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Studying the Analytically the Progressive Collapse of RC-Framed Buildings as a Result of Column Loss Scenarios

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Abstract:- Their designed capacity exceeds limit when the structure becomes altered by loading schemes or boundary conditions. In order to redistribute folded load members, the remaining structures were compelled to locate alternate load paths. For instance, in the event of a natural or man-made disaster, the gravitational stress is moved to the nearby columns of the structure if the local supporting element—specifically, the vertical load-bearing columns—is unable to withstand it, and more resources are reallocated. Gravity charges don't work either. It goes on until the extra load stabilizes, which is what caused a significant portion of the structure to crash. As a result, the first impression might be enhanced more. just constructed The world's buildings are now more susceptible to acts of terrorism, mishaps, explosions, earthquakes, etc. Since reinforced concrete (RC) buildings make up the majority of buildings, these studies are pertinent because it is open to assess how gradually these RC buildings would collapse.Cities have been increasingly concerned about the execution of building structures, especially "iconic buildings," under extreme stacking (such impact events), especially in light of the rise in psychological militant drills that center on open structures. It is necessary to take into account and investigate the behavioral resistance of such systems in order to reduce the possibility of dynamic collapse of crucial structures. It is imperative to advance plan strategies that limit the potential for dynamic collapse by providing a recurrent and adjusted basic framework along the building's height, bridging over the misfortune of a fundamental component, and limiting the extent of damage to a localized zone (Interchange Way). The majority of work done to assess a building's dynamic collapse resistance does so by taking an outline resistance instrument into account.

Keywords:- *ETABS, DCR, RC Frame, progressive collapse, and linear static analysis.Keywords: ETABS, DCR, RC Frame, progressive collapse, and linear static analysis.*

I. INTRODUCTION

Buildings should be constructed to have the strength to support appropriate loads and to remain stable when out of balance. Strength is achieved through the use of sufficiently strong materials, while stability is achieved through the distribution of forces from the various structural elements Load paths are determined by structural engineers by determining the type of structural system But what if one of the main load-bearing structural elements fails for some reason? How would the structure support the load now without one of its main members? In order to understand and predict the behavior of structural systems under this condition, known as the "progressive collapse condition", the following discussion is presented.

II. LITERATURE REVIEW

Progressive Collapse Assessment of RC Structures under Instantaneous and Gradual Removal of Columns , A.R. Rahai, M. Banazadeh, M.R. SeifyAsghshahr& H. Kazem(15th World Conference on Earthquake Engineering, 2012)

Numerous research have addressed the topic of progressive collapse assessment in reinforced concrete structures. The majority of these research have focused on situations where an unanticipated impact, explosion, or earthquake results in the immediate loss of a column.

This study looks at the progressive collapse of reinforced concrete structures when columns are removed suddenly or gradually.

The gradual elimination scenario stems from a zone of partially fire-proved building where the fire spreads slowly and weakens over time.

The stress placed on the sections of the beams next to the removed column in both instantaneous and gradual scenarios, the plastic deformations in adjacent elements, the redistribution of forces following the removal of the column, and the vertical displacement in the upper node of the removed column are all examined.

They investigated the method of instantaneous removal of a load-bearing element (such as a column) to assess progressive collapse in reinforced concrete structures. They also investigated the progressive collapse of reinforced concrete structures with structural defects and low ductility.

After removing load-bearing elements, they investigated how reinforced concrete elements and structures responded using nonlinear dynamic analysis.

Progressive collapse of RC framed structure Due to column loss scenario A.Manjari, International Journal for Research in Engineering Application & Management (IJREAM)

A progressive collapse occurs when a local failure starts and spreads to other elements, ultimately leading to the collapse of the entire structure or a disproportionately large portion of it.

The numerous well-publicized engineering disasters of the last few decades have illustrated the catastrophic effects of progressive collapse.

The primary goal of this work is to examine how the structures react to sudden losses in column design. Demand Capacity Ratios are used to identify critical columns (DCR). The General Services Administration (2016) guidelines are followed in the linear dynamic analysis of a reinforced concrete G+12 framed structure, and the critical columns are redesigned.

ETABS, a structural analysis program used for both static and dynamic analyses of building structures, has been used for the analyses. ETABS 2016 Version 16.2.0 was utilized in this investigation.

The sections that follow offer a description of the modeling specifics. ETABS is used to create a three-dimensional model of the building structure in order to perform linear dynamic analysis. Rectangular framed elements with material and section properties are used to model beam and column elements. Additionally, a slab section with a thickness of 150 mm is regarded as a membrane section.

Many design parameters, including bending moment, axial force, and DCRs, are established based on the structure's response to the sudden column loss design scenario. According to the analytical results, after the initial damage was imposed, the axial force in the linear dynamic analysis increased by five times, while the bending moments in the columns increased by 78 times.

By increasing the column sizes and the percentage increment of area for critical columns in linear dynamic analysis, which varies from 56.25% to 86.5% of the before change of section, respectively, the entire G+12 RC framed structure is made resistant to progressive collapse.

PROGRESSIVE COLLAPSE ANALYSIS OF REINFORCED CONCRETE SYMMETRICAL AND UNSYMMETRICAL FRAMED STRUCTURES BY ETABS, Ramshankarsingh, Yusuf jamal.(International Journal of Innovative Research in Advanced Engineering IJIRAE)

A series of failures that spread throughout the entire structure or just a portion of it, disproportionate to the initial local failure, is known as progressive collapse. When one or more vertical load-bearing members are removed, the building structure begins to gradually collapse.

When a column is removed or becomes weak because of natural or man-made hazards, the load that the removed column carried is transferred to the columns that are nearby in the structure. If the nearby column cannot support the additional load, this will eventually cause the adjoining members to fail, which will lead to the failure of the partial or entire structure.

To stay alive, the collapsing system keeps looking for other load paths. The fact that the final damage is not equal to the initial damage is one of the key features of progressive collapse.

Buildings intended to withstand seismic actions appear to be fairly robust against progressive collapse, according to research on the failure of structures through progressive collapse.

To date, though, no thorough studies have been carried out to evaluate this robustness.

Therefore, the purpose of this study is to investigate whether seismically designed buildings can withstand progressive collapse.

A Five storey reinforced concrete framed structure symmetrical and Unsymmetrical was considered in the study to evaluate the Demand Capacity Ratio (D.C.R.), the ratio of the member force and the member strength as per U.S. General Services Administration (GSA) guidelines.

The Linear static analysis is carried out using software, ETABS V 9.7 according to Indian Standard codes. Analysis and design is carried out to get the final output of design details. To study the collapse, typical columns are removed one at a time, and continued with analysis and design.

Several of these columns are eliminated in various experiments to determine the outcomes of progressive analysis. Details of reinforcement and member forces are computed. Beam DCR values are computed from the analysis.

III. BUILDING MODELLING

In this study we take a G+6, G+9, G+15storey RC Vertical Irregular buildings

The geometrical parameters of the multi-storey frames is as follows:

First Model (G+6) : Span dimension is 36 x 36 m, and each span is 4 m long and 4 m wide. In the x direction, there is a 9 span and in the y direction, there is a 9 span. and floor height is 3.5 m.

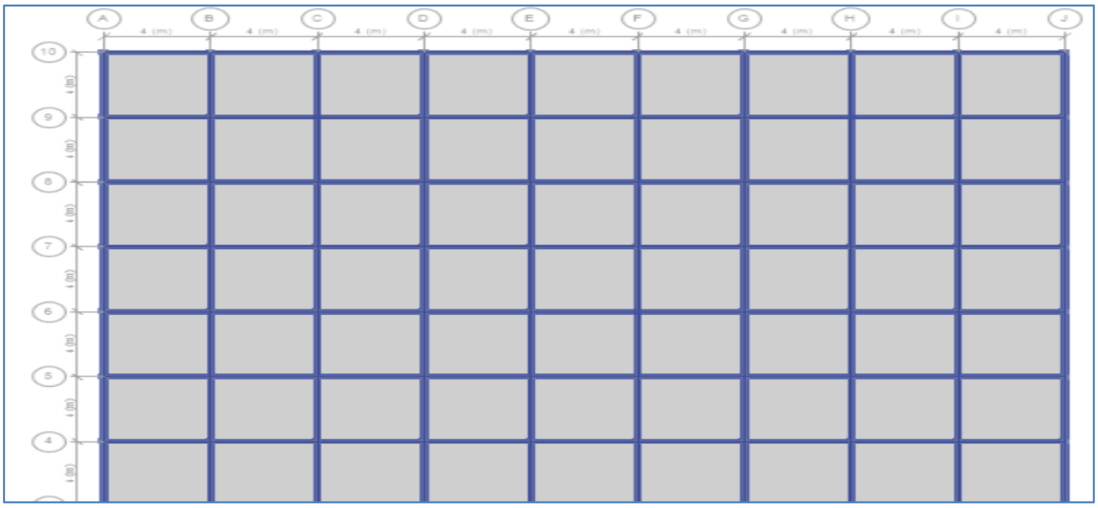

Fig. 1: Plan View of First Model (G+6)

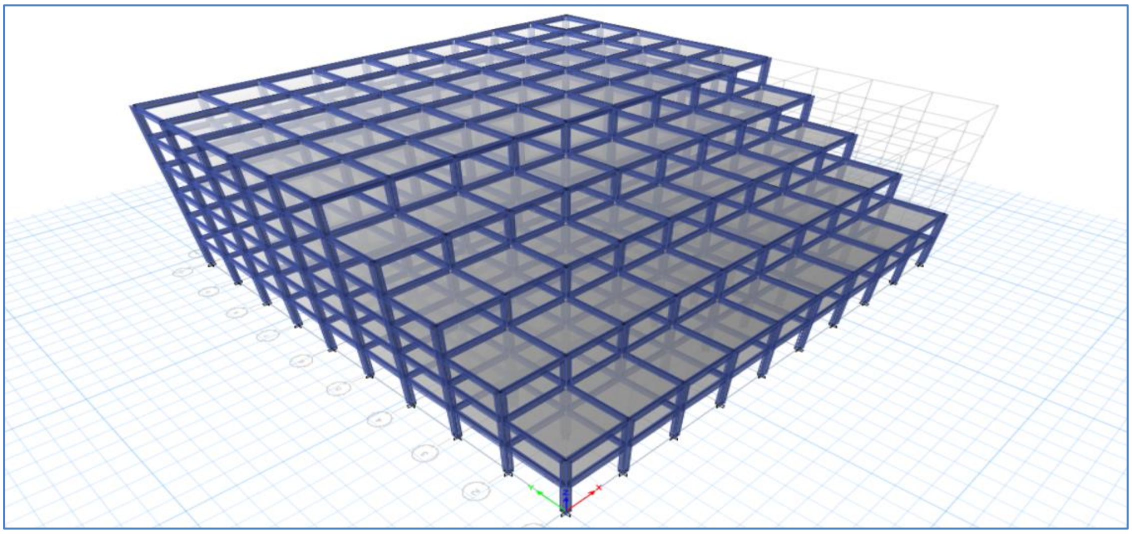

Fig. 2: 3D Model of First Model (G+6)

- **Second Model (G+9):** Span dimension is 36 x 36 m, and each span is 4 m long and 4 m wide. In the x direction, there is a 9 span and in the y direction, there is a 9 span. and the floor height is 3 m.

Fig. 3: Plan of second model (G+9)

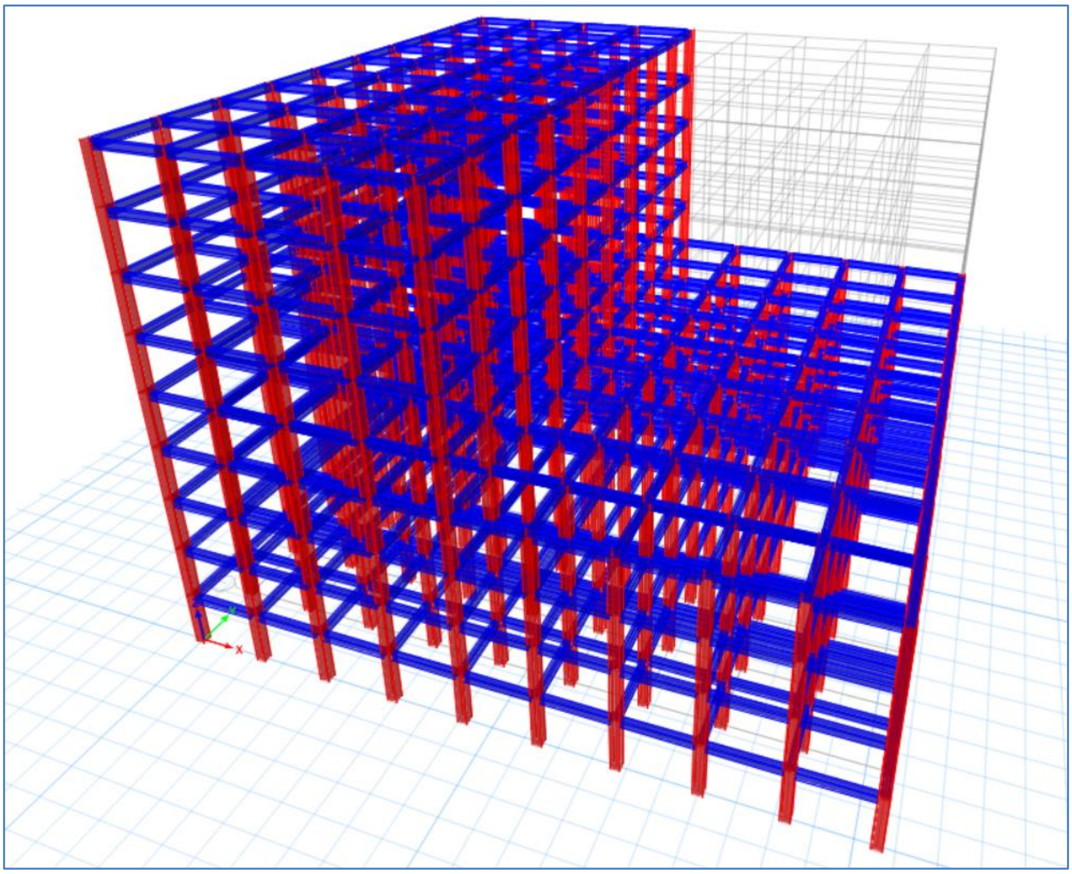

Fig. 4: 3 D Model of second Model (G+9)

- **Third Model (G+15) :**Span dimension is 32 x 36 m, and each span is 4 m long and 4 m wide. In the x direction, there is a 8 span and in the y direction, there is a 9 span. and the floor height is 3 m.

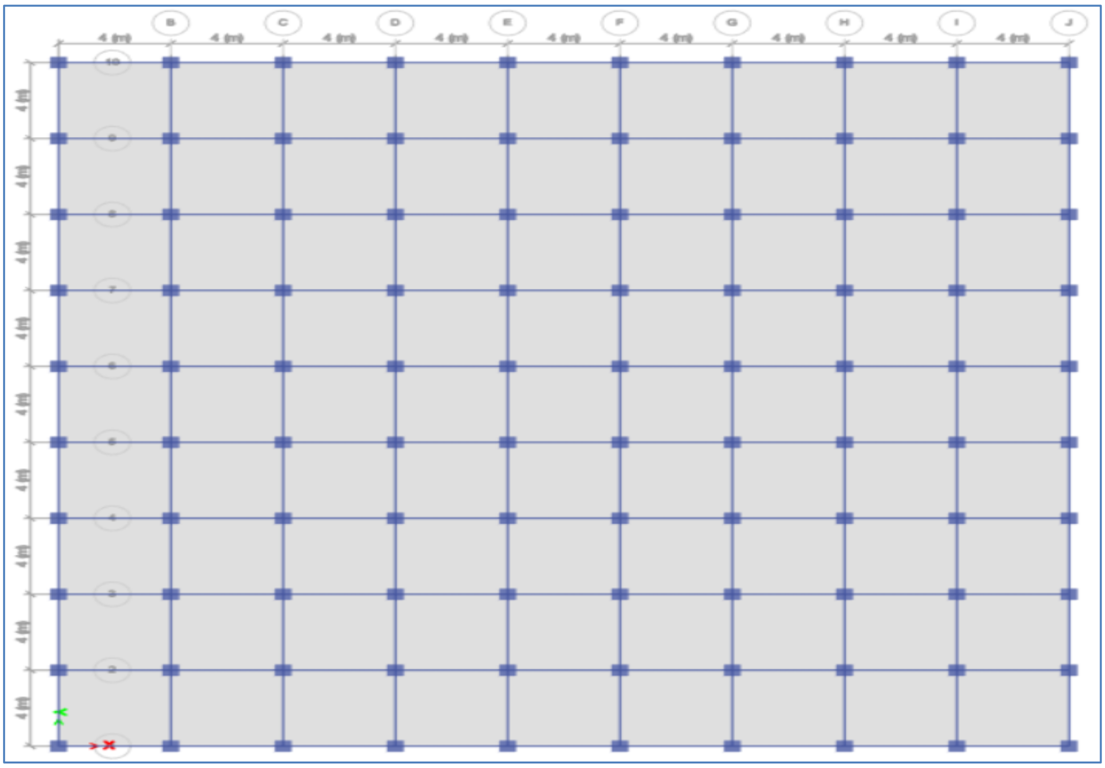

Fig. 5: Plan of third model (G+15)

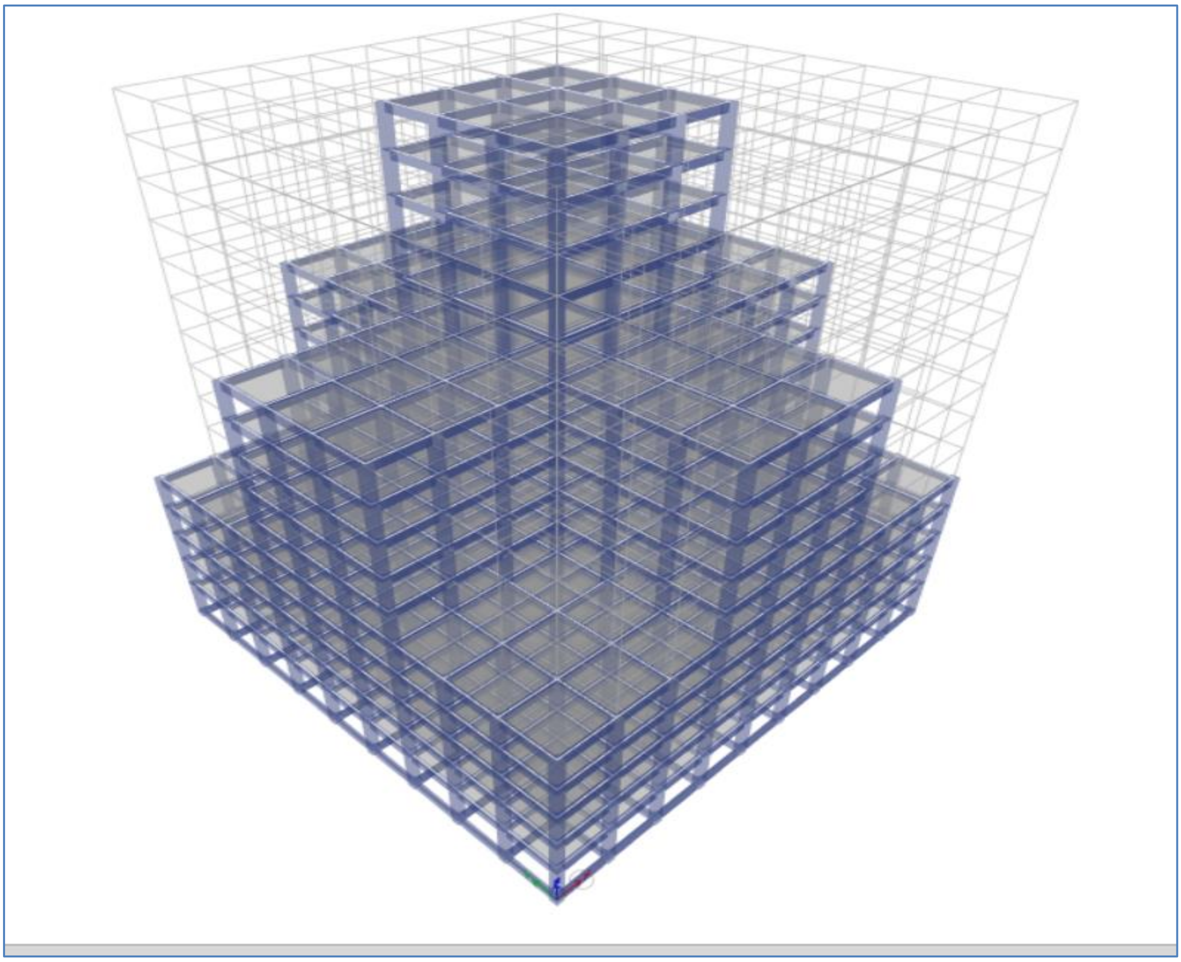

Fig. 6: 3 D Model of third model (G+15)

Table 1: Material Properties (G+6) :

Material Type	Grade
Concrete Grade	M25
Reinforcements	HYSD 415

Table 2 Material Properties (G+9) :

Material Type	Grade
Concrete Grade	M25
Reinforcements	HYSD 415

Table 3 Material Properties (G+15) :

Material Type	Grade
Concrete Grade	M30
Reinforcements	HYSD 415

Table 4: Section properties

Parameter	**Column**	**Beam**
Clear cover	40 mm	30 mm
Longitudinal reinforcement	HYSD415	HYSD415
Transverse reinforcement	HYSD415	HYSD415
Inertia modifier	0.7	0.35

Table 5: Column

Storey	**Columnsize(B mmX Dmm)**
G+6	350X 350
G+9	500X 500
G+15	500X 500

Table 6: Beam

Storey	Beam size(B mmX Dmm)
G+6	230X 450
G+9	300X 400
G+15	300X 450

Table 7: Slab Properties

Storey	Slab Thickness (mm)
G+6	150
G+9	150
G+15	150

Zone Factor: 0.16(Ahmedabad region-ZoneIII)
Soil type: II (Medium or stiff soils)
Importance factor: 1.2(Residential or commercial building)
Response reduction factor: 5(Special Moment Resisting Frame RC building)
Fundamental natural time period(Ta)=0.09*h/sqrt(d) (2)
Where h: Height of building from plinth to terrace level, d: plan dimension along which earthquake is considered.

IV. LOAD COMBINATIONS

The various load combination for G+4, G+7 and G+10 building models are taken asspecified (IS:456-2000, Plain and Reinforced Concrete-Code of Practice) and are listedbelow.

1.5×DeadLoad
1.5×(DeadLoad +LiveLoad)
1.2×(Dead Load + Live Load + Earthquake Load in X-direction)1.2×(Dead Load + Live Load - Earthquake Load in X-direction)1.2×(Dead Load + Live Load + Earthquake Load in Y-direction)1.2×(Dead Load + Live Load - Earthquake Load in Y-direction)1.5×(DeadLoad+Earthquake Load inX-direction)
1.5×(Dead Load - Earthquake Load in X-direction)1.5×(Dead Load + Earthquake Load in Y-direction)1.5×(Dead Load - Earthquake Load in Y-direction)0.9×Dead Load + 1.5×Earthquake Load in X-direction0.9×Dead Load - 1.5×Earthquake Load in X-direction

0.9×Dead Load + 1.5×Earthquake Load in Y-direction0.9×DeadLoad-1.5×EarthquakeLoadinY-direction

A. *Joint Restraints :*

All the joints of the building are defined as semi-rigid in nature. Fixed supports are provided as footings to each column.

➢ *Objective of study*

- To assess the resistance capacity of an RCC building subjected to progressive collapse condition.
- The aim of this research is to do an analysis of progressive collapse on Vertical asymmetric buildings and to find the members which are susceptible to failure under progressive collapse.
- Determine the Demand-Capacity Ratios (DCR) of structural members using ETABS.
- To compare the collapse resistance between different column failure positions for a particular story building.

➢ *Scope of Work*

- Developing RCC building models in ETABS software of G+6, G+9, andG+15 stories with vertical irregularity and subjecting the building to different column failure situations .5% , 12% ,20% Columns from Ground-floors removed for progressive collapse analysis for different Models.

B. *Load and Load combinations*

➢ *Dead Load:*

Self-Weight of each material which includes beams, columns and slabs is taken care by the software itself and no calculation is required. Wall load is considered as uniformly distributed load acting on the span of each beam and is calculated using Equation (1). As upper imposed floor finish load of 1.5 KN/m² is applied on each slab(IS:875(Part-I)-1987,Code of Practice for Design Loads (other than Earthquake) for Buildings and Structures) for typical RCC building.

➢ *Live Load:*

A live load of 3 KN/m² is superimposed on each slab (IS:875 (Part-II)-1987, Code of Practice for Design Loads(other than Earthquake) for Buildings and Structures) for typical RCC building.

➢ *Seismic Load:*

Earthquake load is applied along both the principal directions of the building models. The building structures of G+6, G+9 & G+15 storeys have been designed considering line arstatic method cum seismic co-efficient method, whereas building structure of G+15 storeys has been designed considering linear dynamic method cum response spectrum method. The seismic load is applied to the centre of mass of each diaphragm considering ± 5% eccentricity. The various seismic zone parameters considered are as mentioned.

- **Zone Factor:** 0.16 (Ahmedabad region-Zone III) Soiltype: II (Medium or stiff soils)
- **Importance factor:** 1.2(Residential or commercial building)
- **Response reduction factor**: 5(Special Moment Resisting Frame RC building)

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Fundamental natural time period(Ta)=0.09*h/sqrt(d) (2)

Where h: Height of building from plinth to terrace level, d: plan dimension along which earthquake is considered.

The fundamental natural time period for each building model along each principal direction is calculated using clause 7.6.2 (IS 1893 (Part I)-2016, Criteria for earthquake resistant design of structures). Further, the value of natural time period calculated using Equation(2) for all different building models is highlighted in Table 4.5.

The imposed uniformly distributed loads on the building are above 3KN/m², hence to calculate the seismic weight of the structure a mass source of combination, using Table10

(IS 1893 (Part I)-2016, Criteria for earthquake resistant design of structures), is given inEquation(3).

(1×Dead Load)+(0.5×LiveLoad) (3)

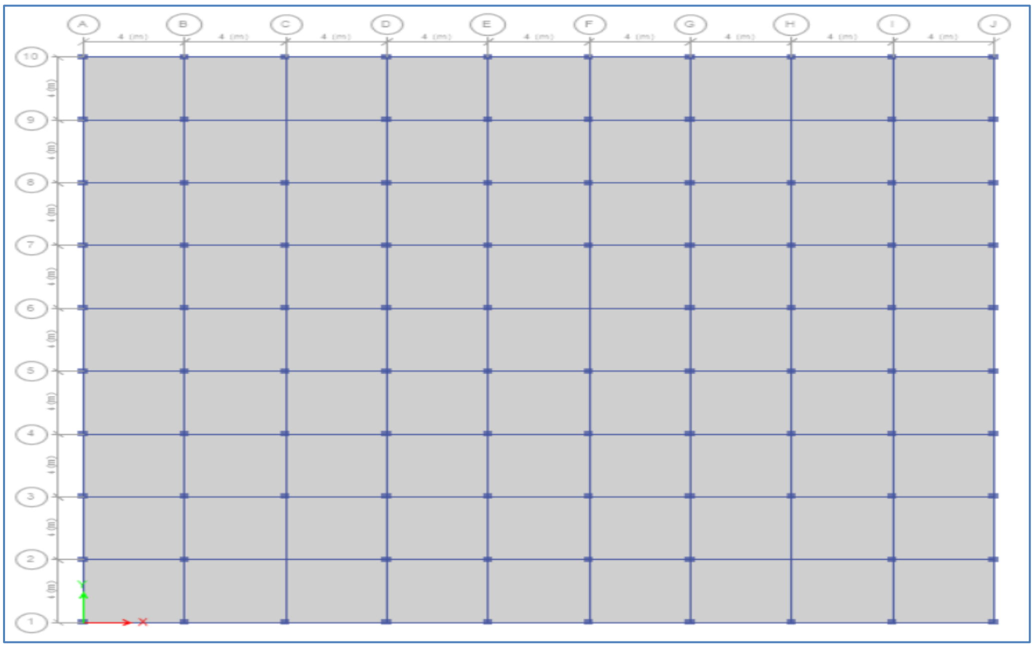

Fig. 7: Model G + 6 – 5 % Column removal

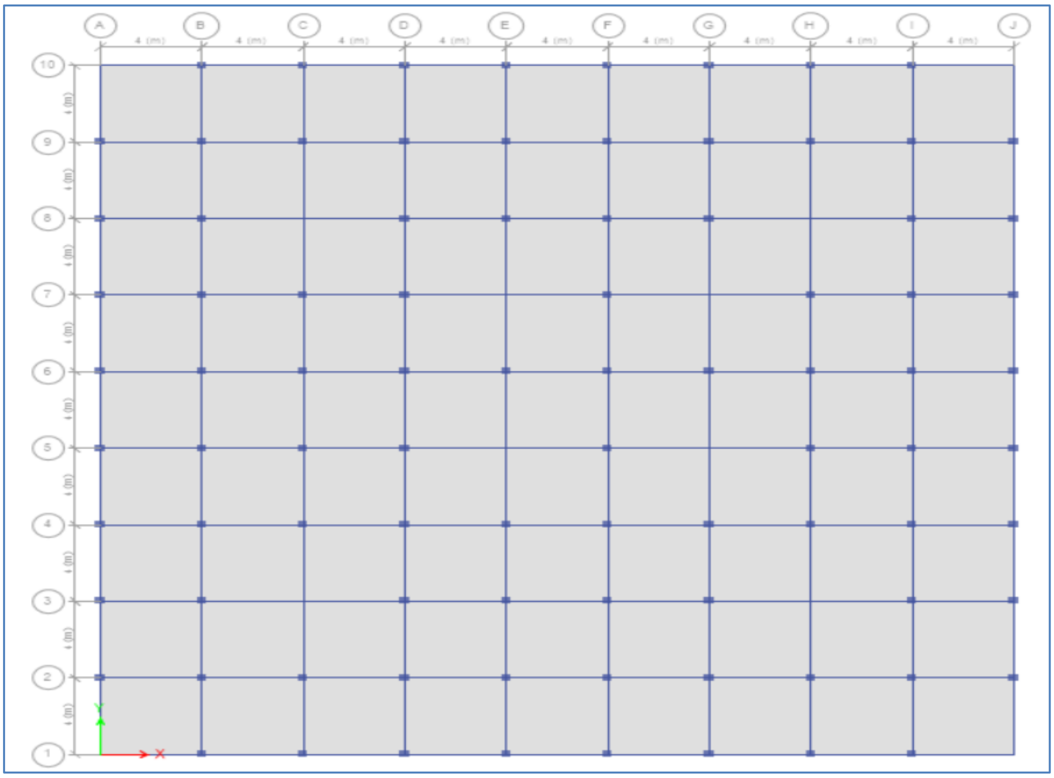

Fig. 8: Model G + 6 – 12 % Column removal

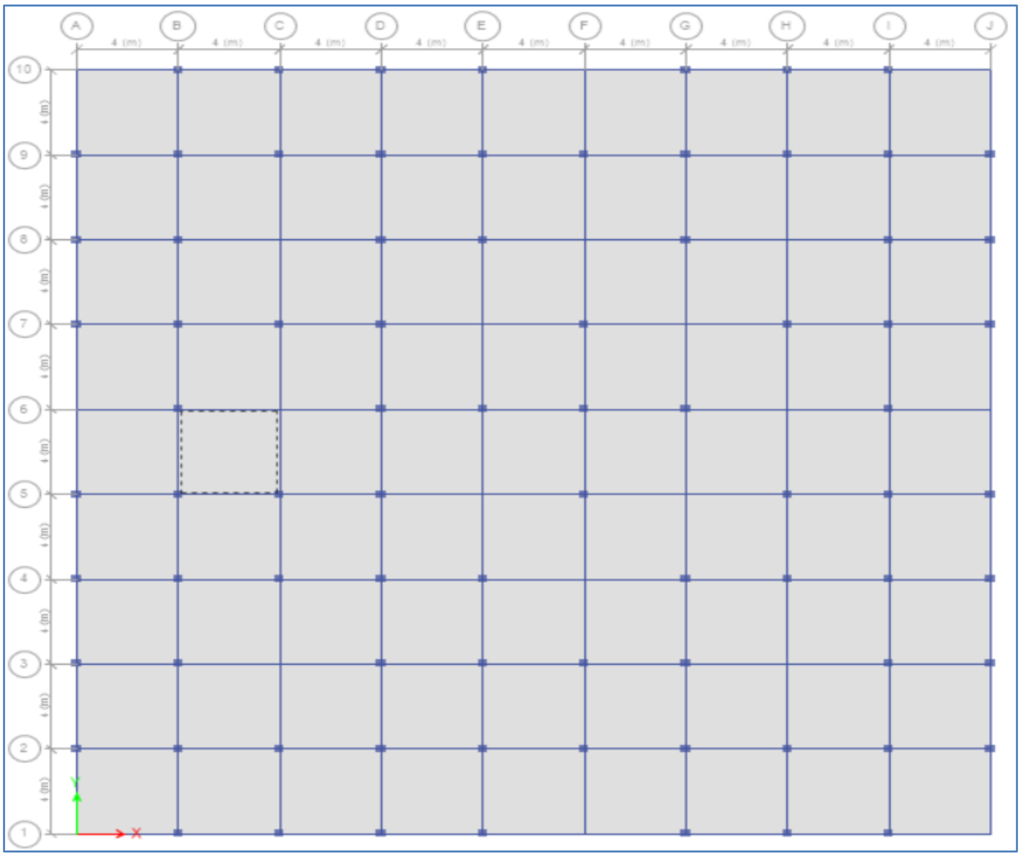

Fig. 9: Model G + 6 – 20 % Column removal

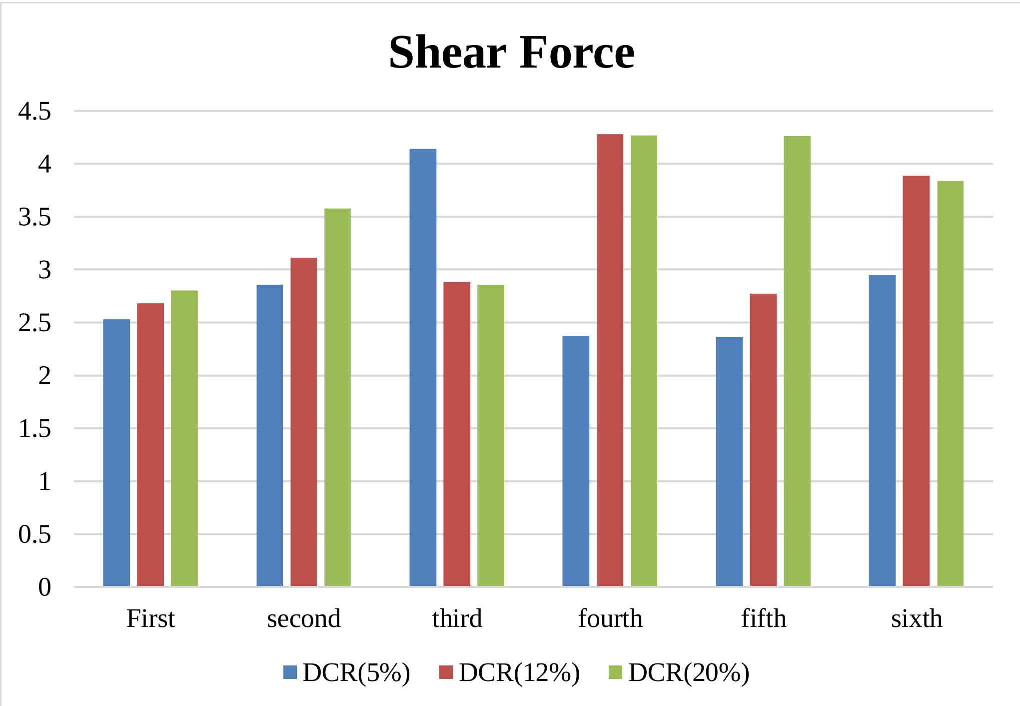

Fig. 10: DCR Comparison (Shear Force)(G+6)

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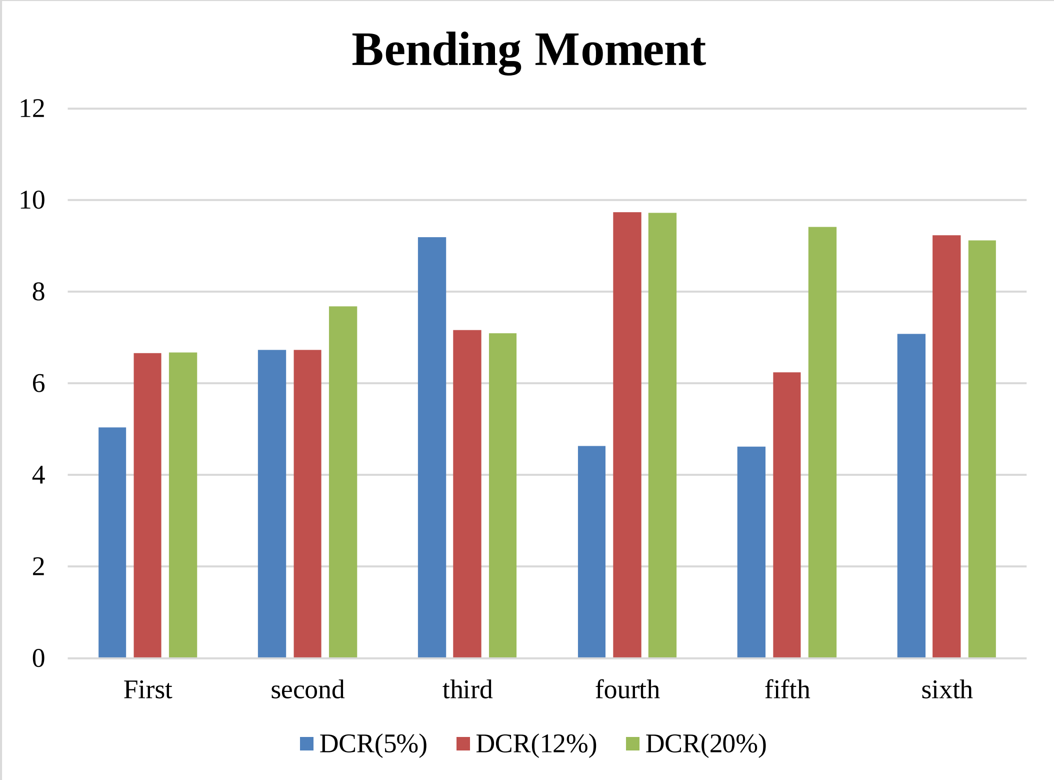

Fig. 11: DCR Comparison (Bending Moment)(G+6)

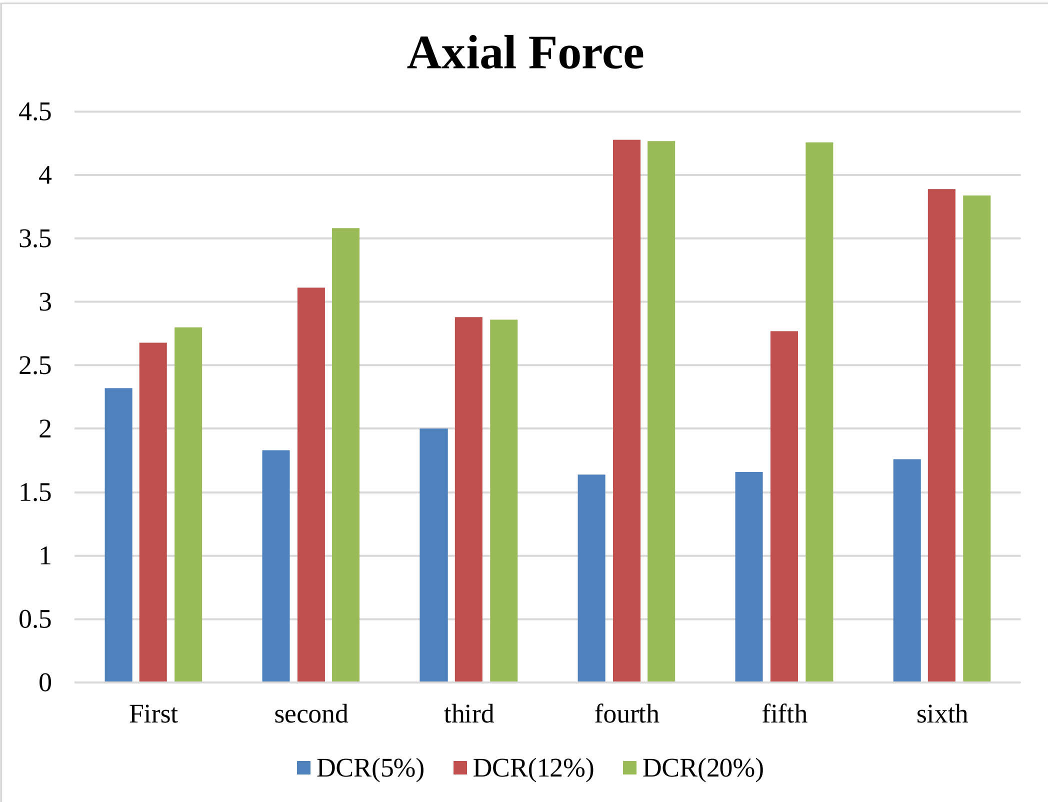

Fig. 12: DCR Comparison (Axial Force)(G+6)

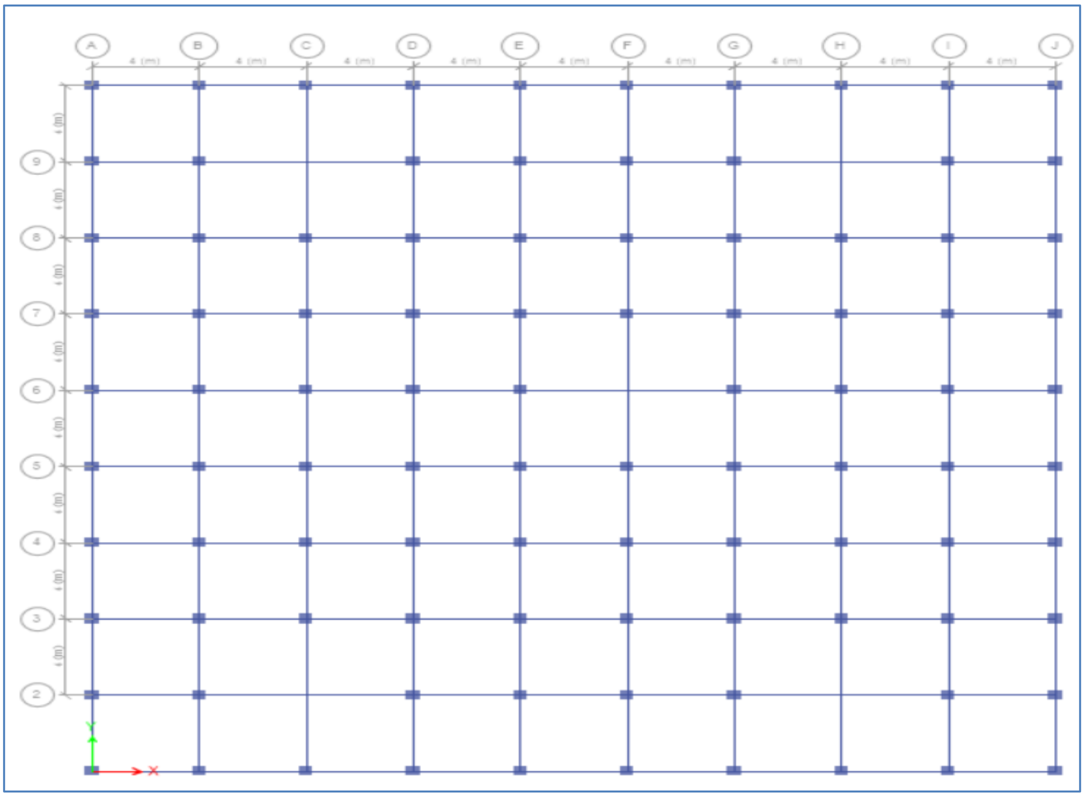

Fig. 13: Model G + 9 – 5 % Column removal

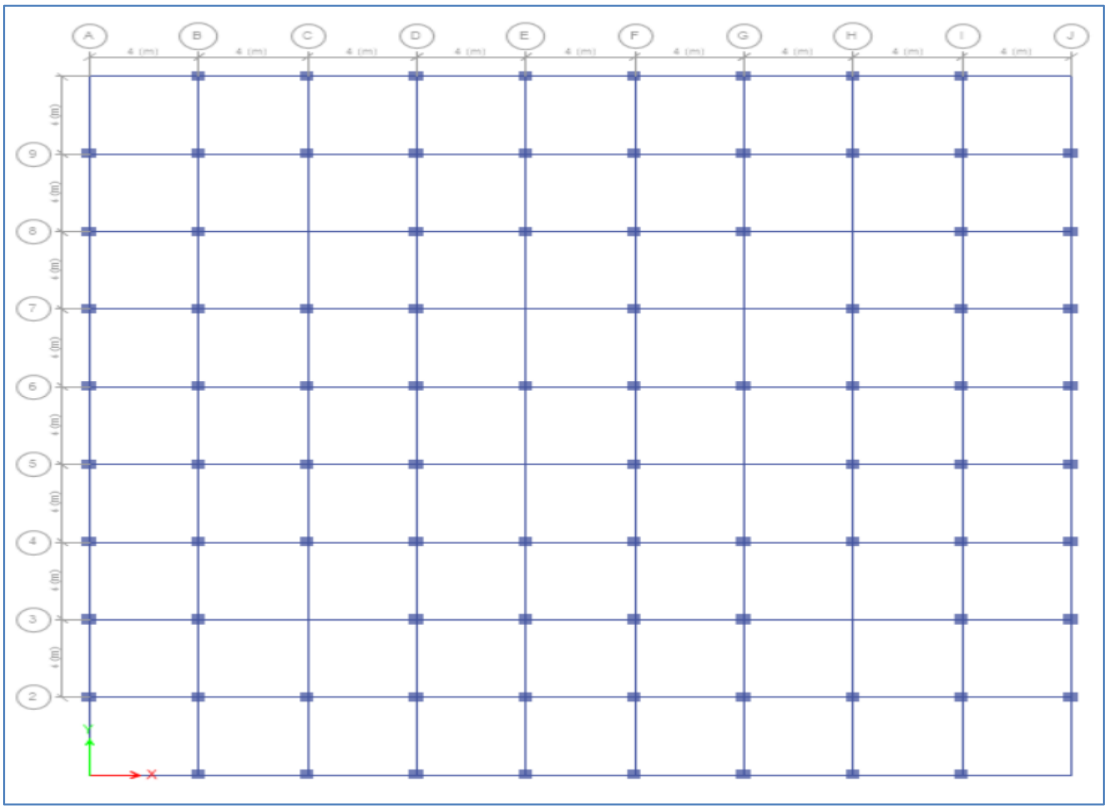

Fig. 14: Model G + 9 – 12 % Column removal

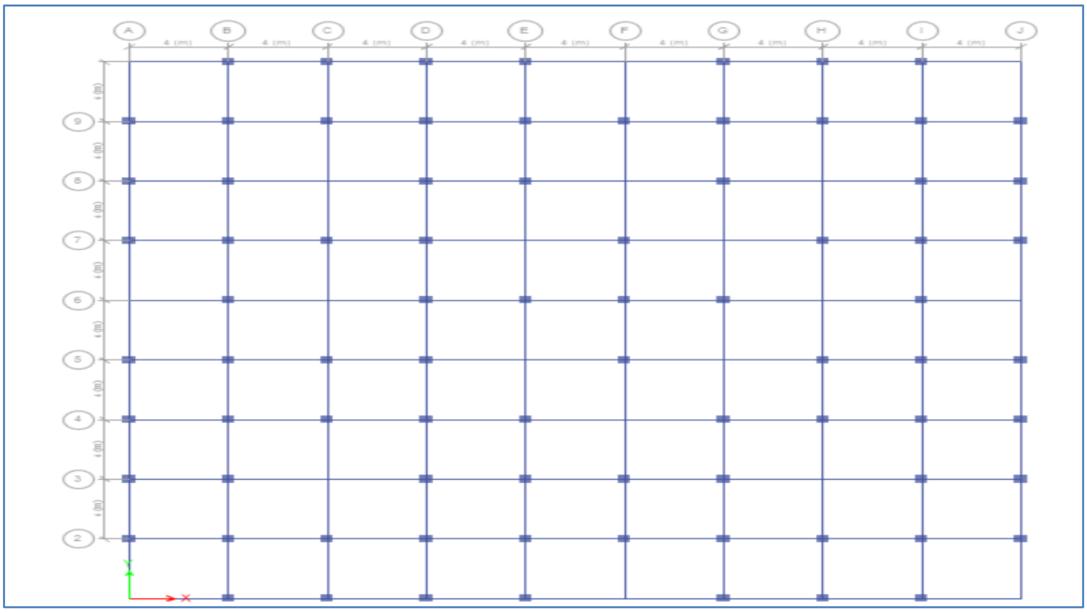

Fig. 15: Model G + 9 – 20 % Column removal

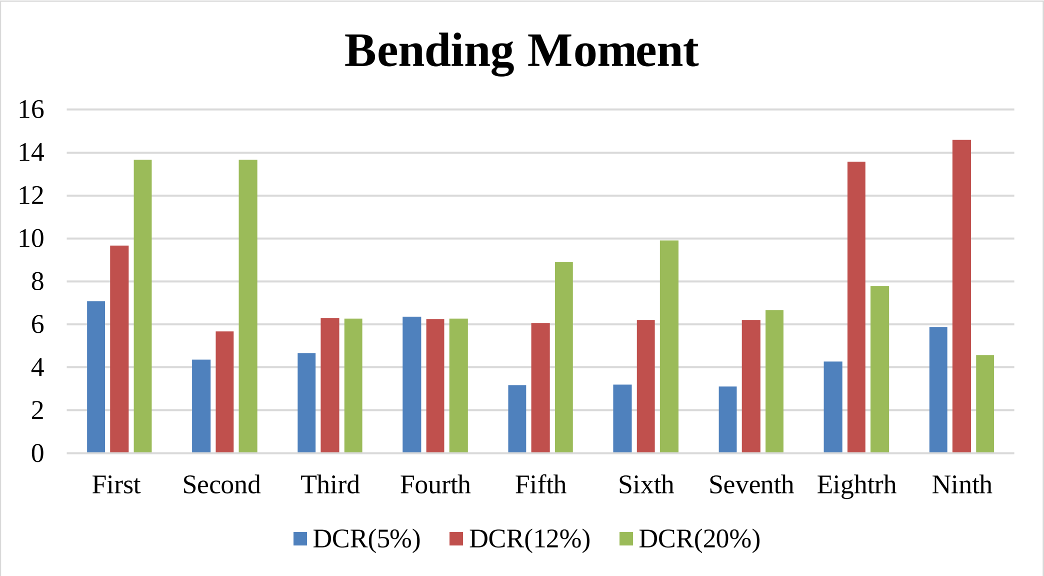

Fig. 16: DCR Comparison(Bending Moment)(G+9)

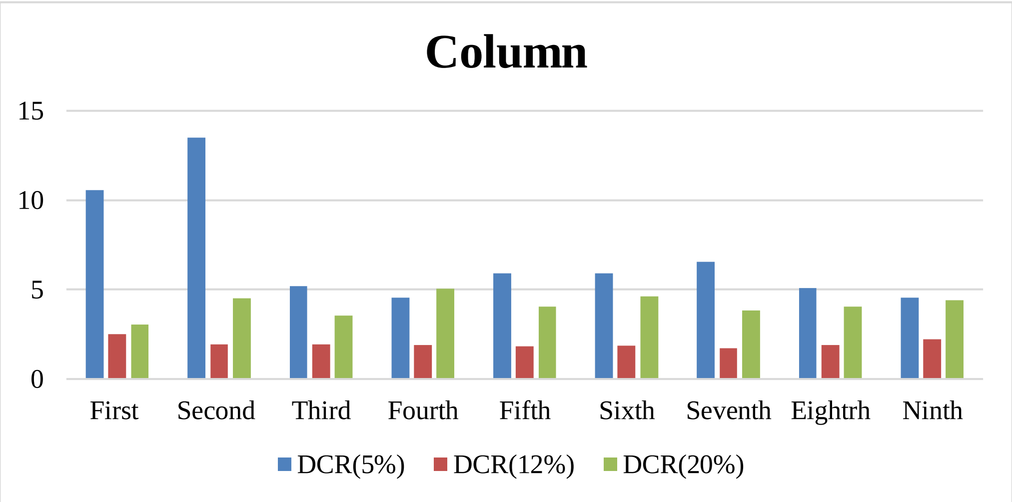

Fig. 17: DCR Comparison(Axial Force)(G+9)

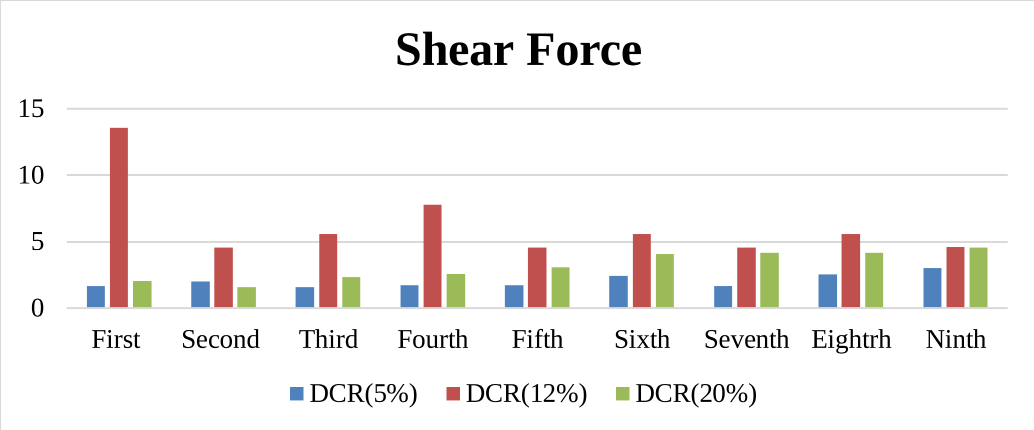

Fig. 18: DCR Comparison (Shear Force) (G+9)

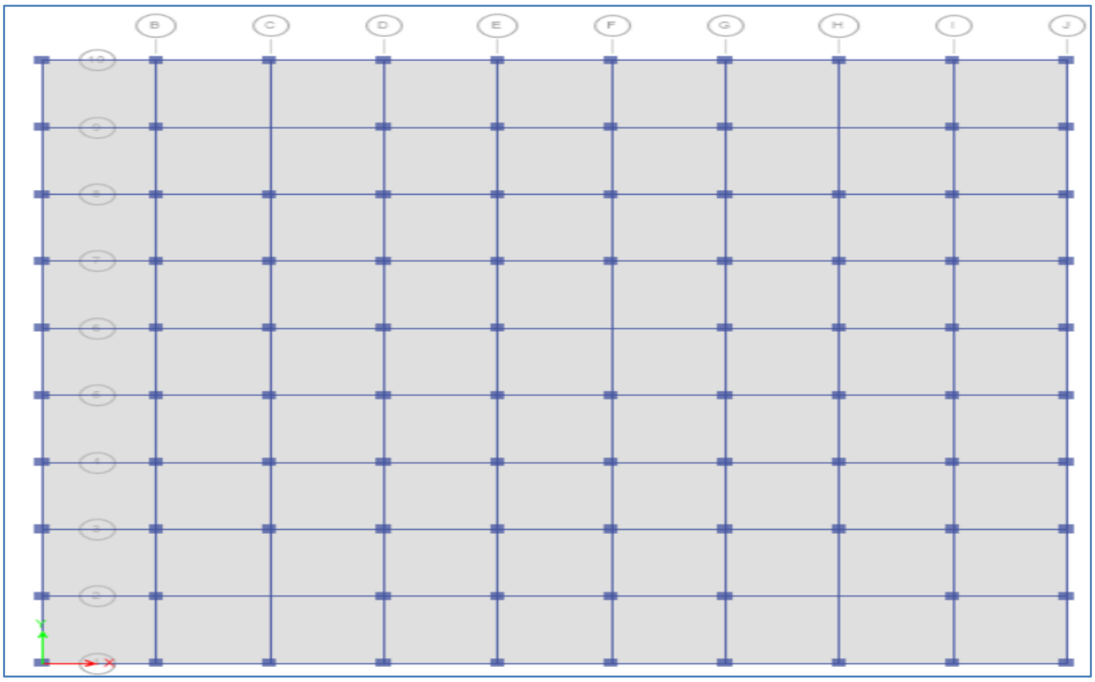
Fig. 19: Model G + 15 – 5 % Column removal

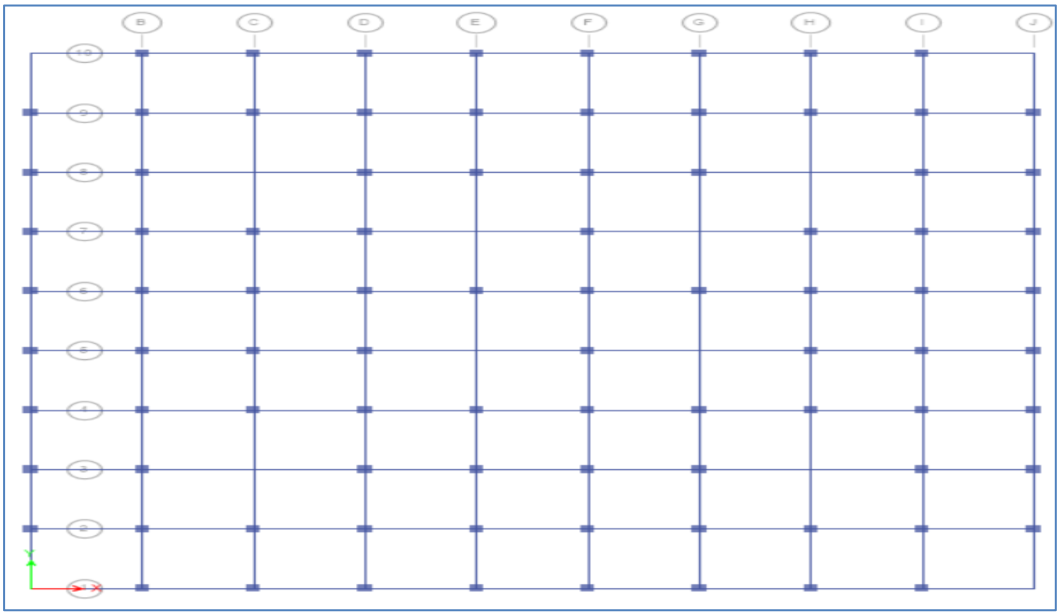
Fig. 20: Model G + 15 – 12 % Column removal

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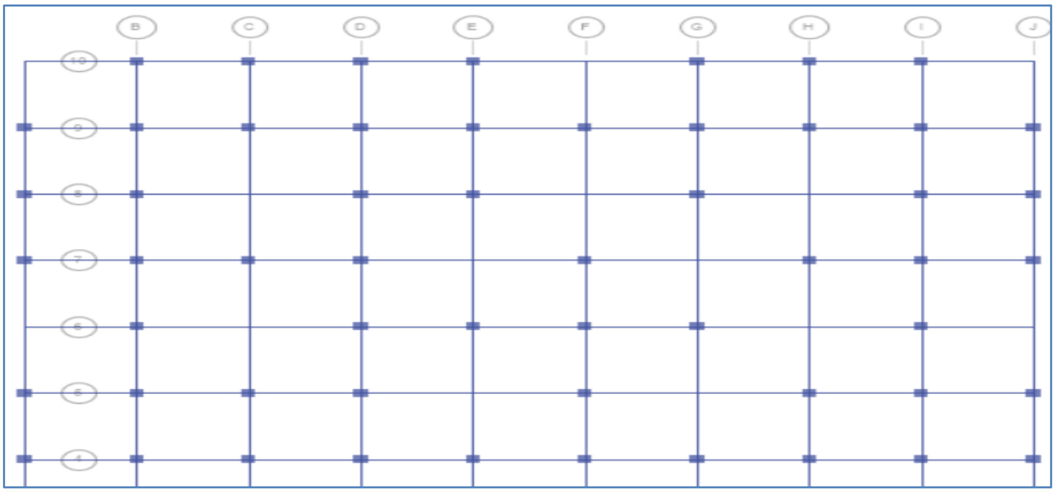

Fig. 21: Model G + 15 –20 % Column removal

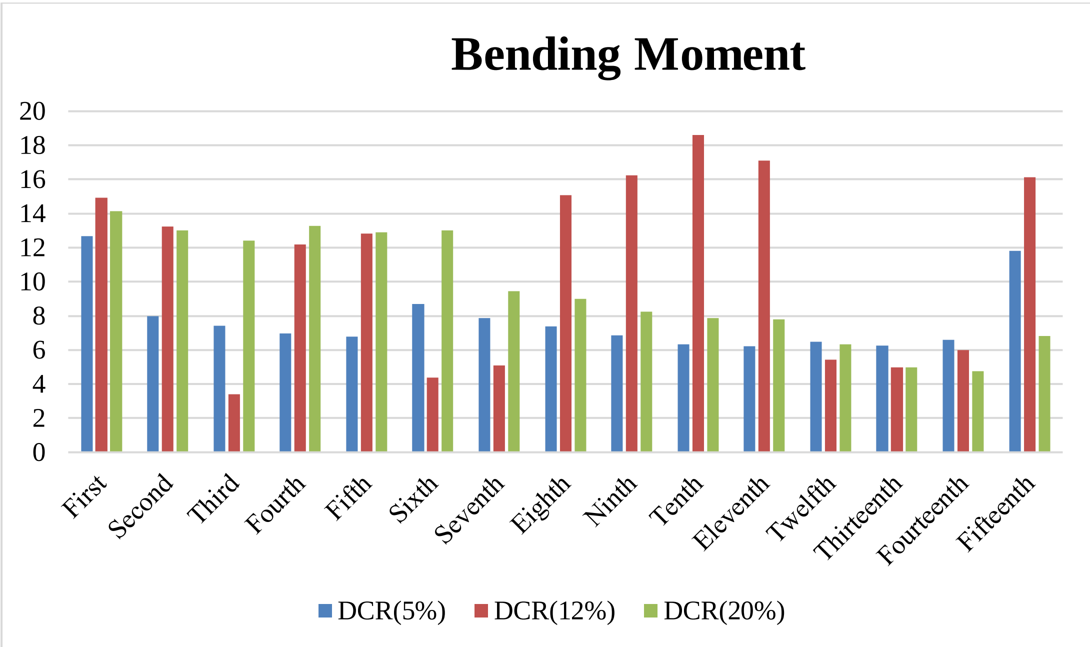

Fig. 22: DCR Comparison (Bending Moment)(G+15)

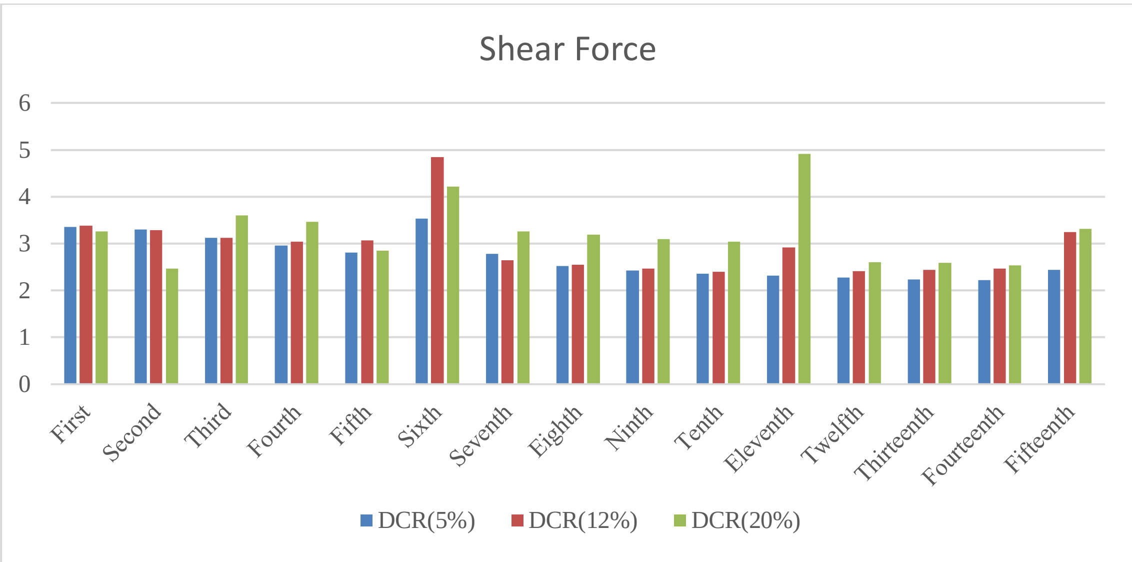

Fig. 23: DCR Comparison (Shear Force)(G+15)

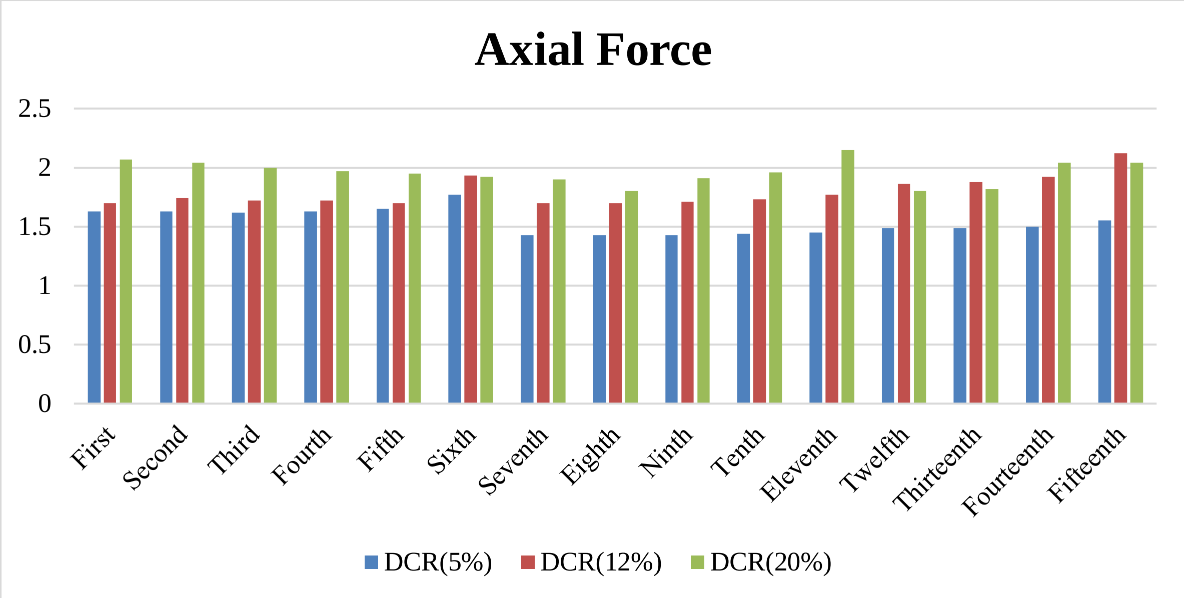

Fig. 24: DCR Comparison (Axial Force) (G+15)

V. PROGRESSIVE COLLAPSE ANALYSIS

As directed by GSA in the ETABS software, linear static analysis was used in this study to examine the possibility of progressive collapse. Through the removal of a crucial column and an analysis of its impact on the structure, the progressive collapse is accomplished. The GSA guidelines provide the criterion for column removal. As recommended by the GSA guidelines, three distinct cases (5%, 12%, and 20%) of column removal at the ground floor are taken into consideration in this study.

VI. ANALYSIS AND RESULTS

The three distinct vertical irregular structures were subjected to a linear static progressive collapse analysis for the three scenarios (5%, 12%, and 20%) of column removal. The study's findings are expressed in terms of the vertical displacement at the site of column removal, the axial force in the column next to the removed column, and the demand capacity ratio (DCR). According to the GSA guidelines, a member's demand capacity ratio should be less than 1.5 in order to prevent progressive collapse. The ratio of the member's capacity to the demand that arrives after a column is removed is known as the demand capacity ratio.

VII. CONCLUSION

- In model 1(G+6), After removal of 5% columns , there are 26.2% beams are going to fail in flexure and 16% beams are going to fail in shear and 22.3% columns are going to fail.
- In model 1(G+6), After removal of 10% columns , there are 46.2% beams are going to fail in flexure and 21.4% beams are going to fail in shear and 26.78% columns are going to fail.
- In model 1(G+6), After removal of 20% columns , there are 53.8% beams are going to fail in flexure and 31.3% beams are going to fail in shear 32.14% columns are going to fail.
- In model 2(G+9), After removal of 5% columns , there are 17.6% beams are going to fail in flexure and 11.8% beams are going to fail in shear 20% columns are going to fail.
- In model 2(G+9), After removal of 10% columns , there are 26.8% beams are going to fail in flexure and 15% beams are going to fail in shear 37.5% columns are going to fail.
- In model 2(G+9), After removal of 20% columns , there are 34.2% beams are going to fail in flexure and 23.6% beams are going to fail in shear 43.6% columns are going to fail.
- In model 3(G+15), After removal of 5% columns , there are 18% beams are going to fail in flexure and 8.5% beams are going to fail in shear 3% columns are going to fail.
- In model 3(G+15), After removal of 12% columns , there are 22% beams are going to fail in flexure and 19% beams are going to fail in shear 16% columns are going to fail.
- In model 3(G+15), After removal of 20% columns , there are 42% beams are going to fail in flexure and 53% beams are going to fail in shear 27% columns are going to fail.

VIII. FUTURE SCOPE

- The Structural behaviour of vertical irregular buildings having different height under progressive collapse.
- To provide nonlinear hinges in equivalent beam and strut models to study the extent of damage and behavior of the structure.
- To determine the change in demand/capacity and percentage collapse load attained ratios by considering bare frame resistance along with slab and wall contribution in the line arstatic method and non linear static method respectively.

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