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Rehabilitation of Full Scale Brick Masonry Cavity Wall Building

ZARIF KHAN, AMJAD NASEER, MUHAMMAD ASHRAF' EID BADSHAH
Department of Civil Engineering, University of Engineering & Technology Peshawar, Pakistan
Email: engrzarif@gmail.com, amjad_naseer@yahoo.com, engineerashraf@yahoo.com, eid_shah@yahoo.com

Abstract: This paper presents comparison of results of a full scale pre damaged and conventionally repaired brick masonry cavity wall room which was tested under quasi static loading system. The damaged specimen already tested by another researcher was repaired conventionally using cement sand mortar (1:5) and retested under same loading conditions.Damage patterns and force-deformation behaviour of the repaired specimen were compared with the pre-damaged ones to quantify their effects on the performance of cavity wall building. Experimental data was analyzed and presented in the form of force-deformation hysteresis loops and envelope curves. During conventional repairing of specimen, lateral peak strength, lateral stiffness and ultimate displacement were restored by 86%, 29% and 100% respectively.

Keywords: *Cavity Wall, Retrofitting, Seismic Performance, Unreinforced Masonry*

1. Introduction:

Unreinforced masonry construction has been the basic construction technique since the mankind started living on earth. Indeed, 30% of the world's population lives in adobe dwellings, which accounts for 20% of the world's urban/suburban population [**1**]. Recent earthquakes have shown that unreinforced masonry buildings are vulnerable to lateral loads produced due to earthquakes [Ashraf 2010 etal]. In Kashmir earthquake of October 2005, many unreinforced masonry buildings suffered severe damages and many of them got partially or fully collapsed [2], [3]. Most of buildings constructed in seismically active regions have not been designed for earthquake loads. Past devastating earthquakes have shown that most low strength masonry structures are vulnerable and seismic retrofitting is required using local existing and economically available remedial measures [4], [5].

According to previous work, several strengthening techniques have been used for deficient structures health restoration [6]. These techniques includes ferrocement overlay (surface coating), application of fiber reinforced polymers (FRP), shotcrete overlay, center core technique, grout injection, application of steel elements, bed joint reinforcement, post tensioning, etc. All retrofitting and rehabilitation techniques have advantages and disadvantages based on construction materials and structures type [7], [8], [9]. However, the reported work has been focused on walls and piers and URM solid buildings. The effectiveness of non-engineered conventional repair on the behaviour of full scale cavity wall building has not been investigated yet. This research project was therefore initiated to evaluate seismic performance of repaired unreinforced brick masonry cavity wall buildings in terms of strength, stiffness and ductility.

The investigation was carried out through testing a full scale cavity wall room in pre damaged and repaired form.

2. Experimental Descriptions:

Specimen Preparation:

The test structure was a single room unreinforced brick masonry cavity wall building. Solid clay bricks (8-1/2" x 4-1/4" x 2-3/5" or 213mm x 106mm x 65mm) were chosen for specimen construction. The specimen was constructed keeping interior wall thickness as 9" (225mm) (113mm) and exterior wall thickness 4 1/2" (113mm). Cavity between two layers of masonry wall was kept 2 inches (50mm). Cement sand (CS 1:6) mortar was used for masonry construction and mortar joints thickness was kept 3/8 inches/10mm to 1/2inches/12mm. Super imposed dead load was placed over specimen slab in the form of 6 concrete blocks having 10 tons (22.04kips). Specimen was tested under cyclic loading to evaluate its seismic performance as part of M Sc research at Earthquake Engineering Center, Department of Civil Engineering, University of Engineering and Technology Peshawar, Pakistan [10].

The specimen, fixed at the base with reinforced concrete foundation, was loaded with a displacement-controlled hydraulic jack system along with roof slab center point in the in-plane direction. The lateral displacement recorded at center of roof slab, was considered as the main controlled displacement. Load cells and displacement transducers were fixed to measure applied load and displacement respectively that were connected to a data acquisition system UCAM-70A. Each displacement cycle was repeated three times. Displacement pattern is given in Figure.

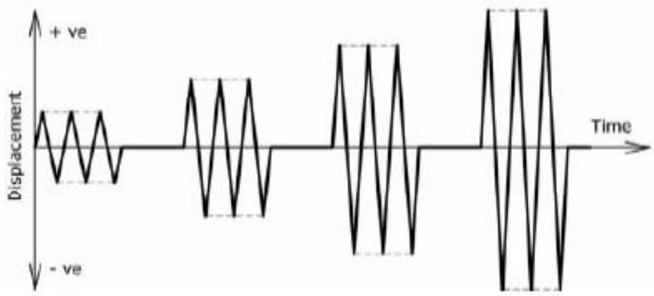


Figure 1: Displacement Controlled Pattern

The test was stopped at the stage when cracks widened up to 1” (25mm) resulting in specimen vulnerability and cracks propagation to a critical level *[Sifat Ullah 2016*].

i. Repair of Test Structure:

The damaged test structure was initially repaired using non engineered conventional repair. All internal and external cracks were cleaned and damaged mortar was removed from brick units. For traditional repair compatibility, a cement sand mortar (1:5) was produced having water to cement ratio of 0.90 for filling of wall cracks. The cracks were filled and made uniform like brick mortar joint. The damaged bricks were replaced with new one bricks with cement sand mortar (1:5). Repaired work was cured for seven days. Repaired full scale specimen is shown in figure 2. After 28 days of repair application, specimen was tested for structural properties evaluation.

ii. Test Setup:

7 Linear Variable Displacement Transducers (LVDT) were connected at various important locations. Displacement transducer-1 and transducer 2 were fixed to measure the in-plane movement at the E-W direction of the slab. Gauges 03 and 04 were connected to record the torsional rotation of the internal 9” (225mm) south wall of building in east west direction. Gauge 05 and 06 were connected to record the movement of the external 4-1/2” north wall of building east west direction. Gauge 07 was installed to record vertical displacement due to rocking effect of the structure. Gauges 01 and 02 were mounted on wall while displacement gauges from 02 to 05 were placed on steel frames.

Figure 2: Repaired Specimen after non engineered conventional repair

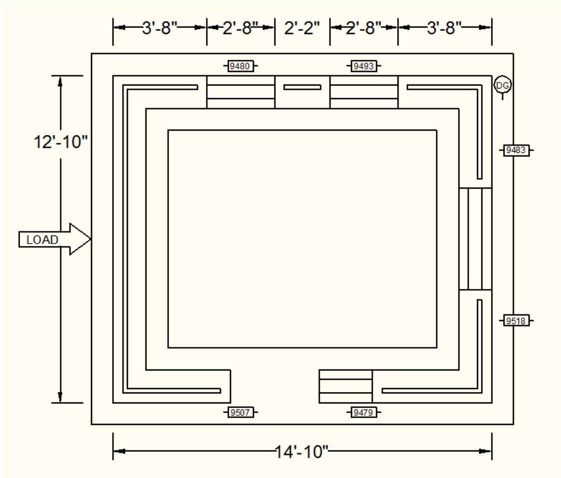


Figure 3: Test set Up (Linear transducer placement and orientation)

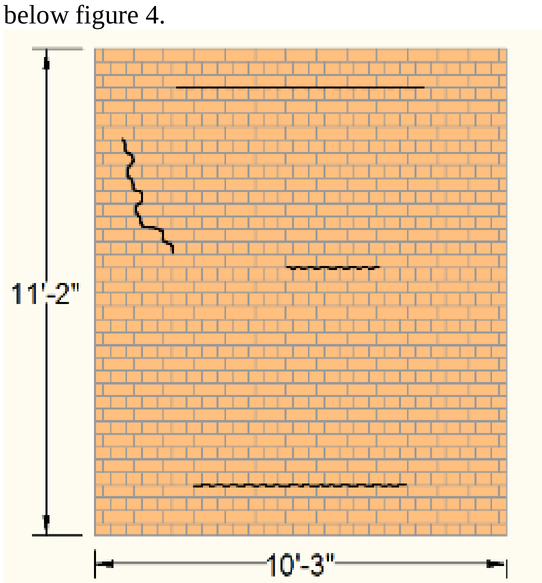
3. Results and Discussions:

i. *Damage Mechanism of Repaired Specimen:*

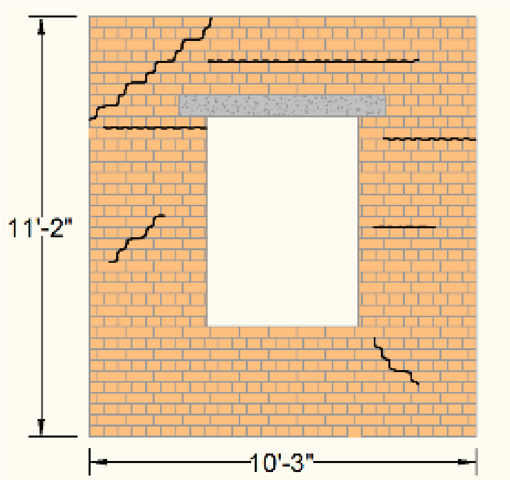
At story drifts of 0.08% corresponding to a displacement of 2.64 mm, cracks started in external 4-1/2” (113mm) wall and some internal hair cracks also appeared. After a displacement of 13.765mm (0.41% story drift), external existing horizontal cracks in south direction started to open from the top of the windows and continued up to three layers diagonally to the top of slab. This pattern was observed externally in all windows where wall thickness was 4-1/2” (113mm).

After 19.83mm displacement (0.61% story drift), all cracks were widened but the behaviour of structure was rocky as toe crushing was observed in east direction and crushing of brick units occurred.

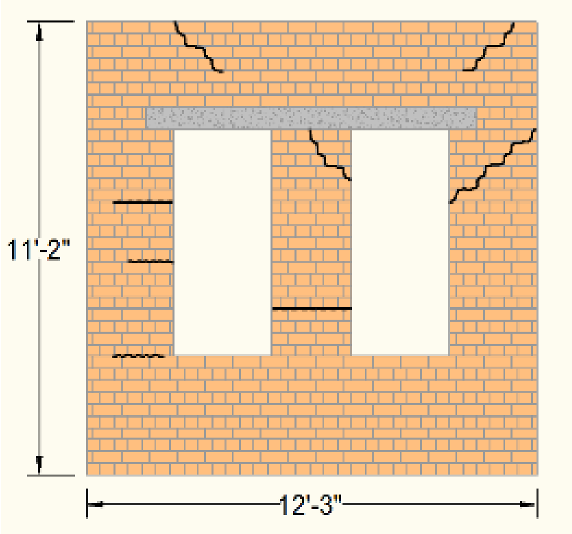
At a drift of 0.61%, test was stopped and all cracks patterns were observed. Internal walls Cracks propagation observed has been shown in figures below figure 4.



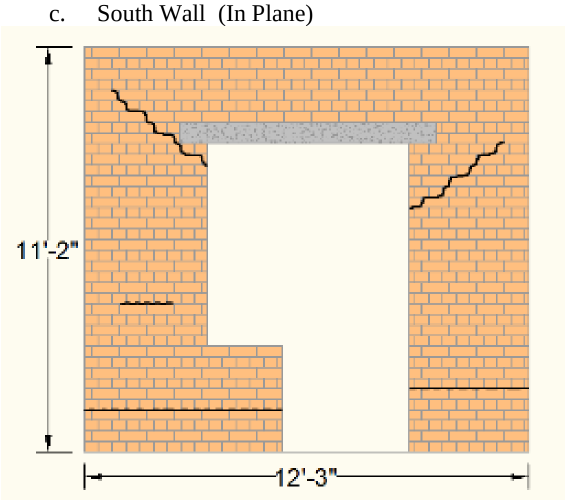
a. East Wall *(Out of Plane)*



b. West Wall (Out of Plane)



c. South Wall (In Plane)



d. North Wall (In Plane)

Figure 4: Final damage pattern of tested specimen after non engineered repair (a to d)

4. Conclusions:

- Lateral load capacity was restored by 86% of the original specimen when non engineered conventional repair was applied to damaged specimen.
- Only 29% stiffness restoration of the original specimen was calculated during non-conventional repair.
- Ultimate displacement was restored by 100% of the intact specimen.

Recommendations:

- Non engineering conventional repair is not an effective tool for strength and stiffness restoration. Hence such technique is not recommended for structurally deficient buildings.
- The technique is a cost effective tool for architectural work restoration having minor cracks.

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