8th International Conference on Seismology & Earthquake Engineering
11-13 Nov. 2019, Tehran, Iran

ANALYTICAL SEISMIC PERFORMANCE EVALUATION OF RETROFITED UNREINFORCED MASONRY WALLS USING DIAGONAL STEEL STRIPS

Delaram OSTAD
M.Sc. Student, Faculty of civil Engineering, Shahrood University of Technology, Shahrood, Iran
Delaramostad@shahroodut.ac.ir

Jalil SHAFAEI
Assistant Professor, Faculty of civil Engineering, Shahrood University of Technology, Shahrood, Iran
jshafaei@shahroodut.ac.ir

Keywords: Seismic retrofit, URM walls, Diagonal steel strips, Finite element modelling

Masonry material is the oldest masonry building, which has been used in existing or historical (URM (Unreinforced Masonry)) structures. The vulnerability analysis of masonry buildings under the impact of the earthquake is very important, because the criteria of the various regulations regarding the masonry of walls are generally based on laboratory studies and amount of damages to these structures in past earthquakes, and there is no suitable analytical relationships to assess the strength and the ductility of masonry. The masonry including mortar and brick are very effective against compressive forces but weak against lateral and tensile forces, and after the maximum strength, they experience crushing. In recent earthquakes, masonry (URM) buildings have not been resistant to earthquake due to high weight and low ductility and low shear strength, and have experienced many damages. The Kermanshah province earthquake which occurred on 2 November 2017, caused destruction in many masonry buildings. The strength and ductility of the wall decreases, when the height to length ratio of the wall increases.

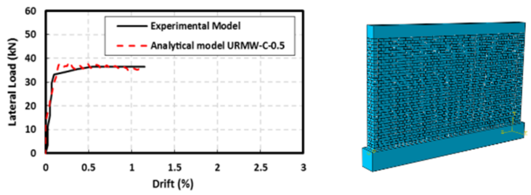
In the ASCE (ASCE/SEL41-06, 2007), FEMA356 (Prestandard, 2000), Journal 360 (Publication360, 1392), and the other building design regulations for earthquake, seismic improvement method for masonry (URM) Building have been proposed. Many laboratory and analytical researches have been carried out to strengthen specimens of masonry walls, including use of FRP on the surface of masonry wall, using stainless steel strip, using geogrid in the joint between the bricks, prevent from failure of shear cracks in masonry walls using steel bars, and other techniques for retrofitted. The purpose of this paper is to investigate the performance of retrofitting of unreinforced masonry walls by using steel ties in a diagonal and vertical on both sides of the wall. The use of steel tie does not require cleaning the surface of the wall, and reduces the costs. Use of steel ties for retrofitting masonry buildings will increase the load and improve behavior against the lateral load of the in-plane applied to the wall.

This paper used experimental model developed by Darbhanzi et al. (2014, 2018) which constructed in laboratory of the Tehran University structure and its details observed in Table 1. Four specimens were built, two of them are unreinforced masonry walls with nominal dimensions of 2700×1400×160 (length×height×thickness) and 1900×1400×110 (length×height×thickness). Two other specimens were built similar to the reference ones, but retrofitted with vertical steel strips (30×3 mm) on both edges of the wall. The characteristics of these four specimens are observed in Table 1. They were built with characteristics similar to existing (URM) building in Iran. The four specimens were half scale with aspect ratios of 0.5 and 0.7 (height to length) and were tested under in-plane lateral load and gravity. The specimens were fabricated with solid clay bricks with dimensions of (105×49×31 mm) and its cement mortar is approximately 6 mm. These experimental specimens are modeled and validation using ABAQUS finite element software Figure 1.

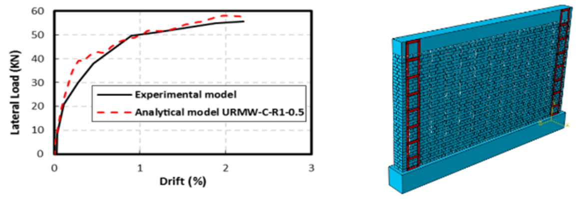
In this paper, the steel straps has used as a diagonal on the masonry walls with vertical steel straps in both the ratio of height to length for ratio (0.5 and 0.7). To investigate the analytical specimens in software, finite element ABAQUS is modeled and their names and shapes are show in Table 2. Then, with the bilinear force-displacement curves after analyze the specimens, according to method FEMA356 (Prestandard, 2000), yield the maximum strength and displacement ductility, and effective stiffness of all specimens are calculated.

Table 1. Experimental masonry wall specifications (Darbhanzi et al., 2014).

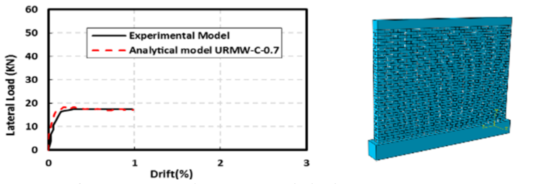
Reference Specimen	Vertical Stress (MPa)	Mortar Shear Strength (MPa)	Length (mm)	Heigh t (mm)	Height to Length Ratio	Reference Retrofitted Specimen
URMW-C-0.5	0.1	0.2	2700	1400	0.5	URMW-C-R1-0.5
URMW-C-0.7	0.1	0.2	1900	1400	0.7	URMW-C-R1-0.7



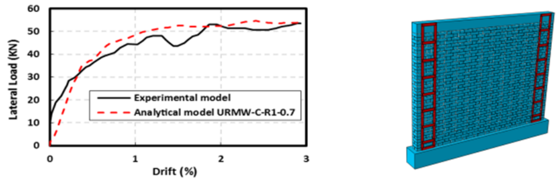
a. Reference specimens modeled URMW-C-0.5



b. Reference specimens modeled URMW-C-R1-0.5



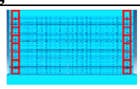
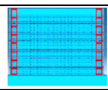
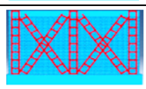
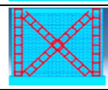
c. Reference specimens modeled URMW-C-0.7



d. Reference specimens modeled URMW-C-R1-0.7

Figure 1. Validation specimens ABAQUS finite element software.

Table 2. Specification of reinforced masonry walls.

h/b=0.5		h/b=0.7	
arrangement of steel straps	**specimens**	**arrangement of steel straps**	**specimens**
	URMW-C-R1-0.5		URMW-C-R1-0.7
	URMW-R2-0.5		URMW-R2-0.7

Discussion of obtained results showed the maximum strength of the diagonal specimen on the two sides is about ten fold increasing and also two fold increase in effective stiffness and ductility in height to length ratio of 0.5 and 0.7. The steel straps which, installed diagonally on the masonry wall, are more effective in increasing the maximum strength than the steel straps installed vertically. Retrofitting the masonry walls using diagonal steel straps, and the reason of masonry walls to be locked inside the steel straps was not abrupt cutting failure, and preventing early failure.

REFERENCES

ASCE/SEL41-06 (2007). Seismic rehabilitation of existing buildings. *American Society of Civil Engineers.*

Darbhanzi, A., Marefat, M., and Khanmohammadi, M. (2014). Investigation of in-plane seismic retrofit of unreinforced masonry walls by means of vertical steel ties. *Construction and Building Materials, 52*, 122-129.

Darbhanzi, A., Marefat, M.S., Khanmohammadi, M., Moradimanesh, A., and Zare, H. (2018). Seismic performance of retrofitted URM walls with diagonal and vertical steel strips. *Earthquakes and Structures, 14*(5), 449-458.

Prestandard, F. (2000). Commentary for the seismic rehabilitation of buildings (FEMA356). *Washington, DC: Federal Emergency Management Agency, 7.*

Publication 360 (1392). *Instruction for Seismic Rehabilitation of Existing Buildings (in Persian).*