



PROGRESSIVE COLLAPSE ANALYSIS OF TYPICAL REINFORCED CONCRETE FRAMED STRUCTURE

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Abstract: This study presents a comprehensive examination of progressive collapse analysis in a reinforced concrete (RC) framed structures, using Extended 3D Analysis of building System ETABS software package 2018, in conjunction with the General Service Administration (GSA). The ETABS software is employed to facilitate linear static simulations of the RC framed structure subjected to a range of loading scenarios, such as blast and impact events. Subsequently, the GSA method is applied to assess the structural response and redistribution of loads following local damage. The DCR method is then utilized to investigate the demand-capacity ratio of critical structural elements, aiding in the identification of vulnerable components and informing necessary design modifications and retrofit strategies. The primary objective is achieved by comparing the DCR values of structural members allowing us to comment whether the structure will enter the collapse state. Incorporating this analysis while designing will help for safer Structural Designs.

Index Terms – Progressive collapse, Demand capacity ratio (DCR), Linear Static Analysis, GSA Guidelines, Column removal.

I. INTRODUCTION

The removal of one or more vertical load-carrying elements (usually columns) causes building structures to gradually collapse. When a column is lost because of an earthquake, fire, car crash, or other man-made or natural disaster, the weight of the building (gravity load) shifts to the columns next to it. A portion of the structure will collapse if these columns are not built to withstand and disperse the increased gravity stress. The vertical load-carrying members of the structure will continue to fail until the additional acting loading is stabilized. As a result, a substantial part of the structure may collapse, causing greater damage than the initial impact.

This research begins with evaluating the General Services Administration (GSA) Progressive Collapse Analysis and Design Guidelines (2003). The GSA guidelines provide general formulas and conditions that determine what members of a structure are susceptible to progressive collapse. Specifically, the demand-capacity-ratio (DCR) is used by the GSA guidelines to determine if individual members will fail leading to progressive collapse. This research analyses and investigates the progressive collapse of an 8-floor structure using the 2003 GSA guidelines.

A G+7 floor building is modelled in ETABS and results are generated for different load combinations for intact and altered RC structures the results are generated as per GSA guidelines and are compared based on DCR values to evaluate the progress of collapse.

II. GENERAL SERVICE ADMINISTRATION GUIDELINES

This guideline aims to prevent global failure, or the breakdown of the entire structure, by ensuring that when member failure happens at the beginning, it is referred to as local failure and that it may be controlled at some time.

Columns are removed as specified in GSA

Case 1: Removal of column on external longer span of structure

Case 2: Removal of column on external shorter span of structure

Case 3: Removal of interior column

Case 4: Removal of corner column

The design is done as per IS: 456 codes using ETABS. As per the guidelines loading is taken as $2[DL+0.25LL]$ after removal of column case.

Where, DL= self-weight and LL= Live Load

According to GSA structural members are safe if the Demand to capacity ratios is within the permissible limits. According to G.S.A, the permissible value of DCR value is limited to 2 for regular structure and 1.5 for irregular structures.

DCR= demand by the member/Capacity of the member

Demand by member=Force taken by member

Capacity of member= Maximum (Ultimate) force taken by member

The forces may be Bending moments, Shear forces or any other combined forces.

III. METHODOLOGY

A rectangular typical structure is considered of 8 storeys with bay size of 5meters in X and Y direction Height of each storey is 3 meters with 5 columns in shorter bay and 6 columns in longer bay.

The details of the building are as follows,

Material information: Concrete used is of M30 grade, $f_{ck} = 30 \text{ N/mm}^2$

Reinforcement steel, $f_y = 500 \text{ N/mm}^2$

Slab thickness – 150 mm

Wall thickness – 300 mm

Beam Size: 300 X 450 mm

Column dimension: 300mm X 600mm

450mm X 600mm

Load Consideration: Live load = 3 kN/m²

Wall load = 13.8 kN/m

Floor finish = 1.5 kN/m²

Parapet load = 3.75 kN/m

Earthquake loads: Zone factors = 0.24 (Zone 3)

Soil type I, II, III, response reduction factor = 5, Importance factor = 1

Linear static analysis is carried for the following cases,

Case 1: Removal of column on external longer span of structure

Case 2: Removal of column on external shorter span of structure

Case 3: Removal of interior column

Case 4: Removal of corner column

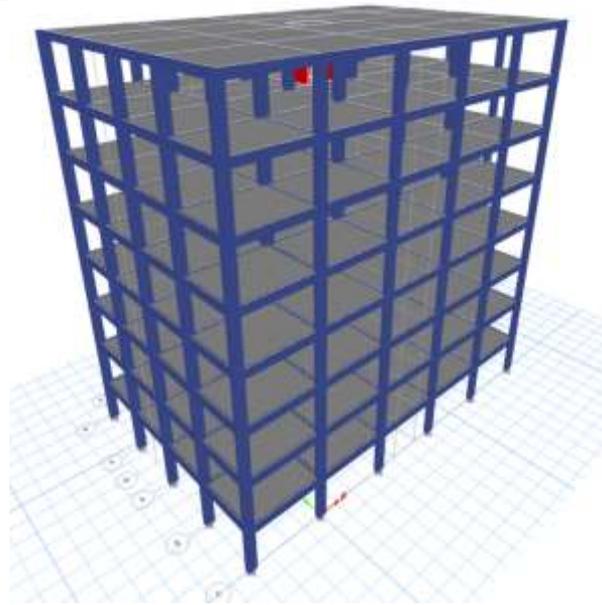


Fig. 1. 3D model of an 8-storey typical building

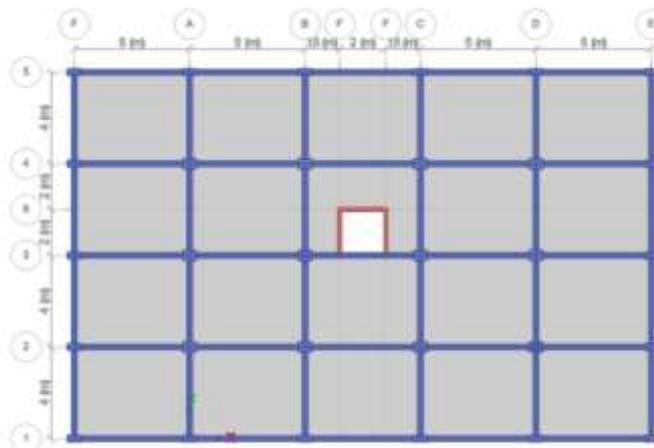


Fig. 2. Plan of typical building

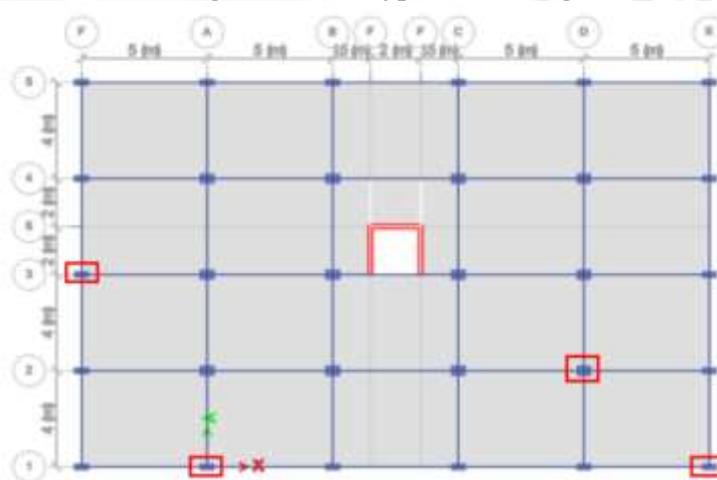
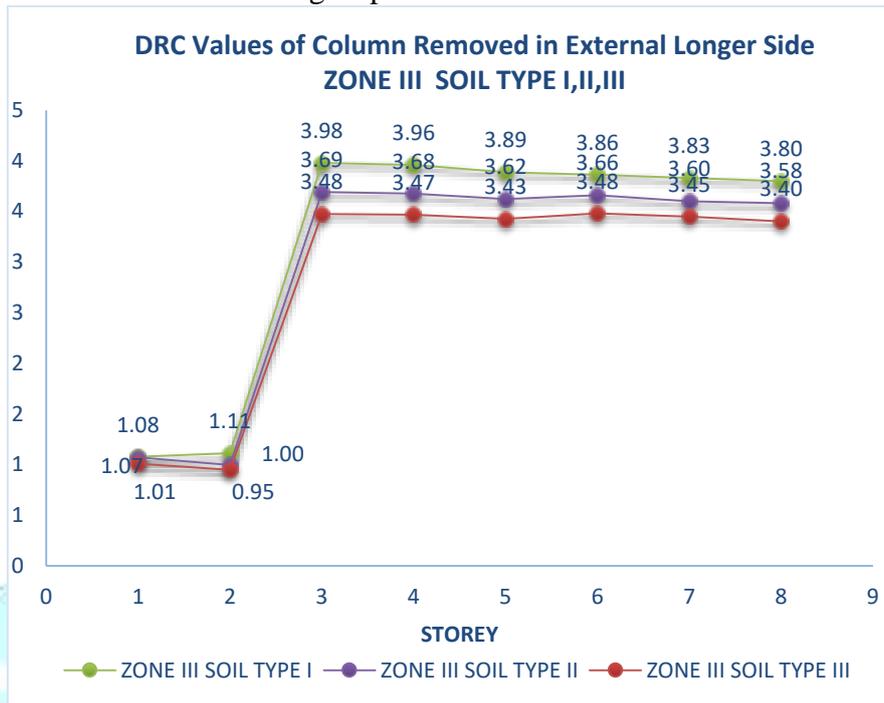


Fig. 3. Location of column removal

IV. RESULTS AND DISCUSSION

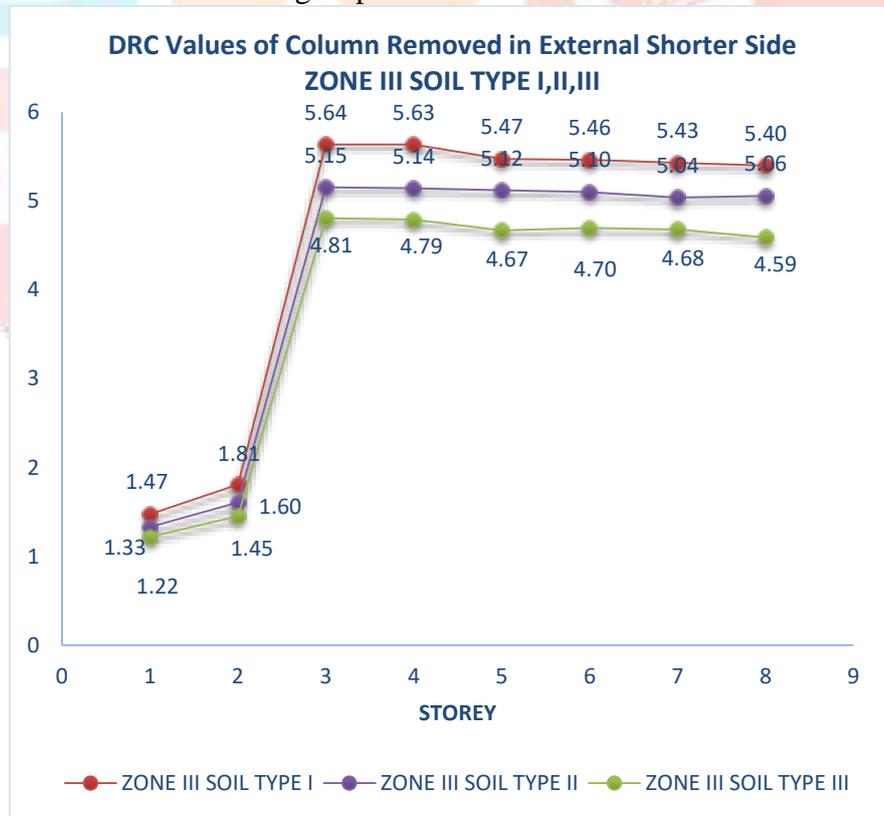
To analysis the state of progressive collapse columns are removed at different locations for zone 3 in all types of soil and the variation of bending moment is observed for all floors and the DCR values are calculated. The graphs are plotted for all the cases as DCR v/s Storeys.

Case 1: Removal of column on external longer span of structure



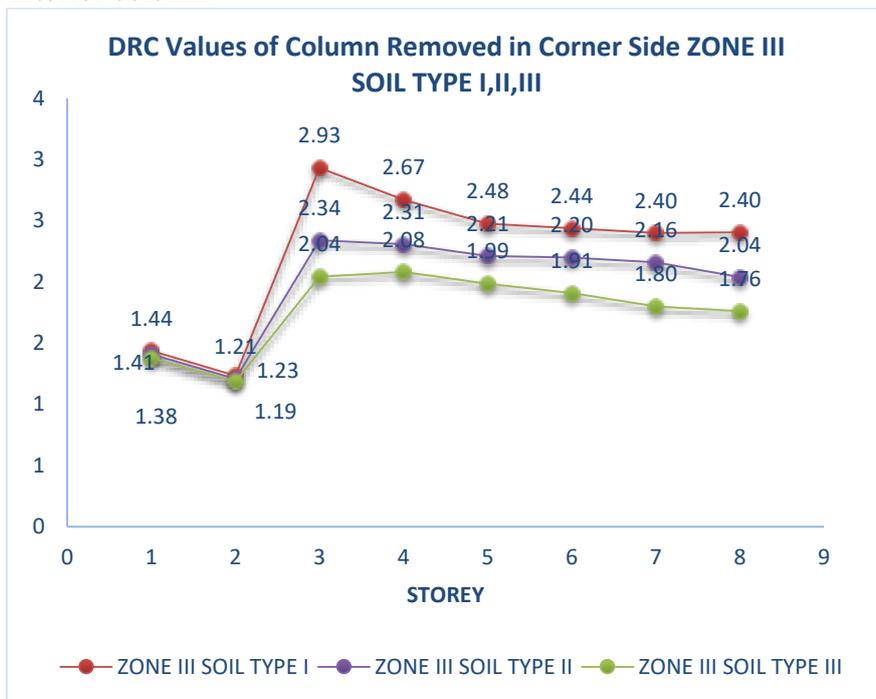
In this case the DCR values of all beams from storey 3 are exceeding the permissible value 2 stating the structure will enter collapse state

Case 2: Removal of column on shorter longer span of structure



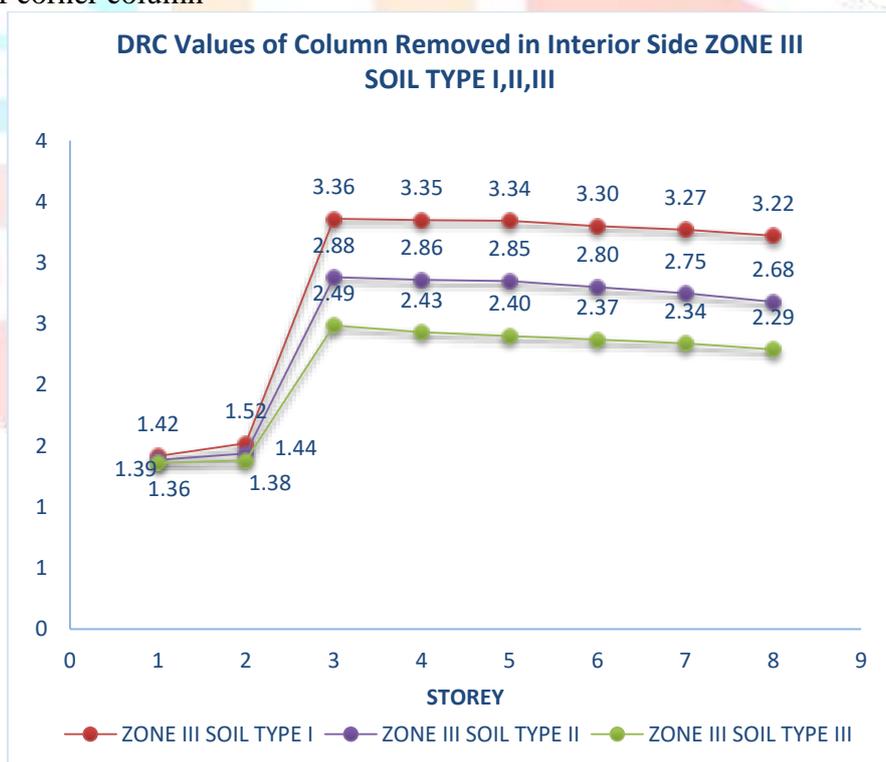
In this case the DCR values of all beams from storey 3 are exceeding the permissible value 2 stating the structure will enter collapse state with highest DCR values making this case more prone to progressive collapse

Case 3: Removal of interior column



In this case the DCR values of all beams from storey 3 are exceeding the permissible value 2 stating the structure will enter collapse state with less DCR values making this case less prone to progressive collapse

Case 4: Removal of corner column



In this case the DCR values of all beams from storey 3 are exceeding the permissible value 2 stating the structure will enter collapse state.

V. CONCLUSION

The current assessment is comparison of progressive collapse of RC framed structures for all three types of soil conditions present in Zone 3. As per the GSA guidelines, column is removed from one storey above the ground in four different location and DCR values are calculated using bending moments. If the DCR value exceeding 2 in a typical frame building indicate severe damage potential.

1. DCR values are linearly varying from bottom to top storeys. Decreasing pattern of DCR values is observed for Soil I to III in all cases with highest values in Soil type I.

2. In all cases the DCR values were less than two for storey 1 and 2 and exceeding 2 for rest stories indicating state of collapse. On column removal the intersecting beams in above floor have DCR value above 2 and other beams were less than 2 in all cases. When considering the DCR values for gravity loads alone, it's evident that the potential for collapse initiation exists, suggesting that the structure may continue to collapse.

3. When column was removed in shorter edge the beams have highest DCR value compared to all cases stating higher potential for progressive collapse followed by case 1.

4. Column removal in corner of structure have less DCR values when compared to all cases indicating redistribution of forces and less susceptibility of progressive collapse.

5. To prevent the progressive collapse of structure, increasing beam sizes and providing adequate reinforcement in unsafe members can create alternate load paths to limit the DCR.

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