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# Influence of Diagonal Strut Action in RC Framed Structure

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**Abstract: Mostly at present in India, all the types of structures are made by Reinforced Concrete (RC) framed structure because of availability of natural sources and scarcity of land. These RC framed structures are fashioned through structural and non structural elements like infilled wall, slab, etc.,. However, infilled wall does not include in the design part of structural members but relatively react with RC frame elements whenever the framed structure subjected to lateral loading. Therefore, research is necessary to study the performance between RC frame elements and infilled wall. The main objective of our research is study and improves the interaction between frame and infilled wall by diagonal strut action in infilled wall through single bay of structure under one-tenth scale model. Here, three types of specimen were cast and tested such as RC framed structure without infill, RC framed structure with brick masonry, RC framed structure with reinforcing band under diagonal strut action conditions. The specimens were formulated as per IS Code recommendations and testing of specimen was carried out through the Universal Testing Machine. Besides, properties of concrete and steel were also measured for analysis of experimental work. Finally, experimental values were examined in the order of strength, ductility and failure mechanism of the RC frame. It is proved that the ultimate load carrying capacity of RC frame with reinforcement band is 3.94 times better than that of RC frame without infill. As well as the initial stiffness and ductility of the frame with diagonal strut is 1.085 and 1.137 times higher than that of the frame without infill respectively.**

***Keywords: Infilled wall, Ductility, Stiffness, RC frame, Framed Structure, Deflection.***

## I. INTRODUCTION

Reinforced concrete framed structure is one of the modes of structure for development the infrastructure in residential, industrial and public structure in India. This structure is generally made of design and non-design elements using natural and artificial materials. Masonry infill is one of typical non-structural elements, constructed between beam to column of the RC framed structures. It was used as interior partitions or exterior partitions in the RC framed structures. Generally, the RC frame is built first and afterwards infilled wall are constructed in the opening between frame elements. Kasim et.al.,[5] presented on earthquake assessment of R/C structures with masonry infill walls. In this study, a 3-story R/C frame structure with different amount of masonry infill walls is considered to investigate the affect of infill walls on earthquake response of these types of structures. The diagonal strut approach is adopted for modeling masonry infill walls. Regarding with the analysis results, the effects of irregularities were determined in the structural behaviour under earthquake. But nowadays, masonry wall is practiced as infilled wall in RC framed structure [6], [9]. As well as infilled wall increases the stiffness of buildings and reduce the ductility of frame members. Many investigations were undertaken for strengthening and repairing of slabs, beams, columns, but a few research works are available for strengthening of infills.That is to improve the interaction between the frames and masonry walls. It is to give additional strength for soft-storey structure. Asteris[1] studied an analysis of brickwork infilled plane frames under lateral loads. In that present paper, the influence of the masonry infill panel opening in the reduction of the infilled frames stiffness has been investigated by means of this technique. It is shown that the redistribution of shear forces is critically influenced by the presence and continuity of infill panels. The presence of infill leads to decreased shear forces on the frame columns. However, in the case of an infilled frame with a soft storey, the shear forces acting on columns are considerably higher than those obtained from the analysis of the bare frame. Therefore, it is necessary to understand the characteristics of brick masonry infill RC frame in order to better understand the structural behaviour of the frame itself. It is very important to determine the effects of infill walls to structural behaviour. Hossain Mohammad et.al.,[3]

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experimented on effect of infill as a structural components on the column design of multi-storied building. It is observed that frames with infill produce much smaller deflections as compared to frames without infill. Although, the infill panels significantly enhance both the stiffness and strength of the frame, their contribution is often taken into account because of the lack of knowledge of the composite behaviour of the frame and the infill. The presence of non-structural masonry infill walls can affect the seismic behaviour of framed building to large extent[7]. These effects are generally positive: masonry infill walls can increase global stiffness and strength of the structure. On the other hand, potentially negative effects may occur such as torsional effects induced by in plan-irregularities, soft storey effects induced by irregularities and short column effects. Rudra srinivasa reddy[8] investigated on validation of indices for assessing seismic vulnerability of multi-storey buildings with typical vertical irregularities using push-over analysis. It was concluded that the indices can indeed be used to identify such typical deficiencies in existing buildings. It has been generally recognized that infill frame structure exhibit poor seismic performance, since numerous buildings have failed in past earthquakes. The infill frames have greater strength as compared to frames without infill walls. The presence of the infill walls increases the lateral stiffness considerably. But recent earthquakes showed that infill walls have an important effect on the resistance and stiffness of building due to poor interaction and ductility between frame and infilled wall[2],[4]. Based on the previous literature study, it showed that infilled wall improves the strength and stiffness of RC framed structure but it weaks in ductility and interaction between framed and infilled wall. Therefore, the main objective is to enhance the performance of RC framed structure with infilled wall.

## II. EXPERIMENTAL METHODOLOGY

The behaviour of RC frame with and without infilled wall is subjected to diagonal loading were studied through an experiment programme. Three numbers of RC frames were cast and tested and they are designated as RC frame without masonry infill, RC frame with masonry infill and RC frame structure with reinforcing band under diagonal strut condition. A detail of the different types of specimen is shown in table 1. The use of formwork, good quality materials and quality control of the specimens were made identical. To cast the RC frame, a wooden mould specially was made for the preparation of specimens and arrangement of the mould is shown in figure 1. The mould is bolted at the bottom wood for table vibrator. The diagonal loading was provided with an steel plate to distribute the load for specimen.

**TABLE 1 DETAIL OF SPECIMENS**

| Sl. No. | Frame Designation | C/s dimensions in mm | | Main Reinforcement |
|---|---|---|---|---|
| | | Breadth | depth | |
| 1 | Without Infill | 50 | 60 | 4 Nos, 6 mm ϕ |
| 2 | With reinforcement band | 50 | 60 | 4 Nos, 6 mm ϕ |
| 3 | Diagonal strut | 50 | 60 | 4 Nos, 6 mm ϕ |
| Shear reinforcement: 4 mm ϕ, 2 legged vertical stirrups | | | | |

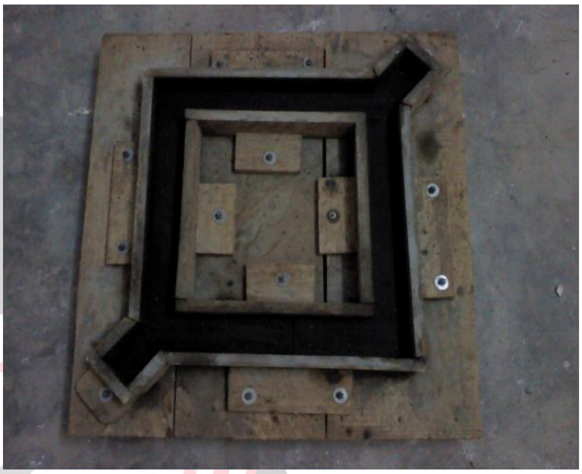

**Fig. 1 Mould for specimen**

### *A. Specification of Materials*

Ordinary Portland cement was utilized for concrete to prepare of these specimens. The cement was in standard gunny bags and transferred later to air tight steel drums to avoid deterioration of quality. The water available in the campus was used for mixing and curing of specimens. The river sand was used for all specimens. The main reinforcement was prepared for all the specimens with plain mild steel bars of 6 mm diameter and the stirrups were utilized with plain mild steel bars of 4 mm diameter. Here, steel plates were provided at corner of specimen to distribute the load to specimen and it is shown in figure 2. Chamber brick were required for infilled wall and it is modeled with size of brick is 6.6 cm x 3 cm x 3 cm. The normal and model size of the brick is shown in figure 3. Here, M20 grade of concrete was designed with mix proportions of 1:1.87:3.3 by using 0.5 water-cement ratio. Finally, the properties of concrete such as compressive strength and split tensile strength were found as 31.47 and 1.15 N/mm$^2$ respectively.

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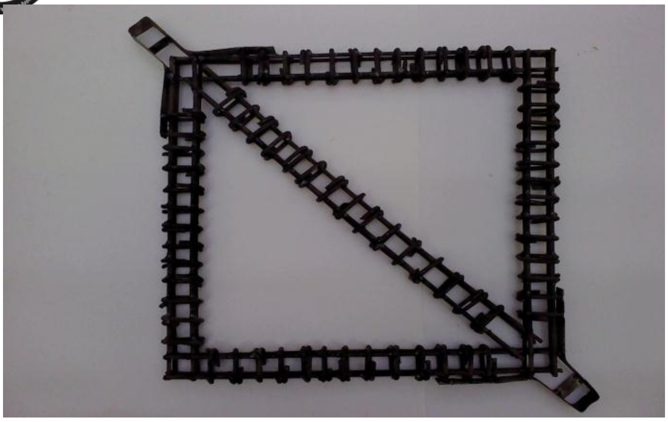

Fig. 2 Steel plate arrangement


Fig. 3 Model of brick

### B. Experimental Test Setup

In this study, three types of specimens were studied such as RC frame without masonry infill, RC frame with masonry infill and RC frame structure with reinforcing band condition. The geometry of RC frame and infilled wall is constant throughout the section. The specimen was erected vertically on the Universal Testing Machine (UTM) to perform the behaviour of RC frame with infill. For every stage of loading, deflections was observed through the arrangement of dial guage. Finally, the loading arrangement of specimen with instrument is shown in figure 4.

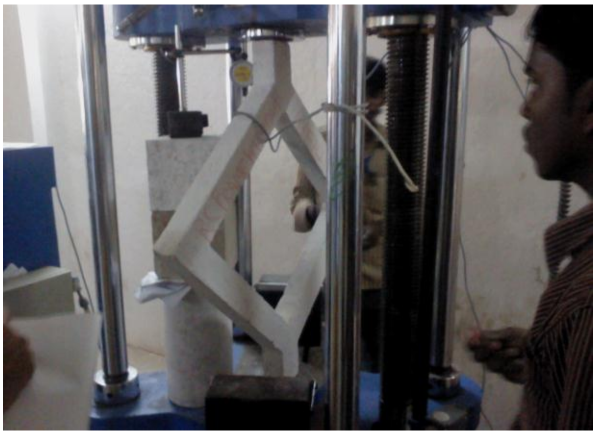

Fig. 4 Loading arrangement for specimen

## III. EXPERIMENTAL INVESTIGATION

### A. Behaviour of RC Frame Without Infill

The experimental behaviour of RC frame without infill was studied under static diagonal loading by using UTM. The load Vs. deflection curves of this specimen was observed and as shown in figure 5. Initially, the crack was observed at the load level of 21 kN at beam-column joints. After the formation of crack in the joint, the specimen was reached at ultimate load and it was found as 27.85 kN. Finally, the failure pattern of R.C frame without infill was observed as shown in figure 6.

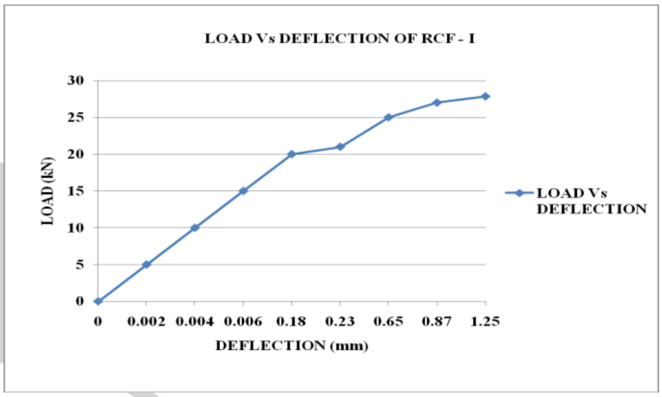


Fig. 5 Load Vs. deflection curve of RC frame without infill


Fig. 6 Failure pattern of RC frame without infill

### B. Behaviour of RC Framed Structure with Infilled Wall

The behaviour of RC framed structure with infilled wall was studied by testing frame with ordinary masonry with constant infill thickness. The load Vs. deflection curve of this specimen is as shown in figure 7. The first crack was observed in the infill at a load level of 30 kN. This crack occurs between along the diagonal side of infill. The frame was also cracked along loaded diagonal simultaneously with the cracking of the infill at the load level of 30 kN. After the formation of crack in the frame, ultimate load was reached. At this ultimate load stage, diagonal tensile crack was observed nearer to the loading point and extended as shear cracks at the support point. The crack was found in the infill at an ultimate load level of 41 kN. The failure pattern of ordinary brick work in RC framed structure is also observed as shown in figure 8.


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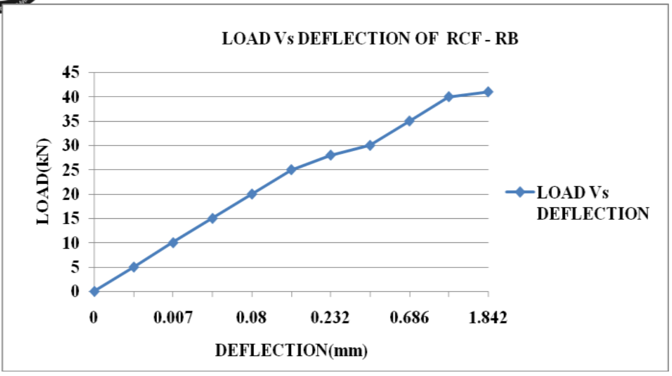


**Fig. 7 RC frame with infill**

**Fig. 8 Failure pattern of RC frame with infill**

### *C. Behaviour of RC Framed Structure with Reinforcing Band*

The failure pattern of RC frame with reinforcing band under diagonal strut is shown in figure 9. The first crack was observed at the joint between frame and band and it was observed as 69 kN. Along with diagonal tensile crack was found nearer to the loading point and extended as shear cracks at the support point. After the formation of crack in the frame, the specimen was reached at ultimate load. At this ultimate stage, finally the crack was observed in the specimen at the level of 110 kN. The load Vs. deflection curve of RC frame with reinforcing band as shown in figure 10.


**Fig. 9 Failure pattern of Frame with reinforcing band**

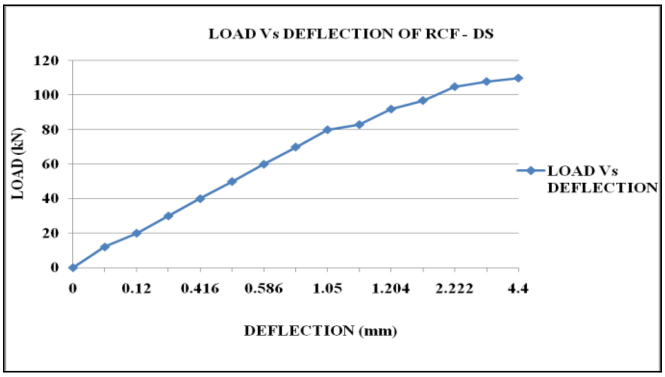


**Fig. 10 Frame with reinforcing band**

### *D. Deflection, Stiffness Degradation and Ductility Factor*

The deflection with respect to maximum load of each three frames such as RC frame without infill, RC frame with infill, RC frame with diagonal strut are shown in the figure 11. The maximum deflection corresponding to ultimate load for RC frame without infill, RC frame with infilled wall and RC frame with diagonal strut was 1.65, 1.84 and 4.42 mm respectively. From figure 11, it was observed that the deflection of RC frame with diagonal strut is 37.33 % greater than RC frame without infill because diagonal bands improve the flexibility of RC frame compare to bare frame. Stiffness is defined as the load required causing unit deflection of specimen. The stiffness degradation of these specimens are shown in figure 12. The initial stiffness of RC frame with diagonal strut is 1.04 kN/mm which is greater than that RC frame without infill as 0.91 kN/mm. It reveals that diagonal band which is allowed the stiffness of member when compare to bare frame. The ductility factor is defined as the ratio between the maximum deflection to the yield deflection. The comparisons of ductility factor of the R.C frames are shown in figure 13. The ductility for RC frame with diagonal strut is 1.23 times greater than the RC frame without infill. It proves that diagonal band which improves the ductility of RC frames when compare to bare frame.

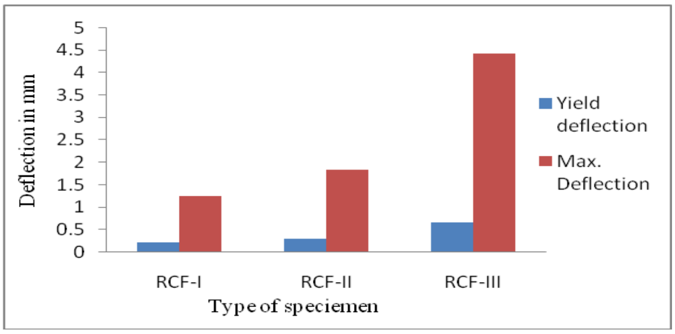


**Fig.11 Comparison of yield and ultimate deflection**


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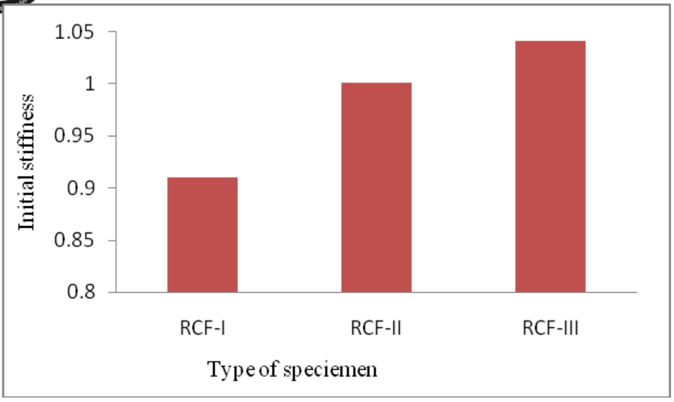


**Fig 12 Comparison of initial stiffness**

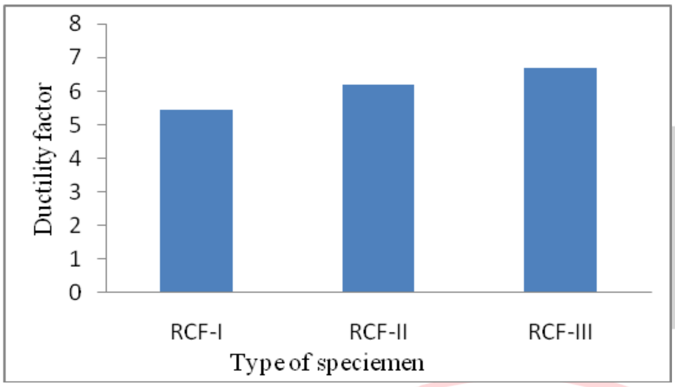


**Fig. 13 Comparison of ductility factor**

## IV CONCLUSION

The conclusion drawn based on the experimental investigation on one-tenth model scale of comparative behaviour of RC frame with infilled under static diagonal loading are discussed and stated that the ultimate load carrying capacity of RC frame with reinforcement band is 3.94 times greater than that RC frame without infill because the diagonal band takes inplane loading of framed structure. As well as, when compare the ultimate load carrying capacity of RC frame with reinforcement band is 2.68 times greater than that of RC frame with infill. Therefore, it shows that infilled wall also partially support the load carrying capacity of RC framed structure. But, the main concern in infilled wall is weak in ductility, when considering the reinforcing band the ductility of RC frame is much greater than that of frame with infill and bare frame because the reinforcing band produces the large inelastic deformation in RC framed structure. Although, it refers that the initial stiffness of the frame with reinforcement band is 1.085 times higher than that of the frame without infill. When comparing the failure pattern, RC frame with reinforcement band improve the load bearing capacity, stiffness and it is control to the soft storey failure in bare frame. Although, this diagonal strut action enhances the strength at joints and it reduces the diagonal cracking failure.

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