COMPARATIVE INVESTIGATION ON USING SHEAR WALL AND INFILL TO IMPROVE SEISMIC PERFORMANCE OF EXISTING BUILDINGS

SHAHABODIN. ZAREGARIZI.[1]

[1] *M.S, Dept. of Civil Engineering, Amirkabir University, Tehran. Iran*
Email: shahabzare@yahoo.com

ABSTRACT:

A large number of reinforced concrete (R/C) framed building in Iran is constructed with unreinforced masonry (URM) infill walls and lack both strength and ductility, so there is a great need for efficient, effective and inexpensive rehabilitation strategies. In this study two techniques including shear walls and concrete infills was used for rehabilitation of a five story reinforced concrete building with URM infill walls and effectiveness of each method was studied through static nonlinear analysis. The results of analysis are discussed in case of pushover curves, plastic hinge mechanism and interstory drift. The comparison of results implies that concrete infills have considerable strength while Brick one has lower strength. On the contrary capability of accepting large displacement in brick infills are superior than concrete ones. As a result, combination of concrete and brick infills can reduces the negative effects of brick and concrete infills. Result of this study also can be used for choosing an appropriate rehabilitation method for low and medium-rise buildings.

KEYWORDS: Masonry infill, Concrete infill, Shear wall, Rehabilitation, RC building

1. INTRODUCTION

Iran has located in a region with high seismic potential. The result of investigation has shown that most of the existing reinforced concrete buildings are seismically deficient. Consequently, rehabilitation of such structures is an increasing concern, because they could endanger the public safety even in the case of the moderate earthquake. As a result, the structural rehabilitation of these buildings is a challenging task. The addition of shear walls and concrete infills was found as two applicable rehabilitation techniques in R/C buildings which required strength to provide superior performance and stiffness and reduces the drift demand. Because of high stiffness of those, the moment frames do not contribute as main lateral frame resistant. Therefore the weak links and problems exhibited in the existing structure are eliminated provided that the deformations are within the range which will not severely damage the existing columns, beam and joints. In this study as first step, vulnerability of the building with and without existing URM infills was investigated. Then shear walls and concrete was used to rehabilitate the building.

2. BUILDING CONFIGURATION AND LOADING

A five-story reinforced concrete residential building with moment resisting R/C frames was selected. The building has one basement and four upper stories. The north view of the building is illustrated in Fig.1. The building consists of three bays by four bays. The N-S bays are 6 meter while the E-W bays are 5 meter wide. The basement and upper floors have 2.5 and 3.0 meter height respectively.

Figure 1 North view of the building

Table 1 present the cross section dimension and reinforcement details for structural frame members.

Table 1 cross section dimension and reinforcement details of columns and beams

Story No.	Cross section dimensions	Longitudinal bars	Stirrups arrangements
Columns			
1,2,3	40x40 cm	12 ϕ 16	ϕ 10 @ 25 *cm*
4,5	30x30 cm	6 ϕ 16	ϕ 10 @ 25 *cm*
Beams			
1-5	30x40 cm	4 ϕ 16 *Bot* 2 ϕ 16 *Top*	ϕ 10 @ 25 *cm*

The result of material strength tests shown that the compression strength of concrete is 25 MPa as well as yielding stress of the steel bars is 400 MPa. Infill walls in this building can be generally categorized into 2 types: masonry infill walls with solid bricks and hollow block walls. Only Solid bricks were considered as lateral load resistant element because of considerable stiffness. The dead load is 500 kg/Cm^2 and the live load is 200 kg/Cm^2. The dead weight of the masonry infill panels assumed to act as a uniformly distributed load on the supporting beams. For simplicity in modeling, only one of the exterior frames was considered for analysis. Fig.2 shows the view of external frame which infilled with solid brick walls.

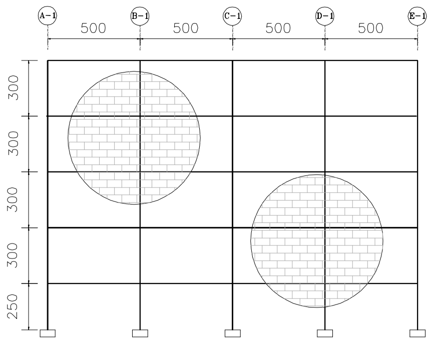

Figure 2 Exterior frame

3. PROPOSED REHABILITATION CASES

In this study, two separate retrofitting schemes analyzed and effectiveness of each cases was demonstrated analytically.

3.1. Concrete Infill

Reinforced concrete infills improve seismic behavior by increasing lateral strength, initial lateral stiffness, and energy dissipation as well as limit both structural and nonstructural damages caused by earthquake. Figure 3 shows a schematic view of a concrete infill.

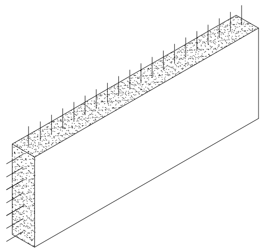

Figure 3 Schematic view of Concrete Infill

The thickness of the concrete layer is 7.5 Cm. Mesh reinforcement was used to prevent out-of-plane collapse consisting of 10mm bars with 40Cm spacing. Fig.4 presents the location of concrete infills in frame. It must be mentioned that only first and fourth bays of RC frame infilled with concrete walls.

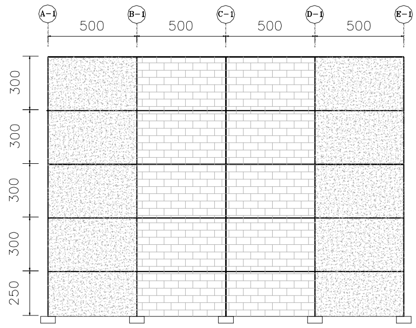

Figure 4 Location of Concrete infills

3.2. Shear wall

As second rehabilitation case, the building was rehabilitated with shear walls and the effect of shear wall on the behavior of RC frame with and without presence of masonry infills was investigated. The thickness and length of shear walls in all floors are 15 and 200 Cm respectively. Fig.5 presents the location of shear walls in frame.

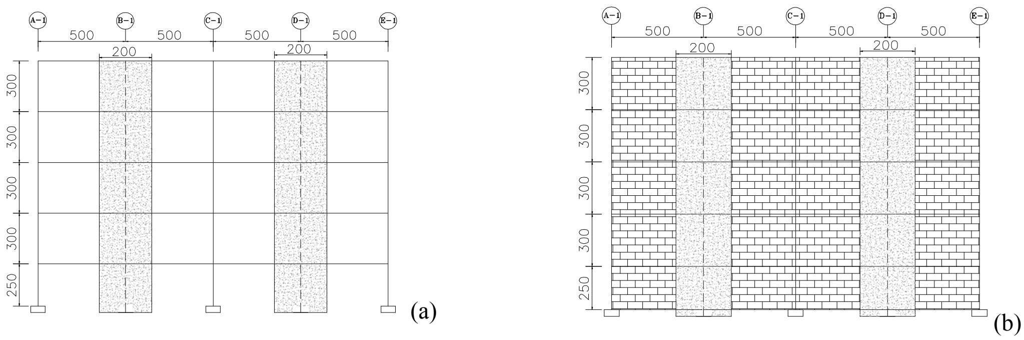

Figure 5 Location of shear wall in RC frame without URM infills (a) with URM infills(b)

4. Modelling

4.1 Modeling of masonry infill

Based of its practicality and ease of implementation in analysis, diagonal strut concept was utilized for modeling of masonry infills. For nonlinear analysis, FEMA 356 provisions also provide. The stress-strain curve for diagonal strut in bottom story was shown in Fig 6.

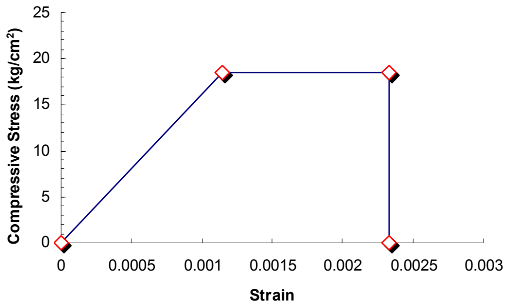

Figure6 Masonry strut stress-strain curve

4.2 Modeling of concrete infill

The use of a multi-strut model rather than a single strut better represent the actual stressed area within the infill and also facilitate the modeling of the progressive failure occurring at the corner contact region, not just at the corner points. Using of three-struts for modeling of infills was studied by El-Dakhakhni (2000). Based on research, it is suggested that at least two additional 0ff-diagonal struts located at the points of maximum field moments in the beams and the columns are required to reproduce theses moments as shown in Fig7[2].

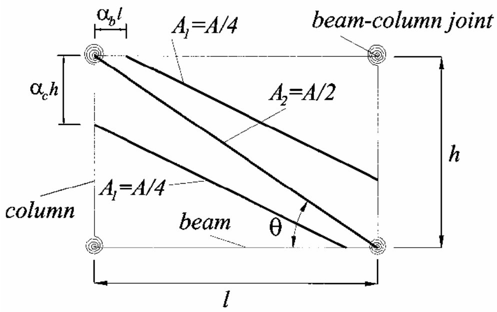

Figure 7 Three-Strut model used for modeling of concrete infills

It is suggested that the total diagonal struts area, A, is to be calculated by

$$A = \frac{(1-\alpha_c)\alpha_c ht}{\cos\theta} \tag{4.1}$$

The stress-strain relation for concrete strut is shown in Fig 8.

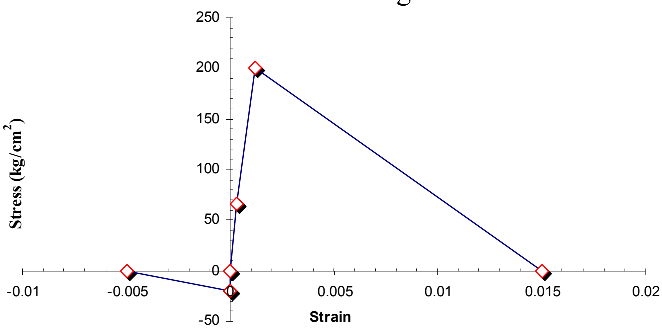

Figure 8 Stress-strain curve for concrete strut.

4.3. Modeling of Shear wall

Adding shear wall for improving seismic behavior of frame with and without existing masonry infills was studied. Shear wall modeling was carried out according to FEMA-356 requirements.

5. PERFORMANCE EVALUATION

A pushover analysis was conducted to evaluate the stiffness and strength characteristics of existing building as well as rehabilitation cases. The analysis was carried out using the inverted triangular lateral load distribution pattern. Two earthquake hazard levels were considered for the building based on the performance objective of providing life safety under 475 and 950 year seismic hazard (10% and 5% probability of exceeding in 50 years respectively). Fig.9 illustrates the base shear versus roof displacement curves for existing building and rehabilitated cases with and without presence of URM infill walls. The performance evaluation results are presented comparatively in the following section.

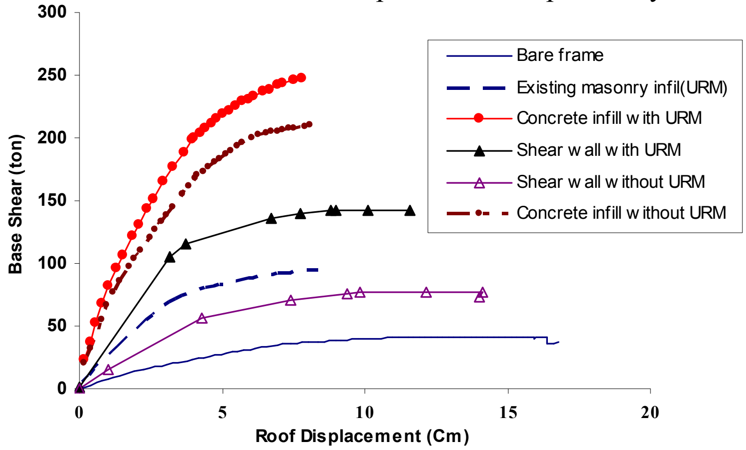

Figure 9 Base shear versus roof displacement curves

The lower curve represents the R/C frame without URM infill walls. It can be observed from fig.9 that brick infills increased the lateral strength and initial stiffness of the five story bare frame by 2.36 and 3.87 times respectively. Results of study show that if masonry infills have out-of-plane resistance, can be remaining in frame under cyclic load are suitable option in strengthening and providing life safety under moderate earthquakes. The lateral strength of concrete infilled frame is about 5 and 2.5 times in comparison with bare frame and URM masonry infilled frame. Figure 9 also shows that concrete infilled frame has not capability of accepting large displacement. Adding shear wall to bare frame increases the strength of frame by about 1.7 and 3.5 times in case of with and with out masonry infills. In comparison with concrete infills, shear wall have capacity of accepting large displacement. Performance of bare frame and rehabilitated frame are described through plastic hinges mechanism in following figures.

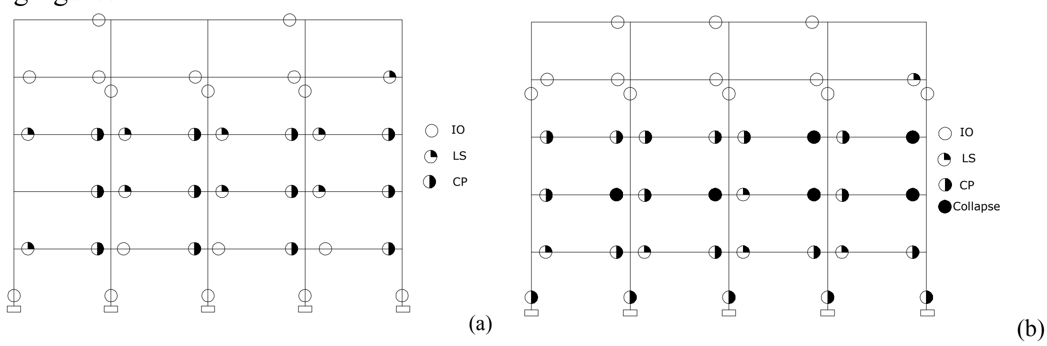

Figure 10 Plastic hinge mechanism in bare frame for hazard level 1 (a) hazard level 2 (b)

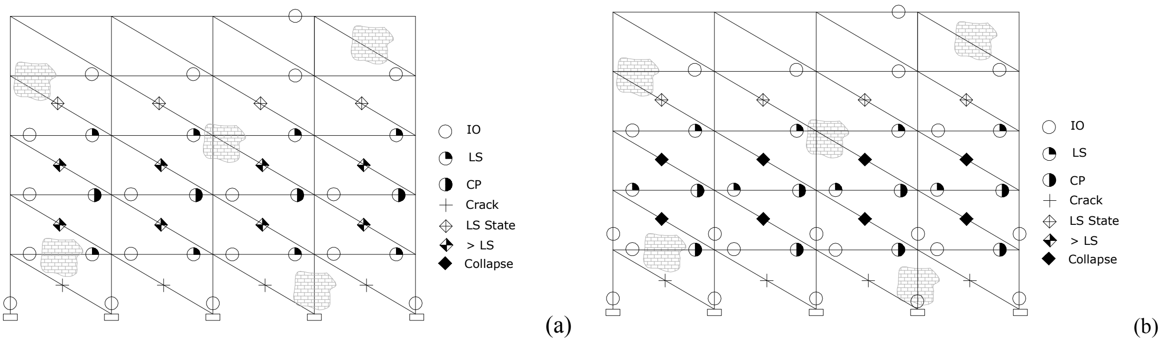

Figure 11 Plastic hinge mechanism in existing infilled frame for hazard level 1(a) hazard level 2 (b)

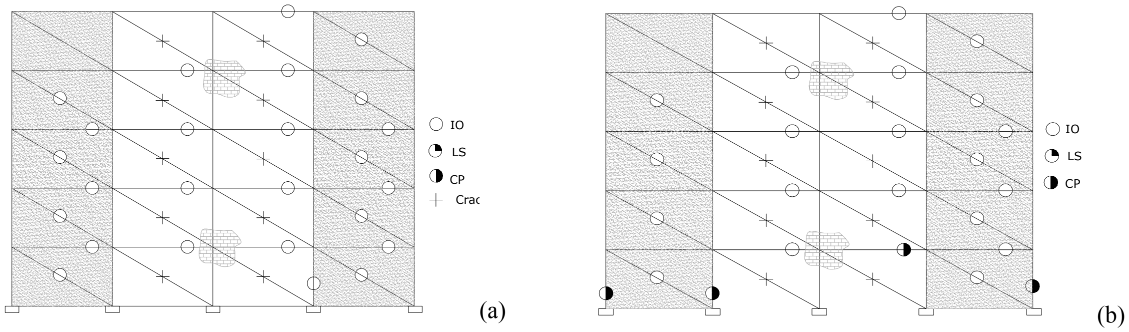

Figure 12 Plastic hinge mechanism for concrete infilled frame in hazard level 1 (a) hazard level 2 (b)

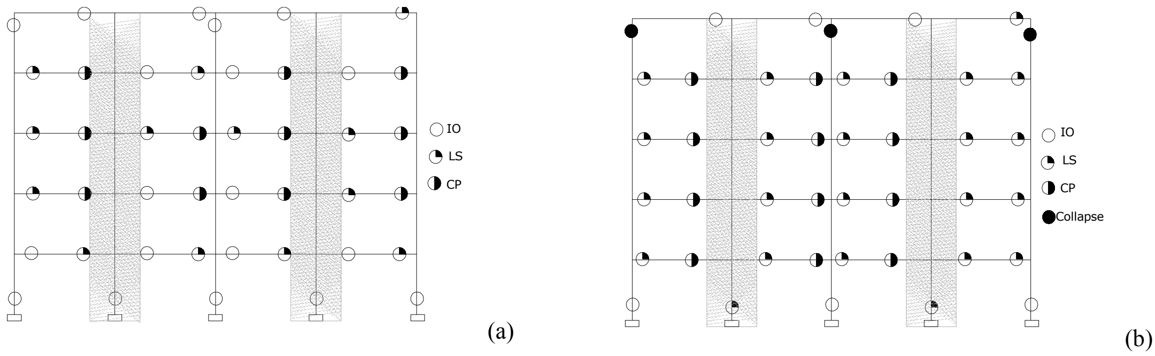

Figure 13 Plastic hinge mechanism for shear wall without URM infill in hazard level 1(a) level2 (b)

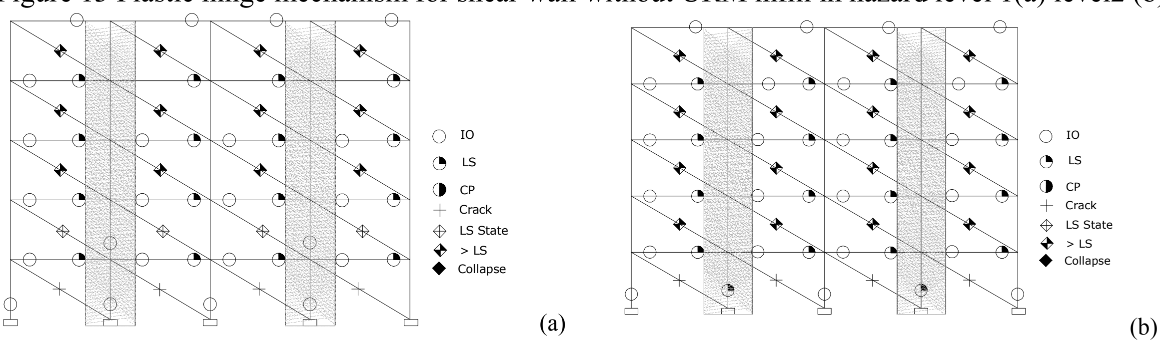

Figure 14 Plastic hinge mechanisms for shear wall with URM infill in hazard level 1 (a) level 2 (b)

The plastic hinge mechanism developed at the target displacement of the bare frame in hazard level 1 and 2 is shown in Figs. 10(a) and 10(b) respectively. In hazard level 1, the beams in first, second and third story are in collapse prevention as well as columns in first story are in immediate-occupancy. In hazard level 2 it is observed that bare frame is extremely vulnerable. Fig. 11 shows plastic hinge distribution for masonry infilled frame in hazard level 1. It is worthwhile to note that infilling panels with wall change load transfer mechanism from frame action to predominant truss action. On the other hand, columns experience increased axial forces but with reduced bending moment and shear forces that might causes crushing in columns. As a result, it must be considered probability of failure in adjacent columns. Figs. 11 and 12 display that infills can reduce interstory drift and prevent failure in beams and columns. It shown in Fig.12 (a) that all hinges in beams are in immediate-occupancy but some hinges in columns are in collapse prevention. In concrete infills large deformation can not be reached duo to the premature failure of columns. On the other hand, performance of a concrete infill depends on adjacent column. Figs.13 and 14 present plastic hinge distribution in frame rehabilitated with shear wall with and without masonry infills respectively. It was observed that although concrete shear walls has more stiffness than masonry infills, but presence of URM infills has considerably effect in improving failure mechanism in structural elements. A limit for interstory drift ratio was proposed by Sozen as 1%, this limit can be considered as an indication of damage level in the RC structures, above 1% interstory drift ratio, structural and nonstructural damage become significant. Figs. 15 and 16 show the story level versus drift in hazard level 1 and 2 respectively. It is evident that interstory drift in concrete infill are lower while in bare frame are higher than other cases. The interstory drift in hazard level 1 and 2 in concrete infill cases, not exceed than 0.005.

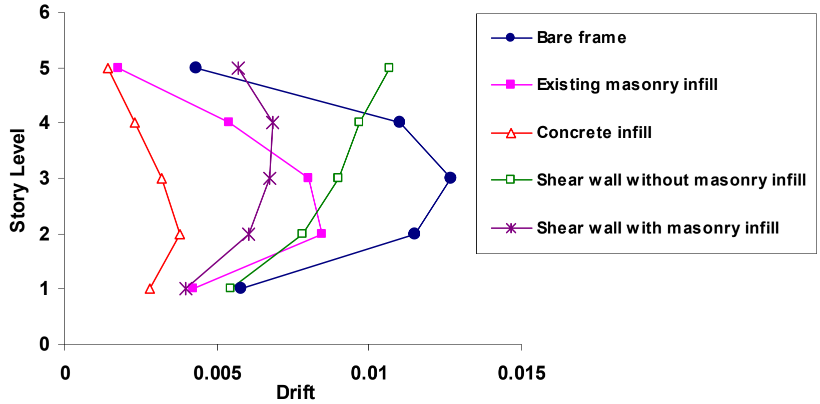

Figure 15 Story level versus drift in hazard level 1

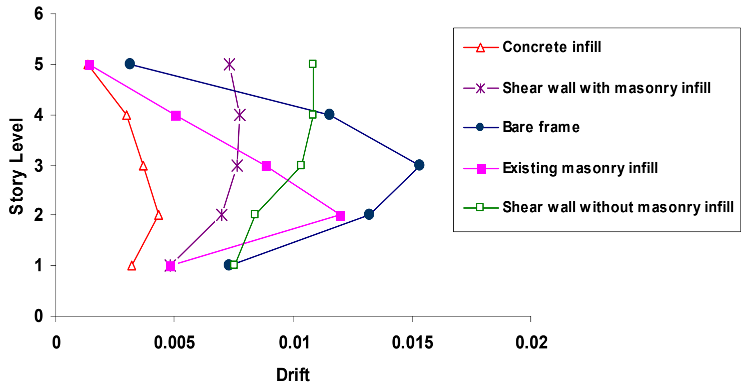

Figure 16 Story level versus drift in hazard level 2

5. CONCLUSIONS

1. Results from the pushover analysis on the existing five-story frame indicated that the concrete infills have considerable strength while Brick one has lower strength. On the contrary large displacement acceptance capabilities in brick infills are higher than concrete infills. So Combination of concrete and brick infills can reduces the negative effects of brick and concrete infills.

2. Masonry infills as lateral resisting element have considerable strength and can prevent collapse of buildings in moderate earthquakes. In presence of shear walls, neglecting effects of existing URM infills may lead to wrong results.

3. Due to the high stiffness of an infill, only a limited number of that is typically required in a structure. Therefore, it is possible to minimize disruption both during and after construction. In addition Infills can be used to provide supplemental stiffness for structures where existing shear walls are inadequate.

4. Performance of a concrete infills is depend on adjacent elements especially columns, so premature failure in columns due to strong axial forces must be considered.

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