Analytical and Experimental Investigation on Reinforced and Unreinforced Brick Wall under Axial Loading

Kuladeep Kumar Narayana, Lingeshwaran Nagarathinam

Abstract: Brick is a building material used to make walls, pavements and other elements in masonry construction. Generally, brick is a unit made up of clay, which is in rectangular shape laid in mortar. Out of total world's population, one third lives in unreinforced masonry (URM) structures and most of these structures were residential houses. Earthquakes which occur mainly causes major effects in these type of structures which leads to mainly socio-economic losses. Most of the residential buildings which is made up of masonry walls needs to improve its structural performance and this can be done by providing reinforcement. In order to overcome this, experimental investigation was conducted on brick wall to improve its lateral strength, flexural capacity and displacement capacity, as well as energy dissipation of both horizontally reinforced and unreinforced wall. The comparison is made for the wall with and without reinforcement techniques which shows relevant advantages. In this present study, the behavior of brick wall with reinforcement and without reinforcement was examined by determining load vs deflection curves. A simple analytical approach has been carried out using Staad Pro.

Index Terms: URM structures, lateral strength, energy dissipation, reinforcement technique, load vs deflection curves.

I. INTRODUCTION

Generally, for past thousand years masonry construction is used frequently for durability purpose. Masonry construction is easy to construct and due to its low cost the aesthetic appearance will be good. In most of the developed and developing countries masonry is still being used by easy construction techniques. Unreinforced masonry (URM) structures are the most common form of building technique existing in the world. URM is recognized as most vulnerable type of construction for earthquakes.

Most of the buildings damaged due to earthquakes are mostly made up of unreinforced (URM) structural walls. The quality of these walls are often varied due to workmanship and material disparities caused by poor quality bricks. Masonry walls have more compressive resistance to transmit vertical forces to the base of the buildings with safety. However, there load bearing capacity against the horizontal loads and deformation capacity will be low. To improve the load bearing capacity, the walls are strengthened by using steel reinforcement and hence the ductility of strengthened wall can be increased by using different reinforcement types such as grid type, m-shape which is incorporated horizontally between the layers of wall specimen [1].The reinforcement provides greater stiffness to the wall .The deformation capacity of the wall can be reduced by using reinforcement in masonry walls [2]. In this paper, experimental study was conducted under axial loading for one unreinforced and one reinforced brick walls which is placed between two beams and by varying steel reinforcement type as mesh shape horizontally in the wall to determine the load vs deflection curves and to enhance the flexural capacity of the walls. A comparison is made between both the walls in which the reinforced wall will change beneficially in terms of deformation, load bearing capacity and resistance against extraordinary loads such as impact loads, earthquake loads and vibrations and experimental results are discussed.

II. RESEARCH SIGNIFICANCE

In this research paper, it can be stated that reinforced masonry structures can be used instead of reinforced concrete frames by providing reinforcement in different directions which examines shear behavior by failure modes, crack pattern of solid masonry walls. The experimental investigation details on brick wall by using steel reinforcement can be examined.

III. EXPERIMENTAL PROGRAM

A. Material Properties

In this investigation, tests were performed to determine the mechanical properties of the materials which is used as per ASTM standards. A cement sand mortar ratio of (1:3) has been chosen for this study. The beam samples were casted as per mix design procedure followed by IS10262:2009& IS 456:2000 [3]. The masonry test samples were constructed using brick of size 220 mm x 100 mm x 100 mm using 1:3 cement sand mortar with the help of local mason. These samples were constructed using English bond with alternate header and stretcher. As per ASTM C109-11, compressive strength test of mortar cube has been carried out [4]. The compressive strength of brick was obtained as per ASTM C67-11 [5].

Table I informs about the mechanical properties of compressive strength that are taken from the ASTM standard.

B. Beam and Wall Details

In this present study, a total of six beams were casted as per mix design procedure followed by IS10262-2009& IS

Revised Manuscript Received on April 09, 2019.

Kuladeep Kumar Narayana, P. G. student, Department of Civil Engineering, Koneru Lakshmaiah Education Foudation, Guntur, A.P., India.

Lingeshwaran Nagarathinam, Assistant Professor, Department of Civil Engineering, Koneru Lakshmaiah Education Foudation, Guntur, A.P., India.

456:2000[3] and it is denoted as B (Beam) 1 to 6. Two brick walls were given codes as BW (Brick wall) 1 to 3. The cross-sectional details are described in Table II.

Table I: Properties of strength

Mechanical Properties	Reference Paper	Average Value
Compressive strength for cube of 1:3 mortar ratio (f_c)	ASTM C109-11	2.5 N/mm^2
Compressive strength of brick (f_b)	ASTM C67-11	10 N/mm^2

Table II: Details of cross-section

Specimen	Beam			Wall	
	B1-6			BW1	BW2
Length (mm)	1500	1500	1500	800	800
Width (mm)	230	230	230	600	600
Depth (mm)	230	230	230	230	230

C. Reinforcement Details

All the six are reinforced with 16 mm and 10 mm diameter of Fe 500 grade high yield strength deformed steel bars confirmed to IS.1786:1985. Table III informs the steel reinforcement details and Table IV informs beam detailing of reinforcement. The cross sectional details of beam are shown in Figure 1.

Table III: Reinforcement details

Specimen	Diameter of Bar	
	16 mm	**10 mm**
	Ultimate Strength	**Ultimate Strength**
Trail 1	585.78	737.31
Trail 2	615.07	712.31
Trail 3	634.603	724.81
Tensile Strength	611.816	724.81

Table IV: Detailing of reinforcement in beams

Specimen	Longitudinal Reinforcement		Shear Reinforcement
Beam (1-6)	**Top**	**Bottom**	7No-10mm
	2No-16mm	4No-16mm	

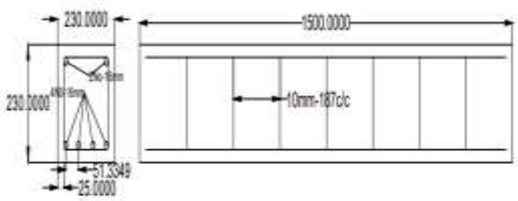


Figure 1*:* Beam Detailing

D. Mesh Type Reinforcement

For this experimental investigation, mesh shape form is used as a construction material in the form of reinforcement as shown in Figure 2. Mesh is used due to the fact that it is good in tension and it has higher ability to distribute load across large area.

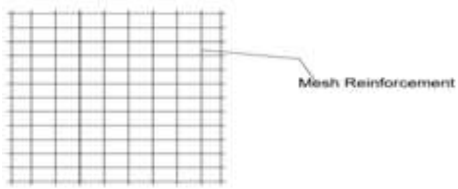


Figure 2: Mesh Reinforcement

E. Casting and Brick wall construction

In this study, a cement sand mortar ratio of 1:3 is chosen. Casting of beams is done by mix procedure followed by IS 10262:2009& IS 456:2000. It can be classified into two stages.

Stage 1: casting of beams : In this stage, four beams were casted for brick wall which is placed at top and bottom of the wall as a support. The beams are casted into a mould size of 1.5mẊ0.23mẊ0.23m as shown in Figure 3 with cement: sand: aggregate proportion of 1:1.27:2.9.

a) Mould with steel reinforcement

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

b) Casting of Beams

Figure 3:

a) Mould with steel reinforcement and
b) Casting of Beams

Stage 2: Brick wall construction: In the second stage, wall is constructed using common building brick of size 220mmẊ100mmẊ100mm. Two walls are constructed, one is conventional wall and other one is reinforced wall with mesh type as steel reinforcement of size 0.6mẊ0.20m as shown in Figure 4. The layout of these brick wall is shown in Figures 5 and 6.

c) Mesh type reinforcement

d) Unreinforced and reinforced brick wall

Figure 4:

c) Mesh type reinforcement
d) Unreinforced and reinforced brick wall

F. Detailing of Brick wall

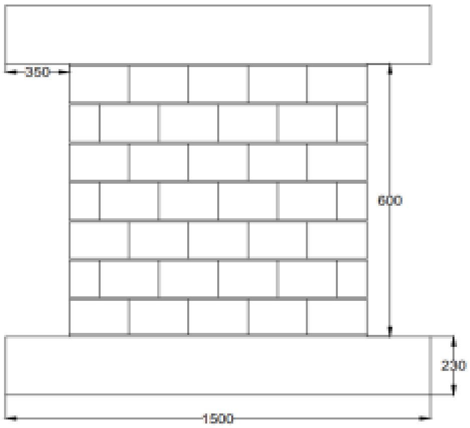


Figure 5: Layout of Unreinforced Brick wall

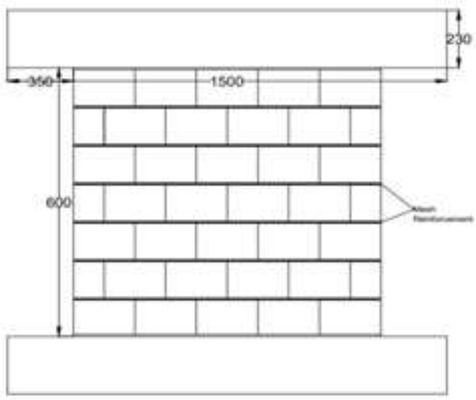


Figure 6: Layout of Reinforced Brick wall

G. Test Setup

In this experimental investigation, in total, two brick walls were constructed. Both the walls are of same size which is placed between the beams, one is unreinforced and other one is reinforced with mesh type shape which is placed alternatively by layer in the construction of brick wall as shown in figure. These brick walls are tested on a loading frame equipment of 200 tons capacity. The load was applied on the brick wall using compression loading cell which is measured and LVDT (Linear Variable Differential Transducer) was placed at side face of the brick wall which is exactly at center to the wall and at that point of member displacement is measured. These LVDTs were connected to a system of data acquisition where load and deflection are measured. Figure 7 shows the experimental setup for the loading and the original test setup of loading frame was shown in Figure 8.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

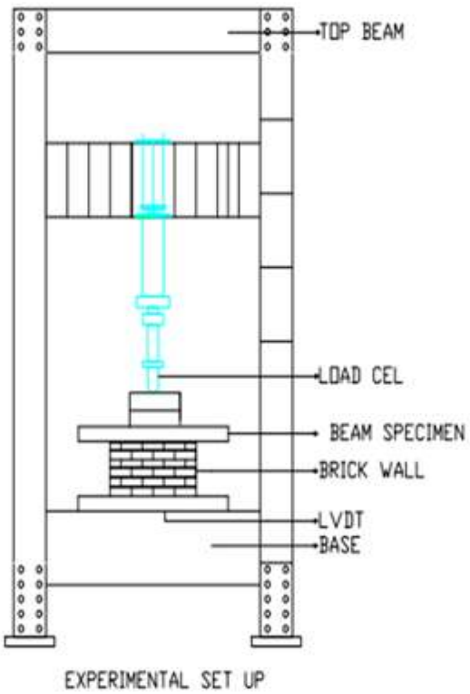


Figure 7: Experimental setup drawn in AUTOCAD

Figure 8: Original load Setup of Brick Wall

IV. ANALYSIS

In this study, along with experimental investigation a simple analytical approach has been carried out using Staad Pro.

A. Specimen Data

A Beam of dimensions 1.5mẊ0.23mẊ0.23m was created using nodal points on plate and brick blocks height of 0.6m was created using plate mesh. The top beam also placed with same dimensions.

B. Loading Condition

A point load of 300kN was applied at the center of wall specimen. As per IS 456:2000, load combinations are considered and analysis were performed as shown in Figure 9.

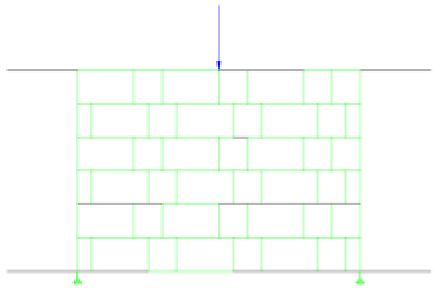


Figure 9: Brick wall Model

In Staad pro

a) Select space, add plate option is chosen for creating a brick wall using nodal points.
b) After creating a model, beam properties and wall thickness is assigned.
c) Support conditions are given to the wall as per requirement.
d) Load combination is chosen as per IS 456-2000.
e) Assigning dead load and live load on brick wall.
f) Start concrete design for beam
g) Run analysis and obtain results.

V. RESULTS AND DISCUSSION

A. By Experimental:

In this study, Experimental investigation has been done on brick wall under axial loading for both unreinforced and reinforced structures by determining load vs deflection curves.

B. Unreinforced Brick wall

In unreinforced brick wall, load was applied and crack patterns are observed as shown in Figure 10 at different loadings.

Figure 10: Unreinforced Brick Wall

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Discussion: When load is applied to the specimen it reaches to a maximum load of 315kN gradually without showing any signs of first cracks and suddenly fails and load vs deflection curve was shown in Figure 11.

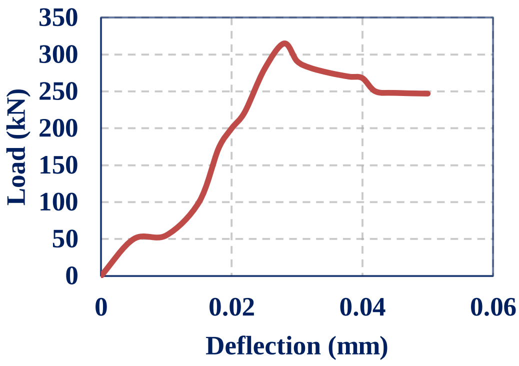


Figure 11: Load Deflection Curve for Unreinforced Brick Wall

C. Reinforced Brick Wall

In reinforced brick wall, Mesh type reinforcement is used and load is applied for determining crack patterns as shown in Figure 12.

Figure 12: Reinforced Brick Wall

Discussion: In this type of reinforced brick wall first crack was observed at 190kN and load deflection curve was obtained. The deflection tends to decrease after it reaches a max load of 347kN and graph is obtained as shown in Figure 13.

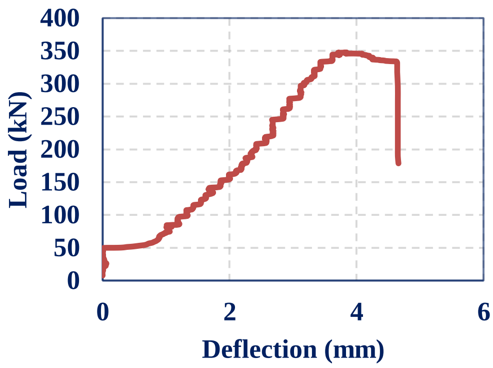
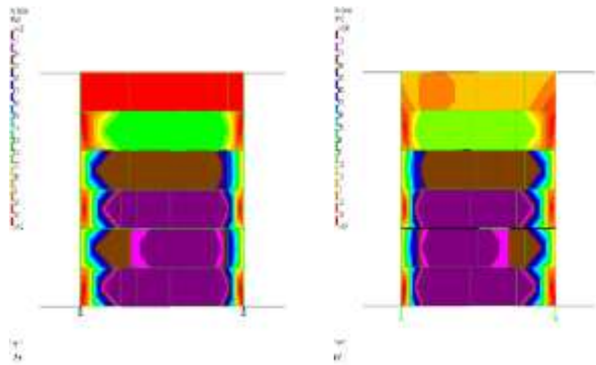


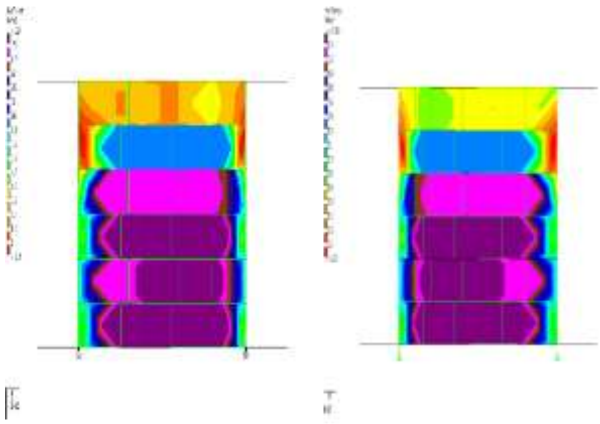
Figure 13: Load Deflection Curve for Reinforced Brick Wall

D. By Analytical:

A Simple analytical approach has been done for both unreinforced and reinforced brick wall using Staad Pro software where max stress behavior are observed as shown in Figure 14.

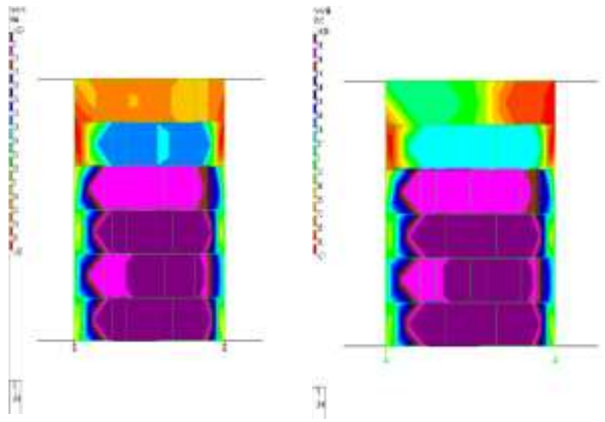


a) Max Absolute Stress for URM and RM Structures



b) Max Tresca Stress for URM and RM Structures

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication



c) Max Von Mises Stress for URM and RM Structures

Figure 14:

a) Max Absolute Stress for URM and RM Structures
b) Max Tresca Stress for URM and RM Structures
c) Max Von Mises Stress for URM and RM Structures

Discussion: In analytical part various stress behaviors of max absolute stress, max Tresca stress and max von mises stresses are determined where max absolute stress describes max top and max bottom stress occurred on the wall. The main difference between max Tresca stress and von mises stress is that Tresca stress gives the value of max shear stress occurred on the wall whereas von mises stress gives the critical stress value in terms of distortional energy which is stored in the wall. From above figure it can be concluded that reinforced wall has greater resistance than unreinforced walls.

VI. CONCLUSION

In this experimental study, behavior of brick wall for both unreinforced and reinforced masonry structures are obtained. Although the results are obtained there is no complete detailed report is predicted using load deflection curves. The following conclusions can be drawn from this paper as

a. The reinforced wall shows greater advantages than unreinforced in terms of load carrying capacity.
b. Steel reinforcement can increase the flexural capacity of walls.
c. When compared to reinforced walls unreinforced walls fails with low deformation and hence it predicts that steel plays a prominent role in masonry structures.

REFERENCES

1. Triwiyono, A., Nugroho, A.S., Firstyadi, A.D. and Ottama, F., “Flexural strength and ductility of concrete brick masonry wall strengthened using steel reinforcement”. *Procedia Engineering*, Vol. *125*, 2015, pp.940-947.
2. Dazio, A., Beyer, K. and Bachmann, H., “Quasi-static cyclic tests and plastic hinge analysis of RC structural walls”. *Engineering Structures*, Vol. *31*, Issue 7, 2009, pp.1556-1571.
3. IS 10262:2009 & IS 456:2000, “Standard test method procedure of mix design for different grades of concrete”.
4. ASTM (American Society for Testing Materials), Standard test method for compressive strength of cement mortar (using 50mm cube specimens), ASTM C109/C109M2011b.
5. ASTM (American Society for Testing Materials), Standard test method for sampling and testing structural brick clay tile, ASTM C67-112011c.
6. Anthoine, A., Magonette, G. and Magenes, G., “Shear-compression testing and analysis of brick masonry walls”. In *Proceedings of the 10th European conference on earthquake engineering*, Vol. 3, 1995, pp. 1657-1662.
7. Maidiawati, Tanjung, J. and Medriosa, H., “Experimental study on the influence of the opening in brick-masonry wall to seismic performance of reinforced concrete frame structures”. In *AIP Conference Proceedings*, Vol. 1892, Issue 1, 2017, p.020013.
8. Anita Fodi, “Experimental and numerical investigation on reinforced and plain masonry walls”, Budapest university of technology and economics.
9. Sadek, H. and Lissel, S., “Seismic performance of masonry walls with GFRP and Geogrid Bed joint reinforcement”. *Construction and Building Materials*, Vol. *41*, 2013, pp.977-989.
10. Shermi, C. and Dubey, R.N., “In-plane behaviour of unreinforced masonry panel strengthened with welded wire mesh and mortar”. *Construction and Building Materials*, Vol. *178*, 2018, pp.195-203.

AUTHORS PROFILE

Kuladeep Kumar Narayana Heis pursuing Master of Technology in Structural engineering as Civil engineering specialization from Koneru Lakshmaiah Education Foundation (Deemed to be University). He has completed Bachelor of Technology (Gold Medalist) in Civil engineering in 2016 from Kuppam Engineering College, Kuppam, Chittoor district, Andhra Pradesh, India..

Lingeshwaran Nagarathinam is working as Assistant Professor at Koneru Lakshmaiah Education Foundation (Deemed to be University), Vaddeswaram, Guntur district, Andhra Pradesh, India. He has completed Master of Engineering in Structural Engineering from Adhiyaman College of Engineering in 2016 and pursuing Ph.D. in Koneru Lakshmaiah Education Foundation (Deemed to be University). His research interests include seismic analysis and design in Staad. Pro, ETABS, SAP, Midas, Earthquake engineering, Composite Structures. He has published 14 research papers in international journals and conferences and guided 5 number of masters. He is a lifetime permanent member of IEI (Institution of Engineers India) & ICI (Indian Concrete Institute).