Available online at www.elixirpublishers.com (Elixir International Journal)

Civil Engineering

Elixir Civil Engg. 79 (2015) 30493-30497

ISSN: 2229-712X

In plane lateral loading of masonry (simple and confined) - A comparative experimental study

Zahid Ahmad Chat, Mohd Hanief Dar and Ahsan ul Haq
National Institute of Technology, Hazratbal Srinagar J&K India.

ARTICLE INFO

Article history:
Received: 21 January 2015;
Received in revised form:
25 January 2015;
Accepted: 19 February 2015;

Keywords
Simple Masonry, Confined Masonry, Earthquake, Bricks, Mortar, Lateral load, Load capacity, Ductility, Stiffness, Tie beams, Tie columns, Reinforcement.

ABSTRACT
In today's era, majority of the residential construction involves masonry. Despite its wide use in structural engineering, masonry is still the least understood especially seismic behavior building material in terms of strength and deformation characteristics due to its heterogeneity. The general behavior of unreinforced masonry under lateral is brittle and thus has high seismic hazard. Confining masonry is found to enhance the seismic behavior of masonry. In this project simple masonry (unreinforced masonry) and confined masonry walls of size 1.25mx1.25mx.1m were tested and compared for their behavior under in plane lateral loads. Confinement to the masonry was provided in the form of reinforced vertical columns and horizontal beam called as tie columns and tie beam respectively. The reinforcement in confinement was provided as per the guidelines issued by Euro code 8 for confined masonry. Their ultimate load strength, deformation capacity (ductility) and initial stiffness are the parameters studied in comparison. Confined masonry showed excellent behavior under lateral loads both in terms of ultimate load capacity and ductility than the simple masonry.

Introduction

Masonry makes up a large part of majority of the constructions in both rural and urban areas because of the following reasons :

a) Low cost
b) Easy to construct
c) Easily available
d) Good insulation

But unreinforced masonry has proven vulnerable during earthquakes and has been a cause of huge losses of life and property. During an earthquake, the ground surface moves in all directions. The damaging effects on buildings are caused by the lateral movements (lateral loads). The poor performance of masonry buildings in earthquakes is because of the following reasons [12]:

a) The masonry itself is brittle and thus fails suddenly
b)Masonry has great weight because of thick walls. Consequently the inertia forces are large. Also strength loss due to repetitive loads is large.
(c) Quality of construction is not consistent because of quality of the locally manufactured masonry units (brick), unskilled labour, etc., that leads to large variability in strength.

Research has continuously been going on for understanding and improving the behavior of masonry. The seismic behavior of simple masonry has been improved by incorporating reinforcement and confinement of the masonry respectively known as confined masonry. In this work a comparison of behavior of unreinforced masonry (simple masonry) and confined masonry will be done under lateral loads. Unreinforced masonry structures have been constructed since ancient times, however confined masonry is has been very recently used in civil constructions. Confined masonry construction consists of masonry walls (made either of clay brick or concrete block units) and horizontal and vertical RC confining members built on all four sides of a masonry wall panel. Vertical members, called tie-columns or practical columns, resemble columns in RC frame construction except that they tend to be of far smaller cross-section. Horizontal elements, called tie-beams, resemble beams in RC frame construction see fig 1(b). To emphasize that confining elements are not beams and columns, alternative terms horizontal ties and vertical ties could be used instead of tie-beams and tie-columns. Confined masonry is different from reinforced concrete frames (RC frames) as in the former first the brick walls are constructed and then the confining elements i.e. tie columns and tie beams. Whereas, in RC frames first the columns and beams are constructed and then are filled in with bricks as shown in fig. 1(a) and 1(b) [2]. Also the grade of concrete used in confined masonry is very low, generally less than M15, as compared to RC frames. Further the amount of reinforcement used in confined masonry is very low as compared to the reinforcement used in RC frames.

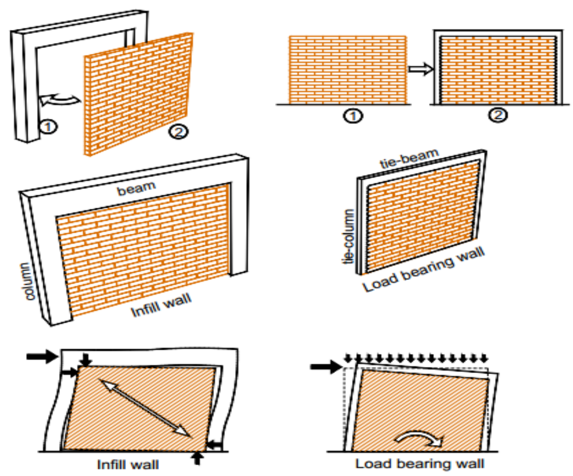

Figure 1(a) reinforced concrete frame. 1(b) confined masonry

Tele:
E-mail addresses: zahidchat@gmail.com

Aim and Objectives

The aim of this study is to understand and compare the structural behavior of the two forms of masonry: simple masonry, confined masonry walls under in plane lateral loads and thus their suitability. The following objectives will be accomplished to achieve this aim:

1. Compare the lateral load capacity of simple masonry, vertically reinforced masonry, and confined masonry walls.
2. Compare the ductility (maximum deformation) of the above stated models of masonry.
3. Compare the initial stiffness of the stated three types of walls.

Research methodology

General

The investigations of this work were supported by experimental work which was conducted in two stages. In the first stage the tests were conducted on the constituent materials – sand, brick, mortar, steel, concrete. . In the second stage four (4) wall specimens were constructed, two for each -

a. Simple masonry.
b. Confined masonry.

The comparison of simple, vertically reinforced, confined masonry walls under lateral loads is done by constructing models of size 1.25mx1.25mx.1m. Two specimens were made for each type of masonry. The bricks were laid in stretcher courses. All the component materials were obtained from local suppliers of Hazratbal (Jammu & Kashmir, India) area and were tested before using them for wall construction.

Characteristics of materials

To better understand the structural behavior of masonry wall it is important to have some knowledge of the properties of component materials. Masonry is a multi-component assembly; in the current study the wall specimens consisted of clay burnt bricks, cement mortar, concrete, and reinforcing steel.

The main purpose of testing the component materials was to characterize the materials, to facilitate the comparisons with other published results and design standards and to ensure that the quality of materials was being maintained. The materials were tested in the following sequence:

I Brick: A brick is a block or a single unit of a kneaded clay-bearing soil, sand and lime, or concrete material, fire hardened or air dried, used in masonry construction. The bricks used in this study are clay burnt bricks. The size of bricks is 9"x4"x3". The average compressive strength of the bricks came out to be 82 Kg/cm2 or 8.2 MPa. The strength classification by IS 3495: 1992 puts it in class B bricks.

Mortar: Mortar is a workable paste used to bind building blocks such as stones, bricks, and concrete masonry units together, fill and seal the irregular gaps between them, and sometimes add decorative colors or patterns in masonry walls. The mortar used in this research is cement-sand mortar. The cement-sand mortar consists of sand, cement and water. The cement-sand ratio used is 1:6 i.e. MM3. The cement used is OPC of grade 43. The average compressive strength of the mortar used at 28 days was found to be 3.8 MPa. The compressive strength of mortar is less than that of the brick which is a requirement laid by IS 4326.

Concrete: The concrete is a composite material composed of water, coarse granular material (the fine and coarse aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space among the aggregate particles and glues them together. The ratio of cement-sand-coarse aggregate used is 1:2:4 (M15) as per nominal mix design. Sand used conformed to zone three. The size of coarse aggregate used is 20mm(60%) and 10mm(40%). Average compressive strength of concrete used in confining elements at 28 days was 16.2 Mpa.

IV Steel: the steel grade used was Fe 415. Three test samples recorded an average tensile strength value of 440 Mpa .

Model Construction

The wall specimens were carefully built on the floor of Structural Laboratory at National Institute of Technology, Srinagar, J&K. The thickness of bond used is 10mm. Bricks were laid in stretcher courses. Also the mortar used in the brickwork is same conforming to the provisions in IS 1905 and IS 4326.

The size of the models was fixed from 1:2 scale down modeling. The guidelines issued by Euro code 8 for confined masonry establish that the tie-column reinforcement should consist of four 10 mm diameter deformed bars (4-10 mm bars) for longitudinal reinforcement, and 6 mm ties spacing @200mm c/c. The spacing between vertical tie columns is 2.5m. The tie beams are placed at each floor. Taking floor height as 2.5m. Thus due to 1:2 scale down modeling the length of model was 1.25m.The longitudinal reinforcing bars in model were 8mm and 6mm ties were used as stirrups (lower diameter bars were not available). Spacing between stirrups is kept 100mm. The size of other models was kept the same for comparison. Two models were constructed for each type of masonry. The size of the models was 1.25mx1.25mx.1m. Toothing was provided in the confining concrete to grip the wall. The models were properly cured for ten days after construction.

The walls were loaded at 28 days from their construction. Load was applied with a hydraulic jack at one of the top corners. The bottom of the wall was perfectly fixed. Deflections were constantly noted down for various loads with the aid of a dial gauge fixed at one of the top corners. The top was allowed to move freely. The wall was prevented from over turning by vertical reactions on the top of the wall.

Results

All the walls developed diagonal cracks. The cracked walls after failure are shown in fig.2 and fig 3.

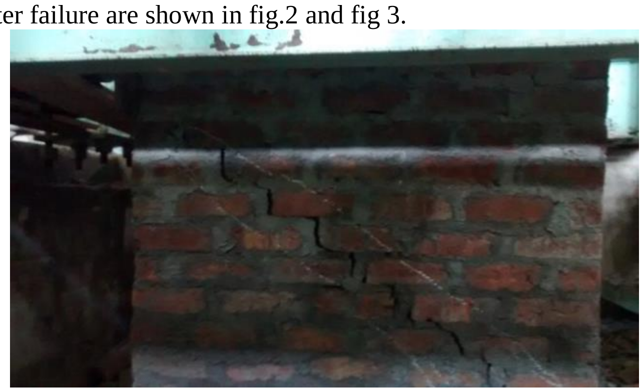

Figure 2 crack pattern in simple masonry

Figure 3 crack pattern in confined masonry

Table 1. Load and Deflection values for Simple Masonry model 1

S. no	Load (tons)	Deflection (cm)
1.	0	0
2.	0.5	0.1
3.	1.0	0.15
4.	1.5	0.25
5.	2.0	0.4
6.	2.5	.7
7.	3.0	1.0
8.	3.5	1.5
9.	4.0	2.0
10.	4.5	3.5
11.	3.5	4.5
12.	2.0	5.5

Table 2 Load and Deflection values for Simple Masonry model 2

S. No	Load (tons)	Deflection(cm)
1.	0	0
2.	0.5	0.05
3.	1.0	0.17
4.	1.5	0.25
5.	2.0	0.4
6.	2.5	0.7
7.	3.0	1.1
8.	3.5	1.4
9.	4.0	2.0
10.	3.5	2.7
11.	3.0	3.5
12.	2.5	5

Table 3 Load and Deflection values for Confined Masonry model 1

S. No	Load(tons)	Deflection(cm)
1.	0	0
2.	1	0.05
3.	2	0.1
4.	3	0.3
5.	4	0.4
6.	5	1.0
7.	5.5	1.5
8.	6	2.0
9.	5	4.0
10.	3.5	6.0
11.	3	8
12.	3	10
13.	2.5	12

Table 4 Load and Deflection values for Confined Masonry model 2

S. No	Load(tons)	Deflection(cm)
1.	0	0
2.	1	0.05
3.	2	0.1
4.	3	0.3
5.	4	0.4
6.	5	0.7
7.	6	1.0
8.	6.5	1.6
9.	6	1.8
10.	5	2.0
11.	3.5	3.5
12.	3	5
13.	3	8
14.	3	10
15.	2.75	11
16.	2.75	12
17.	2.5	13
18.	-	-

Results of tests on simple masonry

The results of the experimentation on simple masonry models, model 1 and model 2, are presented in table1 and table 2, which give the various loads and corresponding (deflections of the top of the wall). The load at the beginning of cracks was also recorded. The load deflection curve for simple masonry model 1 and model 2 is shown in fig. 4 and fig.5 respectively.

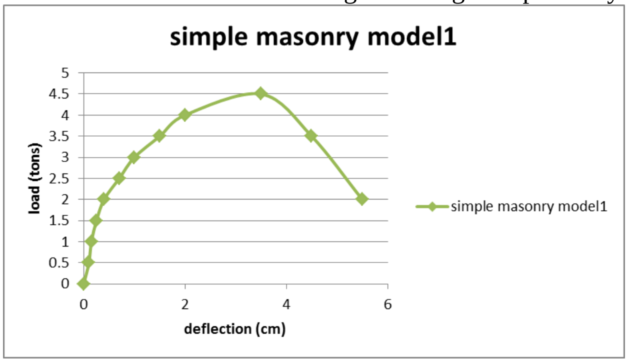

Figure 4 load deformation curve for simple masonry model 1

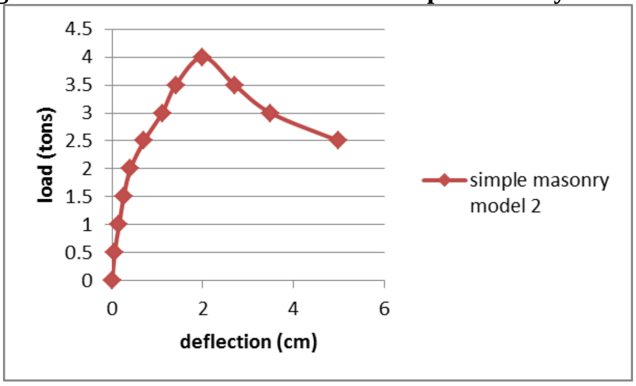

Figure 5 load deformation curve for simple masonry model 2

Average values of the lateral load parameters for simple masonry wall models:

The average collapse load was 4.25 ton (42.5KN).

The average maximum deflection recorded was 5.25 cm.

The average initial stiffness was 6.2 KN/mm.

Also both the models showed first crack at 2 tons (20 KN). The masonry showed brittle behavior collapsing almost immediately after reaching maximum lateral load capacity. The stiffness was initially high and the decreased very shaply.

Results of tests on confined masonry

The results of the experimentation on confined masonry models, model 1 and model 2, are presented in table3 and table 4, which give the various loads and corresponding (deflections of the top of the wall). The load at the beginning of cracks was also recorded. The load deflection curve for confined masonry model1 and model 2 is shown in fig. 4 and fig.5 respectively.

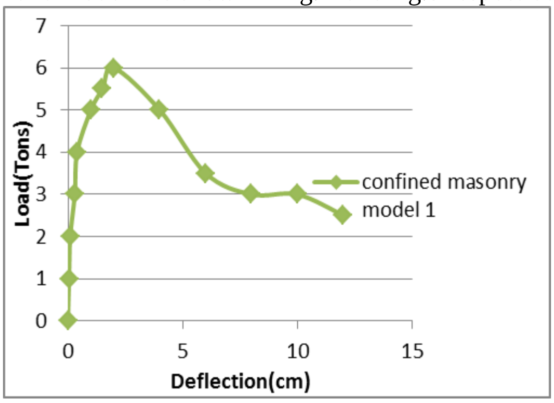

Figure 6 load deformation curve for confined masonry model 1

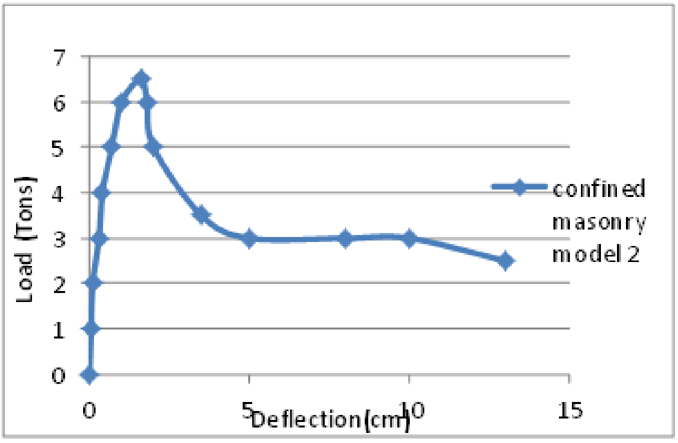

Figure 7 load deformation curve for confined masonry model 2

Average values of the lateral load parameters for confined masonry wall models:

The average collapse load was 6.25 ton (62.5KN).

The average maximum deflection recorded was 12.5cm.

The average initial stiffness was 10 KN/mm.

Also both the models showed first crack at 2.5 tons (25 KN). The masonry showed a very ductile behavior collapsing after undergoing large deflections. The stiffness was initially very high and the decreased very sharply.

Discussion of Results and Conclusions

All the models failed in shear. The cracks were diagonal, extending from the corner where load was applied to the diagonally opposite corner. The pattern of cracks was same in brick masonry and confined masonry. However, in Confined masonry one of the corners (diagonally opposite to where load was applied) got crushed forming a sort of a hinge. Confined masonry behaved much better than simple masonry with respect to the parameters studied i.e, lateral strength and deformation capacity (ductility). These two parameters have a huge influence on the behavior during earthquakes. Better lateral load capacity means better resistance to bigger earthquakes. Higher ductility means brittle failure is avoided which gives ample time to evacuate the building even if damage (excessive cracking) is caused. Fig. 8 gives a comparison between simple masonry and confined masonry for the various lateral load parameters – collapse load, ductility, and initial stiffness.

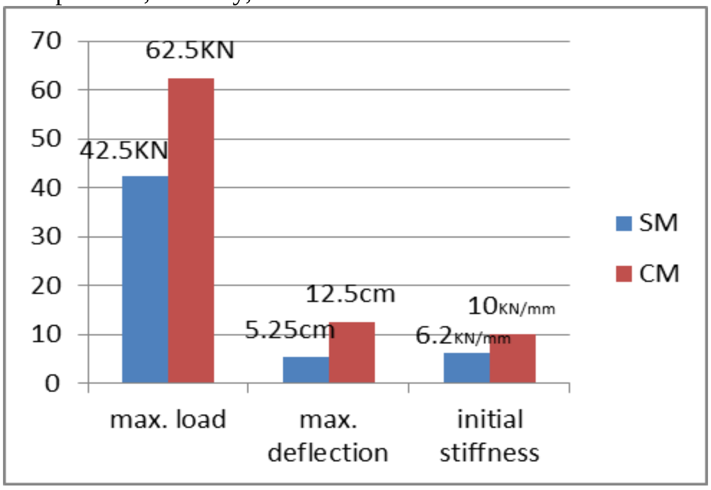

Figure 8: comparative lateral load capacity parameters of simple masonry (SM) and confined masonry (CM).

Based on the study the following conclusions are drawn:

1. Confined masonry has much better lateral strength with respect to vertically reinforced masonry and simple masonry.

The lateral strength of Confined masonry was about 46% more than simple masonry.
2. Confined masonry has higher ductility than simple masonry by 138%.
3. The initial stiffness of confined masonry is about 40% more than that of simple masonry.
4. Failure of simple masonry is sudden.
5. For models with high vertical load failure occurs due to shear in which the cracks are diagonal.

Recommendations

From the study done over the two types of masonry walls, the following recommendations are proposed:
1. For high seismic regions like Kashmir, confined masonry will provide an earthquake resistant residential construction (up to three storeys). For regions with high earthquake vulnerability this type of masonry will reduce highly the devastations and losses caused by it.
2. Since the construction details i.e, reinforcement details in tie columns and tie beams is simple, requiring very less engineering input and less skill during construction, it can be easily used in the rural areas as well.
3. As was seen the ductility of simple masonry was very less which can lead to sudden collapse, hence should be disallowed.
4. Confinement should be provided around openings, which will improve seismic behavior. It will improve both ductility and lateral load capacity.
5. An Indian code should be prepared specially for confined masonry to encourage and make common the construction of confined masonry.

References

[1] Aguilar G.and Alcocer S.M. (2001) "Effect of Horizontal Reinforcement on the Behavior of Confined Masonry Walls Under Lateral Loads". Centro Nacional de Prevención Desastres (SEGOB), Mexico City, Mexico, 181 pp.
[2] Confinedmasonry.org.
[3] Daniel Abrams and Nirav Shah, December " Cyclic lateral load testing of masonry walls" ,1992.
[4] Euro code 8 for confined masonry (1996).
[5] Harry G. Harris, Gajanan Sabnis-Structural Modeling and Experimental Techniques, Second Edition-CRC Press (1999).
[6] IS 4326:1993, "Earthquake resistant design and construction of buildings" – code of practice.
[7] IS 2250: 1981, "code of practice for preparation and use of masonry mortars".
[8] IS 1077: 1992, "common burnt clay bricks and specifications".
[9] IS 2212: 1991, "brick work" - code of practice.
[10] R. Meli. "Behavior of masonry walls under lateral loads".
[11] S. Gouveia, P. Lourenco. "Masonry shear walls subjected to cyclic loading effect of confinement and horizontal reinforcement" , 2012.
[12] S.K.Duggal, Earthquake resistant design,.
[13] S. Brzev. Earthquake resistant confined masonry construction, National information center of earthquake engineering, Indian Institute Of Technology Kanpur, Dec. 2007.
[14] Sheikh, S. A. and Khoury, S. S, "Confined Concrete Columns with Stubs", ACI Structural Journal, Vol. 90,NO.4, July-August 1993, pp.414-431.