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Experimental Investigation of the Seismic Performance of the R/C Frames with Reinforced Masonry Infills

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Abstract. Intensive studies regarding the investigation of seismic performance of reinforced concrete (R/C) frames which are infilled with brick masonry walls have been carried out by several researchers within the last three-decades. According to authors' field and experimentally experiences conclude that the unreinforced brick masonry infills significantly contributes to increase the seismic performance of the R/C frame structure. Unfortunately, the presence of brick masonry infill walls causes several undesirable effects such as short column, soft-storey, torsion and out of plane collapse. In this study, a strengthening technique for the brick masonry infills were experimentally investigated to improve the seismic performance of the R/C frame structures. For this purpose, four experimental specimens have been prepared, i.e. one of bare R/C frame (BF), one of R/C frame infilled with unreinforced brick-masonry wall (IFUM) and two of R/C frames were infilled with reinforced brick-masonry wall (IFRM-1 and IFRM-2). The bare frame and R/C frame infilled with unreinforced brick-masonry wall represents the typical R/C buildings' construction in Indonesia assuming the brick-masonry wall as the non-structural elements. The brick-masonry wall infills in specimens IFRM-1 and IFRM-2 were strengthened by using embedded ϕ4 plain steel bar on their diagonal and center of brick-masonry wall, respectively. All specimens were laterally pushed-over. The lateral loading and its lateral displacement, failure mechanism and their crack pattern were recorded during experimental works. Comparison of the experimental results of these four specimens conclude that the strengthening of the brick-masonry infills wall gave the significantly increasing of the seismic performance of the R/C frame. The seismic performance was evaluated based on the lateral strength of the R/C specimen. The embedded plain steel bar on brick-masonry also reduces the diagonal crack on the brick-masonry wall. It seems that the presence of the embedded plain bar may help reduce the vulnerability of the brick-masonry infill.

INTRODUCTION

Reinforced-Concrete (R/C) frame structures with unreinforced brick masonry infill walls are commonly used in developing countries with regions of high seismicity, such as Indonesia. In many cases, the engineers do not consider brick masonry infill walls in the design process of R/C frame structures, since the final distribution of the masonry infill walls to the R/C frame structure have been not clearly known. Therefore, the infill walls are usually treated as non-structural elements and their interaction with R/C frame structures have been not taken into account. As a consequence, the actual response of the R/C structures will deviate radically from what is expected in the design. A lot of research activities have been devoted for both of experimental and numerical works during last three decades, to investigate the seismic performance of the R/C frames which were infilled by the brick masonry wall, e.g. Calvi, et.al. [1], Maidiawati, et.al. [2], Agrawal, et.al. [3], Tanjung and Maidiawati [4]. Several design's rules as well as recommendations relating to uses of brick masonry infills wall in R/C frame structures have been developed on the basis of these research achievements and observed seismic vulnerability. The field investigation results after earthquake by Maidiawati and Sanada [5] has shown that this topic is still essential at present time, both for existing and new constructions as well.

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Based on the experiences the past earthquakes in the western region of Indonesia have demonstrated the beneficial as well as the ill-effects of the presence of the masonry infill walls in the R/C frame structures. The R/C frame structures with brick masonry infills have shown excellent performance when were shaken by the moderate earthquakes, i.e. approximately in magnitude 6.0 to 6.5 and/or maximum intensity VIII on MMI scale [5]. Unfortunately, the presence of brick masonry infill walls causes several undesirable effects such as short column, soft-storey, torsion and out of plane collapse when suffer the strong ground motion and lead losses of life and financial.

In order to overcome the weakness of the brick masonry infills, indeed, the researchers have been developed several strengthening techniques by using different approaches and materials. These include on the use of Fiber Reinforced Polymer (FRP) sheet as was proposed by Silva et.at. [6], strengthening by using FRP sheet and anchors by Arifuzzaman and Saatcioglu [7] and strengthening by using Reinforced Plastering Mortar as was experimentally conducted by Proenca et.al. [8]. Different configurations, such as diagonal strips, grids, and entire surface coverage were considered to improve shear behavior of brick masonry infill walls. Although overall strength of the brick masonry infill walls was increased by these strengthening techniques, unfortunately due to difficultly to find and the high-price of the FRP sheets, these techniques may be not effectively applied to low-rise R/C construction in Indonesia.

The simple strengthening technique to improve the seismic performance of the R/C frame with unreinforced brick masonry infills is proposed in this study. In the current propose technique, the plain steel bars are embedded on the bed mortal join of the brick masonry infills. The seismic performance of the R/C frames were obtained through experimental works. To do this works, four R/C frame specimens have been prepared and evaluated, i.e. one of the bare R/C frame (BF), R/C frame infilled with un-reinforced brick-masonry wall (IFUM) and two R/C frames infilled with reinforced brick-masonry wall (IFRM-1 and IFRM-2). These specimens were laterally loaded until collapse (pushed-over). The applied lateral loading, obtained lateral displacement, failure mechanism as well as crack pattern of the specimens were recorded and observed during experimental works to define their seismic performance.

EXPERIMENTAL PROGRAM

Four of the 1:4 reduce-scale singe-bay single-storey R/C frame specimens were designed and built in the Material and Structural Laboratory, Civil Engineering Department, Andalas University. Figure 1 illustrates the typical geometry and reinforcement details use for all R/C frame specimens. The columns of the R/C frames were detailed to yield in flexure before shear failure. The dimension of cross-section of columns were 125 mm x 125 mm and reinforced with 4-D10 longitudinal bars with a yield stress 417 MPa and ϕ4@50 transverse hoops with a yield stress 235 MPa.

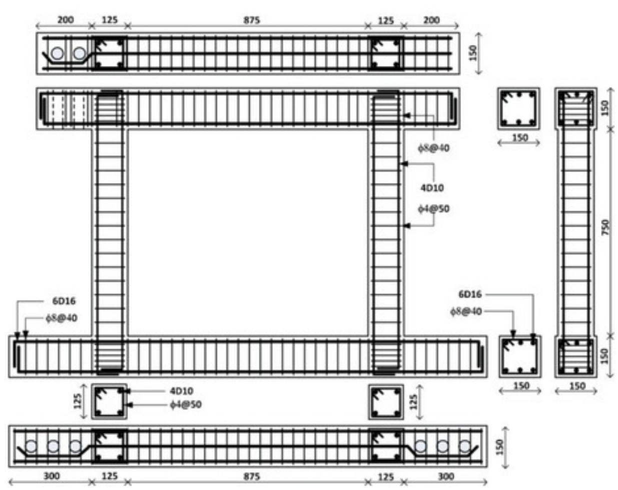
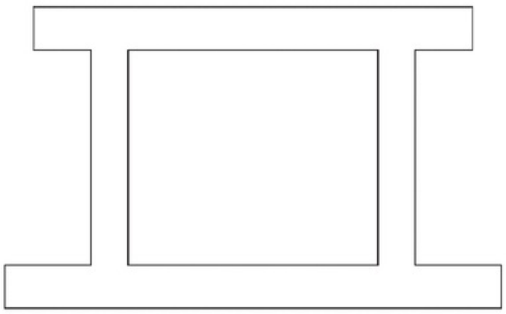
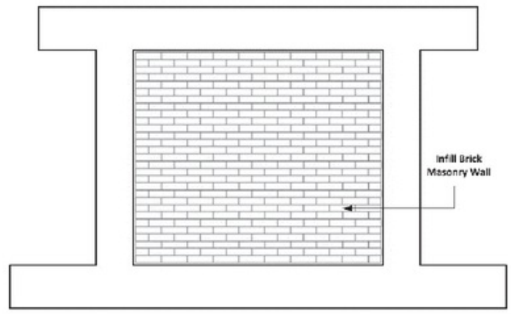


FIGURE 1. Geometry and Reinforcement Details of the R/C Frame

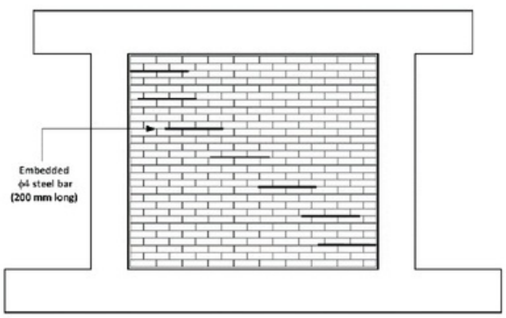
The dimension of cross-section of the columns and their reinforcements were designed considering the scale reduction. The clear height of the columns were 750 mm. An over-reinforced concrete top-beam was constructed on the top of columns for the purpose of applying the lateral loads, while also representing the rigid floor system. The dimension of top-beam was 150 mm wide, 150 mm deep and 1525 mm long and reinforced with 6-D16 longitudinal bars with a yield stress 488 MPa and ϕ8@40 transverse hoops with a yield stress 333 MPa. The columns were supported by the over-reinforced foundation-beam which was fastened to the Loading-Frame by using six post-tensioning rods as is schematically shown in Fig. 3. The dimension of the foundation-beam was 150 mm wide, 150 mm deep and 1725 mm long and reinforced with 6-D16 longitudinal bars with a yield stress 488 MPa and ϕ8@40 transverse hoops with a yield stress 333 MPa. The compressive strength of concrete cylinder at 28 days after casting was 23.1 MPa; i.e. the sample of the concrete was casted to the R/C frame specimens.



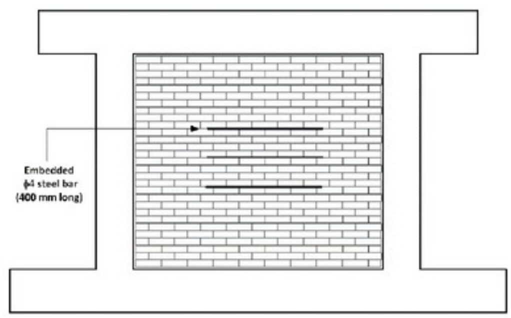
(a) Bare R/C Frame (BF)



(b) R/C Frame Infill Un-reinforced brick Masonry (IFUM)



R/C Frame Infill Reinforced brick Masonry-1 (IFRM-1)



R/C Frame Infill Reinforced brick Masonry-2 (IFRM-2)

FIGURE 2. Experimental Matrix

Except for the bare R/C frame (BF), all specimens were infilled by 1:4 reduce-scale burnt clay brick masonry with dimension of 22.5 mm wide, 12.5 mm deep and 45 mm long. The dimension of wall was 875 mm width and 750 mm height, as is illustrated in Fig. 2. For the specimen, namely R/C Frame Infill Un-reinforced brick Masonry (IFUM), the mortar, i.e. a blend of pozzolan cement and graded sand, was used to build the brick masonry infill walls and both sides of brick masonry infill walls were plastered by using the same mortar covering the entire of the wall's surfaces. For the specimen, namely R/C Frame Infill Reinforced brick Masonry (IFRM), before the brick masonry infill wall was plastered, the plain steel bars were embedded in the bed mortar join by using the chemical epoxy Sikadur-31 on the both surfaces of brick masonry infill wall. The location of embedded of ϕ4 plain steel bars are shown in Fig.2; for the R/C Frame Infill Reinforced brick Masonry-1 (IFRM-1) specimen, were placed on the diagonal of the infill wall, whereas for the R/C Frame Infill Reinforced brick Masonry-2 (IFRM-2) specimen were placed on the center of the infill wall. The specimens IFRM-1 and IFRM-2 used ϕ4 plain steel bars with 200 mm long and 400 mm long, respectively, and were embedded within interval about 100 mm or in every fourth layer of the masonry.

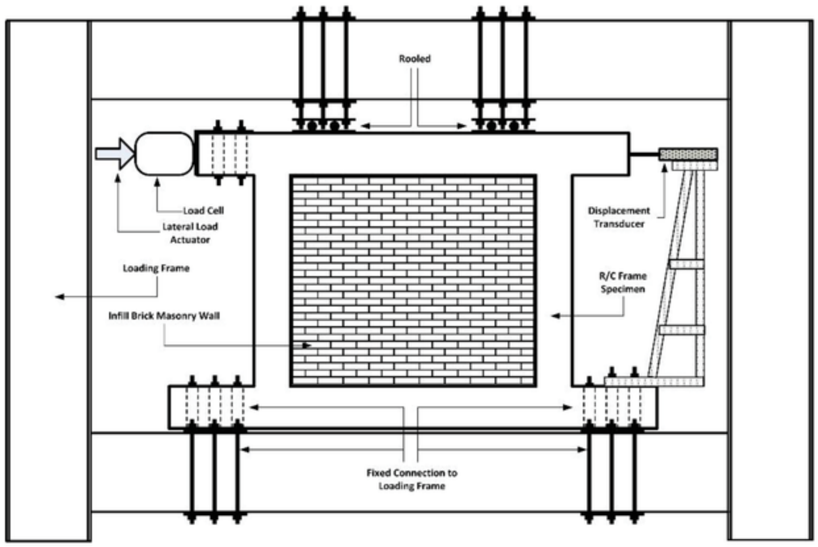


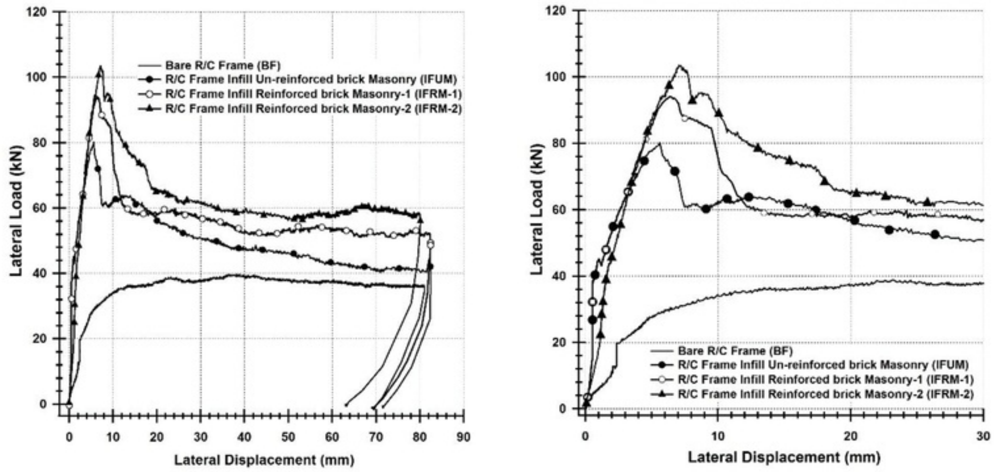
FIGURE 3. Experimental Setup and Instrumentation for In-plane Test

Figure 3 illustrates how the experimental works were conducted. The specimen was placed on the Loading-Frame and the foundation beam was fastened to the Loading-Frame by using 6 post-tensioning rods. The lateral monotonic forces were applied to the left side of the top-beam until the specimen collapse (pushed-over). The lateral forces will result the lateral displacements of the R/C specimen. These lateral forces and the existing lateral displacements were further measured by a load-cell and a displacement transducer, respectively and were directly recorded by the portable data logger. The load-cell was positioned between hydraulic jack and the left side surface of the top-beam, whereas the displacement transduced was installed at mid-height of right side surface, i.e. opposite to the load-cell position. During testing, the top-beam was not allowed to deform in upper direction. To do this, the rollers equipment's were placed between top surface of the top-beam and the Loading-Frame. In addition, during experimental works, the failure mechanism and the crack pattern of the R/C frame specimens were also observed.

TEST RESULTS AND DISCUSSION

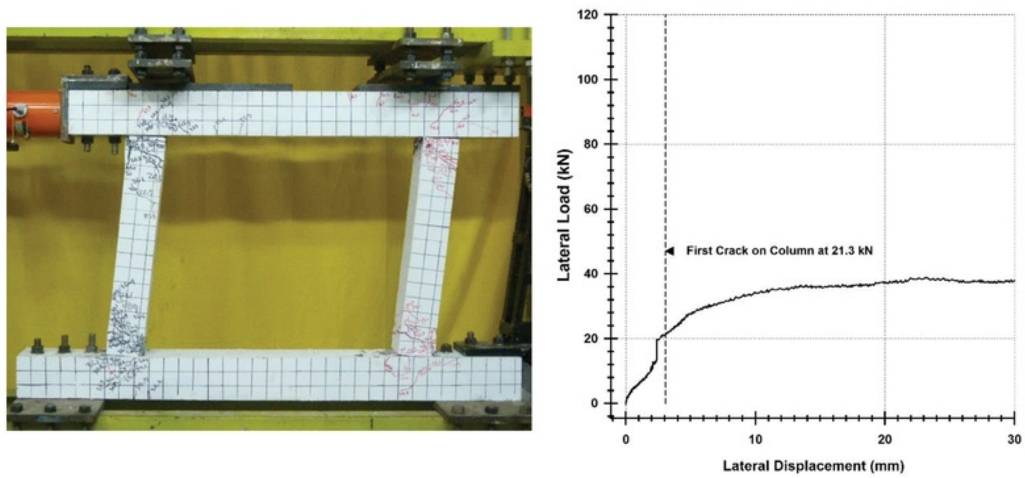
Figure 4.a. presents the complete experimental results as curves of the applied lateral forces versus lateral displacement for all tested R/C frame specimens and Figure 4.b. shows the cropped curves of Figure 4.a. in 30 mm lateral displacement. The separately experimental results are displayed in Fig. 5 to Fig. 8. The initial stiffness of the R/C frames with brick masonry infills are significantly larger than the initial stiffness of the bare R/C frame and there is no significant influence from the presence of the embedded reinforcement in the brick masonry infills. The average initial stiffness of these specimens is about 5.3 times that of the bare R/C frame specimen. In all cases, the lateral forces-displacement curves of the R/C frames with brick masonry infills wall tend to return to the bare R/C frame curve at drifts values relevant to a collapse of the brick infills walls. Compare to the BF specimen, the presence of the brick masonry infills wall in specimens IFUM, IFRM-1 and IFRM-2, increase the lateral strength of these R/C frames about 98%, 135% and 157%, respectively. The R/C frames with reinforced brick masonry infills wall showed much better performance than the companion unreinforced specimen. These lateral strengths increase significantly over the capacity of the IFUM specimen, developing about 1.2 times for IFRM-1 specimen and about 1.3 times for IFRM-2 specimen, respectively. Further, as is expected, the embedded reinforcement in the brick masonry infill wall increase

the ductility of the infilled R/C frame specimens. The average ductility of these R/C frames is about 1.8 times that of unreinforced specimen. When comparing to IFUM specimen, the presence of the embedded reinforcement is also increase the residual lateral strength of the brick masonry infills walls about 40% for IFRM-1 specimen and about 50% for the IFRM-2 specimen, respectively. The residual strength is the lateral strength of the brick masonry infill after collapse.



(a) Complete of the Experimental Results (b) Cropped in 30 mm Lateral Displacement Results

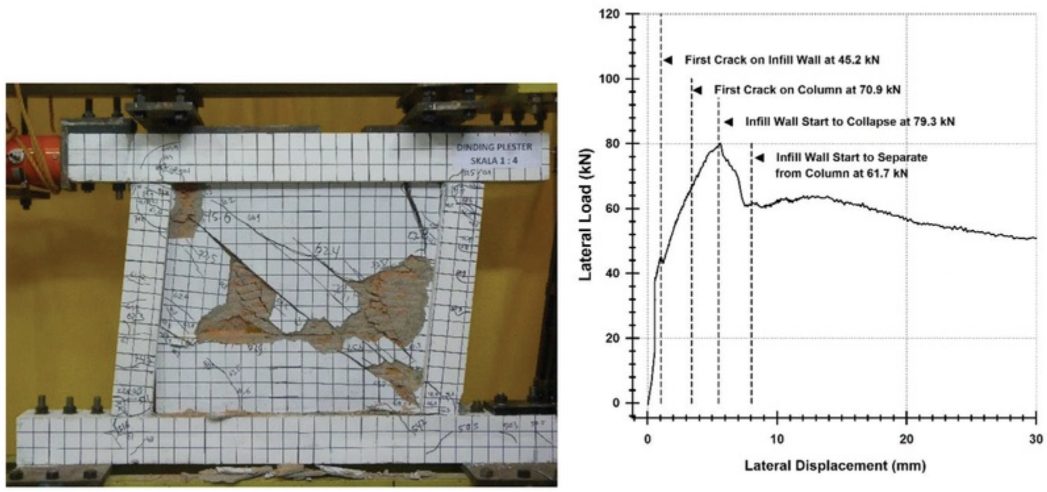
FIGURE 4. Comparison of the Experimental Results for Lateral Force-Displacement Reponses of the R/C Specimens



(a) Failure Pattern of the Specimen at The End of Test (b) Lateral Forces-Displacement Curve

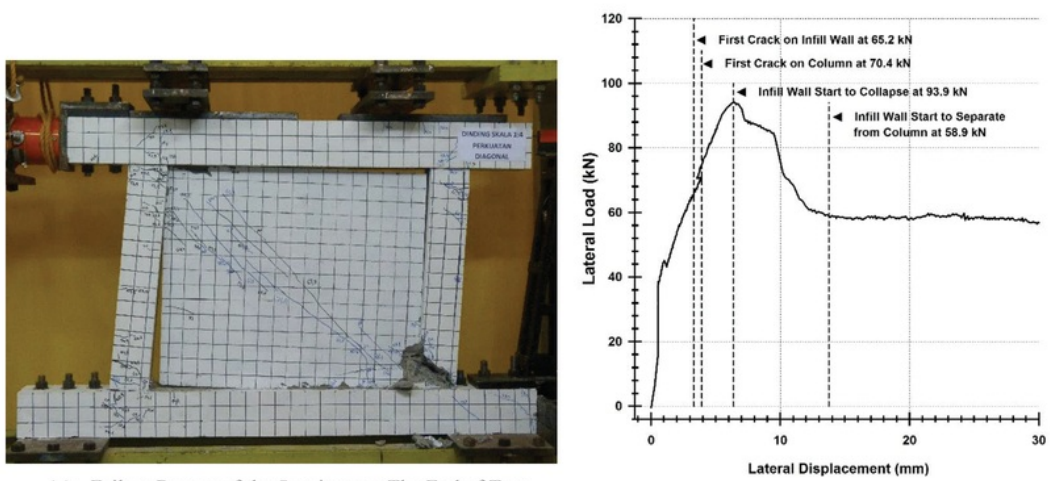
FIGURE 5. Experimental Result of The Bare R/C Frame Specimen (BF)

The embedded reinforcements also improved the shear performance of the infill walls, controlling diagonal shear cracking effectually. After the lateral strength degradation, the infill wall continued resisting lateral load due to the presence of embedded reinforcements and eliminating the diagonal tension failure. The initial diagonal shear crack in the infill walls was delayed and crack did not propagate appreciably due to presence it embedded reinforcements. Figures 6.a., 7.a. and 8.a. show the crack pattern of the infilled R/C specimens at the end of tests. The embedded reinforcements helped ensure the integrity of the masonry wall until end of the test.



(a) Failure Pattern of the Specimen at The End of Test (b) Lateral Forces-Displacement Curve

FIGURE 6. Experimental Result of The R/C Frame with Unreinforced brick Masonry Specimen (IFUM)

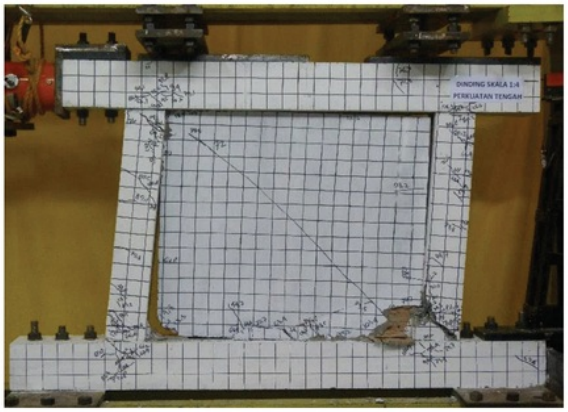


(a) Failure Pattern of the Specimen at The End of Test (b) Lateral Forces-Displacement Curve

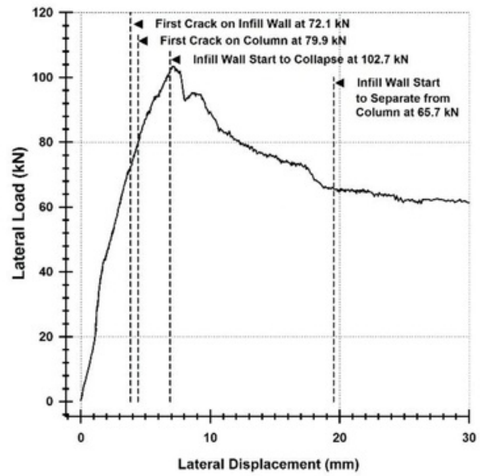
FIGURE 7. Experimental Result of The R/C Frame with embedded Reinforced brick Masonry Specimen (IFRM-1)

The experimental observations showed that the brick masonry infill wall interfere with the lateral deformation of the R/C frame. The separation of the R/C frame and the brick masonry infill was caused by tensile takes along one diagonal and the compression strut forms takes place along the other. As a consequence, the brick masonry infill will add the lateral stiffness of the R/C frame structure. The load transfers in the specimens were changed from frame action to predominant truss action, the columns experience increased axial forces and reduced the bending moments and shear forces.

Indeed, the brick masonry infill possess the large lateral stiffness and hence draw a significant of the lateral force. The embedded reinforcements made the brick masonry infill wall stronger, therefore the strength contribute by the brick masonry infill may be comparable to the strength of the bare frame itself. Due to increasing of the lateral strength of the brick masonry infill, the failure pattern infill change from the diagonal cracks in the infill to corner crushing of the infill as are shown in Fig. 6.a., 7.a. and 8.a. The embedded reinforcement in the brick infill wall was successfully controls the failure.



(a) Failure Pattern of the Specimen at The End of Test



(b) Lateral Forces-Displacement Curve

FIGURE 8. Experimental Result of the R/C Frame with embedded Reinforced brick Masonry Specimen (IFRM-2)

CONCLUSIONS

Four R/C frame specimens have been tested to their ultimate condition. The experimental works were performed on single-bay, single-storey R/C frame specimens. The experimental results show that unreinforced brick masonry infill in the R/C frame specimen increases the lateral strength of the specimens about 98% of that bare R/C frame specimen. On the other hand, the increasing of the lateral strength may up to 157% when the brick masonry infill was strengthened by using embedded reinforcement. The presence of the embedded reinforcement in the brick infill made better seismic performance of the R/C frame specimens than unreinforced specimen. Compare to IFUM specimen, the lateral strength develops about 1.2 times and 1.3 times for specimen IFRM-1 and IFRM-2, respectively. The residual lateral strength higher about 40%-50%. The overall ductility increased in average of 1.8 times of that unreinforced specimen. The presence of the embedded reinforcements improved the shear performance of the infill wall and eliminating the diagonal tension failure. The initial diagonal shear crack in the infill walls was delayed and crack did not propagate appreciably due to presence it embedded reinforcements.

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REFERENCES

1. G. M. Calvi, D Bolognini and A. Penna, "Seismic Performance of Masonry-Infilled R.C Frames: Benefit of Slight Reinforcements", in *Proceeding of SISMICA 6 Congresso Nacional de Sismologia e Sismica.* (2004). pp. 253-276.
2. Maidiawati, Y. Sanada, D. Konishi and J. Tanjung, J. Asian Archit. Build. Eng. **10** (1), 203-210 (2011).
3. N. Agrawal, P.B. Kulkarni, and P. Raut, Int. J. Sci. Res. Publ. **3**(9), 1-8 (2013).

4. J.Tanjung and Maidiawati, Jurnal Teknik Sipil-ITB **23** (2), 99–106 (2016).
5. Maidiawati and Y. Sanada, J. Asian Archit. Build. Eng. **7** (2), 371-378 (2008).
6. P.F. Silva, A. Belarbi, A. Nanni and J.J. Myers, "Retrofit of Un-Reinforced Infill Masonry Wall with FRP", in *Proceeding of CCC Composites in Construction*. (Porto, Portugal, 2001).
7. J. M. Proenca, A.S. Gago, A.V. Costa and A.M. Andre, "Strengthening of Masonry Wall Load Bearing Structures with Reinforced Plastering Mortar Solution", in *Proceeding of 15th WCEE World Conference on Earthquake Engineering.* (Lisbon, Portugal, 2012).
8. S. Arifuzzaman, and M. Saatcioglu, "Seismic Retrofit of Load Bearing Masonry Walls by FRP Sheets an Anchors", in *Proceeding of 15th WCEE World Conference on Earthquake Engineering*. (Lisbon, Portugal, 2012).

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