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PROGRESSIVE COLLAPSE ANALYSIS OF RC FRAMED STRUCTURES USING DIFFERENT TYPES OF BRACINGS

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ABSTRACT

Progressive collapse of a structure happens when significant structural load-bearing sections are suddenly removed, leaving behind failing the structural components incapable of supporting the building's weight. It occurs when a column is removed from an existing structure to provide more space and it can also result from natural and man-made factors. Without strengthening measures, column removal will result in progressive collapse. The seismic retrofitting bracing system can be employed as a defence against the progressive collapse of multi-storey buildings.

This research looks at how various kinds of bracings affect the resiliency against progressive collapse of multistorey reinforced concrete structures. The analysis is done on G+5 and G+15 storey RC buildings using the Non-linear static method, and comparisons are made with various kinds of bracings. The model is built in SAP2000 and analysed using GSA criteria. The hinge formation pattern and displacement of joints with various kinds of bracing systems are compared using nonlinear static analysis, which is produced by the unexpected removal of major load-bearing column member of ground floor from different places.

Keywords - Bracings, Non-Linear static, Progressive collapse, SAP2000.

1. Introduction

Progressive collapse refers to a complete failure of a structure resulting from the propagation of a local failure across the structure's elements. It is also known as disproportionate failure because it deviates from the original cause's path. Man-made or natural hazards such as fire, blast, earthquake, and extreme loading conditions can trigger progressive collapse or Column is removed for increase space for the room. To prevent the loss of crucial structural elements and the complete collapse of the building, it is essential for the collapsing system to have the ability to distribute the loads evenly. The main challenge lies in the structural system's incapacity to redistribute the load during collapse. Following a local failure, the structural members seek alternative load paths for redistribution, and a lack of such paths leads to complete collapse. To resist progressive collapse, techniques that provide an alternate path must be used, and ductility, redundancy, and continuity should be considered for design procedures of beams, columns, and frame connections to allow for potential redistribution of large loads and to prevent collapse [1]. In this paper bracings used for seismic retrofitting is used as a defence against progressive collapse. determining how various bracing types impact the resilience of RC buildings to progressive collapse.

Structural engineers first encountered progressive collapse in 1968 when the Ronan Point Tower was destroyed due to a human error gas explosion. The fall of concrete panels at the 18th level caused the floors above to collapse as well. This event prompted further research into progressive collapse. In recent years, much study has been conducted, primarily due to the rise in the number of victims resulting from terrorist attacks and natural disasters. Traditionally, structural engineers have focused on optimizing the most economical sections while meeting code requirements. Therefore, the majority of structures are made to withstand lateral stresses brought on by wind and earthquakes as well as gravity [2]. In conventionally designed structures, unexpected extreme loads may result in collapse. However, there are complex programs and tools available to building progressive collapse reaction simulation. Any software based on the FEMA (Federal Emergency Management Agency) can be utilized to evaluate the possibility of developing progressive collapse, and GSA (General Services Administration) regulations are utilized for the analysis of progressive collapse [3]. There are four ways for doing the analysis:

linear static, response spectrum, non-linear static, and time history [4].

The main objectives are

- To study about the RCC framed structure's nonlinear static behavior after column removal.
- To study about how various bracing types effect collapse resistance of multistorey reinforced concrete structures
- To study about different positions of column removal situations and strengthen the frame using bracings.

2. Modelling Procedure

Three-dimensional reinforced concrete structure is designed and analyzed using SAP2000. Non-linear Static analysis also known as Pushdown Analysis is employed for the analysis of braced and unbraced G+5 and G+15 reinforced concrete building based on GSA standards. In this paper we consider three types of column removal scenarios as shown in Fig.1.

Case 1: Corner Column removal

Case 2: Middle Column removal of longer side

Case 3: Middle Column removal of shorter side

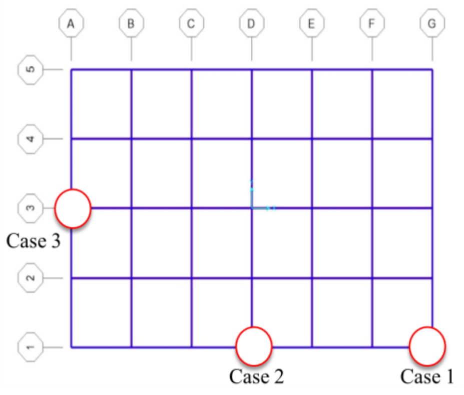

Figure 1. Plan of the G+5 and G+15 model

2.1. Design Parameters

For the analysis G+5 and G+15 storey RC structure model is taken. Bay size is taken as 4 m in both directions. Building plan size is 24x16 m. Base to ground floor height is taken as 3.5 m and typical floor height is 3 m. The column size and beam size are designed as 700x700 mm and 450 x 400 mm. The bracings are designed as steel angle section of 150x150x12 mm. The foundation are designed as fixed connection and the bracings are designed as pinned connection at both ends. The compressive strength is 25 N/mm^2. Fe415 grade steel is used.

2.2. Structural Loading

For the analysis Indian standard codes IS456, IS875, IS1893-2002 are used along with GSA guidelines. Live load at typical floor and roof are 2 kN/m^2 and 1.5 kN/m^2. Wall load on the typical floor is 14.5 kN/m^2. The Parapet wall load on the terrace is 4.9 kN/m^2. Floor finish is taken as 1.0 kN/m^2. The building is designed for low seismic area of 0.16 zone factor and Soil type as 2.

3. Static Non-linear Analysis

Static Non-Linear analysis can be analysed by load-controlled or by deformation-controlled method. This study employs a load-controlled approach for analysis. i.e., the load is added step by step on the structure until maximum load is attained or structure collapse. First do concrete design and finalize the reinforcement then apply the hinges properties to beams and columns. Use auto hinge properties of Table 5-6 of FEMA-356 from SAP2000. Then define nonlinear case with GSA Load combination as 2(DL+0.25LL). Then create case of column loss and add bracings to the model. Then perform nonlinear static analysis and watch the pattern of hinge creation and displacement of the joints.

To define the nonlinear hinges of beams and in the columns, a normalized force displacement curve is utilized, which is illustrated in Fig. 2. The acceptance criteria established by GSA are placed on the line BC of the force displacement curve and include three categories: Immediate Occupancy with low damage, Life Safety represents without danger to the life and Collapse Prevention.

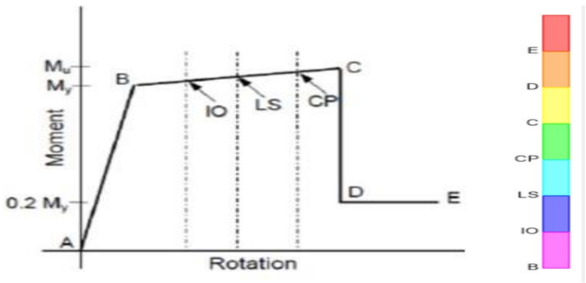

Figure 2 . Hinge properties as Table 5-6 of FEMA-356

4. Results and discussions

Static nonlinear analysis is performed on various column removal case with braced and unbraced frames. X-bracings, V-bracings, Inverted V braces, Diagonal braces and K-bracings are used as the retrofit against progressive collapse. Two types of bracings system are used they are bay-wise bracing system and floor-wise bracing system. The hinge formation pattern and Vertical joint displacement on the column removed point is observed.

4.1. Hinge formation pattern

The hinge creation pattern on column removal case with braced and unbraced frame is observed and analyzed they are;

4.1.1 Corner column removal

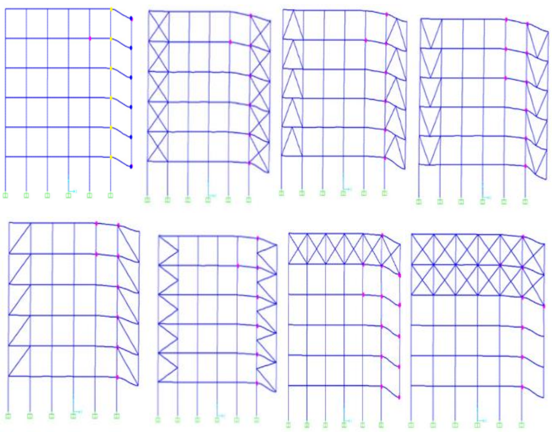

Figure 3. The hinge creation pattern on G+5 building

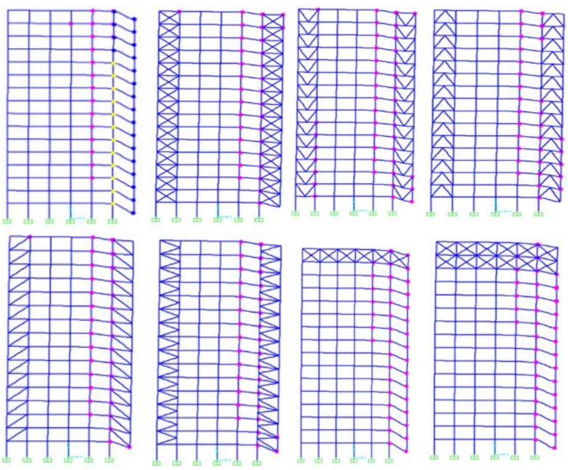

Figure 4. The hinge creation pattern on G+15 building

The hinges formed at beam on G+5 and G+15 storey RC building without braces reach the hinge's maximum capacity as we observe in Fig.3 and Fig.4. Using various kinds of bracings as bay-wise bracing system and floor-wise bracing system with X-bracings show hinges of performance of Immediate occupancy which corresponds to low damage on building.

4.1.2. Middle column removal on longer side

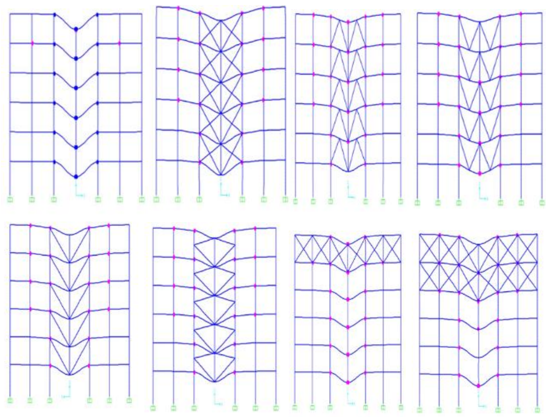

Figure 5. The hinge creation pattern on G+5 building

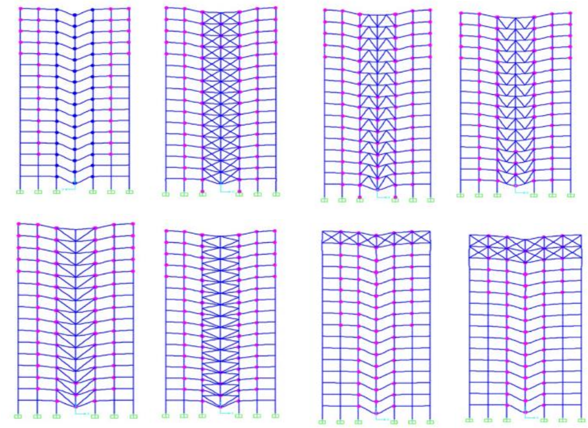

Figure 6. The hinge creation pattern on G+15 building

The hinges formed at beam on G+5 and G+15 storey RC building without brace attain performance standard for life safety, on adding braces as bay wise and floor wise bracing system the hinges formed are of performance of Immediate occupancy as in Fig.5 and Fig.6.

4.1.3. Middle column removal on shorter side

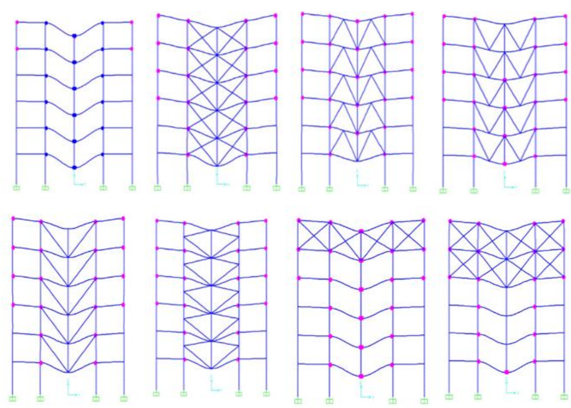

Figure 7. The hinge creation pattern on G+5 building

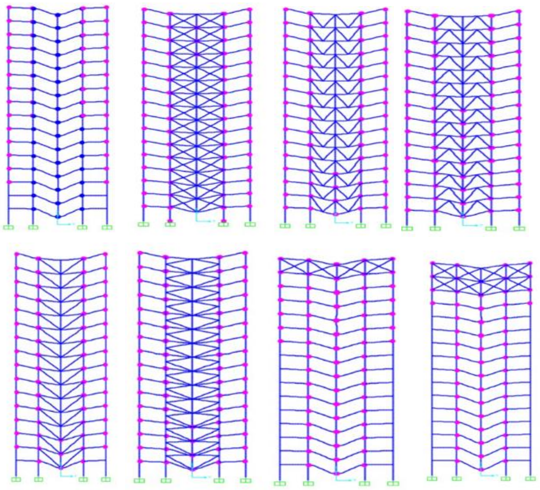

Figure 8. Hinge creation pattern on G+15 building

The hinges formed at beam on G+5 and G+15 storey RC building without brace reach Life safety level, on adding braces as bay wise and floor wise bracing system the hinges formed are of performance level of Immediate occupancy as we observe in Fig.7 and Fig.8.

4.2 Vertical Joint displacement

The vertical Joint displacement at the location of an eliminated column of various column removal cases with and without braces are observed as;

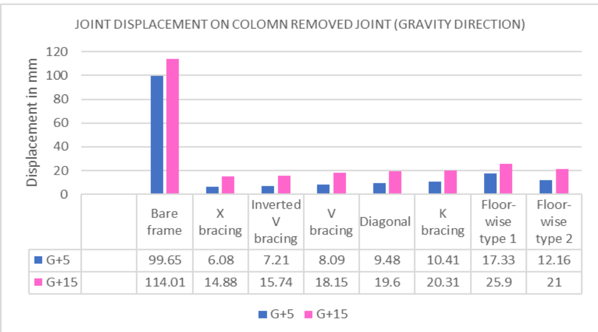

Figure 9. Corner column removal scenario

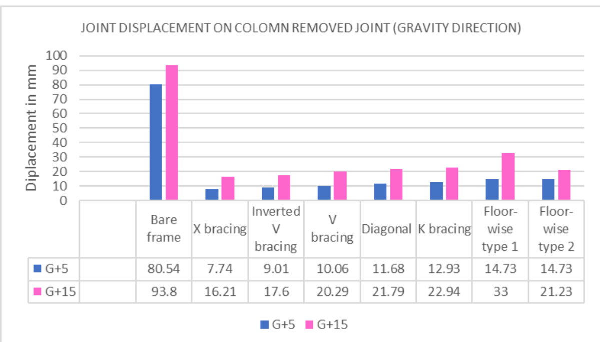

Figure 10. Middle column on longer side removal

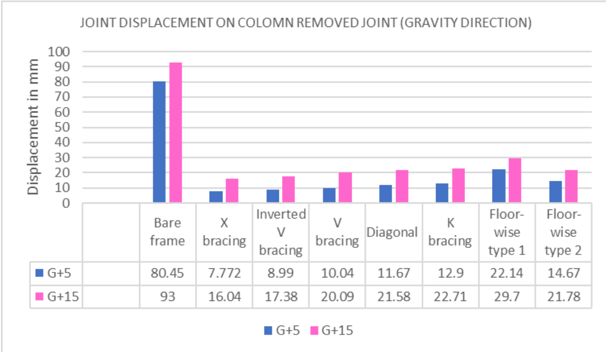

Figure 11. Middle column removal on shorter side

Findings indicate that with the number of storeys the displacement will increase. On a situation for removing a corner column, the X-bracings used as bay-wise bracing system have low displacement as compared to other bracings and floor-wise bracing system with X-bracings as we observe in Fig.9. On both middle column removal case the X-bracings used as bay wise bracing system have low displacement as compared to other bracings and floor-wise bracing system with X-bracings as we observe in Fig.10 and Fig.11.

5. Conclusion

From the result we can understand that the bracings help to retrofit the building to prevent the structure's progressive collapse. The severity and number of hinges are decreased on using bracings. Among the braces, X-bracings performed well to increase the stiffness in the frame and decreases the vertical joint displacement. Bay wise bracing system has low displacement compared to floor-wise bracing system. The floor-wise bracing system is found economical for the three column removal cases because it reduces deformation using less number of braces. The deformations can be minimized by including the bracings to more floors which is recommended.

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