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PROGRESSIVE COLLAPSE ASSESSMENT OF REINFORCED CONCRETE FRAMED STRUCTURE

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ABSTRACT

The Earthquake resistant RCC Structure designed according to IS codes, may not meet the requirements of UFC (UNIFIED Facilities Criteria) limits & have high potential to progressive collapse. In this paper a linear static analysis is carried out according to GSA guidelines by using a Finite Element Method based software ETABS. A RCC structure is under consideration in which columns are removed at different locations and floors and amongst them most critical column is evaluated which could cause progressive collapse also provided different depths to floors so as to explore the importance of slab's depth in resistance of progressive collapse.

Keywords: DCR, ETABS, Linear Static Analysis, Load Combinations, Progressive Collapse.

I. INTRODUCTION

In last few decades several progressive collapse incidents took place. For example ,In 1955 the Murrah Federal office building in oklahoma city collapsed due to explosion of bomb at ground floor. In 1968, the collapse of 22 story Ronan Apartment due to gas explosion at 18th floor lead to partial collapse of building. Till date various studies have been carried out on progressive collapse, following are some of them. In (2012) Hendal Helmy, Hamed Salem, Sherif mourad carried a typical 10 story RC framed structure's design and analysis and showed slabs importance in economy and structural integrity after support removal [1].

In (2013) Vikram Singh Thakur, Dr. C.B.K Rao analysed a six-storey building by removing single column at a time as per GSA Standard [2]. In (2014) Kai Qian, M..ASCE, Bing Li & Jia-Xing Ma have showed the effectiveness of secondary load carrying mechanism in resisting progressive collapse. Progressive Collapse is defined as the spread of an initial local failure from element to element resulting in the collapse of an entire structure. Progressive collapse is also known as disproportionate collapse because removal of a single column leading to collapse of whole frame or structure, is disproportionate. In this paper , a linear Static Analysis of G+12 earthquake resistant RCC building is carried out and DCR's at different locations and floors are evaluated which is very vital parameter for perceiving the building's potential to progressive collapse.

II. OBJECTIVE

The objective of this study is to find the Potential of building against the Progressive collapse , the objective also include the finding of the most critical column removal position and also explore the importance of slab's depth for resistance of progressive collapse.

III. LINEAR STATIC ANALYSIS

A G+12 Earthquake resistant RC framed structure is designed and analysed according to IS codes with the software ETABS. It is a square building with symmetry about both the axis. Such buildings are generally designed for Dead Load, Live Load, Earthquake load & Wind loads but generally not designed for abnormal loads and there is no such provision about what would be the potential of such building under the sudden removal of column. Such conditions can arise due to various reasons such as blast of cylinder or terrorist attack or natural or manmade disasters. Due to failure of major element, load carried by major element is distributed to adjacent elements, which increases load on adjacent member more than its capacity and due to which adjacent member also get fail and transfers loads to its adjacent member. The process continues until all the structure get failed. To examine the buildings performance against such conditions GSA has provided a detailed guidelines.

3.1 GSA (General Service Administration)

These Guidelines address the need to save lives, prevent injury and protect Federal buildings, functions and assets by minimising the potential for progressive collapse. GSA is a step-by-step guidance for a structure subjected to a sudden removal of load carrying structural element. The guidelines have provisions about which members to remove during the analysis including exterior and interior columns and load-bearing walls. GSA provides an acceptance criteria , if DCR exceeds it, structural element becomes unsafe and are liable to progressive collapse.

3.2 DCR (Demand to Capacity Ratio)

To calculate the DCR_s for either framed or load bearing structures ,the capacity is computed from the analysis of an earthquake resistant RCC building & the demand from the analysis of column removed building the ratio of this demand to capacity gives DCR.

$$\mathbf{DCR= Q_{UE} / Q_{UD}}$$

Q_{UE} =Demand determined in Component or Connection/Joint

Q_{UD}=Expected Ultimate Capacity of Component or Connection/Joint.

The structural member or connection having DCR values exceeding the following criteria is considered as severely damaged or collapsed. DCR> 2.0 for the typical structural configurations.

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3.3. System Model

A G+12 Square Earthquake Resistant R.C.C building's geometry i.e Plan and 3-D view are as follows

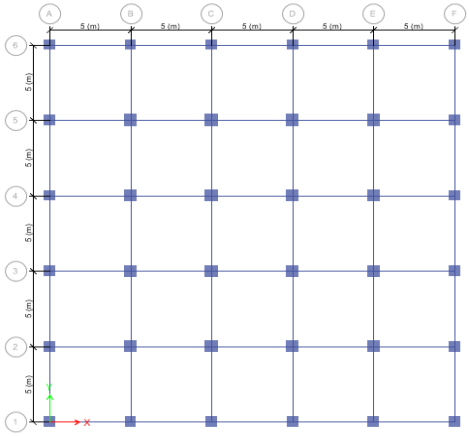

Fig.1 Plan View (G+12) Building

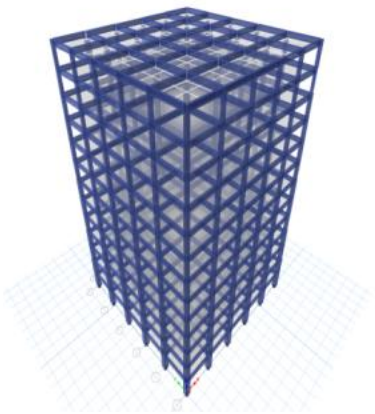

Fig.2 3-D View (G+12) Building

The building under considerations geometric, loading and dimension details are:

Table1. Geometric and loading Specifications

1.	Span in both direction	5m
2.	No. of bays	5 in both direction
3.	Height of each floor	3m
4.	Live load	3 kN/m^2
5.	Floor finish load	1.5 kN/m^2
6.	Zone factor	0.24
7.	Soil type	II
8.	Importance factor	1.0
9.	Type of frame	SMRF
10.	Response reduction factor	5.0
11.	Slab thikcness	175mm
12.	Concerte and steel	M30 and Fe500

Table.2 Beam Specification

Sr.no	Beam	Section Size (mm)
1	1st to 13th Storey	230X600

Table.3 Column Specification

Sr.no	Column	Section Sizes (mm)
1	1st Two Storey	
	I. Interior Columns	800X800
	II. Peripheral Columns	700X700
2	3rd & 4th Storey	
	I. Interior Columns	700X700
	II. Peripheral Columns	600X600
3	5th, 6th & 7th Storey	
	I. Interior Columns	600X600
	II. Peripheral Columns	500X500
4	8th, 9th & 10th Storey	
	I. Interior Columns	500X500
	II. Peripheral Columns	450X450
5	11th, 12th & 13th Storey	
	I. Interior Columns	450X450
	II. Peripheral Columns	380X380

3.4 Capacity (Analysis of without column removed structure)

The Earthquake resistant RC building with above given data is analysed and its reinforcement for the resistance of Bending moment and Shear Force are numerated. With the accounted reinforcement the capacity of beams i.e the sagging capacity and the hogging capacity are evaluated.

Table.4 Sagging Capacity

Sr.no	Storey	Sagging Capacity M_{ur} (KN-m)
1	1st to 13th Storey	88.62

Table.5 Hogging Capacity

Sr.no	Storey	Hogging Capacity (KN-m)
1	1st to 7th Storey	158.01
2	8th & 9th Storey	151.16
3	10th & 11th Storey	135.25
4	12th & 13th Storey	96.13

These are the maximum capacities of beam in flexure. Similar to this the capacity of beam in shear is also computed and compared it with demand & concluded that beam is safe in shear even after the removal of column.

3.5 Demand (Analysis of column removed structure)

For the numeration of demand , the procedure as per the GSA guidelines is that single column is removed at a time and following loads are applied pursuance of their region.

G_{LD}=2 (1.5 DL + 0.5 LL)..... Column Removal Region

G= (1.5DL + 0.5LL)..... Remaining Region

DL=Dead Load

LL=Live Loaad

With the application of this load the demand is evaluated i.e the Bending moment of structural elements. The demand i.e Bending moment of column removed building is divided by capacity of unremoved column building will give DCR .

3.5.1 For Instance

The DCR of the Corner Column removal building are:

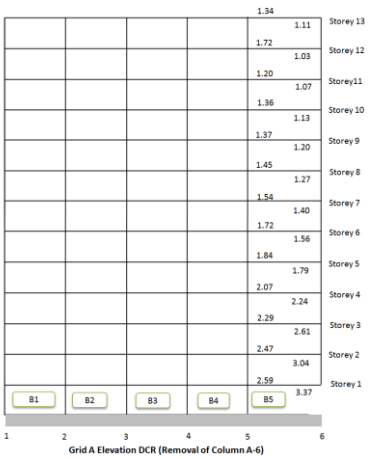

Fig3. DCR of corner Column Removal (Elevation)

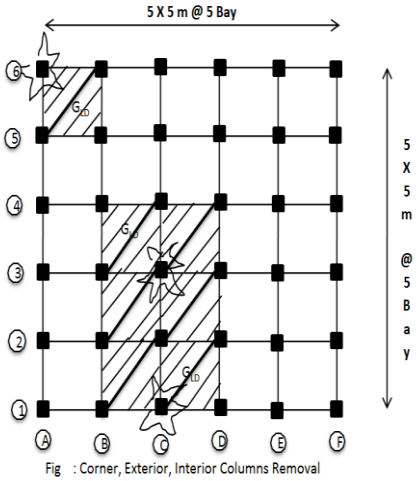

Fig4. Column Removal Positions (Plan)

As Such the above procedure columns are removed at different locations and floors .The Analysis cases will be as follows :

i) At 1st floor Corner, Exterior & Interior Columns are removed & amongst them the most critical column is evaluated based upon their DCR ratios .ii) Just the same as above Corner, Exterior & Interior Columns at 7th floor are removed & amongst them the most critical column is computed.iii) The critical columns amongst above two cases are compared. iv) Different Slab depths i.e 100mm, 175mm, 200mm are assigned , analysed & the results will reveal the importance of slab depths in resistance of Progressive Collapse

IV. RESULTS AND DISCUSSION

The DCR Values exceeding 2.0 are unsafe as per GSA guidelines in linear Static Analysis. Following are the graphical representations of above mentioned comparisons.

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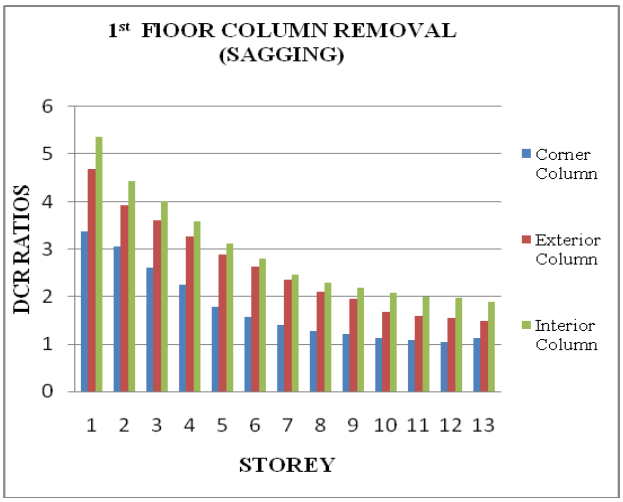
4.1 Graphical Representations



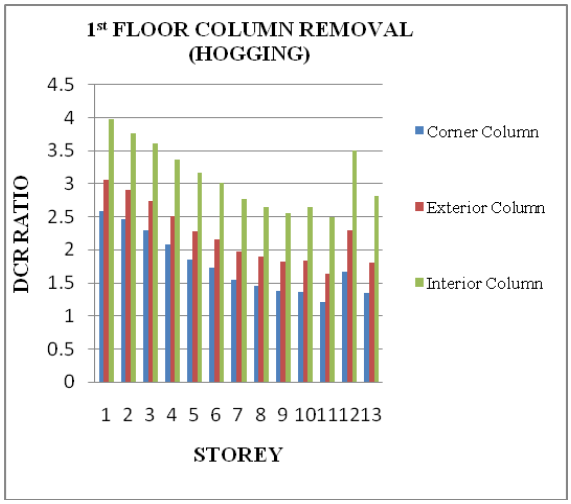
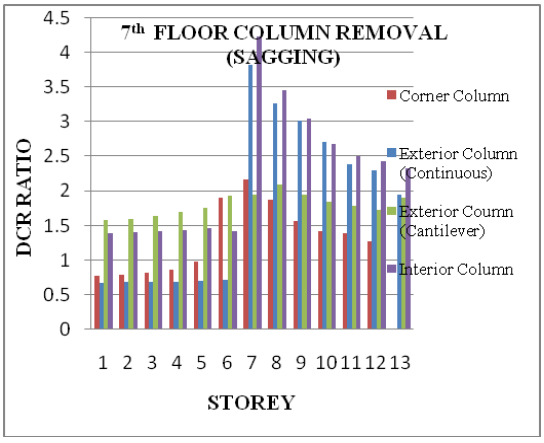


Fig.5 DCR of Column Removal at 1st floor **Fig.6 DCR of Column Removal at 1st Floor**

i) Graph 1 &2 represents that the Structure becomes more critical when the Interior column of the building at 1st floor is removed



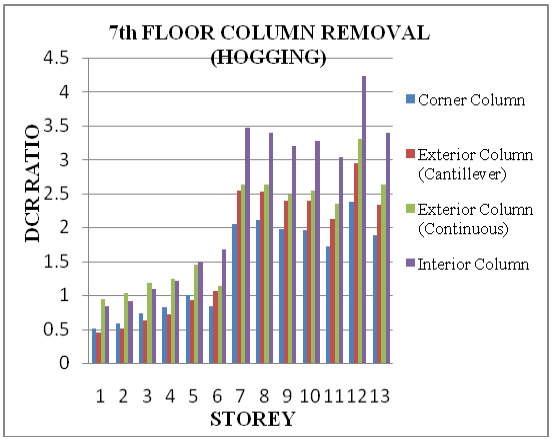
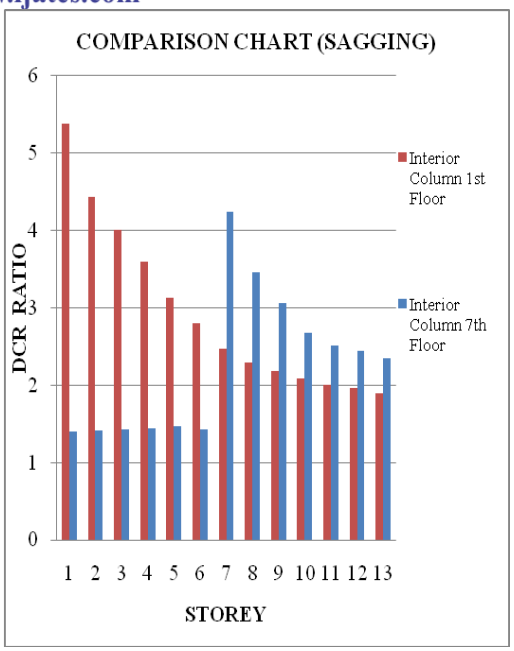


Fig.6 DCR of Column Removal at 7th Floor **Fig.7 DCR of Column Removal at 7th Floor**

ii) Graphs 3& 4 represents that amongst removal of corner, exterior & interior Columns building becomes more critical at removal of interior column at 7th floor.



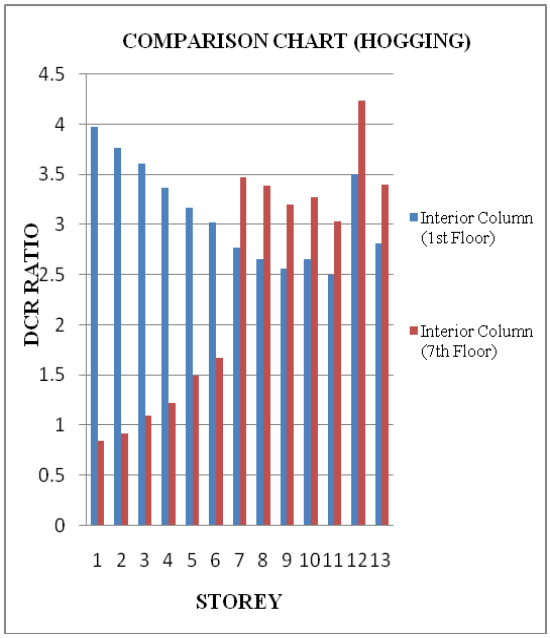
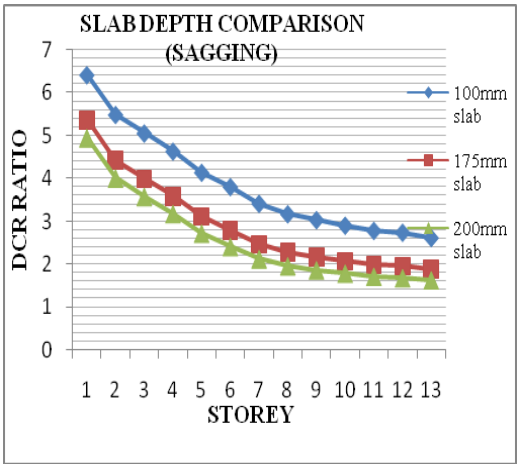


Fig.8 DCR Comparison Between 1st & 7th Floors **Fig.9 DCR Comparison between 1st & 7th Floors**

iii) Comparison amidst most critical Columns at 1st & 7th Floor explored that the structure will become more turbulent at the removal of 1st floor's Interior Column.



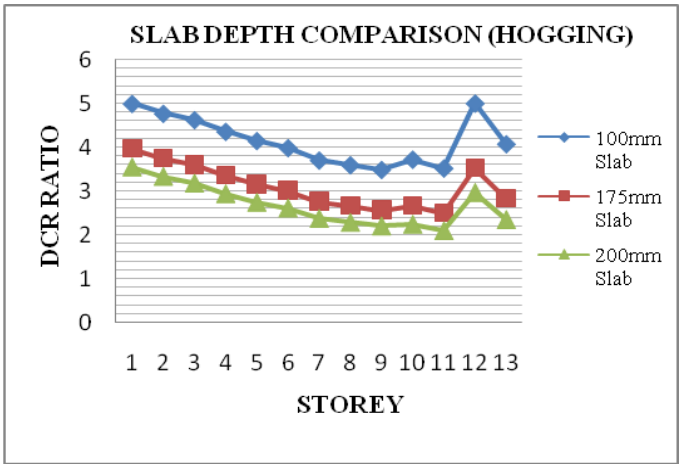


Fig10.DCR Comparison between Different Slab **Fig10.DCR Comparison between Different Slab Depths**

Graphs 7 & 8 reveals that greater will be the slab's depth, less will be the DCR ratios and structure will be less critical.

V. CONCLUSION

The Conclusions regarding G+12 Earthquake resistant RCC building designed and analysed according to IS codes against progressive collapse are:

1] The Structure will become more critical when the Interior Column at ground Floor is removed.2] More will be the Slab Depth more will be the resistance to Progressive Collapse because of its axial resistance capacity.3]

Corner Column removal influences fixed beam to behave as cantilever beam and due to lack of reinforcement at top side, beam is liable to failure.4] Middle Column Removal influences fixed beam to behave as continuous beam leads to the scarcity of reinforcement at bottom side which could be the cause of failure.5] DCR incessantly decreases in Sagging DCR, due to constant Capacity in sagging of square building. 6] DCR in Hogging at last but one floor spruts suddenly because of reduction at top floors column sizes.

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