SIMULATION OF OUT OF PLANE TEST FOR POLYPROPYLENE BAND RETROFITED MASONRY USING APPLIED ELEMENT METHOD

Kawin Worakanchana, Student Member, The University of Tokyo
Paola Mayorca, Regular member, The University of Tokyo
Ramesh Guragain, National Society for Earthquake Technology-Nepal
Sathiparan Navaratnaraj, Student Member, The University of Tokyo
Kimiro Meguro, Regular member, The University of Tokyo

1. INTRODUCTION

Masonry along with timber structures are among the oldest structures that are still used nowadays. With its advantages as residential structure, masonry is widespread used around the world. Nevertheless, masonry structure is also known as one of the most susceptible to earthquake and unsuitable for construction of buildings in seismic zones. In order to improve the situation, the proper retrofitting method must be invented. Several proposed retrofitting method in the literatures includes grout injection and internal reinforcing, ferrocement coatings, FRP composites and adding of steel elements. These methods were reporting successfully for increasing the seismic capacity of the building. Besides, the recent retrofitting scheme considering economic, availability of material and skilled labor is Polypropylene band (hereafter as PP-band) retrofitting technique (Paola, 2003). In order to apply this method effectively, we must understand the behavior of PP-band retrofitting masonry which can be achieve through extensive numerical and experimental studies.

Among typical damage mechanisms in the masonry structure, out of plane failure of masonry wall is considered as one of the most common type of damage. One of the reasons is that strength and stiffness of masonry wall against out of plane behavior are much less than in-plane. In this study, the newly developed 3-Dimensional Applied Element Method (AEM) was used to simulate in-house out-of-plane test for pp-band retrofitted and non-retrofitted masonry wall. Gambarotta model was introduced for non-linear constitutive laws of mortar and masonry. And beam element with normal and shear springs was introduced for simulating pp-band and its connection to masonry wall.

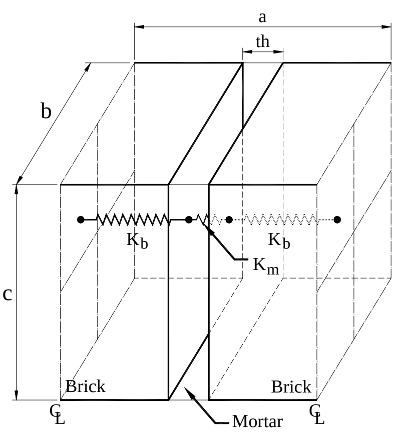


Fig. 1 Concept of equivalent brick-mortar spring

2. 3-DIMENSION APPLIED ELEMENT METHOD

In AEM, the structure is divided in rigid elements, carrying only the system's mass and damping, connected with normal and shear springs representing the material properties (Fig 1). The stress and strain fields are calculated from the spring deformations. 3-D AEM rigid elements with 6 degrees of freedom each are connected through sets of one normal and two shear springs.

Masonry is constituted by two phases: brick and mortar. Therefore, there are two types of springs: one inside brick units, brick spring, and the other at the joint interface, brick-mortar spring, are defined in as.

$$\frac{1}{Kn_{eq}} = \frac{a-th}{E_b \times b \times c} + \frac{th}{E_m \times b \times c} \qquad (2)$$

$$\frac{1}{K1s_{eq}} = \frac{a-th}{G_b \times b \times c} + \frac{th}{G_m \times b \times c} \qquad (3)$$

$$\frac{1}{K2s_{eq}} = \frac{a-th}{G_b \times b \times c} + \frac{th}{G_m \times b \times c} \qquad (4)$$

where E_b and G_b are the Young's and shear modulus of brick and E_m and G_m for the mortar.

The damage model (Fig. 2) proposed by Gambarotta and Lagomarshino (2000) is adopted in the AEM as the material model to capture the masonry cyclic response. This constitutive equation is based on damage mechanics and takes into account the mortar-damage and the brick-mortar de-cohesion which are considered to take place during crack opening and frictional sliding along the interface. Please refer to Guragain et al. (2006) for more details in nonlinear constitutive law.

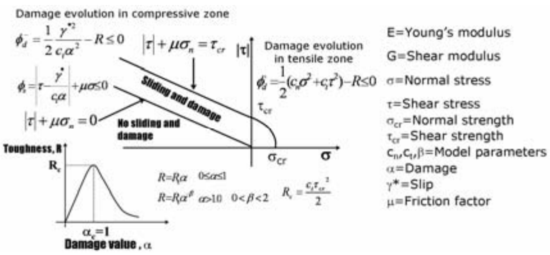


Fig. 2 Constitutive relation to model the cyclic behavior of masonry

Key words: Applied Element Method, Polypropylene band, Retrofitting, Masonry, Out of plane behaviour
International Center for Urban Safety Engineering, Institute of Industrial Science, the University of Tokyo, 4-6-1 Komaba, Meguro-Ku, Tokyo 153-8505, Japan
Tel: 03-5452-6472, Fax: 03-5452-6476

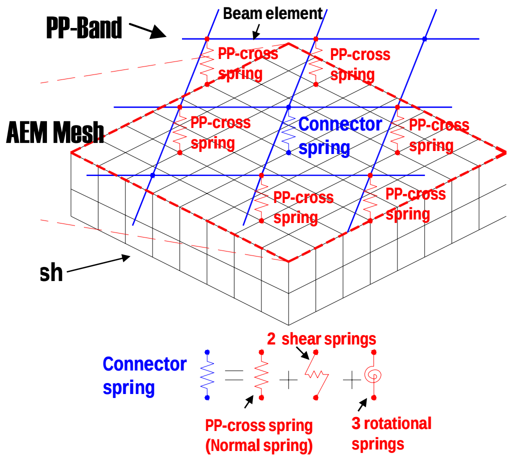


Fig. 3 PP-band mesh modeling

2.1 PP-Band Modeling

The PP-band mesh is modeled through beam elements spanning between band intersections points as shown in Figure 4. These ends were then connected to the masonry structure through a set of three springs: normal, shear, and rotational. By appropriately setting the properties of these springs, it is possible to consider all possible connecting conditions between mesh and structure.

Table 1 Material properties used for the modeling of masonry wallettes

	Young's modulus E (kN/mm^2)	Shear modulus G (kN/mm^2)	Tensile strength σ_{cr} (kN/mm^2)	Shear strength τ_{cr} (kN/mm^2)	Friction coeff. μ
Mortar	0.5	0.25	0.16e^{-3}	0.22e^{-3}	0.6
Brick	15.0	7.5	NA	NA	NA

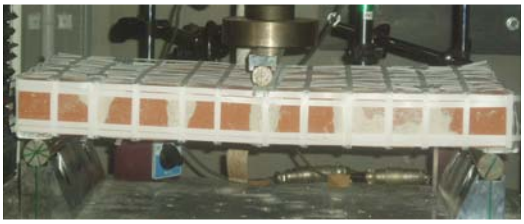
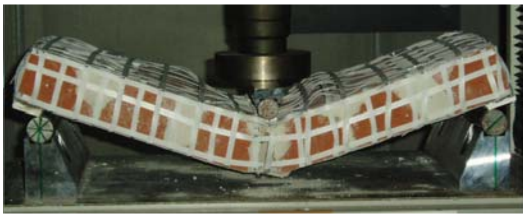


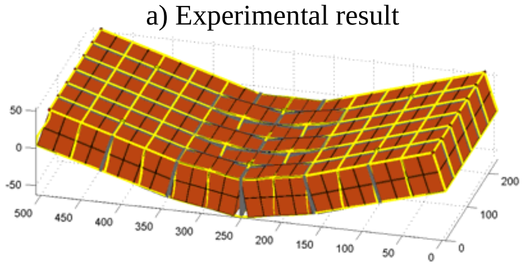
Fig. 4 Boundary condition and loading of the retrofitted masonry wallet for out of plane test

4. SIMULATION FOR OUT OF PLANE MASONRY WALL TEST

3-D AEM was employed to simulate the out of plane test by Sathiparan (2005). The retrofitted wallettes, shown in Figure 6. and Figure 7., were 475x235x50mm3 and consisted of 6 rows of 6 bricks each. The PP-band mesh was made of 6mm-width, 0.32mm-thick PP-bands placed at 40mm pitch. A total of 6 wire connectors were used to attach the meshes to the wallettes. The wallettes were simply supported by high strength steel rods in both ends. The masonry wallettes were tested under line load using another steel rod of 200mm diameter in the mid span. The material properties used for the masonry are summarized in Table 1. The PP-band mesh stiffness was set equal to 9.375 MPa.

From the figure 5, 6 and 7, it can be seen that, with selected parameter from table 1, 3-D AEM can simulate closely the force-deformation relationship and crack pattern for out of plane behavior in both non-retrofitted and retrofitted case. This success is the important step toward the 3-D simulation of masonry structure. Again, numerical results confirm improving ductility from PP-band retrofit.


a) Experimental result



b) Numerical simulation
Fig. 5 Crack pattern

6. REFERENCES

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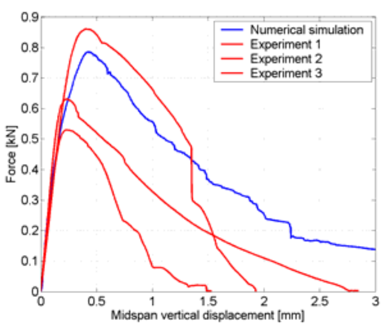
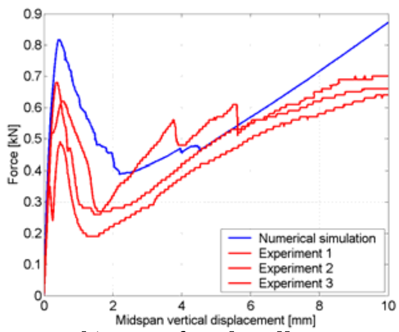


a) Non-retrofitted wallet



b) Retrofitted wallet

Fig. 6 Comparison of numerical and experimental force-deformation curves.