KTP – CPD for PERITI

THE USE OF LOCAL SUSTAINABLE MASONRY AS A STRUCTURAL MATERIAL

MODULE II – STRUCTURAL INTEGRITY OF MASONRY

dhi PERITI
Architects | Structural, Civil, Municipal Engineers |
Valuers | Quantity Surveying Services

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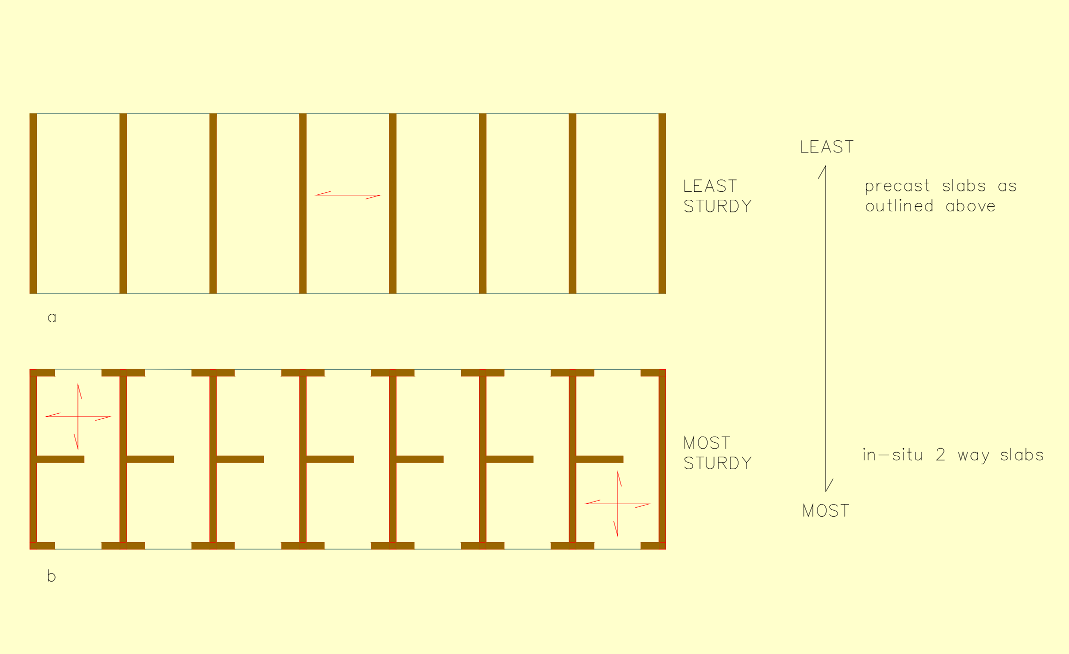
STABILITY - FIG. 1



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

Table 1 - Wind Pressure for the Maltese Islands in KN/m^2 for various building heights & terrains for a basic wind speed of 47m/s, where the greater horizontal or vertical dimension does not exceed 50m, as per CP3:ChV.

H – m	***Sea front with a long fetch***		***Countryside with scattered wind breaks***		***Outskirts of towns and villages***		***Town centers***	
	cladding		***cladding***		***cladding***			***cladding***
3 or less	1.05	1.12	0.90	0.97	0.81	0.86	0.70	0.76
5	1.12	1.19	1.00	1.07	0.88	0.95	0.74	0.81
10	1.28	1.35	1.19	1.26	1.00	1.05	0.84	0.90
15	1.34	1.39	1.28	1.35	1.12	1.19	0.93	1.00
20	1.36	1.43	1.32	1.39	1.22	1.28	1.01	1.07
30	1.42	1.47	1.39	1.44	1.31	1.36	1.15	1.21
40	1.46	1.51	1.43	1.48	1.36	1.42	1.26	1.31
50	1.49	1.54	1.46	1.49	1.40	1.46	1.32	1.38

For Structural Eurocodes, 90% of the above values to be used

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 34KN/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 34KN/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   or 100KN/m length

  where A is the area in mm^2

- Horizontal Tile – in KN, is the lesser of:

  $F_t = 20 + 4\,N_s$ (where N_s is the no of storeys)

  or 60 KN

- Internal Ties in KN/m

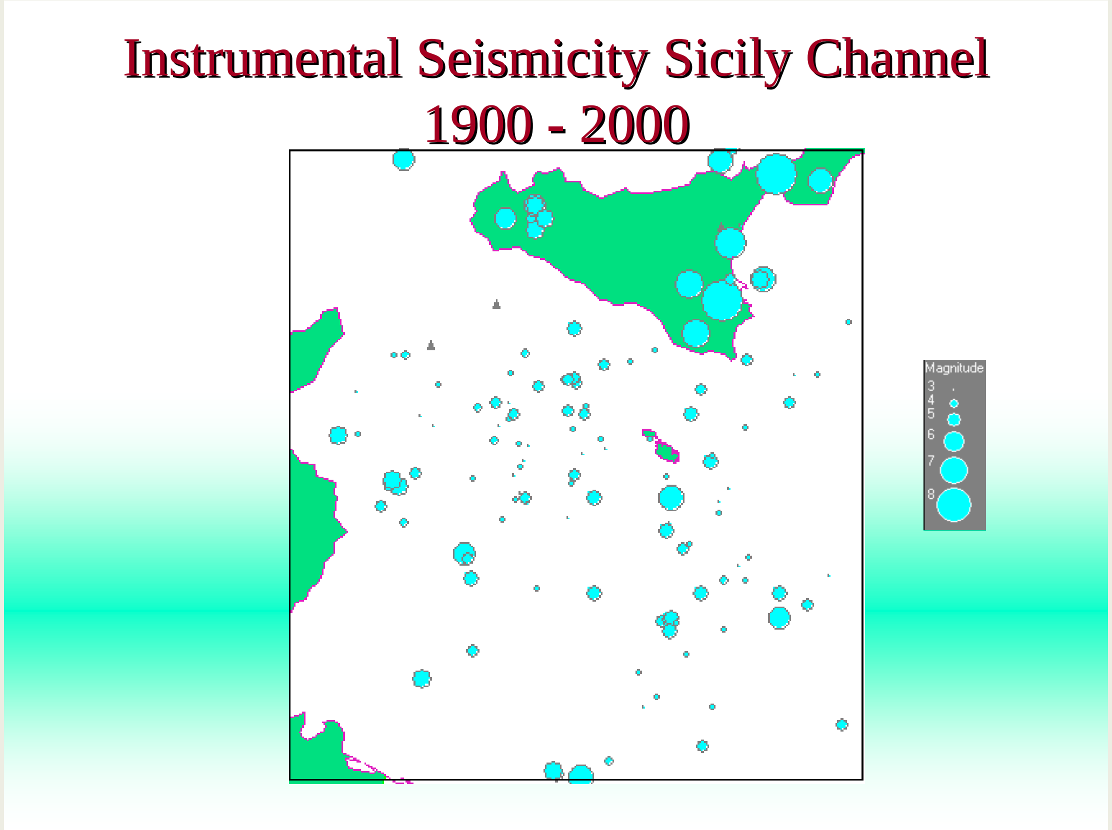
  $f_t' = F_t\,\{(G_k+Q_k)/7.5\}\ X\ L_a/5$

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

  $2F_t$ or $(L/2.5)\,F_t$

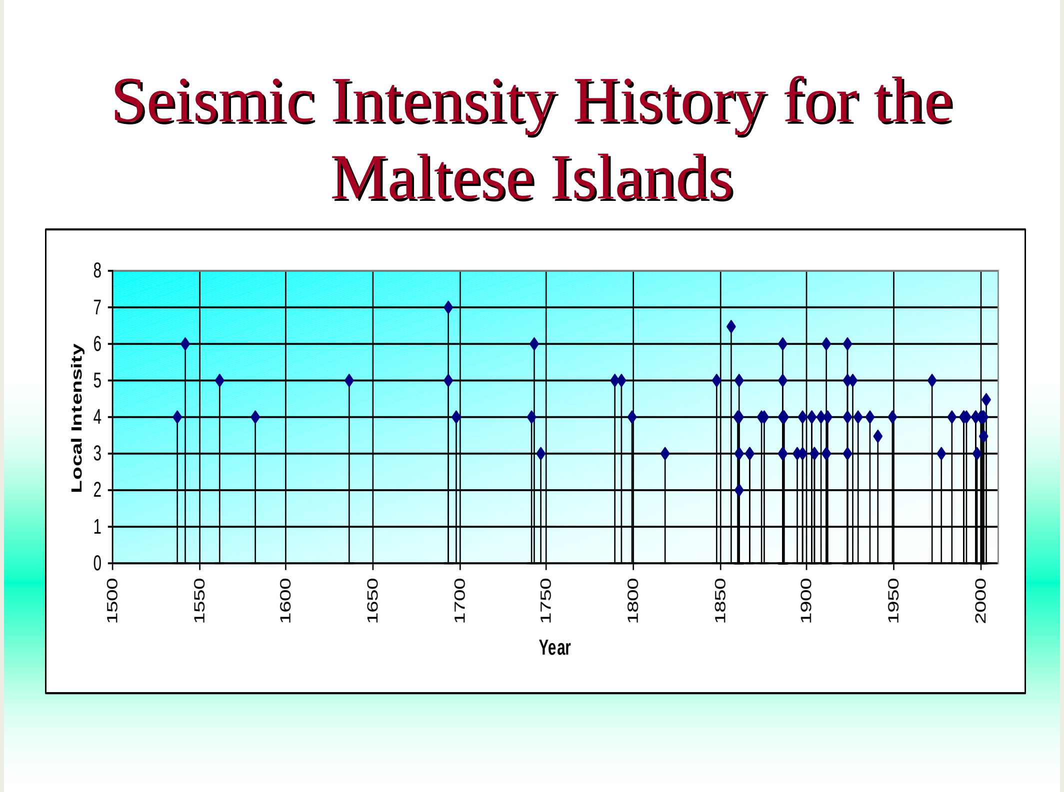
The tie force is based on shear strength or friction

INSTRUMENTAL SEISMICITY SICILY CHANNEL 1900-2000 – FIG. 2



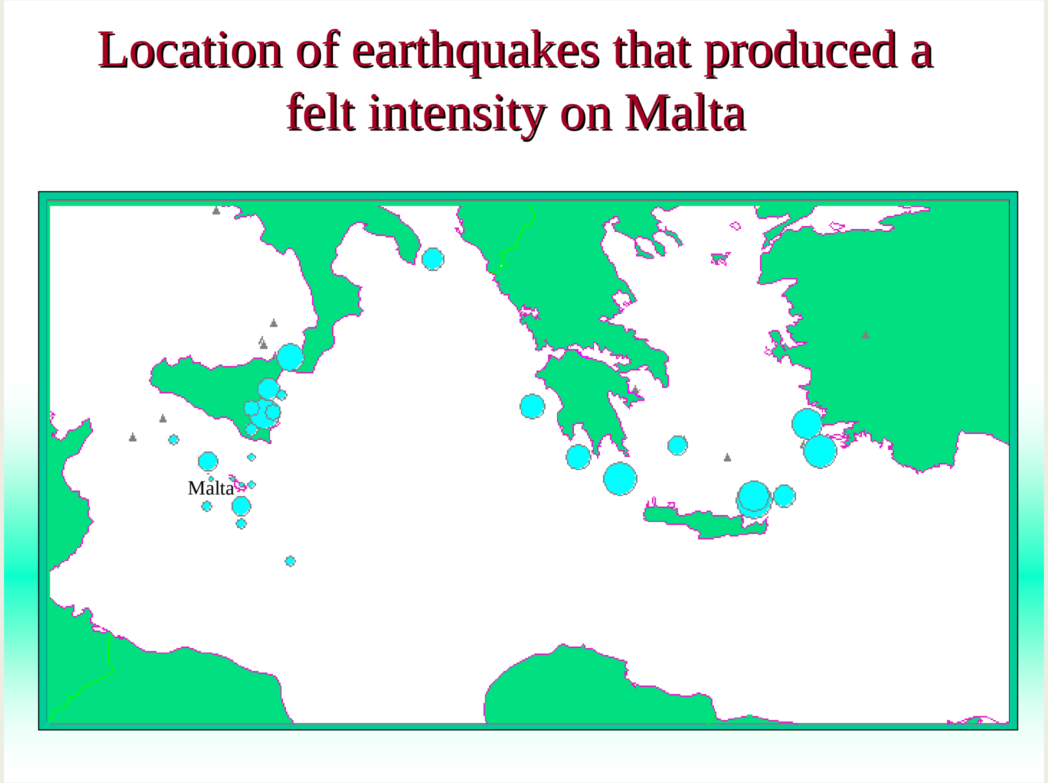
Source: ISC Bulletin, INGV, EMCS

SEISMIC INTENSITY HISTORY FOR THE MALTESE ISLANDS – FIG. 3



Source: Pauline Galea

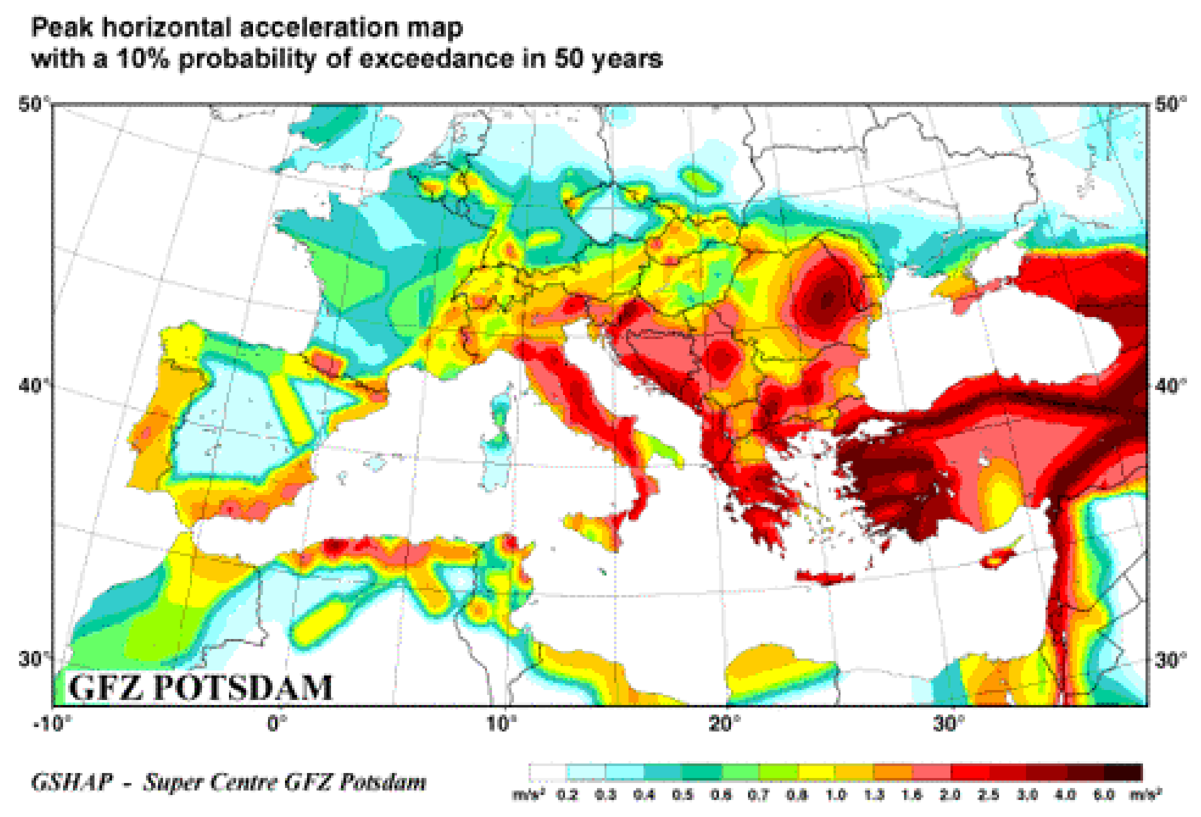
LOCATIONS OF EARTHQUAKES THAT PRODUCED A FELT INTENSITY ON MALTA – FIG. 4



Location of earthquakes that produced a felt intensity on Malta

Source: Pauline Galea

GSHAP – (Global Seismic Hazard Assessment project) map for Europe – FIG. 5



Malta is a green colour corresponding to 0.05g – 0.06g. But the data on which this was complied was probably very sparse for Malta

Malta's Seismic Zoning - EC8

- Design grd. Acceleration for a return period of [475] yrs (EC8) taken at 0.06g (being the ground motion level which is not going to be exceeded in the 50 years design life in 90% of cases

Table 2

MM – Earthquake Intensity	Return Period (years)	Base Shear Design % of g
VI	125	2-5
VII	1000	5-10
VIII	10,000	10-20

- Defined as a low seismicity zone as <0.10g but > 0.04g EC2 concrete provisions to be catered for not EC8

MASONRY DESIGN CRITERIA FOR ZONES OF LOW SEISMICITY (EC8)

1. Shear walls in manufactured stones units

   $t \geq [175]$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 seismieity 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.

Table 3 – Classification of Building according to anticipated Earthquake Intensity Damage

Type	**Description**	**Base shear design % of gravity**
A	**Building of fieldstones, rubble masonry, adobe and clay**	**0.5%**
B	***Ordinary unreinforced brick buildings, buildings of concrete blocks, simple stone masonry and such buildings incorporating structural members of wood;***	***0.7%***
C	***Buildings with structural members of low-quality concrete and simple reinforcements with no allowance for earthquake forces, and wooden buildings, the strength of which has been noticeable affected by deterioration;***	***0.9%***
D_1	***Buildings with a frame (structural members) of reinforced concrete***	***2-3***

Buildings found in Malta are mostly found in types C & D, buildings deteriorated at B. Further buildings classified as D_2 ***up to*** D_5 ***with a*** D_5 ***building frame able to withstand a 20% gravity base shear.***

Table 4 – Mean Damage Ratio (MDR) & Death Rates for building types B & C founded on rock

Building Type	**B**			**C**		
Earthquake Intensity MM	MDR	Death Rate	Mean damage costs as % of re-building costs	**MDR**	Death Rate	Mean damage costs as % of re-building costs
5	2%	-	2.5%	**-**	-	-
6	4%	-	6%	**1%**	-	1.25%
7	20%	0.03%	40%	**10%**	-	15%
8	45%	1%	135%	**25%**	0.4%	62.5%

Source: Swiss Re (1992)

For a type ‘B’ building non structural damage would amount to 50% of MDR, increasing to 70% for a type ‘C’ building

As the quality of a building goes up, the contribution of non-structural damage increasing, the death rate reduces, but a higher number of injuries occur

Table 5 – Amended damage Ratio Matrix for Higher Irregularity & Asymmetry founded on rock

Building Type	C	D_1
EARTHQUAKE INTENSITY		
V	10%	5%
VI	30%	18%
VII	60%	40%
VIII	100%	72%
IX	100%	95%

If founded on clay move up to higher intensity if on fill material to a further higher intensity

TABLE 6 - DAMAGE PROBABILITY MATRIX FOR BUILDING (DPM)

Damage class % of value			Mean Damage Ratio (%)									
			1.5	3	5	10	25	37.5	50	60	70	85
0	- 1.5	(A)	83	73	60	36	9	2				
1.5	- 3	(B)	17	25	26	23	9	3				
3	- 6	(C)		2	10	18	11	5	2			
6	- 12.5	(D)			3	12	18	12	6	2	1	
12.5	- 25	(E)			1	8	24	24	15	7	3	
25	- 50	(F)				3	19	28	29	23	18	10
50	- 100	(G)				1	10	29	48	68	78	90

Source : Swiss Re (1992)

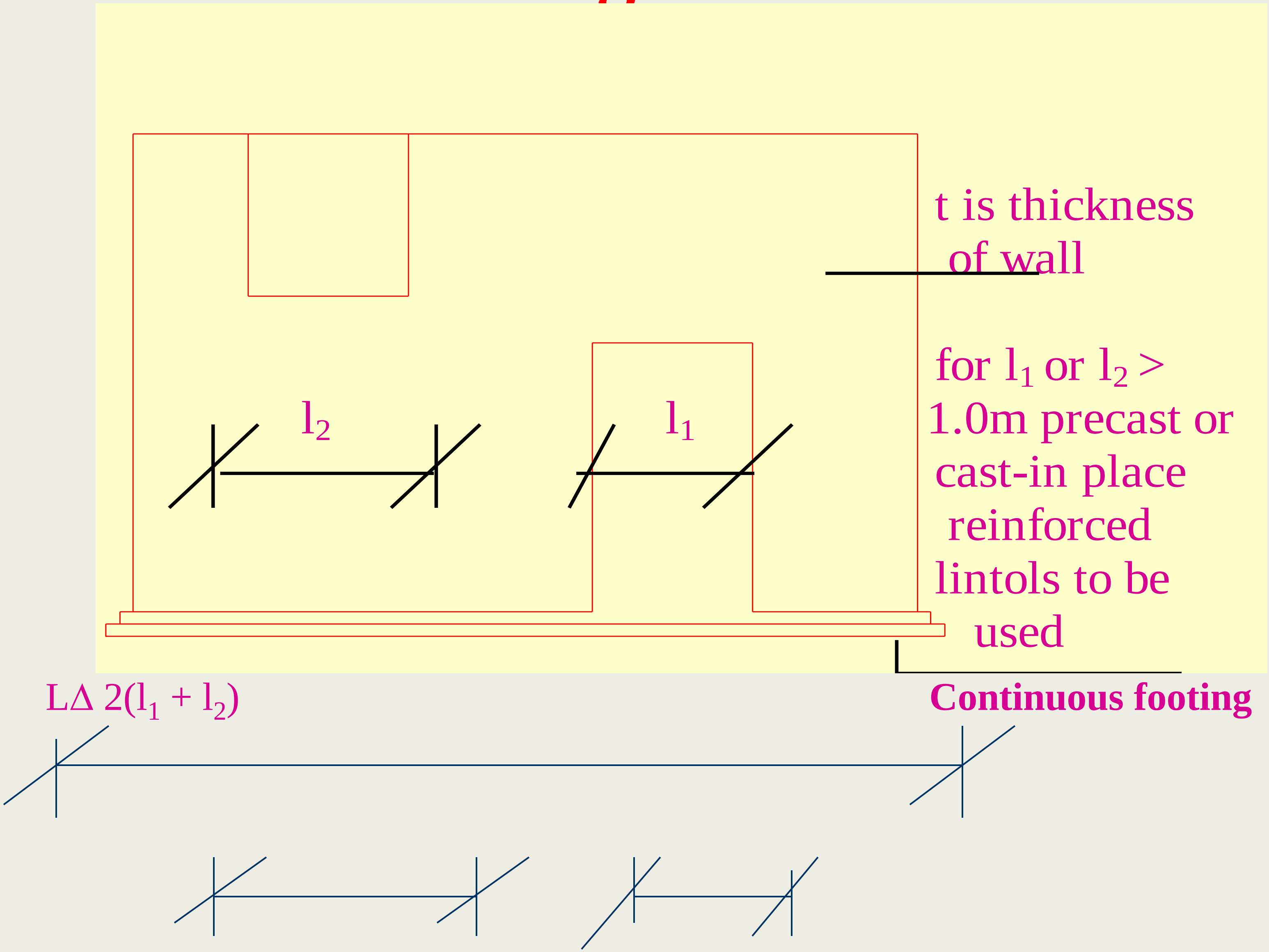
TABLE 7 - PERCENTAGE OF BUILDINGS WIH 80-100% DAMAGE DEPENEDING ON MDR

MDR	10	20	30	40	50	60	70	80	90
Percentage	0.25	3.5	10	20	30	45	56	70	85

Source : Swiss Re (1992)

As a rule of thumb about 1/4 - 1/8 of the population in the 80% - 100% damage class will be killed

Masonry Improved Sturdiness for Aseismic Design - FIG. 6



t is thickness of wall

for l_1 or $l_2 >$ 1.0m precast or cast-in place reinforced lintols to be used

Continuous footing

Example of overcoming unsymmetrical requirements when large opening required on one side FIG. 7

Forming stiffening piers at [7] m centres

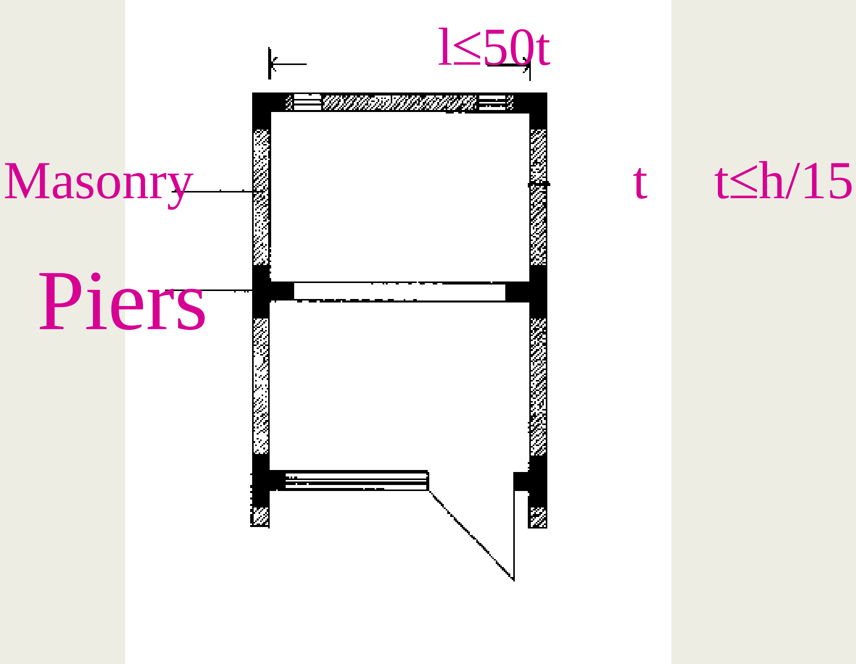
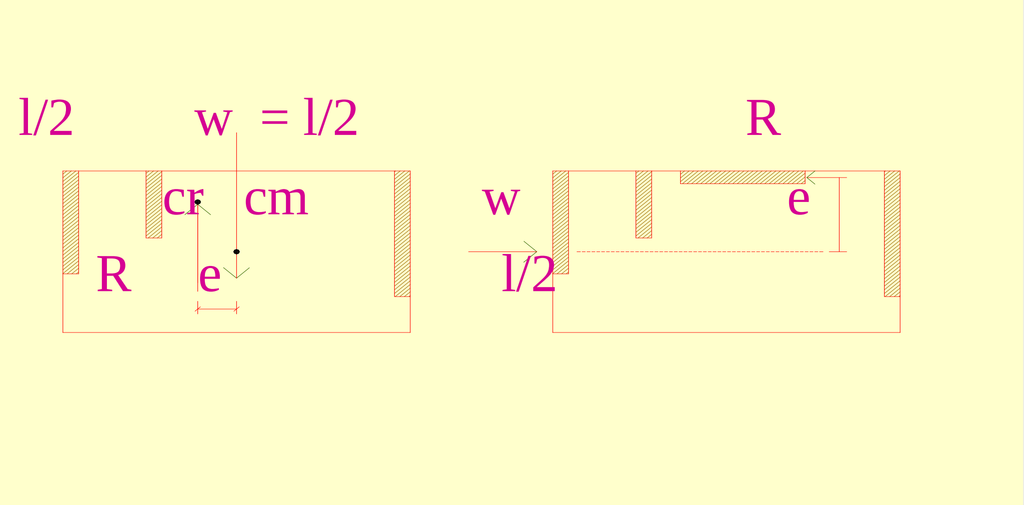


Table 8 - Crack width Classification

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.

Accounting for Torsional Diaphragm effects - FIG. 8



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)

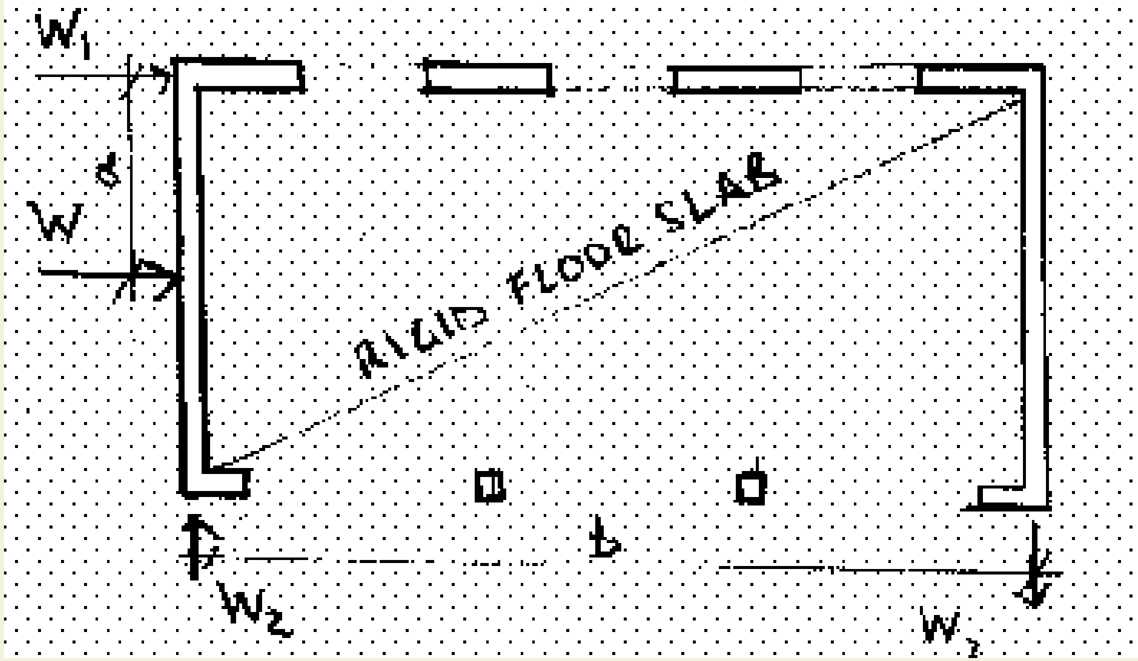
The distribution of the total base shear may be modified where the shear is neither reduced more than 30% or increased more than 50% (EC8)

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

FIG 9

OPEN FRONTED BUILDINGS:

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



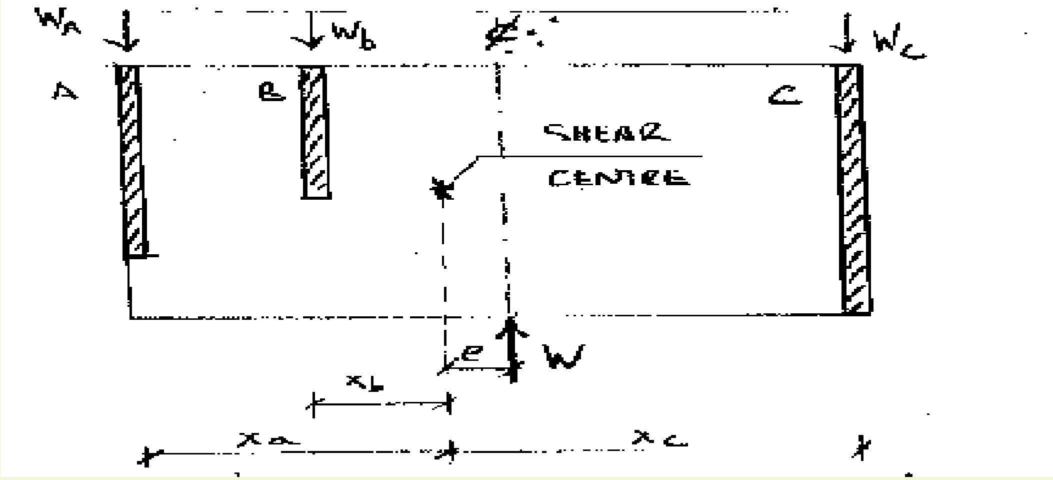
The relatively thin columns at front are of little use in resisting horizontal load.

The total horizontal force W, is resisted by back wall if strong enough – where $W_1 = W$
then by couple action
$W_a = W_2 b$
$W_2 = W_a / b$

FIG 10

Calculations

Output



Because of bending & shear the walls deform as contilevers, with equal deflections at slab level.
The shear deflection is normally neglected if height:width
The Shear Centre is the centroid of MI's
In a symmetrical distribution

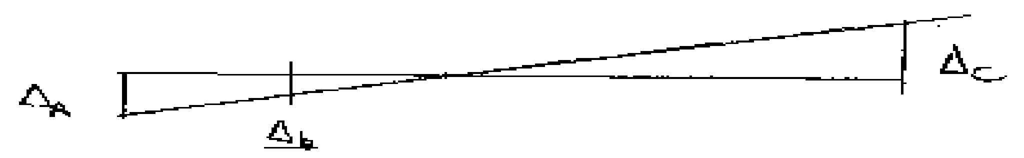
$W_A = WI_A/\Sigma I$

$W_B = WI_B/ \Sigma I$

$W_C = WI_C/ \Sigma I$

However, due to wisting moment We due to varying deflections as shown

The adjusted loading works out at:



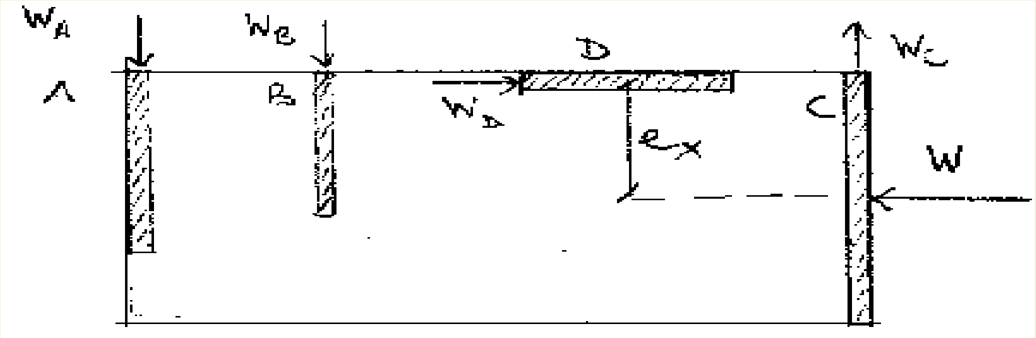
$$W_n = \frac{WI_n}{\Sigma I} \pm \frac{Wex_nI_n}{\Sigma I\ x^2}$$

(Ref: An Introduction to laoding bearing brick design A.W Hendry)

FIG 11

Calculations

Output



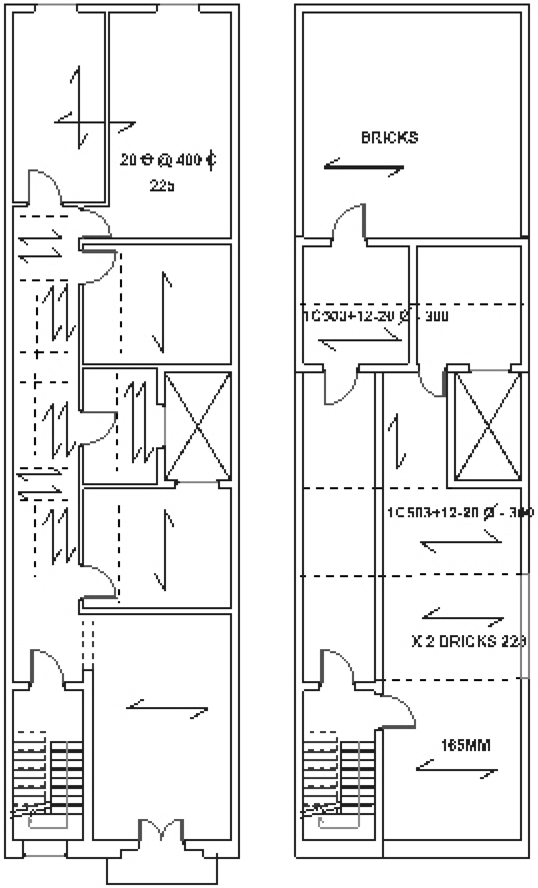
The horizontal load W may be resisted by Wall D.

Because of the eccentricity e_x, a couple produces a moment We_x to be resisted by walls A,B & C given by:

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

where e, x_n are as defined before

FIG 12


20 ⊖ @ 400 ¢
225
BRICKS
1C 503+12-20 Ø - 300
1C 503+12-20 Ø - 300
X 2 BRICKS 220
165MM