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SEISMIC PERFORMANCE OF NEPALESE SCHOOLS: A FULL-SCALE TEST OF A TYPICAL UNREINFORCED MASONRY WALL.

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ABSTRACT

This paper presents the preliminary results of an experimental investigation on the seismic performance of a large-scale typical Nepalese school URM wall. Hence, it proposes a retrofitting method for its strengthening. The test subjected a 5m x 3m masonry brick wall, set in 1:6 cement–sand mortar, to a two-way ramp cyclic loading to determine shear cracking failure. The results show that the wall exhibited a Grade 2 type of failure that indicates a slight structural damage with both diagonal and horizontal cracks, at 4mm displacement loading, in the mortar joints. The failure pattern is similar to those obtained in similar works in the literature.

Introduction

Recent earthquakes have shown the devasting effects of seismic loads on school infrastructure in developing countries. The 2015 Nepal earthquake, known as the Gorkha earthquake, caused 9000 casualties with over 22,000 people injured. In this events, the extent of damage to the education infrastructure was substantial. About 6000 – 8200 schools were badly damaged and destroyed in the mainshock and the Gorkha earthquake's aftershocks [1, 2]. Many of these schools were unreinforced masonry (URM) structures and were shown to be structurally deficient in ensuring life safety during the mainshock and subsequent aftershocks. URM buildings were often poorly constructed with stones (mostly rounded) laid in cement sand, mud mortar and even in dry mortar mixes in some cases and had no seismic detailing, hence little ability to resist the effects of ground shaking [3, 4, 5].

As part of the Seismic Safety and Resilience of Schools in Nepal (SAFER) project (SAFER (EP/P028926/1)*)*, efforts have been made to develop innovative approaches towards safeguarding Nepalese schools buildings against future earthquakes. Structural models of school buildings [6, 7] in the Kathmandu valley in Nepal have been developed to perform seismic fragility assessment studies. In parallel, experimental investigations have been carried out to investigate masonry structures' out-of-plane mechanism [8, 9]. Monotonic experiments have been performed out on large-scale stone masonry walls retrofitted with low-cost wire mesh [10]. However, there is a gap in the understanding the effects of cyclic loading on common wall types that can be found in typical Nepales schools

This research presents the results of an experimental test carried out on a large-scale wall structure. This is representative of a typical Nepalese school URM wall. A 5m x 3m wall specimen was constructed using bricks and mortar with similar properties and strength to those used in Nepal. The wall was subjected to a set of two-way ramp loads in displacement control. The results of this test will be compared to those from a future test carried out on a

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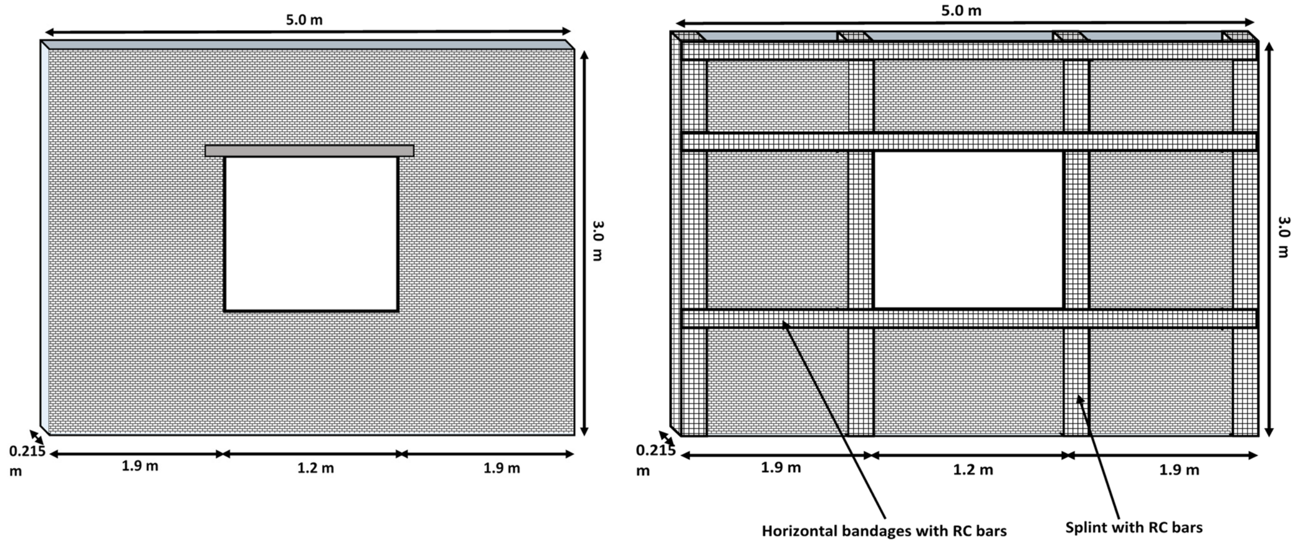
similar wall that is strengthened using an innovative and low-cost retrofitting technique.

Methodology

This paper presents a preliminary report on the experimental testing campaign on Nepalese school walls. This consisted in carrying out tests on a 5m x 3m full-scale masonry walls. Fig. 1 (a and b)) shows the geometry of the wall specimen, which is made of clay bricks that are set in 15mm thick 1:6 cement-sand mortar. The URM wall was built following the standard construction practice in Nepal, without any seismic detailing. The wall geometry is in accordance with one of the five different typologies of unreinforced walls identified by the National Society for Earthquake Technology-Nepal (NSET) as representative of typical school buildings in Nepal [11]. The clay bricks are set in 15mm thick 1:6 cement-sand mortar following the practice in the construction of buildings in Nepal (result of tests conducted on the materials used to construct the school buildings). At the same time, the splint and bandages (wall b) are made with 8mm high yield deformed bars anchored at the top of the wall and the foundation slab.

The wall is tested under a loading protocol that aims to induce the usual shear cracking pattern that has been consistently observed in URM structures. First, the load is applied in displacement control as a two-way ramp cyclic loading by gradually increasing the amplitude of the displacements at a frequency of 1mm/min for each loading cycle. The results of this test are presented in this paper. The second stage of the experimental work is to strengthen the wall with a new and low-cost retrofitting technique. Tests are carried out in the Large Structures Testing Laboratory (LSTL), Boldrewood Innovation Campus at the University of Southampton.



(a) (b)

Figure 1. Schematic diagrams of the masonry wall: (a) unreinforced; (b) reinforced with splint and bandages.

Experimental setup

The test involved applying a two-way ramp cyclic load on the wall using a hydraulically powered 250kN Instron hydropuls linear actuator with a 250mm travel distance. The actuator is fixed laterally to a reaction frame and a 6.05tons reinforced concrete beam connected to the top of the masonry wall (Fig 2). The actuator is also connected to a data acquisition system with multiple channels to record the load and displacement from the actuator. At the same time, linear variable differential transformers (LVDT's) and video imaging are used to get the linear displacements of the wall. The base of the wall is confined at all the sides with six parallel flange channels (PFC) sections (three on both sides) and two angle sections (at the ends of the wall), fixed to the solid concrete base with anchor bolts and resins. The confinement restricts any form of sliding or lateral movement of the wall at the base. Also, the top of the wall is confined with equal angle sections fixed to the bottom of the RC beam. This arrangement allows the masonry wall to move only in the direction of the applied displacement loads without any lateral movements. The wall is painted white with dots marks at approximately 300mm centers for the video imaging to measure the lateral displacements using the Davis imaging software. The images were captured with two cameras: the first one to capture the whole wall while the second focused on the upper edge of the opening on the wall.

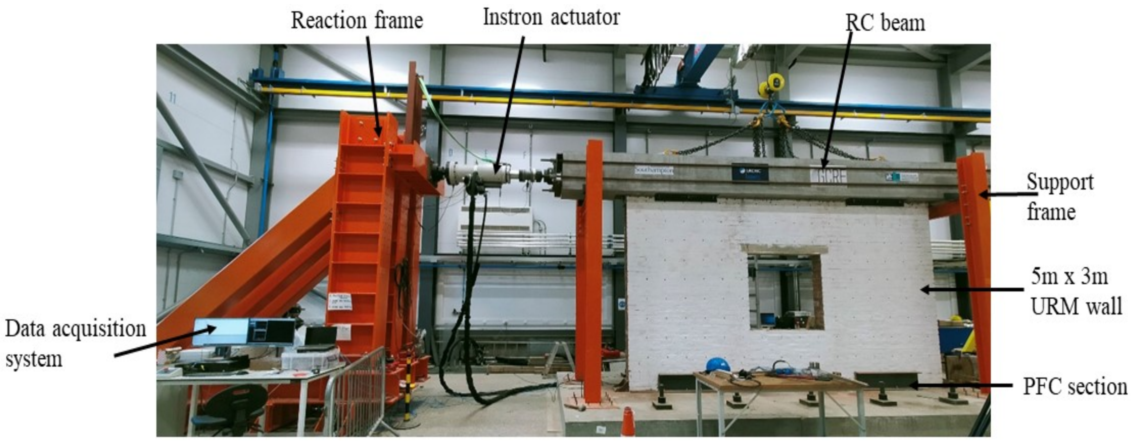


Figure 2: The experimental test setup

Experimental results

The force arising from the applied displacement loading is shown in Fig 3 up to the 4mm displacement curve for the test. The ultimate load increased until about 3mm displacement cyclic loading when the lateral crack at the lower part of the wall occurred (Fig 4a). Then, it decreased further at the 4mm displacement loading with a more significant diagonal crack damage at the edge of the window (Fig 4b). The cracks all occurred in the mortar joints of the URM wall and are classed as shear failures [12,13] which further falls under the moderate damage Grade 2 class of failure according to the European Macroseismic Scale (EMS-98) [14]. The Grade 2 failure refer to a moderate damage with slight structural damage having many vertical and horizontal cracks.

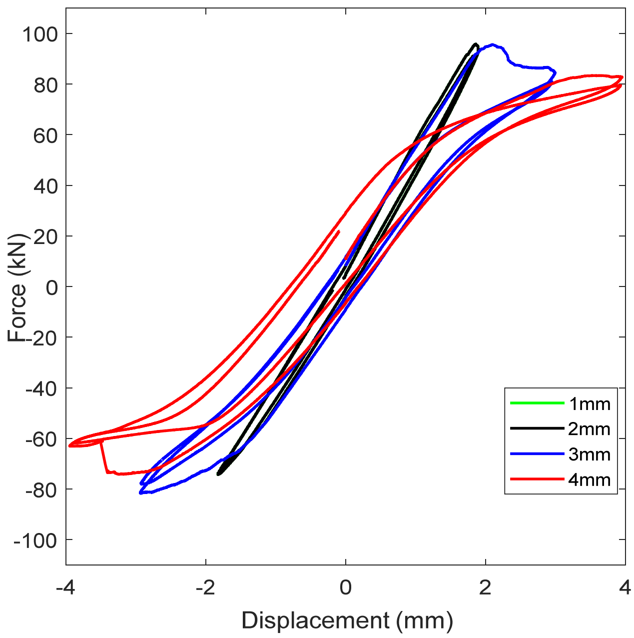


Figure 3. The force-displacement curve of the test

(a) (b)

Figure 4. Failure modes of URM at different displacement loading. (a) Lateral crack at tne base at 3mm (b) diagonal cracks at the edge of window opening towards the top at 4mm

The crack pattern and failure modes observed during the test are anticipated as they are consistent with the failure modes observed in several numerical and experimental studies on URM buildings [4,15-17]. Generally, most of the buildings in Nepal are constructed as non-engineered brick masonry with mainly poor quality materials and construction techniques, making them susceptible to damage under seismic loading.

Conclusions

In this work, large-scale experimental testing under cyclic loading of a typical Nepalese school URM wall was done to understand the failure pattern and hence proposed an appropriate retrofitting method to prevent collapse and damage during seismic activity. The URM wall showed significant stiffness at the lower displacement load until the slight horizontal crack damage occurred at 3mm displacement. After that, the stiffness degradation continues with repeated loading cycles. With the damage observed, the wall will be retrofitted with splints and bandages made with 8mm high tensile rebars and tested for shear and seismic resistance improvement. Furthermore, the strength enhancement will aid the recommendation of the retrofitting method for application in Nepal school buildings.

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