EXPERIMENTAL STUDY ON THE USE OF OLD TYRES FOR SEISMIC STRENGTHENING OF MASONRY STRUCTURES

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ABSTRACT :

The aim of this paper is to investigate the performance of old tyre strips used for seismic strengthening of unreinforced masonry structures. In the proposed method, old tyres are cut into strips and placed in the canals opened in the wall. Strips are covered by high quality or plastering mortar. Six full scale masonry wall experiments were carried out. In the experiments, as well as reference wall models, masonry walls strengthened by tyre strips were exposed to cyclic sway to simulate seismic forces. It is found that the method has minor effect on base shear capacity of the walls. However, it can improve the ductility of the walls significantly.

KEYWORDS: Masonry structures, Strengthening, Earthquake, Old tyres

1. INTRODUCTION

Unreinforced masonry (URM) structures showed poor performance during many past earthquakes. Performance of some of these buildings in recent earthquakes is shown in Fig. 1. Unfortunately, many of the URM buildings damaged or collapsed during the recent earthquakes in many countries (Bayraktar, et. al., 2007; Kaplan, et. al., 2008; Ramazi and Jigheh, 2006).

Figure 1. Damages observed in past earthquakes.

In the existing literature, many strengthening techniques have been presented for masonry structures. Strengthening by steel bars (Taghdi, et.al. 2000), fiber reinforced polymers (Albert, et. al., 2001) and steel mesh with concrete (Sallio, 2005; Russo, et. al, 2006) are popular methods. These and other existing methods are efficient strengthening techniques, but they are still too expensive for many householders of masonry structures. Therefore, development of reasonably priced strengthening methods for masonry structures is an important subject. For this purpose, Turer et. al. (2007) proposed a strengthening method for masonry structures based on post tensioning of scrap tyre rings. Method is relatively low-priced; however it requires technical equipment to

measure the level of post-tensioning load. Therefore, it cannot be applicable by householders.
Presented methods are not suitable for most of the building owners due to economical reasons. Those people living in URM structures in undeveloped countries compose the poorest social fractions of their countries. Therefore, it is essential to provide a cheap and easily applicable strengthening method for them.

In this study, the use of old car tyres as a strengthening material is investigated experimentally. In this method, old tyres are cut into strips and placed in the canals opened in the wall as a reinforcement material. Strips are covered by good quality or plastering mortar. During the experimental program 6 full scale masonry wall (2-D) experiments were carried. Masonry wall models were exposed to cyclic sway to simulate seismic forces.

2. EXPERIMENTAL PROGRAM

2.1. Test Models

Experimental program was carried out for various strengthening schemes. Walls having window openings and walls with no openings were used in experiments. Standard masonry bricks with vertical holes were used for the construction of the walls. Before the strengthening works, all of the walls were constructed as unreinforced masonry like the usual practice in Turkey. Side views of the experimental models are presented in Fig. 2. Walls with openings were strengthened by diagonally placed tyre strips as it is found to be most effective style by the experiments of the walls without openings (Kaplan, et. al., 2008). Additional horizontal and vertical tyre strips were placed around the wall openings in two strengthened models to prevent local crushing around the wall openings.

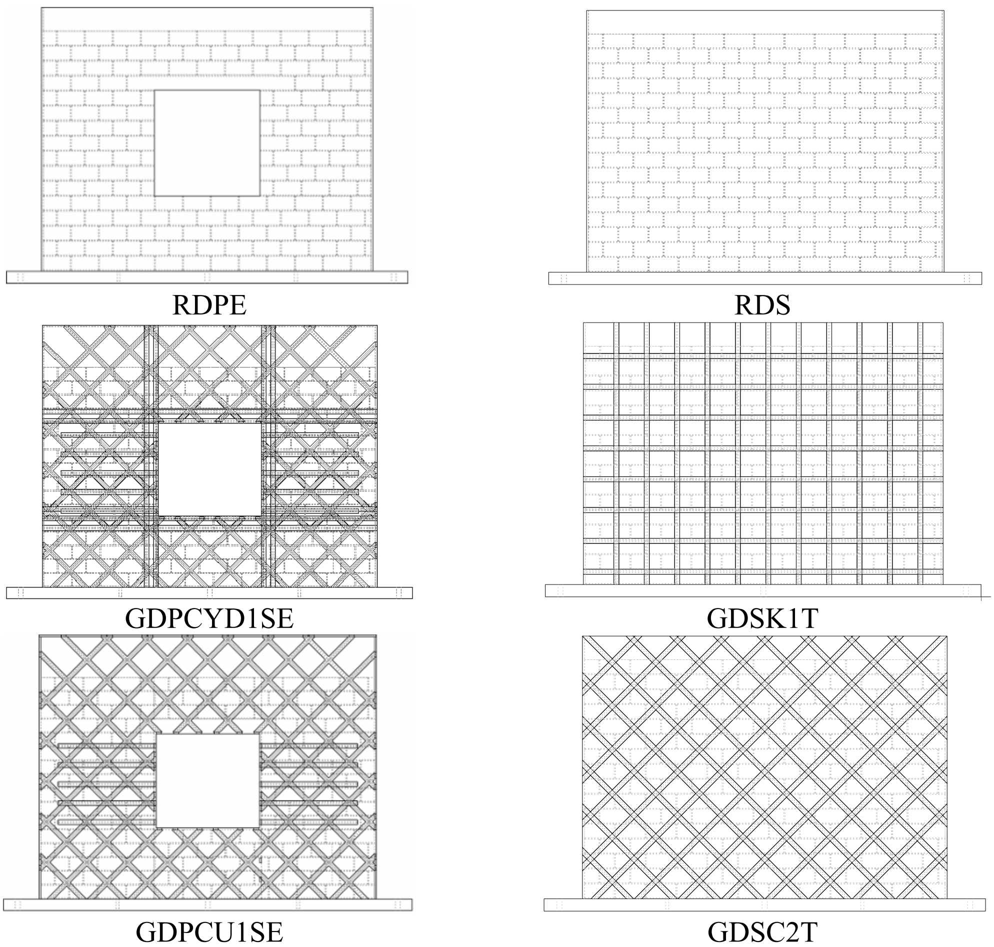

Figure 2. General strengthening schema of experimental models.

Plastering is removed to form a canal for the strips after the construction of a standard masonry wall. Then, the strips are placed in the canals and covered by plastering or high quality mortar (Fig. 3). During the experiment, models were also exposed to the two different axial load levels. Specifications of the models are summarized in Table 1.

Figure 3. Strengthening by old tyre strips

Table 1. Model Specifications

Model name	Average strip interval (cm)	Strip formation	Tyre covering material	Axial Load (kN)
RDPE	-	-	-	180
GDPCYD1SE	30	Diagonal	H. strength mortar	180
GDPCU1SE	30	Diagonal	Plastering mortar	180
RDS	-	-	-	120
GDSK1T	30	Lat./Long.	H. strength mortar	120
GDSC2T	15	Diagonal	H. strength mortar	120

2.2. Test Setup

Experimental setup is shown in Fig. 4. The system is consisted of the strong floor, reaction wall, actuator, actuator support, instrumentation, and control and data acquisition systems. Model walls were axially loaded before the application of lateral loads. Walls were instrumented to record axial-lateral loads and displacement changes. Instrumentation scheme of the specimens is given in Fig. 4.

Footings of the specimens were bolted to strong floor and incremental reversed cyclic imposed sway was applied to the models to obtain hysteretic behavior. Incremental reversed cyclic lateral sway was applied from the top of the model specimens in a direction parallel to the plane of the wall. Sway pattern imposed to the RDP model is given Fig. 5.

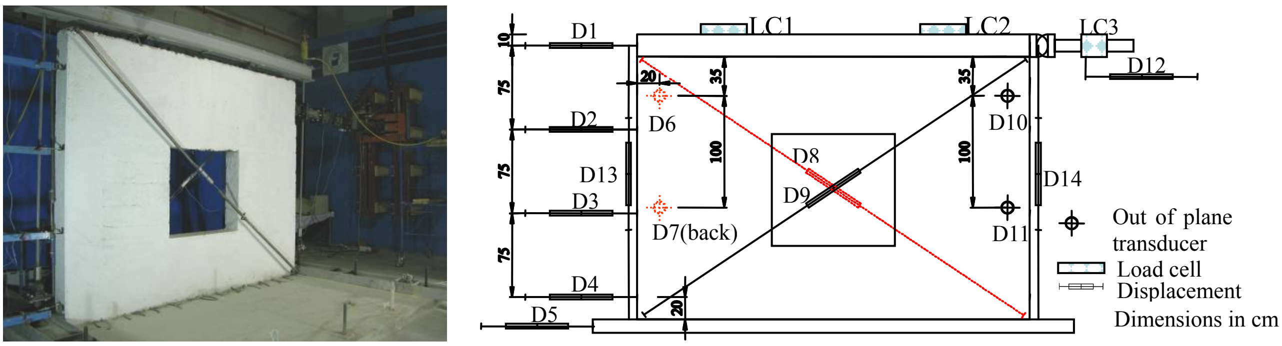

Figure 4. Test setup and instrumentation

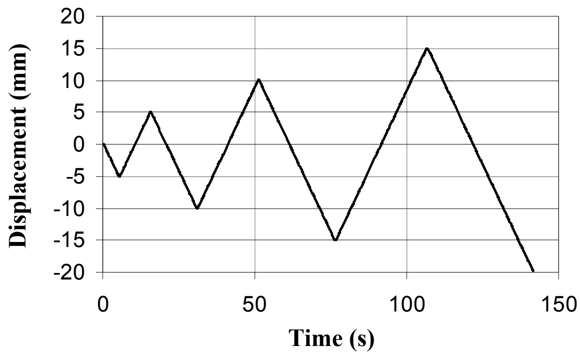

Figure 5. A typical sway pattern applied during the experiments

3. EXPERIMENTAL RESULTS

After the experiments hysteresis curves for all models were obtained as shown in Fig. 6. It is observed that energy dissipation capacities of the walls with no openings were much more than the ones with openings. Whether they have openings or not unstrengthened models have more brittle characteristics than strengthened models.

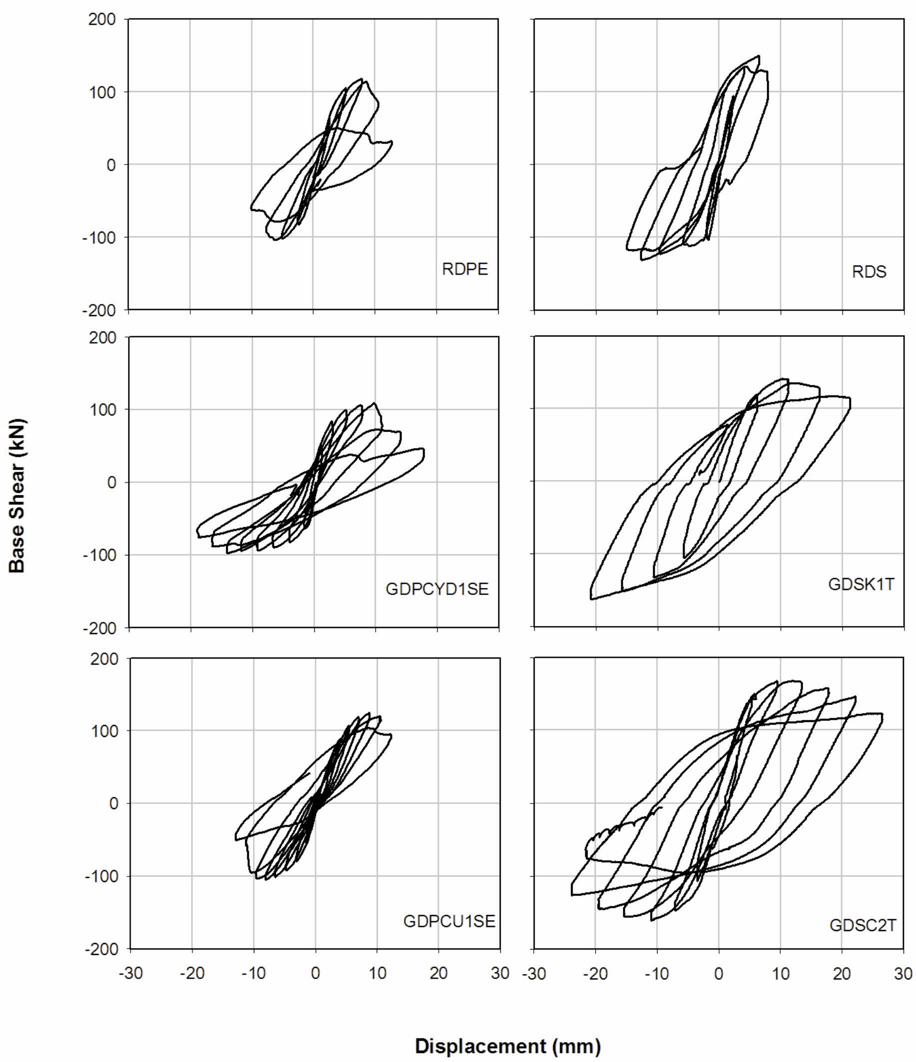

Figure 6. Hysteresis behavior of the test models

Unstrengthened model, RDPE and RDS, showed capacity reduction at 7.6 mm and 6.5 lateral displacement levels respectively. On the other hand, all other strengthened models continue to bear against lateral loads after this displacement level. Model that is strengthened with closely spaced – diagonal strips showed the best performance in terms of improvement in displacement capacity in the models that have no openings. Moreover, additional strips around the windows also improved the performance of the windowed models. Displacement levels before the significant capacity loss is given in Table 2. Improvement in displacement capacity of the models are limited in case of wall openings significantly. It is also observed that the more the amount of reinforcement the more the improvement in ductility.

Table 2. Maximum displacement before the failure

Specimen name	Maximum displacement (mm)	Normalized maximum displacement
RDPE	7,6	1,17
GDPCYD1SE	10,5	1,62
GDPCU1SE	9,8	1,51
RDS	6,5	1,00
GDSK1T	16,2	2,49
GDSC2T	19,5	3,00

Failure modes of the wall models are given in Fig. 7. Failure mode of the specimens with openings had inclined shear cracks and displacement capacity increases about 30~40%. However, full models slipped along the baseline with an improvement in displacement capacity about 250~300%.

RDPE GDPCYD1SE GDPCU1SE

RDS GDSK1T GDSC2T

Figure 7. Failure modes of models

This difference is due to the differences in lateral load resisting mechanisms of two types of models. Sliding friction capacity of the models is not significantly reduced after the sliding of the full walls. Whereas after formation of inclined cracks at windowed walls, load transfer mechanism along the crack is significantly harmed.

Besides the experimental studies, models were also analyzed nonlinearly by ANSYS. Lateral load capacities of the models are well estimated by the analyses. Damage patterns of the numerical models were the same as experimental patterns (Fig.

8). Numerical results for All of the full wall models pointed to base sliding behavior and solutions of the windowed models resulted in a damage pattern with inclined cracks around the openings.

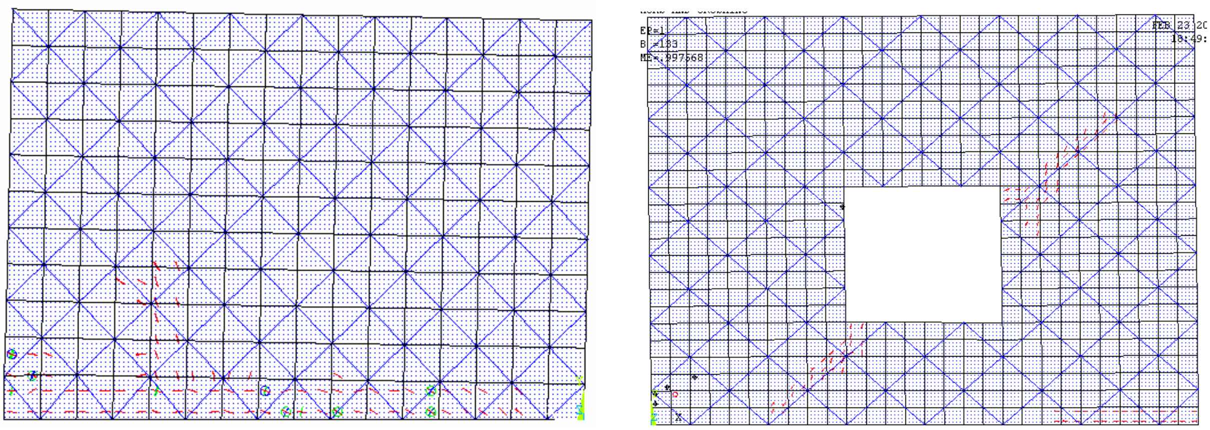

Figure 8. Numerical behavior of full (GDSC2T) and windowed (GDPCYD1SE) models

4 RESULTS AND CONCLUSIONS

This study deals with development of a new strengthening alternative, which will be an economic and easily applicable method, for seismically vulnerable unreinforced masonry structures. Method also has an environmental aspect. It will probably have an important contribution to waste problem caused by old tyres.

Experimental study is carried out on the use of old car tyres as reinforcement for masonry walls. In the experimental program, six masonry walls were tested. Experiments showed that seismic strengthening of unreinforced masonry walls by strips from old car tyres is possible.

Strips have a minor effect on lateral load capacity of the walls, whereas use of the strips improves ductility and energy consumption capacity of the walls significantly depending on the crack pattern. Introduction of strips also do have some minor effect on the damage pattern.

Numerical solutions were carried out by ANSYS. After the experiments, it is shown that numerical and experimental behavior fit to each other.

It is found out that method increases displacement capacity of the walls but has no significant effect on lateral load capacity. Developed strengthening method is an easy and cheap strengthening alternative for masonry structures. Also, it has an environmental aspect. Method is an important contribution to waste problem caused by old tyres.

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REFERENCES

Albert, M.L., Elwi, A.E., Cheng, J.J.R. (2001). Strengthening of unreinforced masonry walls using FRPs. *Journal of composites for construction-ASCE* **5:1,** 76-84.

Bayraktar, A., Coşkun, N., Yalçın, A. (2007). Damages of masonry buildings during the July 2, 2004 Doğubayazıt (Ağrı) earthquake in Turkey. *Engineering Failure Analysis* **14**,147-157.

Kaplan, H., Yılmaz, S., Cetinkaya, N., Nohutcu, H. (2008). Experimental Study on Use of Old Tyres for Seismic Strengthening of Rural Masonry Stocks. *Fourth International Congress on Advances in Structural Engineering and Mechanics*, Jeju, S. Korea.

Ramazi, H., Jigheh, H.S. (2006). The Bam (Iran) Earthquake of December 26, 2003: From an engineering and seismological point of view. *Journal of Asian Earth Sciences* **27**, 576–584.

Russo, G., Pauletta, M., Quagliaro, E. (2006). Experimental Behaviour of masonry walls strengthened by reinforced mortar slabs and subjected to in-plane loads. *First European Conference of Earthquake Engineering and Seismology*, Geneva, Switzerland.

Sallio, N. (2005). Seismic evaluation and strengthening of existing masonry building. MSc. Thesis. Pamukkale University, Denizli.

Taghdi, M., Bruneau, M., Saatcioglu, M. (2000) Seismic Retrofitting of low-rise masonry and concrete walls using steel strips. *Journal of Structural Engineering – ASCE* **126:9**, 1017-1025.

Turer, A., Korkmaz, S.Z., Korkmaz, H.H. (2007) Performance improvement studies of masonry houses using elastic post-tensioning straps. *Earthquake Engineering and Structural Dynamics* **36**, 683-705.