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## RESEARCH ARTICLE

# EXPERIMENTAL STUDY ON ENERGY DISSIPATION CAPACITY OF 3 BAY 4 STOREY MASONRY INFILLED R.C FRAME UNDER CYCLIC LOADING

***,1Sathiaseelan, P. and 2Arulselvan, S.**

1Department of Civil Engineering, PPG Institute of Technology, Coimbatore, India
2Department of Civil Engineering, Coimbatore Institute of Technology, Coimbatore, India

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**ABSTRACT**

This experimental project was to study the structural behavior of a scaled three bay four storey RCC frame with brick infill in the central bay under 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 and thereby diagonal cracks were prevented in the infill. The frame was subjected to cyclic loading to stimulate the earthquake. The effect of infill on load carrying capacity, deflection and energy dissipation were investigated. The crack pattern showed that the potentially adverse effect of the infill was nullified and the frame was ductile in nature and dissipated high energy at the plastic stage.



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## INTRODUCTION

Masonry panels, which contribute a large proportion of the mass of the infill-frame, are usually not having proper interfacing with the surrounding frame. Hence most of the designers ignore its presence in the design calculations. Researchers evolved the concept of diagonal strut when analyzing framed structures with masonry infill. During a strong ground motion, the lateral displacement is high and severe damage occurs at the infill and the frame. Mrs .Umarani and S. Basil Gnanappa (2010) examined the behavior of infilled frames (5 storeys) for lateral loading. It was reported that the strength, stiffness and energy absorption capacity of infilled frame was much higher than the bare frame. Govindan *et al.* (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 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. Mihail Garevski *et al.* (2004) reported that CFRP strips put on the wall significantly improve 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. P.M Pradhan *et al.* (2012) indicated that the partial infill frames were vulnerable to earthquake especially when the height of infill was about 0.4 times the height of floor. Jamnekar *et al.* (2013) observed that the presence of infill guarantied higher overall stiffness and strength and reducing the inter storey drift demand of the structure. Asteris P.G, (2003) reported that the presence of infill decreased the shear forces on the surrounding frame columns In this research, Earthquake code IS: 1893-2002 was used for seismic load calculations.

***Corresponding author: Sathiaseelan, P.**
*Department of Civil Engineering, PPG Institute of Technology, Coimbatore, India.*

### Objective

The objective of this investigation was to quantify the behaviour in terms of load-deflection and energy dissipation capacity of a one quarter size 3-bay, 4-storey R.C.C frame. Two numbers of 6mm diameter bars were extended into the middle bay where the brick work was done. 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 Investigation

## MATERIALS

Ordinary Portland cement of 53 grade was used and tested for various properties in accordance with IS: 4031-1988 and it was found to be satisfied 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 size was used as coarse aggregate and having a specific gravity of 2.71. Natural river sand confirming to IS-383 zone II having specific gravity of 2.60 and portable water confirming to IS 456 were used.

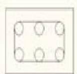
### Details of Frame Sections

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

### 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 are shown in Table1.

**Table 1. Reinforcement details**

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

### 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 1.

**Figure 1. Reinforcement strip**

### 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 ($M_{30}$) strip as shown in (Fig3). The brick infill with RCC strip was as shown in Fig 2.

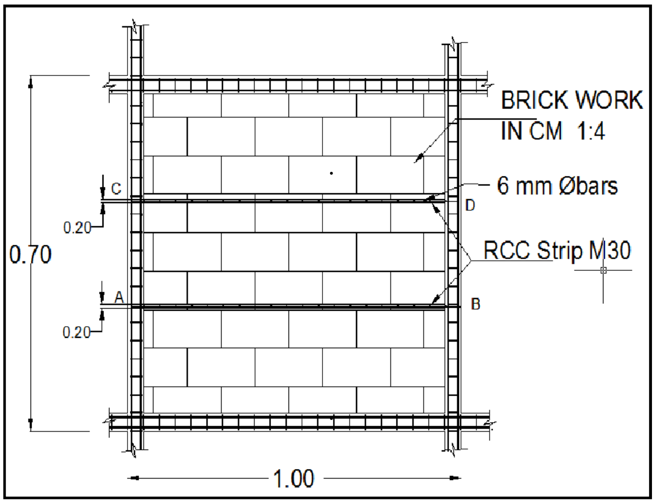



**Figure 2. Brick infill with monolithic RCC strip**

### 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 (fig3). 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.

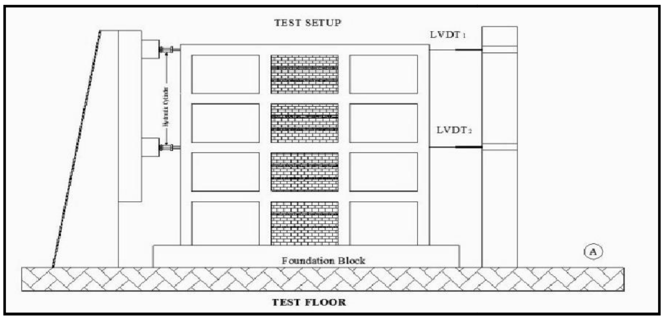



**Figure 3. Test setup**

### 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.

### 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 are 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.

**Figure 4. Final failure of frame**

## RESULTS

At 40kN load initial minor cracks were found at the beam-column joints of the frame.

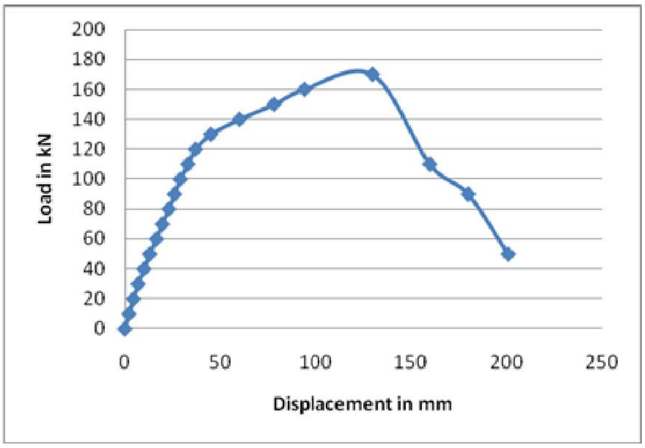



**Figure 5. Load vs Displacement**

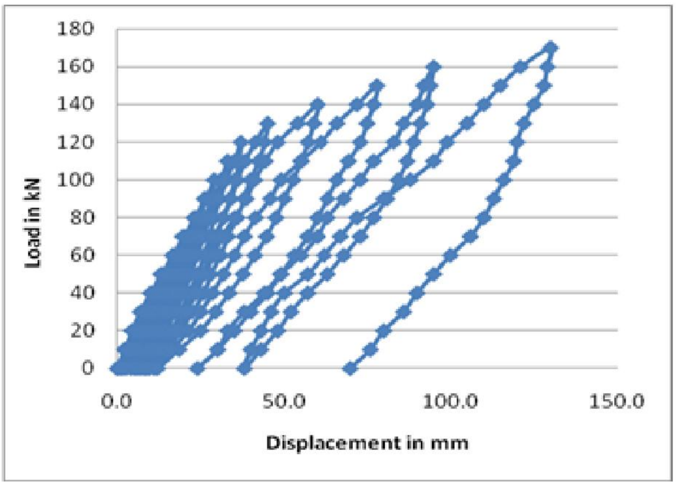



**Figure 6. Load vs Displacement under cyclic load**

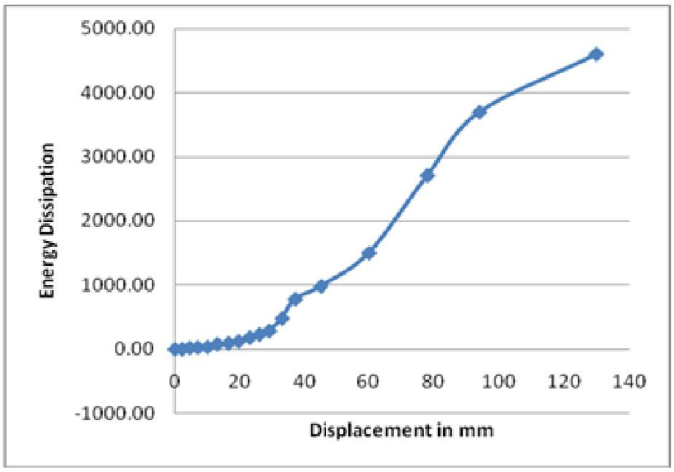



**Figure 7. Energy dissipation vs displacement**

At 50kN the cracks have been further developed for a length of 3-4cm. Increasing the load, budding major cracks 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. At 120kN minor cracks have been found in the bottom of the foundation in the tension side of the frame. At 150 kN horizontal cracks were found in the brickwork.

At 173kN the wind ward column failed due to short column effect as shown in Fig. 4.

**Load vs Displacement**

It was observed that till 120 KN load the displacement was less and slope was higher. Beyond 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. The mathematical expression of load-displacement curve was $y=4E-5\times^3-0.25\times^2+3.8x+4.719$ and $R^2 = 0.981$. The load-displacement curve was shown in Fig 5.

**Load vs Displacement under Cyclic Load**

Hysteresis loops were plotted for 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 6.

**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 high due to wider loops in the final stages. Since the structure was having good ductility capacity, it dissipated high energy, while yielding. The mathematical expression of energy dissipation curve was $y=.004\times^3+1.007\times^2-15.62x+66.3$ and $R^2 = 0.996$. The Energy dissipation Vs displacement curve was as shown in the Fig.7.

**Conclusion**

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 and infill.
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. At the ultimate stage the frame system dissipated high energy due to the ductile behavior Which is very much required to resist ground motion.
4. It was observed that at the ultimate stage infill did not fall as debris due to strips. The cracks in the infill were horizontal in nature
5. This crack pattern was due to proper interfacing of frame and infill monolithic action of the frame and infill.
6. The failure occurred due to the yielding of reinforcement in the column. To avoid such failure column junction may be strengthened or number of RC strips may be reduced.

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