International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 05 | May 2019 www.irjet.net p-ISSN: 2395-0072

Progressive Collapse Analysis for Asymmetrical G+11 Story Tall Building Using STAAD PRO

Vikas Tiwari[1], Sambhav Gangwal[2]

[1] *PG Scholar, Dept. of Civil Engineering, Malwa institute of Science & Technology, Indore, M.P., India*
[2]*Assistant Professor, Dept. of Civil Engineering, Malwa institute of Science & Technology, Indore, M.P., India*

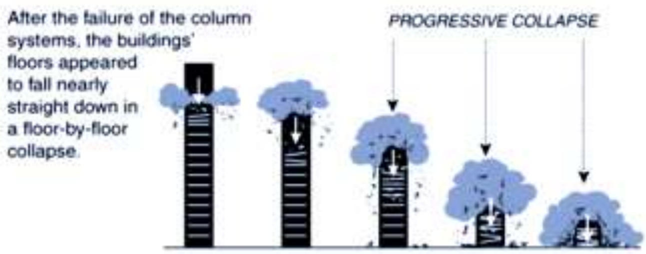
---***---

Abstract - A structure experiences progressive collapse when a primary structural member (generally column) fails due to manmade or natural causes. The failure of a member in the primary load resisting system leads to redistribution of forces to the adjoining members and if redistributed load exceeds member capacity it fails. This process continues in the structure and eventually the building collapses. This phenomenon is referred as progressive collapse of the structure. In the present study progressive collapse potential of 12 Story Tall building which is Asymmetrical U-Shaped concrete framed building is evaluated. Linear static and dynamic analysis is performed by following the General Service Administration (GSA-2003) guidelines for evaluating progressive collapse potential. Modelling, analysis and design of the buildings are performed using STAAD PRO V8 for three different threat-independent column removal conditions by following the alternate load path method. It is observed that demand capacity ratio (DCR) in beams and columns are exceeding the allowable limit for all the cases. This indicates the building considered for study is having high potential of progressive collapse. To reduce the potential of progressive collapse various approaches for mitigation of the progressive collapse are implemented in this research. Different approaches like providing bracing at floor level, also suggest different type of Bracing which we are provided, moderate increase in the size of beam at all the story levels. Comparison between the approaches is presented in this study.

Key Words: Asymmetrical, G+11 Story, Tall Building, Progressive Collapse, GSA 2003, Alternative Steel Bracing, Member wise, Floor Wise,

1.INTRODUCTION

Progressive collapse implies a phenomenon of sequential failure of part of the structure or the complete structure initiated by sudden loss of vertical load carrying member (mostly column). The failure of a member in the primary load resisting system leads to redistribution of forces to the adjoining members and if redistributed load exceeds member capacity it fails. This process continues in the structure and eventually the building collapses. A collapse of this nature is mostly of concern to structural engineers if there is a pronounced disproportion between the initiating event and the resulting collapse.



2. OBJECTIVE & SCOPE

2.1 OBJECTIVE

Keeping the previous chapter mentioned points in view, the main objectives of present study are formulated as under: -

1. To review various guidelines & techniques used for to analysis of progressive collapse analysis and to develop a report in the form of literature review.

2. To identify an appropriate technique and suitable guideline from the reviewed literature for progressive collapse analysis of G+11 story asymmetrical building.

3. To draw an asymmetrical building in software using relevant data and identify the areas for problem formulation from reviewed literature.

4. To analyses the asymmetrical building for identified technique of progressive collapse analysis and to determine different remedial measures for building.

5. To interpret the results derived from chosen technique and to derive conclusion.

In the field of progressive asymmetric collapse analysis, we want to fulfil the above objective following work is outlined:

2.2 SCOPE

1. High rise R.C.C. structure (building) is analyses and design by conventional method for dead load, live load, and earthquake load in STAAD PRO V8 software.

2. The above structure is further analyses for removal column considering load combinations as per GSA guidelines.

3. Results are compared with first case which is without accidental load to see the collapse path by using same software.

4. Remedial measures are provided to avoid progressive collapse like – Bracing system meanwhile provided Alternative Bracing system,

5. Results of various types of graphs & compared in between bracing & Without Bracing cases in progressive collapse analysis condition & also plot the comparative graphs like – member, case, floor, separate, overall analysis.

3. LITERATURE REVIEW

Jain and Patil (July - 2018) adopted a linear static analysis approach for progressive collapse analysis to determine robustness against the local failure and accidental occurrences for a RC framed structure to evaluate the demand capacity ratio and the safety of the structure. In this research, A finite element model had been developed for the 10 storey building and then the analysis was carried under critical column removal scenario as per the guidelines provided in GSA (2003) considering the provisions of IS 1893:2002 to simulate dynamic collapse mechanism using ETABS software v16.2.1 (software for modelling or analysis of structure) to assess the vulnerability to progressive collapse of atypical RC framed structures.

Sonawan et al. (Dec - 2013) assessed the seismic capacity of earthquake vulnerable buildings or earthquake damaged buildings for the future use. In the research, it had been observed that majority of buildings damaged due to earthquake may be safely reused, if they were converted into seismically resistant structures by employing retrofitting measures. This work emphasized on the seismic evaluation & different retrofitting strategies of R.C. buildings.

Tavakoli et al. (DEC - 2012) focused on gravity and blast loading. Observations of buildings damaged by earthquake had shown that earthquake load also may cause local partial or complete failure of critical elements and may lead to progressive failure. This research was based on the three and two-dimensional modelling and push-over analysis of seismically designed special dual system steel frame buildings with concentrically braced frames with complete loss of critical elements.

4. METHODOLOGY

4.1 GENERAL SERVICE AUTHORITY (GSA-2003)

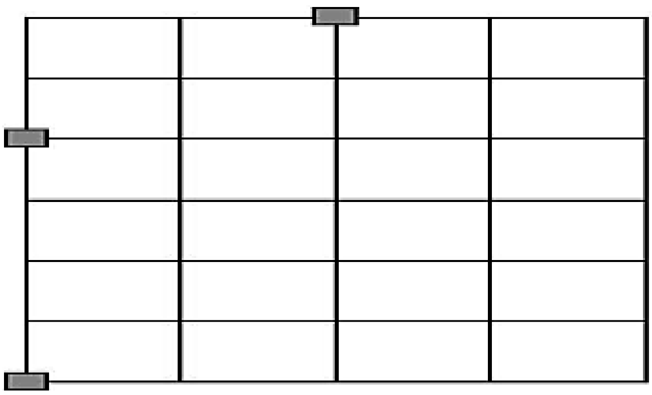
The United States General Service Authority (GSA) released a document entitled "Progressive collapse analysis and design guidelines for new federal office buildings and major modernization projects" in November 2000 and revised in June 2003.

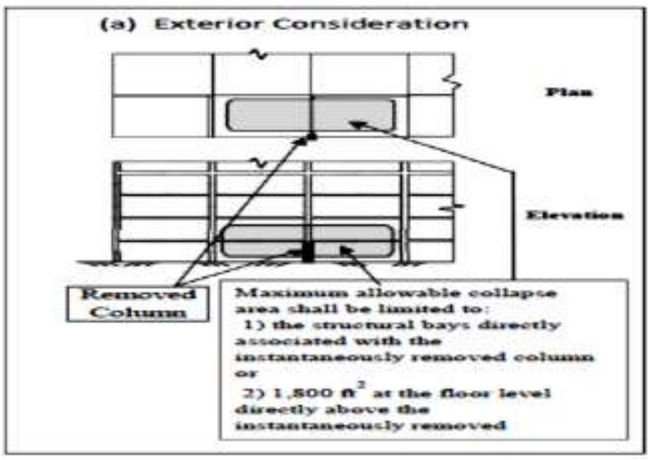
The (GSA, 2003) guideline follows a threat independent methodology for analysis and design of buildings to mitigate the risk of progressive collapse.

This guideline was the first document providing an explicit step-by-step process to aid the structural engineering to assess the potential of progressive collapse of federal facilities.

4.2 GSA GUIDELINE - EXTERIOR CONSIDERATION

Analyse the structure after the notional removal for a load-carrying element for the first floor situated at or near the middle of short side, middle of long side, or at the corner of the building as shown in Figure





4.3 GSA GUIDELINE – LOAD COMBINATION

The (GSA, 2003) guideline specifies that only 25 percent of the live load must be applied in vertical load combination because of the possibility of presence of the full live load during the collapse being very low.

A magnification factor of 2 is used in the static analysis approach to account for dynamic effects.

Load Combination = **2(DL + 0.25LL)**

where,

DL = dead load

LL = live load

4.4 GSA GUIDELINE – DEMAND CAPACITY RATIO

DCR = QUD / QCE

where,

DCR = Demand Capacity Ratio, (**DCR 2.0** for typical structural configurations)

QUD = Acting force (demand) determined in component or connection/joint (moment, shear force,).

QCE = Expected ultimate, un-factored capacity of the component and/or connection/joint (moment, shear forces).

If DCR Value HIGHER Than = 2 = Structure Will not safe. & DCR Value LOWER Than = 2 = Structure Will safe. (As Per GSA 2003)

Then We find our Structures are Safe or not & find out DCR for Forces & Moment Separately. if structures are not safe then provide mitigation.

4.5 METHODOLOGY

OBJECTIVE 1: To calculate the progressive collapse potential of a 12- storey (G+11) asymmetric tall building in as per GSA (2003) Guidelines. Linear static and linear dynamic (response spectrum analysis) analysis have been done.

Dead load - Self-weight of the structural elements

Floor finish = 1.5 kN/m^ 2 and

Wall load on all beams is = 7.13 kN/m

Live load - On roof = 1.5 kN/m^ 2, and

On floors = 3.0 kN/m^ 2

Seismic loading as per IS: 1893 - Seismic zone: III

Soil type – II & Type of soil: Medium

Number of storeys: 12

No of grids/Bays in X direction: 8

No of grids/Bays in Y direction: 8

Spacing between frames: 7.0 m along X and 8.0 m along Y-direction

Floor height: 3.0 m

Ground floor height: 3.0 m

Depth of Slab: 150 mm

Size of beam: (300 X 350) mm

Size of column: (450 X 700) mm

Materials: M 25 concrete, Fe 415 steel Material

Unit weight of concrete: 25 kN/m^2

Live load: 3 kN/m^2 (FLOOR) & 1.5 kN/m^2 (ROOF), Floor finish: 1.5 kN/m

Wall load: 7.13 kN/m (Half brick wall)

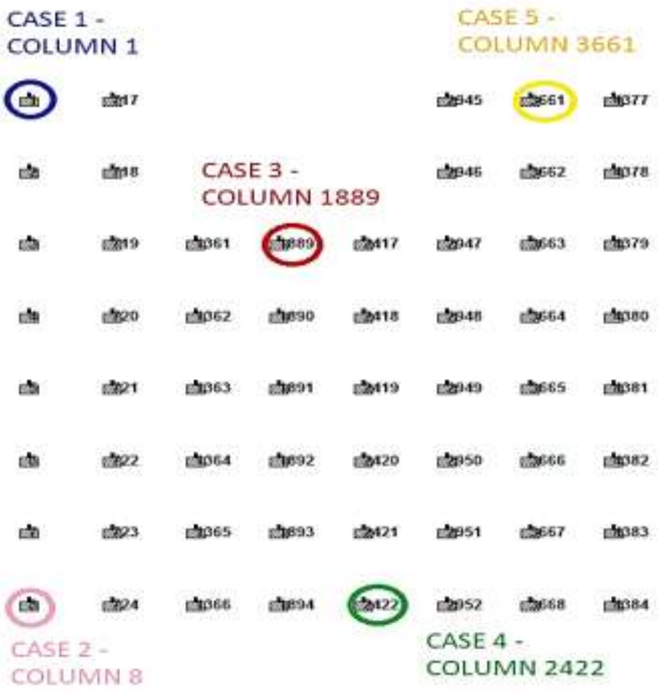
Software Uses – STAAD PRO V8. – Analytical Calculation

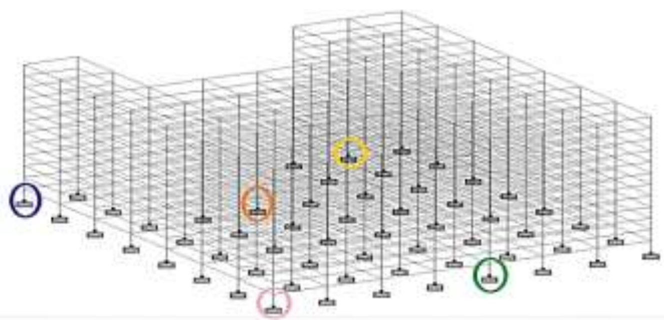
MS OFFICE 365 – Results & Graph Analysis

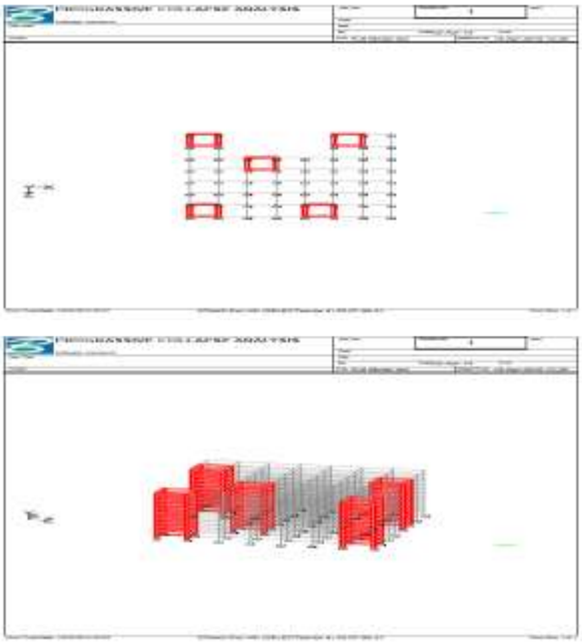
4.6 GROUND FLOOR COLUMN REMOVING CASES

As per the Progressive Collapse analysis guidelines GSA 2003. We carried out the following 5 cases which are unique and uneven shaped for U-shaped structure as per GSA 2003 guideline approach. Cases are the following –

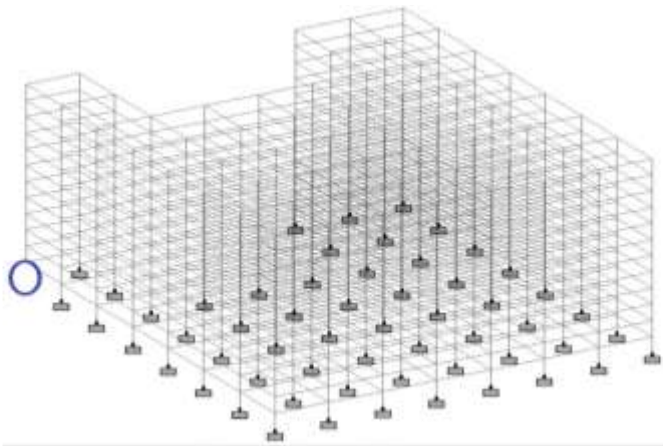
ALL CASES

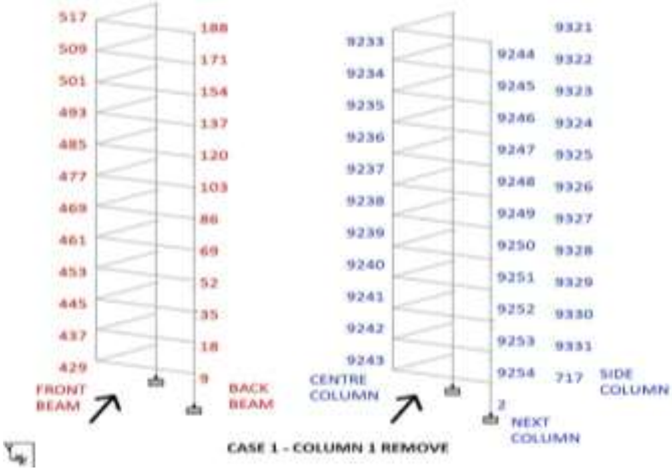




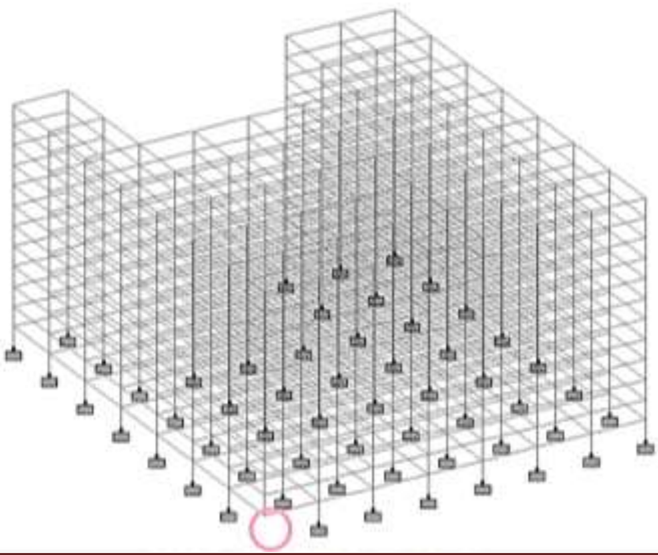


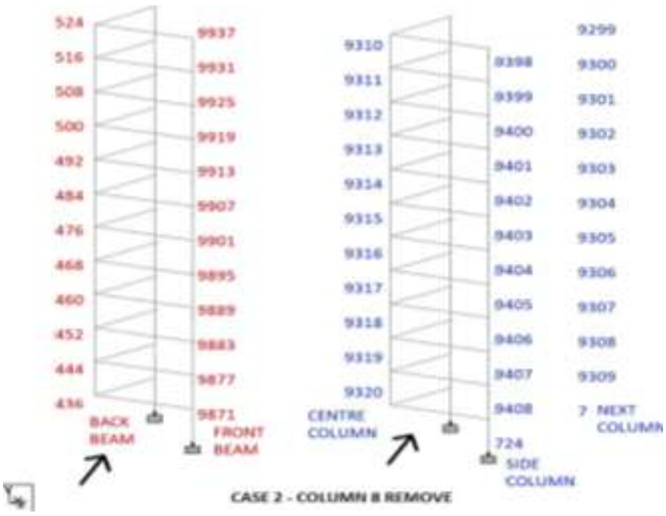
Case 1, – Column no. 1, denote – 1

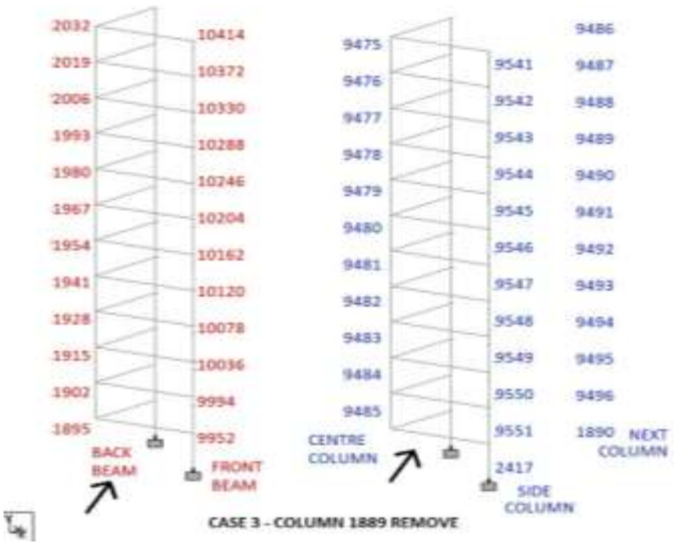




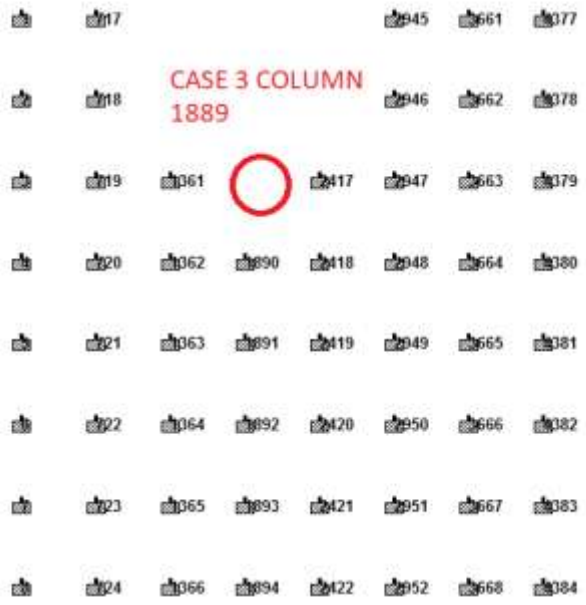
Case 2, - Column no. 8, denote – 8

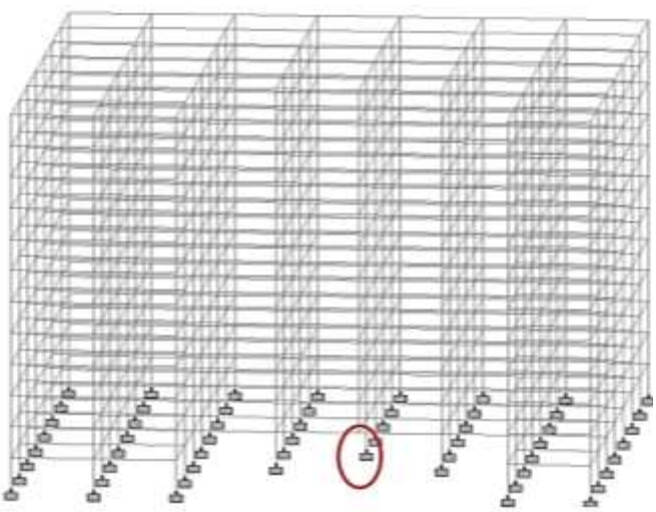




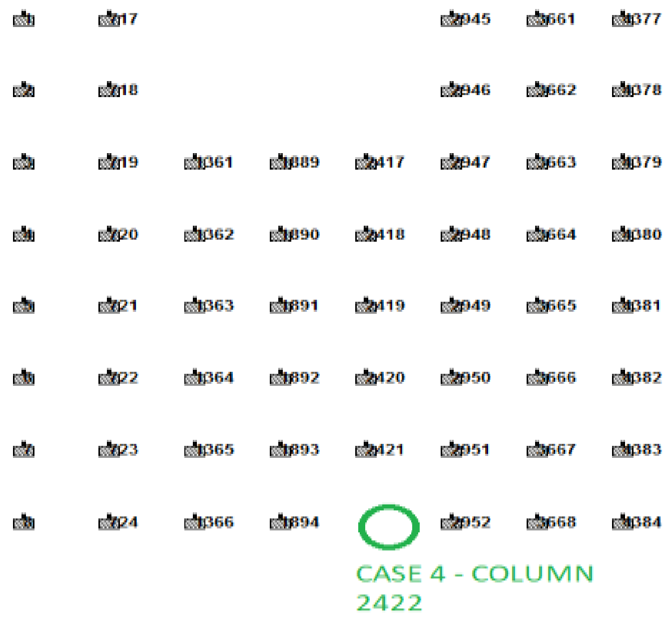


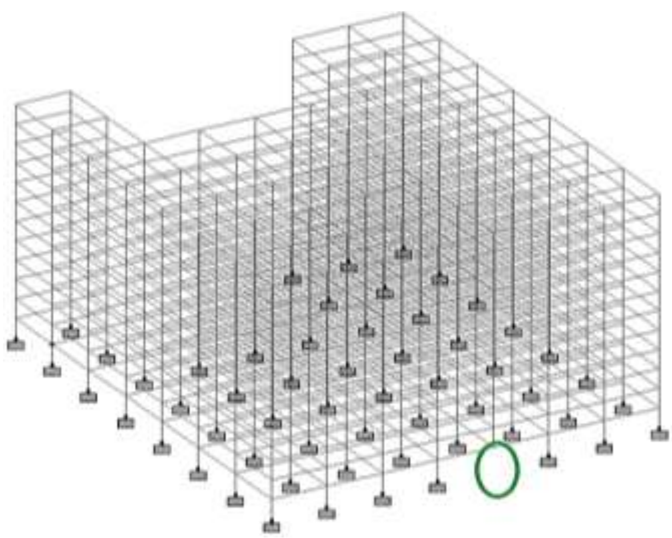
Case 3, – Column no. 1889, denote – 1889

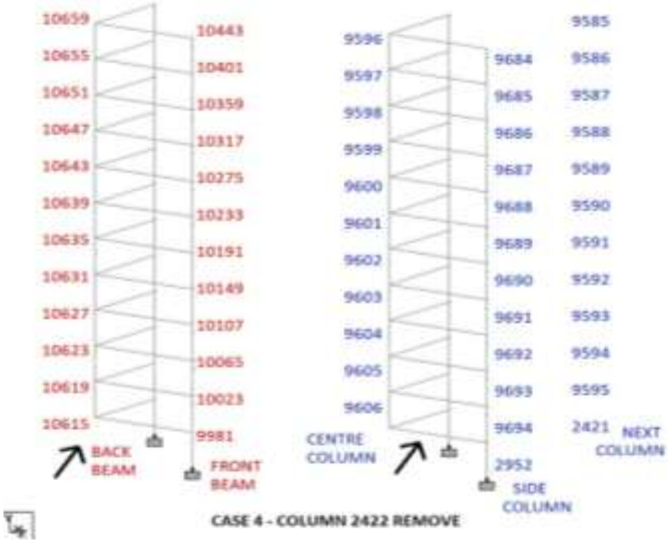




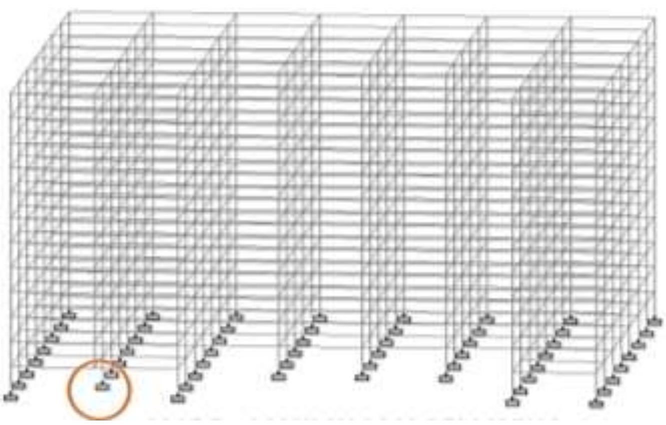
Case 4, - Column no. 2422, denote – 2422

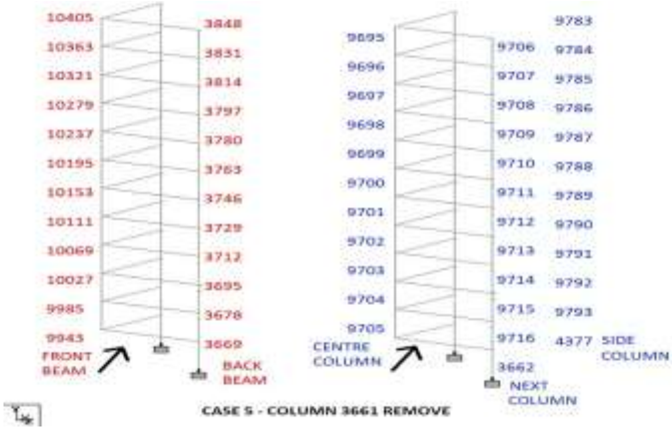






Case 5, – Column no. 3661, denote 3661





4.8 MITIGATE THE PROBLEM

Provision of Alternative path of X- type bracing at top storey level. Here we analysis all 5 Type column removing case with X type alternating Bracing. Bracing Size -

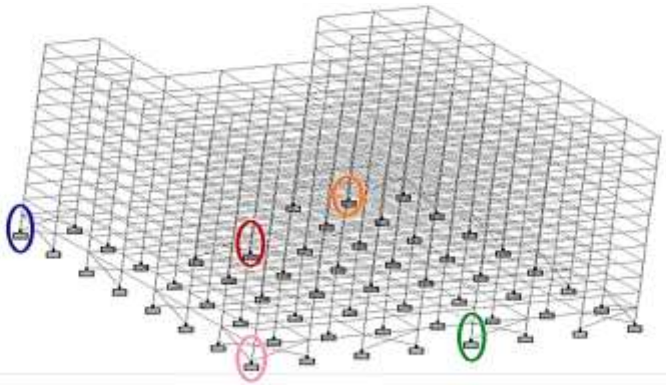
Section - ISWB600H

I-Section – Size – 0.600 X 0.250

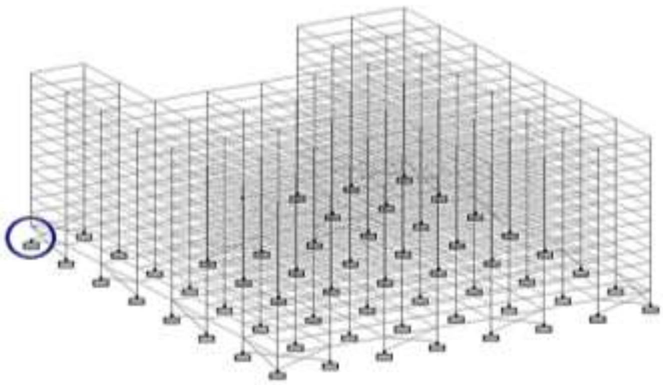
Gauge – 0.012

Bracing Length – 8.54398 (For Y-Axis), & 7.61576 (For X-Axis) There are following Cases –

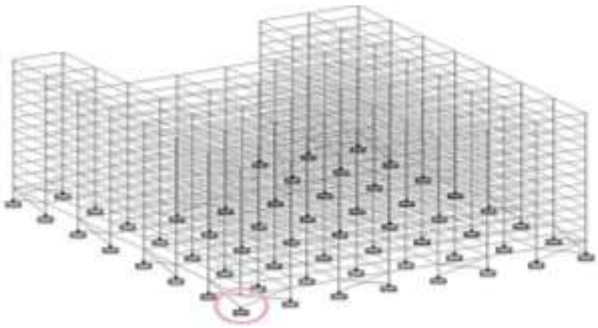
All Cases Bracing



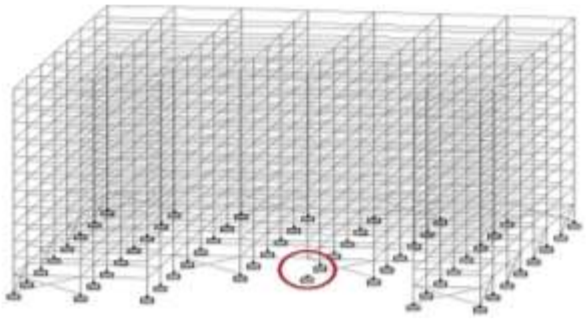
Case 1, – Column no. 1, denote – 1



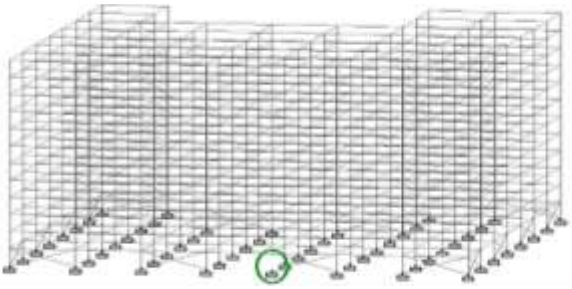
Case 2, - Column no. 8, denote – 8



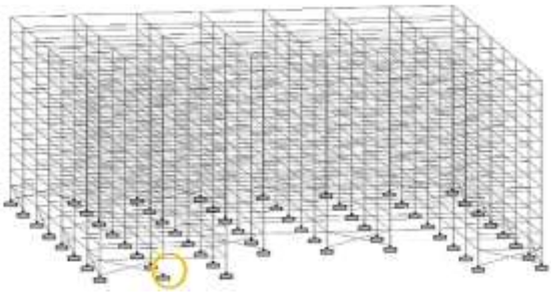
Case 3, – Column no. 1889, denote – 1889



Case 4, - Column no. 2422, denote – 2422

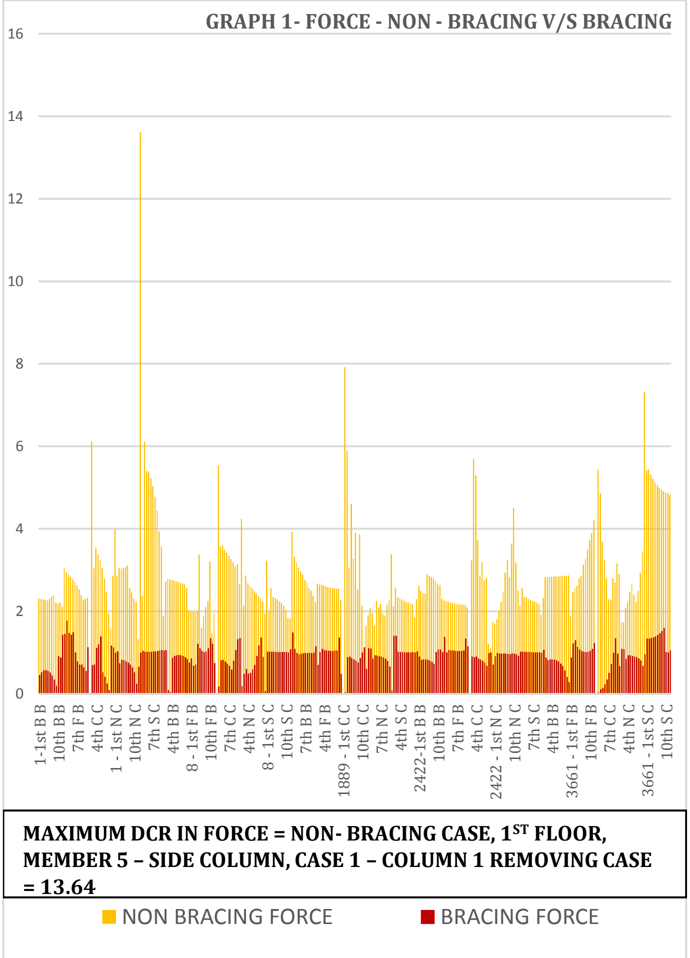


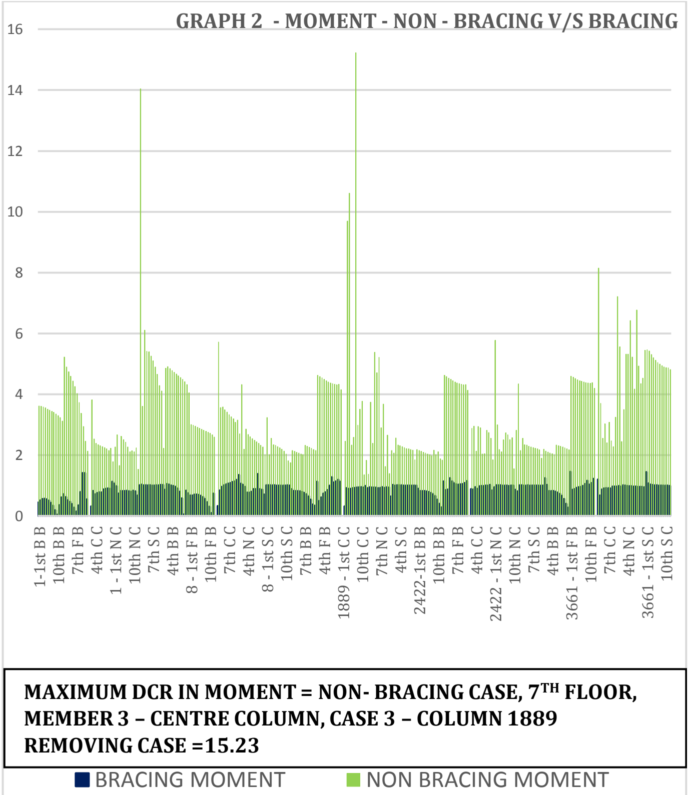
Case 5, – Column no. 3661, denote 3661

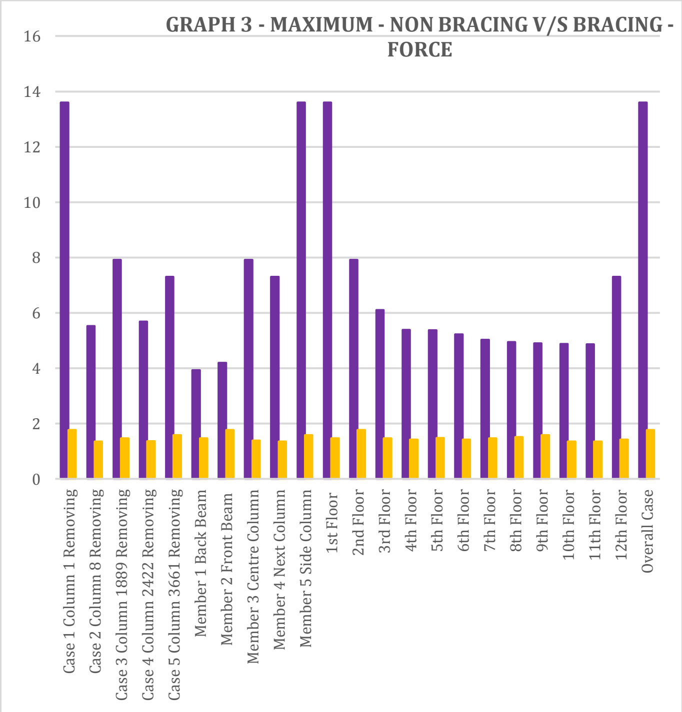


5. OBSERVATIONS

We observed the different types of graphs of member-wise, Case wise, Floor wise, separated, overall, summary wise between Bracing & Non-Bracing conditions. These are the following -

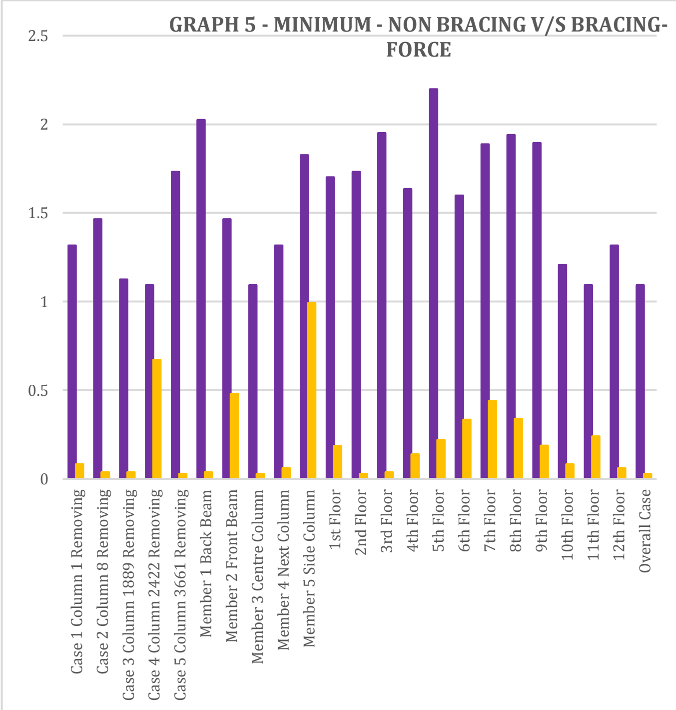






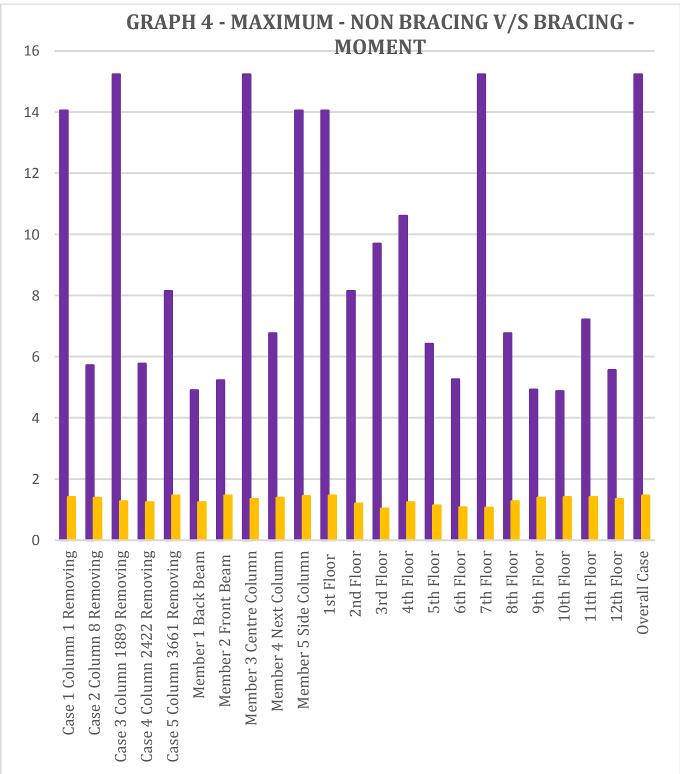
MAXIMUM DCR IN FORCE = NON- BRACING CASE, 1ST FLOOR, MEMBER 5 – SIDE COLUMN, CASE 1 – COLUMN 1 REMOVING CASE = 13.64

NON BRACING FORCE BRACING FORCE



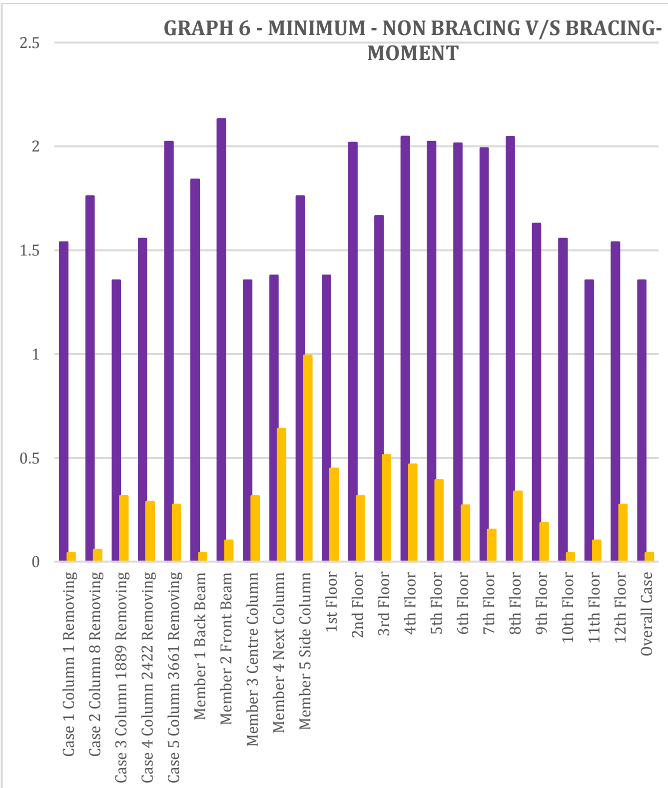
MINIMUM DCR IN FORCE = NON-BRACING CASE, 11TH FLOOR, MEMBER 3 – CENTRE COLUMN, CASE 4 – COLUMN 2422 REMOVING CASE = 1.09

NON BRACING FORCE BRACING FORCE



MAXIMUM DCR IN MOMENT = NON- BRACING CASE, 7TH FLOOR, MEMBER 3 – CENTRE COLUMN, CASE 3 – COLUMN 1889 REMOVING CASE =15.23

NON BRACING MOMENT BRACING MOMENT



MINIMUM DCR IN MOMENT = NON-BRACING CASE, 11TH FLOOR, MEMBER 3 – CENTRE COLUMN, CASE 3 – COLUMN 1889 REMOVING CASE = 1.35

NON BRACING MOMENT BRACING MOMENT

Table 1 – Summary of Results

Positions/ Cases	Force Non-Bracing	Moment Non - Bracing	Force Bracing	Moment Bracing
Case 1 Column 1 Removing - Maximum	13.608	14.045	1.768	1.414
Case 1 Column 1 Removing - Minimum	1.317	1.538	0.082	0.041
Case 2 Column 8 Removing - Maximum	5.531	5.725	1.357	1.385
Case 2 Column 8 Removing - Minimum	1.464	1.759	0.038	0.057
Case 3 Column 1889 Removing - Maximum	7.914	15.232	1.475	1.273
Case 3 Column 1889 Removing - Minimum	1.125	1.355	0.037	0.316
Case 4 Column 2422 Removing - Maximum	5.684	5.778	1.372	1.245
Case 4 Column 2422 Removing - Minimum	1.092	1.555	0.671	0.289
Case 5 Column 3661 Removing - Maximum	7.308	8.149	1.585	1.458
Case 5 Column 3661 Removing - Minimum	1.732	2.022	0.028	0.275
Member 1 Back Beam - Maximum	3.926	4.907	1.475	1.247
Member 1 Back Beam - Maximum	2.025	1.840	0.038	0.041
Member 2 Front Beam - Maximum	4.199	5.230	1.768	1.458
Member 2 Front Beam - Minimum	1.464	2.131	0.480	0.101
Member 3 Centre Column - Maximum	7.914	15.232	1.386	1.345
Member 3 Centre Column - Minimum	1.092	1.355	0.028	0.316
Member 4 Next Column - Maximum	7.308	6.770	1.357	1.385
Member 4 Next Column - Minimum	1.317	1.378	0.061	0.640
Member 5 Side Column - Maximum	13.608	14.045	1.585	1.442
Member 5 Side Column - Minimum	1.825	1.759	0.991	0.993
1st Floor - Maximum	13.608	14.045	1.475	1.458
1st Floor - Minimum	1.702	1.378	0.185	0.448
2nd Floor - Maximum	7.914	8.149	1.768	1.200
2nd Floor - Minimum	1.732	2.016	0.028	0.316
3rd Floor - Minimum	6.106	9.692	1.473	1.039
3rd Floor - Minimum	1.951	1.664	0.038	0.514
4th Floor - Maximum	5.391	10.607	1.422	1.245
4th Floor - Minimum	1.635	2.046	0.139	0.469
5th Floor - Maximum	5.376	6.424	1.486	1.135
5th Floor - Minimum	2.197	2.022	0.219	0.393
6th Floor - Maximum	5.222	5.260	1.422	1.079
6th Floor - Minimum	1.598	2.014	0.334	0.271
7th Floor - Maximum	5.029	15.232	1.465	1.070
7th Floor - Minimum	1.887	1.991	0.439	0.155
8th Floor - Maximum	4.943	6.770	1.518	1.273
8th Floor - Minimum	1.939	2.045	0.338	0.338
9th Floor - Maximum	4.904	4.929	1.585	1.385
9th Floor - Minimum	1.894	1.628	0.187	0.187
10th Floor - Maximum	4.876	4.876	1.357	1.413
10th Floor - Minimum	1.205	1.555	0.082	0.041
11th Floor - Maximum	4.867	7.218	1.352	1.414
11th Floor - Minimum	1.092	1.355	0.239	0.101
12th Floor - Maximum	7.308	5.563	1.424	1.345
12th Floor - Minimum	1.317	1.538	0.061	0.275

6. RESULTS

The text of this chapter deals with the discussion on results obtained by analysis of the 3D model of asymmetrical G+11 story's building. The desired results are based on techniques following GSA 2003 guideline and stepwise analysis as described in previous chapter. Progressive collapse potential of building is found out by considering column removal cases. Demand Capacity Ratio in flexure and shear is calculated for all the 5 type of critical cases. The results obtained are discussed below as:

1. DCR in flexure and shear of beam exceeds the permissible limit of 2.0 in all G+11 story's asymmetrical building for all identified the five cases. The DCR values in beams indicate that building considered for the study is having very low potential to resist the progressive collapse when column is considered as fully damage/removed.

2. The beams adjacent to the damaged/removed column joint experienced more damage as compared to the beams which are away from the removed column joint. Corner column case is found critical in the event of progressive collapse.

3. When mitigation alternatives are adopted, DCR value is reduced within permissible limit. Provision of steel bracing in alternate manner in ground floor is economical solution to reduce the potential of progressive collapse.

4. It is also observed that to avoid the progressive failure of beams and columns, after failure of column due to extreme loading from blast, adequate reinforcement can also be useful to limit the DCR within the acceptance criteria.

5. Floor wise most critical case is 1st floor where DCR = 13.64 in terms of force & 7th floor where DCR = 15.23 in terms of moment & Least critical case is 11th floor where DCR = 1.09 in terms of force & 11th floor where DCR = 1.35 in terms of moment.

6. Member wise most critical case is Side Column where DCR = 13.64 in terms of force & Centre Column where DCR = 15.23 in terms of moment & Least critical case is Centre column where DCR = 1.09 in terms of force & Centre Column where DCR = 1.35 in terms of moment.

7. Separate Case wise most critical case is Column 1 Remove in Case 1 where DCR = 13.64 in terms of force & Column 1889 Remove in Case 3 where DCR = 15.23 in

terms of moment & Least critical case is Column 2422 Remove in Case 4 where DCR = 1.09 in terms of force & Column 1889 Remove in Case 3 where DCR = 1.35 in terms of moment.

7. SCOPE OF FUTURE WORK

There is a scope of extending this work to include the following for future: -

1. The present work has been carried out to calculate the DCR for asymmetric building. The work can be extended to Shear wall type asymmetric buildings.

2. In this study Steel Bracing has been used, other Bracing Methodology also used like - Prestressed Bracing, Heavy Wooden/fibre/other durable & plastic material also used for future scope.

3. In this study STAAD PRO V8 has been used; other software like ETABS, SAP, and ANSYS etc. can be used.

4. In this study, linear static and linear dynamic (response spectrum method) analysis have been performed; Push over Non-linear analysis can be done for same building.

8. REFERENCES

[1] ASCE 7–05. Minimum Design Loads for Buildings and Other Structures. American Society of Civil Engineers (ASCE), Report: ASCE/SEI 7–05. Reston, VA, 2005

[2] A S Patil and P D Kumbhar, 'Time history analysis of multistore', International Journal of Structural and Civil Engineering research, Vol. 2, Issue No. 3, August 2013

[3] FEMA-273 (1997), Federal Emergency Management Agency, NEHRP Guideline for the Seismic Rehabilitation of Building, Building Seismic Safety Council, Washington DC USA

[4] IS: 1893 (Part 1): 2002, Criteria for Earthquake Resistant Design of Structure, B.I.S 2000, Manak Bhavan 9, Bahadur Shah Zafar Marg, New Delhi 110002

[5] IS 456-2000, Plain and Reinforced Concrete-Code of Practice (Fourth Revision), B.I.S 2000, Manak Bhavan 9, Bahadur Shah Zafar Marg, New Delhi 110002

[6] Subramanian (2013), Consulting Engineer, Maryland, Design of Steel Structures, 12th Impression, Oxford Higher Education, @ Oxford University Press.

[7] Ashok K. Jain (2012), Reinforced Concrete Limit State Design, 7th Edition, Nem chand & Bros. Roorkee, India

[8] Bungale S. Taranath (2009), Reinforced Concrete Design of Tall Building, CRC Press, Taylor & Francis Group, Informa Business, New York, USA

[9] GSA. Progressive Collapse Analysis and Design Guidelines for New Federal Office Buildings and Major Modernization Projects. General Services Administration, Washington DC, 2003

9. BIOGRAPHIES

Vikas Tiwari
[1]PG Scholar, Dept. of Civil Engineering, Malwa institute of Science & Technology, Indore, M.P., India

Sambhav Gangwal
[2]Assistant Professor, Dept. of Civil Engineering, Malwa institute of Science & Technology, Indore, M.P., India