BUILDING ADDITIONAL FLOORS/PENTHOUSES ON EXISTING CONSTRUCTION WITH PRECAST PLANKS AT GROUND FLOOR

– THE STRUCTURAL IMPLICATIONS

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BICC – CPD 15/02/2008

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

PRELIMINARY DISCUSSION

- Plan layouts of existing
- Structural details

  (possible supply of pre-stressed slabs receipts)
- MEPA LEVY Lm350

  INFRASTRUCTURAL Lm425

  Lm775

CAR PARKING Lm500 X No?

LOAD PATH ANALYSIS

- Proprietary structural slabs in place
- Safe loads, safe shear values
- Increase of load table with time: note probable concrete enhancement of 25% over 1 year & 50% over 10-15 years
- Can arching be considered?

A NOTE ON ARCHING ACTION BICC AIII – 2001 publication

- A very careful assessment of deformations in the structure would be necessary in order to properly assess the loads to be carried to the transfer beam
- When arching/corbelling action of the masonry & composite action between pre-stressed planks and masonry is taken into account, a re-distribution of the loads is obtained
- Adoption of methodology shall be at the discretion of the Perit together with detailing for robustness and serviceability.

Grd Flr - 14crs high garage (1990)

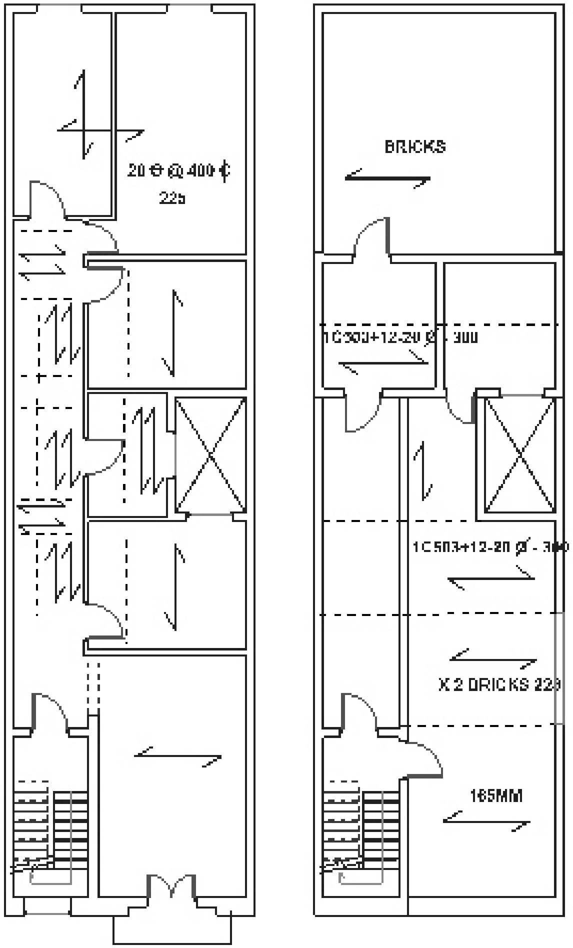
1st flr – 11crs high

Maisonette (1995)

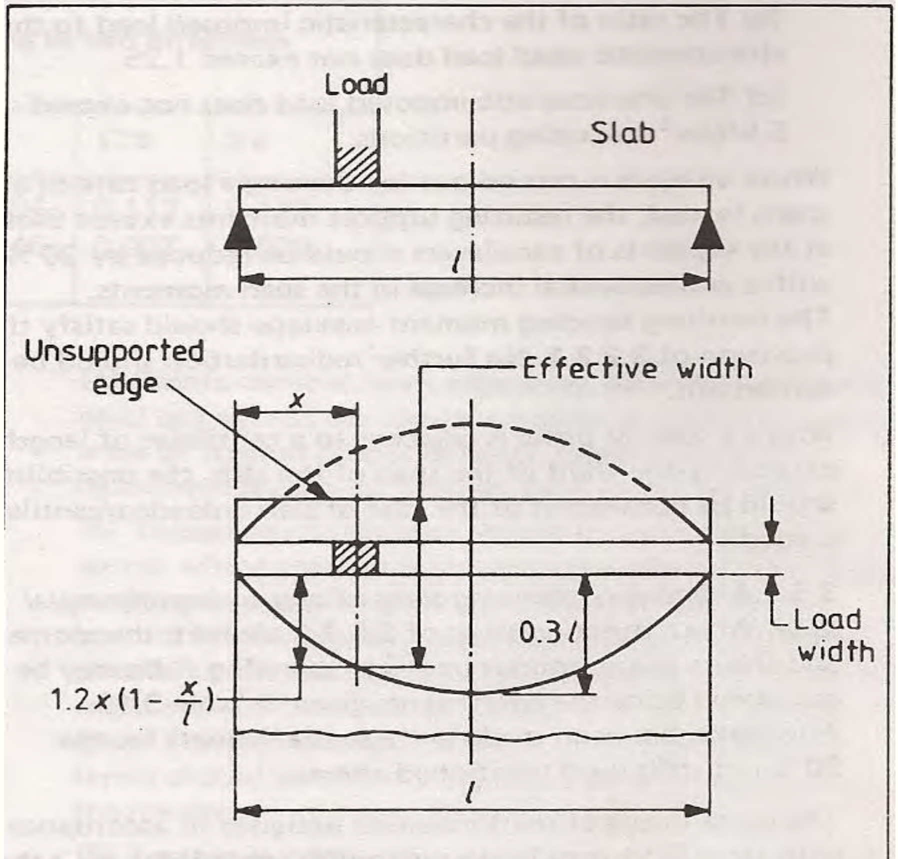
2nd flr – 11crs high

Apartment (1997)

Penthouse (2007)

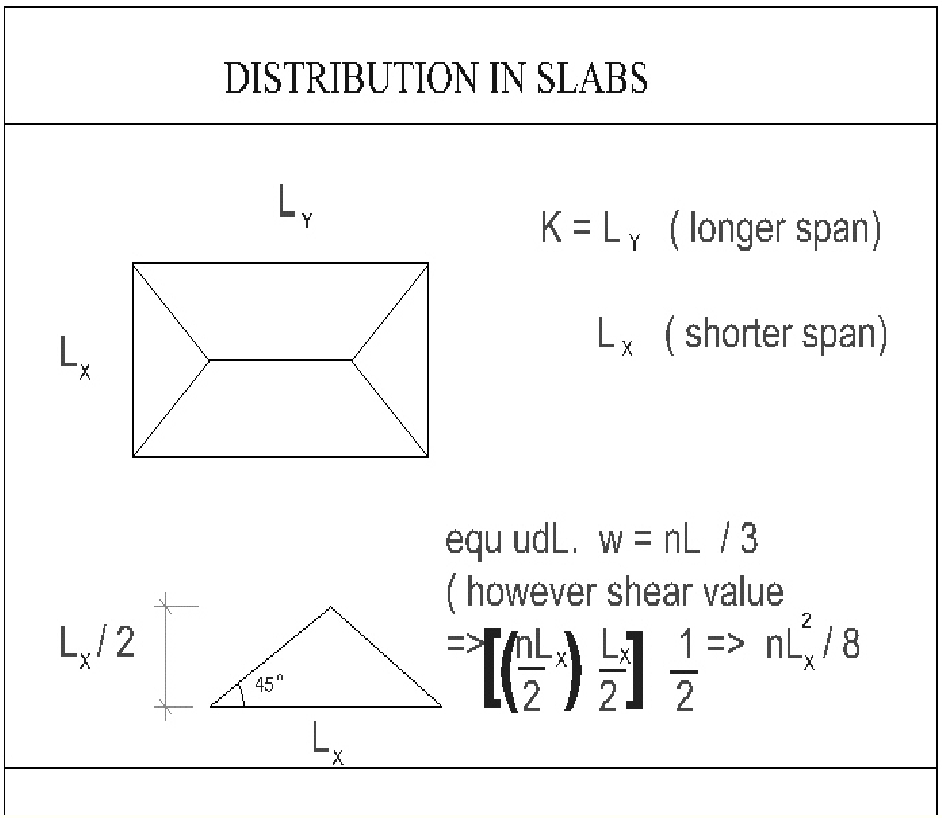


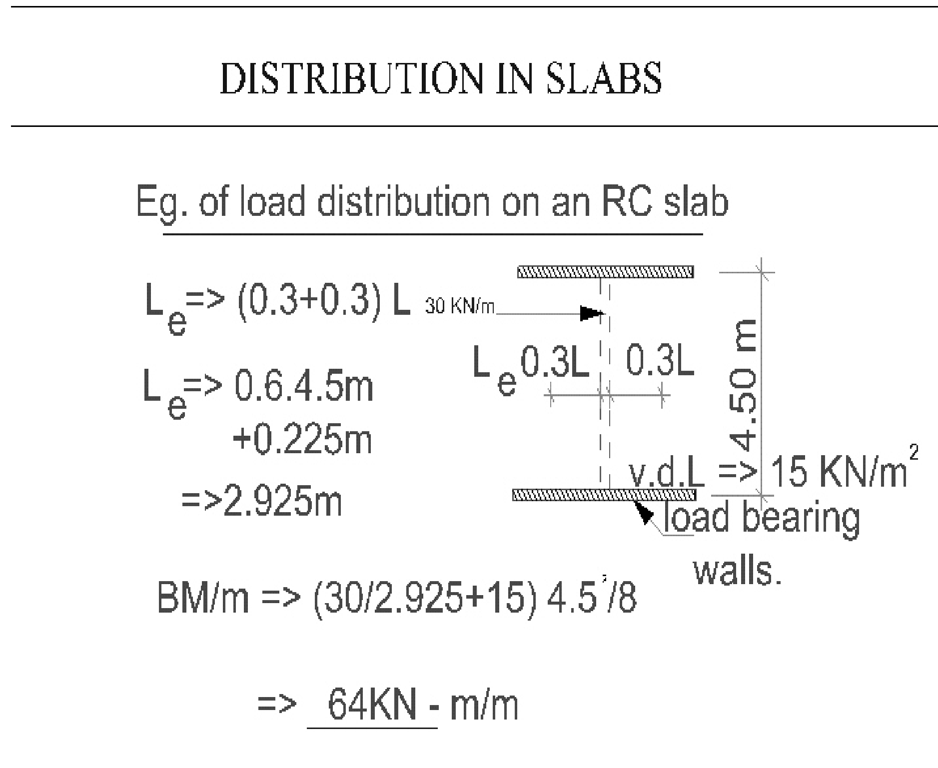
PARTITION LOAD DISTRIBUTION ON RC SLABS (source: BS 8110)

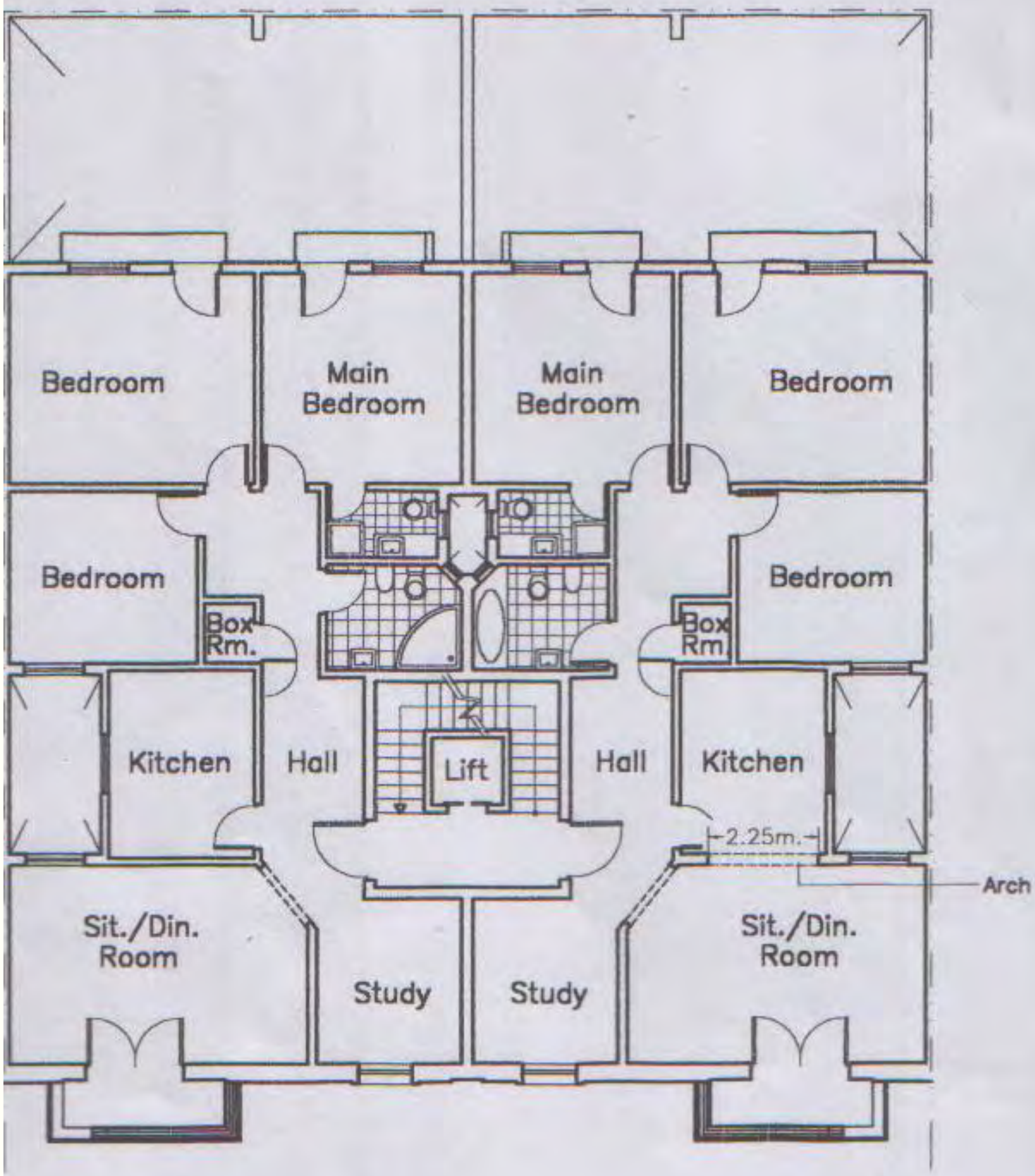


Effective width of solid slab carrying a concentrated load near an unsupported edge

NOTE ALSO 2-WAY ACTION OF SLABS FOR FURTHER DISTRIBUTION ONTO PARTY WALLS






Bedroom
Main Bedroom
Main Bedroom
Bedroom
Bedroom
Bedroom
Box Rm.
Box Rm.
Kitchen
Hall
Lift
Hall
Kitchen
2.25m.
Arch
Sit./Din. Room
Study
Study
Sit./Din. Room

LOAD BEARING PARTITION LOADING ONTO PRE-STRESSED SLABS

- No topping – less of 3 pre-cast units or span/4 on either side (Cl 5.2.2.2.BS8110:Pt:1985)
- Structural topping – less of 4 pre-cast units or span/4 (Cl 5.2.2.3)
- It is advisable to use structural topping with light structural mesh on pre-cast floors, so that risk of cracking in screed and finishings is minimized & diaphragm action ensured

PARTITION DEFLECTIONS ON RC SLABS – REFER TO TSE CORRESPONDENCE

- Code span-to-depth ratios based on final deflection < span/350. Deflection noticeable if it exceeds L/350 with final deflection to partitions & finishes after construction < span/350 or 20mm
- Code then states that damage to partitions, cladding & finishes will generally occur if the deflection exceeds L/500 or 20mm for brittle finishes with L/350 or 20mm for non-brittle finishes
- Concrete blockwalls may seriously be cracked by deflections of span/800 or less (EC2)
- EC2 states to limit deflection after construction to span/500

WALL REINFORCEMENT IN THE LOWER COURSES OF MASONRY PARTITIONS TO LIMIT CRACKING -I

Longitudinal wire – 1.25mm

Cross wire – 0.65 mm

Total thickness 1.5mm

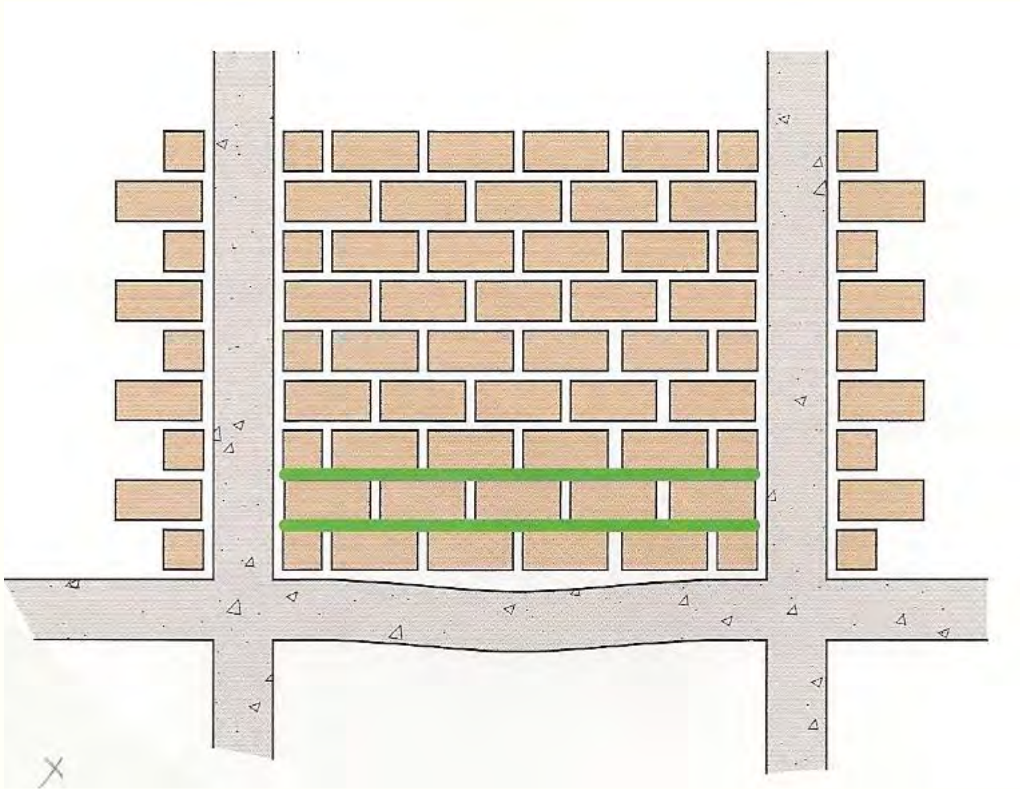
Stainless Steel or Galvanized wire

150 or 180 wide for 180mm/230mm masonry

WALL REINFORCEMENT IN THE LOWER COURSES OF MASONRY PARTITIONS TO LIMIT CRACKING II

http://www.brc-special-products.co.uk

/index.cfm?fuseaction=home.getpage&paget=864&pagever=174



Mesh to be located in lowest bed-joint

AMENDED SPAN : DEPTH RATIOS FOR RC SLABS

BM = WL/8 where W is total load on beam

max stress σ = My/I =(WL/8) y/I = (WL/8)(0.5d)I

Allowable deflection $\alpha = \frac{L}{q} = \frac{5}{384} WL^3/EI = \frac{WL0.5d}{8I} \cdot \frac{5L^2}{24Ed} = \frac{\sigma\, 5L^2}{24ED}$

Span/depth = $\frac{L}{d} = \frac{4.8E}{\sigma q}$ for q = 500

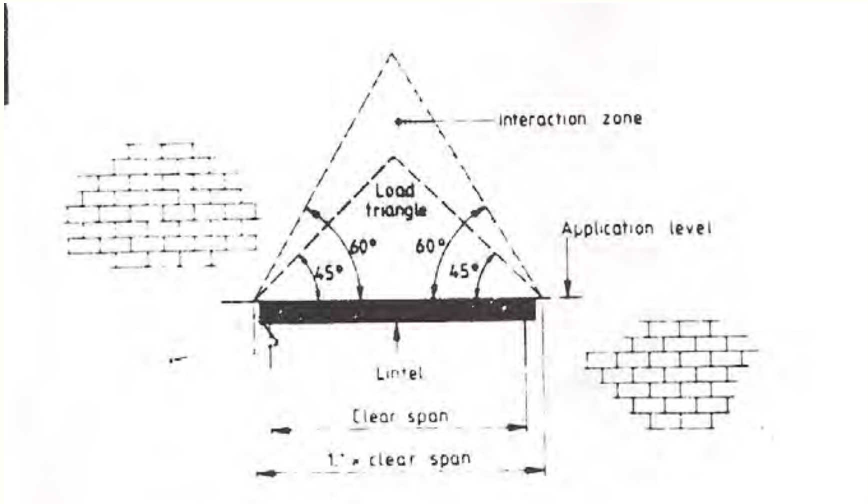
Span/depth = $\frac{4.8 \text{ X } 28KN/mm^2}{25N/mm^2 \text{ X } 500}$ = 10.75

where q is the allowable factor

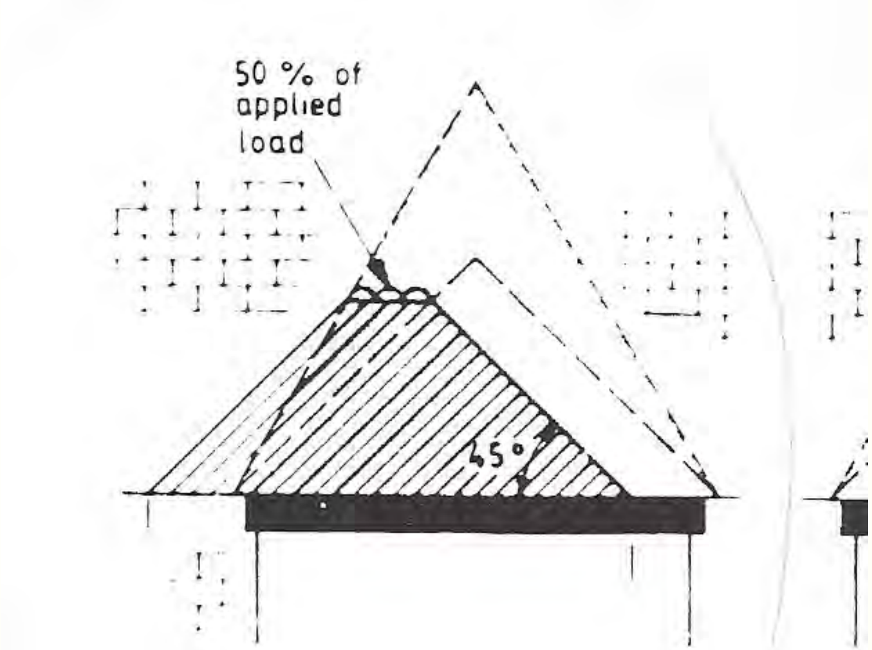
Possibly basic space : depth ratio to be updated to lie in the range of 10-13 for partitions directly supported on slabs instead of 20 as stipulated in BS 8110

LOAD TRIANGLE & INTERACTION ZONES

BS5977:PT1:1981 Lintels



Load triangle and interaction zone



THE COMPOSITE ACTION TO BRICK PANEL WALLS SUPPORTED ON RC BEAM

– RH Wood BRE 1952 - I

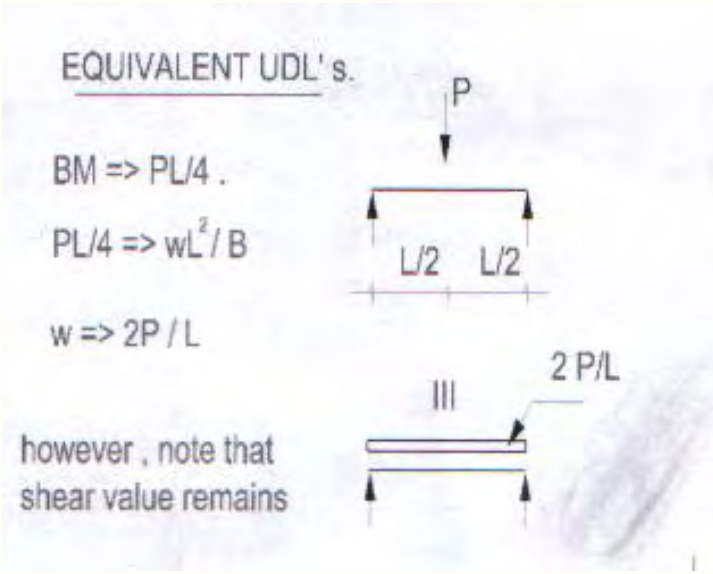
- No shear connection appears necessary when the depth of masonry panel is > 0.6.span
- Arching effects come into play via the creation of a composite beams, much deeper than the existing beam, with the provision of a dpm not preventing this latter effect from occurring
- Testing was carried out to RC beams carrying house walls & spanning short bored piles. However, analysis undertaken caters for any spans to be used

THE COMPOSITE ACTION TO BRICK PANEL WALLS SUPPORTED ON RC BEAM

– RH Wood BRE 1952 - II

- Method for calculating amount of steel reinforcement in the supporting beam is given at design moment of WL/50 where there are door or window opening near the supports and WL/100 for panels where door and window openings are absent or occur at mid-span
- During testings these moments ranged from WL/960 to WL/130
- When using this method the ratio of beam depth to span should range between 1/15 & 1/20

EQUIVALENT UDL'S table 1 BS599



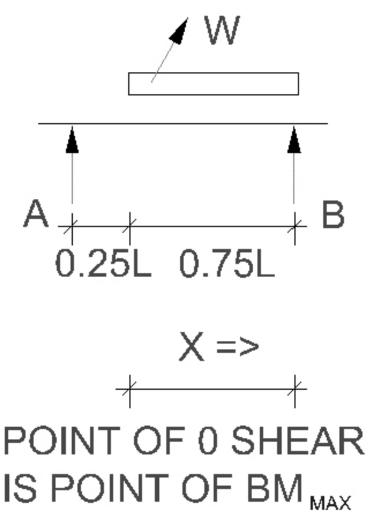
n = 0.75 W = total load

$R_B L = W(0.25+0.75/2)L$

$R_B = 0.625W$

Shear is 0 at (W/0.75L).X =0.625W

X = 0.46875L



$M_x = R_B(0.46875L)-(W/0.75L).0.46875L^2/2$

$M_x = 0.14648WL \cong WL^2/8$

W= 1.172W/L

Eg. LOAD TRIANGLE OR COMPOSITE ACTION METHODS

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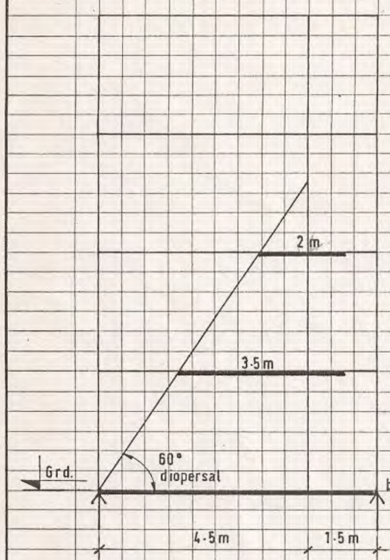
Structural Consultant

Job No.	Sheet No.	Rev.
XX91	Appendix A	

Member / Location LOAD ANALYSIS
Drg Ref.
Made by DHC Date JULY 91 Chd.

Job Title GENERAL

BEAMS AT GRD. FLR at 4·5 m ⊄
DESIGN LOAD taken at 14 KN/m2 to cater for TRANSVERSE PARTITIONS



63KN/m.2.0m/6m => 2I.00KN/m

63KN/m.3.5m/6m => 36.75KN/m

I4KN/m2.4.5m => 63KN/m

20crs I.35KN/cr => 37.8 KN/m

I58.55KN/m

B.M(beam) => I58.55.6²/8 => 7I3.47KN-m

Calculation by method proposed by Wood (8)

loadings from upper flrs. + b/w

(I4KN/m².4.5m + IIcrs.I.35KN/cr I.4) 4flr => 335KN/m

B.M => 63.6²/8 + 335.6²/40

=> 585KN-m

The 2 values for B.M equate for a 6 storey building.

5, Europa Centre, Floriana-Malta. Tel. 233376

FURTHER TO COMPOSITE ACTION IN SHEAR WALL SUPPORT SYSTEMS I
DR Green; IA Maclead; RS Girwidari 1971

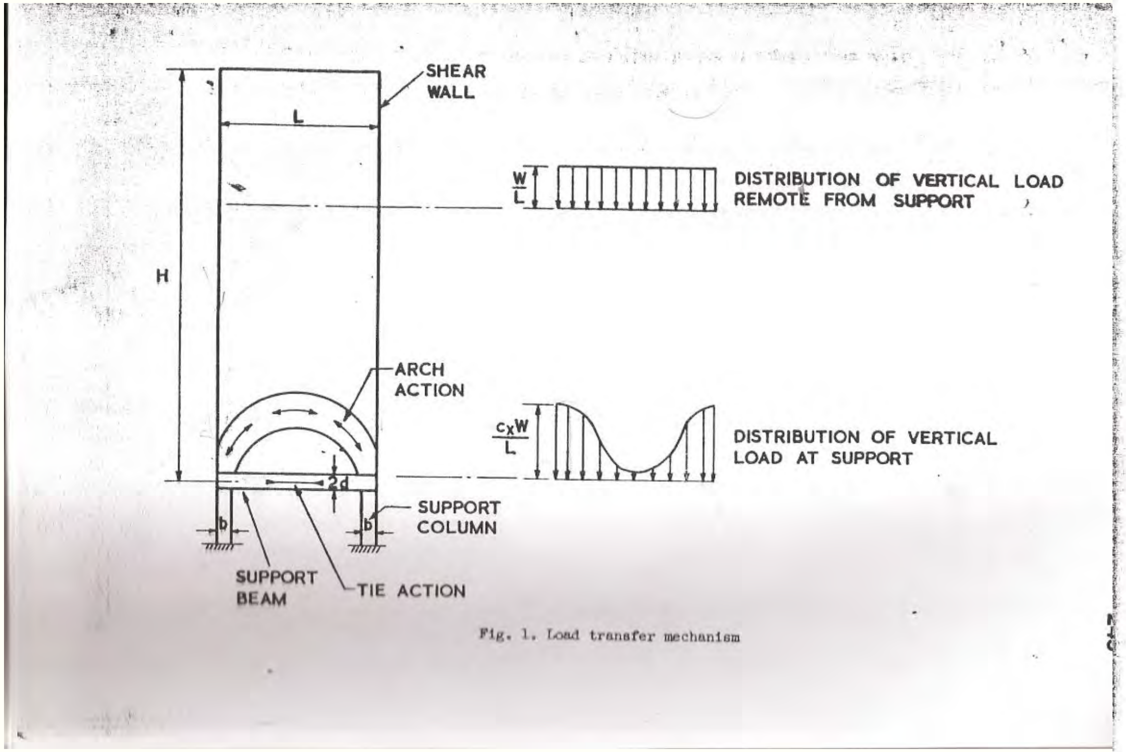


Fig. 1. Load transfer mechanism

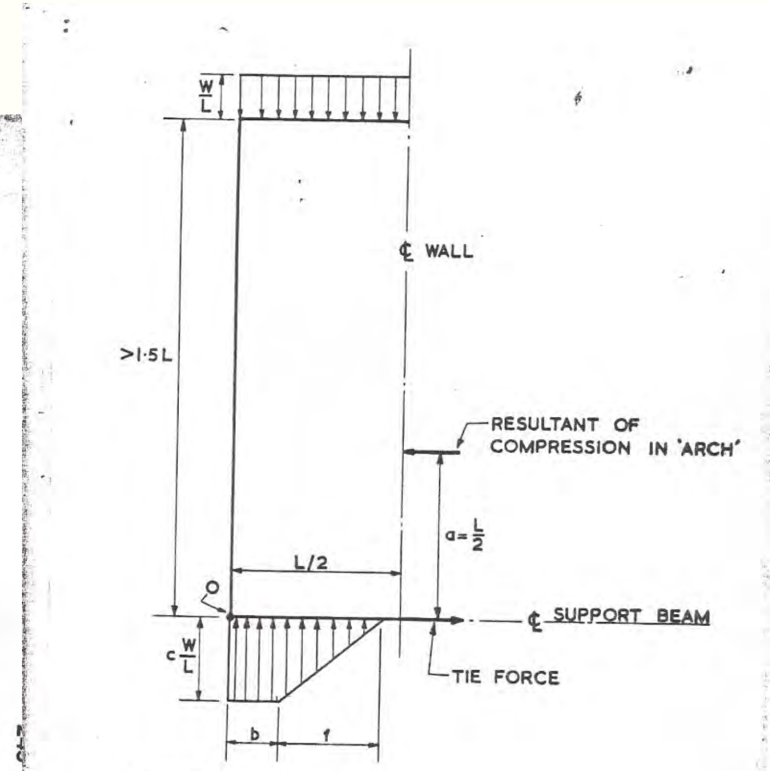


Fig. 4. Idealized force actions

FURTHER TO COMPOSITE ACTION IN SHEAR WALL SUPPORT SYSTEMS II

DR Green: IA Macleod; RS Girwidari 1971

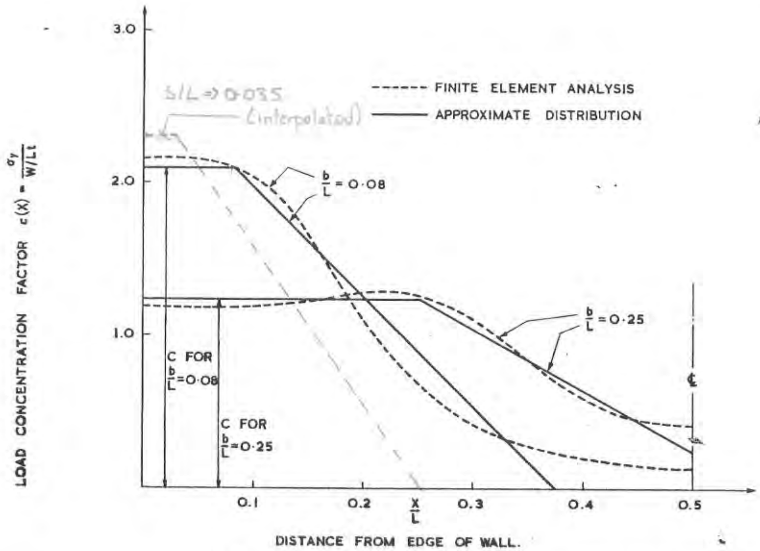


Fig. 2. Vertical load distribution at support beam level

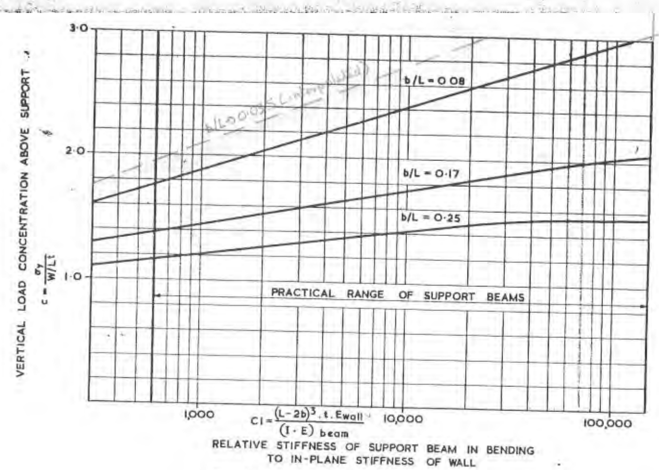


Fig. 3. Load concentration factor

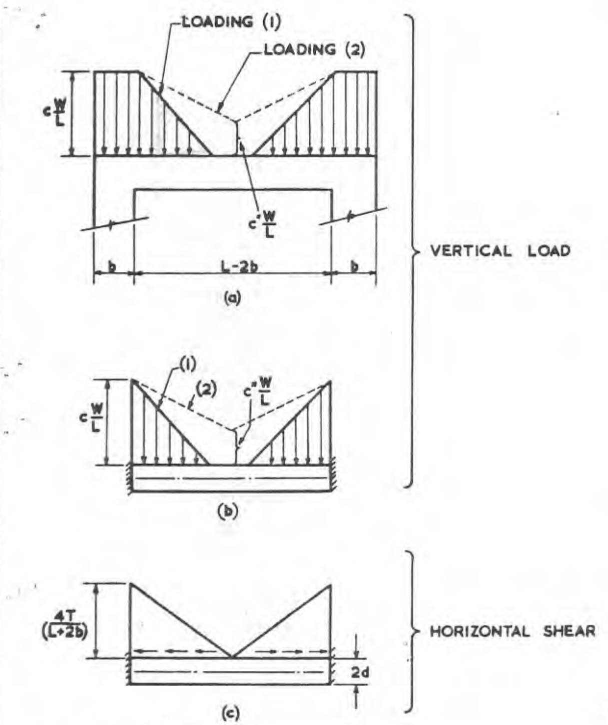


Fig. 5. Force actions for support beam bending moment

FURTHER TO COMPOSITE ACTION IN SHEAR WALL SUPPORT SYSTEMS III
IA Macleod, DR Green 1973

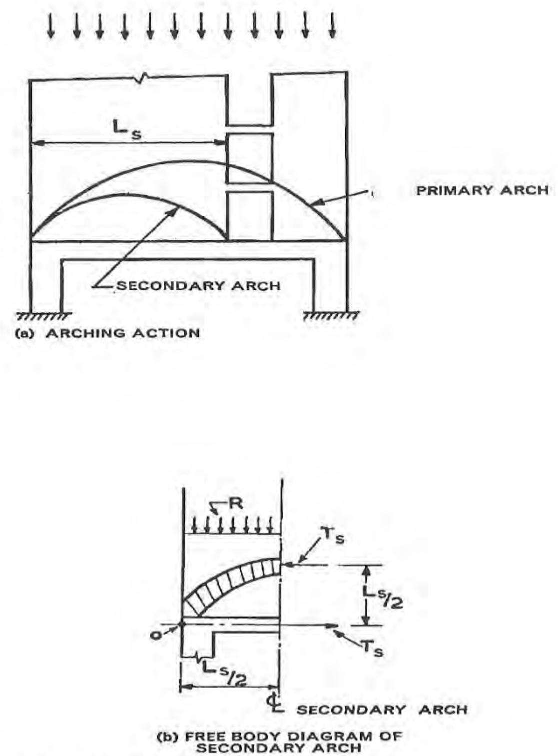


Fig 5. Arch action with off centre openings.

$T = T_p + T_s$

Where $T_s = R/2$

LOCAL DISSERTATIONS ON LOAD DISTRIBUTIONS ON PRECASTING

- Mario Axisa - Load distribution and model analysis
- Stefan Scotto - Finite Element Modelling and analysis based on Mario Axisa's work
- Stephen Grech - Shear strength in concrete joints between hollow core units
- Lara Aquilina - Load distribution and load modelling for hollow core floor units.
- James Mifsud - Load paths in masonry construction : an experimental investigation of hypotheses
- George Schembri - Investigation on the composite action between a masonry wall and its supporting R.C. beam

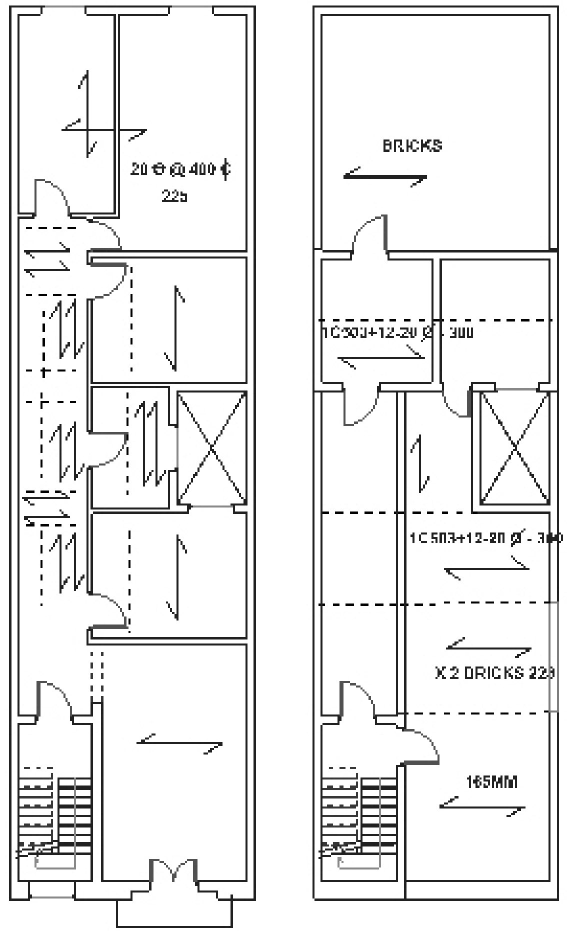

BRICKS
225
165MM

Table 4 - Mortar mixes from BS5628 Pt 1

Mortar designation	Types of mortar (proportion by volume)		Mean compressive strength at 28 days (N/mm^2)	
	Cement: lime: sand	Cement: sand with plasticiser	Preliminary (laboratory) tests	Site tests
(i)	1:0 to ¼: 3	-	16.0	11.0
(ii)	1:1/2:4 to 41/2	1:3 to 4	6.5	4.5
(iii)	1:1:5 to 6	1:5 to 6	3.6	2.5
(iv)	1:2:8 to 9	1:7 to 8	1.5	1.0

The inclusion of lime in our mortars is to be advocated as it improves workability, water retention and bonding properties. Lime mortar is softer and less rigid than cement, and can accommodate slight movement and settlement. Lime is more porous and allows the wall to breathe, reducing the effects of rising damp, applicable in conservatin projects Lime mortar takes longer to achieve strength and so limits the speed of rate of laying.

Table 5 gives the strengths of Maltese Mortars from tests carried out by Debattista (1985)

MORTAR CONSTITUENTS	PROPORTION BY VOLUME	COMPRESSIVE STRENGTH 28DAYS-N/mm^2	FLEXURAL STRENGTH	W/C
Cement, Carolline Sand, Fine Globigerina sand	1:2:10	1.86 (iv)	0.58	3.5
Cement, Carolline Sand, Fine Globigerina Sand	1:2:6	4.48 (iii)	1.30	2.0
Cement, carolline Sand, Coarse Globigerina sand	1:3:12	0.92	0.20	4.4
Cement, White lime, carolline Sand, coarse globigerina sand	1:1.14:2:4	1.43	0.29	2.5
White lime, fine globigerina sand	1:2	1.32	0.56	2.1

LOAD BEARING PROPERTIES OF MASONRY WALL PANELS

a) The horizontal bed joins should be filled completely with mortar. Incompletely filled bed joints may reduce the strength of masonry panels by 33%. Failure to fill vertical joints has little effect on the compressive strength but are undesirable for weather and force, exclusion and sound insulation.

b) Mortar bed joints should not be thicker than 10mm. Bedjoints of 16 –19mm thickness, result in a reduction of compressive strength of up to 25% as compared with 10mm thick joints.

c) Before laying mortar the block is to be well wetted to reduce its suction rate, plus a proportion of lime in the mortar mix will help the mortar mix to retain its water. A high absorbent block will result in a weaker mortar, with a resulting weaker wall panel.

Table 6 - Characteristic Compressive stress f_k of 225mm thick masonry N/mm² for specified crushing strength – as per BS 5638 pt 1

Mortar Designation	*Globigerina*				*Coralline*
	Compressive Strength of Unit (N/mm²)				
	15	***17.5***	***20***	***35***	***75****
I	8.6	9.6	10.6	16.3	27.4
II	7.6	8.4	9.2	13.4	22.6
III	7.2	7.7	8.3	12.2	
IV	6.3	6.8	7.4	10.4	

** as per BS 5628 pt2* *(Source: Structural Integrity Handbook BICC)*

Cachia (1985) noted in testing highest franka crushing value of 32.9N/mm² and the corresponding lowest at 15N/mm²

Table 7 - Characteristic Compressive stress f_k of 180mm thick masonry N/mm2 for specified crushing strength – as per BS 5628 pt1

Mortar Designation	***Globigerina***				***Coralline***
	Compressive Strength of Unit (N/mm²)				
	15	***17.5***	***20***	***35***	***75****
I	9.9	11.0	12.2	18.7	31.6
II	8.7	9.6	10.5	15.4	24.8
III	8.2	8.8	9.5	14.0	
IV	7.2	7.8	8.5	12.0	

** as per BS5628 pt2* (Source: Structural Integrity Handbook BICC)

Shape Factor 265/180 = 1.47

Table (2b)10.6 – 5.2N/mm^2

Table (2k) 2.4 – 10.4/mm^2

Interpolating 5.2 + 5.2, 0.872/1.4 = 8.45N/mm^2

Table 8 – Blockwork Characteristic Strength f_k Data

Blockwork type mm	***Average Characteristic Strength N/mm2***	***Average Coefficient of variation %***	***Period***	***Best Year %***	***Worst Year %***
115	5.86	18.23	1991 1994	1992 13.37%	1991 25.29%
150	7.51	16.25	1991 1996	1993 12.58%	1991 20.28%
225 singlu	7.50	13.01	1991 -1996	1993 9.43%	1996 19.61%
225 dobblu	8.67	12.93	1991 -1996	1995 10.92%	1996 14.86%

Source: Grech (1997)

An important concept to introduce is shell bedding, with mortar laid on the 2 outer edges only. The design strength should be reduced by the ratio of the bedded area to the gross area.

Table 9 - Characteristic Compressive stress f_k of 225 thick concrete hollow blockwork in N/mm²

Mortar Designation	*Compressive Strength of Unit (N/mm²)*							
	2.8	***3.5***	***5.0***	***7.0***	***10***	***15***	***20***	***35***
I	2.0	2.5	3.6	4.4	5.1	6.3	7.4	11.4
II	2.0	2.5	3.6	4.2	4.8	5.6	6.4	9.4
III	2.0	2.5	3.6	4.1	4.7	5.3	5.8	8.5
IV	2.0	2.5	3.1	3.7	4.1	4.7	5.2	7.3

Table 10 - Characteristic Compressive stress f_k of 150 thick concrete hollow blockwork in N/mm²

Mortar Designation	*Compressive Strength of Unit (N/mm²)*							
	2.8	***3.5***	***5.0***	***7.0***	***10***	***15***	***20***	***35***
I	2.6	3.2	4.6	5.4	5.9	6.7	7.4	11.4
II	2.6	3.2	4.6	5.2	5.5	6.0	6.4	9.4
III	2.6	3.2	4.6	5.1	5.3	5.6	5.8	8.5
IV	2.6	3.2	4.1	4.5	4.7	5.0	5.2	7.3

Table 11 - Partial Safety factors γ_m characteristic loading & materials strength for normal design loads.

Ultimate Limit State	BS	EC	
permanent load	1.4	1.35	γ_G
imposed load	1.6	1.50	

Material	*Special Category BS*		*Normal Category BS*		*BS 5628*
Masonry		(EC6/B)		(EC6/C)	
Compression	2.5	(2.8)	3.1	(3.5)	Pt1
Compression/flexure	2.0	(2.8)	2.3	(3.5)	Pt 2
Flexure	2.8	(2.8)	3.5	(3.5)	Pt1
Shear	2.5	(2.5)	2.5	(3.5)	Pt1
Shear	2.0	(2.8)	2.0	(3.5)	Pt 2
Bond	1.5	(2.0)	1.5	-	Pt2
Strength of steel	1.15	(1.15)	1.15	-	Pt 2
Wall ties	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 γ_m of 1.7 and 2.0 for Categories B & C

Table 12 - Design axial loads for various wall types

Material	*Crushing strength N/mm2*	*Mortar type IV KN/m*	*Mortar type III KN/m*	*Morta r type II KN/m*
225 franka	20	537	602	
225 qawwi	75			1640
180 franka	20	493	551	
150 franka	20	469	522	
225 block dobblu	8.5	283	319	
225 block singlu	7	268	297	
150 block	7	217	246	
115 block	5	163	185	
225 infilled block	15	457	522	551
225 infilled block with 12mm bar at 225 centres	15			944
225 infilled block with 20mm bar at 225 centres	15			1206

The above table demonstrates the low load bearing capacity of concrete b/w of crushing strength 7N/mm^2, as being approximately 50% for equivalent thick franka of crushing strength 20N/mm^2.
(Source – Structural Integrity Handbook BICC)