SEISMIC REHABILITATION OF NON-DUCTILE CONCRETE BUILDING USING SHEAR WALL AND INFILL

SHAHABODIN. ZAREGARIZI. [1]

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

ABSTRACT:

In this study, a five story building that Lateral load resistant elements are unreinforced masonry infills (URM), are considered. The analyses are performed in static nonlinear mode. As first step, the vulnerability of the building is investigated and presence of existing URM infills is neglected. Then, shear walls and concrete infills, with and without existing URM infills are used to rehabilitate the building. Results of these analyses are used to determine an appropriate option for seismic rehabilitation of mid rise RC building. 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 capability of accepting large displacement in brick infills are higher than concrete ones. So Combination of concrete and brick infills can reduces the negative effects of brick and concrete infills. In addition Infills can be used to provide supplemental stiffness for structures where existing shear walls are inadequate.

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

1. INTRODUCTION

The addition of infill or shear wall can dramatically increase both the lateral strength and stiffness of the structure in addition to changing its dynamic response. Due to the high stiffness of those, the moment frames do not contribute to the 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.

2. BUILDING CONFIGURATION AND LOADING

A five-story reinforced concrete residential building with moment resisting connections was chosen. 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 wide while the E-W bays are5 meter wide . The basement floor height is 2.5 meter and other floors have 3 meter height.

Figure 1 North view of the building

Cross section dimension of columns and beams as well as their reinforcement are presented in table 1.

Table 1 Dimensions and cross section dimension of columns and beams

Columns			
Story No.	Cross section dimensions	Longitudinal bars	Stirrups arrangements
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 show 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. Due to simplicity in modeling, one of the exterior frames was considered for analysis. Fig.2 shows the façade view of external frame which infilled with solid brick walls.

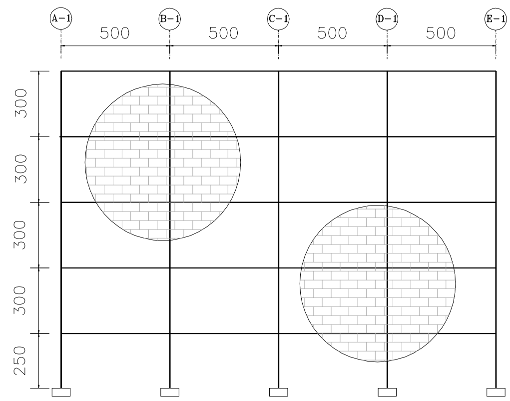


Figure 2 Exterior frame

2. PERFORMANCE EVALUATION OF EXISTING BUILDING

Based of its practicality and ease of implementation in analysis, diagonal strut concept will be utilized for modeling of infills. For nonlinear analysis, FEMA 356 provisions also provide. The diagonal strut model for bottom story was shown in Fig 3.

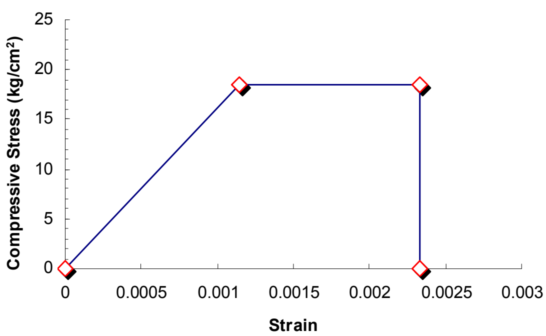


Figure 3 Masonry strut stress-strain curve

3. PROPOSED REHABILITATION SCHEMES

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

3.1. Concrete Infill

Reinforced concrete infills improve seismic behavior by increasing lateral strength, initial lateral stiffness, and energy dissipation capacity of reinforced concrete building, and limit both structural and nonstructural damages caused by earthquake. Figure 4 shows a schematic view of these infills.

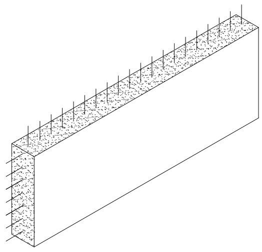


Figure 4 Schematic view of Conc. Infill

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 30Cm spacing. Fig.5. Represent the location of concrete infills in frame. It must be mentioned that only first and fourth bays of RC frame infilled with concrete walls.

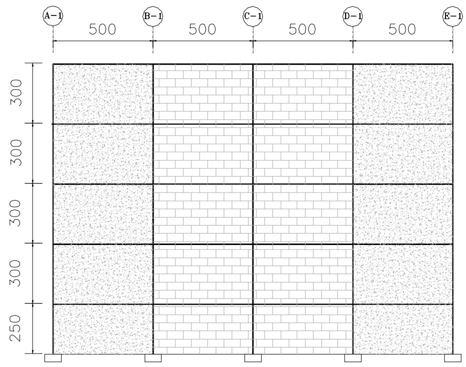
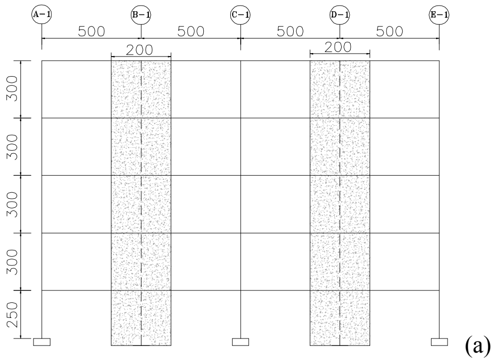


Figure 5 Location of Concrete infills

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 masonry infills was investigated. The Thickness of shear walls in all floors is 15 cm. the length of shear walls are 200 cm. Fig.6 shows the location of shear walls in proposed rehabilitation scheme.



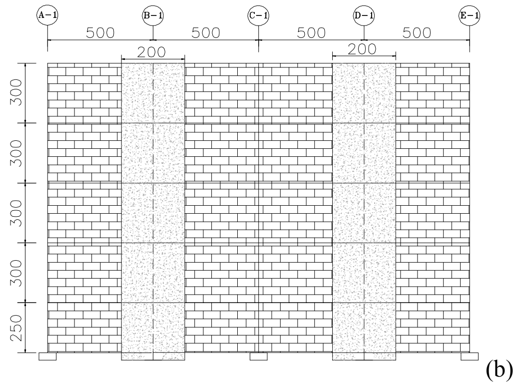


Figure 6 Location of shear wall in RC frame without masonry infills(a) with masonry infills(b)

3.1.1 Modeling of concrete infill

The use of a multi-strut model rather than a single strut will 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.

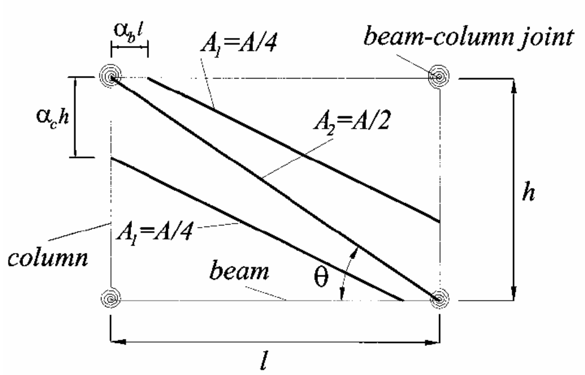


Figure 7 Three-Strut model used for modeling of concrete infills

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

$$A=\frac{(1-\alpha_c)\alpha_c ht}{\cos\theta} \tag{3.1}$$

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

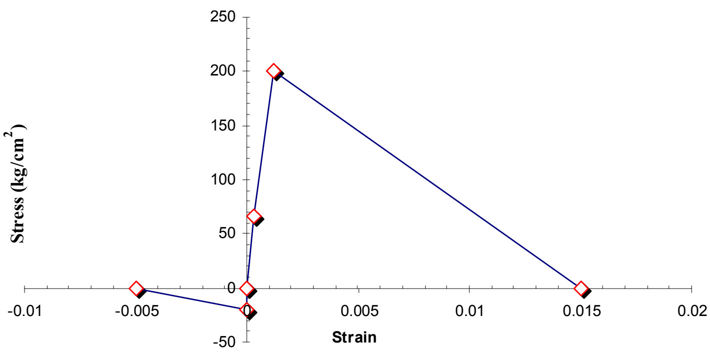


Figure 8 Stress-strain curve for concrete strut.

3.2. 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.

4. PERFORMANCE EVALUATION OF PROPOSED SCHEMES

A pushover analysis was conducted to evaluate the stiffness and strength characteristics of 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). Accordingly the base shear versus roof displacement curves of bare frame, infilled frame and shear wall presented in figure 9.

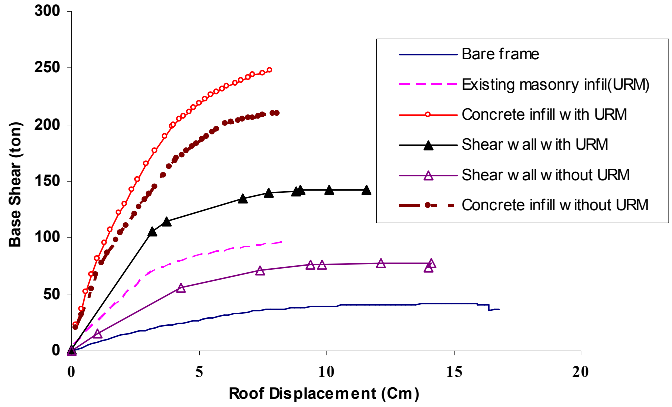
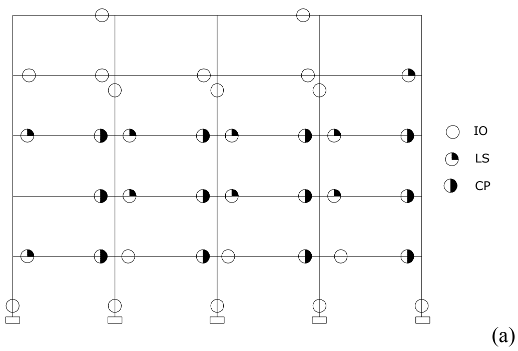


Figure 9 Base shear versus roof displacement curves

The lateral strength of bare frame and existing masonry infilled frame are 41.3 and 94 tons respectively. It should be noted that considering masonry infill, increased the lateral strength of frame to about 130% while roof displacement reduces 100% due to masonry infills. Results of study show that if masonry infills have out-of-plane resistance, can be remaining in frame, under cyclic load and in moderate earthquake they are suitable option for strengthening. The lateral strength of concrete infills is about 5 and 2.5 times in comparison with bare frame. Figure 9 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. Plastic mechanism hinges in bare and rehabilitated frame are described in below figures.



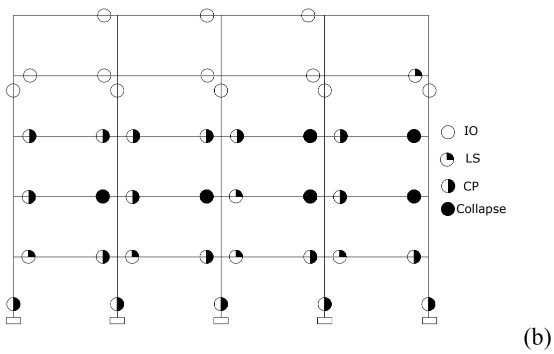


Figure 10 Plastic hinge mechanism in bare frame for hazard level 1 (a) hazard level 2 (b)

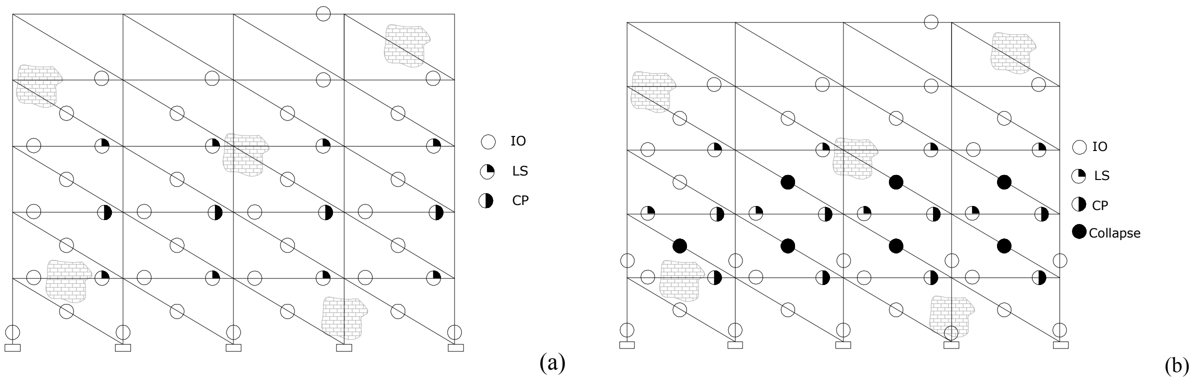


Figure 11 Plastic hinge mechanism in existing infilled frame for hazard level 1(a) hazard level 2 (b)

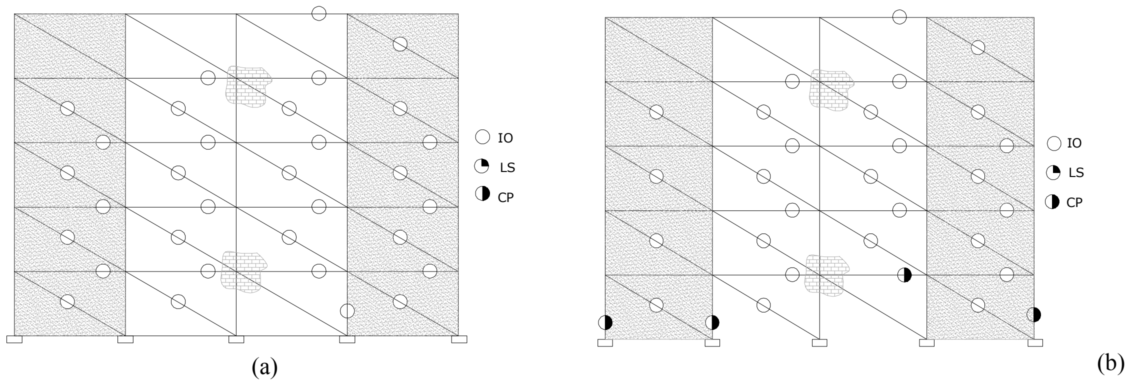


Figure 12 Plastic hinge mechanism for concrete infilled frame in hazard level 1 (a) hazard level 2 (b)

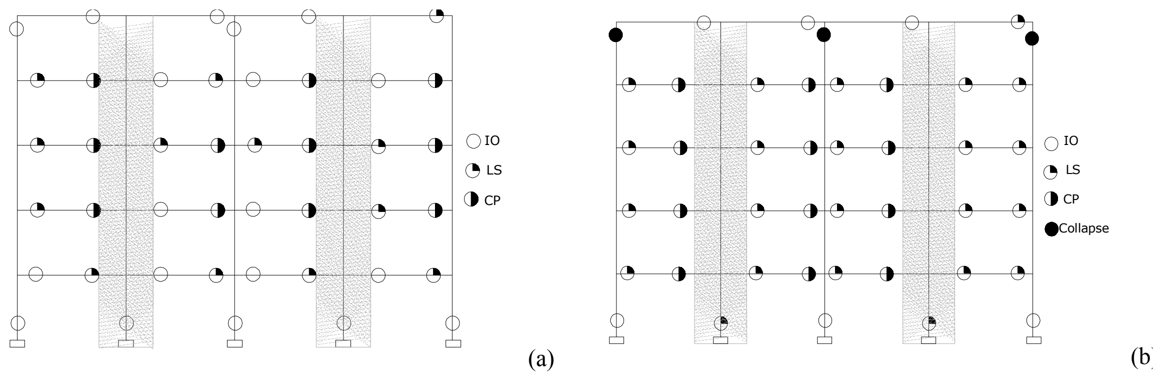


Figure 13 Plastic hinge mechanism for shear wall without URM infill in hazard level 1(a) level2 (b)

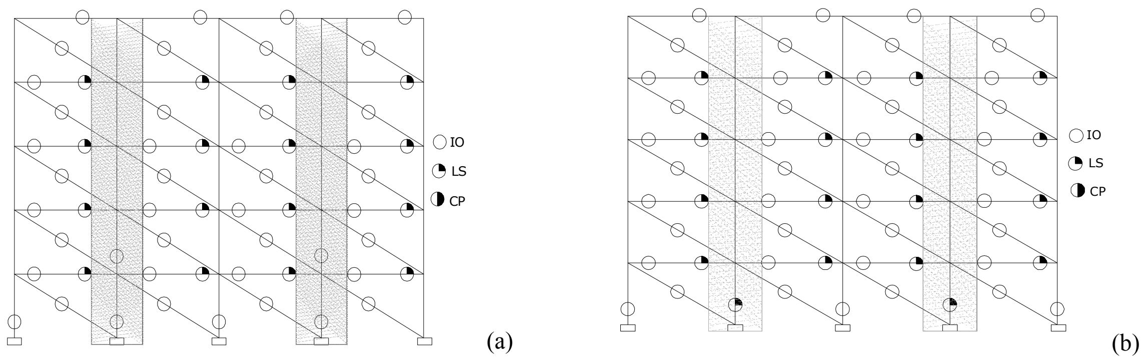


Figure 14 Plastic hinge mechanisms for shear wall with URM infill in hazard level 1 (a) level 2 (b)

Fig 10(a) shows plastic hinge distribution for bare frame in hazard level 1. Due to large inter story drift, beams in first, second and third story are in life-safety state as well as columns in first story are in immediate-occupancy. Fig 10(b) represent frame in hazard level 2. It was observed that beams in second story suffer significant damage. Considering masonry infills in frame changes the plastic hinge distribution in structural elements. Fig 11 shows plastic hinge distribution for masonry infilled frame in hazard level 1. Infilling panels with wall, the structural load transfer mechanism is changed from frame action to predominant truss action. Figure11 (a) shown that infills can change arrangement of hinges in beams. In hazard level 2 collapsing infills causes large drift in second and third stories and creation plastic hinge in columns. Adding RC infill reduces inter story drift significantly and improving the hinge state. It can be shown in Fig 12(a) that all of hinges in beams are in immediate-occupancy. The frame columns now experience increased axial forces but with reduced bending moment and shear forces that might causes crushing in columns. Hinges in bottom columns in fig 12(b) endorse this assumption. So it must be considered strengthening of adjacent columns in concrete infilled frames. Because of high stiffness of concrete infills, it is a good rehabilitation scheme for buildings with weak beams, columns and joints. Fig 13 presents plastic hinge distribution for rehabilitated frame with shear wall in hazard levels. The number of plastic hinges in this rehabilitation case is more than the other cases. Plastic hinges in beams from first to forth stories are in the state of life-safety. In shear wall cases, roof displacements are larger than concrete infill, and most of the building stories contribute to the building overall deformation.

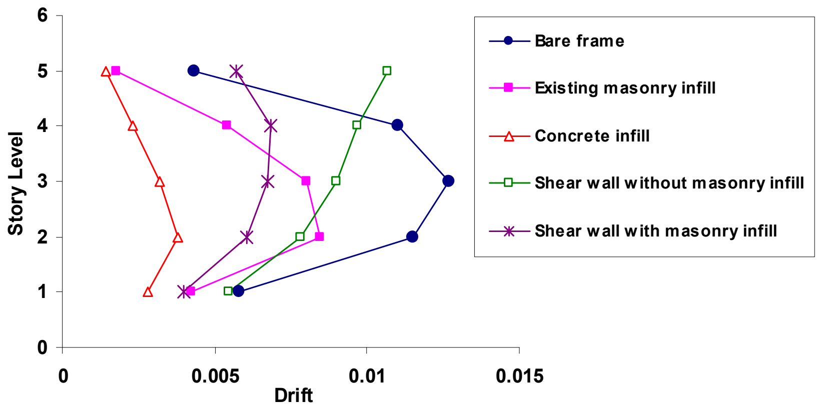


Figure 15 Story level versus drift in hazard level 1

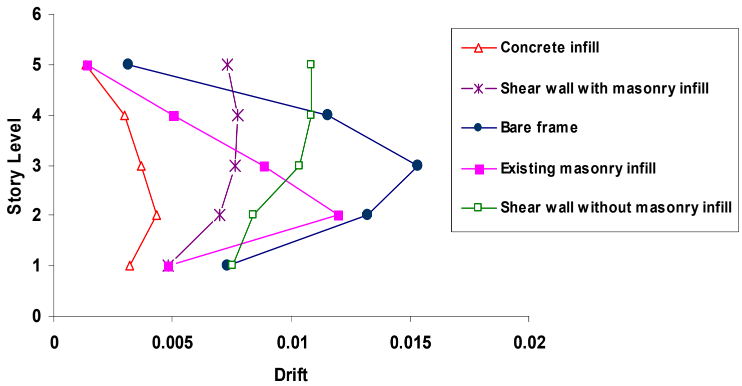


Figure 16 Story level versus drift in hazard level 2

Fig 15 and Fig 16 show the story level versus drift in hazard level 1 and 2 respectively. It is evident that inter story drift in concrete infill cases are lower while in bare frame are higher than other cases. Maximum drift in bare frame and infilled frame accrued in second and third stories respectively while in shear wall cases, drift increase along the height. Abrupt change in inter story drift was not observed in shear wall cases.

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 prevent collapsing of building in moderate earthquake. Neglecting effects of URM infill in building with shear wall system 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.

REFRENCES

Comite. (1996), RC frames under earthquake loading, Tomas Terford Services, Ltd., London

Paulay, T., Priestley, M.J.N. (1995), Seismic Design of Reinforced Concrete and Masonry Buildings, John Wiley & Sons.

Hamid, A. A., and Drysdale, R. G. (1980). Concrete masonry under combined shear and compression along the mortar joint. ACI J. 314-320

Seah, C.K. (1998), Universal approach for the analysis and design of masonry-infilled frames, PhD thesis, Univ. of New Brunswick, Fredericton, N.B, Canada

Shames, I. H. and Cozzarelli, F.A. (1992), Elastic and inelastic stress analysis, Prentice-Hall, Englewood Cliffs, N.j.

El-Dakhakhni, S.M. and Elgaaly, M. and Ahmad, A.hamid. (2002). Tress-strut model for concrete masonry-infilled steel frames. Journal of Structural Engineering 129:2 ,177-185

Stafford-Smith, B., and Carter, C. (1996). Method of analysis for infilled frames. Proc. Inst. Civ. Eng., Struct. Build 44, 31-48

FEMA-356. Prestandard and commentary for the seismic rehabilitation of buildings. Building seismic safety council. Washington (DC); 2000.

RAM international, Ram Perform 3D Software. Carlsbad, CA. October 2000.

Oliveto, G. and Decanini, L.D. (1997). Repair and retrofit of a six storey reinforced concrete building damaged by the earthquake in south-east Sicily on the 13th December 1990. Journal of Soil dynamic and earthquake eng. 17, 57-71

J.Frosch, Robert. (2006). Seismic rehabilitation using infill wall system. Journal of Advances in earthquake engineering for urban risk reduction .395-409