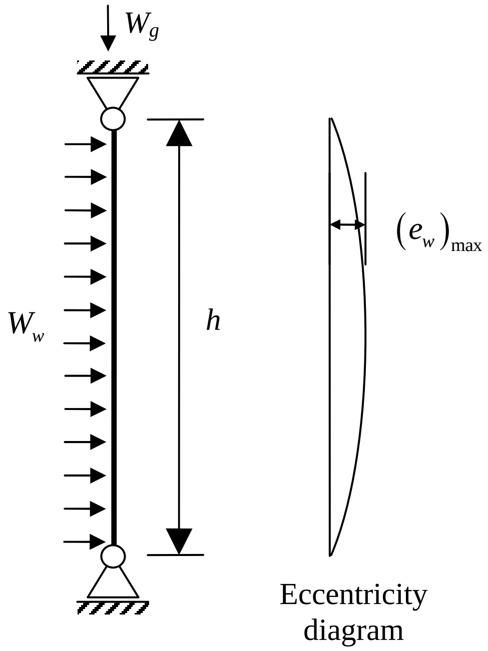
If there are loads from above; $W_g > 0$, then the net eccentricity of both the loads from above (W_g) and the loads from the current floor (W_f) is:

$$e_x = \frac{W_f \cdot e}{W_g + W_f}$$

and if other floors frame in at this level, we have in general $e_x = \frac{M_{net}}{\sum W}$.

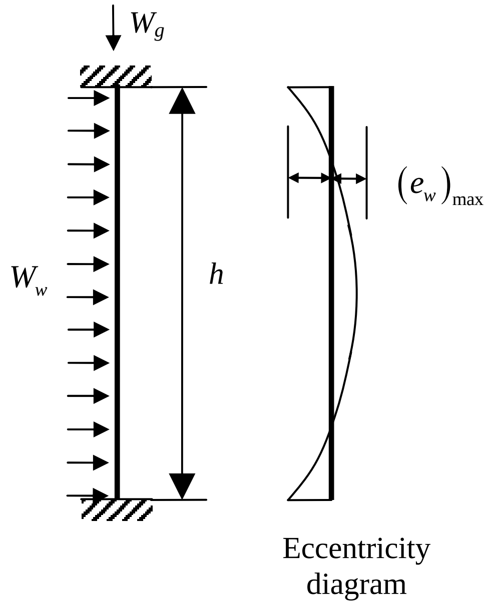
Having calculated e_x we change back to an eccentricity ratio, $\frac{e_x}{t}$.

$\frac{e_w}{t}$ – Eccentricity due to wind loads



Simply Supported

$$M_w = \frac{W_w h^2}{8}$$



Fixed Ends

$$M_w = \frac{W_w h^2}{16}$$

The eccentricity and bending moment are related as:

$$e_w = \frac{M_w}{W_g}$$

Having calculated e_w we change back to an eccentricity ratio, $\frac{e_w}{t}$.

Note that simply-supported is usually conservative.

For cases in between simple and fixed supports, we define the degree of fixity as:

$$\phi = \frac{g_d}{f_k / \gamma_m}$$

where g_d is the design vertical stress based on the $0.9G_k$ load case. Based, on ϕ we can interpolate between the simple and fixed cases.

If $\phi > 1$ the wall is fully restrained.

$\frac{e_a}{t}$ – Additional eccentricity due to slenderness

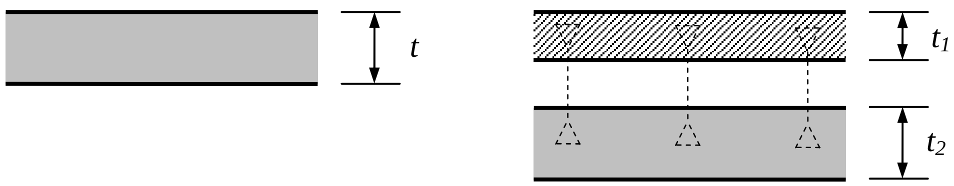
This is given by:

$$\frac{e_a}{t} = \frac{\lambda^2}{2400} - 0.015$$

in which λ is the Slenderness Ratio (SR), and:

$$\lambda = \frac{h_{ef}}{t_{ef}} \leq 27$$

- Effective thickness, t_{ef} :



$$t_{ef} = t \qquad\qquad t_{ef} = \max \begin{cases} \frac{2}{3}(t_1 + t_2) \\ t_1 \\ t_2 \end{cases}$$

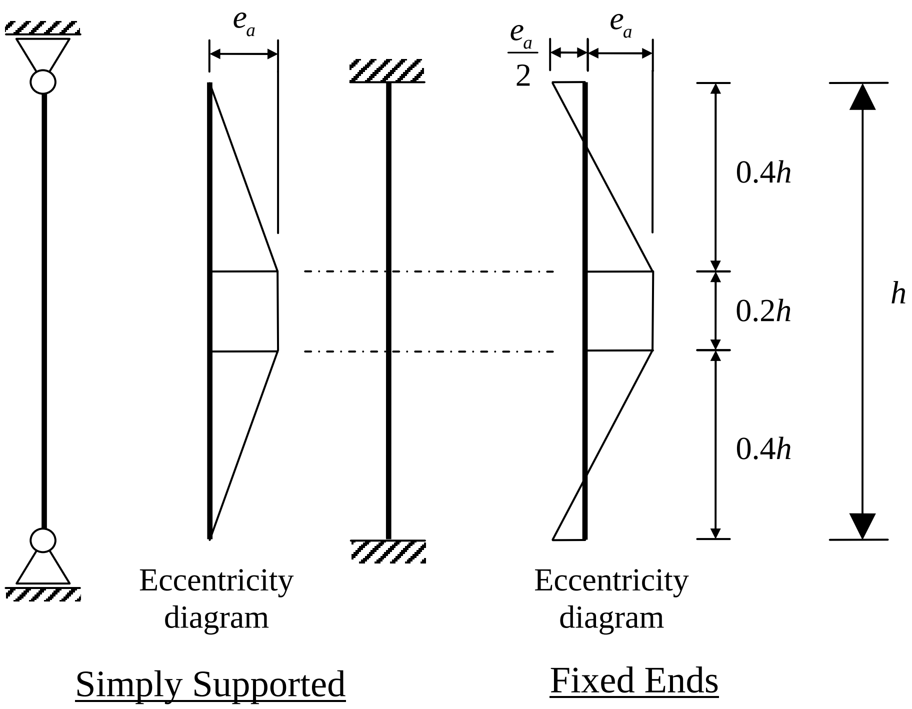
There are more considerations for the effective thickness, such as piers, which we are not examining.

- Effective height, h_{ef} :

There are two cases:

1. Enhanced Restraint, where $h_{ef} = 0.75h$:
    a. The floor passes over the top of the wall;
    b. The floor is a concrete floor and has a bearing length $> t/2$.
2. All other cases, where $h_{ef} = h$.

Once again, there is an assumed distribution of e_a over the height of the wall.



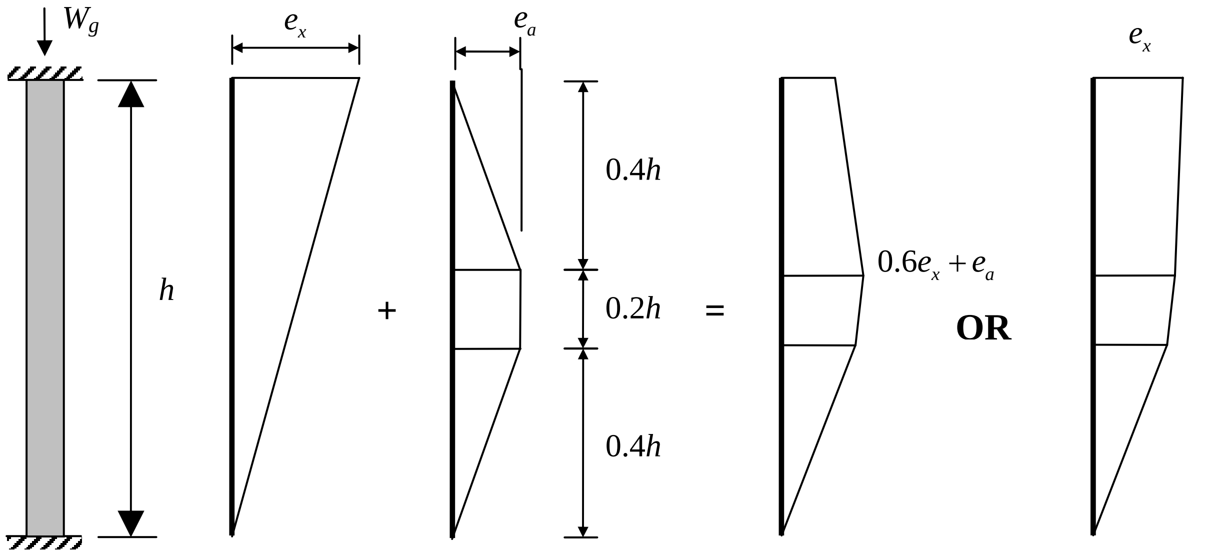
These diagrams can be thought of as inaccuracies in construction. For example, the wall goes most out of plumb in the middle, where it is furthest from its supports.

Interpolation for intermediate degrees of fixity is used for other restraint conditions.

$\frac{e_m}{t}$ – Total eccentricity

The total eccentricity is determined by adding together the eccentricity diagrams.

Ignoring the wind load for the moment, we have, for example:



Hence, the total eccentricity is calculated as:

$$\frac{e_m}{t} = \max\begin{cases} \dfrac{e_x}{t} \\ 0.6\dfrac{e_x}{t} + \dfrac{e_w}{t} + \dfrac{e_a}{t} \end{cases}$$

This is so as wind eccentricity at the top of the wall is beneficial, whereas the wind eccentricity at 0.6h is not. Usually, for simplicity, the maximum wind eccentricity at mid span is added to the $0.6e_x + e_a$ value. The support wind eccentricity (if any) is also taken into account.

Remember! It is usually ok to assume that the governing case is when the wind is blowing, but this may not always be the case. We'll see in an example.

Capacity Reduction Factor

The total eccentricity determined above is used in the expression for the capacity reduction factor:

$$\beta = 1.1\left[1 - 2\cdot\frac{e_m}{t}\right]$$

Often there is no wind load present and this simplifies the calculation as once $\frac{e_x}{t}$ has been calculated, the following table may be used to determine β:

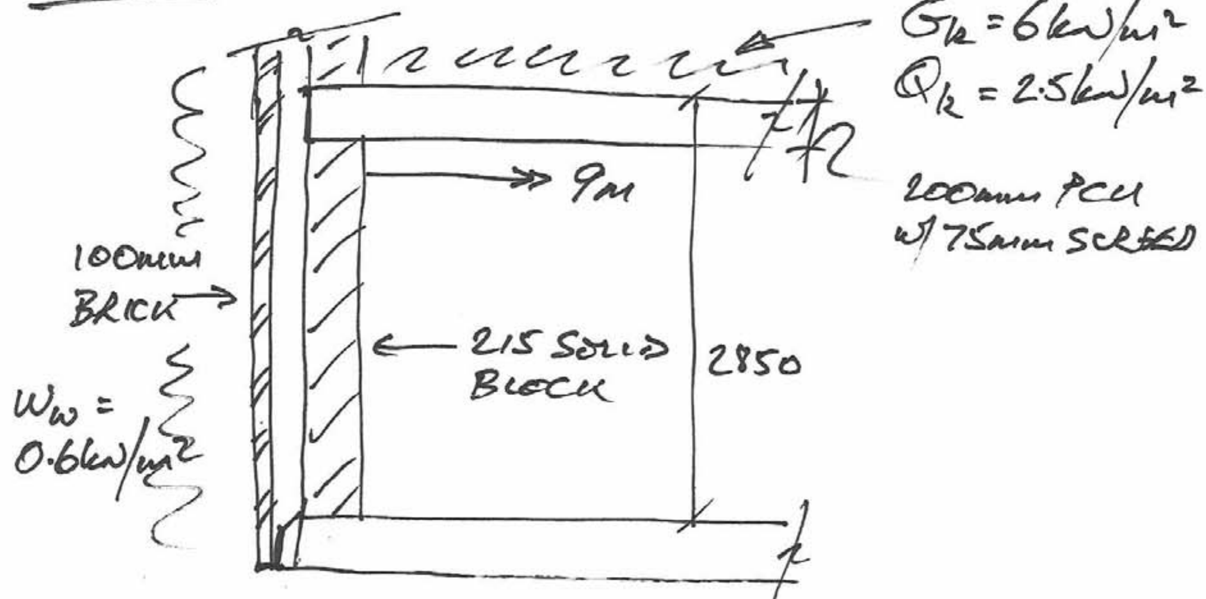
Slenderness ratio h_{ef}/t_{ef}	Eccentrcity at top of wall, e_x			
	Up to 0.5t (see Note 1)	0.1t	0.2t	0.3t
0	1.00	0.88	0.66	0.44
6	1.00	0.88	0.66	0.44
8	1.00	0.88	0.66	0.44
10	0.97	0.88	0.66	0.44
12	0.93	0.87	0.66	0.44
14	0.89	0.83	0.66	0.44
16	0.83	0.77	0.64	0.44
18	0.77	0.70	0.57	0.44
20	0.70	0.64	0.51	0.37
22	0.62	0.56	0.43	0.30
24	0.53	0.47	0.34	
26	0.45	0.38		
27	0.40	0.33		

NOTE 1 It is not necessary to consider the effects of eccentricities up to and including 0.05t.

NOTE 2 Linear interpolation between eccentricities and slenderness ratios is permitted.

NOTE 3 The derivation of β is given in Annex B.

EXAMPLE



Design the inner leaf as the main loadbearing element.

$h = 2850 - 200 - 75 = 2575\text{ mm}$

$L/t = \frac{9000}{215} = 41.9 \nless 30 \quad \therefore$ Use Case (b)

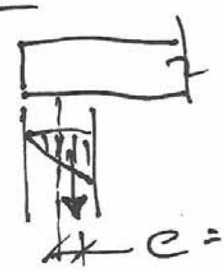
Load from the floor, w_g:

$$w_g = (1.4 \times 6 + 1.6 \times 2.5)\,9/2 = 55.8\ kN/m$$

with wind:

$$w_g = (1.2 \times 6 + 1.2 \times 2.5)\,9/2 = 45.9\ kN/m$$

$\underline{e_x}$:



$e = \frac{2t}{3} - \frac{t}{2} \Rightarrow \frac{e}{t} = \left(\frac{2}{3} - \frac{1}{2}\right) = \underline{\underline{0.1666}}$

$\underline{e_w}$:

Conservatively, use pinned case:

$$M_w = 1.2 \times 0.6 \times 2.575^2/8 = 0.6 \text{kNm}$$

$$\therefore \frac{e_w}{t} = \frac{M_w}{t \cdot w_g} = \frac{0.6 \times 10^3}{215 \times 45.9} = \underline{\underline{0.061}}$$

$\underline{e_a}$

$$\lambda = h_{ef}/t_{ef} \qquad h_{ef} = 1.0h = 2575 \text{mm}$$

$$t_{ef} = \tfrac{2}{3}(100 + 215) = 210 \not< 215$$

$$\therefore t_{ef} = 215$$

$$\therefore \lambda = 2575/215 = 11.9 < 27 \text{ Vok}$$

$$\therefore \frac{e_a}{t} = 11.9^2/2400 - 0.015 = \underline{\underline{0.044}}$$

$\underline{e_m}$

$$\frac{e_m}{t} = \max \begin{cases} 0.1666 \\ 0.6(0.1666) + 0.061 + 0.044 \\ \quad = 0.205 \end{cases}$$

Wind

$$= 0.205$$

Without wind:

$$\frac{e_m}{t} = \max \begin{cases} 0.1666 \\ 0.6(0.1666) + 0.044 \\ \quad = 0.144 \end{cases}$$

$$= 0.1666$$

Thus,

$$\beta_{wind} = 1.1\left[1 - 2 \times 0.205\right] = 0.65$$

$$\beta_{no\ wind} = 1.1\left[1 - 2 \times 0.144\right] = 0.78$$

Try a 5N block, SF = 0.47
$\Rightarrow f_k = 3.6\ N/mm^2$

$$N = \beta \frac{f_k t b}{\gamma_m}$$

$$N_{wind} = 0.65 \times \frac{3.6 \times 215 \times 1000}{3.5} \Big/ 10^3$$

$= 143.7\ kN/m$

$> 55.8\ kN/m \therefore$ ✓ OK
& $45.9\ kN/m \therefore$ OK

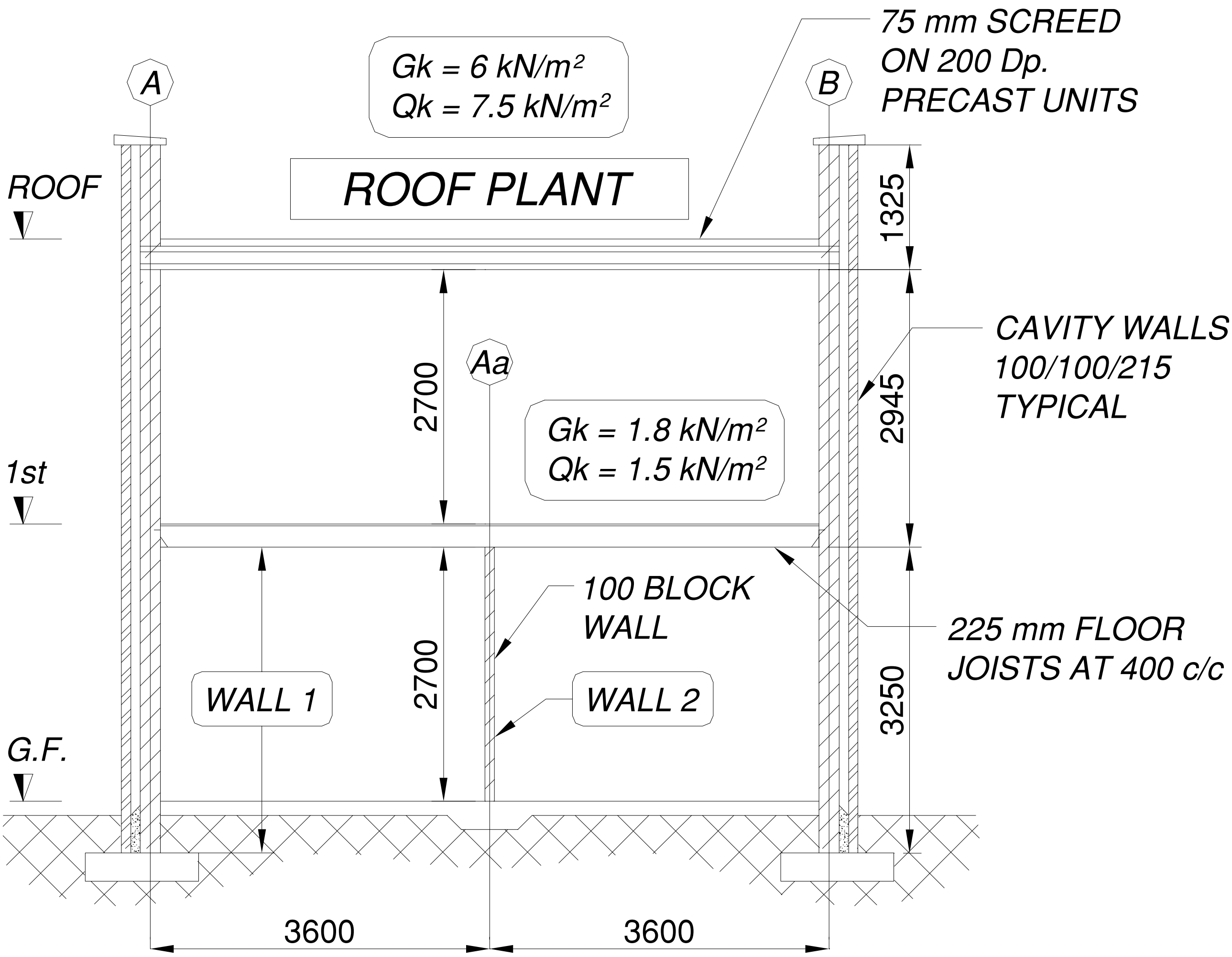
$N_{no\ wind} \rightarrow$ not necessary to check

Example

Design the masonry walls indicated as Wall 1 and Wall 2.

Use the follwing information:

- normal manufacturing and construction controls;
- mortar designation (iii);
- use solid concrete blocks (100 × 215 × 440) in your design for both walls;
- The density of brickwork & blockwork may be taken as 21.2 kN/m^2;
- The roof plant has been allowed for in the roof loading given;
- The joists have a bearing length of 100 mm on the inner leaf of Wall 1.



WALL ①

• LOADING:

Roof: | G_k | Q_k

	G_k	Q_k
$6 \times 7.2/2$	21.6	
$7.5 \times 7.2/2$		27
Walls:		
$21.2 \times 0.315 \times (1.325 + 1.945)$	28.52	
Σ	50.12	27 kN/m

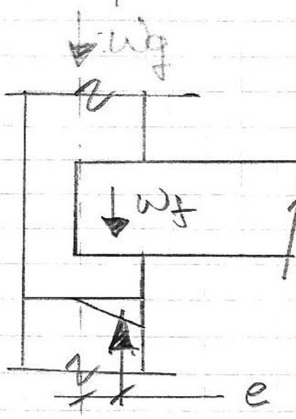
$\Rightarrow W_g = 1.4 \times 50.12 + 1.6 \times 27 = 113.4$ kN/m.

FIRST FLOOR:

	G_k	Q_k
$1.8 \times 3.6/2$	3.24	
$1.5 \times 3.6/2$		2.7
Σ	3.24	2.7

$W_f = 1.4 \times 3.24 + 1.6 \times 2.7 = 8.9$ kN/m

• GRAVITY ECCENTRICITY:



Triangular stress distribution

$\Rightarrow e = \frac{t}{2} - x/3$

$= \frac{215}{2} - \frac{100}{3}$

$= 74.17$ mm

$\Rightarrow e/t = 0.345$

$$\frac{e_x}{t} = \frac{8.9 \times 74.17}{113.4 + 8.9} / 215 = 0.025$$

• ECCENTRICITY DUE TO SLENDERNESS:

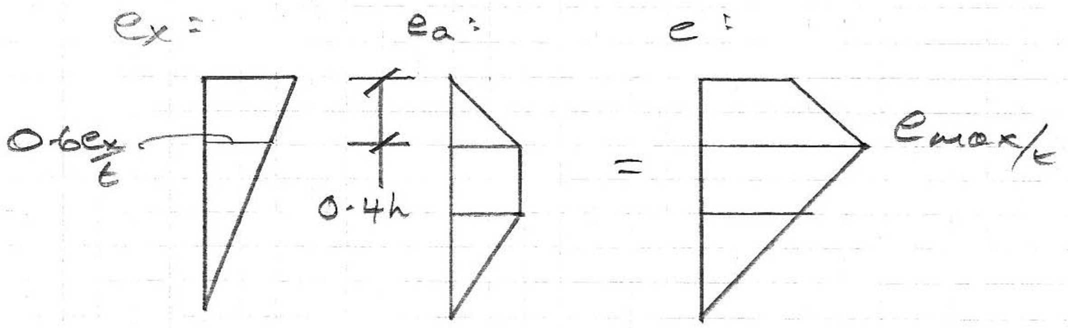
$$t_{ef} = \tfrac{2}{3}(100+215) \nless 215$$
$$= 210 < 215 \Rightarrow t_{ef} = 215\text{mm}$$

$h_{ef} = h$ (Assume no restraint)
$= 3250\text{mm}$

$$\Rightarrow \lambda = 3250/215 = 15.1 < 27 \ \checkmark\text{ok}$$

$$e_a/t = \frac{15.1^2}{2400} - 0.015 = 0.08$$

• TOTAL ECCENTRICITY:



$$\frac{e_{max}}{t} = 0.6\frac{e_x}{t} + 1.0\frac{e_a}{t}$$
$$= 0.6\times 0.025 + 0.08$$
$$= 0.095$$

• DESIGN:

$$\beta = 1.1\left[1 - 2\times 0.095\right] = 0.89$$

Try 5N solid, A.R. = 0.47 $\Rightarrow f_k = 3.6\text{ N/mm}^2$

$$N = 0.89 \times \frac{3.6\times 215}{3.5} = 196.8\text{ kN/m}$$
$$> 113.4 + 8.9 = 122.3\text{ kN/m} \ \checkmark\text{ok.}$$

WALL (2)

· LOADING:

LOADWIDTH = 3·6 m

$\Rightarrow w_f = [1 \cdot 4 \times 7 \cdot 8 + 1 \cdot 6 \times 1 \cdot 5]\, 3 \cdot 6 = 17 \cdot 7$ kN/m

· ECCENTRICITIES:

e_x & e_w do not apply

$\lambda = \frac{2700}{100} = 27 \leq 27$ ✓ ok.

$\frac{e_a}{t} = \frac{27^2}{2400} - 0 \cdot 015 = 0 \cdot 289$

· DESIGN:

$\beta = 1 \cdot 1 [1 - 2 \times 0 \cdot 289] = 0 \cdot 465$

Try 5N solid, A.R. = 2·15 $\Rightarrow f_k = 5$ N/mm^2

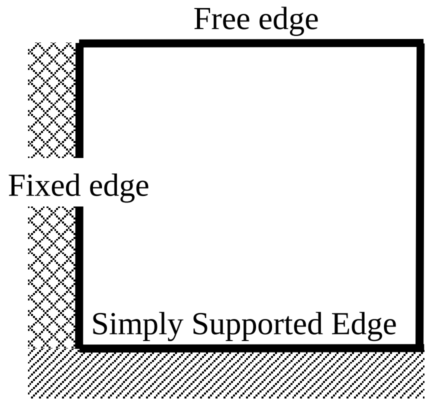
$\Rightarrow W = 0 \cdot 465 \times \frac{5 \times 100}{3 \cdot 5} = 66 \cdot 42$ kN/m

$> 17 \cdot 7$ kN/m $\Rightarrow$ ok.

Masonry Design – Flexural Capacity

Firstly, we introduce some general information:

1. Edge support conditions are identified as:

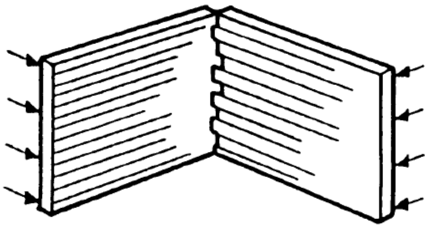
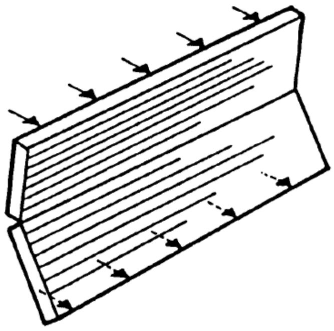


2. Limiting dimensions of panels:
   a. Free Standing wall: $h \le 12 \cdot t_{ef}$
   b. Top and bottom supports only: $h \le 40 \cdot t_{ef}$
   c. 3 supported edges:
      - 2 or more edges fixed: $hl \le 1500 \cdot t_{ef}^2$
      - All other cases: $hl \le 1350 \cdot t_{ef}^2$
   d. 4 supported edges:
      - 3 or more edges fixed: $hl \le 2250 \cdot t_{ef}^2$
      - All other cases: $hl \le 2025 \cdot t_{ef}^2$

   Luckily, it is unusual for these limiting dimensions to be problematic.

3. For irregular shapes we convert to equivalent area rectangles, noting the support conditions.

Design Applied Moments

Plane of failure perpendicular to bed joints	Plane of failure parallel to bed joints
	
$m_{\perp} = \alpha W_k \gamma_f L^2$	$m_{//} = \mu \alpha W_k \gamma_f L^2 = \mu m_{\perp}$

In which:

- $\perp$ – perpendicular to bed joints;
- $//$ – parallel to bed joints;
- α – coefficient from Table 9 of IS 325;
- W_k – characteristic wind load;
- γ_f – partial factor of safety for load:
    - for panels <u>not</u> providing lateral stability: $\gamma_f = 1.2$;
    - for panels providing structural stability: $\gamma_f = 1.4$;
- L – the span of the panel, usually horizontal;
- μ – the *orthogonal ratio* of strength:

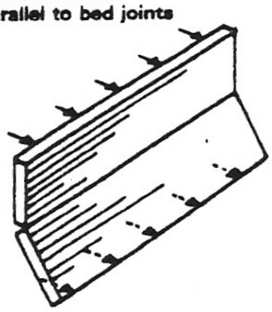
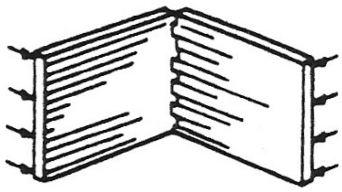
$$\mu = \frac{f_{kx//}}{f_{kx\perp}}$$

- $f_{kx//}$ – $//$ characteristic strength from Table 3 of IS 325;
- $f_{kx\perp}$ – $\perp$ characteristic strength from Table 3 of IS 325.

Table 3 of the code is given next. Note that μ is <u>always</u> less than unity.

$f_{kx\parallel}$ $f_{kx\perp}$

Table 3. Characteristic flexural strength of masonry, f_{kx}, MPa

	Plane of failure parallel to bed joints 			Plane of failure perpendicular to bed joints 		
Mortar designation	(i)	(ii) and (iii)	(iv)	(i)	(ii) and (iii)	(iv)
Clay bricks having a water absorption less than 7% between 7% and 12% over 12%	 0.7 0.5 0.4	 0.5 0.4 0.3	 0.4 0.35 0.25	 2.0 1.5 1.1	 1.5 1.1 0.9	 1.2 1.0 0.8
Calcium silicate bricks	0.3		0.2	0.9		0.6
Concrete bricks	0.3		0.2	0.9		0.6
Concrete blocks of compressive strength in MPa 3, 5, 7, 10, 15 and over; aspect ratio as laid ≮ 1.0*	0.25		0.20	0.4 0.5 0.60 0.75 0.90†		0.4 0.45 0.5 0.6 0.7†
Concrete blocks of compressive strength in MPa 5, 7, 10 and over; aspect ratio as laid of 0.4 to 0.5	0.25		0.20	0.65 0.8 0.90†		0.45 0.6 0.7†

†When used with flexural strength in parallel direction, assume the orthogonal ratio $\mu = 0.3$.
*See 24.2.

Design Moments of Resistance

Resistance <u>parallel to the bed joints</u>, $M_{R//}$:

$$M_{R//} = \left[\frac{f_{kx//}}{\gamma_m} + g_d \right] Z$$

where:

- g_d – the design vertical axial stress, based on $0.9G_k$ only;
- Z – the section modulus, $\frac{bt^2}{6}$, but usually taken per metre, hence $b = 1000$ mm

Resistance <u>perpendicular to the bed joints</u>, $M_{R\perp}$:

$$M_{R\perp} = \frac{f_{kx\perp}}{\gamma_m} \cdot Z$$

where:

- Z – the section modulus, $\frac{ht^2}{6}$, but usually taken per metre, hence $h = 1000$ mm

The <u>required wall thickness</u> is the larger of:

$$t_{//} \geq \sqrt{\frac{6m_{//}\gamma_m}{f_{kx//}h}} \qquad t_{\perp} \geq \sqrt{\frac{6m_{\perp}\gamma_m}{f_{kx\perp}b}}$$

where again as usual; $h, b = 1000$ mm.

NOTE 1 Linear interpolation of μ and h/L is permitted.

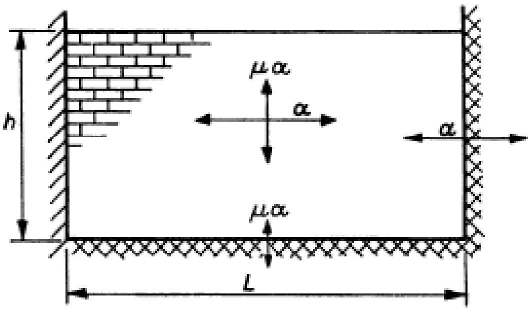
NOTE 2 When the dimensions of a wall are outside the range of h/L given in this table, it will usually be sufficient to calculate the moments on the basis of a simple span. For example, a panel of type A having h/L less than 0.3 will tend to act as a freestanding wall, whilst the same panel having h/L greater than 1.75 will tend to span horizontally.

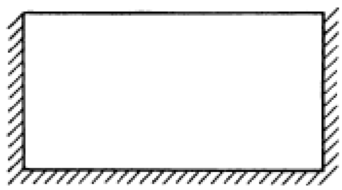
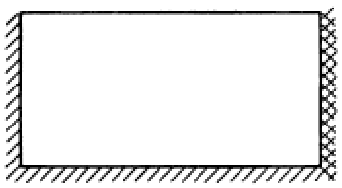
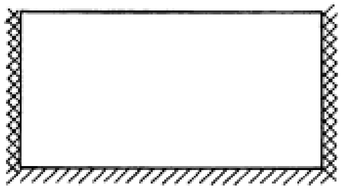
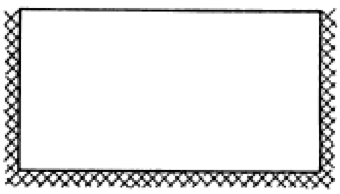
Key to support conditions

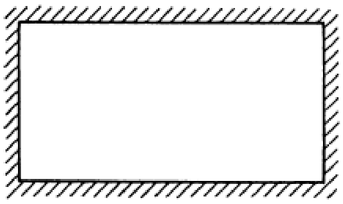
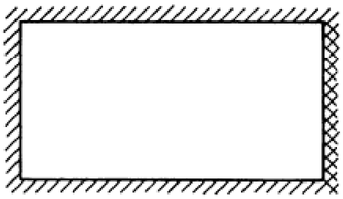
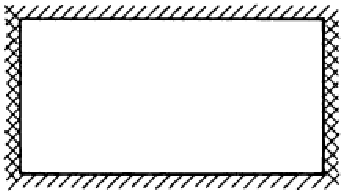
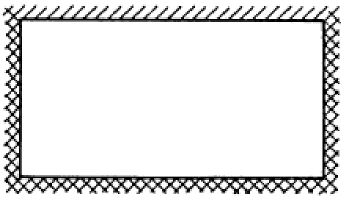
denotes free edge

simply supported edge

an edge over which full continuity exists



	μ	Values of α						
		h/L						
		0.3	**0.5**	**0.75**	**1.00**	**1.25**	**1.5**	**1.75**
	1.00	0.031	0.045	0.059	0.071	0.079	0.085	0.090
	0.90	0.032	0.047	0.061	0.073	0.081	0.087	0.092
	0.80	0.034	0.049	0.064	0.075	0.083	0.089	0.093
	0.70	0.035	0.051	0.066	0.077	0.085	0.091	0.095
 **A**	0.60	0.038	0.053	0.069	0.080	0.088	0.093	0.097
	0.50	0.040	0.056	0.073	0.083	0.090	0.095	0.099
	0.40	0.043	0.061	0.077	0.087	0.093	0.098	0.101
	0.35	0.045	0.064	0.080	0.089	0.095	0.100	0.103
	0.30	0.048	0.067	0.082	0.091	0.097	0.101	0.104
	1.00	0.024	0.035	0.046	0.053	0.059	0.062	0.065
	0.90	0.025	0.036	0.047	0.055	0.060	0.063	0.066
	0.80	0.027	0.037	0.049	0.056	0.061	0.065	0.067
	0.70	0.028	0.039	0.051	0.058	0.062	0.066	0.068
 **B**	0.60	0.030	0.042	0.053	0.059	0.064	0.067	0.069
	0.50	0.031	0.044	0.055	0.061	0.066	0.069	0.071
	0.40	0.034	0.047	0.057	0.063	0.067	0.070	0.072
	0.35	0.035	0.049	0.059	0.065	0.068	0.071	0.073
	0.30	0.037	0.051	0.061	0.066	0.070	0.072	0.074
	1.00	0.020	0.028	0.037	0.042	0.045	0.048	0.050
	0.90	0.021	0.029	0.038	0.043	0.046	0.048	0.050
	0.80	0.022	0.031	0.039	0.043	0.047	0.049	0.051
	0.70	0.023	0.032	0.040	0.044	0.048	0.050	0.051
 **C**	0.60	0.024	0.034	0.041	0.046	0.049	0.051	0.052
	0.50	0.025	0.035	0.043	0.047	0.050	0.052	0.053
	0.40	0.027	0.038	0.044	0.048	0.051	0.053	0.054
	0.35	0.029	0.039	0.045	0.049	0.052	0.053	0.054
	0.30	0.030	0.040	0.046	0.050	0.052	0.054	0.055
	1.00	0.013	0.021	0.029	0.035	0.040	0.043	0.045
	0.90	0.014	0.022	0.031	0.036	0.040	0.043	0.046
	0.80	0.015	0.023	0.032	0.038	0.041	0.044	0.047
	0.70	0.016	0.025	0.033	0.039	0.043	0.045	0.047
 **D**	0.60	0.017	0.026	0.035	0.040	0.044	0.046	0.048
	0.50	0.018	0.028	0.037	0.042	0.045	0.048	0.050
	0.40	0.020	0.031	0.039	0.043	0.047	0.049	0.051
	0.35	0.022	0.032	0.040	0.044	0.048	0.050	0.051
	0.30	0.023	0.034	0.041	0.046	0.049	0.051	0.052

	μ	Values of α						
		h/L						
		0.3	**0.5**	**0.75**	**1.00**	**1.25**	**1.5**	**1.75**
 **E**	1.00	0.008	0.018	0.030	0.042	0.051	0.059	0.066
	0.90	0.009	0.019	0.032	0.044	0.054	0.062	0.068
	0.80	0.010	0.021	0.035	0.046	0.056	0.064	0.071
	0.70	0.011	0.023	0.037	0.049	0.059	0.067	0.073
	0.60	0.012	0.025	0.040	0.053	0.062	0.070	0.076
	0.50	0.014	0.028	0.044	0.057	0.066	0.074	0.080
	0.40	0.017	0.032	0.049	0.062	0.071	0.078	0.084
	0.35	0.018	0.035	0.052	0.064	0.074	0.081	0.086
	0.30	0.020	0.038	0.055	0.068	0.077	0.083	0.089
 **F**	1.00	0.008	0.016	0.026	0.034	0.041	0.046	0.051
	0.90	0.008	0.017	0.027	0.036	0.042	0.048	0.052
	0.80	0.009	0.018	0.029	0.037	0.044	0.049	0.054
	0.70	0.010	0.020	0.031	0.039	0.046	0.051	0.055
	0.60	0.011	0.022	0.033	0.042	0.048	0.053	0.057
	0.50	0.013	0.024	0.036	0.044	0.051	0.056	0.059
	0.40	0.015	0.027	0.039	0.048	0.054	0.058	0.062
	0.35	0.016	0.029	0.041	0.050	0.055	0.060	0.063
	0.30	0.018	0.031	0.044	0.052	0.057	0.062	0.065
 **G**	1.00	0.007	0.014	0.022	0.028	0.033	0.037	0.040
	0.90	0.008	0.015	0.023	0.029	0.034	0.038	0.041
	0.80	0.008	0.016	0.024	0.031	0.035	0.039	0.042
	0.70	0.009	0.017	0.026	0.032	0.037	0.040	0.043
	0.60	0.010	0.019	0.028	0.034	0.038	0.042	0.044
	0.50	0.011	0.021	0.030	0.036	0.040	0.043	0.046
	0.40	0.013	0.023	0.032	0.038	0.042	0.045	0.047
	0.35	0.014	0.025	0.033	0.039	0.043	0.046	0.048
	0.30	0.016	0.026	0.035	0.041	0.044	0.047	0.049
 **H**	1.00	0.005	0.011	0.018	0.024	0.029	0.033	0.036
	0.90	0.006	0.012	0.019	0.025	0.030	0.034	0.037
	0.80	0.006	0.013	0.020	0.027	0.032	0.035	0.038
	0.70	0.007	0.014	0.022	0.028	0.033	0.037	0.040
	0.60	0.008	0.015	0.024	0.030	0.035	0.038	0.041
	0.50	0.009	0.017	0.025	0.032	0.036	0.040	0.043
	0.40	0.010	0.019	0.028	0.034	0.039	0.042	0.045
	0.35	0.011	0.021	0.029	0.036	0.040	0.043	0.046
	0.30	0.013	0.022	0.031	0.037	0.041	0.044	0.047
 **I**	1.00	0.004	0.009	0.015	0.021	0.026	0.030	0.033
	0.90	0.004	0.010	0.016	0.022	0.027	0.031	0.034
	0.80	0.005	0.010	0.017	0.023	0.028	0.032	0.035
	0.70	0.005	0.011	0.019	0.025	0.030	0.033	0.037
	0.60	0.006	0.013	0.020	0.026	0.031	0.035	0.038
	0.50	0.007	0.014	0.022	0.028	0.033	0.037	0.040
	0.40	0.008	0.016	0.024	0.031	0.035	0.039	0.042
	0.35	0.009	0.017	0.026	0.032	0.037	0.040	0.043
	0.30	0.010	0.019	0.028	0.034	0.038	0.042	0.044

NOTE 1 Linear interpolation of μ and h/L is permitted.

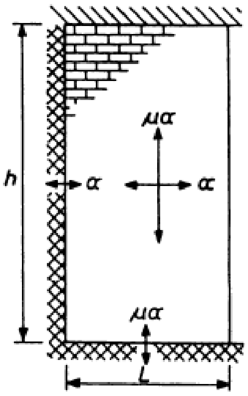
NOTE 2 When the dimensions of a wall are outside the range of h/L given in this table, it will usually be sufficient to calculate the moments on the basis of a simple span. For example, a panel of type A having h/L less than 0.3 will tend to act as a freestanding wall, whilst the same panel having h/L greater than 1.75 will tend to span horizontally.

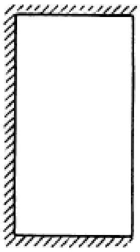
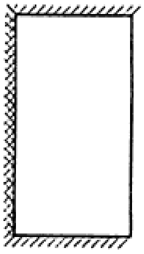
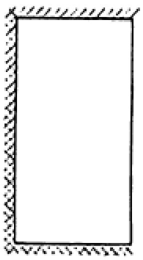
Key to support conditions

denotes free edge

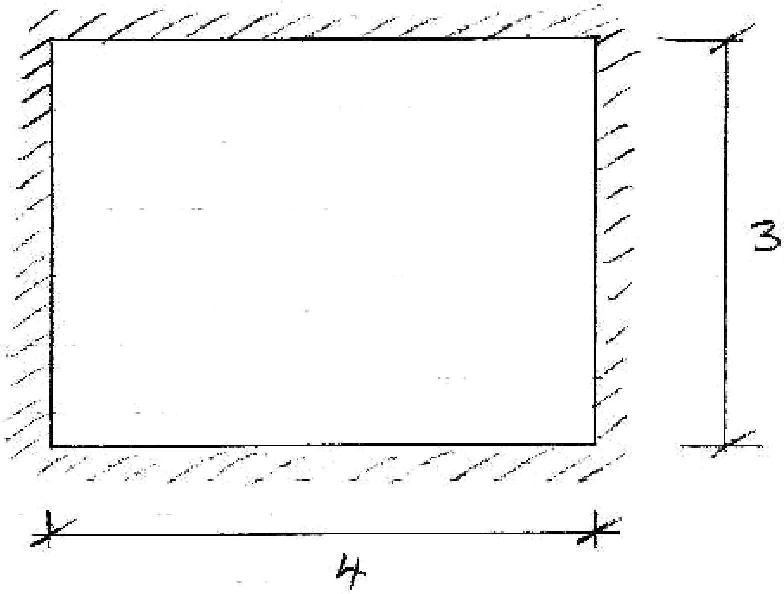
simply supported edge

an edge over which full continuity exists



		μ	Values of α						
			h/L						
			0.3	**0.5**	**0.75**	**1.00**	**1.25**	**1.5**	**1.75**
	**J**	1.00	0.009	0.023	0.046	0.071	0.096	0.122	0.151
		0.90	0.010	0.026	0.050	0.076	0.103	0.131	0.162
		0.80	0.012	0.028	0.054	0.083	0.111	0.142	0.175
		0.70	0.013	0.032	0.060	0.091	0.121	0.156	0.191
		0.60	0.015	0.036	0.067	0.100	0.135	0.173	0.211
		0.50	0.018	0.042	0.077	0.113	0.153	0.195	0.237
		0.40	0.021	0.050	0.090	0.131	0.177	0.225	0.272
		0.35	0.024	0.055	0.098	0.144	0.194	0.244	0.296
		0.30	0.027	0.062	0.108	0.160	0.214	0.269	0.325
	**K**	1.00	0.009	0.021	0.038	0.056	0.074	0.091	0.108
		0.90	0.010	0.023	0.041	0.060	0.079	0.097	0.113
		0.80	0.011	0.025	0.045	0.065	0.084	0.103	0.120
		0.70	0.012	0.028	0.049	0.070	0.091	0.110	0.128
		0.60	0.014	0.031	0.054	0.077	0.099	0.119	0.138
		0.50	0.016	0.035	0.061	0.085	0.109	0.130	0.149
		0.40	0.019	0.041	0.069	0.097	0.121	0.144	0.164
		0.35	0.021	0.045	0.075	0.104	0.129	0.152	0.173
		0.30	0.024	0.050	0.082	0.112	0.139	0.162	0.183
	**L**	1.00	0.006	0.015	0.029	0.044	0.059	0.073	0.088
		0.90	0.007	0.017	0.032	0.047	0.063	0.078	0.093
		0.80	0.008	0.018	0.034	0.051	0.067	0.084	0.099
		0.70	0.009	0.021	0.038	0.056	0.073	0.090	0.106
		0.60	0.010	0.023	0.042	0.061	0.080	0.098	0.115
		0.50	0.012	0.027	0.048	0.068	0.089	0.108	0.126
		0.40	0.014	0.032	0.055	0.078	0.100	0.121	0.139
		0.35	0.016	0.035	0.060	0.084	0.108	0.129	0.148
		0.30	0.018	0.039	0.066	0.092	0.116	0.138	0.158

EXAMPLE:



BRICKS: WATER ABSORPTION $>12\%$

$t = 102.5$ mm

MORTAR: (ii)

CHECK FOR A WIND LOAD OF 0.42 kN/m^2:

$f_{kx1} = 0.3 \text{ N/mm}^2 \quad f_{kx2} = 0.9 \text{ N/mm}^2$

$\Rightarrow \mu = 0.3/0.9 = 0.33$

$h/L = 3/4 = 0.75 \Rightarrow$ Tb 9 (E) $\alpha = 0.053$

$\Rightarrow M_{\perp} = \alpha \gamma_f W_k L^2 = 0.053 \times 1.2 \times 0.42 \times 4^2$

$= 0.427$ kNm per m

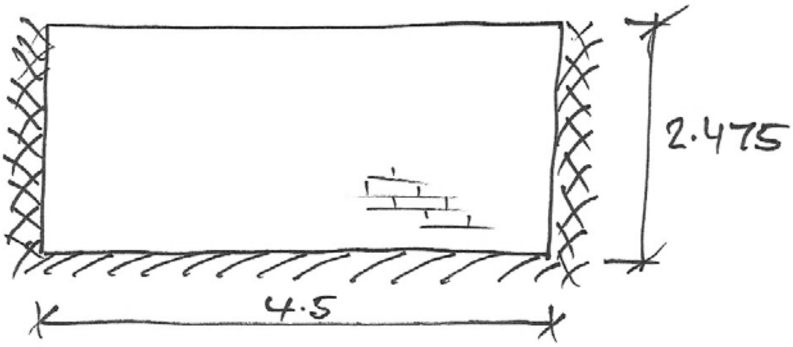
$Z = 1000 \times 102.5^2/6 = 1.75 \times 10^6 \text{ mm}^3$

$M_{RV} = 0.9 \times 1.75 \times 10^6 / 3.5 = 0.45$ kNm per m

$0.45 > 0.427 \Rightarrow$ OK ✓.

EXAMPLE:

DESIGN THE BRICK & MORTAR COMBINATION FOR:



Brick – 102.5mm; $W_k = 0.65\ kN/m^2$

Use Normal control & construction.

Looking at Tb 3 for bricks & mortar, assume $\mu = 0.35$. $h/L = 2.475/4 = 0.62$, Tb C

$\therefore \alpha \sim 0.0425$

$$\therefore M_\perp = \alpha W_k \gamma_f L^2 = 0.0425 \times 0.65 \times 1.2 \times 4.5^2$$

$$= 0.67\ kNm/m\ run$$

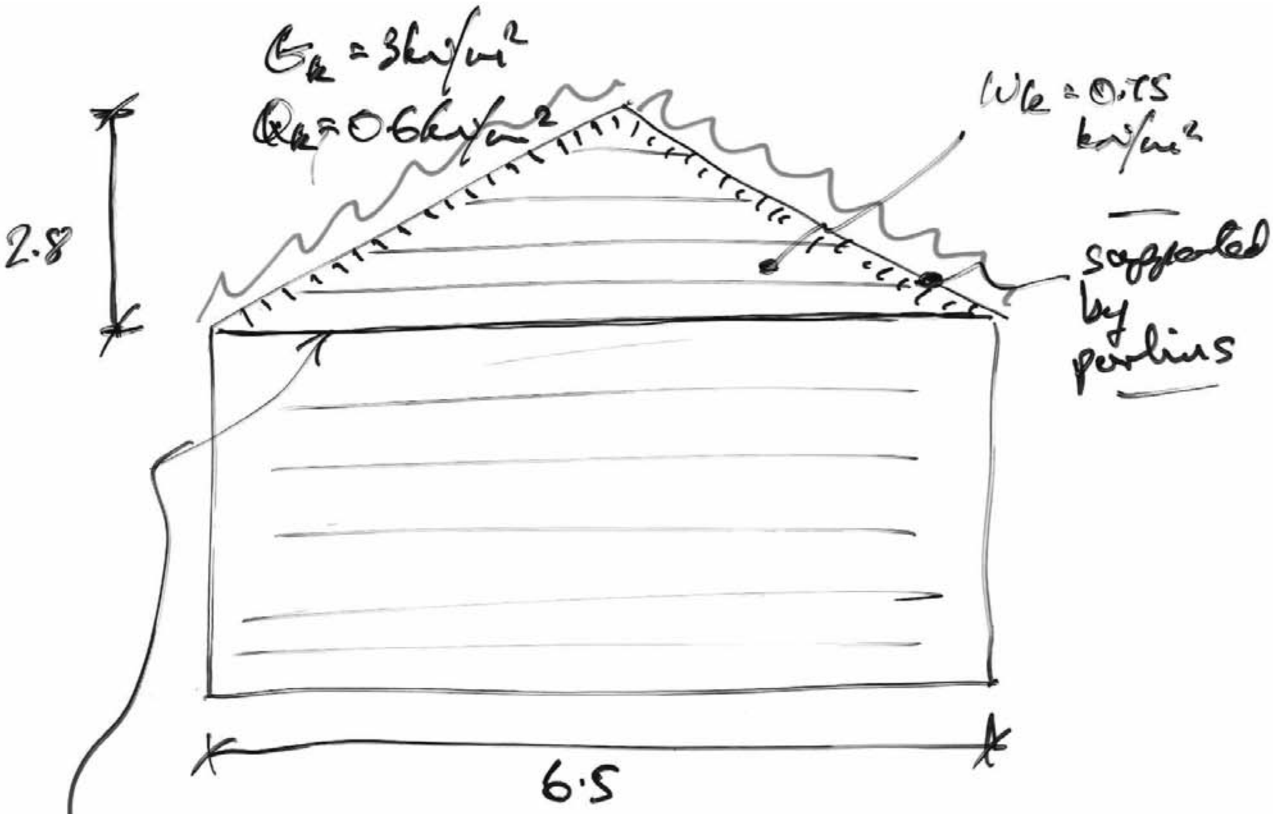
$$M_{R\perp} \geq M_\perp \quad \therefore \frac{f_{kx\perp}}{3.5} \times \frac{1000 \times 102.5^2}{6} \geq 0.67 \times 10^6$$

$$\therefore f_{kx\perp} \geq 1.34\ N/mm^2$$

$\therefore$ Choose Bricks with < 7% moisture & Mortar type (iii)

Check, $\mu = \frac{0.5}{1.5} = 0.33 \sim 0.35 \quad \therefore$ OK ✓

Gable Wall Example:



supported on this line by dormer floor.

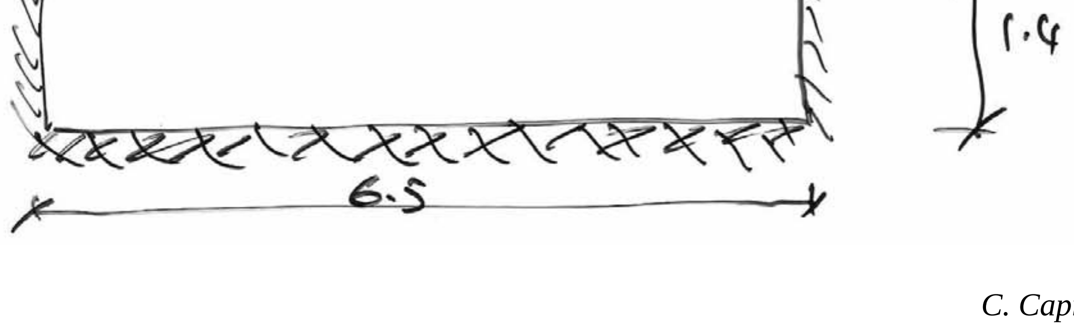
load width onto wall = 3.5m.

Check SW 215 Solid Blocks.

=> Equivalent ~~vertical~~ rectangle height:

$$\cancel{6.5}h = \tfrac{1}{2} \times \cancel{6.5} \times 2.8$$
$$= 1.4m.$$

=>



SW Blocks aspect = 0.47

$\Rightarrow f_{kx2} = 0.25\ N/mm^2 \quad f_{kx1} = 0.65\ N/mm^2$

$\mu = \frac{0.25}{0.65} = 0.39$

Panel type = Say E conservative

g_d: $a_g = 3.5 \times 0.9 \times 3 = 9.45\ kN/m$

$\Rightarrow g_d = \frac{9.45 \times 10^3}{1000 \times 215}$ per metre run

$= 0.044\ N/mm^2$

$M_\perp = \alpha W_k \gamma_f L^2$

α: $h/L = 1.4/6.5 = 0.22$

$\Rightarrow \alpha \simeq 0.011$

$\Rightarrow M_\perp = 0.011 \times 0.75 \times 1.2 \times 6.5^2 = 0.43\ kNm.$

$M_{\parallel} = \mu M_\perp = 0.168\ kNm.$

$M_{RV} = \left[\frac{0.25}{3.5} + 0.044\right]\left(\frac{10^3 \times 215^2}{6}\right) = 0.89\ kNm$

$0.89 > 0.43 \Rightarrow$ OK ✓