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

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Abstract- *This project work presents the progressive collapse analysis of RCC building for blast loading. Progressive collapse analysis performed on low rise, medium rise and high rise building and its validation in accordance with GSA 2013 Guidelines, to check D/C ratio of a respective structure. The response of RCC framed structure under blast and seismic loading is checked in this work. For this purpose, regular framed structure is designed and analyzed using staad.pro V8i SS5. Torsional moment, storey drift and base shear are calculated. D/C ratio is checked and collapsed element has been redesigned in order to save partially stable structure. This work forms a part of the safe multistory project, dealing explicitly with antagonistic actions and threats in the form of explosions. Since multifunctional structures are by nature freely available they are possibly subjected to either think or accidental blast loading from different sources including individuals from the general population or previous workers or activists. This work aims to give a broad overview of this subject area and highlights likenesses between the challenges which are faced by researchers working in the field of blast, explosion engineering and those working in fire engineering, seismic engineering.*

Keywords- Progressive Collapse, DCR ratio, GSA, Removal of column, blast loading, seismic loading, staad.pro v8i ss5.

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”. Department of defence (Dodd) offers another definition as “A progressive collapse is a chain reaction of failure of building members to an extent disproportionate to the original localized damage”. Progressive collapse is defined as the spread of an initial local failure from element to element, through a chain reaction, which leads to partial or even full collapse of an entire structure. 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. Progressive collapse is “the spread of an initial local failure from element to element, eventually resulting in the collapse of an entire structure or a disproportionately large part of it.Progressive collapse is deformation of any load bearing element which initiate the local failure and transfer of additional load progression to the adjoining elements to generate disproportionate collapse. 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.

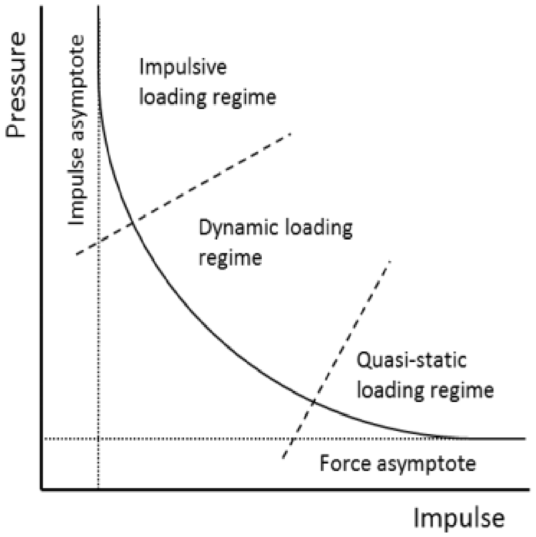

Fig. 1 Pressure impulse diagram for a single degree of freedom elastic sy stem with an ideal blast wave.

PI curves are a type of response spectra developed for structural elements subjected to blast loading. PI curves are specific to the material and sectional properties of the structural element. PI curves are also called iso-damage curves as they represent the combinations of pressure and impulse values that cause a specified damage level in the structural element. 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 stadd 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 check ductility of members and to check its remedial measures eg. Ductile detailing, base isolation etc.
- To check effect of redundancy on steel structures in progressive collapse analysis.
- To analyse the time of collapse of building.
- To determine the resecue plan zone area for safety of people.

II. LITERATURE REVIEW

Yara M. Mahmoud, Maha M. Hassan Progressive collapse involves a series of failures that lead to partial or total collapse of a structure.. This loss is caused by abnormal loads such as bombings, gas explosion, and earthquakes.etc. Progressive collapse due to seismic actions has not received much attention in spite of its importance and repeated occurrences. Author intended to investigate the progressive collapse potential of steel moment resisting and braced frames designed according to Egyptian local standards due to damage caused by seismic actions. One first-storey column is fully removed at arbitrary locations within the building using alternate path method recommended in the UFC guidelines in order to study consequences and check safety of adjacent members. 3-D nonlinear dynamic analyses are employed using SAP2000 is employed in the performed parametric study.

Rohola Rahnavarda, Faramarz Fathi Zadeh Fardb Progressive collapse is defined as the expansion of an initial local failure of an element into another element of the structure and ultimately leading to the collapse of the whole structure or a large part of it in a disproportionate way. Three dimensional modeling, using the finite element method was developed and investigated to understand the progressive collapse of high rise buildings with composite steel frames. The nonlinear dynamic analysis examined the behavior of the building under two column removal scenarios. Two different types of lateral resistance systems were selected to be analysis and compared. The buildings included regular and irregular plans. The response of the building was studied in detail, and measures are recommended to reduce progressive collapse in future designs. The results of this study shows that side case removal in moment frame and moment with centrically braced frame systems was more critical and destructive compared with corner case removal. Comparing the models, for the two different lateral resistance systems, the dynamic response of columns were different, but were not remarkable

Yash Jain Dr.V.D. Patil A linear static analysis approach has been adopted here for determining 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. A finite element model has been developed for the 10 storey building and then the analysis is 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. Thus, the influence of critical eliminated elements has been discussed and the parameters such as Demand capacity ratio, collapse resistance and Robustness indicator has been calculated and checked against the acceptance criteria to draw the final conclusions.

Y.A. Al-Salloum H. Abbas a The world has recently witnessed tremendous increase in terrorist activities. This led to the requirement of blast resistant design of structures.. Although structural engineers are developing methodologies for the mitigation of progressive collapse, there is a lack of adequate tools that can be employed for simulating and predicting the progressive collapse response of structures with acceptable confidence. An attempt has been made in this paper to develop a practical and acceptable procedure for the progressive collapse analysis of reinforced concrete (RC) framed structures. The adequacy of the procedure has been demonstrated by studying the progressive collapse behavior of a typical RC framed high-rise building in Riyadh when exposed to blast generated waves.

Rinsha C1, Biju Mathew In this work numerical simulation will be performed to investigate the progressive collapse potential of a steel frame building during the failure of corner and middle column in an accident. The structure behave pattern is also studied. So middle and corner column was analytically removed from the building to understand the subsequent load redistribution within the building. The axial force and DCR values are studied. By comparing these parameters and conclude that corner column removal in base is more effective in a building. This project is done by using

ETAB.Authorfound that progressive collapse potential decreased as the number of story increased since more structural members participate in resisting progressive collapse and by increasing damping ratios in dynamic analysis the maximum lateral deflection decreased for all frames. Comparison of corner and middle column removal effects in base and 25% of building height are not studied.

Ramon Codina, Daniel Ambrosinia The façade columns in buildings are key elements to protect in order to avoid progressive collapse. In this paper, a numerical-experimental study of the dynamic response of reinforced concrete (RC) columns with different sacrificial layers of protection is presented. Different alternatives of protection of RC columns are designed and studied, from classical steel jacketing to crushable materials. The mitigation of shock and absorption of energy under blast loading conditions is studied by numerical and experimental methods. For comparison purposes, a RC column without protection is also tested and studied. The obtained results are useful to explore new alternatives of protection of RC columns as well as to calibrate numerical codes.

Ahmed Elshaer, Hatem Mostaf In this study, the ‘Unified Facilities Criterion’ guidelines were used in assessing the structure; these guidelines represent one of the codes that discuss progressive collapse using sophisticated approaches. Three-dimensional nonlinear dynamic analyses using the ‘Applied Element Method’ were performed for a structure that lost a column during a seismic action. A parametric study was made to investigate the effect of different parameters on progressive collapse. In this study, a primary structural component was assumed lost during an earthquake. The studied parameters were the location of the removed column in plan, the level of the removed column, the case of loading, and the consideration of the slabs. For the study cases, it was concluded that the buildings designed according to the Egyptian code satisfies the progressive collapse requirements stated by ‘Unified Facilities Criteria’ (UFC) guidelines requirements with a safety factor of 1.97. Also, it was found that losing a column during a seismic action is more critical for progressive collapse than under gravity load.

III. THEORETICAL CONTENT

3.1 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.

In general, an explosion is the result of a very rapid release of large amounts of energy within a limited space. Explosions can be categorized on the basis of their nature as physical, nuclear and chemical events.

- In physical explosion: - Energy may be released from the catastrophic failure of a cylinder of a compressed gas, volcanic eruption or even mixing of two liquid at different temperature.
- In nuclear explosion: - Energy is released from the formation of different atomic nuclei by the redistribution of the protons and neutrons within the inner acting nuclei.
- In chemical explosion: - The rapid oxidation of the fuel elements (carbon and hydrogenatoms) is the main source of energy.

To be an explosive, the material will have the following characteristics.

1. Must contain a substance or mixture of substances that remains unchanged under ordinary conditions, but undergoes a fast chemical change upon stimulation.
2. This reaction must yield gases whose volume under normal pressure, but at the high temperature resulting from an explosion is much greater than that of the original substance.

The change must be exothermic in order to heat the products of the reaction and thus to increase their pressure. Common types of explosions include construction blasting to break up rock or to demolish buildings and their foundations, and accidental explosions resulting from natural gas leaks or other chemical/explosive materials

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3.2 Effects of explosion

There are many forms of high explosive available and as each explosive has its own detonation characteristics, the properties of each blast wave will be different. TNT is being used as the standard benchmark, where all explosions can be expressed in terms of an equivalent charge mass of TNT. The most common method of equalization is based on the ratio of an explosive’s specific energy to that of TNT.

Once the blast wave has formed and propagating away from the source, it is convenient to separate out the different types of loading experienced by the surrounding objects. Three effects have been identified in three categories. The effect rapidly compressing the surrounding air is called “air shock wave”. The air pressure and air movement effect due to the accumulation of gases from the explosion chemical reactions is called “dynamic pressure” and the effect rapidly compressing the ground is called “ground shockwave”. The air shock wave produces an instantaneous increase in pressure above the ambient atmospheric pressure at a point some distance from the source. This is commonly referred to as overpressure. As a consequence, a pressure differential is generated between the combustion gases and the atmosphere, causing a reversal in the direction of flow, back towards the centre of the explosion, known as a negative pressure phase. This is a negative pressure relative to atmospheric, rather than absolute negative pressure in Figure 2. Equilibrium is reached when the air is returned to its original state.

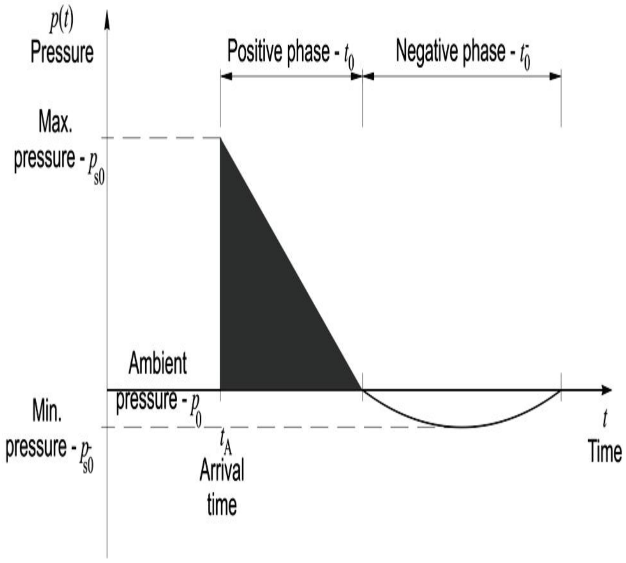


Fig.2.Generalized Blast Pressure History.

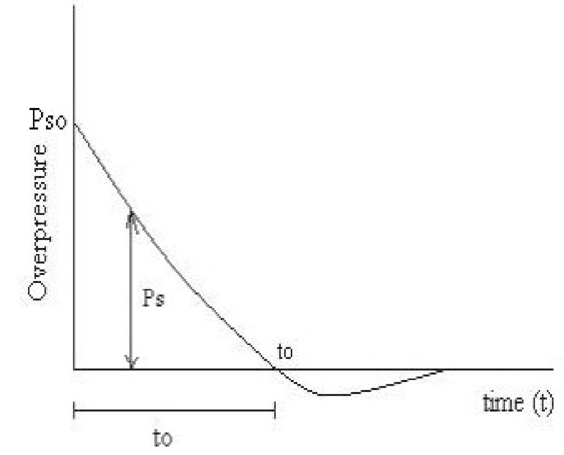


Fig.4.(a)Variation of overpressure with distance at a time from the Explosion.

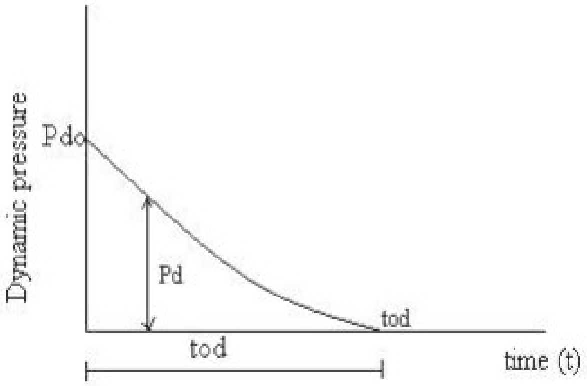


Fig.4 (b) Variation of dynamic pressure with distance at a time from the explosion.

The time variation of the same blast wave at a given distance from the explosion is shown in Fig .4(b); to indicate the time duration of the positive phase and also the time at the end of the positive phase. Another quantity of the equivalent importance is the force that is developed from the strong winds accompanying the blast wave known as the dynamic pressure; this is proportional to the square of the wind velocity and the density of the air behind the shock front.

The peak dynamic pressure decreases with increasing distance from the centre of explosion, but the rate of decrease is different from that of the peak overpressure. At a given distance from the explosion, the time variation of the dynamic Pd behind the shock front is somewhat similar to that of the overpressure Ps, but the rate of decrease is usually different. For design purposes, the negative phase of the overpressure in Fig. 4(b) is not important and can be ignored.As a rough approximation, 1kg of explosive produces about 1m^3 of gas. As this gas expands, its act on the air surrounding the source of the explosion causes it to move and increase in pressure. The movement of the displaced air may affect nearby objects and cause damage. Except for a confinement case, the effects of the dynamic pressure diminish rapidly with distance from source. The ground shock leaving the site of an explosion consists of three principal components. A compression wave which travels radically from the source; a shear wave which travels radically and comprises particle movements in a plane normal to the radial direction where the ground shock wave intersects with the surface and a surface or Raleigh wave. These waves propagate at different velocities and alternate at different frequencies. Using the procedure and the chart in TM 5 -1300, a computer program named AT Blast which calculates. The blast loads for known values of charge weights and distances was developed by applied research associates, ARA. At Blast calculates the equivalent static load and the dynamic parameters for the blast load such as the shock front velocity, time of arrival, impulse and duration

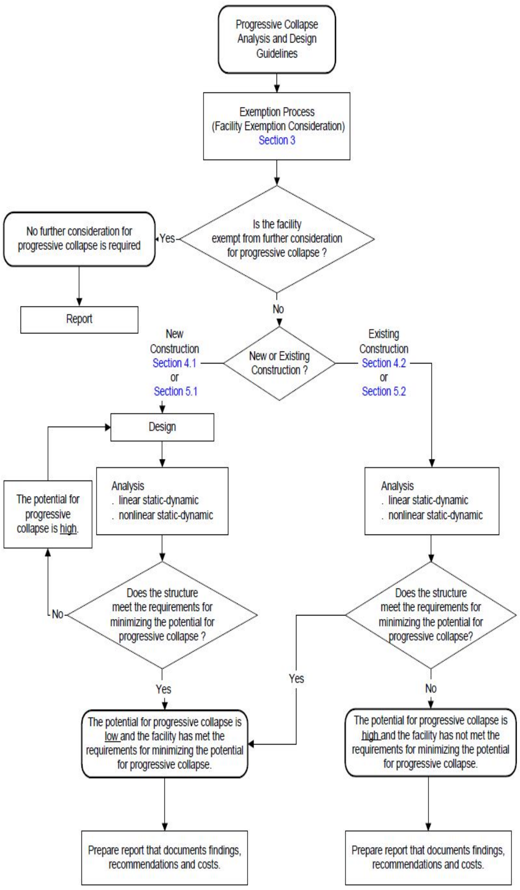
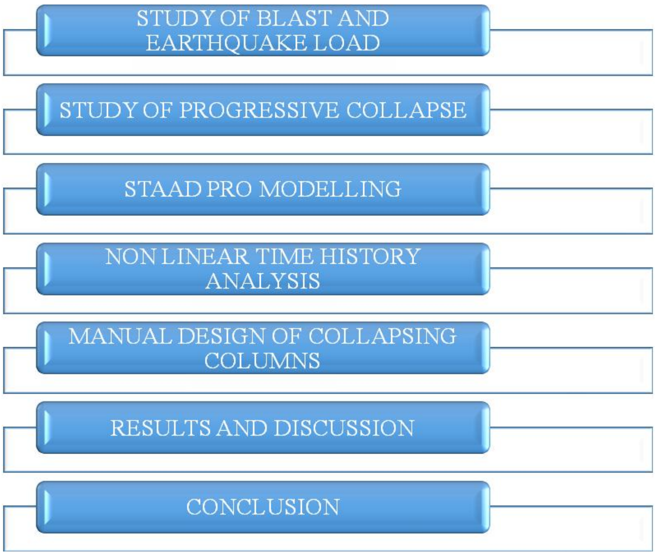


Fig.5 Overall flow for consideration of progressive collapse.

IV. METHODOLOGY



High rise structures are constructed in main areas that may be main targets of terrorist activities. Vehicle bomb or any 00000000man made blast are main weapons of terrorist to attack on highly crowded area. Due to such conditions nowadays there is heavy demand of blast resisting high rise structural design. Not only terrorist activities but also due some of accidental blast, structure can fail. For example Ronan Point building in which gas explosion took place on 18th floor which caused partially collapse of structure. To analyze high rise steel structure for blast loading, we have to make model of high rise steel structure using Stadd-pro software which can resist all types of loading such as dead load, live load, seismic load, using IS800-2000 and IS1893. The following parameters are to be checked after analysis of blast loading on structure, Demand Capacity Ratio (D.C.R.). Bending moments.(B.M). Shear Force.(S.F). Deflection. Story drift. Loading due to blast will not be linear as intensity of loading depends on various criteria so for analysis of structure Non-Linear dynamic analysis is to be done.The blast is applied in X direction. The total column-beam joints are on the front face of building. The forces due to blast loading should be applied to the buildings as triangular loading functions calculated separately for each joint of the front face of the building, taking into account the distance to each joint from the source of explosion. Once the reflected pressure at each beam-column joint is calculated it should be multiplied with Tributary area to get the peak load at that joint. Positive time duration can also be find out, now we can generate the Load-Time history of each joint as input STAAD-Pro. The response of building with and without soft storey in terms of displacement, velocity and acceleration will be obtained. The step-by-step procedure for conducting the linear elastic, static analysis for progressive collapse as per GSA is as follows.

4.1 System Development

Step 1. Remove a vertical support from the location being considered and conduct a linear-static analysis of the structure as indicated in Section 4.1.2.2. Load the model with 2(DL + 0.25LL).

Step 2. Determine which members and connections have DCR values that exceed the acceptance criteria. If the DCR for any member end connection is exceeded based upon shear force, the member is to be considered a failed member. In addition, if the flexural DCR values for both ends of a member or its connections, as well as the span itself, are exceeded (creating a three hinged failure mechanism. the member is to be considered a failed member. Failed members should be removed from the model, and all dead and live loads associated with it.

Step 3.For a member or connection whose Q_{UD}/Q_{CE} ratio exceeds the applicable flexural DCR values, place a hinge at the member end or connection to release the moment. This hinge should be located at the center of flexural yielding for the member or connection. Use rigid offsets and/or stub members from the connecting member as needed to model the hinge in the proper location. For yielding at the end of a member the center of flexural yielding should not be taken to be more than ½ the depth of the member from the face of the intersecting member, which is usually a column

Step 4. At each inserted hinge, apply equal-but-opposite moments to the stub/offset and member end to each side of the hinge. The magnitude of the moments should equal the expected flexural strength of the moment or connection, and the direction of the moments should be consistent with direction of the moments in the analysis performed in Step 1.
Step 5. Re-run the analysis and repeat Steps 1 through 4. Continue this process until no DCR values are exceeded. If moments have been re-distributed throughout the entire building and DCR values are still exceeded in areas outside of the allowable collapse region, the structure will be considered to have a high potential for progressive collapse.

V. MODELING

G+4 Building

A. 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.
Beam Size: 230 X 500 mm
Column Size: 230 X 600 mm
Slab Thickness :150 mm
Storey Height:3m
Grade of concrete:M25
Explosive type: C4 type of explosive

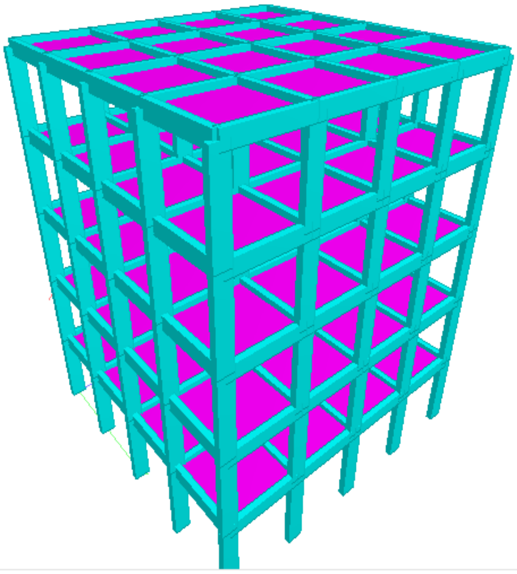


Fig 6 3D view G+4 storey building

G+17 Building

Beam Size: 230 X 500 mm
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
Slab Thickness: 150 mm
Storey Height: 3m
Grade of concrete: M25
Explosive type: C4 type of explosive

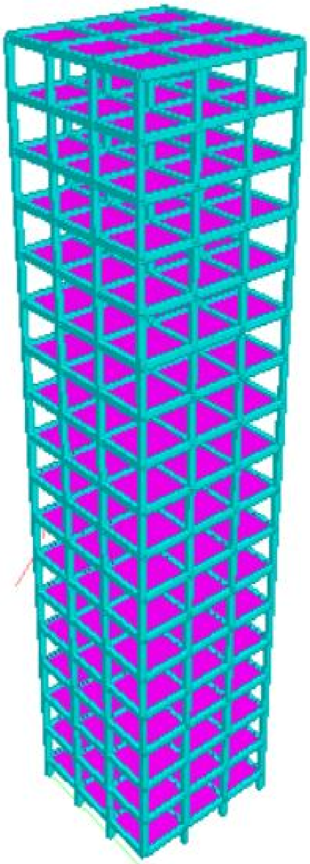


Fig 7 3D view G+17 storey building

G+22 Building

Beam Size: 230 X 500 mm
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: 150 mm
Storey Height:3m
Grade of concrete:M25
Explosive type: C4 type of explosive

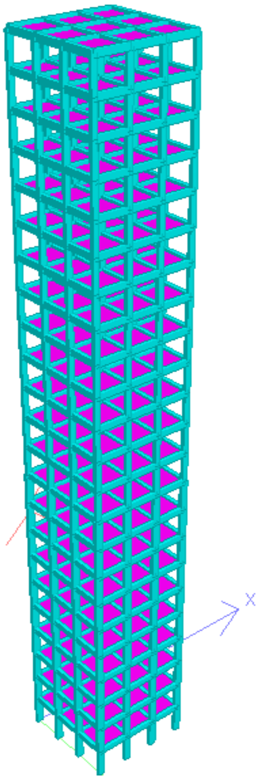


Fig 8 3D view G+22 storey building

VI. 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

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