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Analysis of Blast Loading Effect on High Rise Buildings

Prof. A. V. Kulkarni[1] Sambireddy G[2]
1.Professor, Dept. of civil Engg., BLDEA'S V P Dr. P.G.H CET, Bijapur
2.M-Tech Student in Structural Engineering in Dept. of civil Engg., BLDEA'S V P Dr. P.G.H CET, Bijapur
Email:sambireddy333@gmail.com

Abstract

This paper presents the dynamic response of a High Rise Structure subjected to blast load. The fundamentals of blast hazards and the interaction of blast waves with structures are examined in this study it is about the lateral stability of a high rise building modeled using SAP2000. The model building was subjected to two different charge weights of 800lbs and 1600lbs TNT at a two different standoff distances of 5m and 10m.The blast loads are calculated using the methods outlined in section 5 of TM5-1300 and a nonlinear modal analysis is used for the analysis of the dynamic load of the blast. The primary performance parameters that will be used to evaluate the behavior of the building from a global perspective are the total drift and the inter-storey drift. They are good indicators of nonstructural damage, collapse and ability of the structure to resist P-delta effect. Behavior of R.C frame and concrete infill frame will be computed in Dynamic condition

Keywords: Blast loading; Inter-storey Drift; Standoff Distance; TNT; Positive Phase

1. Introduction

In the past few years, a structure subjected to blast load gained importance due to accidental events or natural events. Generally conventional structures are not designed for blast load due to the reason that the magnitude of load caused by blast is huge and, the cost of design and construction is very high. As a result, the structure is susceptible to damage from blast load. Recent past blast incidents in the country trigger the minds of developers, architects and engineers to find solutions to protect the occupants and structures from blast disasters

Special attention has been given to explosive loads on landmark structures, such as high rise buildings in metropolitan cities, The explosion of bombs in and around buildings can cause catastrophic impacts on the structural integrity of the building, such as damage to the external and internal structural frames and collapse of walls. Moreover, loss of life can result from the collapse of the structure. Understanding the performance of high-rise buildings under explosion is of great importance to provide buildings which eliminate or minimize damage to building and property in the event of explosion. The analysis and design of blast resistant structures require a detailed understanding of explosives, blast phenomena and blast effects on buildings.

2. Blast Load Characteristics

The rapid release of energy due to an explosion is characterized by air pressure and an audible blast. The energy released is divided into two different phenomena which are thermal radiation and coupling with air and ground, known as air blast and ground shock. Air blast is the principle cause of the damage to a building exposed to blast loading. On the other hand, the ground shock -wave propagates by compressing the air molecules in its path, thus producing the ambient overpressure or the incident pressure (Bangash and Bangash, 2006).

Smith and Hetherington (1994) explained the sequence of events that occur when a high explosive material is initiated. A typical conventional pressure wave from detonation is illustrated in Figure 1. There is nearly instantaneous rise to a peak pressure, Pso, and the pressure rise time is well below microsecond. Behind the shock front, the pressure tapers off and eventually goes below that of ambient, later returning to ambient, Po. The area of positive pressure is called the "positive phase" and the area of negative pressure is called the "negative phase". Overexpansion at the center of the explosion creates a vacuum in the source region and results in a reversal of motion (Kinney and Graham, 1985) and causes the formation of the negative phase that trails the positive phase (T. Ngo et al., 2007). In general, the negative phase pressure is lower in magnitude than that of the positive phase but longer in duration than the positive phase (Cormie, Mays and Smith, 2009).

Positive phase loads are more powerful and responsible for most of the pressure damages than the negative phase loads. However, the negative phase pressure may cause secondary damage by propelling artifacts towards the point of origin (Pape et al., 2010). There are many different types of explosives; therefore a datum is needed to describe the characteristics of an explosive. TNT, which is one of the most stable high explosives, is used to quantify the effect of the energy released by other explosives, on weight-to-weight basis (Dusenberry, 2010).

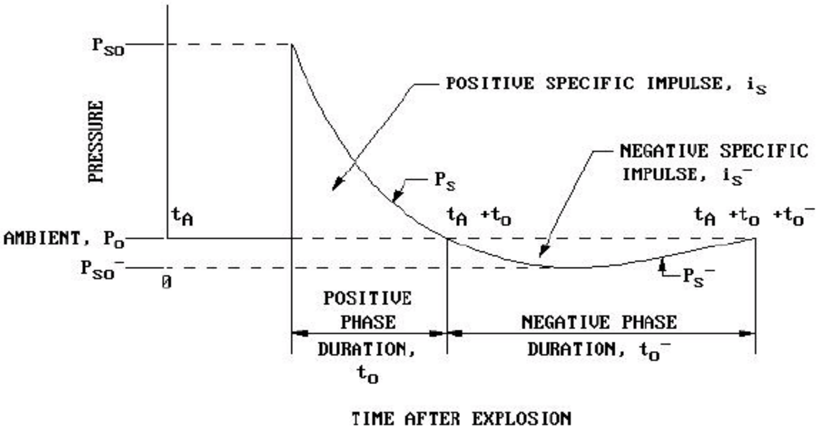

Figure 1 Incident and reflected pressures on building (Remennikov, 2005)

3. Model Development

The structure selected for this study is a 30-storey high-rise reinforced concrete building standing at the height of 91m. The center-to-center plan dimensions are 30 m in length and 30 m in width there are five bays with center -to-center span length arranged as 6m in the longitudinal direction, and five bays with a 6m span in the transverse direction. The storey height is 4m for the first storey and a standard storey height of 3 m is utilized beyond the first storey. The floor plan consists of core wall and rigid frame as shown in fig-2

The structural system of the building was made up of R.C Frames and Infill frames. The typical beamsizeusedis300x700mm; the size of the columns is 900 x900 mm. In infill frames R.C wall is taken as infill element, the thickness of concrete infill Wall is 150 mm and thickness of the slabs is 175mm. Computer modeling of the building was performed using the finite element software sap2000. The 30 story reinforced concrete building were frame structure composed of columns, beams, slabs and having a core wall in the middle. The columns and beams were modeled as frame elements while the slabs and core walls were modeled as shell elements and concrete infill wall were modeled as plate elements. The building model was assigned fixed bottom support condition while a rigid diaphragm constraint was allotted to all floors. The general approach for solving the dynamic response of structural system is Non-linear modal analysis. For most realistic results a very small time step is required to obtain a stable solution. Reducing the time step size will increase the accuracy, the time step size of 0.0001s with 4000 time steps is taken for all models.

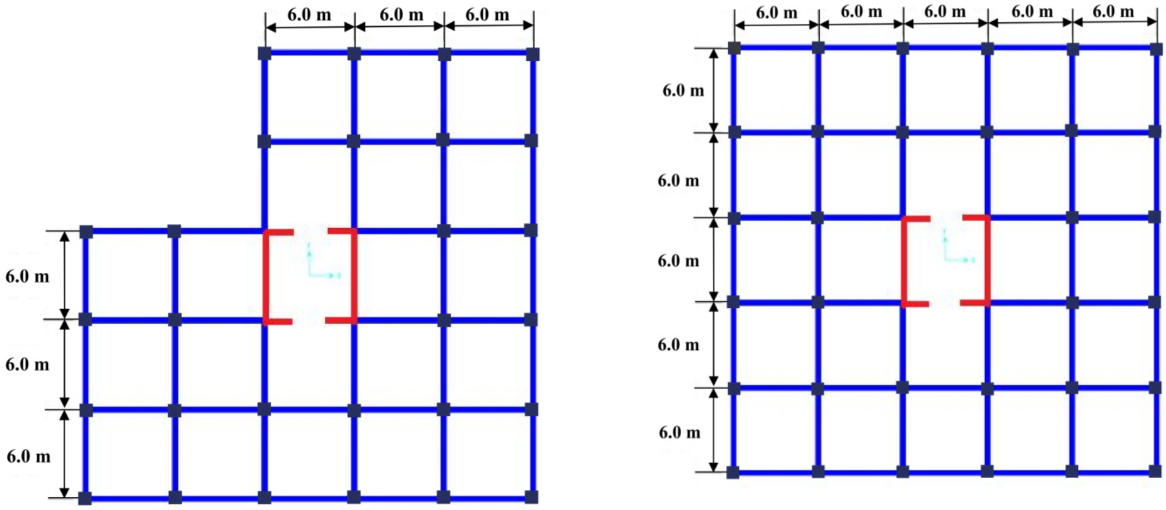

Figure 2: Typical floor plan of the symmetrical and unsymmetrical buildings

4. Blast Load Determination

The procedures outlined in section 5 of TM5 -1300, Structures to Resist the Effects of Accidental Explosions, developed by the US Department of Defense in December 1990, were used to evaluate the maximum blast load that is applied to the structural members of the building. The blast load parameters were generated using two different charge weights which are 800lbs and 1600lbs with a standoff distance of 5m and 10m from the center of the longitudinal direction of the building. The blast loads are distributed on all the structural elements on the front face of the building.

Using the procedure and the chart in TM 5 -1300, a computer program named ATBlast which calculates the blast loads for known values of charge weights and distances was developed by applied research associates, ARA. ATBlast 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.

5. Results

Blast performance evaluation is a complex phenomenon as there are several factors affecting the behavior of the building. The model is analyzed by using Non-linear modal analysis. After the analysis is completed, Relationships were established for lateral displacement verses the height of the building to identify the effects of the blast load on the building. In the conducted analysis, the maximum horizontal displacements (sways) and the inter-storey drifts for all load cases have been determined for the respective storey number.

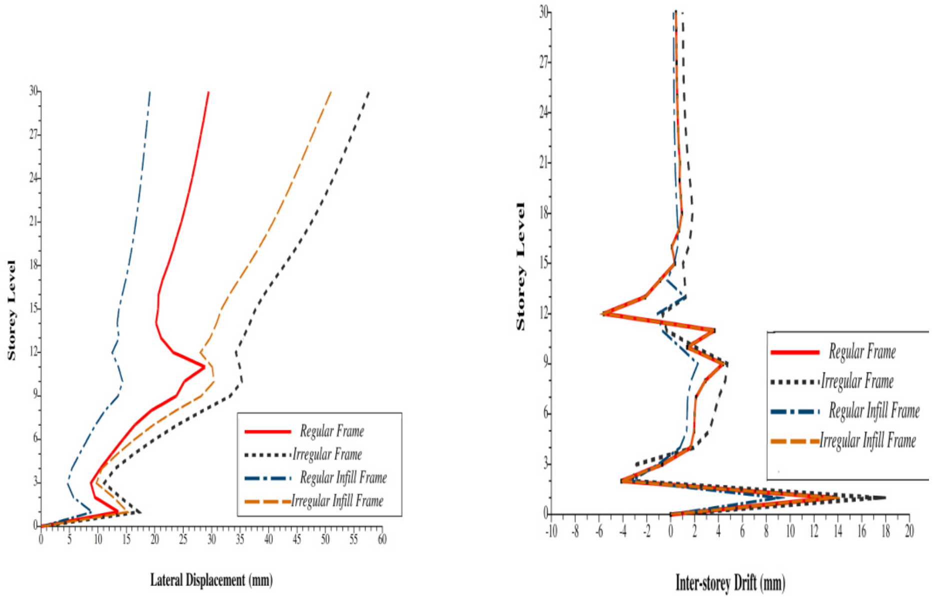

Figure 5.1: Lateral Displacement and inter storey drift results for the charge weight of 1600lbs and 5m standoff distance

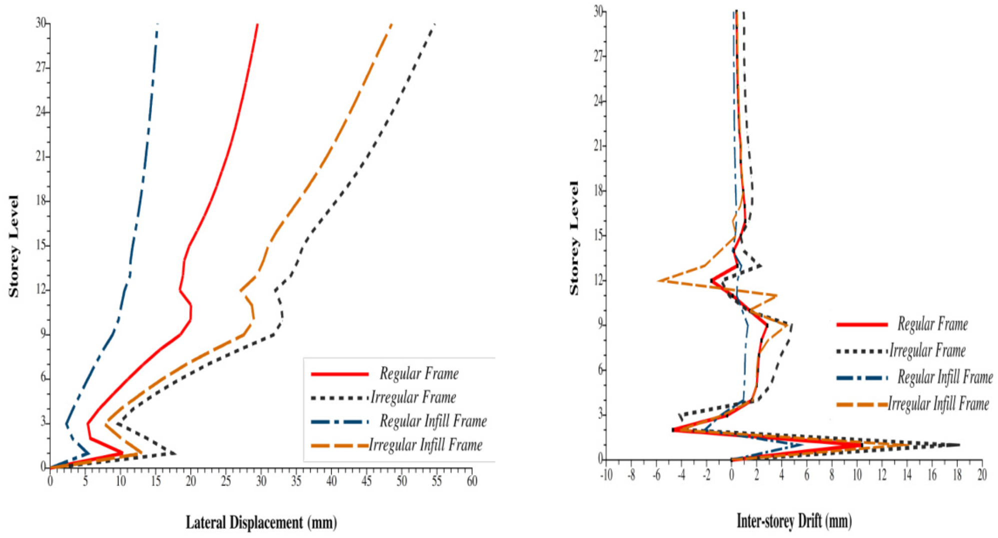

Figure 5.2: Lateral Displacement and inter storey drift results for the charge weight of 1600lbs and 10m standoff distance

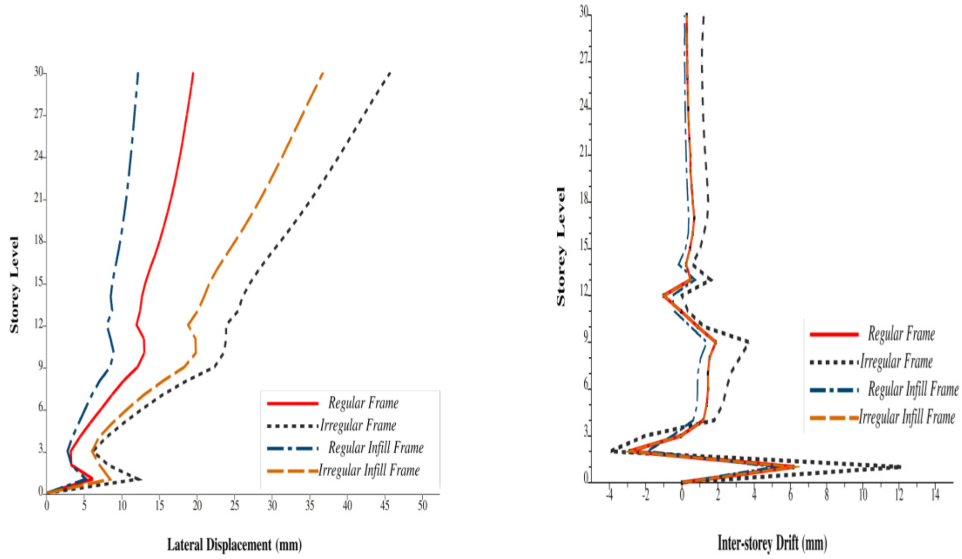

Figure 5.3: Lateral Displacement and inter storey drift results for the charge weight of 800lbs and 5m standoff distance

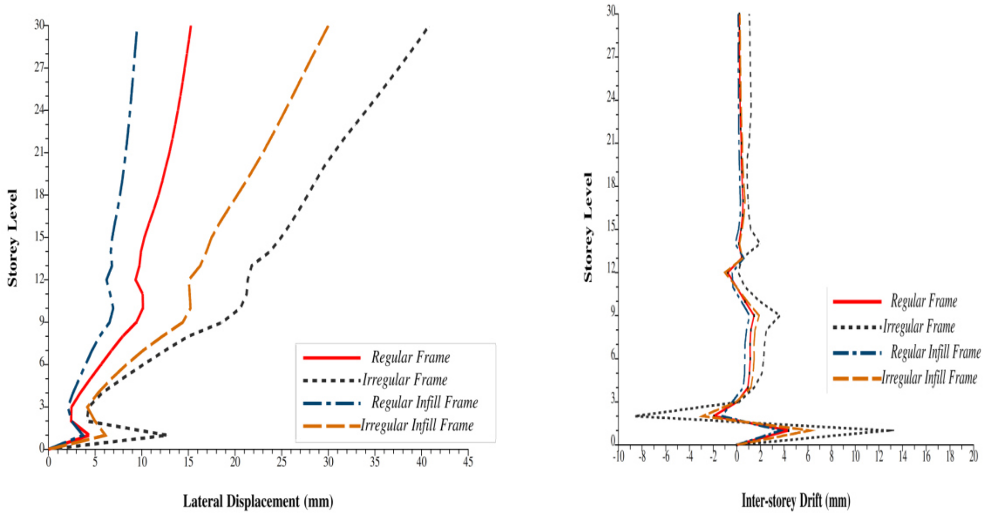

Figure 5.4: Lateral Displacement and inter storey drift results for the charge weight of 800lbs and 10m standoff distance

From graphical representation of later displacement versus the height of the building it is evident that As standoff distance increases the storey drift goes on decrease and explosive weight increases the storey drift goes on increases

As per results obtained from dynamic analysis, it is observed that the maximum storey drift occurs at first storey level for all cases because the first storey level is the nearest point from the explosion and the angle of incident (α) is also minimum therefore the reflected positive pressure (p_{ra}) is very high at the first storey the pressure distribution over a 30 storey building is shown in the fig (5.5) The intensity of the pressure on the building is decreasing with increasing with the storey height (Range)

The maximum storey drift is 16.5 mm which is happen in a irregular frame model with the charge weight of 1600 lbs and at a standoff distance of 5m. The next highest storey drift is 13.5mm which is happen in regular frame model with a charge weight of 1600 lbs at a standoff distance of 5m. The lowest storey drift which is occurs in infill frame model and shows good lateral stability to blast building

5. Conclusions

According to the results the system affects significantly when the charge weight increases and standoff distance decreases respectively. But the actual charge weight of explosive used by the terrorist, the efficiency of the chemical reaction is not reliably predictable.

The standoff distance is the key parameter that determines the blast pressure so far protecting a structure is to keep the bomb as far away as possible by maximizing the standoff distance.

Blast has a characteristic of high amplitude, the results shows that the first storey columns subjected to high pressure they could cause big deformation and exceed the support reaction so the columns which are close to explosion are damaged which leads to sudden loss of critical load bearing columns is lost. Ones the critical load bearing columns lost which leads to sudden changes in the building geometry and load path which initiates a chain reaction of structural elements failure.

In this study it is found that the most optimum model is regular infill frame which shows the lowest value of storey drift and the structure is very good in lateral stability against blast load. Therefore for economical design consideration the column size can reduce.

The most vulnerable structure is irregular frame which shows highest value of storey drift of 16.5mm which is exceed the storey drift limitation as per IS 1893 (part -1) the storey drift which shall not exceed 0.004 times the storey height.

There is no significant affect on the upper floor because of low intensity of pressure on the upper floor due to increase of standoff distance from bottom floors to upper floors, therefore increase of standoff distance will reduce pressure on the upper floors.

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