EXPERIMENTAL STUDY OF A ONE SIDE MASONRY WALL REHABILITATION DESIGN FOR EARTHQUAKE DAMAGED BUILDINGS

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ABSTRACT:

Unreinforced masonry buildings are among the most popular types of construction in Iran. In these buildings, walls are used to resist both gravity and lateral loads. Since brittle materials are used in construction of these walls, they typically, are not ductile and when loading exceeds their capacity they suddenly lose the load carrying capacity. After an earthquake, different kinds of damage to buildings fall into following categories: members with permanent deformation or members with cracks. Rehabilitation is the best way for enhancing behavior of the cracked members. It is important to rehabilitate cracked members with different approaches because: 1-There are a lot of cracked members in the structure after an earthquake 2- Because of the loss of lateral strength in case of cracks in load bearing members, structure is vulnerable to future earthquakes. In this research a design procedure for one side-rehabilitation of damaged masonry walls is proposed and confirmed experimentally on half scale undamaged. One rehabilitated walls, under cyclic loading. Results show that this design strategy has restored most of load carrying capacity of the wall.

KEYWORDS: Infill, Masonry, Rehabilitation.

1. INTRODUCTION

The brick made buildings have a key role in Iranian architecture. During the recent years, these buildings are expanded rapidly due to the local by available materials and the simple methods of construction. Now a large proportion of existing buildings or are under construction ones belong to this group. Since the brittle material is used in construction of these buildings, their behavior is not ductile. Therefore, the response reduction factor (R) is not specified for these buildings in 2800 standard [1]. If reinforced brick walls are used, R=4 is suggested. In these buildings the walls are used as gravity and lateral earthquake loads bearing elements. In unreinforced masonry buildings, if the force exceeds the resistance of the wall, it will suddenly lose its load bearing capacity. As a result, these building are vulnerable to earthquakes and may cause extreme loss of life and property.

The earthquake damaged unreinforced masonry buildings can be divided in two groups: First, buildings with permanent damage. Second, cracked buildings which have lost some of their resistance and cannot resist against future earthquakes. There are different ways to improve the resistance of these buildings such as repair, reconstruction, adding new parts etc. [2-6], which can be applied with technical and economical justifications.

The repair and retrofit of the damaged parts is one of the most practical methods which are economical in large scale but, because of the lack of sufficient research and experiments about the role of repair and retrofit of buildings after the earthquake their efficiency is not fully recognized. The main motivation for conducting this research is the extent of damaged brick-buildings in 26/12/2003 Bam earthquake. In this investigation, a method of reconstruction for earthquake damaged masonry walls have been studied in laboratory with the scale of $\frac{1}{2}$ under cyclic lateral loading.

2. SET UP AND ASSUMPTIONS OF CONSTRUCTION MODEL

A 2D steel frame with hinge joints was modeled with the scale of $\frac{1}{2}$, IPB 120, IPE 270 and 2IPE140 I-beam sections were respectively used for columns, beam and the out of plane support structure. Modeling of the wall was one of the most important stages in this experiment. According to Iranian standard, the minimum thickness for structural walls is 20 cm. The infill was constructed as a 10 cm wall inside the frame. Curing the wall began after the construction of the wall completed.
The experiment set up is shown in Figure 1. Figure 2 shows the location of measurement instruments in both experiments. Four CDP model displacement measures were used. This experiment had the loading rate of 4 mm/s speed for 4mm 8 mm 12mm 16mm 20mm 28mm 36mm and 44 mm displacements steps…. and two times repetition in each step which was exercised by hydraulic actuator.

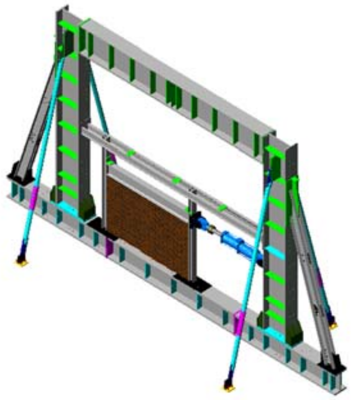

Figure 1 Specimen in reaction wall

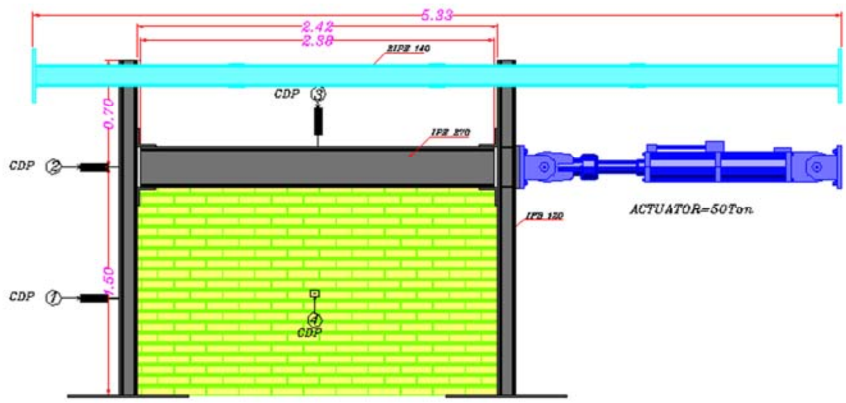

Figure 2 Set up of measurement instruments

3. EXPERIMENTS

3.1. Steel Frame with Original infill (SFI)

3.1.1 The details of the wall

In this experiment, we examined the steel frame with original infill. After the installation of frame, the masonry material made wall should be rested inside it. The bricks and cement sand mortar were used for making walls. The thickness of mortars were about 2 cm and the wall was made considering usual principals of brick work such as brick saturation before work, considering the position of vertical joints in walls, the balance of rows and so on. In last row, oblique bricks were used which were laid with mortar and pressure. After the completing the brick work both sides of the wall had to be covered. So, one side of the wall was cemented with a 1 cm layer of cement sand mortar and the other side was plastered with a 3 cm layer of plaster. Finally, the wall was cured.

3.1.2 The method of experiment

After the preparation and control of measurement equipment, it was the time of loading the specimen. Since there was no gap between the wall and the frame, the load rate increased rapidly. At the first step, with the displacement of 4 mm, the force of 12 ton exerted which in the following steps increased to 22 and 26 ton and then remained constant. After the wall failure in the displacement of 28 mm, the experiment stopped. But for further examination of more destructive effects, the loading started after a short pause and finally the displacement of 44 mm was reached for the specimen. The corners and angles were cracked first, and then it expanded to the centre and diameters. Figure 3 shows stage of cracking process. Because of the excess of deformation, the joints were damaged and some of the welding lines were failure. But there was no deficiency on experiment time.

Figure 3 Crack developments on each of the two sides

3.1.3 The interpretation of the results

The outputs are examined and shown on graphs. Figure 4 shows the loading and displacement of hydraulic actuator in separate curves.

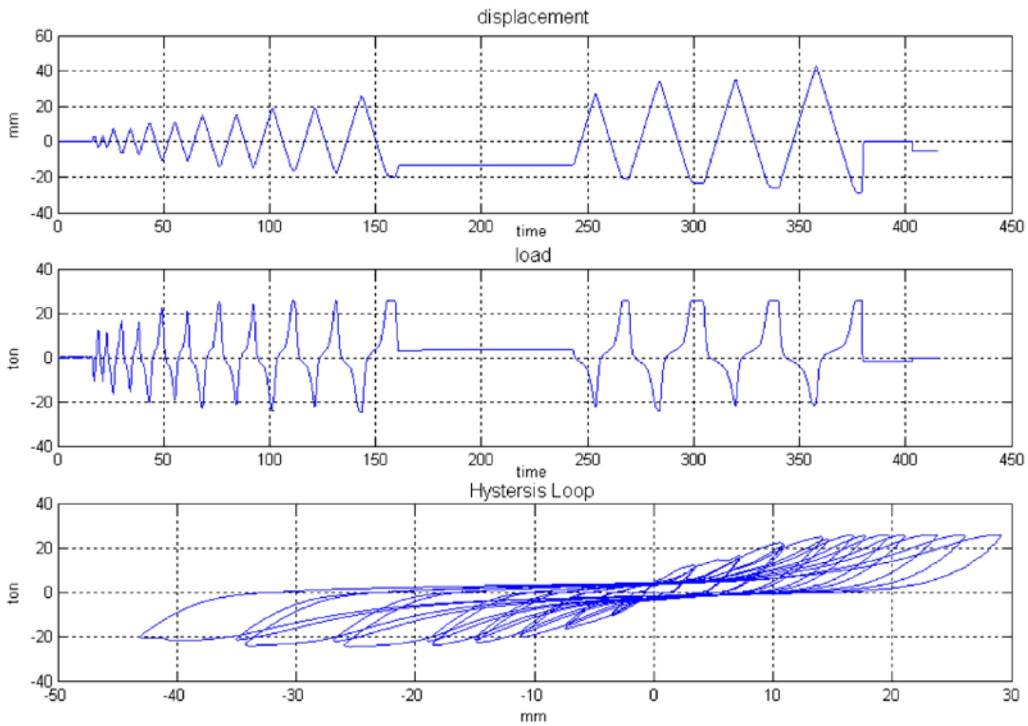

Figure 4 Actuator output information graph

The displacement-load outputs are combined together to form the hysteresis curve. The loading speed of 4 mm/s and the maximum displacement of 44 mm in 350 seconds were recorded. As the figure shows, after increase of force to 26 ton, it remains constant and there is a gap at the peak of the diagram due to the final short pause of the press load on the frame and the horizontal movement of the wall and the frame has led to the deformation of the loading curves.

One of the most important results is the hysteresis curve; so in Table 3.1 hysteresis characteristics are studied.

Table 3.1 Hysteresis characteristics (SFI)

Test	Loop	Slope of Final Loop (Degree)	Absorbed Energy (N/m2)	compression Force (ton)	Tension Force (ton)	Displacement in Compression (mm)	Displacement in Tension (mm)
Steel Frame with Original Infill (SFI)	1	88.07	3100	12.14	10.5	3.4	3.51
	2	87.8	2630	11.25	10.2	3.45	3.5
	3	87.11	10620	16.35	16.5	7.26	7.35
	4	86.4	8620	15.85	15.4	7.3	7.4
	5	86.35	17700	22.45	20.42	10.7	11.1
	6	85.6	14200	21.1	19.13	11.05	11.25
	7	85.58	24000	24.7	23	14.2	14.75
	8	84.68	20430	24	21.4	14.56	15
	9	84.67	29000	25.75	24.1	16.7	18.45
	10	83.65	26000	25.5	22.3	17.6	19
	11	79.87	44000	25.9	24.9	19.7	25.5
	12	82.1	36500	25.8	22.5	21	26.8
	13	81.47	54300	25.8	24.4	23.4	33.9
	14	79.6	45700	25.8	21.6	26.13	34.9
	15	78.2	68000	25.75	22	29.12	43
	Total	80.01	407000				

3.2 Steel Frame with Damage Infill One Side Retrofit Design (SFDIR)

3.2.1 The detail of the infill

In this part, the damaged wall from previous test was used. The proposed retrofitting method initiated with the scraping of wall covers from both sides and it is assumed that it can only be accessed from one side This work was done carefully and fortunately it did not cause that much damage to the cracked wall then the crack track was marked with red color. The 3 cm layer of plaster should be completely cleaned from the wall because if there is any plaster or dust on the surface, the new cement based material won't stick. After the preparation of the wall surface, some wire meshes were provided which were all 4 mm in diameters. These meshes were different in dimensions, then prepared one 50×50 cm mesh for the centre of the wall, four 40×40 meshes for the corners and six 20×40 meshes for the crack tracks. Having divided the distances of the crack tracks, we set the different parts of the grate.

These wire meshes were attached to the wall at 20 cm spacing by some wire nails which were 10 cm in length and 8 to 12 mm in diameters. The position of the wire meshes installation has been shown in Figure 5. The wire nails hammered oblique between vertical Joint bricks therefore mesh has a distance of 2 cm from the wall.

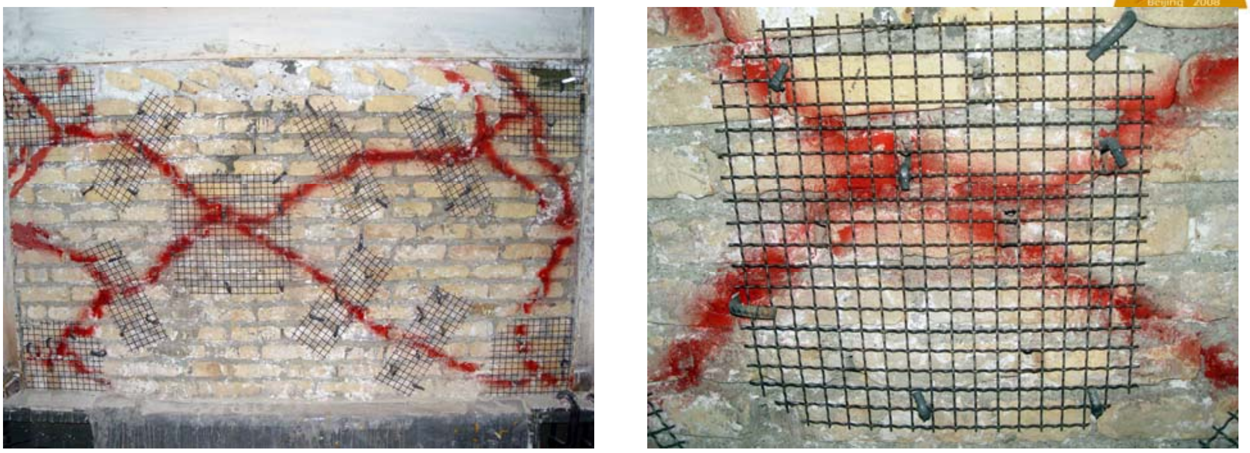

Figure 5 Position of the wire mesh installations

After the mesh installations, a 3 cm concrete cover is made. Instead of applying the shotcrete, the job is done manually which was simple. To increase the efficiency of this method, mortar is applied in different layers. The most important stage is the initial coverage in which the diluted mortar should be pounded to the wall; so that the microlithic materials of the mortar fill the wall pores. The mortar was made of grout–cement and sand with a ratio of 0.5-1-6 respectively. The grout was used to dilute the mortar and increase with the proportion of its resistance. After the cementing on the meshes, the other side of the wall was covered with cement sand mortar in 1 cm thickness then the wall was cured for 20 days. Also, for realizing the cracks and wire meshes position during the experiment, both sides of the wall painted with lime water and the positions of the meshes were drawn on the wall.

3.2.2 The method of experiment

As the load increased, first, some cracks at the lower corners of the wall appeared at the joints 3 and 4, then at the upper corners, the joint 1, then, it expanded to the other parts So during the sixth cyclic of the loading, the lower corner of joint 1 broke. Moreover, joint 3, was damaged extensively that causes the crushing of column at that part, also joint 4 failed. Finally, the experiment was finished with applied displacement and the retrofitted side of the wall had only some cracks at the three corners. There were no cracks neither in the diameters nor in the damaged crack track (Figure 6).

Figure 6 Retrofit side of the wall after test

3.2.3 The interpretation of the results

Figure 7 shows the loading and displacement figures of jack in different curves. Then, the displacement-load measurements were combined together and formed the Hysteresis curve. The loading speed of 4 mm/s and the maximum displacement of 52 mm in 470 seconds were recorded. The maximum of the pressure force is 28 ton in 11th cyclic and the maximum of elastic force is 18.8 ton in 5th cycle. The effect of the corner break in joint 1, the curvature of the column in joint 3 and its effect on the wall displacement can be seen in the curves.

One of the most important results is the hysteresis curve; so in Table 3.2 hysteresis characteristics are studied.

Table 3.2 Hysteresis characteristics (SFDIR)

Test	Loop	Slope of Final Loop (Degree)	Absorbed Energy (N/m2)	Compression Force (ton)	Tension Force (ton)	Displacement in Compression (mm)	Displacement in Tension (mm)
Steel Frame with Damage Infill One Side Retrofit Design (SFDIR)	1	88.14	1847	13.7	10.6	3.6	3.7
	2	87.87	1365	13	10	3.6	3.7
	3	87.58	8890	23.7	16.9	7.4	7.6
	4	87.1	6270	21.7	15.7	7.4	7.6
	5	86.27	19580	23.9	18.8	11.5	11.6
	6	84.88	12260	20.4	15.7	11.5	11.6
	7	84.32	22130	24.8	18.4	15.4	15.6
	8	83.14	17750	22.7	15.7	15.4	15.6
	9	82.72	29700	27	17.7	19.4	19.6
	10	81.04	23150	23.7	15.5	19.4	19.6
	11	79.58	53300	28	17.4	27.4	27.6
	12	75.44	34700	23.3	13.9	27.4	27.6
	13	71.76	51980	25.8	15.7	35.4	35.6
	14	68.75	43400	22.2	13	35.5	35.6
	15	68.22	66000	25.7	14.8	43.4	43.7
	16	61.94	48700	22.2	12.3	43.5	43.7
	17	62.67	68200	27.2	14	51.5	51.7
	18	46.14	52500	24.3	10.5	51.5	51.7
	19	-	28700	-	10.6	-	59.7
	Total	59.78	598200	-	-	-	-

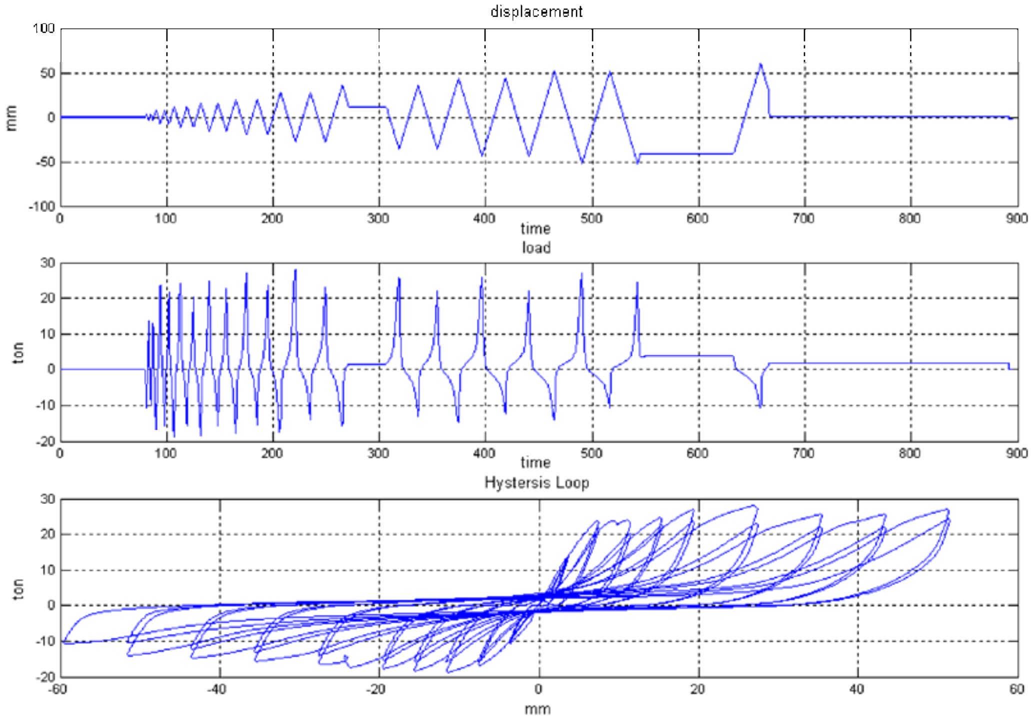

Figure 7 Actuator output information graph

4. CONCLUSION

To make a comparison between the characteristics of these two experiments, their outputs in the 12th cyclic was shown in Table 4.1 as a ratio of the values for steel frame with original infill.

Table 4.1 the results of the experiments

Characteristics	Slope of Final Loop	Reduced stiffness during test	Absorbed Energy	Pressure Force	Tension Force
Steel frame with Original infill (SFI)	1	1	1	1	1
Steel Frame with Damage Infill One Side Retrofit Design (SFDIR)	0.92	1.08	0.983	0.903	0.62

The comparison of the hysteresis curves of both experiments is shown in Figure 8.

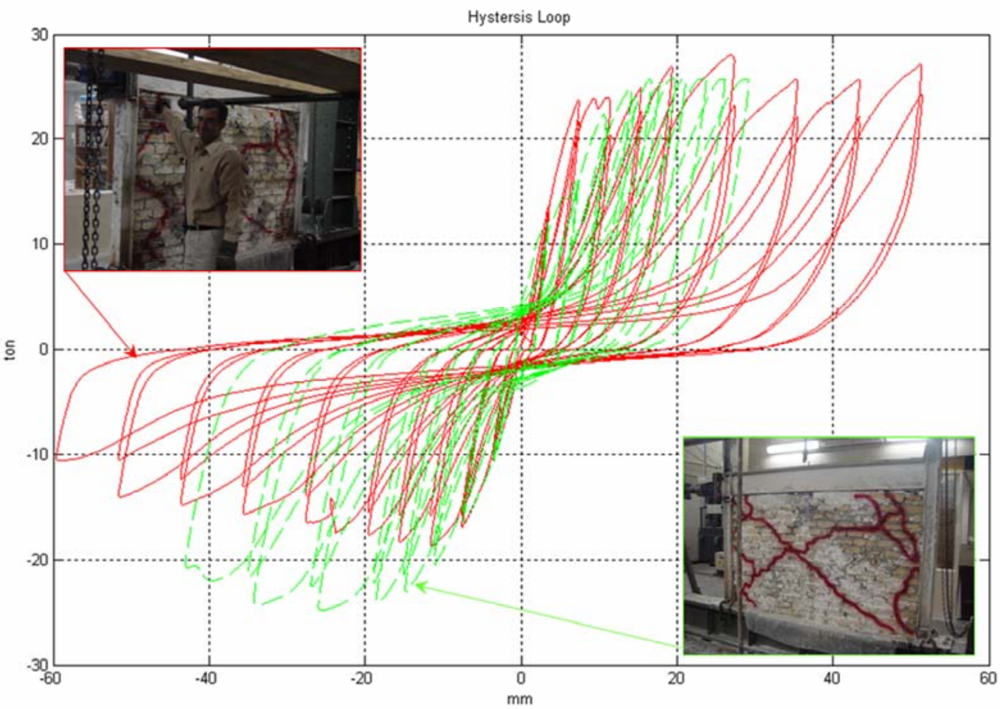

Figure 8 The comparison of the hysteresis curves of both experiments

It is concluded that this local retrofit technique restores 90 percent of the characteristics of a cracked wall. While, in this project, the common materials with preliminary equipment with the minimum thickness were applied only to one side of the damaged infill, this local retrofit project shows promising results and is practical and efficient in reducing future damage.

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