Analysis of Progressive Collpse of RCC Building With Blast Loading And Seismic Loading

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Abstract- *This research work presents the progressive collapse analysis of RCC building for blast and seismic loading. The term progressive collapse defined as the ultimate failure or proportionately large failure of a portion of a structure due to spread of a local failure from element to element throughout the structure. Progressive collapse analysis is performed on low rise for G+4, medium rise for G+17 and high rise for G+22 building and its validation in accordance with General Services Administration 2013 Guidelines, to check Demand Capacity Ratio of a respective structure. The response of RCC framed structure under blast and seismic loading is checked in this work. Regular framed structures of G+4, G+17, and G+ 22 are designed and analyzed using Staad proV8i SS5.Time history analysis method is used for progressive collapse analysis. Columns are removed to initiate the progressive collapse. The Elcentro data is used for sesmic time history analysis and for blast analysis time history load is calculated as per IS 4991.Natural frequency, storey drift ,base shear ,vertical displacement before and after column removal are calculated and Demand Capacity ratio is checked .The obtained DCR values shows that columns are safe for low rise(DCR is 1.5)and high rise building(DCR is1.9) and for medium rise G+17 building (DCR is 2.8)collapsed element has been redesigned and additional reinforcement is required to limit the DCR within the acceptance criteria, in order to save partially stable structure.*

Keywords- Progressive Collapse, Demand capacity ratio, column removal, blast and seismic loading, Staad pro.

I. INTRODUCTION

Explosive loading incidents have become a serious problem that must be addressed quite frequently. Many buildings that could be loaded by explosive incidents are moment resistant frames either concrete or steel structures, and their behavior under blast loads is of great interest. Besides the immediate and localized blast effects, one must consider the serious consequences associated with progressive collapse that could affect people and property. Progressive collapse occurs when a structure has its loading pattern, or boundary conditions, changed such that structural elements are loaded beyond their capacity and fail in the past, structures designed to withstand normal load conditions were over designed, and have usually been capable of tolerating some abnormal loads. Modern building design and construction practices enabled one to build lighter and more optimized structural systems with considerably lower over design characteristics. Essential techniques for increasing the capacity of a building to provide protection against explosive and seismic effects shall be discussed both with an architectural and structural approach. Damage to the assets, loss of life and social panic are factors that have to be minimized if the threat of terrorist action cannot be stopped. Designing the structures to be fully blast resistant is not a realistic and economical option, however current engineering and architectural knowledge can enhance the new and existing buildings to mitigate the effects of an explosions and seismic activities.

1.1 Definition of progressive collapse

The General Services Administration, USA adopt the basic definition of that "Progressive collapse is a situation where local failure of a primary structural component leads to the collapse of adjoining members which, in turn, leads to additional collapse". The abnormal loads, like explosions, vehicle collisions, human errors, represent the main causes that lead to progressive collapse of buildings. The seismic design and detailing of a structure provides it with certain levels of continuity, ductility and redundancy, depending on the provisions for the seismic zone and for the ductility class. An increasing number of progressive collapse around the world lead more disastrous event leading to loss of life, injuries and large number of death and not dealt with common codal provision to address the progressive collapse in conventional design. Considering this an important issue, United States Department of Defence (DOD) and United States General Services Administration (GSA), and Euro codes published a string of various guidelines and specifications. It is not economical as well to design the structures for accidental events unless they have reasonable chance of occurrence. Considering these aspects, many government authorities and local bodies have worked on developing some design guidelines to prevent progressive collapse. Among these guidelines, U.S. General Services Administration (GSA) and Department of Defence (DoD) guidelines by United Facilities Criteria (UFC) - New York, provide detailed stepwise procedure regarding methodologies to resist the progressive collapse of structure. In this procedure, one of the important vertical structural elements in the load path i.e. column, load bearing wall etc. is removed to simulate the local damage scenario and the remaining structure is checked for available alternate load path to resist the load. The dynamic response of the building misevaluated after calculating the loading phenomena on different surfaces of the building as the record of pressure time history

1.2 Interaction between the blast and structure

The degree of damage resulting from an explosion can be graphically determined from a pressure impulse diagram, where the impulse is defined as the integral of the side-on over pressure vs time diagram over the duration of the positive specific impulse, (fig 1.1.) In this diagram, Pressure-impulse lines are drawn which represent an equivalent level of damage for varying combinations of pressure and impulse. A qualitative assessment of blast damage can be made by considering the area bounded between two pressure impulse lines. Alternatively, a more advanced analysis may be carried out; however the type of analysis must take account of the frequency of the structure and the duration of the blast wave.

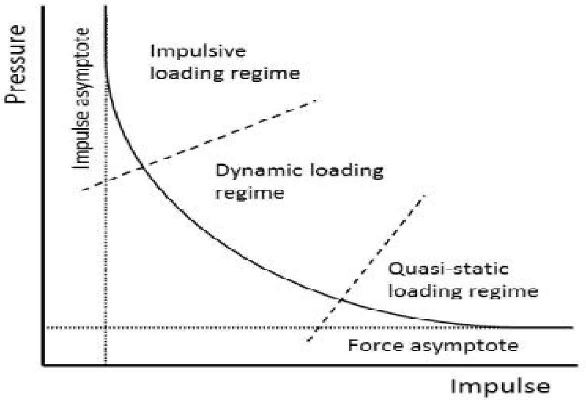

Fig. 1 Pressure impulse diagram for a single degree of freedom elastic system with an ideal blast wave.

PI curves are a type of response spectra developed for structural elements subjected to blast loading. The pressure and impulse values depend on the charge weight and standoff distance of the explosive used. While the pressure considered in PI curves is the peak pressure the structural element is subjected to due to explosion, the impulse is the area of the region bound by the time history curve of the pressure applied.There are three distinct loading regimes in the pressure impulse diagram the impulsive loading regime, the dynamic loading regime and the quasistatic loading regime. These are shown in Figure 1.1. The loading regime for analysis is dependent upon the ratio of the natural frequency of the structure and the duration of the blast wave. For example, flimsy structures with very low natural frequencies will respond quickly to blast loading, and any analysis must take place over the very short timescales associated with the blast wave duration in the impulsive loading regime. Conversely, heavy stiff structures with high natural frequencies may be analyzed assuming a quasi-static loading regime. Where the blast wave duration is similar to the natural frequency of the structure then a dynamic loading assessment must be carried out.

Aim

To Study progressive collapse analysis Of RCC low, medium and high rise building during progressive collapse with blast and seismic loading using staad pro.

Objectives

- To perform progressive collapse analysis on low, medium and high rise building and its validation in accordance with GSA 2013.
- To check Response of RCC frame structure under blast and seismic loading.
- To check c/d ratio of low rise building, high rise building for different earthquake zones in according with GSA 2013.
- To analyse the time of collapse of building.

II. THEORETICAL CONTENT

2.1 Explosion and Blast Phenomenon

An explosion occurs when a gas, liquid or solid material goes through a rapid chemical reaction. When the explosion occurs, gas products of the reaction are formed at a very high temperature and pressure at the source. These high pressure gasses expand rapidly into the surrounding area and a blast wave is formed. An explosion is a rapid release of stored energy characterized by a bright flash and an audible blast. Part of the energy is released as thermal radiation (flash) and part is coupled into the air as air-blast and into the soil (ground) as ground shock, both as radially expanding shock waves.

2.2Ground motions and linear time history analysis

Dynamic analysis using the time history analysis calculates the underground structure responses at discrete time steps using discretized record of synthetic time history as base motion. If three or more-time history analyses are performed, only the maximum responses of the parameter of interest are selected. Time history analysis is the study of the dynamic response of the structure at every addition of time, when its base is exposed to a particular ground motion.

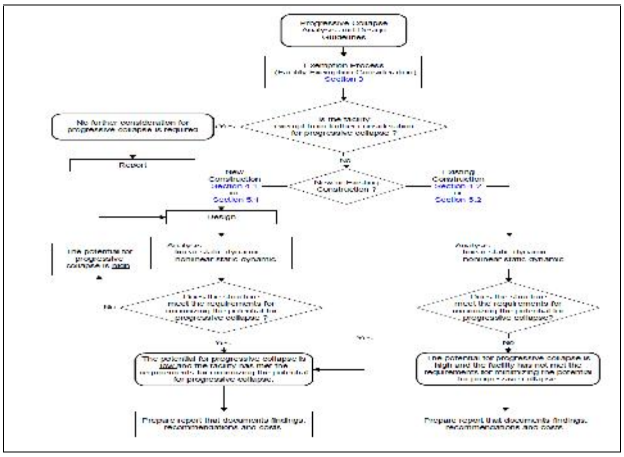

Fig.2 Overall flow for consideration of progressive collapse

III. MODELING AND ANALYSIS

3.1Modeling of frame

The space frame building is modeled in STAAD-Pro. The beams and columns are modeled as beam elements and the slab is modeled as a plate element

Table -1: Models Specifications

Specification	G+4	G+17	G+22
Beam Size	**230*500mm**	230 X 500 mm	230 X 500 mm Slab Thickness: 150 mm Storey Height 3m Grade of concrete:M25 Explosive type: C4 type of explosive
Column Size	**230*600mm**	Column up to fourth floor Size: 230 X450 mm Column up to fourth floor to seventh floor Size: 230 X 420 mm Column up to seventh floor to tenth floor Size 230 X400 mm Column up eleventh floor to seventeen floors: 230 X 380mm	Column up to fourth floor Size: 230 X450 mm Column up to fourth floor to seventh floor Size: 230 X 420 mm Column up to seventh floor to tenth floor Size 230 X400 mm Column up eleventh floor to twenty second floor 230 X 380mm
Slab Thickness	**150mm**	**150mm**	**150mm**
Storey Height	**3m**	**3m**	**3m**
Grade of concrete Explosive type	**M25** **C4 explosive**	**M25** **C4 explosive**	**M25** **C4 explosive**

3D View of models in Staad Pro.

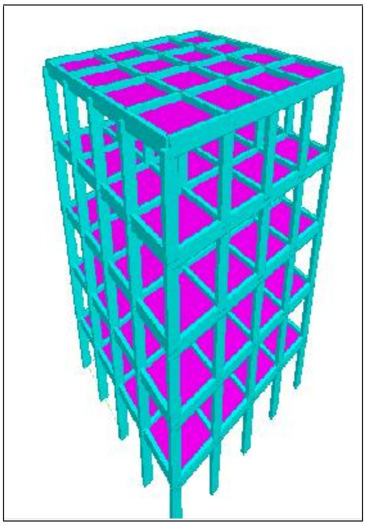

Fig.3.1 G+4 storey building

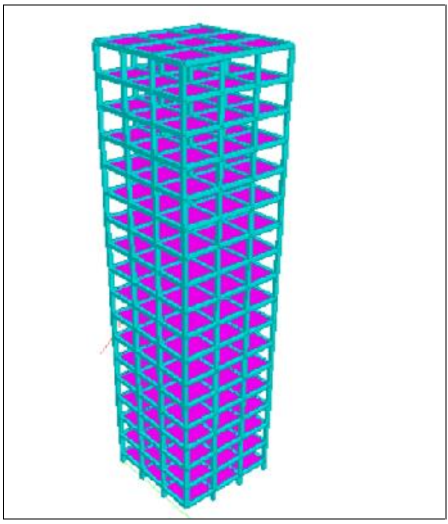

Fig.3.2 G+17 storey building

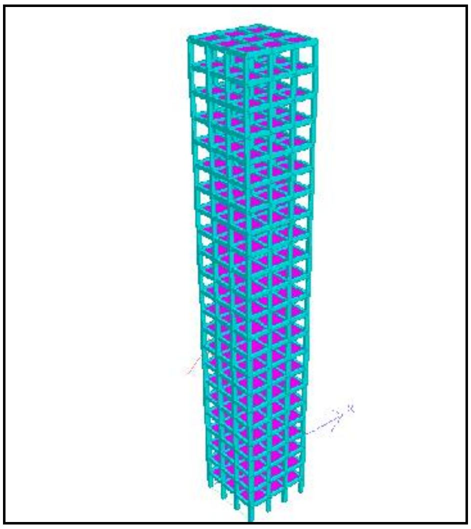

Fig.3.3 G+22 storey building

IV. RESULTS AND DISCUSSION

4.1 Progressive collapse analysis for G+4 building with blast loading results is as follows

Table-2: Natural Frequency Hz

NATURAL FREQUENCY		
Mode	BEFORE REMOVAL	AFTER REMOVAL
1	2.280	2.166
2	2.854	2.711
3	2.860	2.717
4	6.687	6.352
5	6.972	6.623
6	8.582	8.152

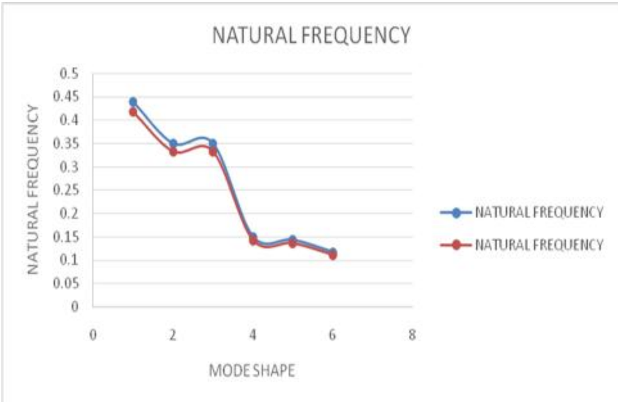

Fig.4 Natural frequency Vs Mode shapes

From the above graph the Natural frequency of frame before removal of column is greater than after removal.

Table -3: Time period

TIME PERIOD		
Mode	BEFORE REMOVAL	AFTER REMOVAL
1	0.439	0.41705
2	0.35	0.3325
3	0.35	0.3325
4	0.15	0.1425
5	0.143	0.13585
6	0.117	0.11115

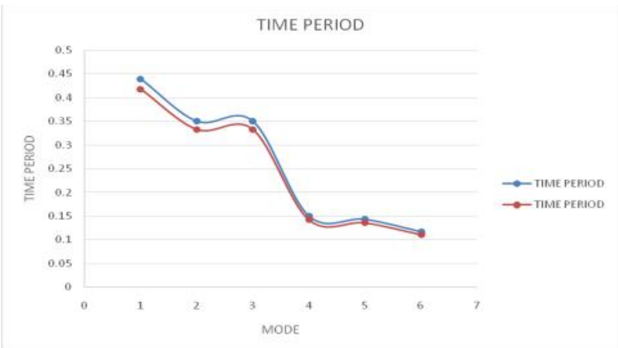

Fig.5 Mode shapes

From the above graph the Time Period of frame before removal of column is greater than after removal.

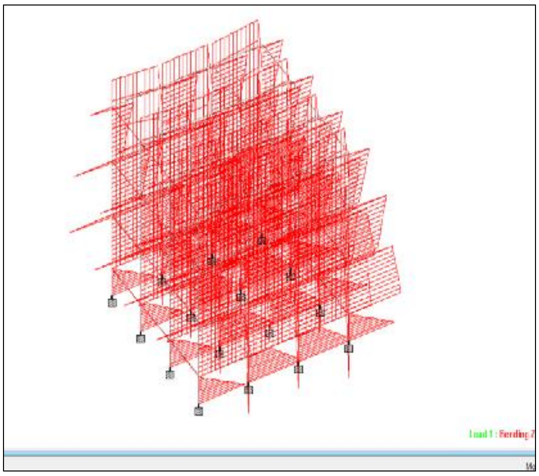

Fig.5.1 Bending moment diagram before removal of column

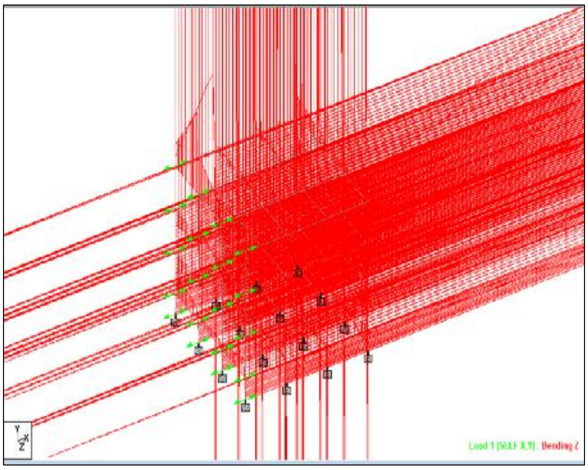

Fig.5.2 Bending moment diagram after removal of column

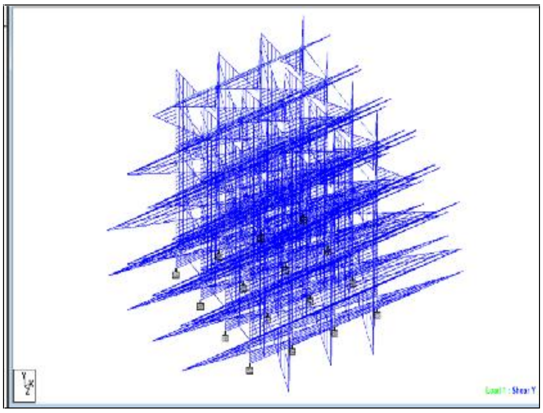

Fig.5.3 Shear force diagram before removal of column

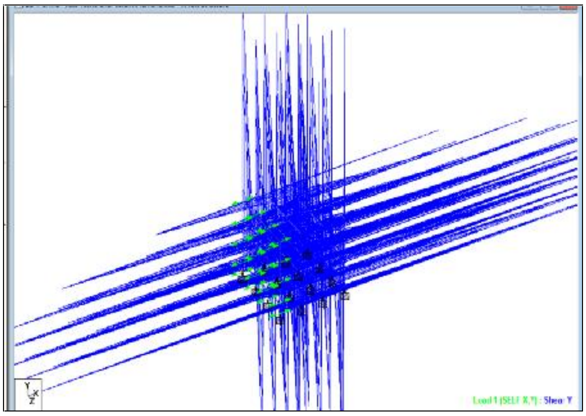

Fig.5.4 Shear force diagram after removal of column

4.2 G+4 Building Storey Drift, Base Shear and Displacement

Table -4: Storey drift

Storey no.	RCC frame	
	Before removal of column	After removal of column
0	0	0
1	1.54	1.54
2	6.16	6.17
3	13.87	13.89
4	24.66	24.7
5	34.35	34.4

Fig. 5.5 Drift in X direction

From the above graph the Drift in X direction before removal of column is up to 34.35 and after removal is up to 34.4, Drift in X direction after removal greater than before removal.

Table-5: Base shear

Storey no.	RCC frame	
	Before removal of column	After removal of column
0	0	0
1	3.91	3.934
2	15.709	15.736
3	35.346	35.405
4	62.838	62.942
5	87.513	87.658

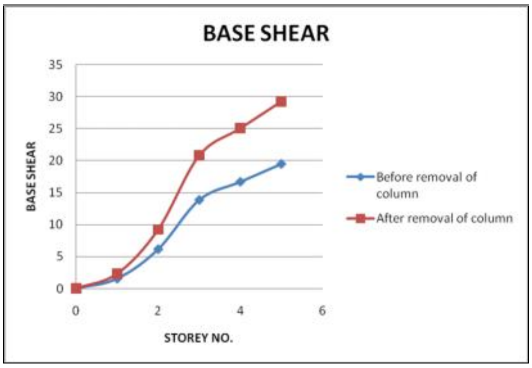

Fig.5.6 Base shear in X direction

From the above graph the Base shear in X direction before removal of column is up to 87.513 and after removal is up to 87.658, Base shear in X direction after removal greater than before removal.

Table-6: Vertical displacement

Storey no.	RCC frame	
	Before removal of column	After removal of column
0	0	0
1	0.464	0.585
2	0.836	1.054
3	1.114	1.405
4	1.296	1.636
5	1.383	1.747

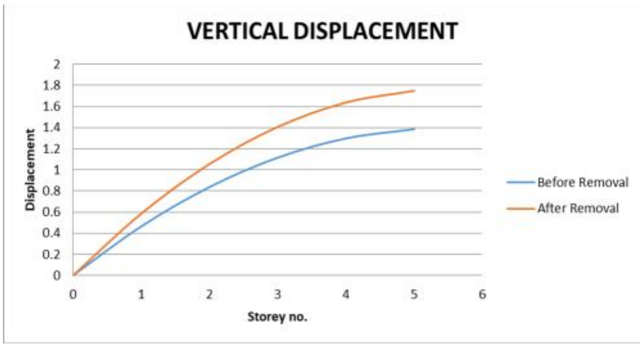

Fig. 5.7 Displacement in X direction

From the above graph the Displacement in X direction, before removal of column is up to 1.383 and after removal is up to 1.747, Base shear in X direction after removal greater than before removal.

4.3. Combined results of all models:

Table-7: Storey drift results

Storey no.	Storey Drift G+4		Storey Drift G+17		Storey Drift G+22	
	Before removal of column	After removal of column	Before removal of column	After removal of column	Before removal of column	After removal of column
0	0	0	0	0	0	0
1	1.54	1.54	1.771	1.9712	1.925	2.079
2	6.16	6.17	7.084	7.8976	7.7	8.3295
3	13.87	13.89	15.9505	17.7792	17.3375	18.7515
4	24.66	24.7	28.359	31.616	30.825	33.345
5	34.35	34.4	39.5025	44.032	42.9375	46.44

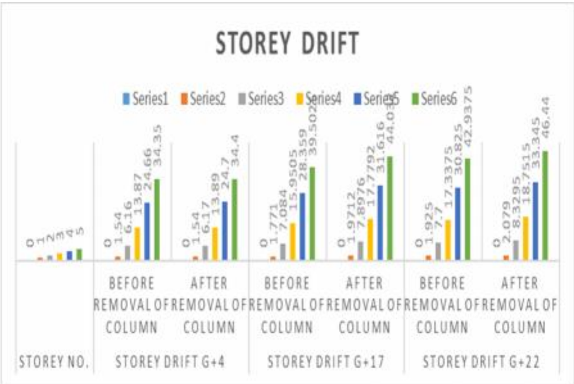

Fig. 6.1 Storey drift results graph

Table-8: Base Shear

Storey no.	Base Shear G+4		Base Shear G+17		Base Shear G+22	
	Before removal of column	After removal of column	Before removal of column	After removal of column	Before removal of column	After removal of column
0	0	0	0	0	0	0
1	3.91	3.934	4.4965	4.9175	4.8093	5.7043
2	15.709	15.736	18.06535	19.67	19.32207	22.8172
3	35.346	35.405	40.6479	44.25625	43.47558	51.33725
4	62.838	62.942	72.2637	78.6775	77.29074	91.2659
5	87.513	87.658	100.64	109.5725	107.641	127.1041

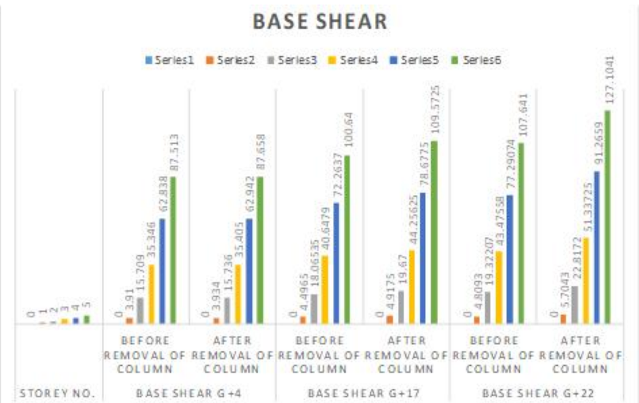

Fig. 6.2 Base shear results graph

Table-9: Natural Frequency

Mode	NATURAL FREQUENCY G+4		NATURAL FREQUENCY G+17		NATURAL FREQUENCY G+22	
	BEFORE REMOVAL	AFTER REMOVAL	BEFORE REMOVAL	AFTER REMOVAL	BEFORE REMOVAL	AFTER REMOVAL
1	2.28	2.166	2.508	2.05656	2.622	2.07138
2	2.854	2.711	3.1394	2.574308	3.2821	2.592859
3	2.86	2.717	3.146	2.57972	3.289	2.59831
4	6.687	6.352	7.3557	6.031674	7.69005	6.0751395
5	6.972	6.623	7.6692	6.288744	8.0178	6.334062
6	8.582	8.152	9.4402	7.740964	9.8693	7.796747

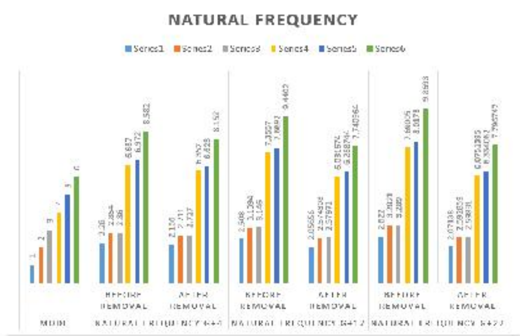

Fig. 6.3 Natural frequency results graph

Table-10: Comparative analysis of all storeys

MODEL	G+4	G+17	G+22
BASE SHEAR	87.513	174.753	186.91
STOREY DRIFT	34.35	68.58	74.55
VERTICAL DISPLACEMENT	1.747	2.5	3.1
NATURAL FREQUENCY	8.582	9.44	9.86
TIME PERIOD	0.117	0.105	0.101
DCR	1.5	2.88	1.9

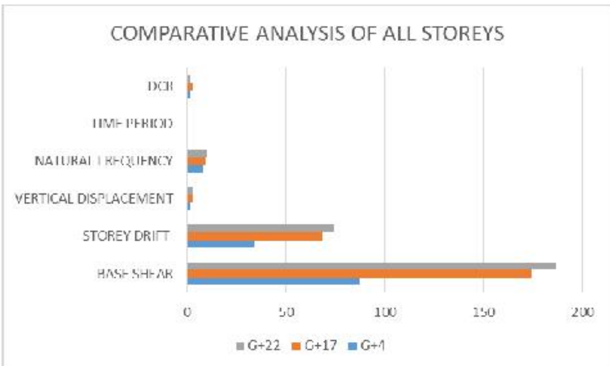

Fig. 6.4 Comparative analysis of all storeys results graph

Table-11: Dcr ratio for earthquake time history analysis

MODEL	G+4	G+17	G+22
BASE SHEAR	51.37	149.326	155.29
STOREY DRIFT	26	13	23
VERTICAL DISPLACEMENT	7.4	20	36.7
NATURAL FREQUENCY	4.017	1.749	1.34
TIME PERIOD	2.5	5.72	7.6
DCR	1.5	2.11	1.4

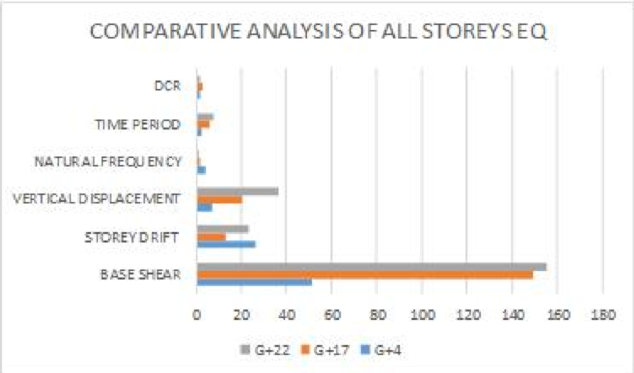

Fig. 6.5 Comparative analysis of all storeys earthquake results graph

V. CONCLUSION

From non-linear dynamic analysis of building subjected to blast load before column removal and after column following conclusions are drawn.

1. Column removals have significant effect on blast performance of buildings.
2. For G+4 100 kg TNT, due to column removal there is 40.82%, 36.10% & 27.83% increase in displacement, velocity and acceleration respectively.
3. For G+4 200 kg TNT, due to column removal there is 44.96%, 32.87% & 23.03% increase in displacement, velocity and acceleration respectively.
4. For G+4 300 kg TNT, due to column removal there is 44.44%, 31.6% & 21.558% increase in displacement, velocity and acceleration respectively.
5. For G+4 400 kg TNT, due to column removal there is 44.186%, 31.24% & 21.51% increase in displacement, velocity and acceleration respectively.
6. For G+17 100 kg TNT, due to column removal there is 17.82%, 16.25% & 14.23% increase in displacement, velocity and acceleration respectively.
7. For G+17 200 kg TNT, due to column removal there is 18.92%, 17.1% & 15.5% increase in displacement, velocity and acceleration respectively.
8. For G+17 300 kg TNT, due to column removal there is 19.4%, 18.2% & 21.58% increase in displacement, velocity and acceleration respectively.
9. For G+17 400 kg TNT, due to column removal there is 21.2%, 19.4% & 22.4% increase in displacement, velocity and acceleration respectively.
10. For G+22 100 kg TNT, due to column removal there is 15.20%, 15.30% &13.15% increase in displacement, velocity and acceleration respectively.
11. For G+22 200 kg TNT, due to column removal there is 17.84%, 15.63% & 14.25% increase in displacement, velocity and acceleration respectively.
12. For G+22 300 kg TNT, due to column removal there is 18.54%, 16.59% & 20.35% increase in displacement, velocity and acceleration respectively.
13. For G+22 400 kg TNT, due to column removal there is 20.26%, 17.56% & 21.35% increase in displacement, velocity and acceleration respectively.
14. DCR ratio in all cases exceeds by 2 hence sections need to be redesigned considering blast load
15. While comparing base shear, storey drift and vertical displacement the amplitude due to removal of column increased by 25-30% for shear, storey drift and vertical displacement because stiffness of structure decreased due to removal of column

For low rise building the difference after column removal is more than that of high rise building as high rise building will have more stiffness.

REFERENCES

[1] Yara M. Mahmoud, Maha M. Hassan, Sherif A. Mourad, Hesham S. Sayed 'Assessment of progressive collapse of steel structures under seismic loads' 2018.
[2] Rohola Rahnavarda, Faramarz Fathi Zadeh Fardb, Ali Hosseinic, Mohamed Suleimand 'Nonlinear analysis on progressive collapse of tall steel composite Buildings'2018.
[3] Yash Jain1, Dr.V.D. Patil2 ' Assessment of Progressive Collapse for a Multi-Storey RC Framed Structure using Linear Static Analysis Technique' Volume 60 Number 3 - June 2018.
[4] Y.A. Al-Salloum a, H. Abbas a, T.H. Almusallam a, T. Ngo b, P. Mendis b 'Progressive collapse analysis of a typical RC high-rise tower' 2018.
[5] Rinsha C1, Biju Mathew2 'Progressive collapse analysis of steel frame structures' Volume: 04 Issue: 05 | May - 2017.
[6] Ramon Codina, Daniel Ambrosini, Fernanda de Borbona 'Alternatives to prevent progressive collapse protecting reinforced concrete columns subjected to near field blast loading' 2017.
[7] Ahmed Elshaer, Hatem Mostafa, and Hamed Salem 'Progressive Collapse Assessment of Multistory

Reinforced Concrete Structures Subjected To Seismic Actions'2016.