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Use of Steel Bracing for Minimizing Captive Column Effect of R.C. Frames

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ABSTRACT: Number of buildings is constructed with partial masonry infill for serviceable or artistic reasons. Sometimes openings have been left a window or ventilator in the wall for architectural necessities. Constructions with such partial masonry infill face serious damages because of captive-column effect at the time of earthquake. Due to complex behavior of partial infill, structures are analyzed and designed as bare frames. The purpose of this research is to investigate the behavior of Reinforced Concrete (R.C.) frames by using steel bracing under horizontal loading and to decrease the potential for captive-column damage. An experimental study is carried out on single, single storey for R.C. frames with bare and corner steel bracing. All such frames were tested up to collapse and subjected only to monotonic static lateral load to obtain an effective and possible solution for captive column. In comparison to bare, braced frames have noteworthy increase in lateral load capacity. Central bracing is more effective than that of corner bracing. For same load braced frames have considerable less deflection than bare frames.

KEYWORDS: Corner bracing, Central bracing, Lateral load, Ultimate load, Captive column.

I.INTRODUCTION

For warehouses and workshops openings are left at top portion as shown in Figure 1, columns with short gap will behave as short column during earthquake and attract larger forces and can damage the column acutely due to severe shear forces, recognized as captive column effect. Since, it is difficult to understand the strength of such partial infills. But actual structural behavior of such partial infill buildings for the duration of earthquake is with captive column effect and is one of the main reasons for the major failures of structure. The failure could be overcome by providing corner and central steel bracing as mentioned in Table 1, above the partially infill walls. The main aim in performing experiment is to observe the failure pattern and to understand the importance of bracings contribution to bear such loads.

Previous experimental research on the behavior of brick infilled R.C. structures by Yaw-jeng Ciou *et al.*[1] and Murti *et al.*[2] have shown that the structural behavior with masonry wall subject to monotonic loading on partial fill masonry wall induce a short column effect and leads to severe failures of the column. Further experimental research of Mehmat Emin Kara *et al.* [3] have shown that partially infilled non-ductile R.C. structures have shown higher ultimate strength and initial stiffness than the bare structures. Santiago pujol *et al.* [4] has shown that masonry infill walls were efficient and enhance in the strength and stiffness are 100% and 500% consonantly in comparison to the original reinforced concrete structures. Salah El - Din Fahmy Taher *et al.* [5] observed that lower location of infill structures yields the higher strength, frequency and stiffness of the system. An experimental investigation was carried out by R. Suresh Babu *et al.* [6] on the '3D' model structure to study the effect of this

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captive column effect and to decrease this effect by introducing brick insert adjacent to column face. This study indicates that due to brick insert, captive column effect is reduced, lateral capacity increases and thus preventing critical damage to the structure during earthquake. A relative study was made between experimental and analytical method and the values are found to be almost equal. C. Jayaguru *et al.* [7] carried out an experimental study two-bay ,two-storey with one-third scale laboratory models having partial infill in the bottom storey. A local retrofitting strengthening R.C. structural elements with Glass-Fibre Reinforced Polymer (GFRP) composites is adopted and is tested under quasi-static cyclic load. The control specimen showed a brittle shear failure in bottom story columns due to the induced captive-column effect while the retrofitted specimen exhibited better performance. Dubey *et al.* [8] conducted experiments to study the effect of braced and partially concrete infilled R.C. frames in comparison to the bare frames. All these frames were tested up to collapse for a possible solution of soft storey frames. It was observed that in comparison to bare R.C. frames, partially infilled frames have an increase by a remarkable amount for lateral load capacity. Based on experimental observations, a mathematical model has been proposed to calculate theoretical ultimate load for braced and partially infilled R.C. frames .Dubey *et al.* [9] studied captive column effect with steel frames and reported that bracings are effective to overcome the problem for such frames.

For each frame two models were tested and average value is considered for all experimental values. Though all the experiments were conducted on single bay, single storey braced frames, the same can be integrated for high rise framed structures.

II.EXPERIMENTAL SETUP

R.C. portal frame of single bay single story with a welded base plate of 10 mm thick was mounted on a supporting girder and rigidly bolted with four bolts of 20 mm diameter. Horizontal load is applied to R.C. frame through column of reaction frame with the help of a jack. The models tested of each category are mentioned in Table 1. The details regarding dimensions, position of proving ring, loading jack and dial gauge are highlighted in Figure 2.The frame consists of two columns of height 400 mm and a beam with a span of 600 mm. The size of column is 60 mm x 100 mm and for beam it is 100 mm x 100mm. For measurement of load proving ring of capacity 10 kN was attached for bare frames and a hydraulic jack of 500 kN was utilized for rest of the frames. Dial gauge of range 20 mm was used to measure the horizontal displacement at the beam level.

2.1 Materials for Models

The following materials were used for the frame and epoxy.

- For main reinforcement Ø8 mm, for ties and stirrups Ø6 mm were used for the R.C. frames. For bracings 10 mm square bars of mild steel was used.
- Cement, sand and coarse aggregate of 12mm in the ratio of 1:1.5:3 was used for concrete. Cubes of size 150mm × 150mm × 150mm were cast and tested to obtain the compressive strength after 28 days.
-

2.2 Test procedure

The R.C. frames were cast and after curing mounted on the reaction frame. The bolts were fully tightened to ensure the fixity of supports. The alignment of jack was checked along the beam axis. The initial reading on the proving ring and the dial gauge was recorded. The application of horizontal load was with the help of a screw/ hydraulic jack and horizontal displacement was noted down from dial gauge. The load was applied at a uniform rate. The loads and the deflections were recorded at regular intervals for each test set up. The load was applied continuously till it remains constant for a particular time on the loading gauge and then moves in a reverse order. This is called as

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plastic state condition. The collapse load corresponding to this stage was recorded as an ultimate load. Load corresponding to this stage was recorded as an ultimate load.

III. OBSERVATIONS AND RESULTS

During load application attention was paid to crack formation. The direction and progress of cracks at different load levels were recorded. The final collapse modes were photographed for full details. The compressive strength of concrete mix cubes tested after 28 days was observed to be 24.2 N/mm^2. The characteristic strength of 8 mm and 6 mm tor steel is 419 and 350 N/mm^2 respectively. The increase in lateral load capacity of braced frames R2 and R3 with respect to bare frame R1 is 167.3% and 220.8% correspondingly. The load Vs deflection curves for R1 and R2, R3 is shown in Figures 3 and 4 consonantly. These figures show that central braced is more effective than that of corner braced frames for deflection criteria. Figures 5 and 6, illustrate the crack patterns for braced frames R2 and R3 accordingly.

IV. DISCUSSIONS

The behaviour of partial infilled braced R.C. frames subjected to lateral load was studied with different patterns of steel bracings such as corner and central .It is observed that due to compressive force along diagonal compression band, tensile cracks are developed along tension column for all bare and braced R.C. frames. As the partial walls are provided and contribution of such walls with bare frame are not remarkable. So, only bare and braced R.C. frames were tested and neglected the effect of unsupported partial infill masonry wall. The cracks developed at various places are indicated by the red painted lines on frames as shown in Figure 7 .It can be observed from photo plates that failure was predominately caused due to sway mechanism. All such frames were tested up to collapse and subjected only to monotonic static lateral load to obtain a useful and probable solution for captive column effect. In comparision to bare frames, braced frames have shown a remarkable increase in lateral load capacity and it will increase stability of overall structure. Central bracing is more effective than that of corner bracing; practically any system can be implemented competently. For same load braced frames have considerable less deflection than bare frames. The main objective is to develop a sustainable structure to overcome the seismic failure due to captive column effect.

V. CONCLUSIONS

If R.C. frame is braced, then on application of lateral load at column-beam juction, the collapse mode corresponds to the sway mechanism.In comparision to bare frames, braced frames have shown a remarkable increase in lateral load capacity .All braced frames have significant less deflection in comparision to bare frames for similar loads.Though central braced system show better results than that of corner braced system, practically any system can be implement effectively as it would not hinder the required openness around the space. Based on a comparison with the bare R.C. frames, braced frames have shown an increase of 167.3% and 220.8% in lateral load capacity. It specifies that the contribution of bracings is up to a significant level for the lateral strength for such frames and efficient to overcome problem of capative column effect.Braced frames are considerably stiffned in comparision to bare frames and be a feasible solution against the problem of capative column defects.

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Table1.

Description of various frames

Sr. No.	Frame Notation	Description
1	$R1_A$ } R1 $R1_B$	Bare R.C. Frame
2	$R2_A$ } R2 $R2_B$	Corner top bracing Frame.
3	$R3_A$ } R3 $R3_B$	Central top bracing Frame.

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Table2.

Comparison of Ultimate Loads for various Frames

Frame	Experimental Ultimate Load kN	Contribution of bracings in comparison to bare R.C. frames (%)
R1	9.35	-
R2	25	167.3
R3	30	220

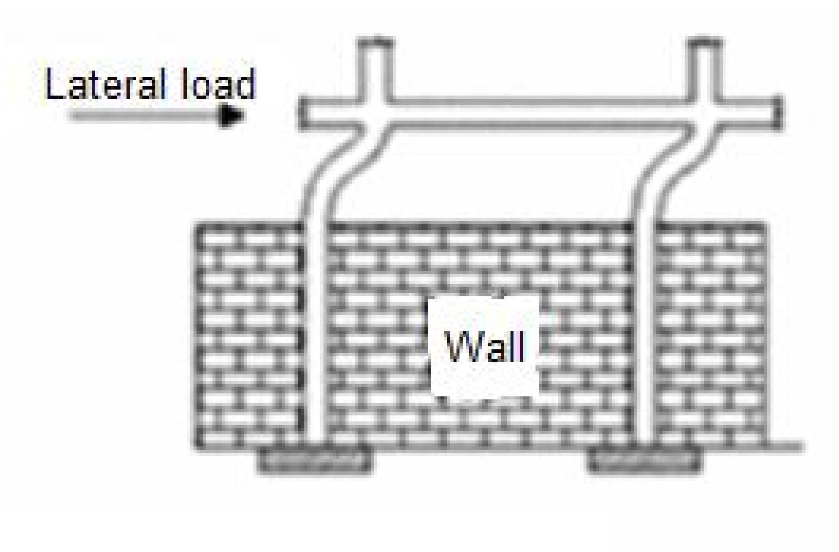

Figure1. Partially infilled frames subjected to Lateral load

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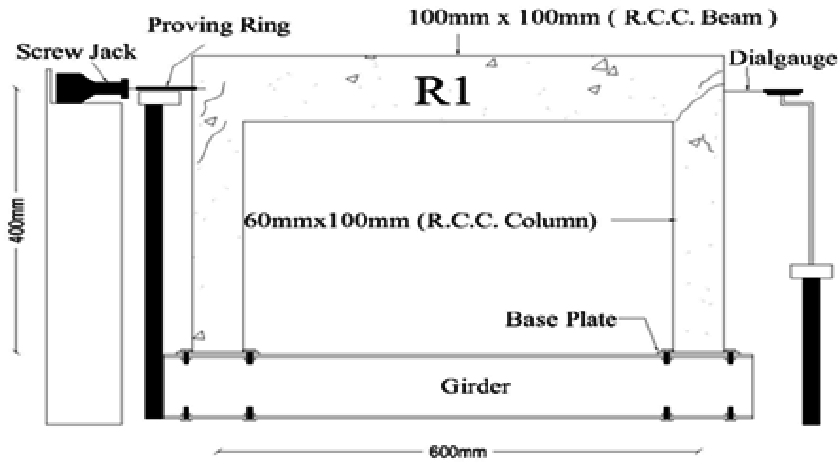

Figure2. Experimental set up

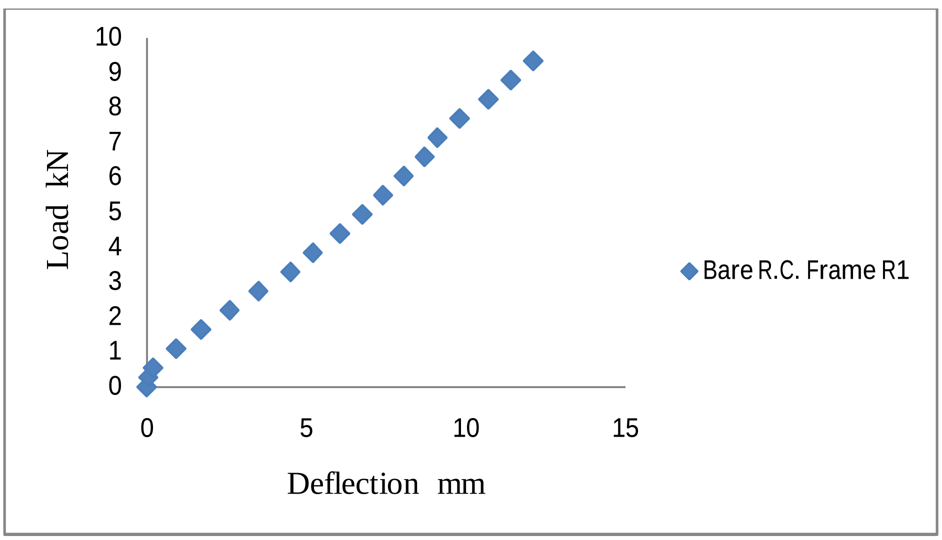

Figure3. Effect of Load over Deflection for Bare R.C. Frame

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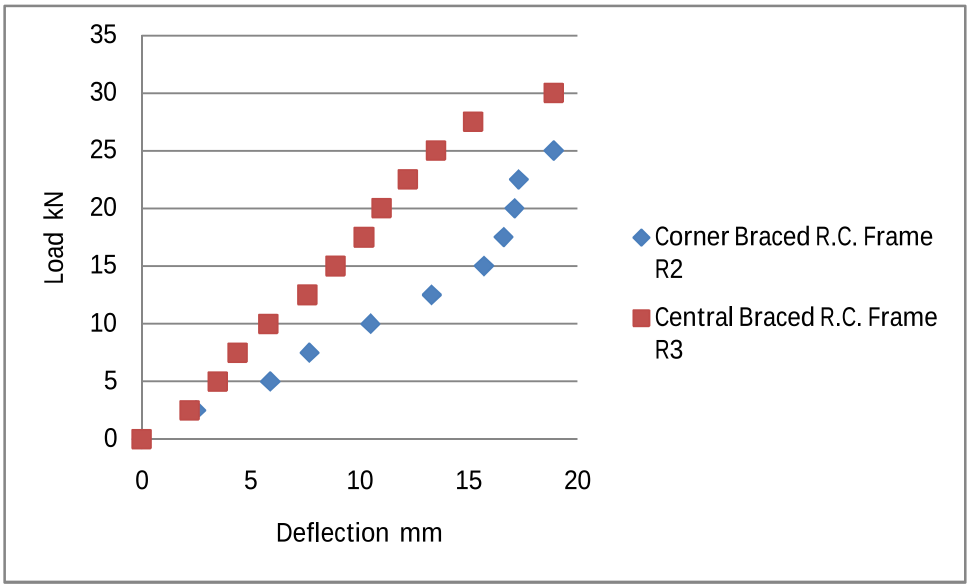

Figure4. Effect of Load over Deflection for Braced R.C. Frames

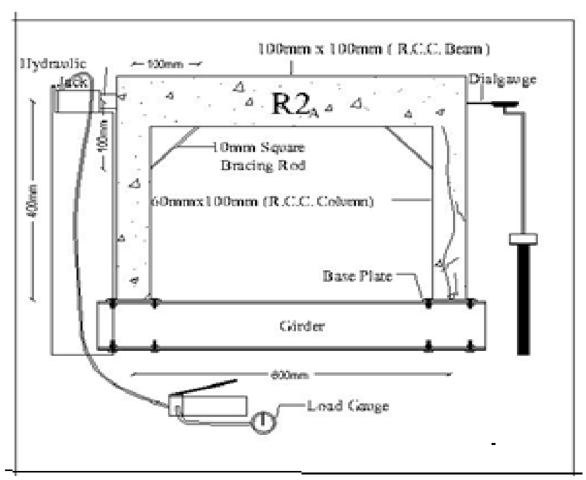

Figure5. Crack pattern for corner braced frame $R2_A$

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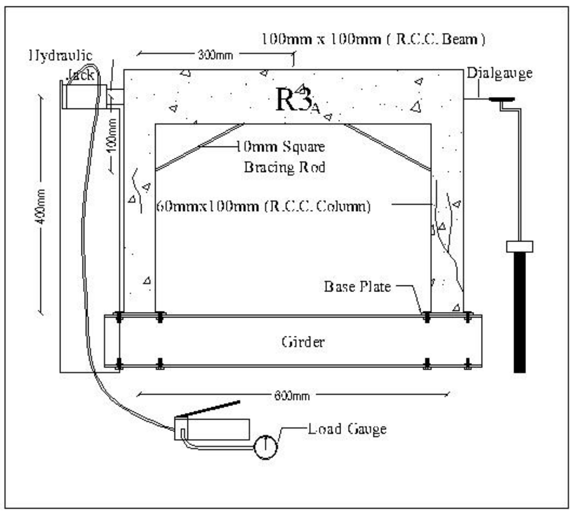

Figure6. Crack pattern for central braced frame $R3_A$

Figure7. Photograph of Corner Braced R.C. Frame $R2_B$