Examination of anchorage of mesh wire on seismic response of infill walls in RC frames

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ABSTRACT

The infill walls may lose their positive effects during the first stages of earthquakes, either by leaving their plane or through breakage. That is why it is common to strengthen these walls before design earthquakes or to repair and strengthen them after suffering slight or moderate damage due to the occurrence of an earthquake. In this study, the effects of adding and strengthening these walls on the structural behavior of reinforced concrete structures were investigated. For this purpose, the infill walls were strengthened with a single mesh of reinforcement and covered with plaster. Five one-story, single bay, and ½ scaled reinforced concrete frames were cast: one was built without infill, the second with a bare infill wall, and the other three with strengthened infill walls with anchorage of different diameters. All these specimens were tested under cyclic loading type reverse. The tests resulted in important relationships and curves, including the lateral load-lateral displacement, envelope curve-lateral load, and lateral displacement, as well as stiffness-lateral displacement and others. Through these results, the effects of adding infill walls and the strengthening procedure of these walls on the structural behavior of the structures were discussed.

Keywords: Anchorage; Infill wall; RC frames; Seismic response; Strengthening.

INTRODUCTION

Concept of Strengthening

It is known that a majority of reinforced concrete buildings in Turkey and abroad do not have enough capacity to resist even moderate-sized earthquakes. The strengthening of these buildings before a design earthquake or improving, repairing, or strengthening them with little or moderate damage after earthquakes is commonly performed in practical life.

For all or some of the structural member systems with or without damage by an earthquake, the intervention procedures are generally called reinforcement. This happened in the case of the same or equivalent magnitude of earthquakes and when improving the load carrying capacity throughout their economic life.

It is inferred that there are a significant number of buildings that need to be strengthened. Many research studies present in the literature have expressed that the strengthening of so many buildings to a required level is economically unfeasible. On the other hand, these structures must be prevented from collapsing during possible design earthquakes in order to minimize the loss of life and property.

The development of economical and fast procedures that enable the strengthening of structures and industrial structures in use without hindering structural function and purpose of the use is necessary.

Strengthening of Infill Walls

It is known that the infill walls of a building have a positive effect on the structural behavior of the building in terms of their properties. These properties include stiffness, load carrying capacity, and structural viscous damping. The infill walls increase the horizontal stiffness of a structure and reduce the horizontal displacements. Therefore, the second-order effects (nonlinear) decrease in a structure. Another effect is that the infill walls change the modal vibration characteristics of the system as it increases the stiffness of the structure and accordingly, the natural vibration period of the system decreases (Malekkianie, 2006).

Some researchers and engineers consider that the infill walls are nonload bearing element of the building systems. Therefore, the infill walls are considered only as mass (weight) in modeling and analyzing building systems, and solutions are made in this way (Malekkianie, 2006). However, for the reasons mentioned above, it is a shortcoming that the infill walls are not considered in the structural solution.

It is known to everyone that the brick infill walls significantly increase both stiffness and lateral strength of reinforced concrete structures as long as lateral deformations remain under certain levels. However, when lateral displacement exceeds a certain threshold, the infill walls lose their function by being crushed in-plane or by toppling out of the plane. In such cases, they cannot contribute to the behavior of reinforced concrete structures throughout the entire earthquake. The efforts to strengthen the partition walls are still in progress in order to fully utilize them during the earthquake time history.

The first study on filled frames was performed by Whitney et al. (1955). The authors commenced an experimental study program for the US Army in 1949 and published the results of the studies in 1955. It was observed that filling the gaps in the structures with the infill wall significantly increased the lateral strength and stiffness of the frame. The study determined that this increase could be between 10 and 20 times in comparison to the bare frames. Smith (1968) investigated the effects of the vertical load on the horizontal stiffness and strength of the masonry wall in the steel frame. The horizontal stiffness and strength of the system when there was a small vertical load on the system were higher than those of a system when there were no vertical loads on the system. The collapse mode of infill wall, diagonal cracking and corner compression failure, was determined to be the same when there was only a horizontal load on the structure. Ersoy and Uzsoy (1971) tested 9 reinforced concrete-filled frames. The behavior of the single-story frame was simulated by applying a concentrated load in the middle of the frame. In the experiments, the applied horizontal loading was uniformly increased. As a result, it was understood that the horizontal load capacity of the frame increased by seven times, and the resulting displacement capacity decreased. Klingner and Bertero (1978) conducted an experimental study by applying a semistatic load to the 1/3 scale model on the first three floors of an 11-story building. The structure consisted of three openings, and the outer openings were constructed with infill walls. Simple and large scale mathematical models have been created in order to model the behavior of the bare frames and infilled frames. The horizontal dynamic loading tests for 4-storey steel frame structures with reinforced concrete infill walls were conducted by Liauw (1979). Factors such as the interconnection between the frames and infill walls and the effect of gaps in the infill were investigated for the stiffness and strength of the models. Yüzügüllü

(1979) carried out the strengthening works of a single-story, single-span structure. The strengthening process was made of reinforced concrete prefabricated panels, and the results were published in a technical report. Govindan et al. (1986) investigated the difference of seven-story reinforced concrete frame with and without infill walls exposed to horizontal loads. Altın (1990) conducted the tests for 14 frames with infill walls under cyclic loading type reverse. The frames within the doctoral thesis study were prepared from 1/3 scale, single-span, and two-story models. Such factors as the strength of the frame elements, reinforcement in infill walls, axial load level, and infill wall-frame connection details were used as parameters in the experimental study. The effects of masonry infill wall panels on the seismic performance of reinforced concrete (RC) frames designed following the existing code provisions were examined by Mehrabi et al. (1996). Two types of frames were considered. One of the frames was designed for wind loads, and the other for strong earthquake accelerations. Twelve 1/2-scale, single-bay frames were tested. The strengthening of brick-filled reinforced concrete structures with fibrous polymer composites (CFRP) was examined in experimental and analytical studies by Özcebe et al. (2003). In the study, seven 1/3 scale, single-span and two-story frames were tested. As a result of the experiments, no significant improvement was observed in frame stiffness, although there was an increase for frame strength with CFRP. Albanesi et al. (2006) conducted a three-dimensional shake table experiment for one-story and one-span full-scale reinforced concrete frame. In the experiments, infill wall models with and without gaps were used. Kara and Altin (2006) examined the behavior of reinforced concrete frames reinforced with nonductile and partial fill. The frames were subjected to a horizontal cyclic load. Within the study, seven single-spans, two-story and 1/3 scale test specimens were constructed and tested. In the test frames, it was accepted that there were deficiencies widely encountered in the concrete frames in Turkey. Güney and Boduroğlu (2006) stated in their study that the effects of the stiffness of the infill walls on the structural behavior were not taken into consideration during the analysis and design phase. However, they stated that they affected the structural behavior under earthquake forces with the symmetric or asymmetric plan due to the stiffness they had. Özdemir (2008) studied the reinforced concrete structures with brick infill walls, which were assumed to be produced insufficiently. The reinforced concrete frames were strengthened by applying steel mesh reinforcement and plaster to the infill wall surface. In the experimental study, ten 1/2 scale, one-story and single-span reinforced concrete elements were produced. Different test elements were formed as a result of different strengthening details made on the infill wall surface.

EXPERIMENTAL STUDY

In experimental study, five one-story, single bay and ½ scaled reinforced concrete frames were cast. These reinforced concrete specimens represent damaged buildings designed and manufactured practically with insufficient details. As a strengthening technique, steel reinforcement mesh is placed on the infill wall, and then plaster is applied following the specifications. The geometric and physical properties of the specimens to be tested are given in Table 1. The size of the anchorage diameter applied to the specimens differs in the experiments.

Table 1. Physical and geometrical properties of designed specimens.

Specimen no	Specimen name	Specimen properties	Frames dimensions m×m	Infill wall dimensions m×m
1	B	Bare frame	2.10×1.45	1.70×1.20
2	I	Brick infill + plaster	2.10×1.45	1.70×1.20

3	I-FA30 Ø8-WA8-P1	Brick infill + plaster + frame anchorage distance 30cm and 8mm diameter + 8 wall anchorage bars 8 and 8mm diameter + plaster of 3.5cm per Earthquake Code	2.10×1.45	1.70×1.20
4	I-FA30 Ø10-WA8-P1	Brick infill + plaster + frame anchorage distance 30cm and 10mm diameter + 8 wall anchorage bars and 8mm diameter + plaster of 3.5cm per Earthquake Code	2.10×1.45	1.70×1.20
5	I-FA30 Ø12-WA8-P1	Brick infill + plaster + frame anchorage distance 30cm and 12mm diameter + 8 wall anchorage bars and 8mm diameter + plaster of 3.5cm per Earthquake Code	2.10×1.45	1.70×1.20

Production of Specimens

A total of 5 reinforced concrete frame samples having a single story and a single bay are produced. Strengthening is carried out by a steel mesh application on the infill walls. The amount of reinforcement, cross-sectional details, and geometry used in the experimental elements represent the structures considered to be improperly produced. The samples are built on a rigid foundation by assuming that the samples are fully fixed at the supports. The test specimens are designed to have low concrete compressive strength and weak column-strong beam analogy. The foundations of the specimens have dimensions of 3.10 m × 1.00 m and a height of 0.50 m. The production of the foundation is shown in Figure 1. The concrete of the foundations of all samples is poured from the same concrete mixer and also at the same strength of C25. After casting the foundation, the concrete foundation is cured as shown in Figure 2. Then, the molds of the frames are prepared, and concrete and beam reinforcements are placed in the mold.

Figure 1. Foundation construction.

Figure 2. Curing of concrete foundation.

After the completion of the molds and the placement of the reinforcements, the concrete is poured, as shown in Figure 3. Concrete pouring of all five specimens is performed at the same time. In order not to cause any difference in the concrete compressive strength of the test specimens, concrete is poured from the same mixer. As seen in Figure 4, plenty of concrete samples are cast. The completed frame, once the concrete has set and the brick infill wall has been put in place, is shown in Figure 5.

Figure 3. Pouring of frame concrete.

Figure 4. Cylindrical samples.

Figure 5. Application of plaster on the outer face of the infill wall.

Since the strength of the concrete used in the samples is desired to be low, curing is not done sufficiently in terms of amount and level. In the frame members, the ties are designed with 90° but without hooks. Ribbed reinforcements are used in the experimental elements. The confinement zones as per the earthquake code are not formed, but the minimum reinforcement is used in the concrete members. The dimensions and reinforcement details of the test samples are given in Figure 6.

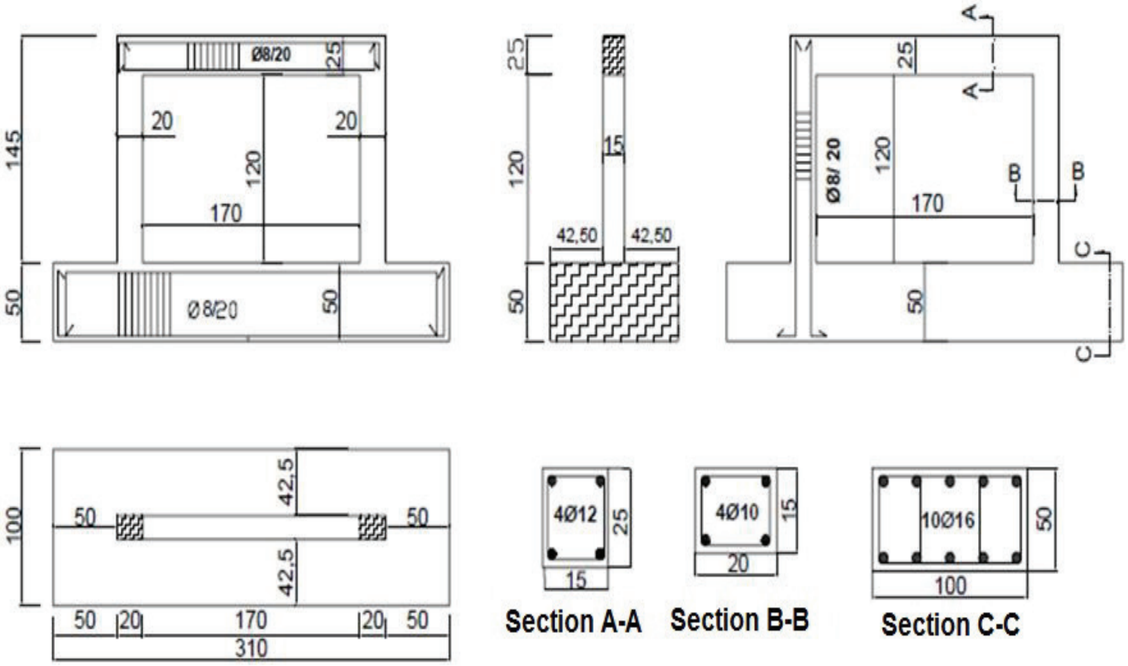

Figure 6. Dimensions of specimens and reinforcement details in cm (according to TS 500, 2000).

Strengthening of the Specimens

Five sample tests with the same characteristics are performed. Four specimens are constructed with infill walls, the first of which is not strengthened by any means. The remaining three are strengthened, and all parameters are kept the same except anchor diameter, and accordingly, the specimens are tested under the influence of horizontal loads.

The first of the specimens is coded as sample number 1 and is tested as a bare frame. This specimen is named as sample B as shown in Table 1. The sample no. 2 is the specimen with the infill wall. The outer surface of the wall is plastered with 1.5 cm, and the inner surface is plastered with a 1 cm thick plaster. The frame will be damaged as the infilled frame, and the contribution of the infill wall to the behavior under horizontal loads will be investigated. This specimen is named as sample I.

The remaining samples are strengthened test specimens. In strengthening these samples, anchorages are planted at certain distances to the foundation and frame members. Anchorage bars are made of Ø8 ribbed reinforcement. In all samples, the depth of the holes where the anchors will enter is ten times the diameter of the reinforcement (10Ø). The length of the anchor bars outside the frame is 40 times the diameter of the reinforcement (40Ø). Epoxy is used to anchor reinforcements for existing concrete members. The anchor holes are drilled with a large diameter (Ø10) and a depth of 8 cm (10Ø). The dust of the drilled holes is cleaned and then washed with water. The anchors vertical to the wall plane are in shape ∟. Each leg of these anchors is prepared to be 10Ø, and anchorages are made over the mesh reinforcement which rests against the wall. Figure 7 shows the first of three strengthened specimens with reinforcement details. The last two strengthened specimens are not shown here because of the difficulty of taking a photo in this region due to the interference of the mesh reinforcement with the anchorage bars.

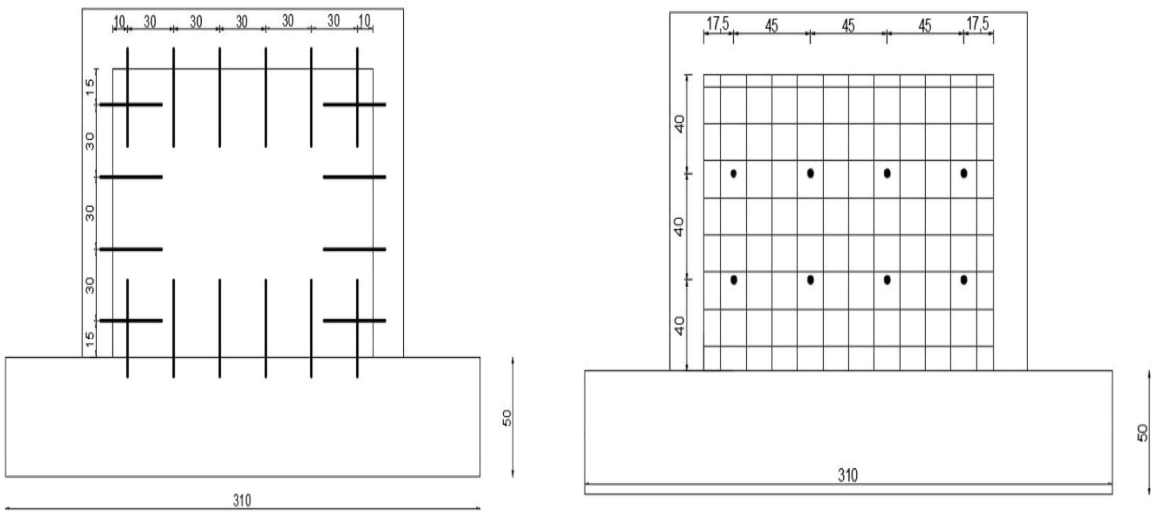

Figure 7. I-FA30 Ø8-WA8-P1 (Frame anchorage of 8 mm diameter and spacing distance of 30 cm, the number of anchorages perpendicular to wall plane is eight, and plaster thickness is 3.5 cm) (according to Turkish Earthquake Code, 2007).

Experimental Setup

In the laboratory where the tests are carried out, there was an L-shaped RC to which the test specimens are restrained. The loading wall (retaining wall for hydraulic system to avoid the effect of pull and push loading during the test) is 7 m length and 50 cm thick and a hard floor covering of 60 cm thick. Figure 8 shows the loading wall and test setup, along with a specimen placed. Linear Variable Differential Transformers (LVDTs) are used to measure displacements in the experiments. The loading is applied with a jack, and the load values read from the load cell in the front of the jack load transferred to the data collector. Data from the channels to which the LVDTs are connected are also transferred to the data logger and from there to the computer. A total of 13 LVDTs are used in the tests. Figure 9 shows the position of LVDTs. Four of them are used to measure roof displacements. Diagonal readings are taken with two LVDTs placed on the inner side of the wall at an angle of 39.13°. Four LVDTs are connected to the lower end of the column where the measurements are taken, and two readings are obtained therein. LVDTs are also connected and readings are obtained to check if there is any foundation displacement or rotations. These readings were neglected because they were very small.

It is thought that the infill walls strengthened with mesh reinforcement and anchorage bars could cause movement out of the RC specimens during the application of lateral force. In order to prevent this movement, a steel frame system is built around the frame elements.

The experiments are carried out with displacement control. Data from the data acquisition devices placed on the test elements are simultaneously collected on the computer. Push and pull cycle is applied in double cycles. At the end of the second cycle, the experiments are halted for a short time, and the cracks and damage of the elements are determined and recorded.

Figure 8. Loading wall and test setup of sample B.

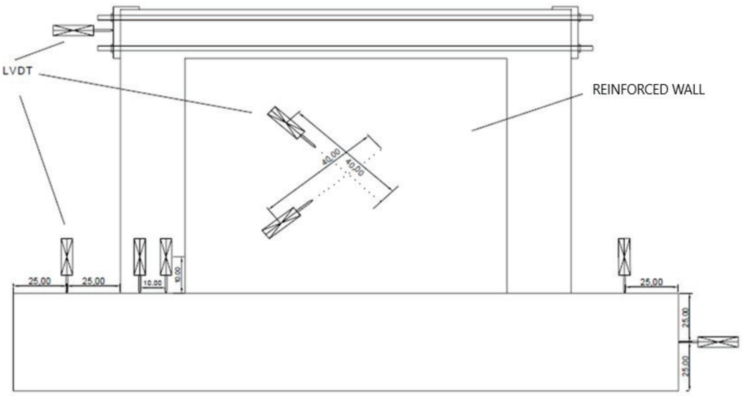

Figure 9. Position of LVDTs on the frames.

RESULTS AND DISCUSSION

For the first of the specimens, sample B, the target or requested displacement is computed by multiplying the displacement ratio with 1330 mm, which is the distance between the levels of LVDTs, where the displacements are measured, as well as the foundation. The test is initiated at the displacement ratio of 0.0005 (target or requested displacement 0.665 mm) and is terminated at the displacement ratio of 0.07 (target or requested displacement 93.1 mm). The specimen is pushed and pulled twice at same displacement level up to the target displacement. In the second cycle of push and pull, the experiment is interrupted for a short time, and the damage is recorded. At the same time, photographs are taken, which are not shown here due to the interference problem. The force-displacement curve for the bare frame obtained at the end of the push and pull cycles is given in Figure 10. In the infill walled frame (sample I), the measured LVDT distance is 1330 mm for the target displacement. The displacement ratio started at 0.0005 (the target displacement at 0.665 mm), and the displacement ratio is terminated at 0.01 (the target displacement at 13.3 mm). The load-displacement curve obtained after the push and pull cycles for the brick filled reference frame is presented in Figure 11.

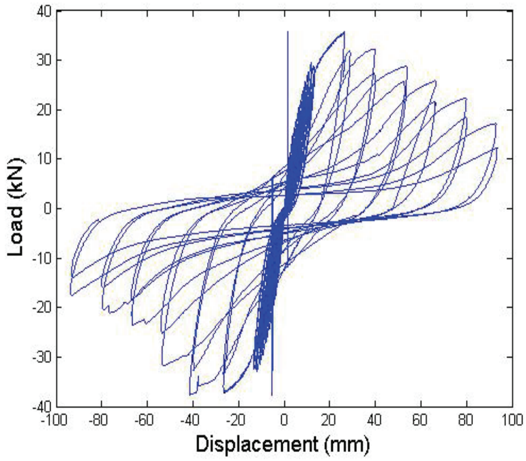

Figure 10. Load-displacement curve for bare frame.

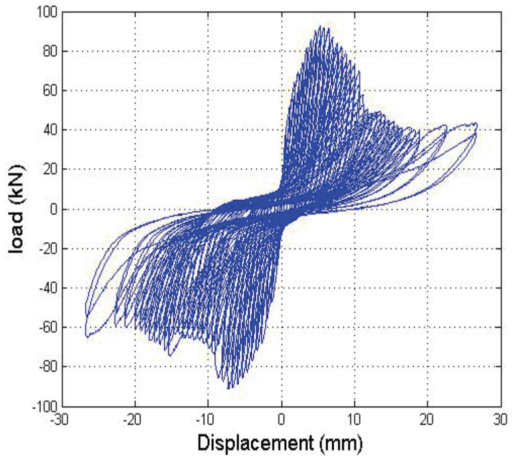

Figure 11. Load-displacement curve for the frame (I) with brick infill wall.

The same loading protocol is applied for the strengthened RC frame with infill wall (I-FA30 Ø8-WA8-P1). The displacement ratio is started at 0.0005 (the target displacement at 0.665 mm), and the displacement ratio is terminated at 0.01 (the target displacement at 13.3 mm). In this experiment, the specimen is subjected to a total of 32 cycles. Figure 12 displays the load-displacement curve obtained at the end of these cycles. The same method for loading is extended to the reinforced sample (I-FA30 Ø10-WA8-P1). A maximum of 32 cycles are applied to the experiment. Figure 13 displays the load-displacement curve produced as a product of these intervals. Figure 14 shows the load-displacement curve for the specimen (I-FA30 Ø12-WA8-P1).

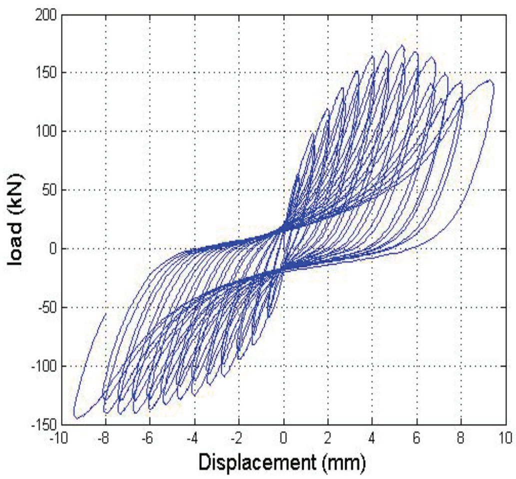

Figure 12. Load-displacement curve of the strengthened frame (FA30 Ø8) with brick infill wall.

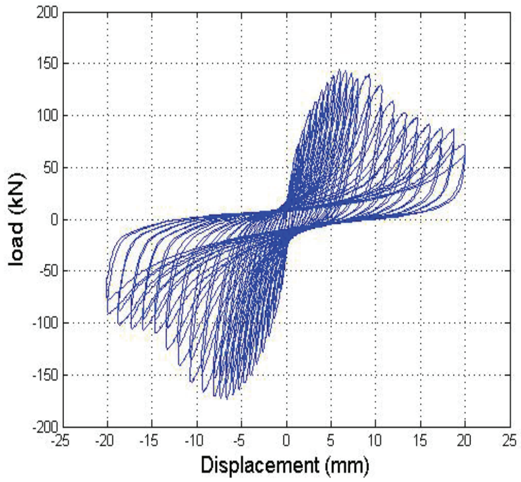

Figure 13. Load-displacement curve of the reinforced frame (FA30 Ø10).

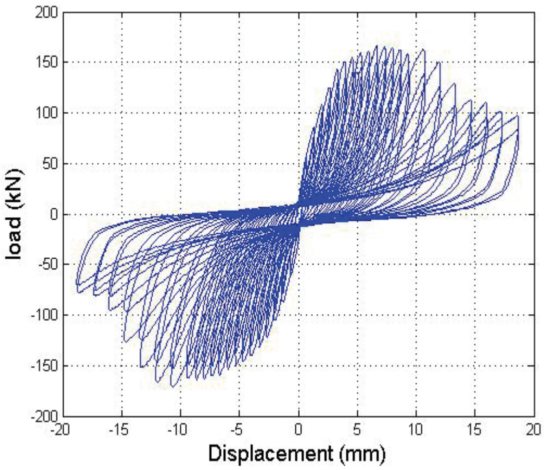

Figure 14. Load-displacement curve of the reinforced frame (FA30 Ø12).

The horizontal load-displacement envelope curve for bare frame is shown in Figure 15 (those of the other four are not shown for brevity). According to the above data, the maximum load values of the samples in push and pull are illustrated in Table 2. It is noticed that a capacity increase of 92.1 / 35.5 = 2.6-fold is calculated with the bare frame turned into the infilled frame. This conclusion illustrates that the effect of the infill wall is thoughtfully displayed. However, during a possible earthquake, the plain wall will most likely be tilted out of the wall plane, and this contribution of the infill wall will be lost without full utilization.

Table 2. The maximum load values in push and pull cycles of test specimens.

Frame	Maximum Load (KN)	
	Push	**Pull**
Bare frame (sample B)	35.5	37.6
Frame with infill wall (I)	92.1	91.2
Strengthened frame (I-FA30 Ø8-WA8-P1)	173.6	145.1
Strengthened frame (I-FA30 Ø10-WA8-P1)	143.7	173.2
Strengthened frame (I-FA30 Ø12-WA8-P1)	166.5	166.2

However, after the strengthening, the contribution of both the wall and the strengthening to the load carrying capacity will be preserved due to the anchorages provided. In the experiments, the out-of-plane movement of the frame is prevented, and this contribution of the infill wall is seen in a serious sense. The horizontal load-carrying capacity of the specimen by strengthening the infill wall frame with mesh reinforcement and plaster is increased by 173.6 / 92.1 = 1.88 times in comparison to the load carrying capacity of the infilled frame. For the Ø10 and Ø12 anchor bars, the increasing ratio is 143.7 / 92.1 = 1.56 and 166.5 / 92.1 = 1.81, respectively. In other words, by strengthening the infill wall frame according to the specification in earthquake code with mesh reinforcement and plaster, the horizontal load-bearing capacity increased by 88%, 56%, and 81% for Ø8, Ø10, and Ø12 anchorages, respectively. Figure 16 shows the effect of the partition wall and strengthening on the load-displacement curves for all the frames tested.

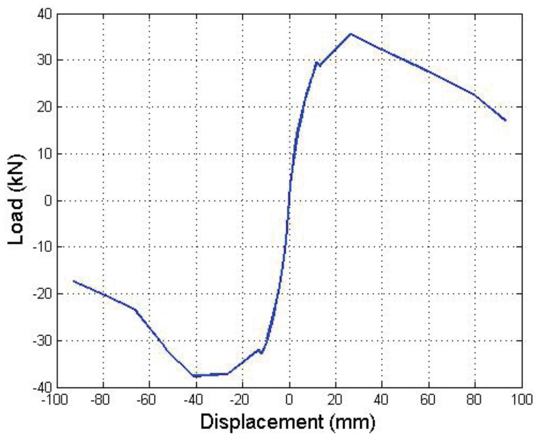

Figure 15. Load-displacement envelope curve for bare frame.

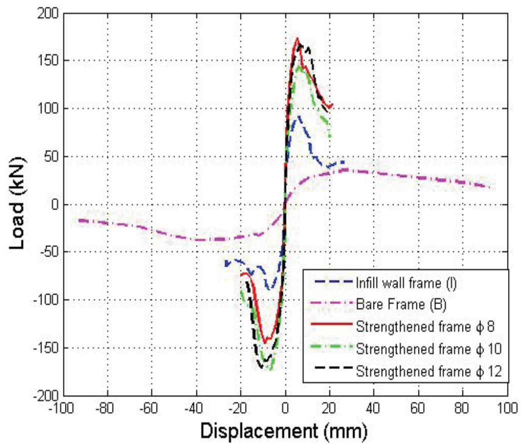

Figure 16. Horizontal load-displacement envelope curves for the bare frame, infilled frame, and strengthened frames.

The initial stiffness of the frames can be calculated by averaging the pull and push stiffnesses. The initial stiffness for bare frame (B) is 6.54 KN/mm, for infilled frame (I) 57.94 KN/mm, for strengthened frame with infill wall (I–FA30- Ø8-WA8-P1) 95.97 KN/mm, for strengthened frame with infill wall (I–FA30- Ø10-WA8-P1) 84.64 KN/mm, and for strengthened frame with infill wall (I–FA30- Ø12-WA8-P1) 88.97 KN/mm. By turning the bare frame (B) into the infilled frame (I), an increase in the initial stiffness of 9 times is obtained. A 15-fold stiffness increase is observed when the empty frame (B) is compared with the strengthened wall frame (I–FA30- Ø8-WA8-P1). With the infill wall being strengthened, the initial stiffness increased by 1.66-fold. In other words, a stiffness increase of 66% is achieved. With the diameter of the frame anchorage bar being increased from Ø8 to Ø10, a 12% reduction in stiffness is observed. With the diameter of the frame anchorage bar being increased from Ø8 to Ø12, a 7% reduction in stiffness is observed. The stiffness-drift curves of all frames are presented in Figure 17.

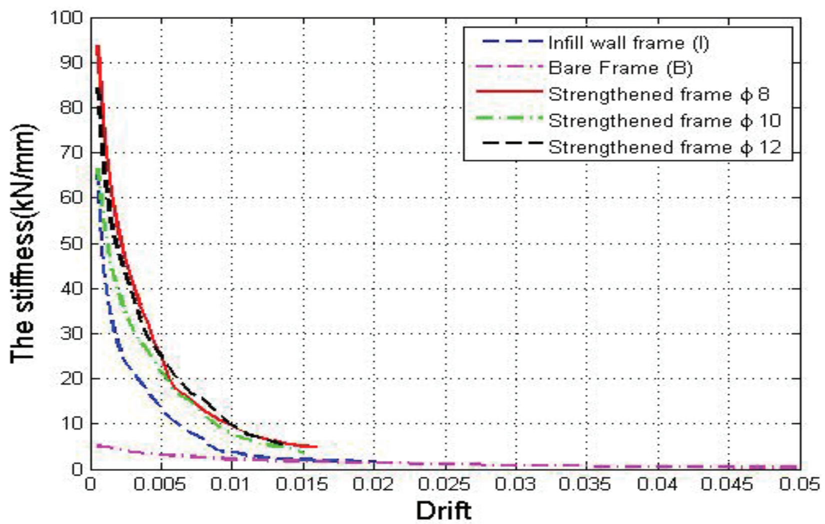

Figure 17. The stiffness-drift envelope curves for the bare frame, infilled frame, and strengthened frames.

CONCLUSIONS

In this study, the effect of wall strengthening according to Turkish Earthquake Code (TEC) 2007 is investigated. For this purpose, five single-story, single-span and ½-sized frames are cast. The first specimen is the unfilled (bare) frame, the second is the brick filled frame, and the other three are the strengthened wall frames. The frame column and beam dimensions and reinforcement details have been chosen to represent frames produced practically in the defect. The difference between the three strengthened frames is the diameter of the anchor bars. The distance between anchorage bars is 30 cm, and the diameters are 8, 10, and 12 mm.

The horizontal load-carrying capacity of the bare frame is increased by 2.6 times using the infilled frame. In addition to the infill wall, strengthening was performed through anchorage bars with a spacing distance of 30 cm and Ø8 and the application of plaster. The capacity of the strengthened frame is 4.9 times of the bare frame and 1.9 times of the infilled frame. When the bar diameter increased to 10 mm and 12 mm, the horizontal load-bearing capacity decreased. In other words, increasing the diameter does not make a positive contribution to the designed concrete frames. The altering of the anchor diameter does not cause any changes in the pull or push capacity of the reinforced concrete frames.

If a comparison is made in terms of the stiffness of the frame, the stiffness for bare frame is increased by 9 times of the infilled frame. In addition, with wall strengthening, this increase becomes 15 times. With the infilled frame and strengthened wall and anchorage bars, the determined stiffness increases by 1.66 times. By changing the diameter of the anchorage bar from Ø8 to Ø10, a 12% decrease is observed. With a change in anchorage bar diameter from Ø8 to Ø10, a decrease of 7% is computed. The stiffness of the strengthened infill wall frames with high initial stiffness decreases rapidly with a horizontal displacement ratio.

No axial loading on the frame elements has been applied. In future studies, this factor needs to be taken into account in order to achieve more accurate results.

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REFERENCES

Albanesi, T., Biondi, S., Candigliota, E. & Nuti, C. 2006. Experimental analysis on a regular full scale infilled frame. First European Conference on Earthquake Engineering and Seismology. Geneva, Switzerland: 1608.

Altın, S. 1990. Strengthening of reinforced concrete frames with reinforced concrete infills. PhD Thesis. Ankara Middle East Technical University, Turkey.

Ersoy, U. & Uzsoy, Ş. 1971. The Behavior and Strength of Infilled Frames TÜBİTAK Investigation Project Report. Project No. MAG-205. 95. Ankara, Turkey.

Govindan, P., Lakshmipathy, M. & Santhakumar, A. R. 1986. Ductility of infilled frames. ACI Structural Journal 83(4): 567-576.

Güney, D. & Boduroğlu, M. H. 2006. Deprem etkisi altındaki simetrik ve asimetrik yapıların, lineer olmayan tepkilerine dolgu duvarlarının katkısı. ITÜ Dergisi/Mühendislik 5(3): 165-174.

Kara, M. E. & Altin, S. 2006. Behavior of Reinforced Concrete Frames with Reinforced Concrete Partial Infills. ACI Structural Journal. 103(5): 701-709.

Klingner, R. E. & Bertero, V. V. 1978. Earthquake Resistance of Infilled Frames. ASCE. Journal of Structural Engineering 104: 973-989.

Liauw, T. C. 1979. Tests on Multistory Infilled Frames Subject to Dynamic Lateral Loading. ACI Structural Journal 76(4):551-563.

Malekkianie, B. 2006. Dolgu duvarlı betonarme çerçevelerde karbon lifler kullanılarak güçlendirme. M.Sc. Thesis. Istanbul Technical University, Turkey.

Mehrabi, A. B., Shing, P. B., Schuller, M. P. & Noland, J. L. 1996. Hysteretic response of reinforced concrete infilled frames. ASCE Journal of Structural Engineering 122(3): 228-237.

Özcebe, G., Ersoy, U., Tankut, T., Erduran, E., Keskin, R. S. O. & Mertol, C. 2003. Strengthening of Brick-Infilled RC Frames with CFRP. Technical Report. 69. Middle East Technical University. Ankara, Turkey.

Özdemir, H. 2008. Dolgu Duvarlı Çerçevelerin Hasır Çelik Donatılı Sıva İle Güçlendirilmesi. PhD Thesis. Istanbul Technical University, Turkey.

Smith, B. S. 1968. Model Test Results of Vertical and Horizontal Loading of Infilled Frames. ACI Structural Journal. 65(8): 618-625.

Whitney, C. S., Anderson, B. G. & Cohen, E. 1955. Design of Blast Resistant Construction for Atomic Explosions. ACI Structural Journal. 26(7): 589-683.

Yüzügüllü, Ö. 1979. Strengthening of Reinforced Concrete Frames Damaged by Earthquake Using Precast Panel Elements. TÜBİTAK Investigation Project Report. Project No. MAG-494. Ankara, Turkey.