

**MASONRY CODES &  
STABILITY  
WITH REFERENCE TO  
EARTHQUAKE  
DETAILING**

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# MASONRY CODES

- ❖ **BS 5628 pt 1 – Design of Plain Masonry**
- ❖ **BS 5628 pt 2 – Design of Reinforced & prestressed Masonry**
- ❖ **EC 6 ENV 1996-1-1 Rules for reinforced/ prestressed & unreinforced masonry**

**(EN Date due 2003/4)**

**EC 8 ENV 1998-1-1; 1996**

**Design Provisions for Earthquake Resistance of Structures**

# Contents of EC6

**Part 1: The design of masonry structures: General rules for buildings**

**Part 2: Design, selection of materials and execution of masonry**

**Part 3: Simplified calculation methods and simple rules for the design of masonry**

**Part 10: Fire performance of masonry structures**

Of these, Part 1 is well advanced. Part 2 published 1998 and part 3 in 1999 as ENVs. Part 10 (now 1-2 published 1996) and part 1.3 on laterally loaded masonry are to be published with part 1 – 1, together with part 1-x: Complex shapes sections in masonry structures.

# Scope of Part 1 – 1 of Eurocode 6

Part 1- 1 of Eurocode 6, DD ENV 1996 –1-1, containing principles & rules of applications, gives a general basis for the design of buildings and civil engineering works in unreinforced, reinforced, prestressed and confined masonry made with the masonry units laid in mortar.

- Section 1 : General
- Section 2 : Basis of design (EC 1)

## Fundamental Combination

$$\xi \gamma_{G,j} G_{k,j} + \gamma_{Q,1} Q_{k,i} + \sum_{i > 1} \xi \gamma_{Q,i} \Psi_{O,i} Q_{k,i}$$

Sum of factored  
Permanent loads

Factored dominant  
variable load

Sum of other factored  
variable loads

# Scope of Part 1 – 1 of Eurocode 6 (cont.)

**Section 3 : Materials**

**Section 4 : Design of masonry**

**Section 5 : Structural detailing (chases & recesses where essential should be placed within 7th of storey height)**

**Section 6 : Construction**

**Unreinforced masonry does not usually require the consideration of the Serviceability Limit State, as satisfying the Ultimate Limit State usually avoids cracking and deflection problems. This is not so for Reinforced Masonry, when both the Ultimate and Serviceability Limit States need to be addressed**

# Table 1 - Partial Safety factors $\gamma_m$ characteristic loading & materials strength for normal design loads.

Ultimate Limit State	BS	EC	
permanent load	1.4	1.35	$\gamma_G$
imposed load	1.6	1.50	

<i>Material</i>	<i>Special Category BS</i>		<i>Normal Category BS</i>		<i>BS 5628</i>
<i>Masonry</i>	(EC6/B)		(EC6/C)		
<i>Compression</i>	2.5	(2.8)	3.1	(3.5)	Pt1
<i>Compression/flexure</i>	2.0	(2.8)	2.3	(3.5)	Pt 2
<i>Flexure</i>	2.8	(2.8)	3.5	(3.5)	Pt1
<i>Shear</i>	2.5	(2.5)	2.5	(3.5)	Pt1
<i>Shear</i>	2.0	(2.8)	2.0	(3.5)	Pt 2
<i>Bond</i>	1.5	(2.0)	1.5	-	Pt2
<i>Strength of steel</i>	1.15	(1.15)	1.15	-	Pt 2
<i>Wall ties</i>	3.0	(2.5)	3.0	(2.5)	Pt 1

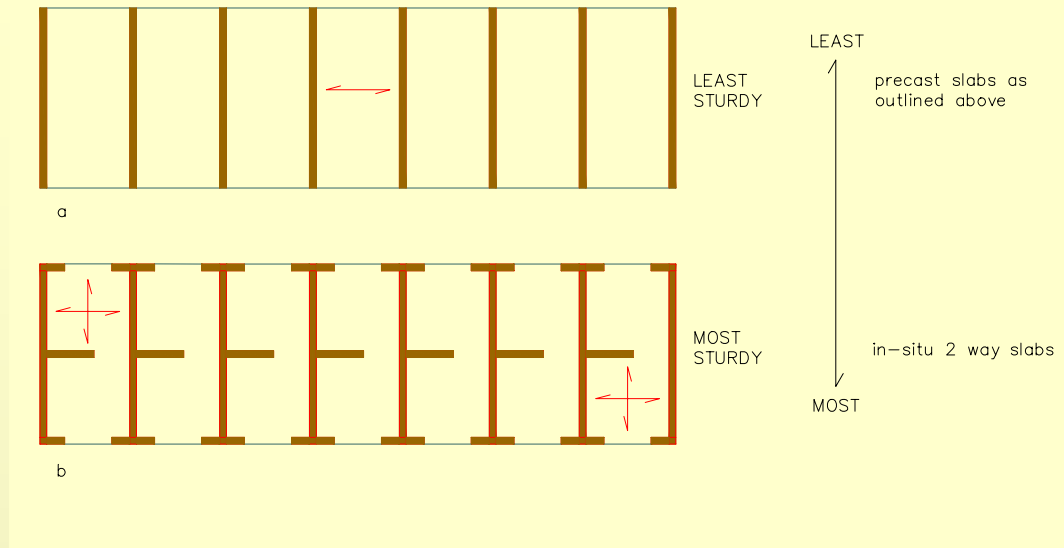
When considering the probable effects of misuse or accident, the values given should be halved.  
 EC8 gives a  $\gamma_m$  of 1.7 and 2.0 for Categories B & C

## Table 2 - Characteristic values of imposed loads on floors in buildings and $\Psi$ values to EC1

Loaded areas	UDL (kN/M <sup>2</sup> )	Conc. Load (kN)	$\Psi_0$	$\Psi_1$	$\Psi_2$
Domestic	2.0	2.0	0.7	0.5	0.3
Offices	3.0	2.0	0.7	0.5	0.3
Assembly	4.0	4.0	0.7	0.7	0.6
With fixed seats	5.0	4.0	0.7	0.7	0.6
Storage	5.0	7.0	1.0	0.9	0.8
Wind			0.6	0.5	0.0

$\Psi_{Ei} = \phi \cdot \psi_{2i}$  (where  $\psi$  varies from 0.5 – 1.0 depending on occupancy)

# STABILITY



**FIG 1**

**THE EXTENT OF DAMAGE SHOULD NOT BE DISPROPORTIONATE TO ITS CAUSE**

**BS 5628 specifies the minimum lateral load at 1.5% of the total characteristic DL above that level.**

**EC6 gives this at 1% of the combined vertical characteristic dead and imposed load at the particular floor divided by  $\sqrt{h_{tot}}$**

**Their effect may be ignored if less onerous than other horizontal actions eg. wind**

# ACCIDENTAL DAMAGE

For buildings with 5 storeys or more & clear spans exceeding 9.00m:

BS 5628 pt 1 - Table 12 - 3 options given:

- ❖ option 1 based on members being able to withstand a pressure of  $34\text{KN/m}^2$  in any direction
- ❖ option 3 prescribes horizontal & vertical ties as in BS 8110
- ❖ option 2 is a hybrid between options 1 & 3 where in masonry construction it may be difficult to provide vertical tying. Unless member defined as protected (can withstand pressure up to  $34\text{KN/m}^2$ ) the effect of removing one vertical member at a time is to be considered.

# TIEING PROVISIONS TO BS5628 pt 1

❖ Vertical Tie the greater of :

$$T = (34A/8000) (h/t)^2 N \quad \text{or} \quad 100\text{KN/m length}$$

where A is the area in mm<sup>2</sup>

❖ Horizontal Tie – in KN, is the lesser of:

$$F_t = 20 + 4 N_s \quad (\text{where } N_s \text{ is the no of storeys})$$

or 60 KN

❖ Internal Ties in KN/m

$$f'_t = F_t \{(G_k + Q_k)/7.5\} \times L_a/5$$

❖ External Wall or Column Tie in KN for columns & KN/m for walls is the lesser of

$$2F_t \quad \text{or} \quad (L/2.5) F_t$$

The tie force is based on shear strength or friction

# SEISMIC ZONING

**Table 3 – Return Periods for Earthquake Intensity of the Maltese Islands**

<i>MM – Earthquake Intensity</i>	<i>Return Period (years)</i>	<i>Base Shear Design % of g</i>
<i>VI</i>	333	2 –5
<i>VII</i>	1800	5 –10
<i>VIII</i>	100,000	10- 20

**Design grd. acceleration for a return period of [475] yrs (EC8) taken between 0.05g – 0.8g.**

**Defined as a low seismicity zone as <0.10g (EC8) < 0.10g, but > 0.4g EC 8 provisions to be catered for**

# MASONRY DESIGN CRITERIA FOR ZONES OF LOW SEISMICITY (EC8)

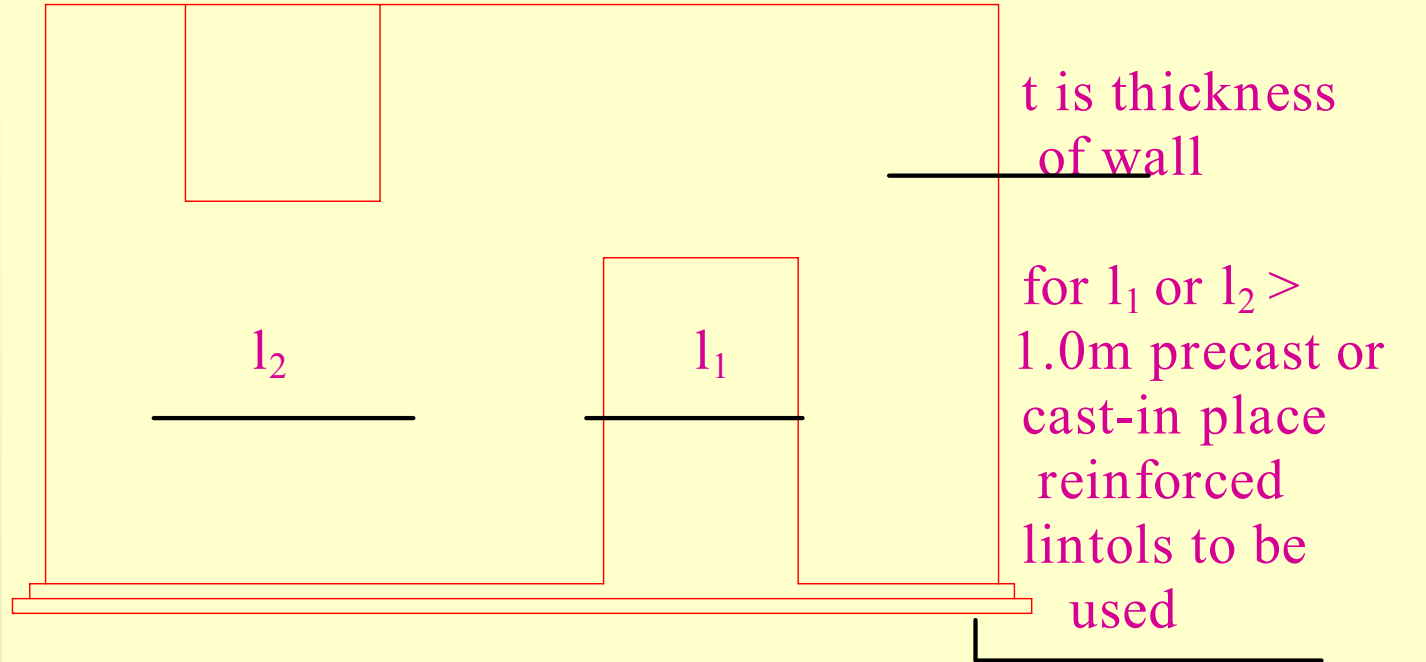
## 1. Shear walls in manufactured stones units

$$t \geq [175] \text{mm}$$

$$h_{ef}/t \leq [15]$$

2. A min of 2 parallel walls is placed in 2 orthogonal directions. The cumulative length of each shear wall > 30% of the length of the building. The length of wall resisting shear is taken for the part that is in compression.
3. For a design ground acceleration < 0.2g the allowed no of storeys above ground allowed is [3] for unreinforced masonry and [5] for reinforced masonry, however for low seismicity a greater no allowed.
4. Mortar Grade (III), (M5) although lower resistance may be allowed. Reinforced masonry type IV (M10). No need to fill perp. Joints.

# FIG 2 -Masonry Improved Sturdiness for Aseismic Design



$$L \Delta 2(l_1 + l_2)$$

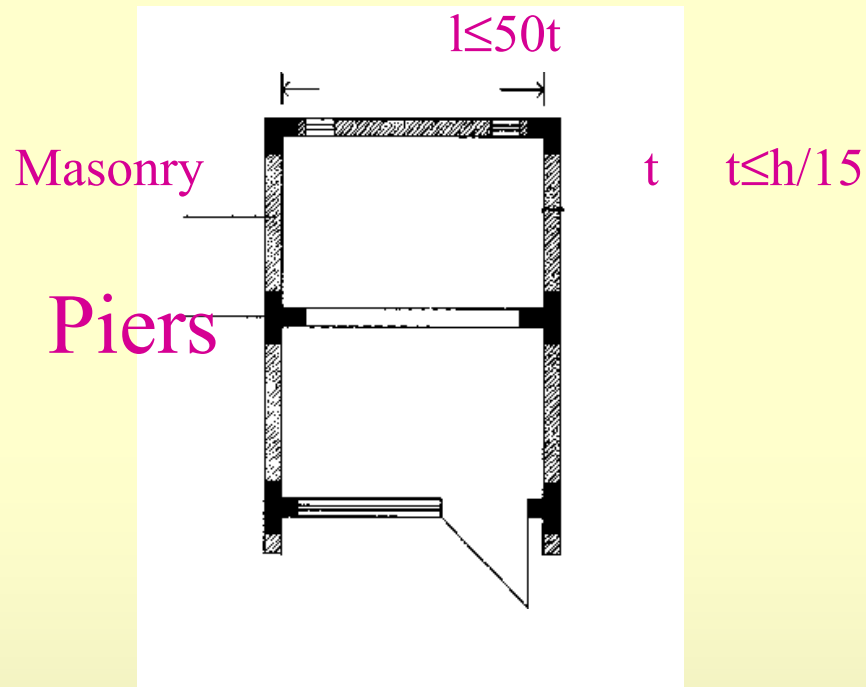
Continuous footing

$$\Delta 50\text{cm or } 2t$$

$$\Delta 50\text{ cm}$$

# Fig 3- Example of overcoming unsymmetrical requirements when large opening required on one side

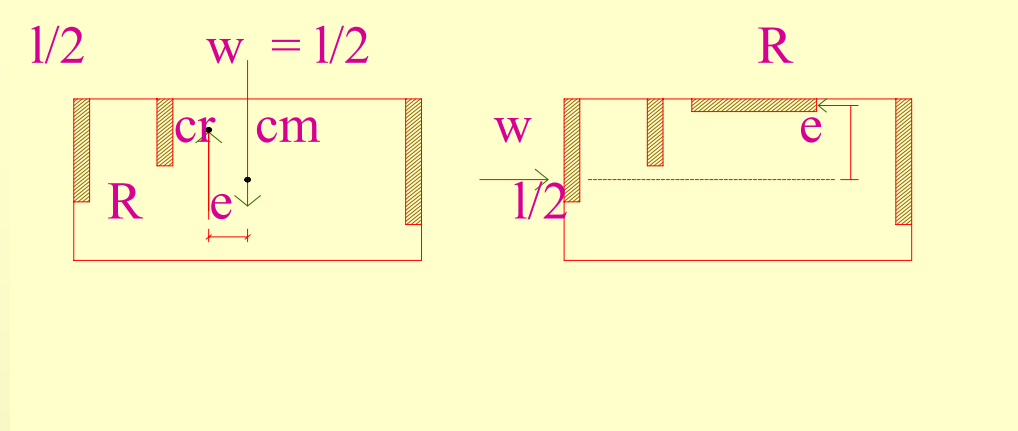
Forming stiffening piers at [7] m centres



# Crack width Classification

Category	Damage Extension	Action
0 No Damage	Hairline crack widths 0.1mm	No action needed
1 Light non-structural damage	Fine cracks on plaster. Typical crack widths up to 1 mm	Not necessary to evacuate the building.
2 Moderate structural damage	Small cracks on masonry walls. Generalized failures in non-structural elements such as cornices and chimneys. Typical crack widths up to 5mm.	Not necessary to evacuate the building. Ensure conservation, such as external re-pointing to and erasing/adjusting of sticky doors
3 Severe structural damage	Large and deep cracks, in masonry wall, chimneys, tanks, stair. The structure resistance capacity is partially reduced. Typical cracked widths exceed 15mm.	The building must be evacuated and shored. It can be re-occupied after retrofitting.
4 Heavy structural damage	Wall pieces fall down, interior and exterior walls break and lean out of plumb. Typical crack widths exceed 25mm.	The building must be evacuated and shored. It must be demolished or major retrofitting work is needed before being re-occupied.

# FIG 4 - Accounting for Torsional Diaphragm effects



Calculated Torsion  $M_1 = W_e$   
distributed into 3 walls according  
to angular rotation and displacement.

$M_1 = W_e$  (distributed into the  
orthogonal walls by couple  
action)

The distribution of the total base shear may be modified where the shear is  
neither reduced more than 30% or increased more than 50% (EC8)

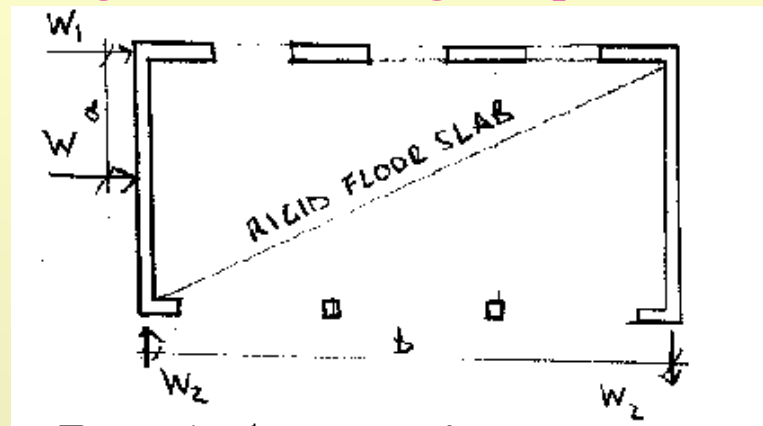
EC6 states that due to reduced stiffness due to cracking 15% re-  
distribution permissible.

<b>BICC Building Industry Consultancy Council</b>	<b>Project</b> STRUCTURAL REGIDITY – CPD MASONRY	<b>Job ref</b>
	<b>Part of Structure:</b> DISTRIBUTION INTO SHEAR WALLS	<b>Sheet No</b> PO1
	<b>Drawing ref:</b> Done by DHC	<b>Date:</b> 02/02

<b>Calculations</b>	<b>Output</b>
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## OPEN FRONTED BUILDINGS

(frequently employed on the grd. Flr with large shop windows)



The relatively thin columns at front are of little use in resisting horizontal load.

The total horizontal force  $W$ , is resisted by back wall if strong enough – where  $W_1 = W$

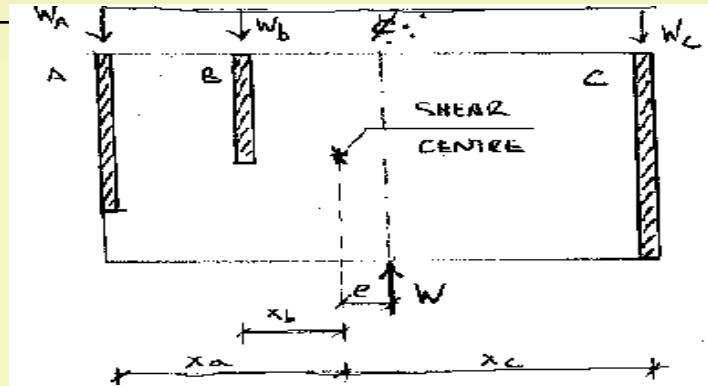
Then by couple action

$$W_a = W_2 b$$

$$W_2 = W_a / b$$

<b>BICC Building Industry Consultative Council</b>	<b>Project: STRUCTURAL RIGIDITY CPD MASONRY</b>	<b>Job ref:</b>
	<b>Part of Structure: DISTRIBUTION INTO PARALLEL SHEAR WALLS</b>	<b>Sheet No: Po2</b>
	<b>Drawing ref:</b> Done by: DHC	<b>Date 02/02</b>

<b>Calculations</b>	<b>Output</b>
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Because of bending & shear the walls deform as cantilevers, with equal deflections at slab level.

The shear deflection is normally neglected if height:width >5

The Shear Centre is the centroid of MI's.

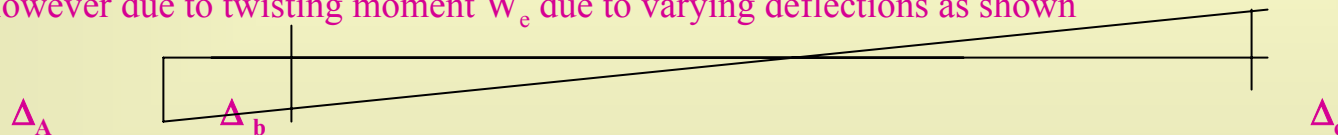
In a symmetrical distribution

$$W_A = \frac{W I_A}{\Sigma I}$$

$$W_B = \frac{W I_B}{\Sigma I}$$

$$W_C = \frac{W I_C}{\Sigma I}$$

However due to twisting moment  $W_e$  due to varying deflections as shown



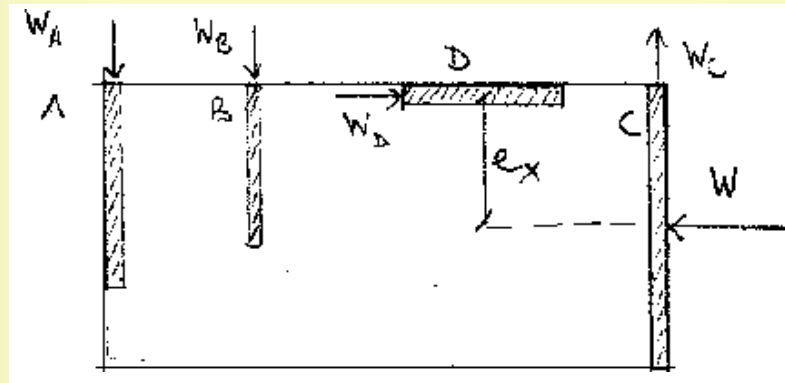
The adjusted loading works out at

$$W_n = \frac{W I_n}{\Sigma I} \pm \frac{W e x_n I_n}{\Sigma I x^2}$$

**Ref:**  
An  
introduction  
to load  
bearing  
brick design  
A.W.  
Hendry

<b>BICC Building Industry Consultative Council</b>	<b>Project:</b> STRUCTURAL RIGIDITY – CPD MASONRY	<b>Job Ref:</b>
	<b>Part of Structure:</b> LONGITUDINAL SHEAR WALL DISTRIBUTION	<b>Sheet No.</b> P03
	<b>Drawing ref:</b>	<b>Done by:</b> DHC <b>Date:</b> 02/02

<b>Calculations</b>	<b>Output</b>
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The horizontal load  $W$  may be resisted by Wall D.  
 Because of the eccentricity  $e_x$ , a couple produces a moment  $We_x$  to be resisted by walls A, B & C given by:

$$\frac{W_n}{\Sigma I x^2} = \frac{We X_n I_n}{\Sigma I x^2}$$

where  $e$ ,  $x_n$  are as defined before