Global Journal of Researches in Engineering: E
Civil And Structural Engineering
Volume 16 Issue 2 Version 1.0 Year 2016
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Experimental Investigation of Unreinforced and Reinforced Masonry Slab

By Mahmudul Hasan Mizan & Mishuk Majumder
Khulna University of Engineering & Technology, Bangladesh

Abstract- Unreinforced Brick masonry is a non-homogeneous material made of bricks as the building units and the mortar as the interface material. Brick masonry has a high compressive strength under vertical loads but has a low tensile strength against bending. Reinforced brick masonry show greater resistance against shear and bending. Brick masonry slab have good appearance, fire resistance capacity, thermal and acoustics performance, free from corrosion of reinforcement etc. Two types of masonry slab with herring bone bond pattern were fabricated using wire mesh and minimum reinforcement in addition to that one traditional RCC slab was also fabricated using minimum reinforcement. The masonry slabs failed due to brick failure without any advance warning. The crack pattern of masonry slabs using wire mesh and minimum reinforcement were flexure-tension and web-shear respectively. The crack pattern of RCC slab was flexure-shear. The maximum flexural stress carried by RCC slab, masonry slabs with wire mesh, with minimum reinforcement were 488 psi, 194 psi and 387 psi respectively where the maximum deflections were 0.157 inch (3.98 mm), 0.083 inch (2.1 mm) and 0.05 inch(1.28 mm), respectively. Reduction of cost of masonry slabs using wire mesh and minimum reinforcement from RCC slab are 24.14% and 2.85% respectively.

GJRE-E Classification : FOR Code: 090599

Experimental Investigation of Unreinforced and Reinforced Masonry Slab

Mahmudul Hasan Mizan [α] & Mishuk Majumder [σ]

Abstract- Unreinforced Brick masonry is a non-homogeneous material made of bricks as the building units and the mortar as the interface material. Brick masonry has a high compressive strength under vertical loads but has a low tensile strength against bending. Reinforced brick masonry show greater resistance against shear and bending. Brick masonry slab have good appearance, fire resistance capacity, thermal and acoustics performance, free from corrosion of reinforcement etc. Two types of masonry slab with herring bone bond pattern were fabricated using wire mesh and minimum reinforcement in addition to that one traditional RCC slab was also fabricated using minimum reinforcement. The masonry slabs failed due to brick failure without any advance warning. The crack pattern of masonry slabs using wire mesh and minimum reinforcement were flexure-tension and web-shear respectively. The crack pattern of RCC slab was flexure-shear. The maximum flexural stress carried by RCC slab, masonry slabs with wire mesh, with minimum reinforcement were 488 psi, 194 psi and 387 psi respectively where the maximum deflections were 0.157 inch (3.98 mm), 0.083 inch (2.1 mm) and 0.05 inch(1.28 mm), respectively. Reduction of cost of masonry slabs using wire mesh and minimum reinforcement from RCC slab are 24.14% and 2.85% respectively.

I. Introduction

Brick masonry is one of the oldest forms of building construction material. Brickwork is a composite material with bricks as the building units and the mortar as the jointing material (Freeda Christy C. *et. al*, 2013).The strength of the bricks-work primarily depends upon quality and strength of the brick, the type of mortar and the method of bonding adopted in construction, type of material used, nature of workmanship and supervision. Brick masonry plays a significant role in the construction industries of bangladesh where natural stones are not available and other type of building materials like concrete, MS sheets or CI sheets, and artificial materials are costly. The rapid progress over recent past in the understanding of the materials and considerable advances in the method of design have increased acceptance of load bearing masonry as a variable structural material. (S.P. Bindra, 2013). In residential buildings, roof system is a vital part. The selection of the type of material and construction is made, keeping in view the requirements of strength, water proofing, thermal insulation, fire resistance, durability and economy. It was therefore felt to investigate the local carrying capacity of different type of masonry slab. Reinforced brickwork is a typical type of construction in which the compressive strength of bricks is utilized to bear the compressive stress and steel bars are used to bear the tensile stresses in a slab. In other words the usual cement concrete is replaced by the bricks. However since the size of a brick is limited, continuously in the slab is obtained by filling the joints between the bricks by cement mortar. The reinforcing bars are embedded in the gap between the bricks which is filled with cement mortar. The designs of reinforced bricks slab are similar to these of reinforced concrete slab. (B.C. Punmia, 2012).Ahmed, T. and Junayet, A.,(1996) carried out a comparison study between Ferro cement slab and conventional R.C.C. slab in terms of their flexure behavior and cost. In terms of appearance, durability and cost, brick masonry is comparatively superior to other alternatives (Hossain, M. M. *et al*., 1997). The main aim of this study is to investigate the mechanical properties of masonry slabreinforced with alternative materials (wire mesh and minimum reinforcement) to evaluate their performance and economy compared to conventional RCC slab. An endeavor will make to evaluate the feasibility of masonry slab to replace RCC slab.

II. Materials and Methods

a) Specification of Materials

In this study Bricks, Portland Composite Cement, Sand and Reinforcement (wire mesh and deformed bar) from the local manufactures has been used and the properties of brick and mortarare given in Table 1 and Table 2.

Author α: Lecturer, Department of Civil Engineering, Khulna University of Engineering & Technology, Bangladesh.
e-mail: mahmud0859@gmail.com
Author σ: Graduate, Department of Civil Engineering, Khulna University of Engineering & Technology. e-mail: mishuk4647@gmail.com

Table 1 : Physical Properties of Bricks

Serial	Frog mark	Compressive strength (Ksi)	Water Absorption Capacity (%)	Price (tk/ 1000 nos)
No	NEWB	2.21	13.37	6500
1	SHAH	2.65	13.47	7000
2	CITYI	2.3	16.21	6000
3	FMB	2.6	16.78	7000
4	FINE	3.24	10.35	6500
5	AKIJ	5.70	12.22	8000

From table 1, it is found that the AKIJ brand brick have maximum compressive strength. The water absorption capacity is 12.22 % which is less than 1/6 of it's own weight. AKIJ brand brick was uniform in color, size and shape is regular, campact, free from crack and other flaws such as air, bubbles, stone nodules etc. Although it's cost is maximum but don't vary too much from the other brand. So AKIJ brand brick was selected for the final work.

Table 2 : Tests Results for compressive strength of Cement Mortar

Age	Ratio (1:2)	Average Compressive Strength (psi)
3 days	Cement : Kushtia Sand	2950
	Cement : Sylhet Sand	3125
	Cement : Sylhet + Kushtia Sand	3045
7 days	Cement : Kushtia Sand	3790
	Cement : Sylhet Sand	3750
	Cement : Sylhet + Kushtia Sand	3630

Bashundhara cement with Khustia sand having fineness modulous of 1.65 in ratio 1:2 gives greater compressive strength. So it was selected for the final work.

b) selection of slab

Two types of masonry slab reiforeced with wire mesh and minimum reinforcement and one traditional RCC slab having dimension 4ft x 2.5ft x 4.5 inch were selected for the test.

c) Design of Masonry and Rcc Slab

The slabs were designed as one way slab. In case of masonry slab reinforced with wire mesh 0.5 inch spacing wire mesh was used. The bottom clear cover was 0.75 inch and top mortar layer was 0.5 inch.

In masonry slab using minimum reinforcement 10 mm dia bar was used. The number of reinforcement in long direction was 5 nos and in short direction was 7 nos. Reinforcement was used only in tension zone. No shear reinforcement was used. Bottom clear cover was 0.75 inch and top mortar layer was 0.5 inch.

In traditional RCC slab the number of reinforcement was kept as same as masonry slab using minimum reinforcement so that they can be compare in a similar way. Bottom clear cover was 0.75 inch.

Herring bone bond pattern was used in masonry slabs. The contribution of brick in slabs thickness was 2.75 inch. In this arrangement of brick work, bricks are laid above bottom surface inclined at 45^0 in two directions from the center. Cross-section of the above mentioned slabs are shown in figure 1(a), figure 1(b), and figure 1(c) respectively.

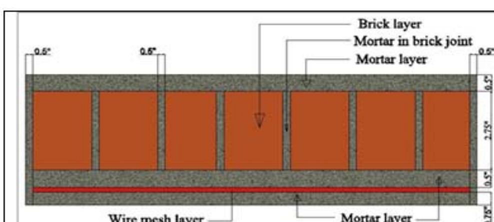

Figure 1(a) : Detailed design of masonry slab using wire mesh

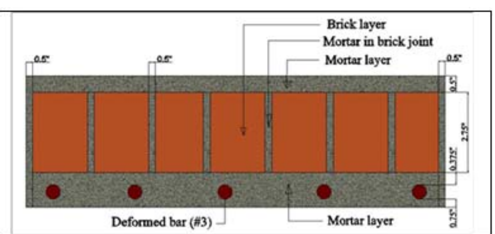

Figure 1(b) : Detailed design of masonry slab using minimum reinforcement

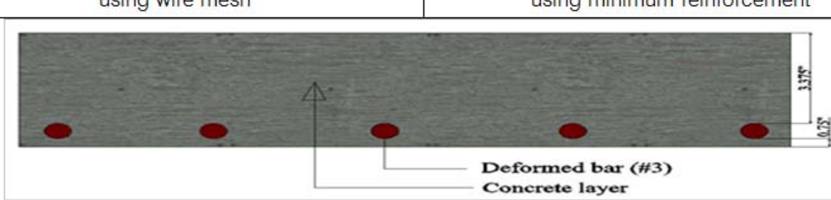

Figure 1 (c) : Detailed design of RCC slab using minimum reinforcement *d) Casting, Curing and Testing of Slabs*

Three types of slabs were casted according to the design specified above and cured for 28 days. After curing the slabs were tested in the laboratory. The typical and laboratory experimental setups are shown in figure 2(a) and figure 2(b) respectively.

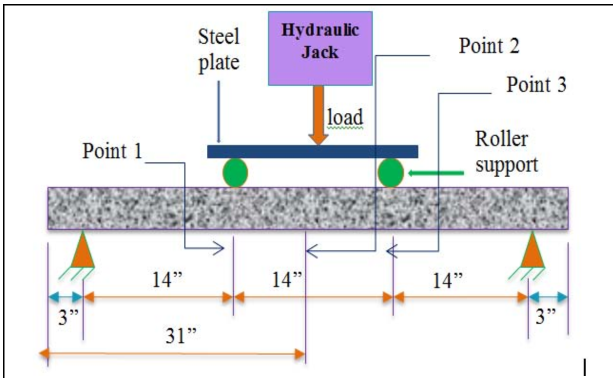

Figure 2(a) : Typical Experimental setup for two point load test.

Figure 2(b) : Laboratory Experimental setup.

The load was applied by the hydraulic jack by pumping it. The reading of deflection gauge at each point was taken with respect to each small division of pressure gauge. The data were recorded untill the failure of slab.

III. Results and Discussion

a) Masonry slab using Wire mesh

Table 3 : Load test result for masonry slab using wire mesh

Observed Pressure gauge Value	Load (kN)	Load (kip)	At Point1 Deflection (mm)	At Point1 Deflection (in)	At Point 2 Deflection (mm)	At Point 2 Deflection (in)	At Point 3 Deflection (mm)	At Point 3 Deflection (in)
0	0	0	0	0	0	0	0	0
1	15.8	3.55	0.015	0.00059	0.15	0.0059055	0.021	0.00082
2	22	4.94	0.019	0.00074	0.265	0.0104331	0.034	0.00133
3	28	6.29	0.048	0.00188	0.5	0.019685	0.055	0.00216
4	34	7.64	0.2	0.00787	1.6	0.0629921	0.168	0.00661
5	40.1	9.01	0.617	0.02429	2.1	0.0826772	0.475	0.01870

In masonry slab using wire mesh no deformed bar was provided. After curing for 28 days the slabs failed under load and the loads are shown in table 3. Deflection was measured at 3 points as remarked in the typical experimental setup. The masonry slab using wire mesh was found to take 9.1 kips load before failure which is equivalent to 1000 psf load. Maximum deflection is 2.1 mm at mid point.

b) Masonry slab using minimum reinforcement

Table 4 : Load test result for masonry slab using minimum reinforcement

Observed Pressure gauge Value	Load (kN)	Load (kip)	At Point1 Deflection (mm)	At Point1 Deflection (in)	At Point 2 Deflection (mm)	At Point 2 Deflection (in)	At Point 3 Deflection (mm)	At Point 3 Deflection (in)
0	0	0	0	0	0	0	0	0
1	15.8	3.55	0.04	0.00157	0.35	0.01377	0.014	0.00055
2	22	4.94	0.07	0.00275	0.48	0.01889	0.025	0.00098
3	28	6.29	0.092	0.00362	0.57	0.02244	0.037	0.00145
4	34	7.64	0.112	0.00440	0.7	0.02755	0.049	0.00192
5	40.1	9.01	0.14	0.00551	0.8	0.03149	0.065	0.00255
6	46.1	10.36	0.168	0.00661	0.98	0.03858	0.087	0.00342
7	52.25	11.74	0.215	0.00846	1.05	0.0413	0.12	0.00472
8	58.45	13.14	0.262	0.01031	1.1	0.04330	0.154	0.00606
9	64.15	14.42	0.298	0.01173	1.15	0.04527	0.189	0.00744
10	70.25	15.79	0.332	0.01307	1.18	0.04645	0.223	0.00877
11	76.7	17.24	0.37	0.01456	1.21	0.04763	0.264	0.01039
12	83	18.65	0.398	0.01566	1.25	0.04921	0.29	0.01141
13	89	20.00	0.45	0.01771	1.28	0.05039	0.425	0.01673

Deformed bar were used in masonry slab using minimum reinforcement. The masonry slab using minimum reinforcement carried 20 kips load before failure which is equivalent to 2000psfload. Maximum deflection was found 1.28 mm at point 2.

c) RCC slab using minimum reinforcement

Table 5 : Load test result for RCC slab using minimum reinforcement

Observed Pressure gauge Value	Load (kN)	Load (kip)	At Point1 Deflection		At Point 2 Deflection		At Point 3 Deflection	
			(mm)	(in)	(mm)	(in)	(mm)	(in)
0	0	0	0	0	0	0	0	0
1	15.8	3.55	0.03	0.00098	0.54	0.02125	0.037	0.00145
2	22	4.94	0.04	0.00173	0.96	0.03779	0.063	0.00248
3	28	6.29	0.08	0.00314	1.4	0.05511	0.125	0.00492
4	34	7.64	0.19	0.00740	1.85	0.07283	0.205	0.00807
5	40.1	9.01	0.27	0.01062	2.5	0.09842	0.29	0.01141
6	46.1	10.36	0.36	0.01417	2.8	0.11023	0.372	0.01464
7	52.25	11.74	0.46	0.01811	2.95	0.11614	0.465	0.01830
8	58.45	13.14	0.59	0.02322	3.1	0.12204	0.58	0.02283
9	64.15	14.42	0.71	0.02803	3.22	0.12677	0.79	0.03110
10	70.25	15.79	0.89	0.03484	3.4	0.13385	0.84	0.03307
11	76.7	17.24	0.95	0.03740	3.68	0.144881	1.005	0.03956
12	83	18.65	0.99	0.03897	3.85	0.15157	1.25	0.04921
13	89	20.00	1.02	0.04015	3.88	0.15275	1.305	0.05137
14	95	21.35	1.09	0.04291	3.91	0.15393	1.398	0.05503
15	100.5	22.59	1.29	0.05078	3.98	0.15669	1.435	0.05649

RCC slab using minimum reinforcement took 22.59 kips load before failure which is equivalent to 2500 psf load. Maximum deflection is 3.98 mm.

IV. Variation of Deflection at Points

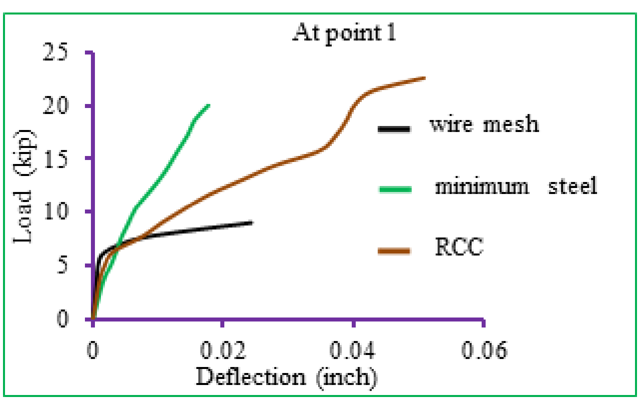

Figure 3 : Variation of Deflection (inch) with Load (Kip) at Point 1

Figure 3 shows the variation of deflection with load for all types of slab at point 1 which is located at a distance 17 inch away from the right support. The deflection at point 1 is maximum for RCC slab, second maximum deflection was found for masonry slab using wire mesh. This is due to the elasticity of the wire mesh. Masonry slab using minimum reinforcement shows minimum deflection due to use of deformed bar and brittleness of brick.

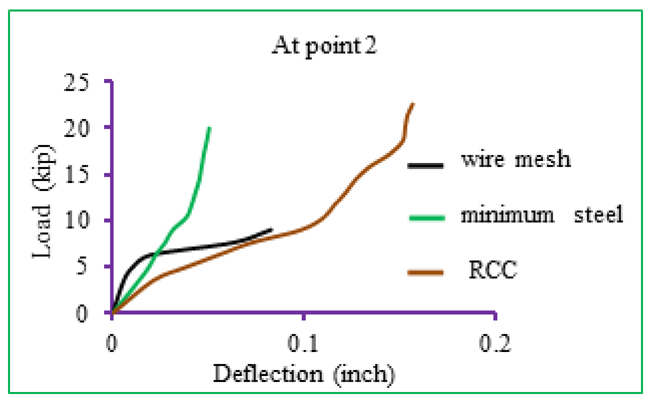

Figure 4 : Variation of Deflection (inch) with Load (Kip) at Point 2

Figure 4 shows the variation of deflection with load for all types of slab at point 2 which is located at the midpoint of the slab. All slabs show maximum deflection at point 2. Maximum deflection is 3.98 mm for RCC slab.

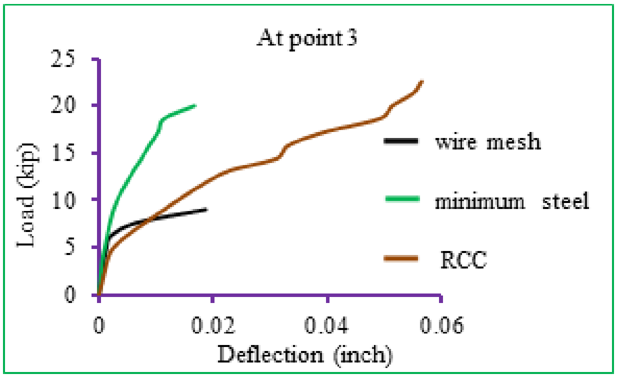

Figure 5 : Variation of Deflection (inch) with Load (Kip) at Point 3

Figure 5 shows the variation of deflection with load for all types of slab at point 3 which is located at a distance 17 inch away from the left support. The minimum deflection is for masonry slab using minimum reinforcement and maximum deflection is for RCC slab. Masonry slabs failed suddenly without any advanced warning due to the brittleness of brick. There is no yield point in the figures which ensure the sudden failure of slabs.

V. Crack Pattern

a) Masonry slab using wire mesh

Figure 6 : Failure pattern of masonry slab using wire mesh

The failure pattern of masonry slab using wire mesh is flexure-tension type. Failure occurred at almost midpoint. This type of failure may be initiated due to the increase of principle tensile stress greater than combined tensile stress of brick and mortar. The failure was sudden due to the brittleness of brick and the deflection was greater than masonry slab using minimum steel due to the greater elastic property of wire mesh.

b) Masonry slab using minimum reinforcement

Figure 7 : Failure pattern of masonry slab using minimum reinforcement

The failure of masonry slab using minimum steel occurred near the support. The failure occurred due to the shearing stress. So the crack pattern is named as web-shear. The reason of failure is the absent of shear reinforcement. Failure was brick failure and there was no advanced warning due to the brittleness of brick.

c) RCC slab using minimum reinforcement

Figure 8 : Failure pattern of RCC slab using minimum reinforcement

The crack of RCC slab using minimum steel initiated due to the flexure but the failure occurred due to the combined action of flexure and shear. This type of failure occurred due to the increase of combined flexure and shear stress greater than principle tensile stress of concrete.

VI. Economy Analysis

The amount of materials required in the manufacture process and the cost of three types of slab is shown in table 6 and table 7

Table 6 : Amount of Materials required in different types of slabs

specifications	Masonry slab		RCC
	with wire mesh	with minimum reinforcement	
Cement (kg)	17	19	19
Fine Aggregate [1] (cft)	0.924	1.06	1.2
Fine Aggregate [2] (cft)	0.013	0.013	-
Coarse Aggregate (cft)	-	-	1.8
Steel (kg)	-	6.5	6.5
Brick (nos)	31	31	-
Wire mesh(sft)	7.9	-	-
Brick work (cft)	2.29	2.29	0
Casting (cft)	0	0	3.75
Plastering (sft)	10	10	0
Fabrication of steel (kg)	2	6.5	6.5

Table 7 : Amount of Cost required in different types of slabs

specifications	unit cost (tk)	Cost (tk)		
		with wire mesh	With minimum reinforcement	RCC slab
Cement (kg)	8.3	141.1	157.7	157.7
Fine aggregate [1] (cft)	60	55.44	63.6	73.2
Fine aggregate [2] (cft)	35	0.455	0.455	0
Coarse aggregate (cft)	160	0	0	292.8
Steel (ft)	55	0	357.5	357.5
Brick (nos)	8	248	248	0

Wire mesh(sft)	35	276.5	0	0
Brick work (cft)	9	20.61	20.61	0
Casting (cft)	20	0	0	75
Plastering (sft)	8	80	80	0
Fabrication of steel (kg)	6	12	39	39
Total cost		834.10	966.86	995.20

VII. Deviation of Performance and Cost of Slabs

Deviation of load carring capacity of masonry slabs using wire mesh and minimum reinforcement from RCC slab are 60.11% and 11.46% respectively; deflections are 47.24% and 67.84% respectively; flexural stresses are 60.25% and 20.70% respectively and costs are 24.14% and 2.85% respectively. The deviation of performance and costs of masonry slabs from RCC slab in shown in the following bar diagrams.

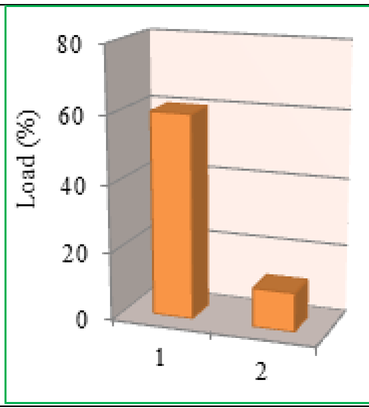

Figure 9(a) : Deviation of load capacity

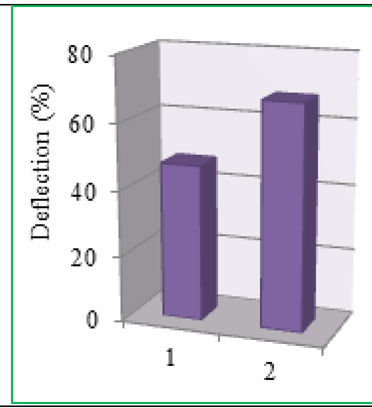

Figure 9(b) : Deviation of Deflection

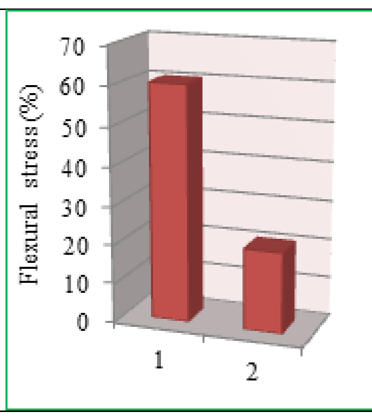

Figure 9(c) : Deviation of flexural stress

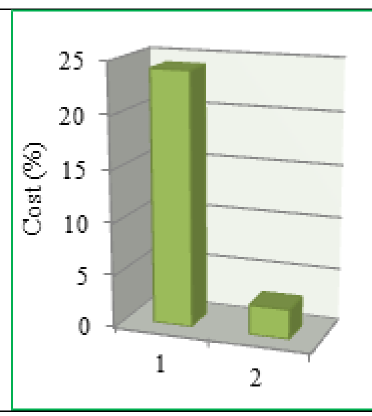

Figure 9(d) : Deviation of cost

VIII. Conclusion

- Maximum deflection of RCC slab, masonry slabs using wire mesh and minimum reinforcement are 0.157 inch (3.98 mm), 0.083 inch (2.1 mm) and 0.05 inch (1.28 mm) under load 22.59 kips, 9.1 kips and 20 kips respectively.
- Deviation of load carring capacity of masonry slabs using wire mesh and minimum reinforcement from RCC slab are 60.11% and 11.46% respectively; deflections are 47.24% and 67.84% respectively; costs are 24.14% and 2.85% respectively.
- Masonry slabs failed due to brick failure without any advanced warning. The crack pattern of RCC slab, masonry slab using wire mesh and minimum reinforcment are flexure-shear, flexure-tension and flexure-shear respectively.
- Masonry slab using wire mesh can be used in case of small span slab, restricted roof and waffle slab system. For long span slab and higher tension, masonry slab using minimum steel or RCC slab can be used. As the cost of RCC slab is only 2.85% greater than the masonry slab using minimum steel, so RCC slab is preferable for higher tension. But in case of architectural appearance and deflection restriction, masonry slab using wire mesh can be used.

References Références Referencias

1. Freeda Christy C*, Tensing D and Mercy Shanthi R. (2013): Experimental Study on Axial compressive Strength and Elastic Modulus of the Clay and Fly Ash Brick Masonry, Journal of Civil Engineering and Construction Technology, Vol. 4(4), pp. 134-141.
2. Bindra, S.P. and Arora, S.P. (2013): A Text Book Building Construction, 5th Edition, Dhanpat Rai Publication, New Delhi.
3. Punmia, B.C.; Ashok, K.J. ; Arun, K.J. (2012): A Text Book of Building Construction, 20th Edition, Laxmi Publications LTD. New Delhi.
4. Hossain, M.M. ; Ali, S.S. ; Rahman, A.M. (1997): Properties of Masonry Constituents, Journal of Civil Engineering, IEB, Bangladesh, vol. CE 25, No. 2, pp.135-155.
5. Thohid, A. and Abu, J. (1996): Low Cost Building, Undergraduate Thesis, Khulna University of Engineering and Technology, Bangladesh.