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Wrecking and Pushover Analysis of Reinforced Concrete Framed Structure

Subramanya P G [1], ARYAVARDAN [2]

[1] Professor, Department of Civil, SJM Institute of Technology, Chitradurga, Karnataka,

[2] P G scholar, Department of Civil, SJM Institute of Technology, Chitradurga, Karnataka, India

ABSTRACT

Progressive collapse occurs when key members of a supporting structure are separated due to accidents or terrorist attacks, causing the remaining structural elements to fail. This study conducted linear and non-linear static analysis on a reinforced concrete frame structure to determine its ability to prevent growth and save lives in an accident. The results showed weak connections and failure modes as load strength increased. The model was found to be safe according to GSA guidelines and could withstand explosions, making the stone more affordable and saving lives. Improvements in the design of the long beam and plastic hinges could further enhance safety..

Keywords: Pushover, accidental avoid, Demand Capacity Ratio, Wrechking pushover, concrete

1. INTRODUCTION

Progressive collapse refers to the propagation of an initial localized crack, similar to a chemical reaction causing a portion or entire building to fail. It is characterized by the eventual failure being disproportionately greater than the failure that initiated it. ASCE Standard 7-05 defines aging as spreading the initial failure zone from one season to the next, eventually directing to the failure of the entire structure or large portion of it. Designing buildings that resist progressive collapse may require analytical methods not used in design. The project aims to provide construction professionals with ideas to reduce the risk of growth in buildings subject to abnormal characteristics. Although progress in the construction industry has improved, there are still areas of uncertainty in the construction process, leading to environmental stress and efficiency. Risk cannot be eliminated but must be controlled. A risk-based assessment and decision-making process is essential to reduce losses. Historical data suggests that the risk of a building collapsing is very low, but the risk of death or serious injury is significant if the building collapses partially or completely.

Figure 1 Ronan Point building after collapse, London 1968.

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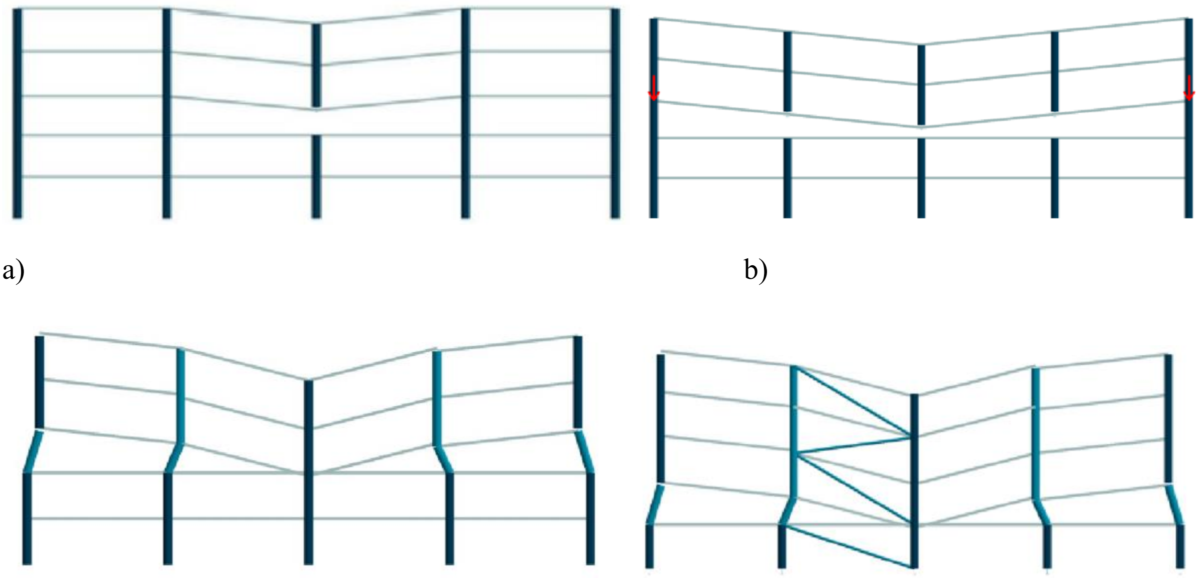
Progressive collapse refers to the spread of structural failure due to an initial localized event, causing a chain reaction resulting in a disproportionately large portion of the structure collapsing. There are several types of progressive collapse, each based on how the failure propagates through the structure. Pancake collapse occurs when an upper floor or roof fails, causing cascading failure of successive floors. Zipper collapse starts at one point of a structural element and propagates along it, similar to falling dominoes. Domino collapse occurs when one vertical structural element tips over, causing adjacent elements to fail in sequence. Instability collapse occurs when a structure loses its stability due to buckling or lateral forces. Mixed mode collapse can involve multiple types of failures.



a) b)

c) d)

Figure 2 a) Pancake type b)Zipper type c) Domino type d) instability collapse

2. LITERATURE REVIEW

This paper focuses on the seismic vulnerability of reinforced concrete structures by applying pushover analysis techniques. The study evaluates the performance of various RC frames subjected to lateral loads and identifies weak points in structural design. [1]

The research explores retrofitting techniques for aging RC buildings using pushover analysis. It highlights how the method helps in identifying deficiencies and improving seismic resilience by applying reinforcement solutions. [2]

The study investigates performance-based seismic design using pushover analysis to assess the behavior of multi-story reinforced concrete frames. Results show how frame irregularities affect the failure mechanism.[3]

This paper addresses progressive collapse scenarios in RC frames due to extreme loadings like explosions and wrecking. The use of pushover analysis helps predict failure sequences and structural vulnerabilities.[4]

The research focuses on nonlinear static pushover analysis for RC frames with plan and vertical irregularities. Findings suggest that irregularities significantly influence collapse patterns and structural performance.[5]

The paper compares pushover analysis with nonlinear dynamic analysis for assessing the seismic performance of RC frames. Results demonstrate the effectiveness and limitations of pushover methods for different seismic intensities. [6]

This study examines various wrecking methods for RC structures and the importance of pre-demolition structural analysis, including pushover analysis, to ensure safety and efficiency during demolition processes. [7]

3. METHODOLOGY & ANALYSIS

This analysis focuses on a residential live RCC building with a height of 19.5m and area of 25.02mX 28.4m. The building has 6 columns and 2 beams, with cross sections varying throughout. Floor slabs are 150mm thick plates, walls are 115mm thick on beams, and supports are fixed. Linear analysis is conducted on each model.

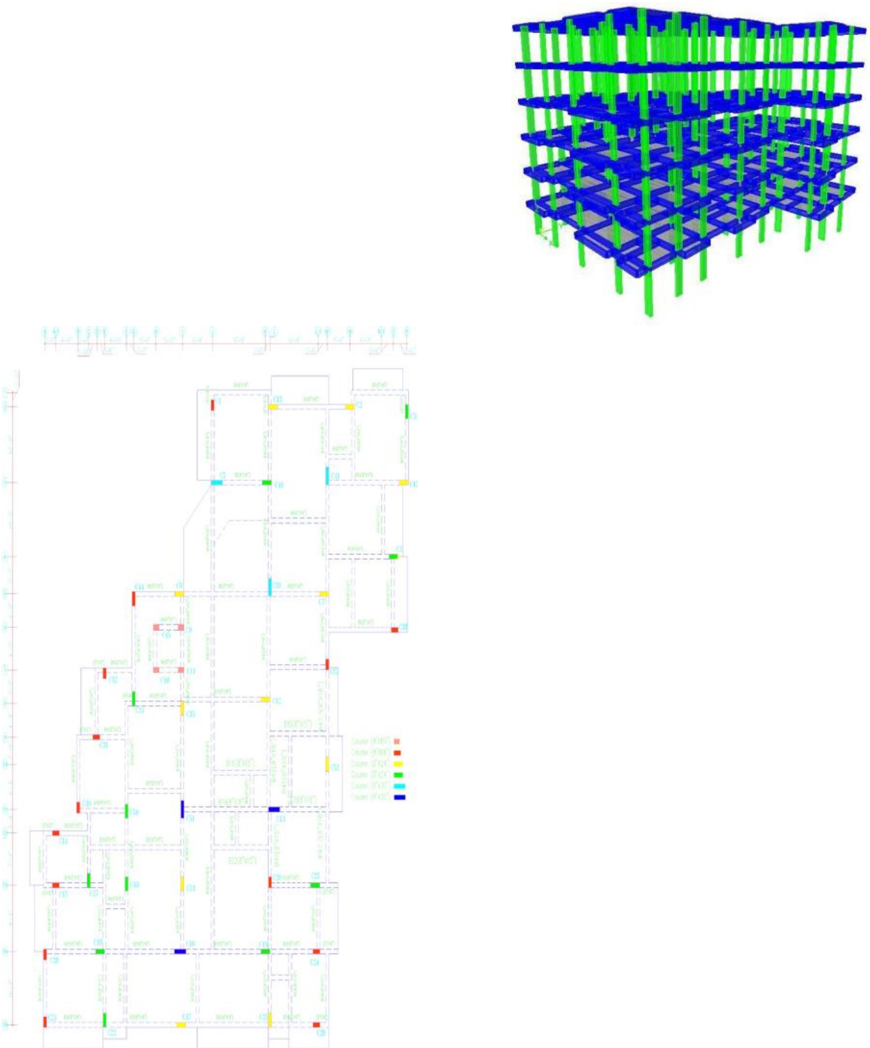


Figure 3 3D diagram of RC framed structure and Plan of framed RC Structure with different column and beam cross section

Types of load considered for analysis during earthquake or accidents are as follows

The study evaluates the progressive collapse capacity of a six-story symmetrical concrete building using linear static analysis. The building was designed in ETABS 2013 for IS 1893 load combinations and then separated linear static analyses were performed on each extraction scenario. Bending application capacity ratios are calculated for all slabs for column failure. The dead load, live load, earthquake load, and wind load are obtained from IS 875. The reinforced framed structure in earthquake zones 2 is designed using the ETABS program for dead, live, wind, and seismic loads.

The demand capacity ratio (DCR), member force, and strength are calculated using the Area of Steel obtained in the design results of the ETABS program according to IS 456-2000 code.

Estimation of loads in the tool etabs are tabulated in table 1 and the calculations are given below,

Designed Wind Speed, Vz [IS 5.3] $Vz = Vbk1k2k3Vz$ = 43.12kN

Lateral Loading

Designed Wind Speed, Vz [IS 5.3] $Vz = Vbk1k2k3Vz$ = 50

Designed Wind Pressure, pz [IS 5.4] $pz = 0.6Vz2$

Table 1 Calculated base shear

Direction	Period Used (sec)	W (kN)	Vb (kN)
X	0.329	14975.05	623.96
Y	0.35	14975.05	623.96

The loads which are applied on the building are

- The nonlinear static type
- Displacement is applied according to the codes as:
- For dead ,live
  - H/350 = 19500/350 = 55.714mm
- For EQ loads
  - H/250 = 19500/250 =78mm
- For EY loads
  - H/250 = 19500/250 =78mm
- For wind loads
  - H/500 = 19500/500 =39mm

Table 2 Nonlinear static loads

Load ID	Type of Load
DEAD	Nonlinear Static
PUSH1	Nonlinear Static
PUSH2	Nonlinear Static
PUSH3	Nonlinear Static

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4. RESULTS AND DISCUSSION

This chapter presents results from linear and nonlinear static analysis on a structure's vulnerability, including soil types in seismic zone II, beam-door application capacity ratio, and steel reinforcement percentage, after removing Class II columns resting on soil.

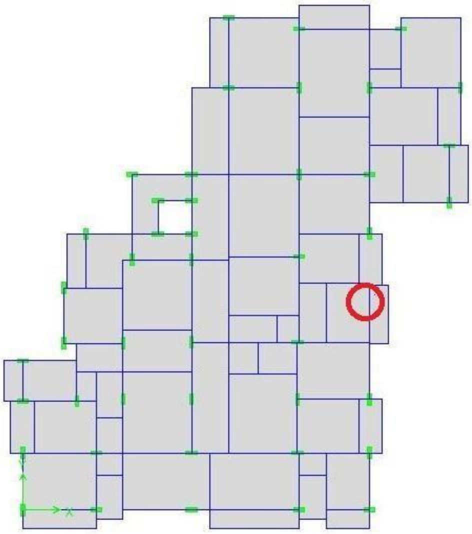
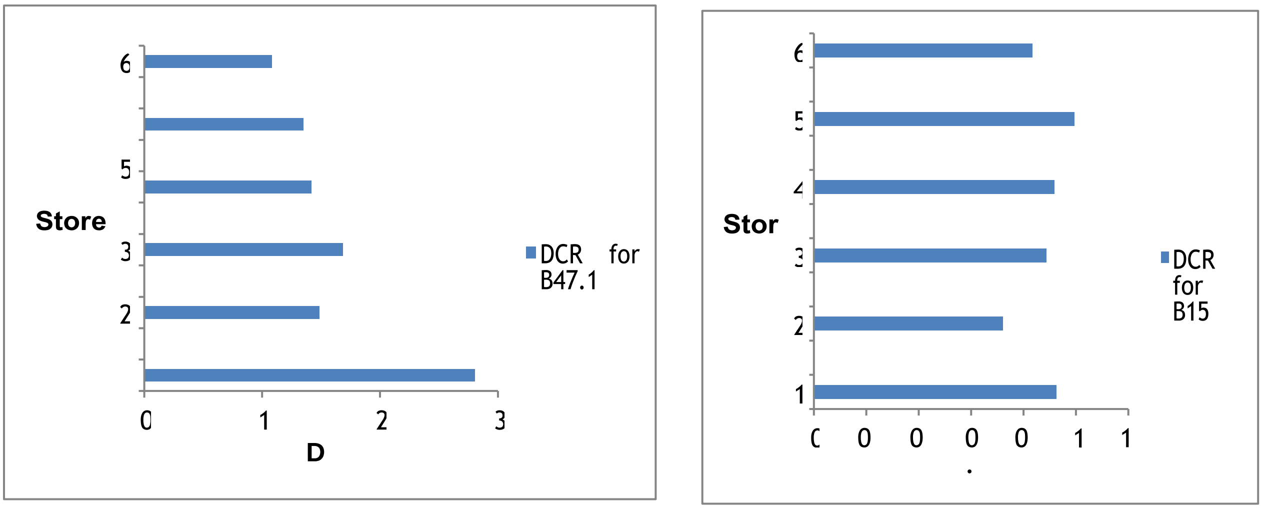


Figure 4 plan of framed RC section where column C52 is removed

4.1 **Graphical representation of DCR values of beams connected to column C52**



a) b)

Figure 5 a) DCR of beam 47.1 b) DCR for B15

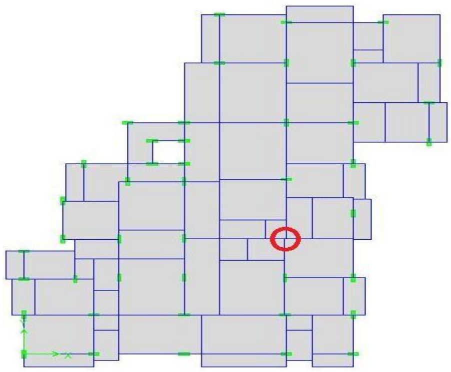


Figure 6 Plan of framed RC section where column C52 is removed

4.2 Graphical representation of DCR values of beams connected to column C13

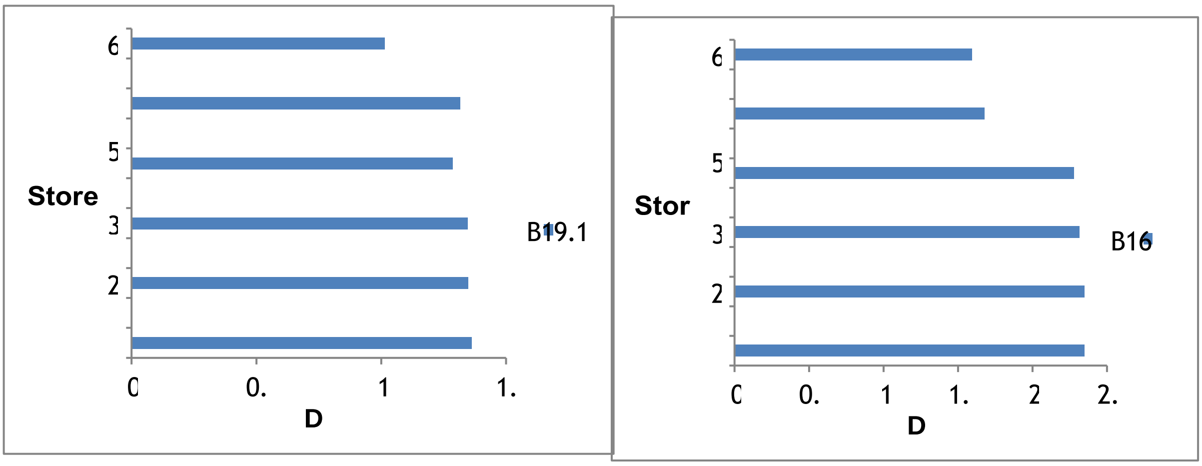
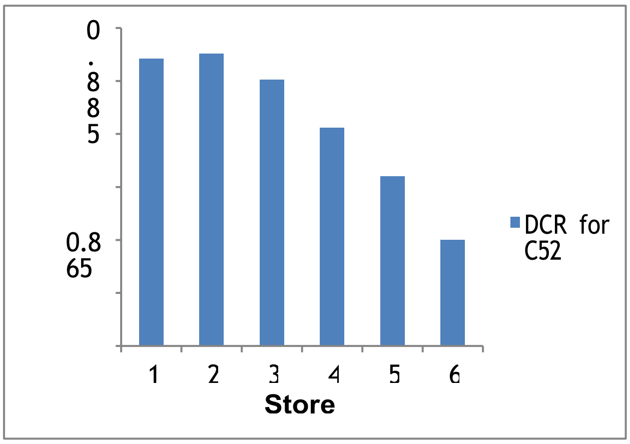


Figure 7 DCR of beams

From the graphs, it is noticed that the demand capacity ratio of C52's adjacent columns is more than 2 hence it is observed removing external column of the plan is not safe to avoid progressive collapse all the adjacent columns of C52 (fig 4.1) have to be reinforced additionally. To reduce effect of this corner column collapse increase the stiffness of the nearby members according to requirement.

4.4 Demand -Capacity Ratio for Column C13

From the graphs, it is noticed that the demand capacity ratio of C13 adjacent columns is less than 2 which indicates that all columns have the potential to resist progressive collapse.



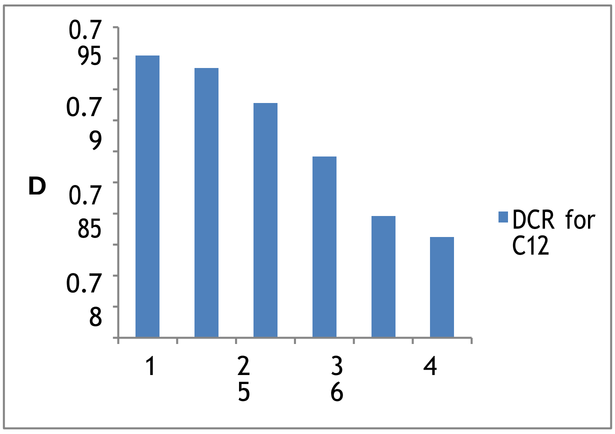
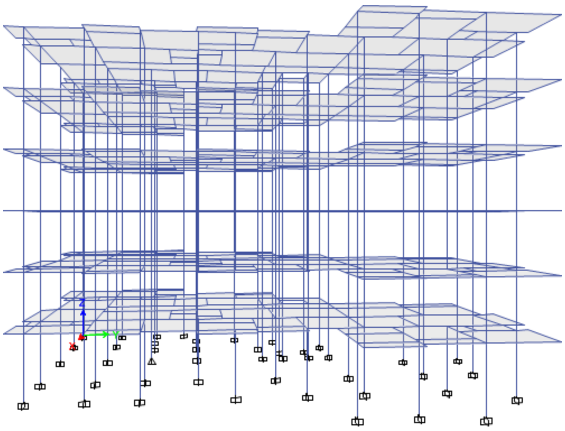


Figure 8 DCR for columns

From the graphs, it is noticed that the demand capacity ratio of C13 adjacent columns is less than 2 which indicates that all columns have the potential to resist progressive collapse.

4.5 Pushover analysis

This subsections shows pushover analysis with presence of C52 and removal of C52 in ETABS software. The ETABS software is used for linear static analysis on the RCC frame, followed by non-linear static analysis, and the construction of a hinge, as shown in Figure 9.



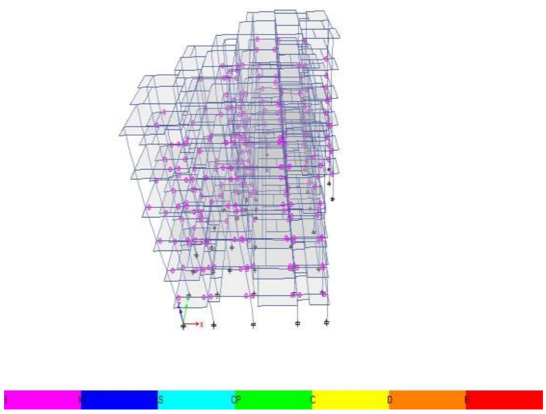


Figure 9 Linear analysis of RCC Frame and formulation of hinges

Removal of column C52 is as shown in figure 10. The ETABS software is used for linear static analysis on the RCC frame, followed by non-linear static analysis, and the construction of a hinge shown in figure.

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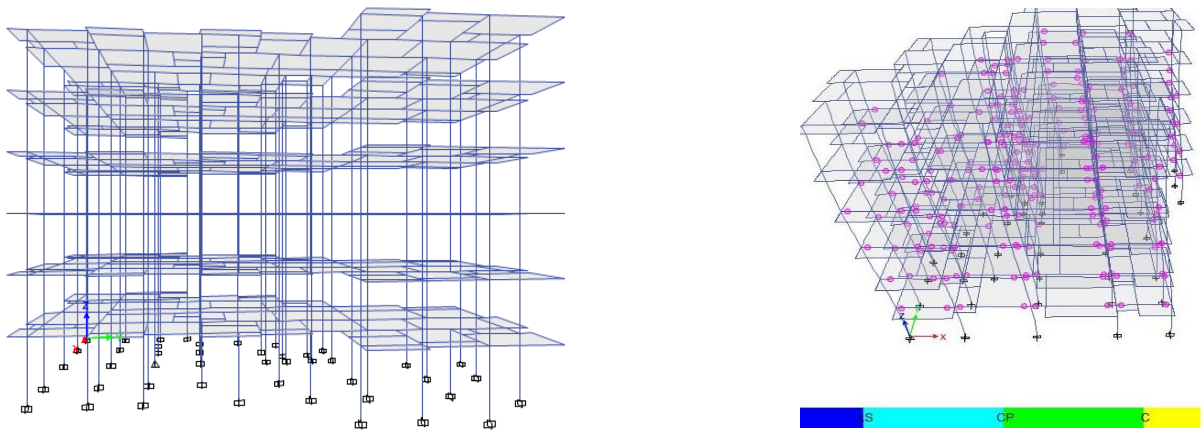

Figure 10 Linear analysis of RCC Frame and hinges are introduced

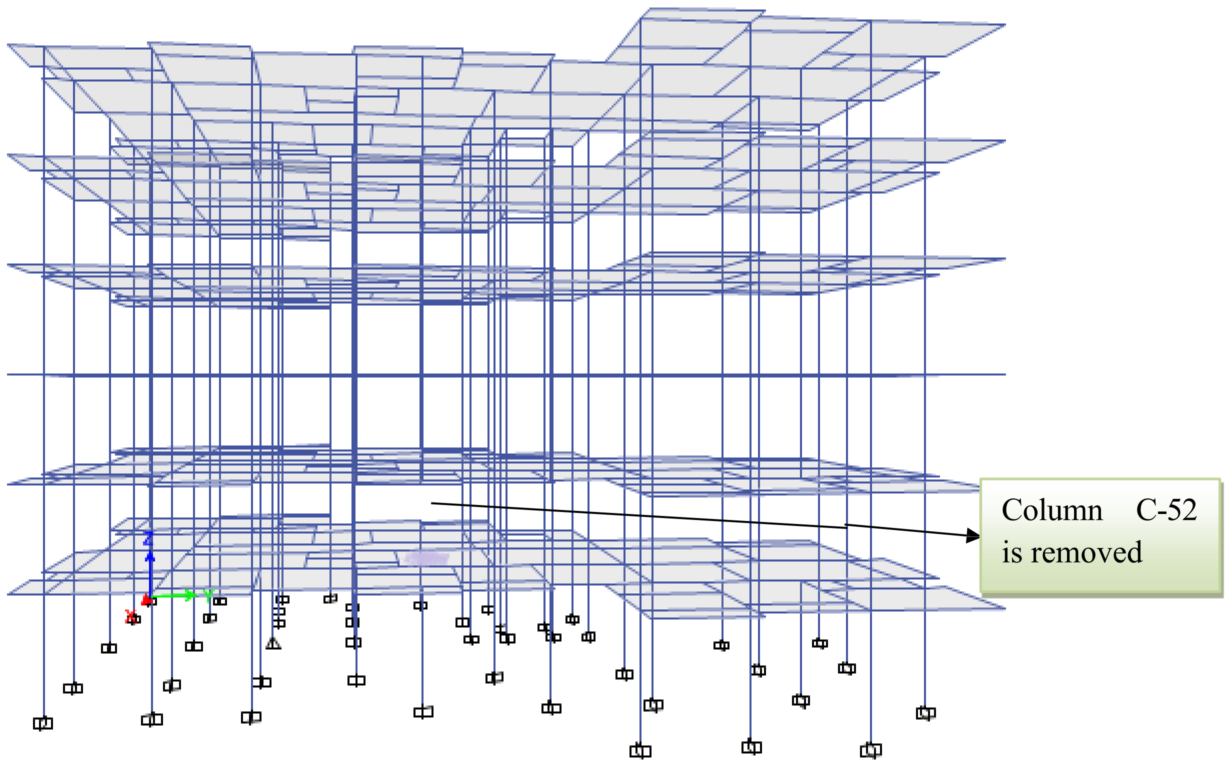

Figure 11 Linear static analysis of RCC Frame after column removal

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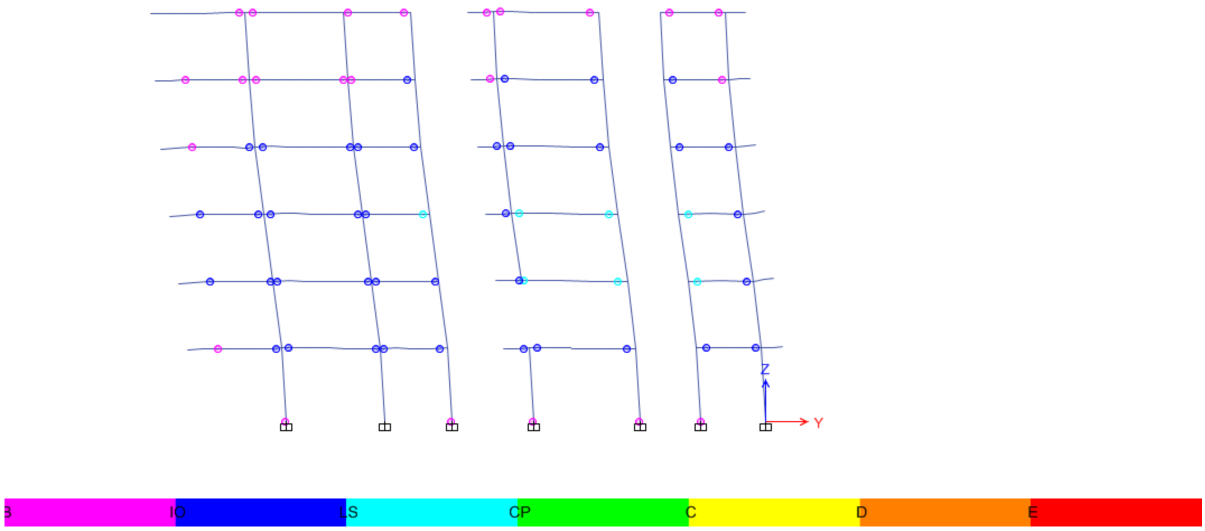

Figure 12 Formation of hinges at final push in cross section view after column removal

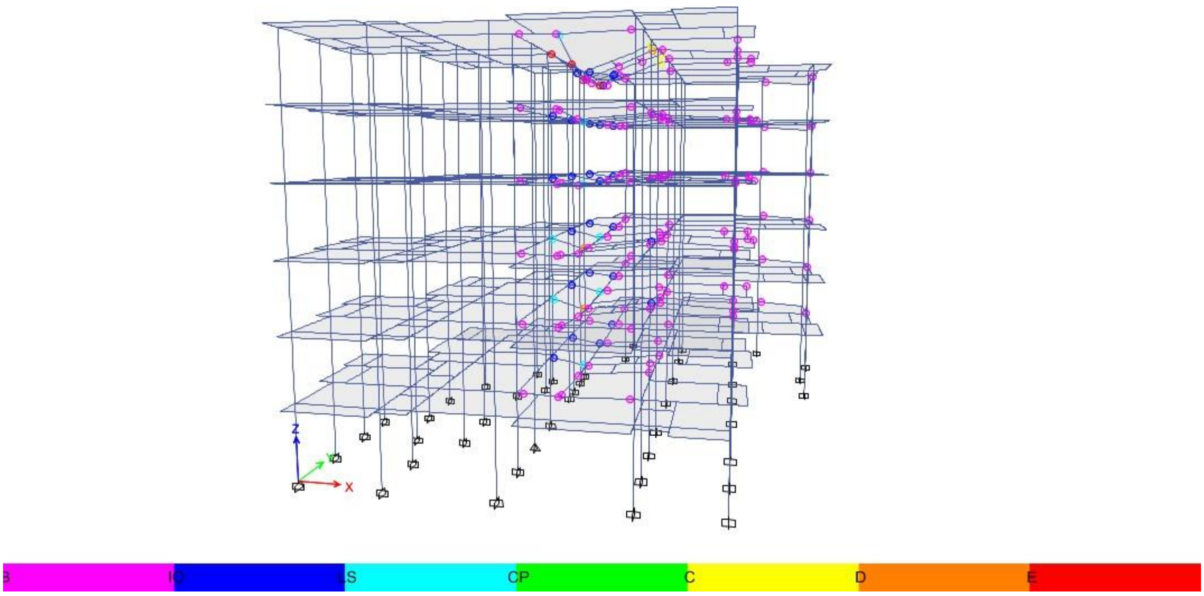

Figure 13 Formation of hinges at dead load for column removal

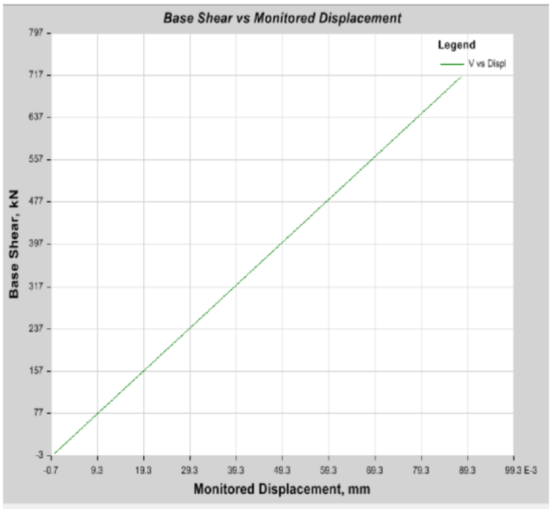

Figure 14 Formation of hinges at final push after removal of column

According to GSA guidelines, the beams in the structure should meet Collapse Protection (CP) performance levels, while columns should meet Life Safety (LS) levels. In this case, most hinges are located on the executive level. Under dead load, two hinges form in the beam at its bearing capacity, which can be addressed by strengthening the beam components to meet CP levels. These hinges do not pose a threat to the structure. Structural collapse typically occurs when three hinges exceed their strength limits. All ties are secure, indicating the structure will remain stable without slipping.

5. CONCLUSION

The study examined a 6-storey reinforced concrete structure in earthquake zone II using GSA guidelines for progressive collapse analysis. The structure's performance was assessed by removing critical columns, revealing acceptable stability. However, the removal of external column C52 increased the risk of failure due to increased load demands. To prevent system failure, adequate support and reinforcing substandard beams are crucial.

5.1 Future scope

This analysis method can be used for controlled demolition of multistoried buildings, considering infills and other factors. It can be extended for non-linear time history analysis and user-defined hinge properties. The method can be applied to various earthquake zones and soil types, preventing collapse in structures with any geometry. Dynamic analysis can account for cyclic behavior, strength degradation, and dynamic collapse. The analysis can be conducted for different earthquake zones and worst combinations.

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