Experimental study of seismic behavior of scaled non-engineered masonry structures retrofitted by pp-band mesh

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1. Introduction

Most residential structures in developing countries are masonry structures which are highly vulnerable to earthquake and increase the structural damage and the death toll. This paper discusses the seismic capacity of non-engineered common masonry structures in Pakistan, which have heavy slab, by experimental approach using 1/12 miniature models. These models were constructed using acryl blocks which can be used several times. This paper also includes the comparison of retrofitted masonry model by PP-band method with non-retrofitted one [1,2]. The PP-band retrofitted masonry model showed almost 4 and 16 times greater seismic capacity than the non-retrofitted one in terms of ground acceleration and arias intensity, respectively.

2. Experiment program

Three 1/12 scaled single room models were constructed for shake table test as shown in Figure 1. The size of the model was determined on the basis of permissible payload of shake table [i-e ~ 18 Kg]. The plan size of the models was approximately 290mm x 290mm. The model height and wall thickness were 240mm and 20mm, respectively. The door was placed on the one side of the model and window was placed opposite to it. The dimension of the door opening was 84mm x 156mm in horizontal and vertical direction, respectively. The dimension of the window opening was 84mm x 84mm.

The concrete slab of prototype structure was modeled by using wood plate, and additional steel plates were attached to make the weight of slab proportional to 1/12 scaled concrete slab weight. The slab was placed on walls without any connection between wall and slab in case of S-NR-XSC and S-R-XSC models as shown in Figures 1(a) and 1(b), while, in case of S-R-SC model, the slab was connected to walls by the PP-band as shown in Figure 1(c). The model was placed on the shaking table and input motion was applied to the model parallel to the walls having openings.

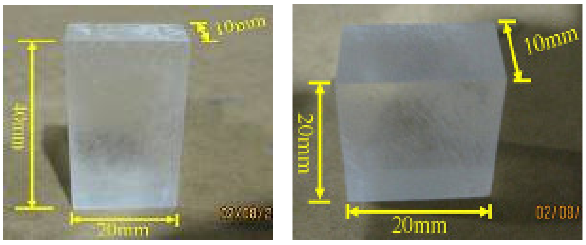
In the experiment, sinusoidal motions of frequencies from 2 to 6Hz with 5 and 15mm amplitudes were applied to the specimen, parallel to the walls having openings. The duration of motion of each frequency applied was 30sec. Arias Intensity, I_A, was also calculated from the input motion as shown in Equation (1) below;

$$I_A = \frac{\pi}{2g}\int_{0}^{\infty} a_t^{2}\,dt \qquad \text{Eq. (1)}$$

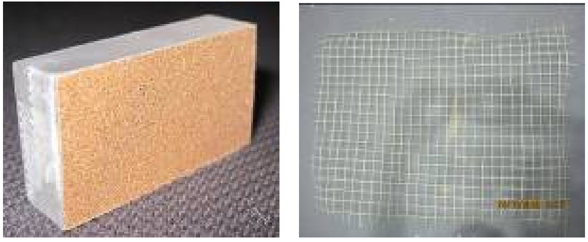
(a) S-NR-XSC (b) S-R-XSC

(c) S-R-SC

Figure 1 Masonry models used for experiments



(a) Full block (b) Half block



(c) Acryl block with sandpaper (d) PP-band mesh

Figure 2 Materials for model construction

(a) S-NR-XSC (b) S-R-XSC (c) S-R-SC

Figure 3 Experimental Results

Key Word: unreinforced masonry, PP-band retrofitting, shake table test, Damage level

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3. Materials

The two sizes of the acryl blocks, 40 x 20 x 10 mm^3 and 20 x 20 x 10 mm^3, were used as shown in Figures 2(a) and 2(b). The half blocks were used for break of joints among the layers. The surface of acryl blocks was very smooth and inefficient to provide required friction; we used sandpapers to solve this problem. Two basic tests, 'Friction Coefficient Tests' and 'Direct Shear Tests' were conducted, by using acryl blocks with sandpapers pasted on the both sides by double sided tape as shown in Figure 2(c). For the selection of appropriate sandpaper, the more weightage was given to shear test. The shear test demonstrated the sandpaper of Grit# 80 as the most appropriate sandpaper to achieve the require shear strength.

The mortar with the mixture ratios of cement: lime: sand: water = 1:8:30:10 [by weight] were finally selected based upon the shear strength. The above described mortar gave the shear strength nearest to the target shear strength.

The cross sectional area of the PP-Band was approximately 1mm x 0.3mm. These PP- bands were placed with a pitch of 20mm from center to center to make meshes as shown in Figure 2(d). The pitch of 20mm was selected so that each acryl block was covered by two PP-bands. The PP-Band meshes were connected across the wall at a grid of 40 and 20mm in horizontal and vertical direction, respectively.

4. Results Discussion

The first model, S-NR-XSC performed well and it did not show any considerable damage until the input acceleration was below 141 gal [$I_{JMA} < 5.0$]. But when the acceleration was further increased, the collapse of structure occurred suddenly at an acceleration of 300 gal [$I_{JMA} > 5$] as shown in Figure 3(a).

On the other hand, the retrofitted model, S-R-XSC, showed higher seismic capacity due to holding effect by PP-band mesh, the energy dissipation capacity was improved which prevents complete collapse. But when the amplitude of input motion was changed to 15mm [at which acceleration was 903 gal, $I_{JMA} \simeq 6$], the slab of model started sliding because slab was not connected with walls as shown in Figure 3(b).

The retrofitted masonry model, S-R-SC, whose slab was connected with walls, was tested by shake table. In this model, as the slab was covered by PP-band meshes to prevent its movement, the slab did not move during the shake table test as shown in Figure 3(c).

The collapse point of each type of model was recorded in terms of JMA Intensity, Arias Intensity and time except S-R-SC which did not collapse completely even an input motion of more than 1,000 gal was applied [$I_{JMA} > 6$]. These observations are shown in graphical form in Figure 4.

The European Macro-seismic Scale (EMS) Grades were used for damage level definition. The EMS Grade 1 and Grade 2 occurred at almost same Arias Intensity [time] for all three models. However after EMS Grade 2 [considerable cracks], the PP-Band became effective and a considerable seismic capacity was observed in retrofitted model as compare to non-retrofitted one as shown in Figure 5.

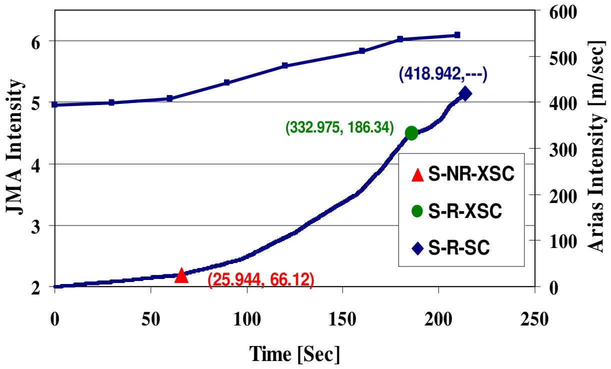

Figure 4 Collapse points w.r.t Arias Intensity, Time and JMA intensity of all three models

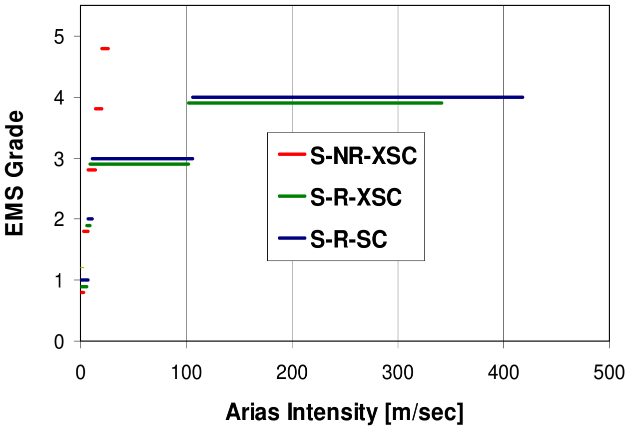

Figure 5 EMS grades and corresponding Arias Intensity

5. Conclusions

It was clearly observed that PP-Band retrofitted masonry house could have much higher seismic capacity as compare to non-retrofitted one. The seismic capacity improved by PP-Band retrofitting was almost 4 and 16 times higher than non-retrofitted model in terms of ground acceleration Arias Intensity, respectively. The retrofitted model can tolerate 8 times larger lateral sway displacement than non-retrofitted one.

The heavy slab of structure accelerated the crack generation in walls but if the structure retrofitted properly by PP-band, the energy dissipation capacity could be improved and complete collapse could be thwarted. Furthermore, the shear connection between slab and walls of the structure further could increase seismic capacity

Reference:

1) Mayorca P. and Meguro K. (2001), Strengthening of Masonry Structures –An ongoing research, Proceedings of EQTAP Workshop, Lima-, Peru.
2) Sathiparan, N. and Meguro, K. (2004), Shaking Table Experiment of Masonry Buildings and Effectiveness of PP-band Retrofitting Technique, Seisan-kenkyu, Institute of Industrial Science, University of Tokyo, Japan.

Key Word: unreinforced masonry, PP-band retrofitting, shake table test, Damage level

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