Long Term Performance Test of Low Span Low Cost Masonry Slab (without reinforcement) under Static Load, Repeated Load and Impact

Abstract

In residential buildings, low cost is a vital demand. Slab made of brick module with or without beam is found to be practiced locally. Moreover brick masonry slab is easy to construct and durable with respect to fire proofing and corrosion if nominal or zero reinforcement is possible. Therefore a study was under taken in the Department of Civil Engineering, Khulna University of Engineering and Technology (KUET) to investigate the long-term performance of brick masonry slab of dimensions 1.52m × 3.65m, with a slab thickness of 75mm. Tests were performed subjected to static, repeated and impact loading system. Test results revealed that brick masonry slab did not failed and no crack were observed though it was loaded by a uniform pressure of 12kN/m^2. Similar phenomena were observed when repeated load up to 12kN/m^2 was imposed on the slab. However punching shear failure was observed when an impact load was applied 9 times by a hammer of 23kg of 1m free fall. Combined failure both in joint and brick module was observed.

Keywords: Masonry slab, full scale test, long term effect, static load, repeated load and impact.

1. Introduction

The construction of using stone, brick, block etc is termed as masonry. It may be defined as building units bonded together with mortar. 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. Brick masonry is one of the oldest building materials comparatively superior to other alternatives in terms of appearance, durability and cost (Hossain M M et al., 1997). Roof system of a residential building is an indispensable part .There are several type of roof system which are usually constructed in rural and urban areas namely, conventional R.C.C. slab beam, wooden rafter and beam covered with tile followed by lime surki mortar finish, brick masonry roof reinforced by MS bar or other indigenous material. Sometime unreinforced brick masonry is found to be constructed from long past. Effort of lowering cost has become burning need for low income group of people. Room with comparatively short span length is used in rural adobe buildings. For cost optimization and broaden utility, its possibility needs to be verified by full scale tests.

2. Background of Research

Reinforced brick slab are widely used in low cost rural housing. Design and code related to reinforced brick slab are well established (Dayaratnam P, 1988 and Kumar S, 2005). Higher rate of corrosion in reinforcing steel and high cost of reinforcement has necessitated the study on brick slab without reinforcement for the interest of economy and durability of the slab (Siddiqi and Ashraf, 2000). Rabbani and Nahid (2006) investigated the parametric study on more than 30 brick slabs without reinforcement. Parameter included – brick line, span and filler. Figure 1 shows one of their typical laying pattern and Figure 2 shows the loading arrangement for the test of slab.

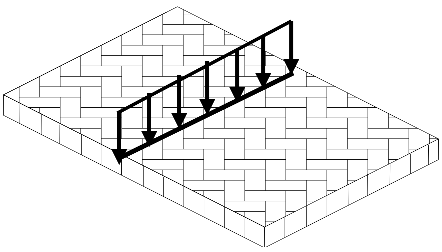

Figure 1: Model of herring bone bond slab of size (0.91m×0.61m×0.075m)

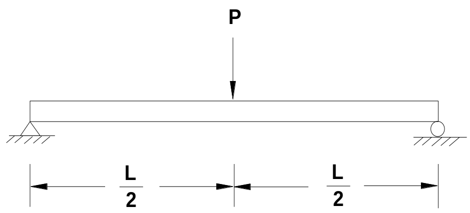

Figure 2: Loading arrangement of model slab (L=787 mm)

They concluded that herring bone bond masonry slab of 75 mm thickness can resist flexural stress of about 1.70 MPa. Therefore in this study low cost housing masonry slab of 3.65m×1.52m ×0.075m has been constructed and tested with uniform distributed load, repeated load and impact.

3. Preparation of Test Slab

In this study, a two panel masonry slab each of 3m×1.5m ×0.075m are cast with brick module placed flat providing 0.075m thickness for the slab. The interspaces between the modules (12.7 mm) are sealed with mortar.

3.1 Materials Specifications

First class brick the average compressive strength 30 MPa

Cement mortar ratio 1:1.5

Ordinary Portland Cement

Washed Local sand with fineness modulus of 1.5

3.2 Construction Sequences

First of all, wooden platform was prepared and leveled before laying the bricks. Bricks are then laid in staggering pattern placed with frog mark at to side keeping 12.7mm. Layout and support position of the masonry slab has shown in Figure 3. On the other hand, Figure 4 and 5 shows the detailing of the support size in cross-section and long section respectively. A 75mm thick slab was made keeping 12.7mm gap in between two adjacent bricks. Figure 6 shows a close view photograph of the same. Top surface of the slab was finished with 12.7 mm mortar with neat finish. After 24 hours a 75 mm height of brick border was made to store water for curing purposes. After completing 28 days of curing period the formwork was removed and the slab was prepared for test.

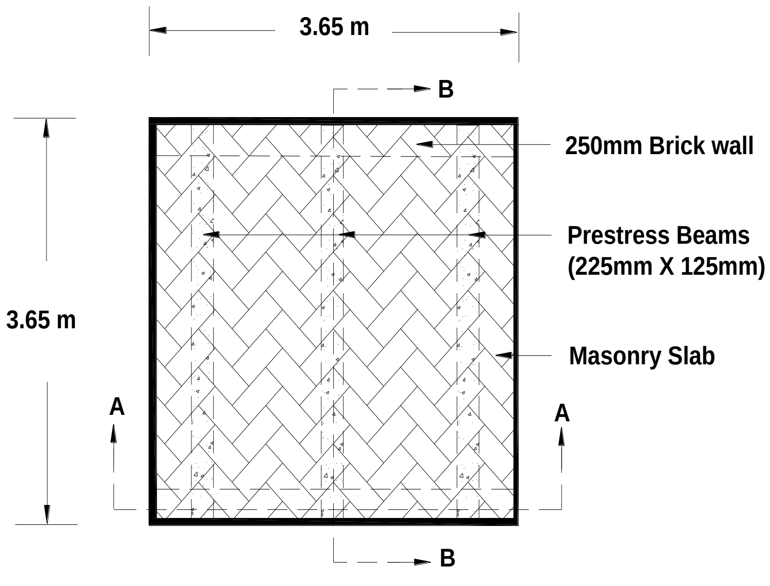

Figure 3: Layout and support position of slab

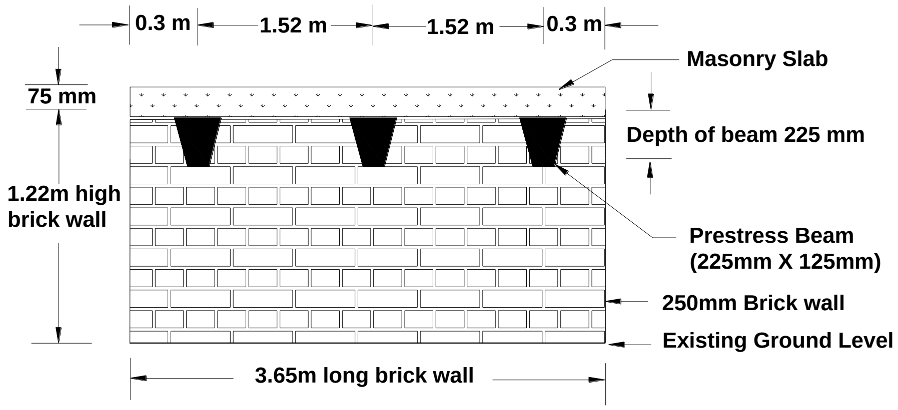

Figure 4: Section A-A

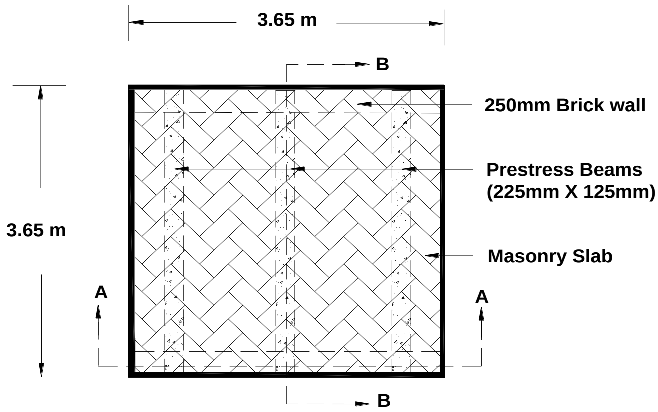

Figure 5: Section B-B

Figure 6: Photograph of Close view - showing the interspaces 12.7mm in bricks

3.3 Instrumentation and Testing

Instrumentation and testing was performed in two phase. In first phase, only load bearing capacity of the full scale slab was tested and the test was done after 28 days of slab construction. Second phase test was done after 5 years of slab construction. This paper deals with the instrumentation and results of the second phase.

Testing of second phase involved the application of static load, repeated load and impact.

To perform the static load test, a brick wall of height 1.2m and 125mm in thickness was constructed around the 3.65m×1.52m slab. Then water pump was used to fill the 3.65m×1.52m×1.2m chamber on the slab. Linear Voltage Displacement Transducers (LVDTs), portable data logger and computer arrangements were used for data acquisition. LVDTs were instrumented as shown in Figure 8 and connected with data logger (Figure 9).

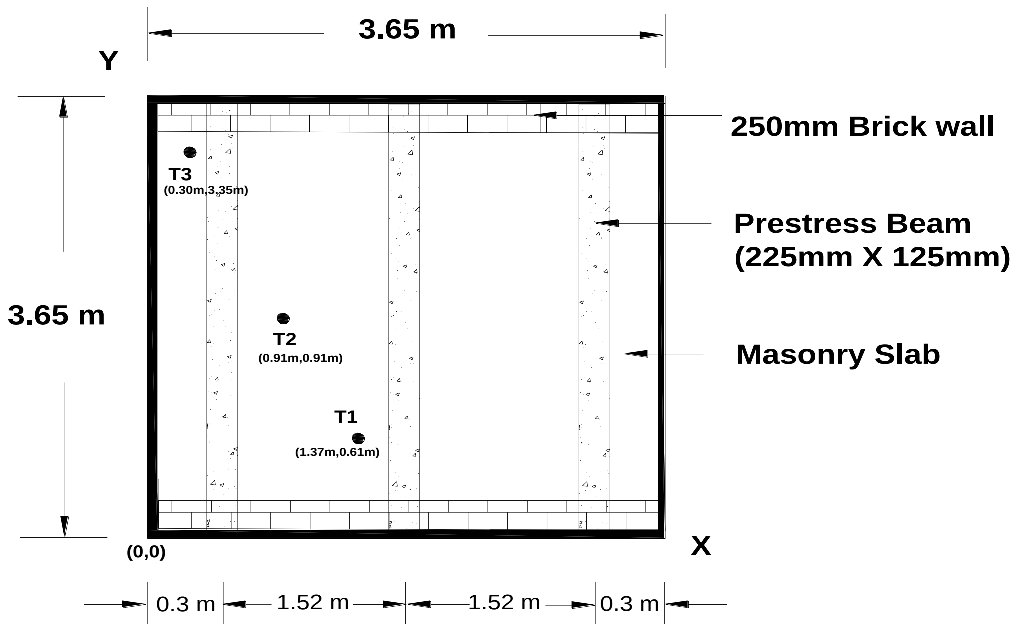

Figure 7: Location of LVDTs

Figure 8: LVDT setup

Figure 9: Portable Data Logger

Figure 10: Data acquisition devices

To perform the repeated load test, similar instrumentation was done. In this case, the height of water was increased again deceased gradually with respect to time and the reading changes in the data acquisition devices were observed. This was repeated 10 times.

To perform the impact load test on the masonry slab a weight of 23 kg was set to free fall on the slab from a height of 1 m as shown in Figure 11. Figure 12 shows the indigenous arrangement for the application of impact load.

Figure 11: Impact test setup with round hammer ball, 1m free fall on slab

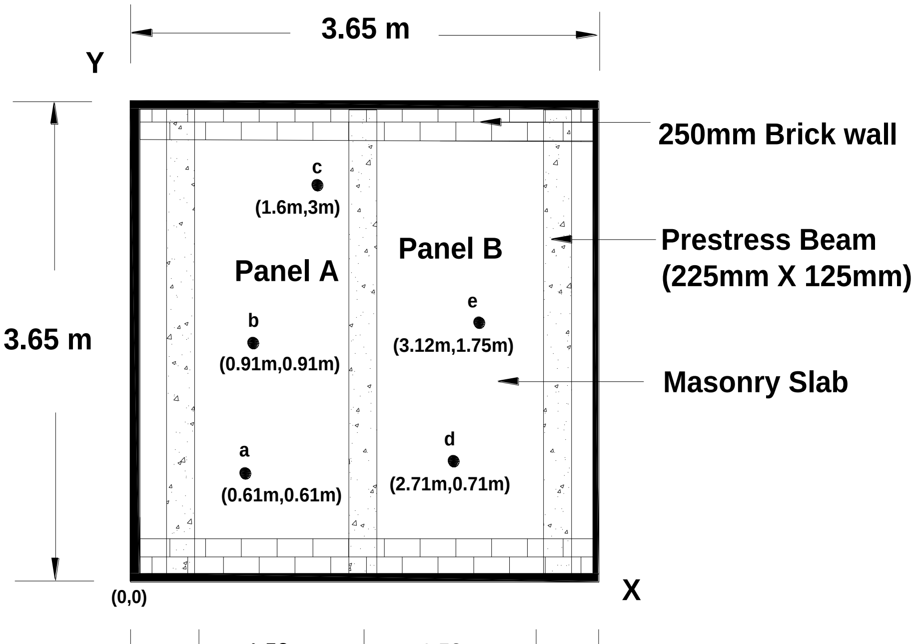

Figure 12: Location on slab where impact load was applied

4. Test Results and Discussion

4.1 Final Phase

This has been done after the construction period of 5 years and data acquisition systems corresponding to deformation such as LVDT's and strain gauges in slab has been taken. In this phase mainly three types of loading were induced on slab panels, namely:

a. Static load
b. Repeated load and
c. Impact load

4.1.1 Static loading on slab panel

From the test no significant change in deformation was recorded from the data acquisition devices. However the slab carried a water column height of 1.22m on the area of 3.65m×1.52m which equivalent to 12kN/m^2. Hence the slab carried a uniform distributed load 4 times than traditional load of residential buildings. Moreover no crack and leakage of slab panel was observed.

4.1.2 Repeated loading on slab panel

No significant change in deformation was observed when repeated was induced on slab panel.

4.1.3 Impact loading on slab panels

In this case impact hammer was dropped to five different locations as shown in Figure 12 on the slab.

Table 1: Result of Impact Test

Location		*Number of drop applied to fail*	*Equivalent Diameter of the Punched section (mm)*
Panel A	*a*	*7*	*40*
	b	*9*	*30*
	c	*8*	*35*
Panel B	*d*	*8*	*50*
	e	*6*	*55*

Table 1 shows the number of drop required for punching failure. From the test it was observed that the masonry brick slab though a brittle material, it did not failed catastrophically rather than just failed locally due to punching. In Panel A at ‘b’ point was tested first, but no significant crack was showed after punch of this point. On the other hand when ‘c’ point was tested it showed few cracks as shown in Figure 13. However significant cracks were observed when impact load were induced at points ‘d’ and ‘e’ of Panel B (Figure 14 and 15). Crack patterns showed the brick failure of the slab rather than joint failure. Hence it reveals combined action of the matrices while the structure induced to load.

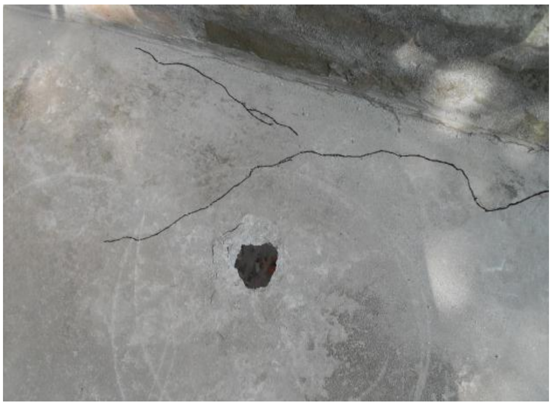

Figure 13: Crack at Point c

Figure 14: Crack at Point d

Figure 15: Crack at Point e

Maximum flexural stress induced in the slab while applying the impact load can be calculated from equation,

$$\sigma = \sqrt{\frac{6mghEc^2}{LI}}, (\text{Pytel A. and Singer L. F., 1999})$$

$$Where, m = 23kg$$

$$g = 9.81m/s^2$$

$$h = 1m$$

$$E = 670MPa, (Rosenhaupt S., 1962)$$

$$c = 37.5mm = 0.0375m$$

$$L = 1.52m$$

$$I = \frac{bh^3}{12} = \frac{3.15 \times 0.075^3}{12} = 1.107 \times 10^{-04} m^4$$

Therefore maximum flexural stress developed in the masonry slab while impact load induced on it, $\sigma = 2753259.28N/m^2 = 2.75MPa$

5. Conclusions

In this study low span full-scale masonry slab without reinforcement has been investigated. Following conclusions can be made from this investigation:

- Masonry slab (3.65m×1.52m×0.075m) without reinforcement carried uniform distributed load of 4 times than conventional residential building after its construction period of 5 years. No leakage of water ensured absence of cracks in the slab panels.

- Slab carried repeated load 10 times while varying the height of water pressure. However no cracks and no change in deformation were found.

- Slab carried impact load of 23kg hammer ball from 1m height at least 6 times to maximum 9 times before failure and punching of slab were observed with diameter 5cm.

- Flexural stress of masonry slab under impact load was calculated as 2.75 MPa.

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