



# Analytical study of seismic performance of retrofitted unreinforced masonry walls using steel plates

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**ABSTRACT:** In recent earthquakes, masonry structures experienced a lot of damage due to high weight and low ductility and low shear strength. Retrofitting of masonry wall is challenges in urban construction. The unreinforced masonry walls cannot resistant to the earthquake and their basic weakness is in ductility. The wall ductility is reduced when the aspect ratio of wall decrease in comparison to the wall strength. The purpose of this study is to investigate the seismic performance of unreinforced masonry walls with two aspect ratio of 0.5 and 0.7 with scale 1:2 and retrofitting of masonry walls using different layouts of steel ties. The analytical evaluation of seismic behavior of unreinforced masonry wall has been done using ABAQUS finite element software. The force-displacement curve of specimen was bilinearized FEMA356 method. Analytical results were compared in terms of ultimate strength, effective stiffness and ductility. The ultimate strength, effective stiffness and ductility of retrofitted specimens using steel tie increased in comparison to the referenced specimen.

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## 1. INTRODUCTION

Masonry material is the oldest material, which has been used in existing or historical unreinforced masonry wall building. The vulnerability analysis of masonry buildings under the impact of the earthquake, is very important. In recent decades there have been devastating earthquakes in Iran, including Gilan province in year 1990 (Rudbar-Manjil) and Kerman province in year 2003 (bam) in Kermanshah province earthquake which occurred on 2 November 2017, caused collapse of many masonry buildings.

In the ASCE [1], FEMA356 [2] 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 [3], using stainless steel strip [4], using geogrid in the joint between the bricks [5], 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 retrofitted of unreinforced masonry walls by using various steel ties layouts in vertical, horizontal, diagonal on both sides of the masonry walls. 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 building will increase the strength and improve the performance against the lateral load of the

in-plane action applied to the wall.

Finite element analytical results showed that the maximum strength of the retrofitted specimen using diagonal steel tie increase ten times more than control specimen the effective stiffness and ductility also increased two times more than control specimens in height to length ratios of 0.5 and 0.7. The steel ties which, installed diagonally on the masonry wall, are more effective in increasing the maximum strength.

## 2.DETAILS OF LABORATORY MODEL FOR ANALYTICAL MODEL VALIDATION

In this paper, the experimental program developed by darbhanzi et al which constructed in laboratory of the Tehran university was used [6, 7]. 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 on both edges of the wall. The dimensions of steel ties were 30×3 mm (width×thickness). The vertical and horizontal spaces between steel bolts were 200 mm and 150 mm, respectively. They were built with characteristics similar to existing unreinforced masonry 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

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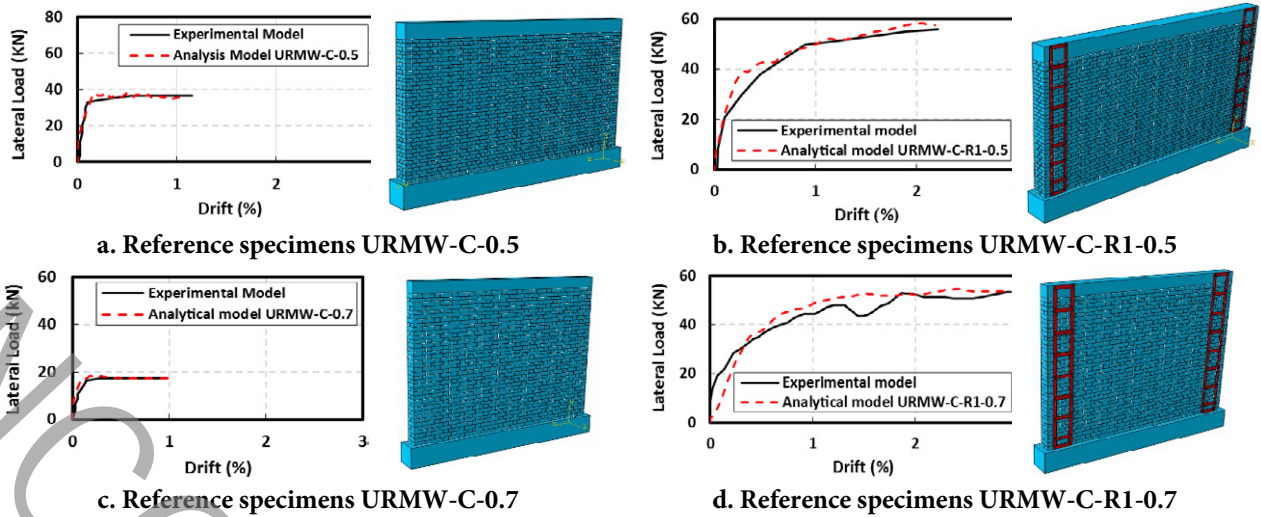


Fig. 1. Validated of experimental program using ABAQUS finite element Software

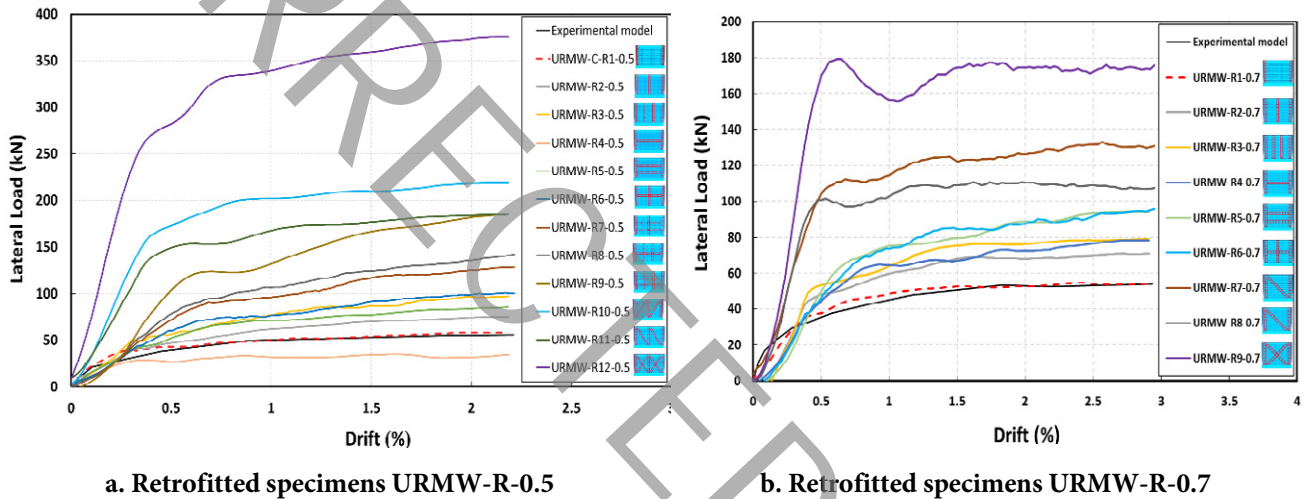


Fig. 2. Comparison of force-displacement curves of retrofitted specimens

(105×49×31 mm) and its cement mortar is approximately 6 mm. These experimental specimens are modeled and validated using ABAQUS finite element software as shown Fig. 1.

### 3. ANALYTICAL MODELS AND PARAMETRIC STUDY

To investigate various parameter on retrofitted specimens the Finite element analytical model of specimens was modeled in ABAQUS software. From the analytical force-displacement curve of retrofitted specimens the yield load, strength, and ductility of all specimens calculated.

### 4. ANALYTICAL RESULTS OF RETROFITTED SPECIMENS

The effects of different layouts of steel ties force-

displacement curve on the masonry walls are shown in figure 2. Layout of diagonal steel ties have the most impact on the masonry walls with height to length ratios of 0.5 and 0.7, so that it increase the effective stiffens and ultimate strength of the specimen.

### 5. CONCLUSION

The force-displacement curve of the specimens were compared after bilinearization. The most important parameter on improving the seismic performance of the masonry wall include:

1- Unreinforced masonry wall specimens with height to length ratios of 0.5 and 0.7 retrofitted using steel ties have an average ultimate strength increase of 161.5 kN and 100 kN, respectively, compared to the reference masonry wall

specimens retrofitted.

2- For specimens with height to length ratios of 0.5 and 0.7, the ultimate strength of the masonry wall steel ties on either side of the wall is higher than that of wall without steel ties.

3- Diagonal layout of steel ties have a more effective role in increasing ultimate strength than other layout.

4- Retrofitting the masonry walls using diagonal steel ties, and the reason of masonry walls to be locked inside the steel ties was not abrupt cutting failure, and preventing early failure.

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