Study of Response of RC Tall Buildings Subjected to Blast Loads

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Abstract:
An Explosion is defined as a rapid chemical reaction that occurs for few milliseconds resulting in the very fast release of energy and hot gases into the surrounding atmosphere. It results in the generation of high pressure and temperature. During explosion the hot gases that are generated occupy the space surrounding, resulting in wave propagation through space which is transmitted spherically or hem -spherically through a surrounding medium. Unlike earthquake force, blast pressure acts for a significantly shorter period of time on a structure. Thus, effects of material strain rate become vital and should be accounted to assess the Performance of connections for shorter duration loads i.e. blast loads. This high impulsive load generally act non-uniformly on the structure i.e. the aberration of load extent transversely to the face of the structure and greatly reduces the amplitudes of the blast pressure on the sides and back end of the structure far from the explosion point. The effects of blast load on the RC structures are studied by varying distance of the point of explosion. Structures having different characteristics are subjected to blast overpressure at distances of 30 m, 50 m, 70 m, 90 m, 110m and 150 m. A finite element package ETABS is used for the analysis.

Keywords: Blast load, Impact load, RC structures

I. INTRODUCTION

In the recent few years, effect of blast load on structure gained importance due to accidental events or natural events. The explosion due to bombs in and around structures can results in to catastrophic impacts on the structural integrity of the building, such as damage to the external and internal structural frame members and sometimes collapse of the structure. Thousands of lives lost in the past bomb blast due to collapse of the structure. The consequences bomb attack by some terrorist organizations of those attacks proved the vulnerability of structures to explosion. One more common blast load is by Vehicle bombing attacks against structures have been a weapon of choice used by many terrorist organizations. The use of vehicle bombs to attack a structure has been a common type of terrorist attack. Many countries have become victims of bomb explosion attacks in the last few decades. 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. Past blast incidents though-out world made architects and engineers to find solutions or alternatives to protect the occupants and structures from these blasts loading. Generally conventional structures are not designed for blast load because the cost of design and construction is very high when blast load is considered in design.

II. SIGNIFICANCE OF BLAST LOADS

In the design of any structures to resist blast loads, generally two important considerations

- Prevention of catastrophic failure or progressive collapse of structure and
- Reduction of projectiles due to fragmentation.

Criteria’s for blast resistance or protection have become an important consideration for professional design structural engineers as terrorist attacks continue at an alarming rate in the world. A conventional structure generally not designed to resist blast loads and because the magnitude of design loads is lower than the load produced by blast load explosion. No public buildings can be designed to withstand the kind of extreme attack that happened to the World Trade Centre in USA.

![Figure 1. Explosions possible cases](http://ijesc.org/)

The main difference between blast loads from other types of dynamic loadings is it’s impulsive in nature, where the loads usually act for a very short duration but transmit very high impulsive pressures. The losses from these events cannot be measured from the economic aspects alone since most of the target buildings are iconic and carry substantial heritage, architectural, and sentimental values. 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 explosion.
III. EXPLOSION & EXPLOSIVES

An explosion is a rapid release of stored energy usually with the generation of high temperatures, the release of gases and an audible blast. Part of the energy is released as thermal radiation and part is coupled into the air as an air-blast and into the ground as ground shock, both as radially expanding shock waves. Supersonic explosions formed by very high explosives are known as detonations and travel via supersonic shock waves. The rapid discharge of energy causes wave-form of a pressure in the surrounding space described as Shock front. Due to the explosion, accumulation of hot gases occurs. As a result of this, wave of a pressure is generated in the medium. The waves propagate with the speed of sound. The temperature in the surrounding region is around 3000° - 4000° and pressure is about 3x10⁷ kPa.

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

- It should contain a substance or mixture of substances that remains unaltered under ordinary conditions, but undergoes a fast chemical change upon stimulation.

- 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.

Many types of explosive materials can be used in explosions and they vary from home-made to military or commercially available types. Explosives differ from one to another by their explosion characteristics such as detonation rate, effectiveness, and amount of energy released. Therefore, it is necessary to have a datum to assess the detonation characteristics of each type of explosive material. TNT (Trinitrotoluene) had been used as the reference explosive and is regarded as the standard “Explosion Bench Mark” in the area of explosion.

IV. STANDOFF DISTANCE IMPORTANCE IN EXPLOSION

Blast-resistant design requires use of different material and geometric non-linearity in structure configuration to exploit energy absorption mechanisms. When the explosion occurs, the blast shock waves travel with a rapidly increasing overpressure front. The pressure behind the front face of structure may even drop below the normal atmospheric pressure within a few milliseconds of time.
Therefore, the distance between asset and threat is important and referred to as stand-off distance. It is explained in the above Figure 6 (FEMA-426 2003). The threat of an explosion will rapidly decrease over the stand-off distance and its contribution to the intensity of the blast loads. When structures subjected to blast loading, so many parameters associated are blast pressure, ground shock, and fragment impact, mostly in the near-range region. Whereas in the far-field region, structures are exposed to only blast pressure. In case of nuclear blast, the resulting shock wave produces very high blast pressure and large impulse loading, which results in destruction of structures situated at even at large distance from the source of blast.

Unconfined explosions

Unconfined explosions have three kinds of bursts, namely

- Free air burst,
- Air burst and
- Surface burst.

If the explosion happens in free air high above ground level, it is classified as a free-air burst explosion as shown in Figure 7. Although the air burst occurs in free air high above ground level, the amplification of blast waves takes place due to ground reflections and is explained in Figure 8. A surface burst occurs when the explosion takes places close to or on the ground surface level as shown in Figure 9.

V. PROBLEM DEFINITION

The work involved in this study is to assess the behaviour of structures under blast load. The investigation on the behavior and response of structure are carried out by using the finite element models in FEM package ETABS. A 30 storey Structure with following specification considered for this study are

- RC Frame structural system.
- RC Frame structure with the shear wall at outer periphery (Shear wall structure).
- RC Frame structure with the masonry wall at outer periphery (Masonry wall structure).

Investigate the Blast load phenomenon completely for the analysis of structures. To study the dynamic performance of a high-rise structure of different conditions subjected to a particular blast pressure at distances of 30 m, 50 m, 70 m, 90 m, 110 m and 150 m.

VI. MODEL SPECIFICATION

Blast loading is defined as a load-time triangular function in the model using finite element package ETABS. The dynamic behaviour of high rise RC structures are considered which are subjected to an impact loads of 10 kN weapon charge. Plan of the model is 25m x 25m.

Table 1. Member sizes of building model

<table>
<thead>
<tr>
<th>Member</th>
<th>Size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column (M40 Grade)</td>
<td>800x800 (BASE TO Story 5)</td>
</tr>
<tr>
<td></td>
<td>600x600 (Story 5 TO Story 10)</td>
</tr>
<tr>
<td></td>
<td>500x500 (Story 10 TO Story 15)</td>
</tr>
<tr>
<td></td>
<td>400x400 (Story 15 TO Story 30)</td>
</tr>
<tr>
<td>Beam (M30 Grade)</td>
<td>300mm x 600mm</td>
</tr>
<tr>
<td>Slab (M30 Grade)</td>
<td>125 mm</td>
</tr>
<tr>
<td>Shear wall thickness (M40 Grade)</td>
<td>300 mm</td>
</tr>
</tbody>
</table>

General data:

- Grade of concrete = M30, M40
- Grade of steel = Fe500
- Live load = 3.0 kN/m² for floor
- Live load = 1.5 kN/m² for roof
- Floor finish = 1.0 kN/m² for floor
- Floor finish = 0.7 kN/m² for roof
- Wall load = 12 kN/m
Closed RC Structure with shear wall-plan view

Closed RC Structure with shear wall-3D view

RC Frame system-plan view

RC Frame system-3D view

Masonry RC Structure – plan view

Masonry RC Structure – 3D view
VII. RESULT DISCUSSIONS & CONCLUSIONS

Von Mises Stresses:

Figure 10. Von Mises Stress, MPa at Standoff distance 0.050 km

Figure 11. Von Mises Stress, MPa at Standoff distance 0.070 km

Figure 12. Von Mises Stress, MPa at Standoff distance 0.090 km

Figure 13. Von Mises Stress, MPa at Standoff distance 0.110 km

Figure 14. Von Mises Stress, MPa at Standoff distance 0.150 km

Figure 15. Maximum Von Mises Stress, MPa at different Standoff distance

Top Storey Acceleration:

Figure 16. Top Storey Acceleration for all models, mm/sec^2

Top Storey Velocity:

Figure 17. Top Storey Velocity of all models, mm/sec
From above results following observations are made during study

- As the standoff distance or the critical distance increases, the stress values on the wall element reduces.
- At a distance of 0.050 km the stress generated in the shear wall frame structure is 106.13 MPa and at a distance of 0.150 km the stress generated is 2.68 MPa.
- Similarly, the stress in RC frame structure at a distance of 0.050 km is 84.44 MPa and that at a distance of 0.150 km is 8.90 MPa.
- In the case of masonry wall frame structure, the stress at a distance of 0.050 km is 90.05 MPa and that at a distance of 0.150 km is 2.36 MPa.

The variation of the acceleration with respect to standoff distance is inversely proportional. As the distance increases, the acceleration of particular joint decreases in all the three cases of the study.

The variation of the velocity with respect to standoff distance is inversely proportional. As the distance increases, the velocity of a particular joint decreases in all the three cases of the study.

Following are the conclusions:

- Von Mises stress is one which helps in determining the stability of a structure. The design is said to be failed when the maximum value of Von Mises stress obtained by the analysis after the application of blast load is greater than the strength of the material.

- It is observed in this work, For an RC frame structure, the stresses developed on the walls are approximately 1.5 to 2 times the stresses developed on the walls of the closed structure

- Therefore, the critical distance or the minimum safe distance below which the structure is damaged severely is 0.070 km for Shear Wall Structure and 0.090 km for RC frame Structure and Masonry Wall structure.

- The possible near and far distances that could be measured are taken into consideration.

VIII. REFERENCES


IX. IS CODES

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X. BIOGRAPHY

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