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Analysis of Progressive Collapse 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, 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 seismic 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 is 1.9) 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 Defense (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 Defense (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.

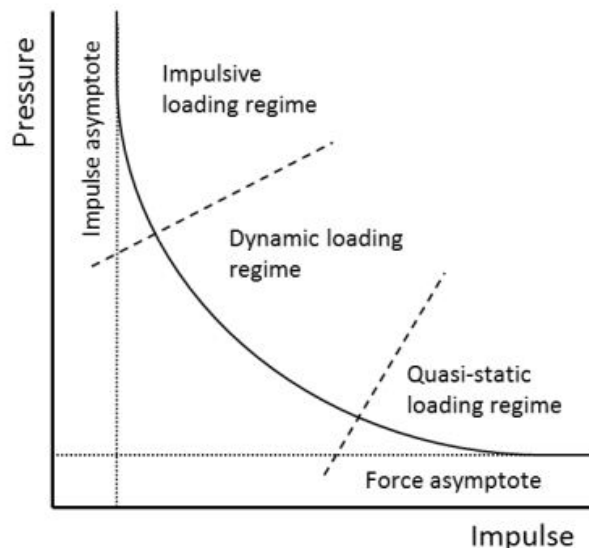


Fig. 1 Pressure impulse diagram for a single degree of freedom elastic system with an ideal blast wave

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.

2.2 Ground motions and linear time history analysis[3]

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.

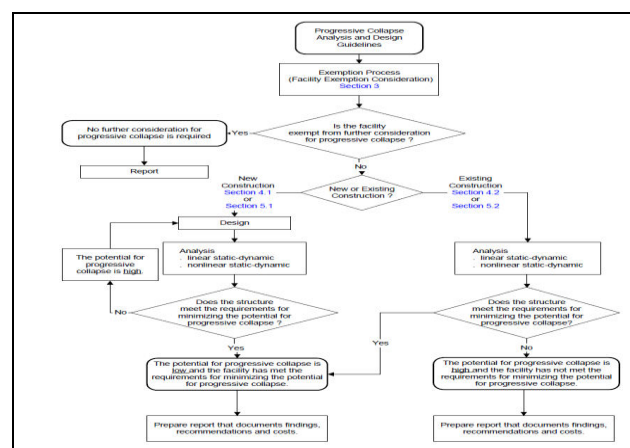


Fig.2 Overall flow for consideration of progressive collapse

III. MODELING AND ANALYSIS

3.1 Modeling 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

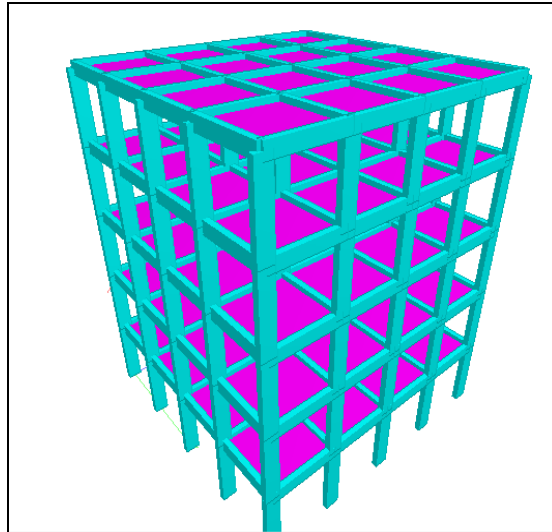


Fig.3 G+4 storey building

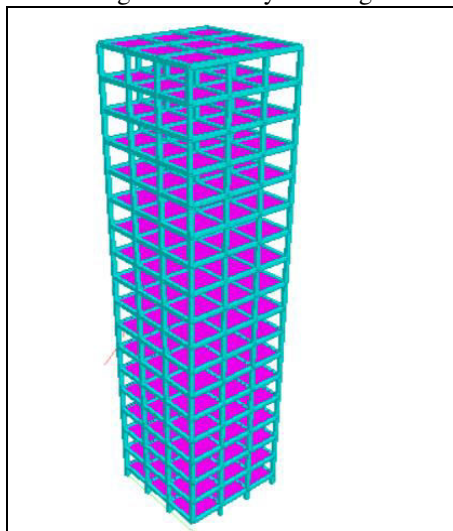


Fig. G+ 17storey building

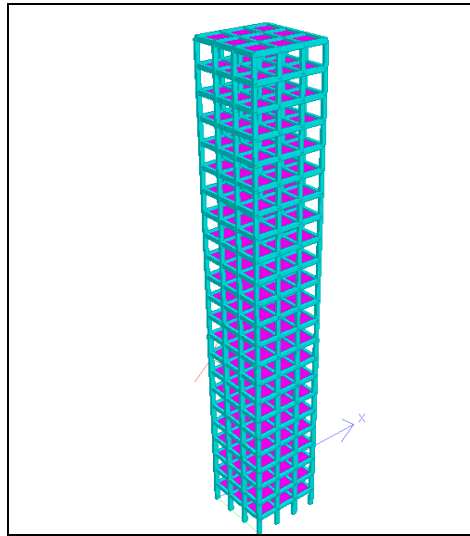


Fig.5 G+22 storey building

IV. RESULTS AND DISCUSSION

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

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

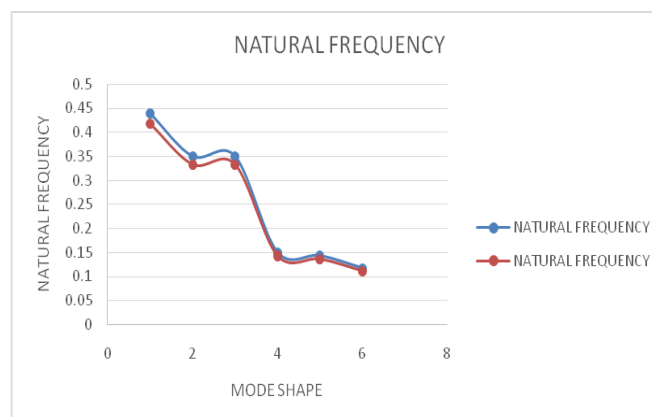


Fig.6.Natural frequency Vs Mode shapes G+4

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

4.2 Progressive collapse analysis for G+17 building with blast loading results is as follows

Mode	NATURAL FREQUENCY G+17	
	BEFORE REMOVAL	AFTER REMOVAL
1	2.508	2.05656
2	3.1394	2.574308
3	3.146	2.57972
4	7.3557	6.031674
5	7.6692	6.288744
6	9.4402	7.740964

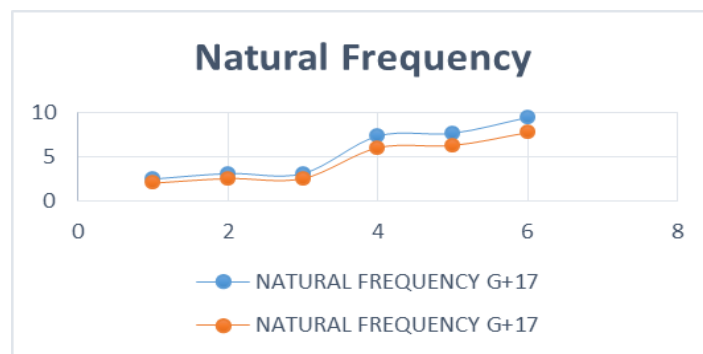


Fig.7. Natural frequency Vs Mode shapes G+17

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

4.2 Progressive collapse analysis for G+22 building with blast loading results is as follows

Mode	NATURAL FREQUENCY G+22	
	BEFORE REMOVAL	AFTER REMOVAL
1	2.622	2.07138
2	3.2821	2.592859
3	3.289	2.59831
4	7.69005	6.0751395
5	8.0178	6.334062
6	9.8693	7.796747

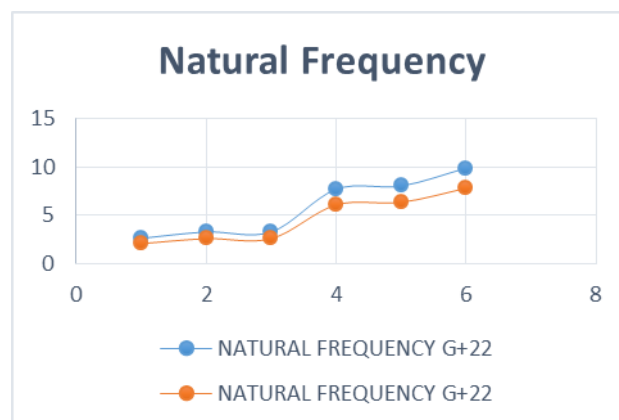


Fig.8 Natural frequency Vs Mode shapes G+22



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

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. Step by step procedure of column removal is done and DCR is checked for low, medium and high rise building. DCR value, story drift, Base Shear, Time period, natural frequency is compared for G+4, G+17, G+22 for earthquake analysis and blast load analysis
3. For seismic analysis the column from extreme left i.e. plinth level first column is removed and it's observed that low rise and high rise is safe. However, for blast load analysis the columns for maximum load is removed and it's observed that low rise and high rise building is safe same as in seismic loading

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