BUILDING DIGEST

CENTRAL BUILDING RESEARCH INSTITUTE, INDIA

REINFORCED BRICK AND REINFORCED BRICK CONCRETE SLABS FOR FLOORS AND ROOFS

Introduction

Reinforced brick (R.B.) and reinforced brick concrete (R.B.C.) can economically be used for floor and roof slabs especially at places where good bricks are available and the cost of aggregate is high. This digest describes the principles of design, materials and workmanship for these constructions.

Reinforced brick work (Fig. 1–a) is practically the same as reinforced concrete in all its essential features except that brick work in cement mortar is substituted for cement concrete. In reinforced brick concrete construction (Fig. 1–b), cement concrete is used in conjunction with bricks. The thickness of concrete is generally 3 to 5 cm and it is laid on top of bricks as also in joints. The compression zone is resisted by concrete alone and bricks may be considered as fillers only since they are generally placed below the neutral axis.

Reinforced brick slabs are easier to construct than reinforced concrete because they do not require the same amount of close and skilled supervision.

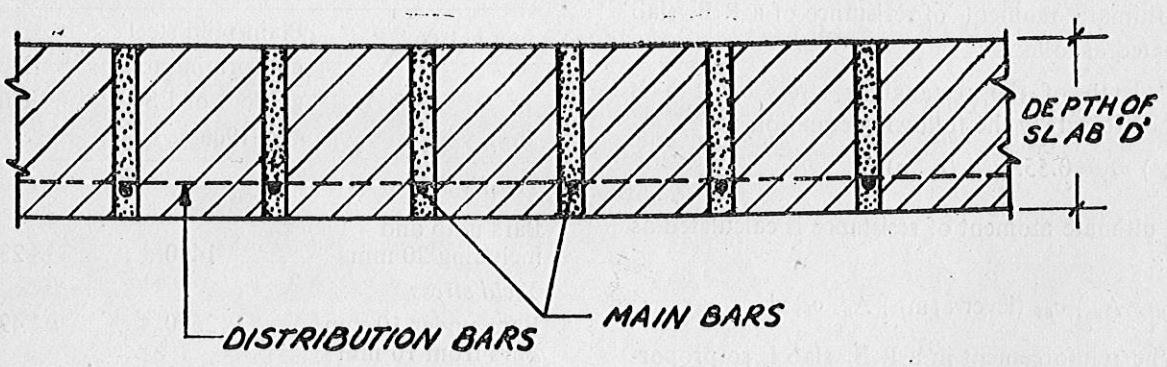
Principles of Design

Reinforced Brick Work

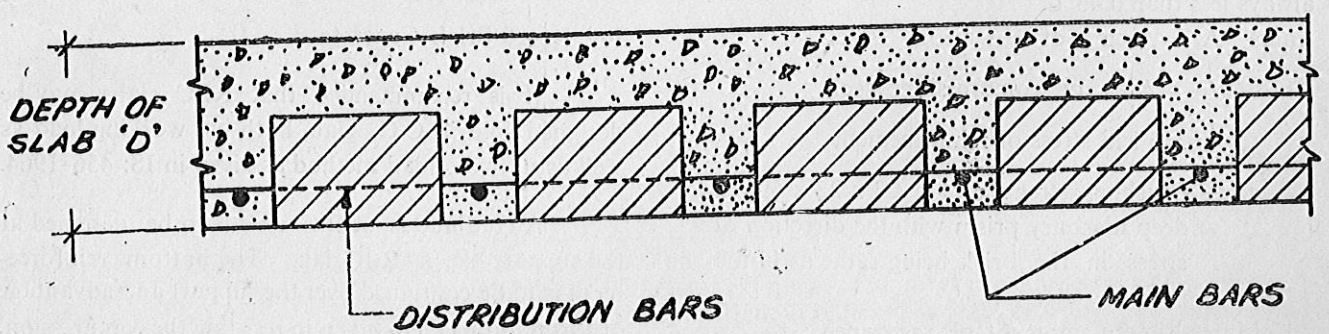
Based on numerous tests on R.B. slabs, both in India and abroad, it has been observed that the behaviour of reinforced brick slab is similar to that of reinforced concrete. The relative magnitudes of shear, tensile and compressive strength of brick masonry are however different from those of reinforced concrete. Within the range of practical applications of reinforced brick slabs, failures are generally by yielding of tensile reinforcement. It is, therefore, recommended that R.B. slabs may be designed by the same methods as followed in R.C.C.

Working Stress Method

In this method of design, the permissible



a—Cross Section of R.B. Slab



b—Cross Section of R.B.C. Slab

Fig.—1 Reinforced Brick and Reinforced Brick Concrete Slabs

TABLE I

Design Factors for R.B. Slabs

Crushing strength of brick (kg/cm²)	Permissible compressive stress in flexure kg/cm² (σ_m)*	Maximum modular ratio	Value of		
			Neutral axis factor 'N'	Lever arm ratio 'J'	Moment factor Q in kg/cm² (Q = 1/2 σ_m JN)
70 to 105	21·0	33	0.33	0.89	3.08
105 to 140	27.0	26	0.33	0.89	3.96
140 to 175	32.0	22	0.33	0.89	4.70
175 to 210	36.5	19	0.33	0.89	5.36
210 to 245	40.0	17	0.33	0.89	5.87
245 to 280	43.5	16	0.33	0.89	6 39

*National Building Code of Canada, 1965.

stresses, modular ratios and other design constants may be taken in relation to the crushing strength of the brick as given in Table 1.

The permissible shear stress of reinforced brickwork and bond stress between mortar and reinforcement may be taken as 2 and 6 kg/cm² respectively. The permissible stresses in reinforcement are given in Table II. The permissible compressive stress in reinforcement may be taken as the compressive stress in the surrounding brickwork at that level multiplied by the modular ratio.

Ultimate Load Method

Ultimate moment of resistance of a R.B. slab is calculated as follows :

1. The depth of the rectangular stress block 'a' is determined to satisfy the following equation :

$$(A_{s_t} - A_{s_c})\ \sigma_{sy} = 0.55.\ \sigma_{mu}\ (b\ .\ a)$$

2. The ultimate moment of resistance is calculated as follows :

$$M_u = (A_{s_t} - A_{s_c})\ \sigma_{sy}\ (\text{lever arm}) + A_{s_c}\ \sigma_{sy}\ d_s$$

The reinforcement in a R.B. slab is so proportioned that the depth of rectangular stress block 'a' is always less than 0.43 d.

where A_{s_t} = Area of tension steel

A_{s_c} = Area of compression steel

σ_{sy} = Yield stress of reinforcement

σ_{mu} = Crushing strength of a 23 x 23 x 69 cm deep masonry prism with the direction of stress in the brick being same as in the slab

M_u = ultimate moment of resistance

b = width of slab considered in the design viz. 100 cm

d = effective depth of the slab section

d_s = distance between centroids of tension steel and compression steel

In a balanced rectangular section--

$$M_u = 0.185\ .\ bd^2\ .\ \sigma_{mu} \text{ and}$$

$$A_{s_t} = 0.236\ .\ bd.\ \frac{\sigma_{mu}}{\sigma_{sy}}$$

3. Shear and bond is checked by the working load method considering the working load and the permissible shear and bond stresses.

TABLE II

Permissible Stresses in Reinforcement

	Plain mild steel conforming to grade I of I.S. : 432-1966	Deformed bars
Tensile stress		
Bars upto and including 20 mm	1400	2300
Yield stress		
Bars under 10 mm	2600	4950
Bars from 10 mm to 20 mm	2600	4250

Reinforced Brick Concrete

It is recommended that RBC slabs may be designed like R.C.C. slab, both by working load as well as ultimate load method as given in IS: 456-1964.

A continuous R.B.C. slab is to be designed at the support like a R.B. slab. The bottom reinforcement is to be continued over the support and advantage of this reinforcement taken in resisting the compression. It is necessary, since reinforced brickwork which takes compression over the support is weaker than R.C.C.

Reinforcement for taking negative moment over the support is to be provided in the top concrete.

A design Table for floor and roof slabs for different spans varying from 2.5 to 4 m has been given in the Appendix. The slabs have been designed for residential loadings. Use of M 150 grade of concrete (corresponding to 1:2:4 nominal mix) has been assumed.

Recommendations for Good R.B. and R.B.C. Work

1. First class bricks having a minimum crushing strength of 70 kg/cm² should be used. Bricks should have smooth rectangular faces with sharp corners and should emit clear ringing sound when struck. Tolerance in dimensions of individual brick should be upto ±3 percent.

2. Over-burnt bricks having any trace of a smooth glaze on the surface should not be used.

3. Medium absorption bricks (about 15 per cent) should be preferred since these develop comparatively high bond strength with mortar.

4. Bricks should be thoroughly wetted and preferably soaked in water before use but at the time of laying it should be ensured that they are skin-dry.

5. Mortar to be used for R.B. work should consist of one part of cement and 3 parts of coarse sand by volume and should be used in the form of grout.

6. The clear cover of mortar or concrete from the underside of the slab should be at least 12 mm or equal to the diameter of the bar, whichever is more. The side cover should be a minimum of 8 mm in the case of R.B. and 12 mm in the case of R.B.C. slab.

7. In the case of R.B.C., the top layer of concrete should be laid simultaneously along with filling of the joints.

8. The spacing of main reinforcement should not be more than three times the effective depth and that of distribution reinforcement, five times the effective depth.

Concluding Remarks

R.B. and R.B.C. slabs are cheaper by about 5–15 per cent as compared to R.C.C. slab based on the prevailing market rates in Northern U.P. The use of ultimate load method of design leads to an economy of 6–8 per cent as compared to working stress method of design. The design procedures described in this digest may therefore be made use of in achieving economy in construction of slabs especially at places where good bricks are locally available. The use of R.B. and R.B.C. slabs is, however, not recommended in coastal areas.

APPENDIX

1. Simply Supported and Continuous Reinforced Brick (R.B) Slab

Span of slab (m)	Thickness (cm)		Steel			
			Main tensile bars		Distribution bars	
	Overall	Effective	Size (mm)	Spacing (cm)	Size (mm)	Spacing (cm)
			Simply Supported Slabs†			
2.5	11.0	9.2	12	25.5	8	24.5
3.0	11.0	9.4	8	9.5	8	24.5
3.5	11.0*	9.3	10	9.5	8	24.5
4.0	15.0	13.2	12	13.5	10	24.5
			Continuous Slabs			
2.5	11.0	9.4	8	17.5	8	24.5
3.0	11.0	9.2	12	25.5	8	24.5
3.5	11.0	9.2	12	17.5	8	24.5
4.0	11.0*	9.3	10	9.5	8	24.5
	15.0	13.3	10	13.5	10	24.5
4.5	15.0	13.2	12	13.5	10	24.5

Note :—1. The design details are based on:
(i) Brick strength of 105 kg/cm² except in cases marked with aestrick (*). In these cases the minimum strength required is 140 kg/cm².
(ii) Ultimate load method of design.

†2. In simply supported slabs bend up every third bar at 1/5th span from the supports.

2. Simply Supported and Continuous Reinforced Brick Concrete (R.B.C.) Slabs.

Span of slab (m)	Thickness (cm)				Steel			
					Main tensile bars		Distribution bars	
	Overall	Brickwork	Topping c. concrete M–150	Effective	Diameter (mm)	Spacing (cm)	Diameter (mm)	Spacing (cm)
			Simply Supported Slab†					
2.5	10.0	7.0	3.0	8.2	12	26.5	6 and 8 alternately	24.5
	11.0	7.0	4.0	9.4	8	15.0	8	24.5
3.0	10.0	7.0	3.0	8.2	12	15.5	6 and 8 alternately	24.5
	11.0	7·0	4.0	9.3	10	15.5	8	24.5
3.5	11.0	7.0	4.0	9.2	12	15.5	8	24.5
4.0	14.0	11.0	3.0	12.2	12	11.5	8	24.5
4.5	14.0	11.0	3.0	12.2	12	11.5	8	24.5
			Continuous slabs					
2.5	10.0	7.0	3.0	8·3	10	26.5	6 and 8 alternately	24.5
3.0	10.0	7.0	3.0	8.3	10	15.5	–do–	24.5
	11.0	7.0	4.0	9.2	12	26.5	8	24.5
3.5	10.0	7.0	3.0	8.2	12	15.5	6 and 8 alternately	24.5
	12.0	7.0	5.0	10.3	10	15.5	8	24.5
4.0	12.0	7.0	5.0	10.2	12	15.5	8	24.5
	14.0	11.0	3.0	12.3	10	11.5	8	24.5
4.5	14.0	11.0	3.0	12.2	12	11.5	8	24.5

Note : (i) The design details are based on the ultimate load method of design.
(ii) Topping concrete M–150 corresponds to 1:2:4 nominal mix of ordinary concrete.
†In simply supported slabs bend up every third bar at 1/5th span from the supports.

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