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Experimental comparison of burnt clay brick walls in Kerala under in-plane loading

Liby Elizabath., Dr. C. Justine Jose

Abstract - This Paper focuses on the experimental comparison of clay brick walls under different aspect ratios and different materials that are locally used in Kerala for construction. Mainly clay brick walls of burnt clay brick and burnt clay hollow bricks are used. A total of eight unreinforced masonry (URM) walls are constructed with four different aspect ratios. It was observed from the test results that the URM wall did not behave as a brittle structure. It could dissipate energy without loss of strength. For the highest aspect ratios burnt clay brick behave as a strong material under lateral in-plane loads. An idealisation of these eight walls are also done. In order to make the calculation simple, the actual hysteretic behaviour of a masonry wall, subjected to a combination of constant vertical load and a sequence of lateral load reversal is represented by an idealised bi- or trilinear resistance envelop. As the experiments indicate, strength degradation in the non-linear range of behaviour of masonry walls before collapse is relatively large. The value of the strength degradation factor is 0.5 was obtained from the experiment. And the failure modes show the diagonal cracking for all the aspect ratios except the highest aspect ratios of burnt clay hollow bricks.

Index Terms -URM walls in Kerala, In-plane loading, Aspect ratio of walls, Pre-compression level, wall failure pattern, idealisation curve.

1 Introduction

Masonry construction is common from the beginning of civil construction. Clay bricks have been employed for at least 10,000 years. Older buildings mostly consist of unreinforced brick masonry. Because brick Masonry is bonded in to an integral mass by mortar and grout, it is considered to be a homogeneous construction. It is the behaviour of combination of materials that determines the performance of the masonry as a structural element. There are numerous methods of brick making, and their properties influenced by the method of construction.

2 Methodology

This project follows the methodology given below. Every research works need a strong reason to conduct that study. The reason rises from the shortcoming of the previous literatures or gaps in those literatures. This project also conducted the literature survey for the problem identification. This is one of the experimental and numerical assessment of different types of walls in Kerala under different aspect ratio. This is achieved by dividing the project into four stages,

1. Material properties determination stage

2. Experimental program

3. idealisation of the results

In the first stage, studied the properties of clay bricks. Then determine the properties of the masonry i.e. Prism test and bond strength.

The second stage experimental work was conducted. The experimental program deals with testing of unreinforced masonry walls. The wall of size varies depends on the aspect ratios, mainly four different types of aspect ratios are used. 1.245,0.99,0.713 and 0.444. The test was tested under increasing lateral load and constant axial load. The third stage is the idealisation of the result.

3 Characterisation Of Bricks

In this chapter experimental investigations are carried out to determine the properties of burnt clay bricks and burnt clay hollow bricks. Because of its composite nature and different properties, they exhibit distinct directional properties. For a finding the better fundamental understanding of masonry behaviour it is to be need to find out the properties brick materials. All these values satisfies the IS code recommendation and ASTM standards.

TABLE 1
Properties of bricks

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BRICKS			
W.A of burnt clay bricks (%)	W.A of burnt clay hollow bricks (%)	Masonry compressive strength of burnt clay bricks(N/mm2)	Masonry compressive strength of burnt clay hollow bricks(N/mm2)
5.084	13.98	1.67	2.84
Compressive strength of burnt clay bricks (N/mm2)	Compressive strength of burnt clay hollow brick(N/mm2)	Triplet strength of burnt clay bricks (N/mm2)	Triplet strength of burnt clay hollow brick (N/mm2)
7.07	2.51	2.31	0.2

4 Lateral Load Resisting Behaviour Of URM Walls

This chapter mainly deals with the experimental program to study the behaviour of URM wall panels under four different aspect ratio, monotonic lateral loading and pre-compression. This chapter begins with the detailed experimental setup, description of the test specimen and the results obtained from the experimental investigation.

4.1 Test specimen

Eight wall panels of varying dimensions are tested for in-plane monotonic lateral loads. For each specimen the axial compressive loads were maintained as a constant during testing. Two different materials with four different aspect ratio was used.

4.2 Test setup

The experimental set up consists of a loading frame of 100-ton capacity. The loading was done though a hydraulic jack, of 20-ton capacity, with the help of a hydraulic pump of 100-ton capacity. A load cell of 40-ton capacity was used to measure the applied load. It is attached to the bottom of hydraulic jack. The magnitude of the applied load can be seen from the digital indicator. It expresses the load in tons with a least count of 0.01 ton. Each wall panel were placed on a 250 mm thick foundation. The setup of the loading frame is shown in the figure 1. The pre-compression was applied to the test specimen by hydraulic load cell attached to the horizontal rigid frame of the loading frame. And the in-plane monotonic lateral loads were applied to the test specimen by hydraulic load cell attached to the vertical rigid frame of the loading frame. Two LVDT's are placed, one at the middle of the top beam. And another one at the top of the 1st layer of the brick shown in the figure.

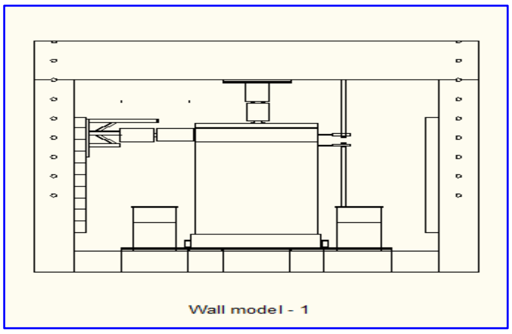

Fig.1 Test setup

4.3 Idealisation of the results

In order to make the calculation simple, the actual hysteretic behaviour of a masonry wall, subjected to a combination of constant vertical load and a sequence of lateral load reversal is represented by an idealised bi- or trilinear resistance envelop. To idealise the experimental envelope three limits states in the observed behaviour of the tested wall are first defined.

- ✓ Crack limit, determined by displacement dcr and resistance Hcr at the formation of the first cracks in the wall, which changes the slope of the envelop.
- ✓ Maximum resistance, determined by maximum resistance Hmax, attained during test, and corresponding displacement dHmax.
- ✓ Ultimate state, determined by maximum displacement attained during test dmax and corresponding resistance hdmax.

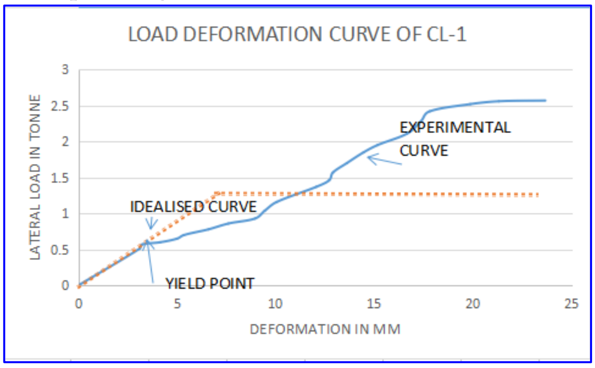

Fig.2 Idealised curve of burnt clay brick wall of aspect ratio 1.245

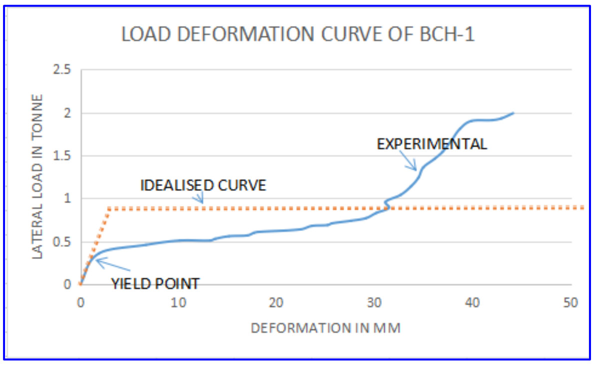

Fig.2 Idealised curve of burnt clay hollow brick wall of aspect ratio 1.245

Obviously, the initial slope of the idealised envelope is best defined with a secant stiffness of cracks, which is called effective stiffness of the wall Ke. It is calculated as the ratio between the resistance and displacement of the wall at crack limit:

$$Ke = Hcr/dcr$$

If the resistance envelope is idealised with a bilinear relationship, the ultimate resistance of the idealised envelope, Hu is evaluated by taking in to account the equal energy dissipation capacity of an actual and idealised wall: the area below the actual wall and idealising the experimental curve, and knowing the initial stiffness Ke, the ultimate resistance Hu can be calculated from the Eq.

$$Hu = Ke(d\max - sqrt(d\max^2 - (2Aenv/Ke))$$

where,
Aenv = the area below the experimental resistance envelope.
It should be emphasised, at this point, the ultimate resistance Hu does not represent the design, but the idealised maximum experimental value. The average value of Hu/Hmax ratio is 0.5. consequently, in the case of bilinear idealisation of resistance envelope, the calculated values of maximum resistance should be multiplied by 0.5.

$$Hu = 0.5H\max$$

As the experiments indicate, strength degradation in the non-linear range of behaviour of masonry walls before collapse is relatively large. The value of the strength degradation factor is 0.5. it may vary from (0.4-0.8). however, because of severe deterioration of the wall before collapse it is recommended that no more than 20% strength degradation be tolerated in practical calculations.

TABLE 2

Dimensions of the specimen

Specimen name	Description of the specimen	Aspect ratio	Length	Thickness	Height
CL-1	Laterite	1.245	94 cm	21.5 cm	117 cm
CL-2	Laterite	0.99	94 cm	21.5 cm	93 cm
CL-3	Laterite	0.713	94 cm	21.5 cm	67 cm
CL-4	Laterite	0.447	94 cm	21.5 cm	42 cm
BCH-1	Solid concrete blocks	1.245	94 cm	20 cm	117 cm
BCH-2	Solid concrete blocks	0.99	94 cm	20 cm	93 cm
BCH-3	Solid concrete blocks	0.713	94 cm	20 cm	67 cm
BCH-4	Solid concrete blocks	0.447	94 cm	20 cm	42 cm

TABLE 3
Idealised chart of specimens

specimen	ke	Aenv	hu	hu/hmax
CL-1	2180	30.39025	1.266	0.493
BCH-1	1471.5	43.8795	0.99	0.497
CL-2	3924	67.83	1.995	0.500
BCH-2	405.93	70.35	1.49	0.499
CL-3	1962	32.05625	1.105	0.495
BCH-3	6180.3	15.9285	1.225	0.498
CL-4	8583.75	15.232	1.1716	0.492
BCH-4	2452.5	39.10075	1.117	0.492

4.4 Effect of aspect ratio

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The figure shows the load deformation behaviour of walls with same aspect ratios. From this load deformation curves it is understood that for all the aspect ratios except the lowest aspect ratio concrete block wall carries maximum ultimate load.

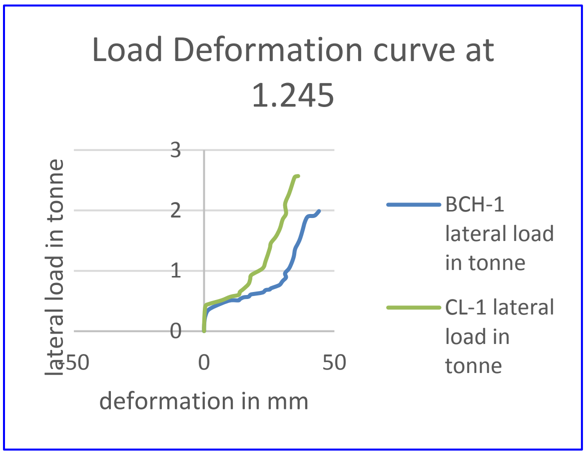

Fig.5 Load-deformation curve of burnt clay brick and burnt clay hollow brick of aspect ratio 1.245

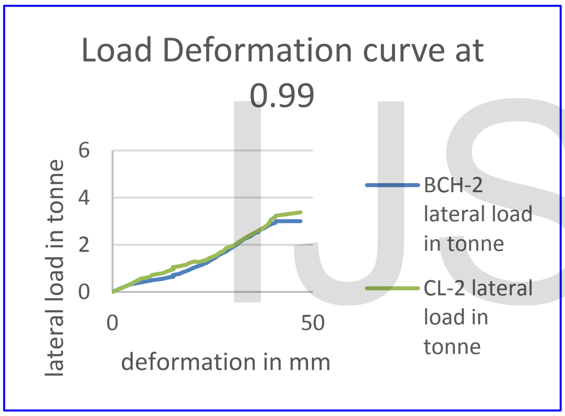

Fig.6 Load-deformation curve of burnt clay brick and burnt clay hollow brick wall of aspect ratio0.99

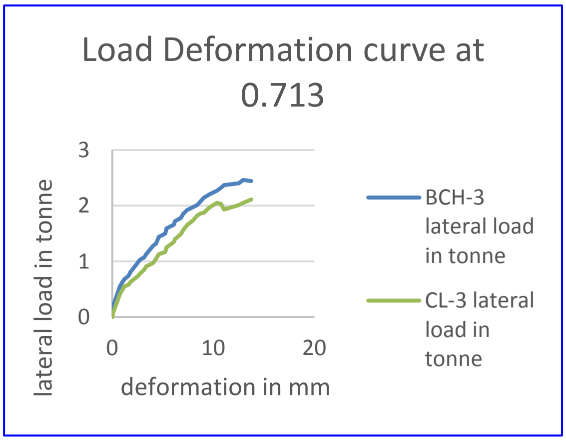

Fig.7 Load-deformation curve of burnt clay brick and burnt clay hollow brick wall of aspect ratio 0.713

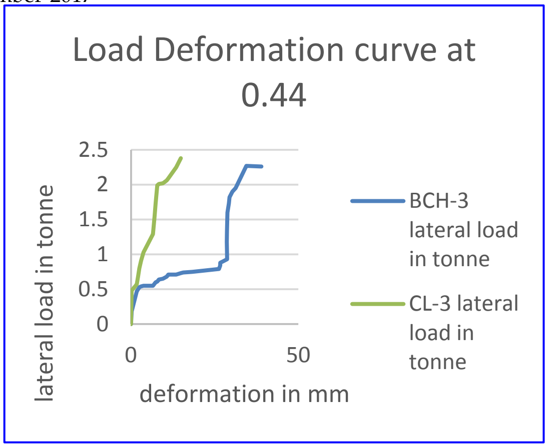

Fig.8 Load-deformation curve of burnt clay brick and burnt clay hollow brick wall of aspect ratio 0.44

4.4 Effect of Failure modes

The figure shows the load deformation behaviour of walls with same aspect ratios. From this load deformation curves it is understood that for all the aspect ratios except the lowest aspect ratio concrete block wall carries maximum ultimate load.

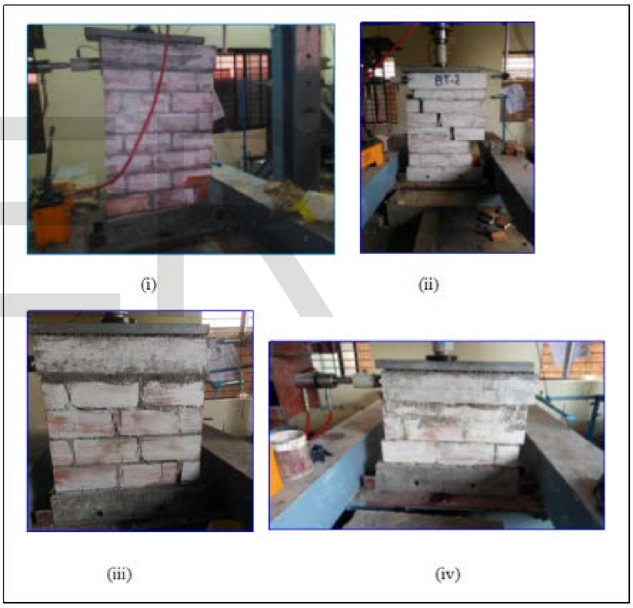

Fig.3 failure pattern of burnt clay brick wall of aspect ratio i) 1.234 ii) 0.99 iii) 0.713 iv) 0.444

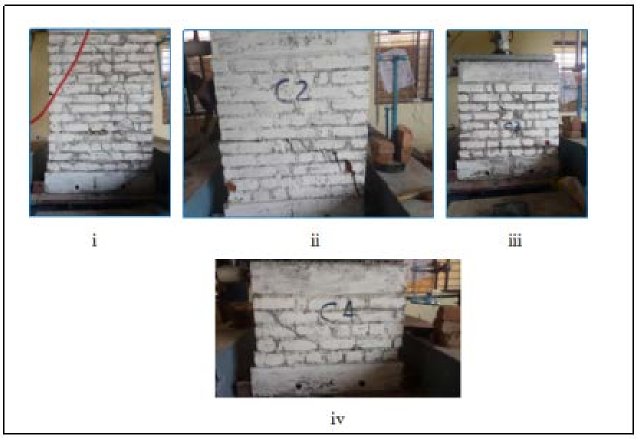

Fig.4 failure pattern of burnt clay hollow brick wall of aspect ratio i)1.234 ii)0.99 iii)0.713 iv) 0.444

TABLE 4
Failure pattern of walls

Specimen name	Description of the specimen	Aspect ratio	Failure pattern
CL-1	Burnt clay brick	1.245	Diagonal failure
CL-2	Burnt clay brick	0.99	Diagonal and bond failure
CL-3	Burnt clay brick	0.713	Diagonal failure
CL-4	Burnt clay brick	0.447	Diagonal failure.
BCH-1	Burnt clay hollow brick	1.245	Rocking failure
BCH-2	Burnt clay hollow brick	0.99	Diagonal failure
BCH-3	Burnt clay hollow brick	0.713	Diagonal failure
BCH-4	Burnt clay hollow brick	0.447	Diagonal failure

5 Discussion

This report covering the effect of tensile and shear bond strengths of the masonry to the failure mode capacities and deformation characteristics of un-reinforced burnt clay brick and burnt clay hollow brick masonry wall. The aim will be achieved through the following objectives. 1) examine the in plane shear behaviour of un- reinforced masonry using laterite, solid concrete block, which are locally available materials in Kerala. 2) Examine the various modes of failure of URM with different aspect ratio.

To achieve the above objectives, a detailed literature review on unreinforced masonry buildings was first carried out.

An experimental program on masonry materials has been carried out as part of this research. Detailed study on material properties and masonry compressive strength and triplet tests are discussed in Chapter III.

An experimental program has been carried out as part of this research. The experimental setup, details of the test specimens and the results obtained from the experimental investigations load-deformation curves are discussed in Chapter IV.

Eight wall panels of varying dimensions are tested for in-plane monotonic lateral loads. For each specimen the axial compressive loads were maintained as a constant during testing. Two different materials with four different aspect ratio was used. A comparison of the same aspect ratio was also studied.

6 Conclusion

Based on the work presented in this thesis following point-wise conclusions can be drawn

- ✓ From the results of the presented research and reviewed literature, it can be concluded that, the burnt clay brick masonry possesses distinct lateral strength than other types of local masonry wall in Kerala for high aspect ratios. For lowest aspect ratio both burnt clay brick and burnt clay hollow bricks have same lateral strength.
- ✓ Testing of walls in a four range of aspect ratios with two different materials allowed direct comparison is among the walls. It was found that the maximum shear strength of wall did not depend upon the aspect ratio, and could be accurately predicted by its failure pattern and properties of bricks.
- ✓ It can also be concluded that from the experiment as the aspect ratio increases the failure pattern of wall changes to rocking type failure and for low aspect ratio the failure pattern is diagonal failure.
- ✓ From the idealisation curve the strength degradation factor obtained is 0.5. thus the equation developed

for walls in Kerala is $Hu = 0.5H\max$ .Hu does not represent the design, but the idealised maximum experimental value.

7 RECOMMENDATIONS FOR FURTHER RESEARCH

- ✓ These experiments have only been carried out for an in-plane URM wall under different aspect ratios by using the locally available materials in Kerala. There is a need for further research of the URM wall under quasistatic-reversed cyclic lateral loading by using the same materials
- ✓ Further study needs to be done to evaluate the effect of openings in wall panels in Kerala
- ✓ There is a scope of research on the behaviour of vertical and plan irregular URM building in Kerala

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