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EXPERIMENTAL STUDY OF SEISMIC BEHAVIOUR OF TYPICAL IRANIAN URM BRICK WALLS

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ABSTRACT :

Lack of integrity and ductility are two main reasons for seismic vulnerability of un-reinforced masonry (URM) walls and buildings. Constructing the walls without head joint is another reason for the low seismic behaviour of URM walls and buildings around the world and Iran. For evaluating the seismic behaviour of URM walls, some approximate analytical approaches as finite elements, discrete elements, equivalent frame and simple guideline methods are available in literature. But for calibrating the above approaches and study of the seismic performance of typical URM walls, the experimental data was needed. In this paper firstly, experimental data of prism test, flexural tension test and diagonal-compression test of typical brick wall samples were performed. Then the experimental results of the cyclic test on one solid and two perforated URM walls, with dimensions of 315*270*20.5 cm, are presented. These results show although lateral capacity of the walls is decreased due to openings, but the possibility of changing the wall behaviour from shear sliding in solid wall to the rocking mode in perforated walls, is caused the ductility of the perforated walls No.2 and No.3 to be increased about 2.7 and 3.5 times higher than the solid wall, respectively. Increasing the ductility of URM walls is caused the seismic behaviour of URM buildings to be increased. Experimental set-up and the results obtained during testing is the main contribution of this paper which will be discussed in details.

KEYWORDS: Cyclic Test, URM Walls, Seismic Behaviour.

1. INTRODUCTION

The recent earthquakes that occurred in Iran have enlightened the vulnerability of un-reinforced masonry (URM) buildings and need to reliably assess their seismic capacity. The URM buildings capacity can be evaluate by numerical approaches such as storey mechanism [1], equivalent frame [2,3], discrete elements [3,4], finite elements [3,4] , and traditional codes and guidelines methods. Due to non-homogeneous and orthotropic materials, lack of reliable experimental data and uncertain the calibration of numerical models, the results of the above methods sometimes are not close to experimental data. On the other hand, most of typical URM walls and buildings in Iran were constructed without head joint mortar and no laboratory data have about seismic behaviour of these kinds of buildings.
In this study, firstly the results of prism test, flexural tension test and diagonal compression test of brick masonry unit are offered and the compressive and diagonal tension (shear) masonry unit, with and without head joint mortar, have been comprised. Then the experimental results of the full-scale cyclic test on one solid and two perforated URM walls are presented. Finally based on the laboratory results, the effects of changing the wall failure modes from brittle shear mode in solid wall to the ductile rocking mode in perforated walls on increasing the ductility and seismic behaviour, is studied. All of the tests that the results are presented in this paper were done at IIEES structural laboratory in Iran.

2. MASONRY UNIT TESTS

In the following the results of compressive, tensile and diagonal tension strength of brick masonry unit that obtained from test are presented.

2.1. Prism Tests

The prisms were constructed of three types:

I. Three bricks with two mortar bed joints.
II. Six bricks with two mortar bed joints and head joints.
III. Six bricks with two mortar bed joints(figure 1.a.).

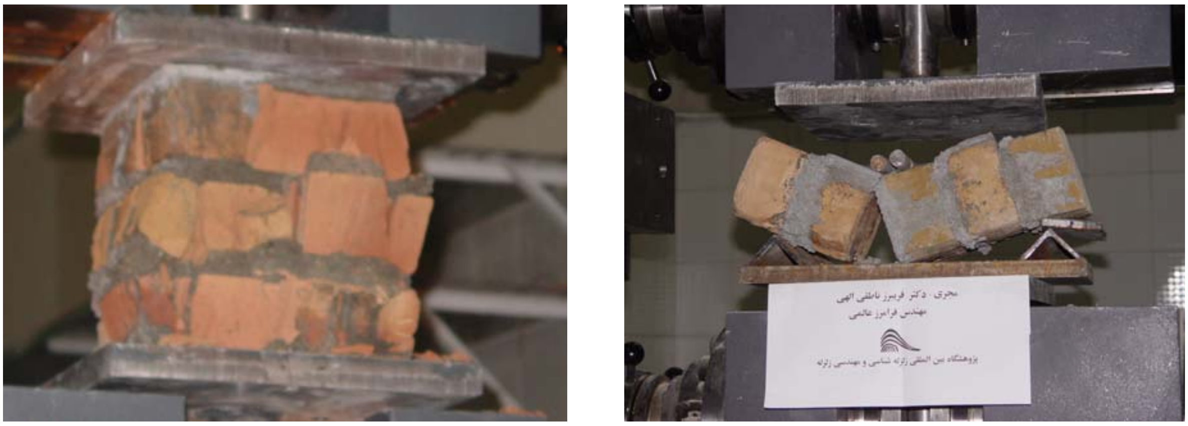
Each end of the prism was coated to provide a uniform bearing surface. The prisms were the compressed until failure, with the highest load resisted, recorded. The failure mode for the prisms was typical compression splitting of the masonry units. This load was divided by the plan area of the prism to determine the compressive strength. The average of compressive strength of type (I), type (II) and type (III) were 81.4, 76.8 and 78.8 respectively. These results show that the effect of head joints mortar on increasing the compressive strength is 2% only.

2.2. Flexural Tension Tests

This test consisted of a horizontal five bricks masonry beam, simply supported, loaded vertically by a two point load application system (figure 1.b.). The load was gradually increased until the beam failed. The tensile stress reported, f_t, is calculated using equation 1.

$$f_t = (P + 0.75P_S)\frac{L}{bd^2} \tag{1}$$

Where P is the applied load, P_s, is the weight of the beam, L is the distance between supports, and b and d are the depth of the beam, respectively. The average of four tests gave f_t as $1.83(\frac{kg}{cm^2})$.



a: Prism Test b: Flexural Tension Test

Figure 1: Prism and Flexural Tension Tests

2.3. Diagonal compression Tests

In this test, a square masonry panel is loaded in compression between two opposite corners (figure 2).The panels were constructed of two types:

I- Brick masonry panel with bed joints mortar.

II- Brick masonry panel with bed joints and head joints mortar

a: Before Test b: After Test

Figure 2: Diagonal compression Test

This type of test provides a measure of the diagonal tension (shear) strength of the masonry. The average of diagonal tension strength of the panels type (I) and type (II) are 2 $(\frac{kg}{cm^2})$ and 2.8 $(\frac{kg}{cm^2})$, respectively. These results show that the effect of head joints mortar on increasing the diagonal tension (shear) strength is 40%.

3. CYCLIC TEST OF FULL-SCALE URM WALLS

The experimental results of the cyclic test on one solid and two perforated URM walls, with dimensions of 315*270*20.5 cm, are presented in this section. The test set-up that was designed in this research is Shown in Figure 3.

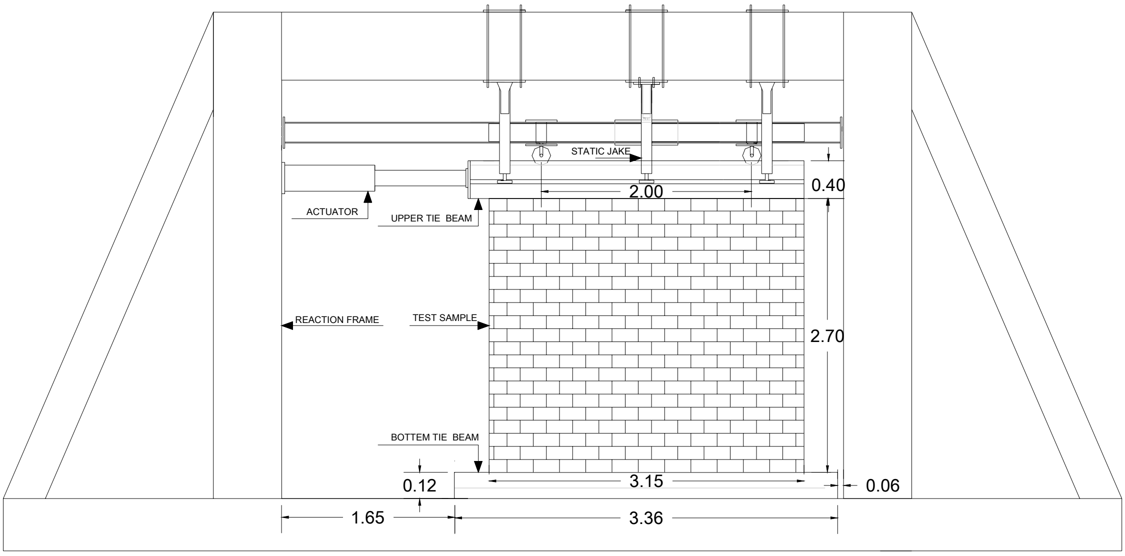


Figure 3: Test Set-up

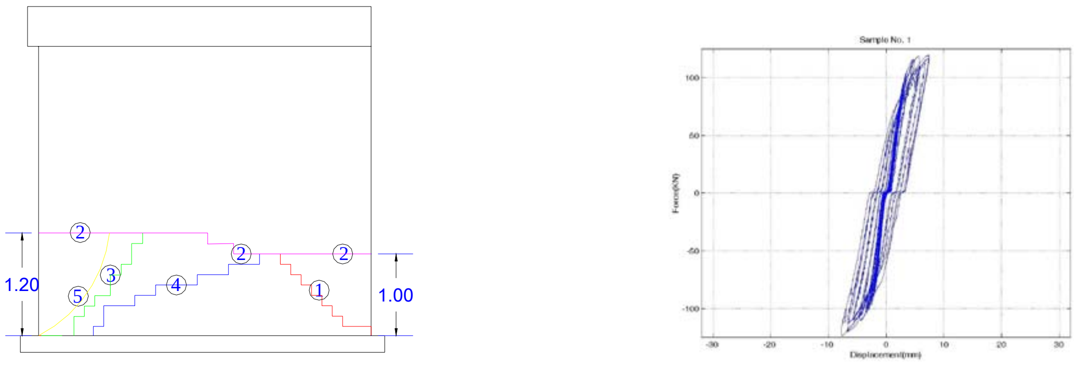
3.1. Solid wall

Figure 4 shows the URM solid wall before and after the cyclic test.

a: Before Test b: After Test

Figure 4: Brick masonry solid wall

The modes of failure of perforated wall after cyclic test and the force- displacement hysteresis curve are shown in Figure5. The maximum capacity and maximum displacement of the solid wall were 12.0 ton and 7.4 mm, respectively.



a: Modes of Failure b: Hysteresis curve

Figure 5: wall No.1 after cyclic test

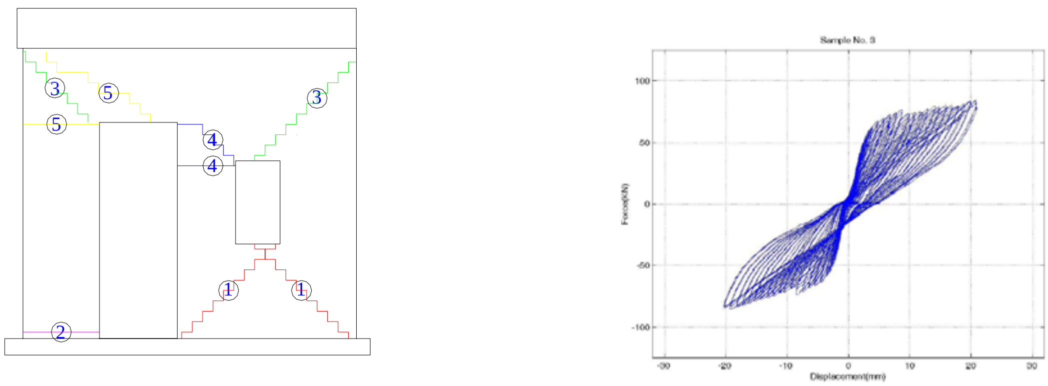
3.2.Perforated Wall with one Door & one Window

Figure 6 shows the URM perforated wall (with one door & one window) before and after the cyclic test.

a: Before Test b: After Test

Figure 6: Brick masonry perforated wall (with one door & one window)

The modes of failure of perforated wall after cyclic test and the force- displacement hysteresis curve are shown in Figure7. The maximum capacity and maximum displacement of the solid wall were 9.0 ton and 12.4 mm, respectively.



a: Modes of Failure b: Hysteresis curve

Figure 7: wall No.2 after cyclic test

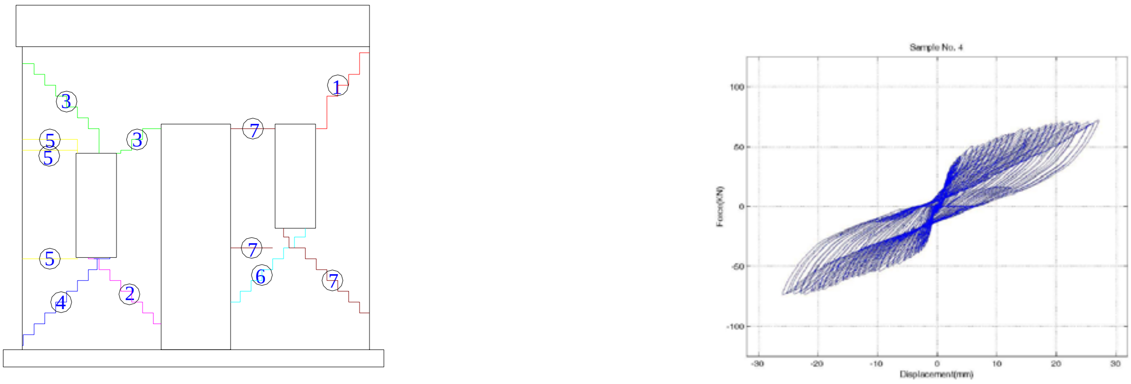
3.3. Perforated Wall with one Door & two Window

Figure8 shows the URM perforated wall with one door & two windows before and after the cyclic test.

a: Before Test b: After Test

Figure 8: Brick masonry perforated wall (with one door & two windows)

The modes of failure of perforated wall after cyclic test and the force- displacement hysteresis curve are shown in Figure9. The maximum capacity and maximum displacement of the solid wall were 8.5 ton and 20.4 mm, respectively.



a: Modes of Failure b: Hysteresis curve

Figure 9: wall No.3 after cyclic test

4. COMPARISON BETWEEN TEST RESULTS OF THE SOLID & PERFORATED WALL

The in-plane rocking behaviour of URM walls is classified by FEMA356 as a "displacement-controlled" action. This behaviour characterized with rather large post cracking deformations that remain stable for many cycles [5]. Also the experimental results were obtained in this study are approved the ductile behaviour of rocking mode in URM walls.
In this section, test results of the above solid and perforated walls are comprised together (Table 4.1).

Table 4.1 Comparison of capacity and displacement ratio of walls No.1 to No.3

No.	Capacity	displacement	Capacity Ratio	Displacement Ratio
1	12.0	7.4	1	1
2	8.5	20.4	0.71	2.76
3	7.2	26.0	0.60	3.51

Table 4.1 shows that although lateral capacity of the walls is decreased due to the openings about 29% and 40% in wall No.2 and wall No.3, respectively, but due to changing the wall behaviour from dominant shear mode in solid wall to dominant rocking mode in perforated walls, is caused the ductility of the perforated walls to be increased about 2.7 and 3.5 times higher than the solid wall, respectively.
Also the comparison between the histeresis force-displacement curves of the solid wall with the perforated walls shows the better cyclic behaviour in perforated walls.
Therefore by using opening in suitable situation in the URM walls and changing the aspect ratio of the pier elements we can be increased ductility and seismic behaviour of the URM walls and buildings. This method is very simple, economic and applicable for rehabilitation of URM existing buildings. For assessing the seismic behaviour of rehabilitated walls and buildings by this method, we need to theoretical methods. Comparisons between experimental and theoretical results show that equivalent frame modelling and push over analysis is applicable and suitable for this evaluating [6, 7].

5. CONCLUSIONS

The main results from this experimental study are:

1. The test results show By using opening in suitable situation in URM walls and changing the behaviour from shear brittle mode to ductile rocking mode, the seismic behaviour of the URM buildings can be increased.

2. Using this method is caused the ductility of the perforated walls No.2 and No.3 to be increased about 2.7 and 3.5 times higher than the solid wall, respectively.

3. This method is very simple, economic and applicable for rehabilitation of URM existing buildings.

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