Evaluation of retrofitting masonry structures with polypropylene band meshes by means of diagonal compression tests

Navaratnarajah SATHIPARAN, Student member, Institute of Industrial Science, University of Tokyo
Paola MAYORCA, Regular member, Institute of Industrial Science, University of Tokyo
Kourosh Nasrollahzadeh NESHELI, Regular member, Institute of Industrial Science, University of Tokyo
Kimiro MEGURO, Regular member, Institute of Industrial Science, University of Tokyo

1. Introduction

Unreinforced masonry is one of the most used construction materials in the world. It is also unfortunately, the most vulnerable during earthquakes. In seismic prone regions of the world, large number of casualties resulted due to the collapse of this type of structures.

Several retrofitting methods for masonry structure have been proposed to improve strength, ductility and energy dissipation capability. However, in developing countries, strengthening masonry structures should be economic, the retrofitting material accessible and the local available workmanship used. Considering these points, a new retrofitting technique has been proposed based on the use of polypropylene bands (PP-bands), which are commonly utilized for packing [1)]. In order to evaluate the effect of retrofitting masonry walls by PP-bands, a series of diagonal compression tests were carried out on masonry wallettes with and without retrofitting as a means to assess its seismic strength. The initial results of these are reported in this paper.

2. Experiment program

The wallette dimensions were 292.5×290×50 mm^3 and consisted of 7 brick rows of 3.5 bricks each. The mortar joint thickness was 5mm. A mortar mix of Cement: Lime: Sand=1:7.9:20 and Cement/Water ratio = 0.14 was used. To observe the efficiency of different mesh orientations, two types of PP-band mesh arrangement shown in Fig.2 were used.

Type-1: PP-band mesh oriented parallel to the masonry joints.

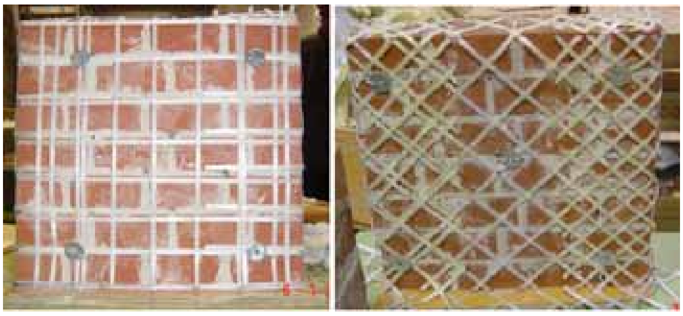
Type-2: PP-band mesh oriented 45° from the masonry joints.

Both had mesh pitch equal to 40mm. A total of 4 wire connectors were used to attach the mesh with the masonry. In the retrofitted case epoxy was used for connecting PP-meshes from both sides.

In this study five brick walls were constructed. In order to identify the effect of the external overlay on the efficiency of the mesh retrofitting and strength, some wallettes were applied an 8-mm thick lime surface paste with a mix proportion lime: sand = 2:5. The specimens were named according to the following convention: **A-B-N** in which **A** is **U**: Unreinforced or **R**: Reinforced; **B** is **P**: With external paste or **X**: without external paste; and **N** is 1 or 2 according to the mesh type.

Specimens were tested 28 days after construction under displacement control. The loading rate was 0.3mm/min and 2mm/min for the unreinforced and retrofitted cases respectively. The retrofitted wallettes were applied 50mm vertical displacement. In order to determine the masonry mechanical properties, direct shear and bond strength of the masonry assembly were also evaluated.

Figure 1 Polypropylene band mesh used for retrofitting



(a) Type-1 **(b) Type-2**

Figure 2 Masonry wall specimen retrofitted by PP-band mesh

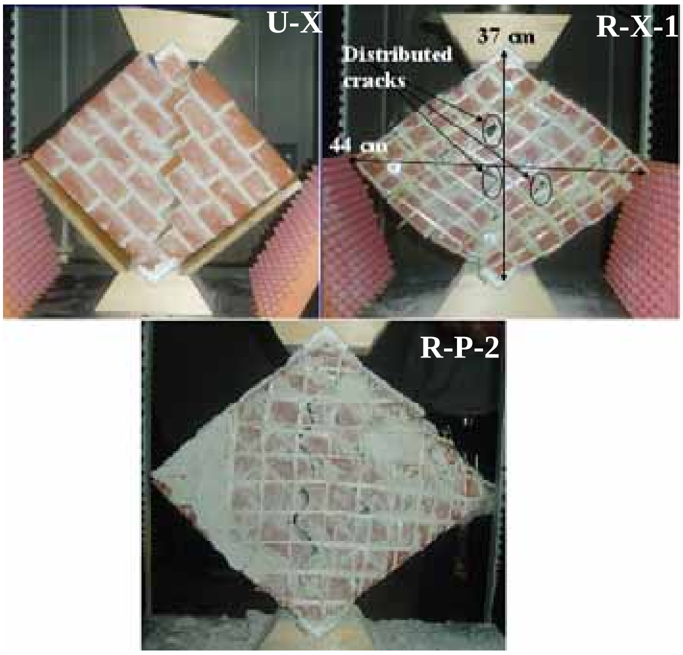


Figure 3 Failure patterns of brick masonry wallettes without and with retrofitting by PP-band mesh.

Key Word: unreinforced masonry, polypropylene band, diagonal compression test, residual strength, wire connectors, wallettes

Contact Address: 4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Tel. 03-5452-6385, Fax. 03-5452-6476

3. Results and discussion

The direct shear and bond strength of the mortar assembly were 0.032 and 0.046 MPa, respectively. The diagonal compression strength was 1.57 and 1.84 kN for the wallettes without and with lime paste, respectively. This shows that only a 17% of strength increment can be attributed to the external paste. Furthermore, no great difference in the strength was observed due to different loading rates.

Figure 3 shows the unreinforced and retrofitted specimens at the end of the test, which corresponded to vertical deformations equal to 0.71 and 50mm, respectively. In this paper, the first 30mm of displacement are considered for discussion. In the unreinforced case, the specimens split in two pieces after the first diagonal crack occurred and no residual strength was left. In the retrofitted case, on the other hand, diagonal cracks appear progressively, each new crack followed by a strength drop. Although the PP-band mesh influence was not observed before the first cracking, after it, each strength drop was quickly regained due to the PP-band mesh effect. Although at the end of the test almost all the mortar joints were cracked, the reinforced wallettes did not lose stability.

Figure 4 shows the diagonal compression strength variation with vertical deformation for the unreinforced and retrofitted specimens. In the unreinforced case, the initial strength was 1.55kN and there was no residual strength after the first crack observed. In the retrofitted case, although the initial cracking followed by a sharp drop, at least 50% of the peak strength remained. Subsequent drops were associated with new cracks like the one observed at the deformation of 6mm. After this, the strength was regained by readjusting and packing by PP-band mesh. When the strength exceeded 3.0kN individual PP-bands failed. However, this did not reduce considerably the strength of the specimen, because stresses were redistributed to other PP-bands. The specimen quickly recovered its strength. The final strength of the specimen was equal to 3.0kN relatively higher than initial strength of 1.5kN.

Figure 5 compares the diagonal compression strength of retrofitted masonry wallettes with Type 1 and Type 2 meshes. Generally Type 2 mesh provides larger strength than Type 1 mesh arrangement. This was expected because the confining effect on the masonry wall is larger in the former case. Cracks become gradually wider as the vertical deformation increased. In this condition, the reinforcement oriented perpendicular to the crack. i.e. Type 2 worked under optimum conditions. In the particular case shown in Fig.5, the epoxy broke at around 1.8kN in the specimen R-P-1. After this, there was no additional strength increment observed in specimen, Because of this, direct comparison of the strengths of R-P-1 and R-P-2 is difficult. On the other hand, if the results of R-X-1 and R-P-2 are compared, the maximum strength difference was 30%. When appropriately set, no epoxy failure was observed before 2.9 KN.

Although Type 2 mesh retrofitted wallette had higher strength, when installation procedure and workmanship is considered Type 1 mesh retrofitting is the optimum solution for retrofitting. From the above result, it can be seen that PP-band retrofitted masonry wallettes had larger residual strength after the formation of the first diagonal shear crack. Small pieces of broken brick were kept inside the mesh, even when almost all the mortar joints were cracked. It is clear that that PP-band mesh retrofitting improved the overall stability and ductility of the masonry wallettes.

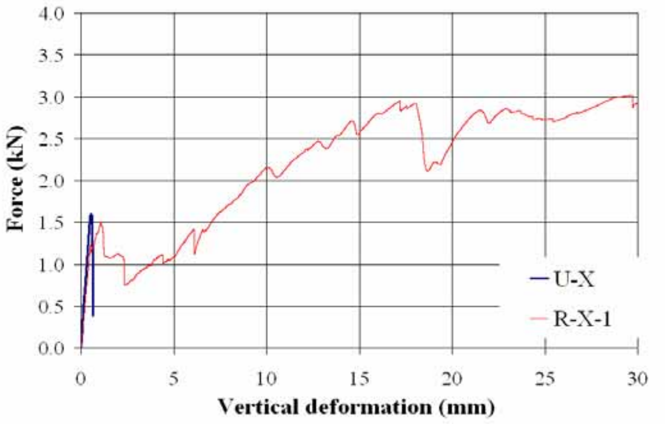


Figure 4 Force vs. Vertical deformation graph for masonry wall specimen with and without retrofitting.

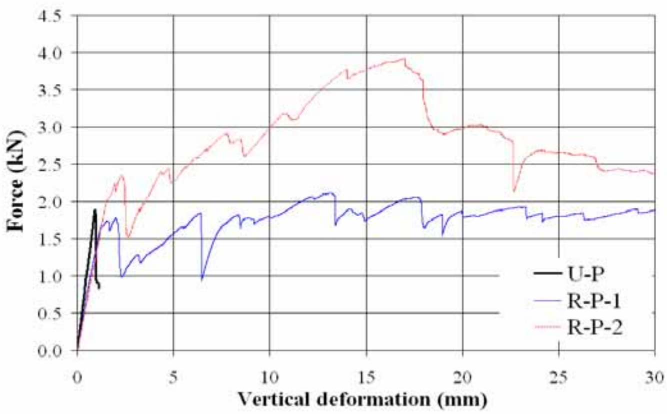


Figure 5 Comparison between masonry wallettes retrofitted by Type 1 and Type 2 PP-band mesh.

4. Conclusions

This paper discusses the results of a series of diagonal compression tests that were carried out on unreinforced and retrofitted wallettes. The tests showed that,

(1) The residual strength at the end of the test was higher than 100% of the initial peak strength.

(2) Type 2 mesh retrofitted wallettes with bands oriented 45° from the masonry joints, had a maximum strength 30% higher than that of Type 1.

(3) When appropriately set, no epoxy failure was observed before 2.9kN.

The mesh effect was not observed before the wall cracking. After cracking, the mesh presence positively influenced the wallette behavior. This testing program mainly aimed at investigating the effect of PP-band mesh pasted with epoxy. Epoxy is an expensive material to be considered as an economic retrofitting technique. Further testing on masonry wallettes without epoxy, only mesh overlapping, is necessary to evaluate the beneficial effects of the PP-band mesh under more applicable conditions.

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Reference:

1) Mayorca P and Meguro K Proposal of an efficient technique for retrofitting unreinforced masonry dwellings, 13th Conference on Earthquake Engineering, Vancouver B.C., Canada, 2004 Paper No.2431.