Experimental Analysis of Seismic Performance on bed Joint Reinforced Solid Brick Masonry Walls – a State of the Art

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Abstract: ***The paper reports on a comprehensive review of state of art on the performance of bed joint reinforced masonry walls for structural applications under lateral loadings. In severe seismic zone regionsstill need to improve performance of masonry buildings. In current scenario lack of design and construction on reinforced masonry walls and experimental investigations on bed joint reinforced shear walls to study the effect of reinforcement on deformation, stiffness and strength. In past international and national literature reviewers shown that bed-joint reinforcement provides only marginal improvement of in-plane shear capacity, but satisfactory improvement in ductility capacity. In the unreinforced masonry walls crack distribution with large energy dissipation to prevent this one should go with horizontal reinforcement. However almost no research on bed joint reinforced,shear wall is available.The current study includes the analysis & experimental study on full-scale solid burnt brick masonry walls of different aspect ratio, with and without bed-joint reinforcement, through displacement-controlled in-plane cyclic loading to understand the difference in performance of unreinforced masonry walls, walls with IS 4326 (1993) detailing and reinforced masonry walls in terms of strength, stiffness, ductility and energy dissipation.***

Index Terms: Bed joint reinforcement, Energy dissipation, Load vs deflection, Stress parameters.

I. I.INTRODUCTION

Masonry is a traditional material long associated with tradesmen who were essentially artisans at a time when design was as much art as it was science. Masonry has been used, in a wide variety of forms, as a basic construction material specially to make a load bearing walls (structural walls) and infill walls (non-structural walls) for public and residential buildings. But in most countries, masonry is still used as a traditional, non-engineered construction material. Hence engineering approach to masonry construction has to be encouraged by giving more emphasis on earthquake resistant masonry design. Masonry is a typical construction system which consists of masonry units, mortars, grout and reinforcing steel. Masonry constructions are categorized into Unreinforced Masonry (URM), confined masonry, Reinforced Masonry (RM) and pre-stressed masonry. The use of plain or URM is limited in scope, as adequate structural capacity is required for large building systems especially when the wind and earthquake forces are significant. In the presence of lateral forces, reinforcing masonry is essential with horizontal and vertical reinforcement provides higher flexural and shear capacity to walls required in seismic zones for masonry constructions. They improve the deformation and energy dissipation capacity of the walls. Out-of-plane failure can be prevented in URM by the introduction of bands (RC) at lintel and floor levels. Reinforced and confined masonry walls have higher overturning resistance to out-of- plane loads. Only when out-of-plane failure, a local mechanism, is prevented, the global seismic response mechanism i.e. in-plane shear resistance of walls can be harnessed. IS 1905 (1987), the BIS code for structural use of masonry addresses only URM constructions and design is based on the working stress method. IS has not formulated any design or detailing code for RM possibly as the quality of bricks in our country, on an average is not suitable for RM. Bricks should be of high strength and dense so that the moisture absorption should be less, otherwise the life expectancy of reinforcement will be lowered.

II. SEISMIC BEHAVIOUR OF MASONRY

If there are no lateral forces (wind and earthquake) then the stability of masonry structures should only be verified for gravity loads. Structures will be subjected to a series of horizontal cyclic actions under earthquake excitation which will cause high shear and bending stresses in structural walls which are the basic resisting elements in load bearing masonry buildings. Severe damage to shear walls could cause complete collapse of a building. Masonry buildings are box type structures composed of walls and floors connected in every direction. During seismic excitation, floors should act as rigid diaphragms and distribute the inertia forces among structural walls according to their stiffness.

Broadly, the response of masonry buildings under seismic loading can be classified as either in-plane global mechanisms or out-of-plane, which are local mechanisms. Earthquake shaking in a direction normal to the wall causes out-of-plane failures of walls (e.g. partial or total collapse of facade). Once the connections between floors and walls are adequate and if walls are not very slender then out-of- plane failure mechanisms are prevented. The connections are provided in terms of adequate strength in masonry at corners and provision of horizontal ties or bands in tension resisting materials. The in-plane shear capacity of masonry wall can then be utilized. Under in-plane mechanisms, the stiffness of walls continuously degrades and finally leads to complete

Revised Manuscript Received on April 15, 2019.

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collapse of structure, as the gravity load carrying capacity of the wall is compromised after significant stiffness and strength loss. The stiffness of walls continuously degrades, if wall is subjected to in-plane mechanism, and finally leads to complete collapse of structure.

III. IN-PLANE SHEAR STRENGTH OF REINFORCED &UNREINFORCED MASONRY WALL

Generally masonry walls are subjected to combined loading in practice (in-plane and vertical pre-compression). Mann-Mϋller (1982) has developed a relationship between local and global states of stress for combined loading at isolated unit level. The basic assumption of this theory is that the mortar strength and stiffness is significantly inferior to the brick units, and head joints are ineffective. Three fundamental failure mechanisms of failure are defined based on the observed modes of failure in experimental investigations.

- **Failure of mortar joints:** Typically occurs when low values of average compression in masonry
- **Failure due to shear tension in the unit:** Occurs for intermediate values of average compression in masonry
- **Failure due to crushing of masonry:** Occurs when average masonry compression is close to the uniaxial compressive strength of masonry

IV. BASE PAPER

In this paper, the salient results from literature regarding in-plane cyclic experiment on masonry shear walls with different typologies, reinforcement, varying amount of reinforcement, and pre-compression loading are presented. The test setup and programme for conducting in-plane cyclic tests are reviewed from the literature. This helps to establish the current programme of test incorporating real boundary conditions for cyclic test with maximum use of resources available. The effect of typology, pre-compression loading, aspect ratio and amount of reinforcement on masonry shear walls is briefly discussed. Literature related to analytical studies to calculate the in-plane shear strength of masonry wall with and without reinforcement is reviewed and briefly discussed.

To find the effect of pre-compression loading, effects of cracks due to load, effects of typology and amount of horizontal and vertical reinforcement is improving the energy dissipation, displacement ductility, ultimate shear strength of walls many researchers have carried out in-plane cyclic tests on Unreinforced masonry wall (URM) and Reinforced masonry wall (RM). Introduction of reinforcement in masonry increases ductility and provides better energy dissipation capacity from the studies of many researchers.

Bartlett (1965)has shown good solution for control tensile crack is use of reinforcement horizontal or vertical in the masonry wall. Priestley and Bridgeman (1974) also showed that efficient of reinforcement is less in horizontal compared vertical in resisting shear loading (Shear by dowel action is transferred to vertical steel, while shear by tension is transferred to horizontal steel). If the crack developed due to dowel action steel flexural resistance is rapidly decreases and to protect and hardening a large crack widths due to direct tension of horizontal bars.

Tomazevic and Zarnic(1987) have carried tests on concrete, ceramic blocks with different mortar strengths and reinforcement in cyclic loads tests on walls shown the significant influences and effect in the masonry. They have also proved that deformability of walls is increased by bed joint reinforcement, but inadequate bond and anchorage conditions is not fully effective by the larger amount of reinforcementin the tests being referred to. The work made an important source on the effect of horizontal reinforcement in reinforced masonry walls in the database available are 32 scaled masonry walls(1:3) are tested with only horizontal reinforcement.

Shing et al. (1989)have did the experimental analysis with combination of both vertical and horizontal to increase the flexural capacity of walls. **Khattab and Drysdale (1993)** have noted that the horizontal and vertical reinforcement only resist the shear stress.**Aguilar et al. (1996)** have introduced deformed wires in masonry walls as horizontal reinforcement and showed the improved deformation capacity and reduced stiffness. In the energy dissipation, displacementductility and ultimate strength are very useful in the addition of bed-joint reinforcement in masonry shear wall and there should limited amount of bed joint reinforcement. **Schultz (1996)** has carried out an analytical study of reinforced masonry with horizontal reinforcement. Subsequently, **Porter and Braun (1997)** have provided different aspect ratios in masonry shear wall for experimental evidence regarding minimum bed joint reinforcement in the presence of vertical reinforcement,supporting the analytical results and experimental reported by **Schultz (1996)** on reinforced and unreinforced masonry. **Schultz et al. (1998)** has carried out in-plane cyclic load tests with different aspect ratio and bed joint reinforcement ratio in order to compare behavior parameters such as stiffness, strength, dissipation and deformation capacity for the partially grouted concrete masonry shear walls and experimental findings show that the length to height aspect ratio, horizontal reinforcement haseffect on ultimate shear stress andone on deformationdissipation capacities but not affect the dissipation capacity on reinforcement.**Kubika and Piekarczyk (2004)** have found that, reduces the crack due to the distribution of shear stresses.

Voon and Ingham (2006)have confirmed from vertical and horizontal reinforcement of masonry walls that shear strength of masonry increases with the pre compression loading and amount of shear reinforcement is used in-plane cyclic tests and decreases inversely with length to breath wall aspect ratio, confined that post crack behavior walls on shear dominated improved the shear reinforcement in disturbed on uniformly manner. **Gouveia and Lourenço (2007)** have carried out introduction of horizontal reinforcement in the cyclic tests on sandwiched from four edge sides of the reinforced concrete confinement under

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vertical constant precompression level and the bed joint reinforcement addition on the masonry walls and the confined concluded that significant advantage. **Penna et al. (2007)** have carried tests on infill walls in hollow bricks and shown better results on unreinforced masonry.**Porto et al. (2010)** have elaborated the properties and behavior of horizontal perforated units on the reinforced masonry system with trusses as horizontal reinforcement. At the edges confining columns were built vertical reinforcement. In the experimental analysis, effects of horizontal and vertical reinforcement, pre-compression load, wall aspect ratio, and type of reinforcement on in-plane behavior of masonry wall were investigated. It was shown that pre-compression load enhances the shear capacity of wall, at the expense of displacement capacity.

Haach et al. (2010) have also carried out the in- plane cyclic test on innovative masonry system similar to the system on which **Voon- Ingham (2006)** and **Porto (2010)** have worked. From their experimental analysis, a conclusion has been drawn that easier construction method is good option due to no significant in the pattern of masonry effects of overall behavior of wall. The behavior ofmasonry walls influences in vertical axial compression. The reinforcement efficiency is reduced by lateral length and loading is increased but its lead to failure of brittle. In the open literature it is identified addition of bed joint reinforcement in improving global seismic response of a masonry structure in the absence of vertical reinforcement and also identified that bed joint reinforcement using brick solid clay improving the seismic response. However, due to the lack of Indiancode on reinforced and unreinforced masonry and use of solid clay bricks in India,solid bricks with different types of steel parameters experimental investigations on this type of combination are essential to evaluate whether increment in shear capacity, displacement ductility and energy dissipation is substantial or marginal.

Songbo Li et al (2015) investigate the failure process of reinforced and unreinforced masonry under seismic loadings with the lower level of reinforcement, mortar grades and its discuss forms of reinforcement and their effects, determine the shear strength of brick walls under axial and seismic loading. And author suggests reinforced masonry wall better performance due to material strength has been increased on reinforcement and distribution of steel bars.

Umadevi et al (2015)studied the parameters such as base shear, natural frequency, time period, storey drift and bending moments for different types of frame, infill frames for closed and open storey building for the different models. The software ETABS, Staad.Pro is used for analyze the frame models. Analysis are carried to obtain natural frequencies, mode shapes and results compared with experimental results obtained from shake table tests conducted on laboratory and models are validated

V. TEST CONDITION AND SETUP

The effects of typology, aspect ratio, pre-compression loading and amount of reinforcement on masonry shear walls have been reviewed. The test setup and programme has also been reviewed for conducting in-plane cyclic test having particular brick size and strength with suitable type of mortar. The different amounts of pre-compression loading and aspect ratios have also been reviewed along with the wall thickness. This helps to formulate the entire experimental setup incorporating real boundary condition with some modifications. According to IITK-GSDMA (Indian Institute of Technology Kanpur-Gujarat State Disaster Mitigation Authority, 2005), the minimum compressive strength of masonry unit used for RM should not be less than 7 MPa. It also suggests that the minimum thickness of load bearing walls in building should not be less than 230 mm. According to these guidelines, only high strength mortar (H1 or H2) should be used for reinforced masonry. According to IS 1905 (1987), the cement and sand proportion of H1 and H2 mortar is 1:3 and 1:4 respectively which should give minimum 10 MPa and 7.5 MPa compressive strength after 28 days of casting. Depending upon the wall geometry, shear walls are classified into following two categories:

- Flexural shear wall with h/l ratio of 1.0 or higher
- Squat shear walls with h/l ratio of less than 1.0

Masonry walls are usually subjected to combined in-plane and vertical loading in experimental setup so that the weight of upper storeys can be accounted for. According to Tomaževič (1999), axial compression load changes during earthquake due to restraints that prevent the rotation of wall at large displacements in reality. However, it is very difficult to simulate exact boundary conditions; the walls are usually tested with constant vertical load. IS 4326 (1993) gives typical details of providing vertical steel bars in cavities in brick masonry. Bed-joint reinforcement can be anchored to vertical reinforcement and this facilitates yield of bed-joint reinforcement during testing. IS 4326 (1993) has provisions for reinforcement at corners of the wall within grouted columns which, act as a confining elements (tie column) resisting larger forces due to increased stiffness. But the role of these elements in increasing the displacement ductility needs experimental verification.

VI. TYPES OF JOINT REINFORCEMENT

Reinforcement in masonry system is not a new concept. Reinforcement in brickwork was used in early twentieth century even in India by CPWD in state of Bihar and Orissa (Brebner, 1922). Nowadays, the reinforcement types used in masonry are reinforcing bars and cold driven bar products. Reflecting its multiple purposes in masonry walls, it can serve as a vertical reinforcement, horizontal reinforcement and bond beam reinforcement as shown in **Fig.1**Joint reinforcement comes in different configurations such as ladder type joint reinforcement, truss type joint reinforcement or in the forms of ties and seismic clips. Ladder type joint reinforcement consists of longitudinal wires or reinforcement flush welded with perpendicular wires creating the appearance of a ladder. It is recommended for multiwythe walls with cavity spaces or unfilled collar joints. Truss type joint reinforcement consists of longitudinal wires or reinforcement connected with cross wires. Truss type joint reinforcement should not be used in vertically reinforced or grouted walls because the diagonal

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cross wires may interfere with the placement of vertical steel reinforcement and grout.

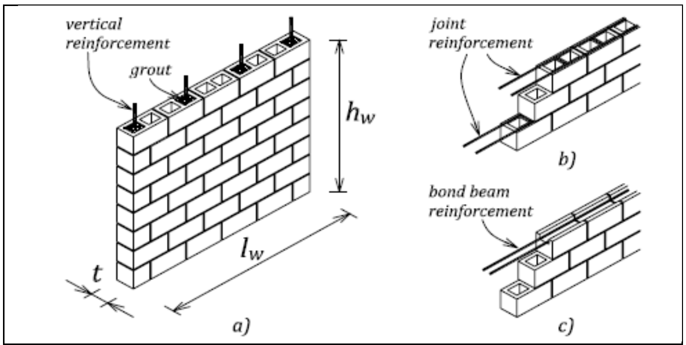

Fig. 1 Typical reinforced masonry concrete block walls a) Vertical reinforcement b) Joint reinforcement c) Bond beam reinforcement (Anderson and Brzev, 2009)

VII. CONCLUSION FROM LITERATURE REVIEW

The paper collects several experimental results on the merits and demerits of bed-joint reinforcement masonry walls with axial and lateral load of different types of height to width aspect ratios and its shown in presented case study, this may give better results inseismic performance of masonry buildings, with an increase ofboth structural safety andcompetitiveness of this construction system. The need for further is to develop masonry walls with reinforcement, shear walls with edge type minimum and maximum reinforcement on different materials for the future seismic design on zone areas. And experimental analysis shows the enhanced capacity for the design of structural members.

REFERENCES

1. Aguilar .G, Meli .R, Vazquez-Del-Mercado .R, (1996). “Influence of horizontal reinforcement on the behavior of confined masonry walls.’’ Eleventh World Conference on Earthquake Engineering, Paper No.13.
2. Anderson .D, & Brzev .S, (2009). “Seismic Design Guide for Masonry Buildings". Toronto: Canadian Concrete Masonry Producers Association.
3. Anderson .D.L, Priestley .M.J.N, (1992) “In plane shear strength of masonry walls, 6th Canadian Masonry Symposium’’, June 15-17, 1992, Saskatoon, Canada, pp. 223-234.
4. AS 3700-2001 (2001). “Masonry structures”, Standards Australia, January 1, 2001.
5. ASTM E 2126. (2005). “Standard test methods for cyclic (Reversed) load test for shear resistance of walls for buildings”, ASTM internationals, United States of America.
6. ASTM. E519/E519M-10. “Standard test methods for diagonal tension (shear) in masonry assemblages”, ASTM internationals, United States of America
7. Bartlett .W.H, (1965). “Masonry wall reinforcement” – When, where, how much? C/M Magazine.
8. Benedetti .D, and Tomazevic .M, (1984). “Sulla verifica sismica di costruzioni in muratura.” Ingegneria Sismica 1, 9-16, (In Italian).
9. BIS 1905: 1987. “Code of practice for structural use of unreinforced masonry”, Bureau of Indian Standards, New Delhi.
10. BIS 2250: 1981. “Code of practice for preparation and use of masonry moratars”.
11. BIS 4326: 1993. “Earthquake resistance design and construction of buildings – code for practice”, Bureau of Indian Standards, New Delhi.
12. BIS 4326: 2013.“Earthquake resistance design and construction of buildings – code for practice”, Bureau of Indian Standards, New Delhi.
13. BIS 3495: 1992. “Methods of tests of burnt clay building bricks”, Bureau of Indian Standards, New Delhi.
14. Brebner A, (1922). “Notes on Reinforced Brickwork.” – Volume 1, Public Works Department, Government of India, Calcutta pp. 53.
15. BS 5628-2:2005 (2005). “Code of practice for the use of masonry. Structural use of reinforced and prestressed masonry”, British Standards Institution, p.68.
16. Calvi .G.M, Kingsley .G.R, and Magenes G, (1996), “Testing of Masonry Structures for Seismic Assessment, Earthquake Spectra.” Vol. 12 (1), pp. 145-162.
17. Drysdale .R, (1994). “Masonry structures: behaviour and design”, Prentice hall, Englewood cliffs, New Jersey.
18. EN 1996-1-1 (2006). “Eurocode 6: Design of masonry structures - Part 1-1: General rules for reinforced and unreinforced masonry structures”.
19. FEMA461, 2007. “Interim Testing Protocols for Determining the Seismic Performance Characteristics of Structural and Nonstructural Component”, Washington D.C.: Federal Emergency Management Agency (FEMA) and National Earthquake Hazards Reduction Program.
20. Gouveia .J, and Lourenco .P, (2007). “Masonry shear walls subjected to cyclic loading: Influence of confinement and horizontal reinforcement.” North American Masonry Conference, St. Louis, Missouri, USA.
21. Haach .V, Vasconcelos .G, Lourenco .P, (2010). “Experimental analysis of reinforced concrete block masonry walls subjected to in-plane cyclic loading.’’ Journals of Structural Engineering @ ASCE, 10.1061/ (ASCE)ST.1943-541X.0000125.
22. Hoque .N, (2013). “In-plane cyclic testing of reinforced concrete masonry walls to assess the effect of varying reinforcement anchorage and boundary conditions”.Calgary, Alberta.
23. IITK-GSDMA (2005). “Guidelines for structural use of reinforced masonry.’’ Gujarat state disaster management authority, Gujarat.
24. Janardhana. M, (2010). “Cyclic behavior on glass fibre reinforced gypsum wall panels.” IIT Madras, Chennai.
25. Karki .N, (2014). “Seismic behavior of reinforced masonry.” IIT Madras, Chennai.
26. Khattab .M. M, and Drysdale .R. G, (1993). “The effect of reinforcement on the shear response of grouted concrete masonry.” TMS Lett., 12(1), 38-44.
27. Kubica .J, and Piekarczyk .A, (2004). “Tests of vertically sheared claybrick masonry walls with and without bed-joint reinforcement.” Proc, 13th Int. Brick and Block Masonry Conf, Eindhoven Univ of Technology, Amsterdam, The Netherlands 10.
28. Magenes .G, Calvi .G, (1997). “In-plane seismic response of brick masonry walls.’’ Earthquake engineering and structural dynamics, VOL. 26, 1091-1112 (1997).
29. Matsumura .A, (1988). “Shear strength of reinforced masonry walls.” Proc., 9th World Conf. on Earthquake Engineering, Vol. 7, Tokyo, 121–126.
30. NEHRP, 1997. "National Earthquake Hazards Reduction Program: Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, Part- 1 Provisions", Washington D.C: Building Seismic Safety Councils.
31. Penna .A, Menon .A, (2010). “Improving the seismic performance of masonry buildings by flat-truss bed joint reinforcement.’’ Proc.8th International masonry conference, Dresden.

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32. Porter .M. L, and Braun .R. L, (1997). "Elemental strength tests of joint reinforcement in masonry." Iowa State University, Department of Civil Engineering, Ames, USA.
33. Porto .F., Mosele .F, Claudio. M, (2011). "In-plane cyclic behaviour of new reinforced masonry system" 10.1016/j.engstruct.2011.05.003.
34. Priestley M. J. N, and Bridgeman D. O, (1974). "Seismic resistance of brick masonry walls." New Zealand Nat, Soc, Earthquake Eng, Bull, 7(4), 167–187.
35. Schultz A. E, (1996). "Minimum horizontal requirements for seismic design of masonry walls." TMS Journals, The Masonry Society, 14(1), 49-64.
36. Schultz. A. E, Hutchinson .R. S, and Cheok .G. C, (1998). "Seismic performance of masonry walls with bed joint reinforcement.'' Proc. Structural Engineers World Congress, San Francisco (1998):T119-4.
37. Shing .P.B, Noland. J. L, Klamerus. E, and Spaeh .H, (1989). "Inelastic behaviour of concrete masonry shear walls." J. Struct. Eng., 115(9), 2204–2225.
38. Standard Association of New Zealand (SANZ), (2004). "Design of reinforced masonry structures." NZS 4320: 2004, Wellington, New Zealand.
39. Sveinsson .B. I, Mayes.R. L, and McNiven. H. D, (1985). "Cyclic loading of masonry single piers". Vol. 4: Additional test with Height to Width Ratio of 1. Report No. UCB/EERC-85/15, Earthquake Engineering Research Center, Univ. of California, Berkeley, Calif.
40. Tomazevic .M, (1999). "Earthquake-resistant design of masonry buildings, Series on Innovation in Structures and Construction", Vol. 1, Imperial College Press, London.
41. Tomazevic .M, Lutman. M, & Petcovic. L., (1996). "Seismic Behaviour of Masonry Walls: Experimental Simulation". Journal of Structural Engineering, Issue September, pp. 1040-1047.
42. Tomazevic .M, Lutman .M, (1988). "Seismic resistance of reinforced masonry walls", Proc. 9th World Conference on Earthquake Engineering, August 2-9, 1988, Tokyo-Kyoto, Japan (Vol. VI), pp. 97-102.
43. Vasconcelos .G, (2005). "Experimental investigations on the mechanics of stone masonry: Characterization of granites and behaviour of ancient masonry shear walls." Ph.D. thesis, Univ. of Minho, Guimaraes, Portugal.
44. Vasconcelos .G, Lourenco .P, (2005). "Evaluation of the in-plane seismic performance of stone masonry wall." 5th international conference AMCM 2005, Poland.
45. Zepeda .J.A, Alcocer .S.M, Flores. L.E, (2000) "Earthquake-resistant constructions with perforated clay brick walls", Proc. of 12th World Conference on Earthquake Engineering, Auckland, New Zealand, pp.1541-1548.

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