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The Structural Behavior Of 4-Storey R.C Frame With Brick Infill

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Abstract-This project studied the structural behavior of a quarter scale three bay four storey RCC frame with brick infill in the central bay with cyclic loading. Normally brick infill contributes as shear wall up to failure and subject to diagonal failure. An attempt was made to extend the reinforcement from the columns of the frame to the brick layers and embed with concrete to form a monolithic RCC strip to strengthen the interface of infill walls and RCC frame. This reduced diagonal crack in the infill. The frame was subjected to cyclic loading to stimulate the earthquake. The effect of infill on load carrying capacity, deflection, energy dissipation, stiffness, and ductility were investigated. The crack pattern showed that the potentially adverse effect of the infill was nullified and the frame was ductile in nature.

Keywords: RC frame, Stiffness, Reinforcement in Brick in fills, cyclic loading, Ductility, etc.

Introduction

Masonry panels, which contribute a large proportion of the mass of the infill-frame, normally consist of anisotropic materials with a wide range of strength, deformation and energy dissipation properties. Unlike other conventional materials such as concrete and steel which have, to some extent, standard properties regardless of the region in which they are produced, masonry materials vary significantly based on the local constituent materials (the bricks and the mortar) and workmanship. In the usual practice, design of infill-frames, the contribution of infill is ignored. This implies that the infill has no influence on the structural behavior of the building except for its mass. During a strong earthquake, the lateral displacement is high and severe damage occurs at the infill and the frame. The poor shear and tensile strength and brittleness of the brick infill, the construction industries restrict its usage. In spite of this, it is continued to be used in many countries because, the masonry infill panels are often cost-effective and suitable for temperature and sound insulation purposes. Mrs. .Umarani and S. Basil Gnanappa [2010] examined the behavior of infilled frames (5 storey) for lateral loading. It was reported that the strength, stiffness and energy absorption capacity of infilled frame was much higher than the bare frame. P. Govindan [1986] experimentally compared the behavior of a quarter size seven-storey infilled reinforced concrete frame with that of a reinforced concrete frame without infill subject to lateral loads, and assessed the failure mode of the brick infilled frame. They quantified the strength, ductility and energy absorption capacity characteristics of the infilled frame subjected to the repeated cyclic loads, which exposed the ductility requirement of the brick infill. Dubey et al [1996] conducted experimental analysis on the effect of reinforcement on ultimate strength of infilled frames, subjected to lateral loads. He reported that 0.15% of steel reinforcement increased the ultimate load carrying capacity of the frame. Mehrabi Armin et al [1996] reported the influence of masonry infill panels on the seismic performance of reinforced concrete frames that were designed in accordance with current code provisions S.Z.Korkmaz et al [2010] used the existing brick infill walls and the strengthening was done with the application of external mesh reinforcement and plaster. 5 non ductile 1/2 scaled, one bay, two storey RC specimens were tested under a reversed cyclic loading. It was observed that, at low levels of lateral forces, the frame and infill wall behaved monolithically. However, as the lateral force level increased, the frame deformed in a flexural mode while the infill corners damaged. Lila M. Abdel-Hafez et al (2014) reported that the ductility of infilled frame strengthened with ferrocement was the best among different methods. He strengthened the interface of the frame and infill with dowel bars. Mihail Garevski et al (2004) reported that CFRP strips put on the wall significantly improved the RC frame behavior under strong seismic excitation. Xilin Lu et al [2010] showed that adding additional bars was a promising approach in the reinforcement concrete structures since only fewer cracks were occurred in the column. In this research, Earthquake code IS: 1893-2002 was used for seismic load calculations.

Objective

The objective of this investigation was to quantify the behaviour in terms of load-deflection, ductility, energy dissipation capacity, and stiffness of a one quarter size 3-bay, 4-storey R.C.C frame. The middle bay of the frame was constructed with brick infill in which the 20mm thick reinforced concrete strip was present in between each two layers of brick. The frame was subjected to lateral static cyclic loading, simulating earthquake effects.

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Experimental Investigations

Materials

Ordinary Portland cement of 53 grade was used and tested for various properties as per IS: 4031-1988.It was found confirming to various specifications of IS: 12269-1987 and having a specific gravity of 3.0. 100mm thick brick work construction was carried with first class bricks using cement mortar 1:4. Crushed granite angular aggregate of size 12 mm nominal size from local source was used as coarse aggregate having specific gravity of 2.71. Natural river sand confirming to IS-383 zone II having specific gravity of 2.60 and locally available portable water confirming to IS 456 were used.

Details of Frame Sections

The frame was scaled to one fourth and the cross section of the beams and columns in the three bays four storey frame were 100x150 mm. The width of the storey was 1m whereas the height was 0.7m. The design mix ratio was 1:1.7:2.72

4.3 Reinforcement Detailing:
Six numbers of 10mm bars were used for columns. Two numbers of 10mm RTS at bottom and two numbers of 8mm RTS were used in beams. 8mm RTS were used as stirrups and ties for both beams and columns. Two numbers of 6mm MS rods were used in the 20mm thick cocrete in between the two layers of brick work. The reinforcement details were shown in table1.Fabrication of reinforcement for frame was shown in fig.1.

Section	Width	Depth	Main reinforcement	Bar Diameter	Stirrups	Detail
Beam	100	150	2 Nos	8mm(Top) 10mm(bott om)	8mm dia @100mm c/c	
column	150	100	6 Nos	10mm	8mm dia @100mm c/c	

Table.1. Reinforcement details

Fig.1. Reinforcement Detailing

Fabrication of Frame

The frame was cast using M_{30} concrete mix. Test cubes of size 150x150x150mm and prisms of size100x300mm were cast. The test specimens were tested after 28days curing and compared with the specified strength and found to be satisfactory. The frame was erected on the test floor. The reinforcement strip was as shown in figure 2.

Fig.2. reinforcement strip

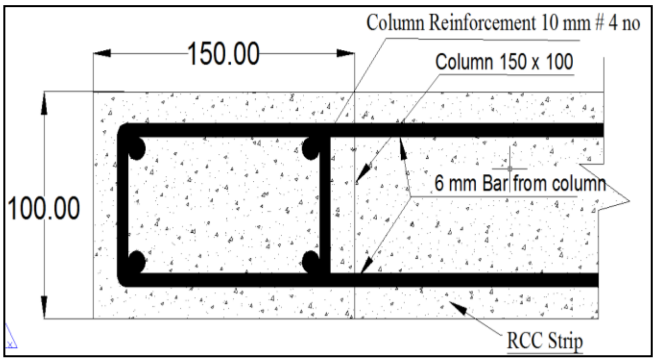

Fig.3. Interfacing of Frame and Brick work

Brickwork

Two numbers of 6mm ms rods extended from frames were tied up with distributors in between the two layers of brickwork. The brickwork was carried out with bricks of size

220x100x70mm with a compressive strength of 4.5N/mm^{2}The reinforcement was embedded with 20mm thick concrete (M_{30}) as shown in (fig3). The brick infill with RCC strip was as shown in fig 4.

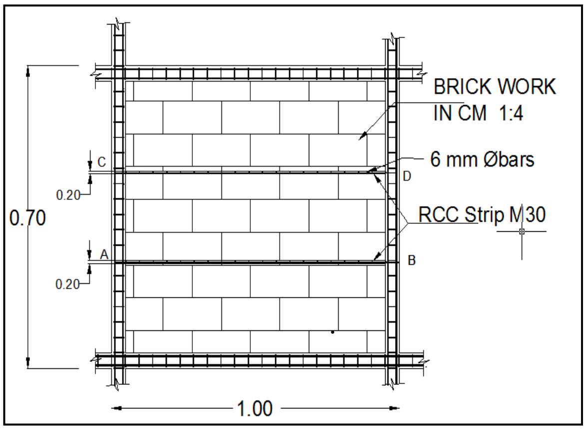

Fig.4. Brick infill with monolithic RCC strip

Test Setup

The two load points were located at the fourth storey level and second storey level. The loads were applied through double acting hydraulic jacks of capacity 500kN and 100kN respectively. The jacks were fixed to the existing reaction frame and controlled by a common console. Pressure gauges were used to measure the applied load, which was calibrated earlier through proving rings. The hand operated oil pumps were used to have control over the loads. The loading arrangements were shown in the test setup (fig5). The displacement was measured by LVDT of 200mm capacity and 0.01mm least count. The steel studs, which were provided on the main steel reinforcement of beam and column, were attached with demec points which were fixed to the beam and column faces at selected position i.e. at 100 mm c/c to measure the strains in concrete using Demec strain gauges.

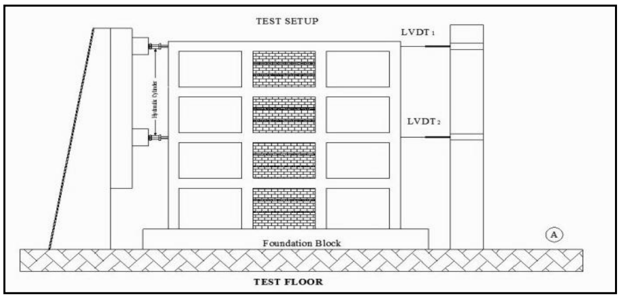

Fig.5. Test setup

Load Distribution

Load was applied at the top (Q4) and middle (Q2) storey of the frame from the left side with the help of load cells. The loads were distributed as per the Table2.

Table.2. Distribution of Loads in Load Cells

LOADS (kN)	Q_2 (kN)	Q_4 (kN)
10	3.25	6.75
20	6.50	13.50
30	9.75	20.25
40	13.00	27.00
50	16.25	33.75
60	19.50	40.50
70	22.75	47.25
80	26.00	54.00
90	29.25	60.75
100	32.50	67.50
110	35.75	74.25
120	39.00	81.00
130	42.25	87.75
140	45.50	94.50
150	48.75	101.25
160	52.00	108.00
170	55.25	114.75
180	57.50	121.50

Testing of the Frame

- Cyclic loading was applied on the frame i.e. 0 10 0, 0 10 20 10 0, etc in kN with the help of load cells till the frame failed.
- For each loading the readings were noted in L1, L2 & D1, D2 and strain readings were also taken on both steel and concrete
- Concrete strains were noted till the initial failure of concrete and steel strains were noted for the zero loading and ultimate load in the cycle.

Result

At 40kN load initial minor cracks were found at the beam-column joints of the frame. At 50kN the cracks further developed for a length of 3-4cm as shown in fig.8 (a).

Fig.8 (a) Initial crack at the joints

Fig.8 (b) Cracks at the joints

Increasing the load, budding major cracks (fig.8 (b)) were found and the concrete strain was not noted further. At 90kN few minor cracks developed in the brick layers for 2-4mm length in the bottom storey.

Fig.9. Occurrence of cracks in brick layers

At 120kN minor cracks were found in the bottom of the foundation in the tension side of the frame. At 150kN horizontal cracks were found in the brickwork as shown in fig. 9. At 173kN the wind ward column failed due to short column effect as shown in fig. 10.

Fig.10. Final failure of frame

Load vs. Displacement

It was observed that till 120 KN load the displacement was less and slope was higher. After this cycle the steel started to yield and stiffness of the frame was reducing. Also minor cracks were found in brick works. The slope of the curve was reduced due to yielding of steel and more displacement. At collapse load of 173 kN the displacement was 130mm.The huge displacement was achieved due to the fact that interaction between the frame and infill was occurred as a whole. It was noted that at the ultimate stage the frame failed and still the brick work did not get total failure. The mathematical expression of load-displacement curve was $y=4E\text{-}5x^3-0.25x^2+3.8x+4.719$ and $R^2 = 0.981$.The load-displacement curve was shown in fig.11.

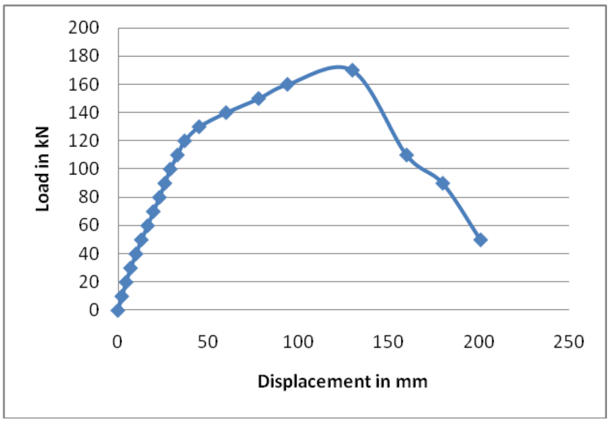

Fig.11. load vs. Displacement Curve

Load vs. Displacement under Cyclic Load

Hysteresis loops were found in cyclic load. Narrow loops were found up to 120kN and the loops were broader beyond this load. This was due to yielding of steel and cracks in beam, columns and brick work. It was observed that at the ultimate stage the deflection was very high. The hysteresis curve was shown in fig.12.

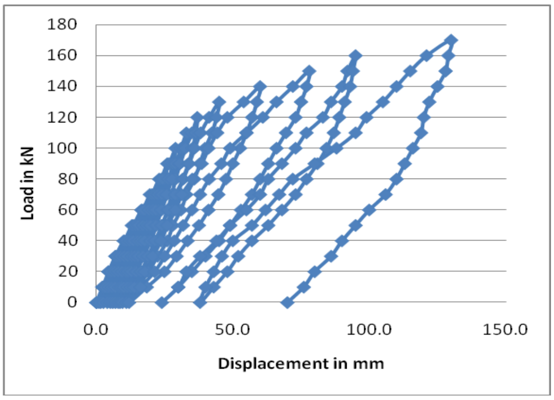

Fig. 12.Load vs. Displacement curve

Ductility vs. Load Cycle

The ductility was found from displacement. The ductility was linear up to 40mm displacement. Due to higher yielding of steel and bond failure of brick work the ductility increases appreciably after 40mm displacement. The mathematical expression of ductility curve was $y=-3E\text{-}06x^3-0.000x^2+.113x-.529$ and R^2 = 0.989. The ductility curve was shown in fig.13.

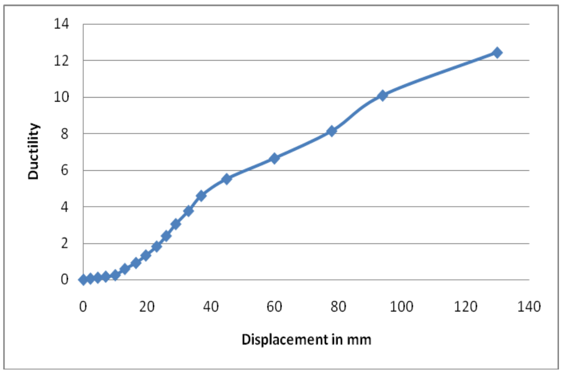

Fig.13. Ductility factor vs. Displacement

Stiffness

Stiffness degradation was found to be steep till10mm deflection and it was gradual beyond this displacement. This was obtained due to monolithic action of the frame and the brickwork. The brickwork contributed more to stiffness in the initial stages. When the crack occurred in the infill the stiffness was getting reduced. The mathematical expression of the stiffness degradation curve was $y=-2E\text{-}07x^3-0.000x^2-.046x+4.538$ and R^2 = 0.987. The Stiffness curve was shown in Fig.14.

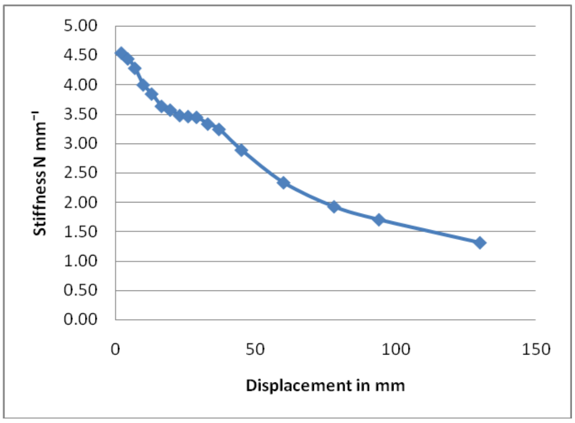

Fig.14. Stiffness vs. Displacement

Load cycles vs. Energy Dissipation

The energy dissipation was less until 40mm displacement and it was increasing very rapidly to the tune of 4500KN-mm at the final stage. Energy dissipation found was lesser in the initial cycles due to closed loops in the load-deflection and wider loops in the final stages. Since the structure was having good ductility capacity, it dissipated high energy, while yielding. The mathematical expression of ductility curve was $y=.004x^3+1.007x^2-15.62x+66.3$ and R^2 = 0.996. The Energy dissipation Vs displacement curve was as shown in the fig.15.

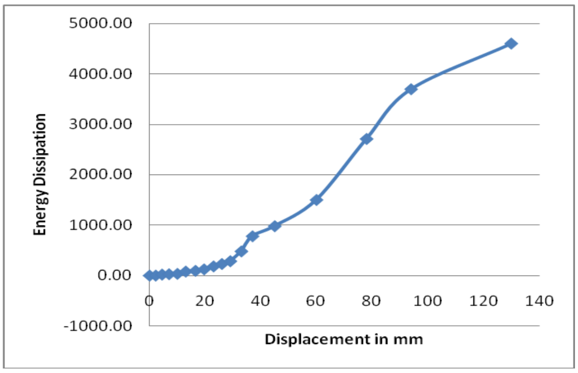

Fig.15. Energy dissipation vs. displacement

Conclusions

1. It was observed that the influence of reinforced concrete strips embedded in brick work along with RCC frame changed the whole behavior of the frame.

2. At the initial stage brickwork contributed more to stiffness and at later stage reinforced concrete strips and frame took lead to contribute stiffness.

3. Even at the stage of failure, the brick work did not collapse. It was due to the proper interfacing of the frame and the infill.

References

[1] S.Umarani and Basil Gnanappan, , "Structural Behavior of RC Frame with Confined Infill under Cyclic Loading ", International Journal of Earth Science and Engineering, .pp 904 – 911, 2011

[2] P. Govindan , 'Ductility of infilled frames', Journal of American Concrete Institute, Vol. 83, No. 4, July-Aug, pp. 567-575, 1986.

[3] S.K Dubey , "Ultimate strength of infilled frames under horizontal load", Journal of Structural Engineering, Vol. 23, pp.129-135, 1996.

[4] A.B. Mehrabi, "Behavior of Masonry Infilled Reinforced Concrete Frames Subjected to Lateral Loadings," Journal of Structural Engineering,ASCE, 1996 122:3(228) , 1996.

[5] S.Z.Kormax, M.Kamanli, H.H.Korkmax, M.S.Donduren and M.T.Cogurcu, "Experimental study of nonductile infilled RC frames strengthened with external mesh reinforcement and plaster composites", Natural Hazards and Earth System Sciences, 10, 2305-2316, 2010.

[6] Lila M.Abdel-hafez,A.E.Y.Abouelezz, Faseal F.Elzefeary"Behavior of masonry strengthened infilled reinforced concrete frames under in plane load" HBRC Journal 2014.

[7] Mihail Garevski, Viktor Hristovski, Kostas talaganov, Marta stojmanovska, "Experimental investigations of 1/3-scale r/c frame with infill walls building structures" 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada. August 1-6, Paper No. 772, 2004.

[8] Xilin Lu, H.Tonny Urukap, Sen Li and Fangshu Lin, (2012),"Seismic behavior of interior RC beam -column joints with additional bars under cyclic loading", Earthquakes and Structures, Vol. 3, No. 1, 37-57, 2012.