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Seismic capacity evaluation of fly ash brick masonry walls after retrofitting

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Abstract

The objective of this study was to examine the in-plane lateral load behavior of two full-scale fly ash brick masonry walls one unreinforced and the other confined before and after retrofitting. The quasi-static load test findings are shown here. The construction of the walls closely followed the masonry methods prevalent in Pakistan and throughout South Asia. Prior to retrofitting, the walls were tested to their peak resistance. The damaged walls were then retrofitted using grout injection followed by a ferrocement overlay and retested until they ultimately failed under identical condition. The damage pattern, energy dissipation, and force-deformation behavior of the walls evaluated both before and after retrofitting were used to evaluate the efficacy of the suggested confinement and retrofitting plan. Prior to retrofitting, test findings indicate that restricted masonry walls have nearly double the capacity of unreinforced masonry walls. The test findings following the retrofit show that the applied retrofitting strategy greatly increased the unreinforced masonry wall's lateral load capacity, while it had only a little positive impact on the confined masonry walls.

Keywords: Unconfined masonry; Reinforced masonry; Retrofitting; Seismic performance; SWWM

1. Introduction

Over 70,000 people were killed on October 8, 2005, when a catastrophic 7.6-magnitude earthquake rocked Northern Pakistan and Kashmir. The buildings suffered partly or complete destruction, numbering in the thousands. Including the cost of rehabilitation and reconstruction, the financial damage was projected to be $5.2 billion [1]. Block masonry, brick, or unreinforced stone made up the majority of the destroyed buildings. You may find a more thorough explanation of the harm done to unreinforced masonry (URM) structures during the 2005 Kashmir earthquake elsewhere [2,3]. The state of the economy was made worse by the destruction of those partially damaged structures for which repairs were financially feasible. Most partially damaged buildings would have been preserved if people had known about affordable, practical, and locally feasible solutions.

To improve the seismic performance of URM structures, a variety of traditional and non-conventional rehabilitation and retrofitting options are available globally. Methods such as using fiber-reinforced polymers (FRP), ferrocement or shotcrete overlays, grout injection, the center core method, steel components, reinforcing bed joints, post-tensioning, and polypropylene bands (PP bands) are examples of these approaches. Over the past 20 years, a significant amount of research on URM retrofitting has been conducted globally. Ashraf et al. and ElGawady, Lestuzzi, and Badoux (2004a) examined the different retrofitting technologies utilised for URM structures [4,5]. Steel strip effects on concrete and masonry walls were investigated by Taghdi Bruneau and Saatcioglu (1998). Researchers Maria, Alcaiano, and Ludwigs (2006) and Stratford et al. (2004) examined the behaviour of masonry walls reinforced using fiber-reinforced polymer sheets [6,7]. Cycle tests were performed on URM walls by ElGawady, Henger, and Lestuzzi (2004b) both prior to and during composite retrofitting. The hysteretic behaviour of URM piers reinforced with steel parts was investigated by Rai and Goel (1996) [8]. Polypropylene band, or PP band, is a novel material that Japanese researchers (Mayorca, Navaratnaraj, and Meguro, 2006) proposed for use in retrofitting masonry structures [9].

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Although these methods are proven, they have not been examined for their effectiveness with locally produced materials and construction systems prevalent in Pakistan. Therefore, several Pakistani institutions have launched research projects to explore retrofitting and restoration of URM structures using local materials and technology. A study on seismic strengthening of URM structures with ferrocement overlays and grout injection has been carried out at the University of Engineering and Technology in Peshawar, Pakistan. In this method, plaster is applied after a steel welded wire mesh is screwed onto the masonry surface. The decision to use a cement overlay was based on its cost-effectiveness, simplicity of application, and rapid construction benefits, which are crucial in developing nations like Pakistan where resources like advanced equipment and skilled workers are scarce. The success of this method depends on how well the plaster coating transfers shear between the surfaces and its bond with the masonry wall. The connection is made in part by the glue that holds plaster mortar to the wall surface and in part by the fasteners that fasten steel wire mesh to the wall. To repair the damaged masonry walls, cracks were filled with grout injection.

Ferrocement is a relatively new method for URM structures, however it has been around for a while in terms of application. The research team of Prawel and Reinhorn carried out the first systematic study on retrofitting URM structures with ferrocement overlay (Prawel and Reinhorn, 1985; Reinhorn and Prawel, 1985) [10,11]. Different mesh arrangements were used to evaluate a range of masonry walls reinforced with multiple layers of ferrocement. Compared to walls that were not modified, the seismic performance of repaired walls was almost twice as high. The masonry walls' in-plane and out-of-plane capacity might be enhanced by the surface coating, as stated by Lizudia et al. (1997) [12]. Because of the confinement effect in the earlier scenario, double side coating was thought to be more effective than single side coating. The method was used on buildings and walls made of compacted masonry by Alcocer et al. (1996) [13]. The method increased the deformation capacity in addition to the lateral strength. Working with ferrocement overlays, Abrams et al. (2007) investigated the rehabilitation of rocking-critical masonry piers under quasi-static pressure [14]. The researcher saw a little rise in the initial elastic strength. The strength of the pier decreased due to the lack of rehabilitation after the wire mesh failed. This led to the conclusion that the method was less effective for important piers subjected to shaking.

This research evaluates the seismic performance of two full-scale brick masonry walls with apertures (perforated walls) subjected to quasi-static cyclic loads, focusing on both unreinforced and retrofitted brick masonry. The walls were tested to their maximum resistance before retrofitting, after which they were repaired using grout injection and ferrocement overlay and then retested under the same conditions until failure occurred. A comparison of the walls' behavior before and after retrofitting is also included.

2. Experimental Program

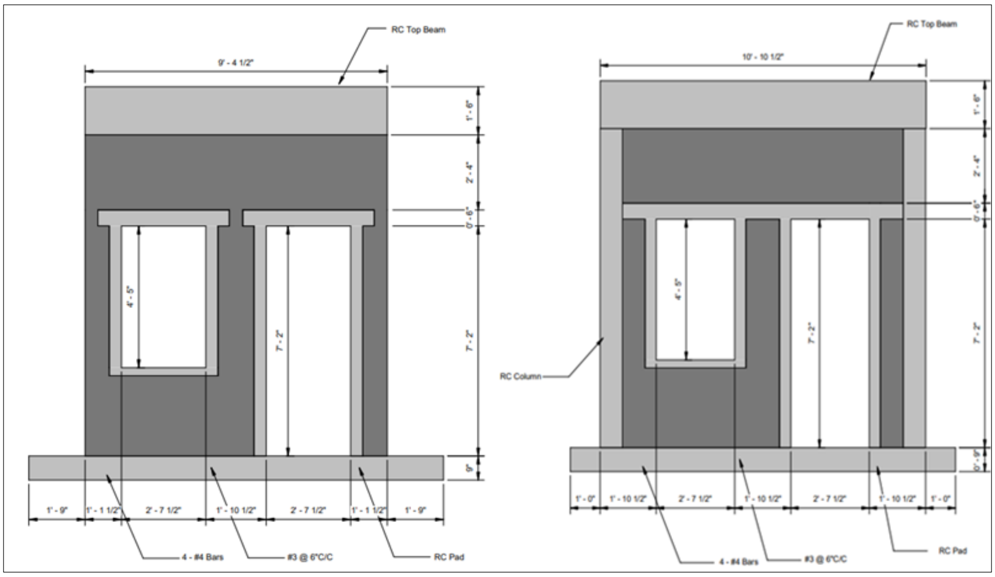

Figure 1 Schematic diagram of (a) Unreinforced retrofitted fly ash brick masonry wall and (b) Confined retrofitted fly ash brick masonry wall

In the Structural Engineering Laboratory of the Department of Civil Engineering, University of Engineering and Technology, Peshawar, Pakistan, two full scale perforated walls of the same size and configuration, reflecting a typical brick masonry structure in Pakistan, were built. The walls were constructed using limited brick masonry in one and unreinforced brick masonry in the other. Prior to retrofitting, cyclic loads were applied to the walls until their maximum resistance was reached. Next, using the identical load and boundary circumstances, the damaged walls were retrofitted and retested. Both of the walls are shown in Figure 1 above.

3. Results and discussion

Under Quasi Static load test, full-scale Unreinforced and confined fly ash brick masonry wall was tested after retrofitting. The in-plane walls exhibited no damage up to a displacement of 5 mm (story drift of 0.12%), which translates to a force of 73.26 KN in the positive cycle. The remarkable rigidity of the structure made possible by the Ferro Cement Overlay coating is demonstrated by the high load at such a small drift ratio. Apart from that the idealized elasto-plastic curve shows the full behavior of the wall. The curves were very steep and closely spaced at the beginning of the test which showed the effectiveness of ferro-cement overlay. As the test proceeds the curves becomes wider and wider due to formation of cracks. On the other hand, there were less energy dissipation in both the walls after retrofitting. The stiffness of the retrofitted walls was improved significantly than the one before retrofitting. Table 1 shows the various parameter that were improved after retrofitting.

Table 1 Parametric comparison of fly ash and conventional brick masonry walls before and after retrofitting

Parameters	Confined Masonry Walls		Unreinforced Masonry Wall	
	Fly Ash Bricks	Conventional Bricks	Fly Ash Bricks	Conventional Bricks
Peak load (KN)	180.21	150.36	78.96	89.54
Displacement ductility ratio, μ	40.23	20.12	29.32	21.12
Yield displacement, Δy (mm)	2.01	4.56	1.89	1.23
Ultimate Displacement, Δu (mm)	52.36	25.69	30.22	23.25
Yield strength (KN)	102.12	79.89	57.58	51.22
Elastic stiffness (KN/mm)	56.23	45.89	30.78	23.58

4. Conclusion

The following conclusions were drawn from the experimental study:

- A cost-effective retrofitting solution for both constrained and unreinforced walls is ferrocement overlay.
- Applications of FCO coating greatly enhance the responsiveness of the structure because of the confinement effect. The use of wire mesh has enhanced the structure's cracking pattern and increased the reinforcing ratio.
- Energy dissipation and stiffness deterioration are significantly impacted by confining components at first, but their effects diminish with time.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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