PARAMETRIC STUDY OF DIAGONAL SHEAR TESTS ON MASONRY WALLETTES RETROFITTED BY PP-BAND MESH

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Unreinforced masonry is one of the most used construction materials in the world. It is also unfortunately, the most vulnerable during earthquakes and large number of casualties resulted due to the collapse of this type of structures. It reveals that development of proper retrofitting technique for masonry buildings, especially existing buildings, is the main challenge to increase seismic safety in those countries. PP-band (Polypropylene band) Technology is a simple, economical and efficient retrofit method developed at International Centre for Urban Safety Engineering (Meguro Lab 2003[1]), Institute of Industrial Science, The University of Tokyo. This technology has been developed considering economical affordability and social acceptability together with technical feasibility.

Key Words: *unreinforced masonry,retrofit,polypropylene band,diagonal shear test,residual strength, PP-band mesh retrofit*

1. INTRODUCTION

A real scale model test makes possible to obtain data similar to real structures [2]. However, it requires large size testing facilities and large amount research funds, so it is difficult to execute parametric tests by using full scaled models. Recently, structural tests of scaled models become well-known as the overall behavior of the system can be also understood from scaled model. In this experimental program, ¼ scale models was used to investigate the static behavior of masonry walls.

To evaluate the beneficial effects of the proposed PP-band mesh retrofitting method, diagonal shear tests were carried out using masonry wallettes with and without retrofitting. In addition to them, efficiency of different mesh-pitch and effect of looseness in attachment were also examined by diagonal shear tests. The test results are reported in this paper.

2. AXIAL TENSILE TEST OF POLYPROPYLENE BANDS

Preliminary testing of the PP-band was carried out to check its deformational properties and strength. To determine the modulus of elasticity and ultimate strain, 3 bands were tested under uni-axial tensile test as shown in Figure 1 (left). The test was carried out under displacement control method. The results are shown in Figure 2 (right). To calculate the stress in the band, its nominal cross section 15.5×0.6mm^2 was used. As the matter of fact, the band has a corrugated surface and therefore its thickness is not uniform.

All of the bands exhibited a large deformation capacity, with more than 13% axial strain. The stress-strain curve is fairly bilinear with an initial and residual modulus of elasticity of 3.2 GPa and 1.0 GPa, respectively. Given its large deformation capacity, it is expected that it will contribute to improve the structure ductility.

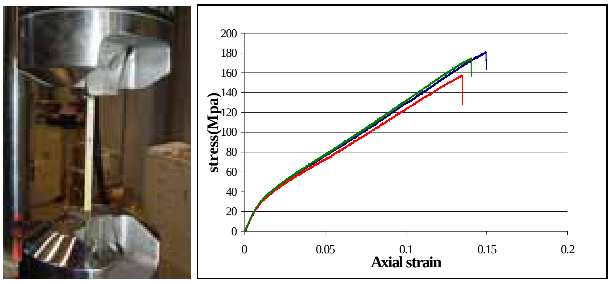

Figure 1 Tensile test setup (left) behavior of PP band under tension (right)

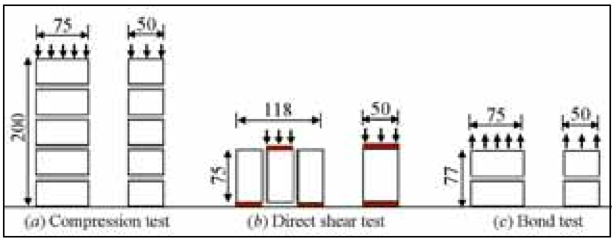

Figure 2 Layout of specimens used for direct compression, direct shear and bond test (unit:mm)

3. DIAGONAL SHEAR TEST

To evaluate the beneficial effects of proposed PP-band mesh retrofitting method, diagonal compression tests were carried out on masonry wallettes with and without retrofitting for both burned and unburned units. The wallette dimensions were 275×275×50 mm^3 and consisted of 7 bricks row of 3.5 bricks each. The mortar joint thickness was 5mm for both cases. Mortar joint material mixing ratio as follows;

- For burned brick model
  Water Cement Sand Lime = 1.00:0.14:2.80:1.11
- For unburned brick model
  Water Cement Sand Lime = 1.00:0.33:2.80:0.92

The specimens were named according to the following convention: **A-T-L-S** in which **A** is masonry unit, **B**: Burned or **U**: Unburned; **T** is retrofitted condition, **NR**: Non-retrofitted, **RE**: Retrofitted by PP-band meshes; **L** is PP-band mesh pitch in mm; and **S** is surface condition, **X**: no surface finishing applied or **P**: surface finishing applied.

Specimens were tested 28 days after construction under displacement control. The loading rate was 0.3mm/min for first 10mm and 2mm/min for remaining loading. The retrofitted wallettes were applied 50mm vertical displacement. Average measured mechanical properties of the masonry at the time of testing are shown in Table 1. Direct compression, direct shear and bond tests were carried out to obtain these properties.

Table 1: Mechanical properties of masonry

	Burned Brick	Unburned brick
Compressive strength (MPa)	21.78	4.45
Shear strength (MPa)	0.075	0.006
Bond strength (MPa)	0.055	0.006

Specimens used in these tests were shown in Figure 2.

(1) Behavior of burned brick specimens

Figure 3 shows the non-retrofitted and retrofitted specimens at the end of the test, which corresponded to vertical deformations equal to 0.71mm and 50mm, respectively. In the non-retrofitted 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 retrofitted wallettes did not lose stability.

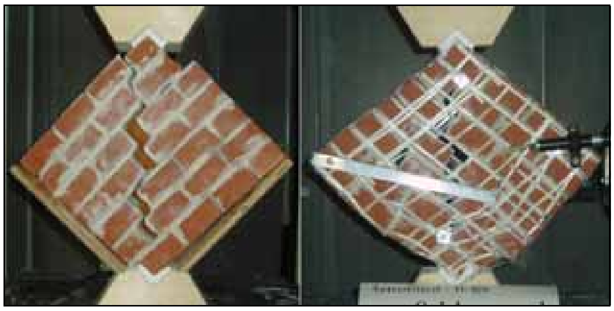

Figure 3 Failure patterns of brick masonry wallettes with retrofitting (left) without retrofitting (right)

Figure 4 shows the diagonal compression strength variation with vertical deformation for the non-retrofitted and retrofitted specimens. In the non-retrofitted case, the average initial strength was 1.5kN and there was no residual strength after the first crack. However, in the retrofitted case, although the initial cracking was 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 4mm. After this, the strength was regained by readjusting and packing by PP-band mesh. When the strength exceeded 3.0kN individual PP-bands started to fail. However, this did not reduce considerably strength of the specimen, because stresses 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.

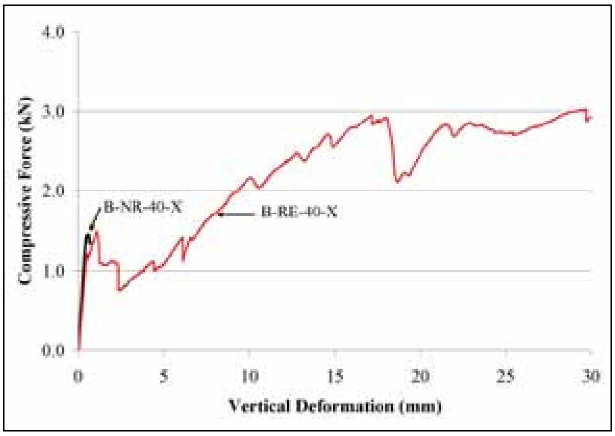

Figure 4 Force vs. vertical deformation for burned brick masonry wallette

(2) Behavior of unburned brick (adobe) specimens

Figure 5 shows the diagonal compression strength variation with vertical deformation for the non-retrofitted and retrofitted specimens. In the non-retrofitted case, the initial strength was 0.89kN and there was no residual strength after the first crack. In the retrofitted case, although the initial cracking was followed by a sharp drop, at least 70 % of the peak strength remained. As expected, the initial strength of unburned brick (adobe) specimens was relatively lower than that of the burned brick one.

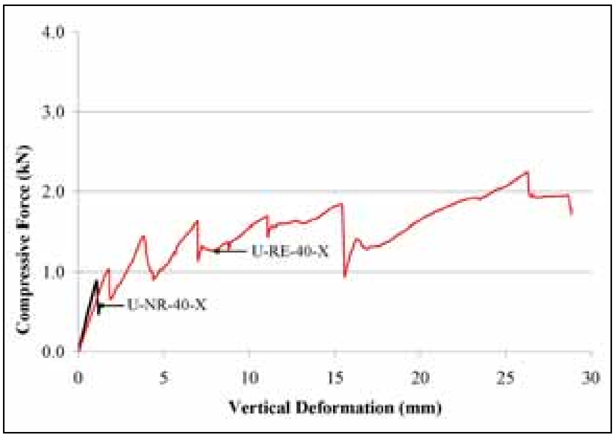

Figure 5 Force vs. vertical deformation for unburned brick (adobe) masonry wallette

(3) Effect of PP-band mesh pitch

For retrofitted specimen, four cases varying PP-band mesh pitches of 33mm, 40mm, 50mm, 66mm were used for retrofitting keeping other parameters same. To easy compare the behavior of retrofitted masonry wallettes; the behavior idealized as shown in Figure 6. Initial strength (Vo) and Initial stiffness (Ko) were mainly depending on the masonry properties. Residual strength after initial crack (Vr) and residual stiffness (Kr) mainly depend on PP-band properties and PP-band density.

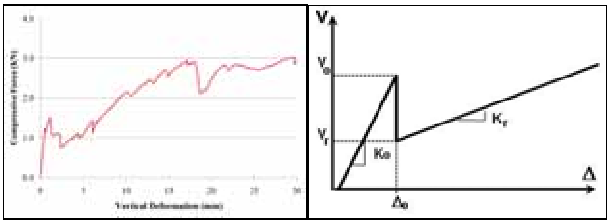

Figure 6 Real (left) and ideal (right) behavior of PP-band mesh retrofitted wallette.

Figure 7(a) shows the residual strength/initial strength (Vr/Vo) variation with number of PP-band per one side of the masonry wallette. From the experiment it was found that there is a significant role of PP-band pitch in behavior of masonry wallettes.

In general residual strength after crack initiation and residual stiffness of masonry wall with PP-band mesh retrofitting are directly proportional to PP-band density up to some value. But when it exceeds the optimum value, improvement ratio of residual strength after crack initiation and residual stiffness are not increase with amount of the PP-band density.

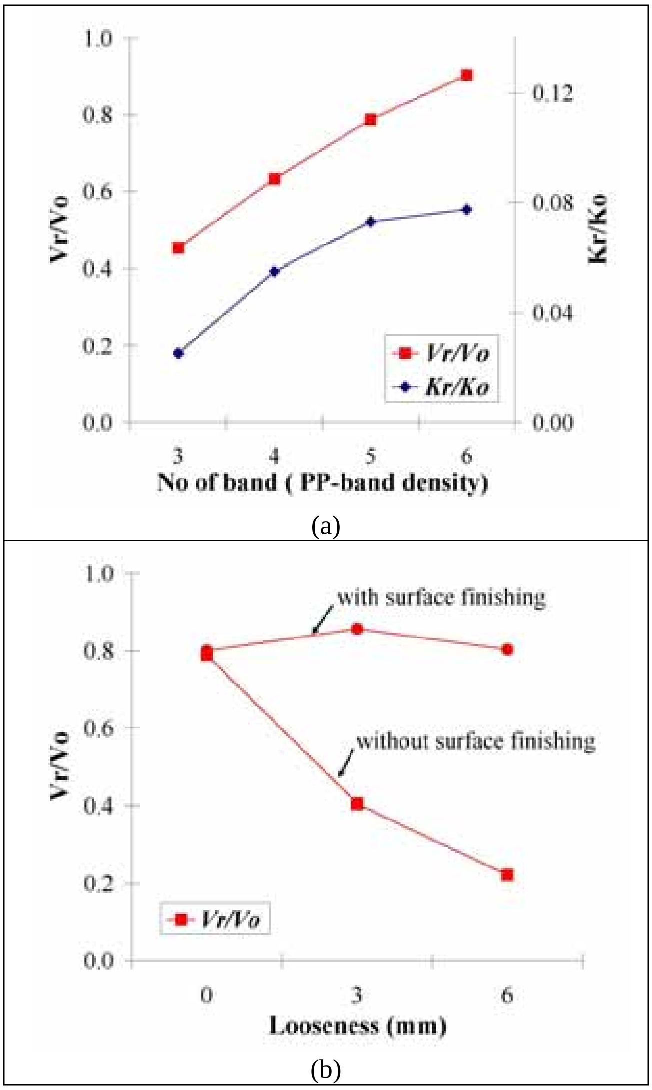

Figure 7 (a) Effect of PP-band density (b) Effect of looseness between wallette and PP-band mesh

(4) Effect of attachment condition between PP-band mesh and masonry wallette

To verify the effect of looseness of the retrofitting attachment on retrofitted specimen, 0mm (fully fixed), 3mm and 6mm of gap between PP-band mesh and wallette were provided. Figure 7(b) shows the residual strength/initial strength (Vr/Vo) variation with looseness of attachment between PP-band mesh and masonry wallettes. The result shows that; when there is looseness, it does dramatically reduce the residual strength of the masonry wallettes after initial crack. Bet when we applied the surface finishing above the masonry wallette, because to surface paste fill the gap between PP-band mesh and masonry wallette; even after the initial crack, at least 80% of the initial strength remained.

4. CONCLUSIONS

This paper discusses the results of a series of diagonal compression tests that were carried out using non-retrofitted and retrofitted wallettes by PP-band meshes. The diagonal compression tests showed that:

1. Masonry wallette without PP-band mesh would loose the entire load bearing capacity immediately after crack appeared,
2. Masonry wallette with PP-band mesh retrofitting loose some of load bearing capacity immediately after the crack-initiation, but with the effect of the PP-band meshes, it could regain the load bearing capacity and recover immediately, and its strength and deformability improves.
3. Residual strength after crack initiation and residual stiffness of masonry wall with PP-band mesh retrofitting are directly proportional to PP-band density up to some value. But when it exceeds the optimum value, improvement ratio of residual strength after crack initiation and residual stiffness are not increase with amount of the PP-band density.
4. Looseness of the PP-band attachment with specimen reduces the residual strength after crack initiation of the specimen. But application of surface finishing makes beneficial effect in residual strength.

Considering the overall performance of the specimens, it can be concluded that PP-band meshes can effectively increase the seismic capacity of masonry houses.

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