Analysis of Reinforced Concrete Building under Blast Loading

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Abstract- In the past few years, structures 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. A bomb explosion near by a building can cause damage on the building's external and internal structural frames, collapsing of walls, blowing out of large expanses of windows, and shutting down of critical life-safety systems. Loss of life and injuries to occupants can result from many causes, including direct blast-effects, structural collapse, debris impact, fire, and smoke. The increase in the number of terrorist attacks especially in the last few years has shown that the effect of blast loads on buildings is a serious matter that should be taken into consideration. Due to the threat from such extreme loading conditions, efforts have been made during the past three decades to develop methods of structural analysis and design to resist blast loads. Studies were conducted on the behaviour of reinforced concrete building subjected to blast loads. Although these kinds of attacks are exceptional cases, manmade disasters; blast loads are in fact dynamic loads that need to be carefully calculated just like earthquake and wind loads. The present study is concerned with analysis of blast load considering two variations of charge weights and standoff distance. In this study reinforced concrete buildings are analysed. The blast parameters are calculated using IS code 4991-1968. Results are compared using ETABS 2016. The parameters considered in this study are storey displacements and story drifts.

Key Words: Blast Phenomena, Standoff Distance, Charge Weight/TNT, Positive Phase, Story Displacement and Story Drift

I. INTRODUCTION

In recent years, because of increased terrorist activities, civil structures are exposed to threats from blast-induced impulsive loads. Several such incidents have taken place around the world, causing serious threat to life and property. Structural engineering is a field that has entered into this area to reduce losses and examine the nature of the phenomenon and its effects on buildings where people gather and are the target of such attacks. In addition to these studies, some researchers have been conducted on issues related to non-terrorist and accidental explosions as well as side phenomena of explosion. Further, extremists are using newer chemicals and technological advancements that have increased blast event magnitudes. Therefore, in addition to strategically important and heritage structures, even important commercial buildings and complexes are required to be designed for an adequate level of blast resistance. On the other hand, blast-resistant design of structures is treated as a specialized area to which, commonly, structural engineers are not exposed comprehensively, and most of the knowledge about blast-resistant design of structures remains limited to military setups. Due to the impulsive load developed by an explosion is highly nonlinear and cause pressure in an extremely short duration, analysis of the reinforced concrete frame structure is difficult.Pressure intensities will be depend upon the charge weight (bomb size) and standoff distances between blast source and impacted structure (target). Reflected pressure, incident pressure and arrival time are the three important parameters which is obtained from incident wave shown in below Figure1.1.

II. BLAST WAVE PHENOMENA

The sudden release of energy from a detonation in a gaseous medium gives rise to sudden pressure increase in that medium. The pressure disturbance, termed the blast wave is characterized by an almost instantaneous rise from the ambient pressure to a peak incident pressure (Pso). Incident pressure is the pressure on a surface parallel to the direction of the blast wave. This pressure increase or shock travels radially from the burst point with a diminishing velocity (U) which is always in excess of the sonic velocity of the medium. Gas Molecules, making up the front move at lower velocities (u). This latter particle velocity is associated with a dynamic pressure or the pressure formed by the winds produced by the shock fronts and it's a function of air density and wind velocity. As the shock front expands into increasingly larger volumes of the medium, the peak incident pressure at the front decreases and the duration of the pressure increases.

At any point from the burst, the pressure disturbance has the shape shown in Figure 2-1. The shock front arrives at time (tA) and, after the rise to the peak value, the incident pressure decays to the ambient value in time (to) which is the positive phase duration. This is followed by a negative phase with duration (to-) longer than the positive phase and characterized by a pressure below the pre-shot ambient pressure (maximum value of Pso -) and a reversal of the particle flow.

The incident impulse associated with the blast wave is the integrated area under the pressure-time curve and is denoted as (Is) for the positive phase and (Is-) for the negative phase as shown in Figure 3.2.

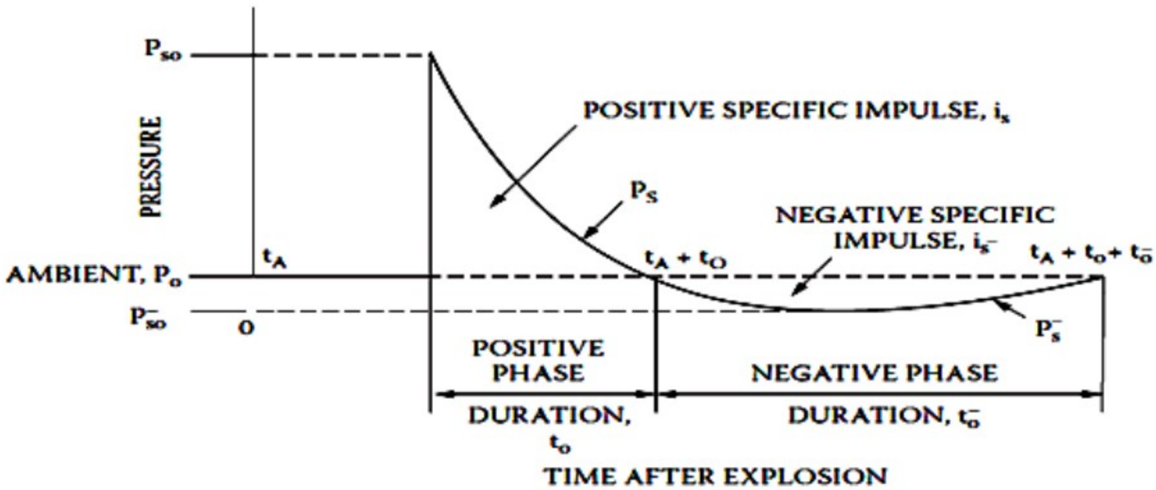

Figure: 1 Typical blast-induced pressure-time history Surface Burst Loads

The explosion is located close to or on the ground so that the shock wave is amplified at the point of detonation due to ground reflection. Only this type of blast loads considered in this thesis.

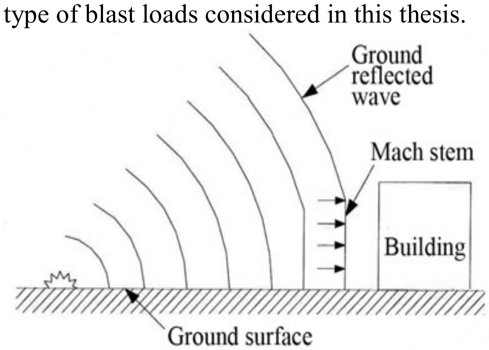

Figure: 2 Surface burst

Prediction of Blast Pressure

For most structures a triangular shape is assumed for the dynamic blast load with a sudden rise and linear decay as shown in Figure 3.4. The negative phase is neglected because it usually has little effect on the maximum response.

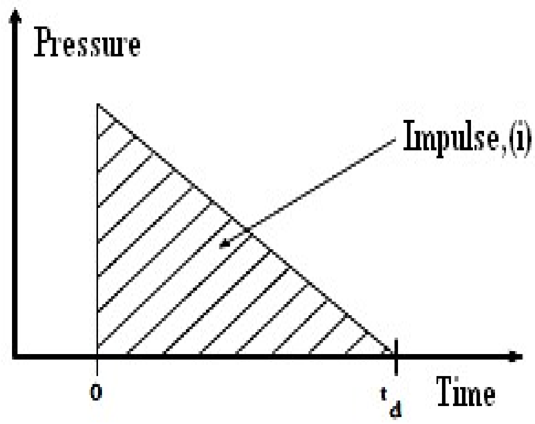

Figure: 3 Blast pressure vs time

III. AN EXAMPLE OF CALCULATION OF BLAST LOAD ABOVE GROUND BUILDING AS PER IS 4991-1968

1. Blast parameters due to the detonation of a 10kg explosive are evaluated on an above ground, square structure, 18 m high, 12 m wide and 12 m long, situated at 10 m from ground zero.

a) Characteristics of the Blast

Scaled distance x (z) =$R/W^{1/3}$ = $10/(0.01)^{1/3}$ =33.334mts
From Table 1 assuming pa= I.00 kg/cm and
Linearly interpolating between 33 m and 36 m for the scaled distance 33.334 m,
The pressures are directly obtained from table 1(Is 4991-1968):
PS0 = 1.1778 kg/cm^2
PRO= 3.372 kg/cm^2
Q0 = 0.04248 kg/cm^2
The scaled times to, and td obtained from Table 1 for scaled distance 33.334 m are multiplied by $(0.1)^{1/3}$ to get the values of the respective quantities for the actual explosion of,10kg charge.
t0 =25.145 $(0.01)^{1/3}$ = 16.492milliseconds
td =16.492 $(0.01\ )^{1/3}$ = 3.56 milliseconds

M=Mach number=1.413
a = 344 m/s
U = Ma
1.134X344=486.209 m/s
= 0.486 m/millisecond

b) Pressures on the Building

Here H = 18 m, B = 12 m, L = 12 m, h=3
Then S = 6 m
tc = 3xS/U =3X6/(0.486) = 37.04 milliseconds> td
tt = L/U =12/(0.486) = 24.7 milliseconds> td
tc = 4S/U = 4X6/(0.486) = 49.4 milliseconds> td
As tr >td no pressure on the back face are considered.

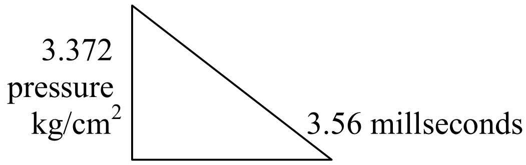

Figure 1.4 pressure vs time diagram for 10kg 10mts case

Table 1.1: Upper limits of charge weight by means of transportation.

Carrier	**Explosive weight(TNT) [kg]**
Suitcase	10
Medium car	200
Large car	300
Pick-up truck	1400
Van	3000
Truck	5000
Truck with trailer	10000

IV. ANALYTICAL STUDY

The study in this thesis is based on nonlinear analysis of RC structures under blast loading .This chapter presents a summary of various parameters defining the computational models, the basic assumptions and the RCC frames geometry considered for this is study..

The present study is to evaluate the behaviour of G+5 reinforced concrete frame structure subjected to blast loading under 6 different cases. Then the structure was subjected to 2 different blast loads 10kg and 20kg TNT weight at different standoff distances 10, 15 and 20mts. The blast loading was calculated using code IS: 4991-1968. The analyses have been done by using Etabs 2016 software. Finally its results are obtained and compared The reinforced concrete structures are analysed by nonlinear static analysis (time history Analysis) using ETABS software. From this we found frequency, time periods, story displacements and story drifts.

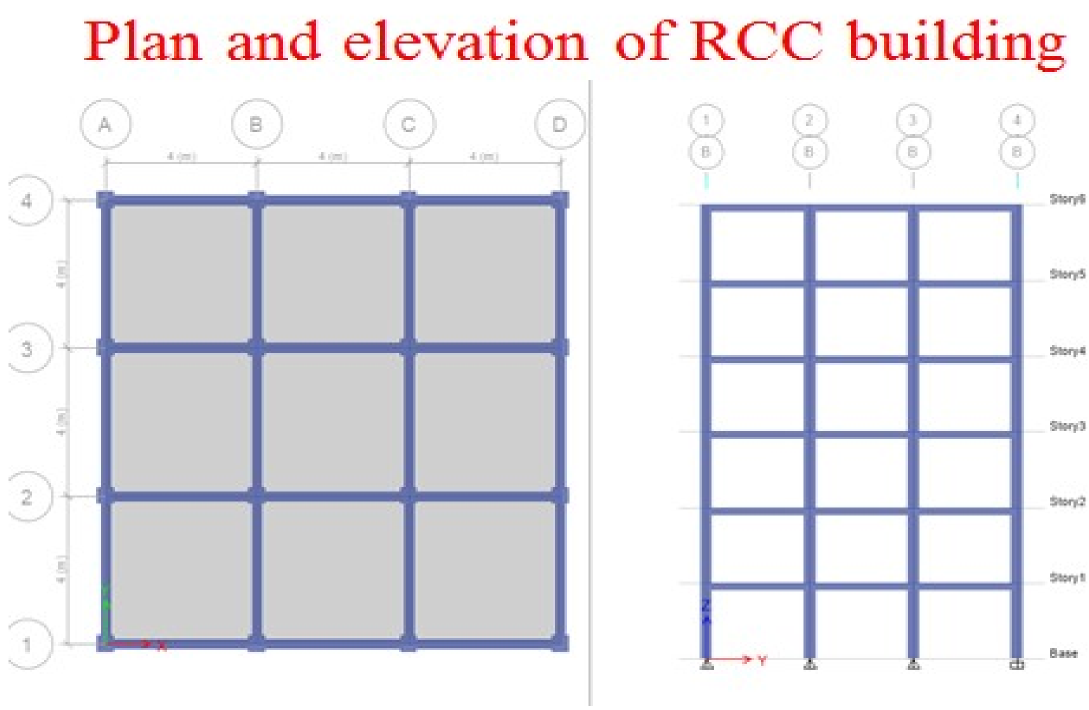

Figure: 5 Plan and elevation

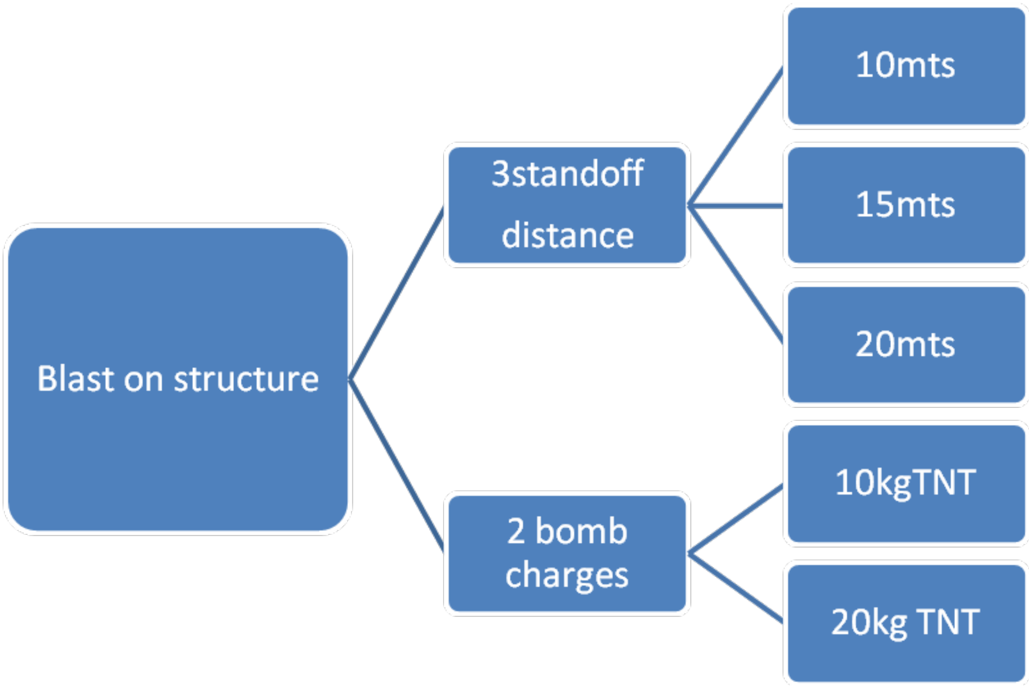

Figure: 6 Blast loading models

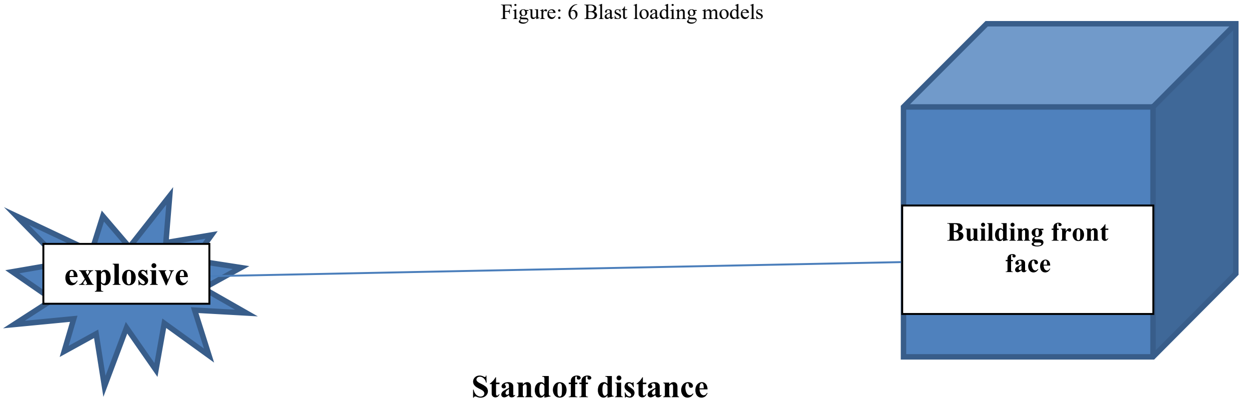

Figure 1.7 Blast loading on structure

6.Geometry

The RCC structure is consist of columns, beams and slab as shown in figure 4.7. The overall dimensions of the structure are 12 m x 12 m. The plan of building is shown in figure 4.7. the building is planned to facilitate the basic requirements of commercial building. The plan dimension of the building is 12 x 12 m. Height of each storey is 3m. Entire height of the structure is 18mColumn dimensions for G+5 are 450mm x 450mm , beam dimensions are 230 x 300mm and slab thickness is 120mm.

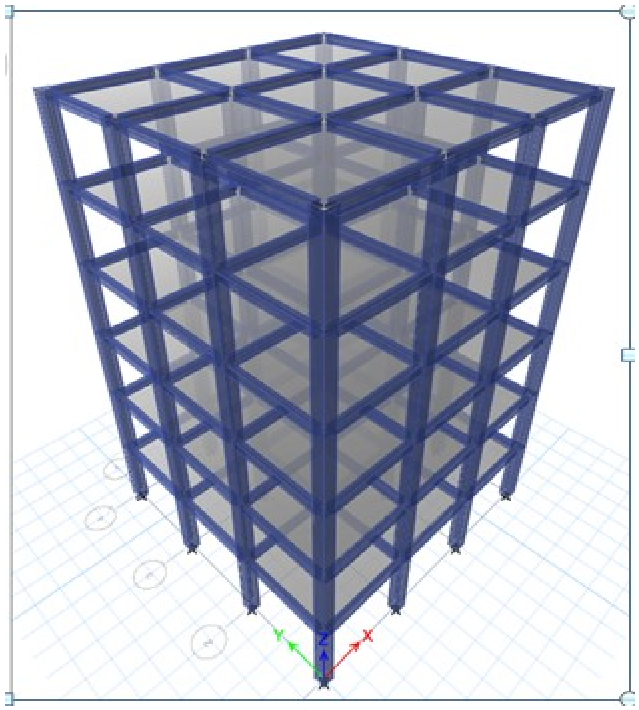

Figure: 7 Building model in 3d

Maximum loads and maximum time for all 6 cases
Time history method

Cases	Front face	
	Max time (sec)	Max load (kN/m2)
10kg10m	0.0036	330.48
10kg15m	0.0055	131.49
10kg20m	0.0062	74.53
20kg10m	0.0032	907.12
20kg15m	0.0047	284.39
20kg20m	0.0068	148.08

Time history method of analysis shall be based on an appropriate ground motion and shall be performed using accepted principles of dynamics. Time history analysis is the study of the dynamic response of the structure at every addition of time. Static techniques are applicable when higher mode effects are not important. This is for the most part valid for short, regular structures. In nonlinear dynamic method, the structures are modelled as a multi degree of freedom (MDOF) system with a linear elastic stiffness matrix and an equivalent viscous damping matrix. The blast input is modelled utilizing time history analysis, the displacements and internal forces are found using non-linear analysis. In order to study the behaviour of structures subjected to high blast loads, dynamic analysis is required. ETABS software is used to perform nonlinear time history analysis.

Table 1.3: Time period and frequency results

Mode Shape No	Time period (sec)	Frequency
1	0.93	1.072
2	0.87	1.038
3	0.73	1.37
4	0.271	3.691
5	0.262	3.81
6	0.222	4.51
7	0.135	7.423
8	0.133	7.526
9	0.113	8.831
10	0.08	12.449
11	0.08	12.51
12	0.069	14.51

This table shows the time period and frequency of the building maximum time period is 0.93sec and minimum is 0.069sec. whereas the maximum frequency is 14.51sec and minimum is 1.038sec

Story displacement

Definition: It is total displacement of n^{th} story with respect to ground.

This shows story displacement plot for all 6 cases obtained from time history analysis results at specified story due to blast loading. The maximum value of displacement is at story 6 in 20kg 10mts case the X as shown in figure 5.

Table-1.4 : Story displacements for all cases under blast loading

STORY	**10kg10m**	**10kg15m**	**10kg20m**	**20kg10m**	**20kg15m**	**20kg20m**
Story6	0.1	0.061	0.04	0.247	0.114	0.088
Story5	0.096	0.058	0.038	0.238	0.11	0.084
Story4	0.088	0.054	0.035	0.218	0.101	0.077
Story3	0.075	0.046	0.03	0.186	0.086	0.066
Story2	0.056	0.034	0.022	0.14	0.064	0.049
Story1	0.032	0.02	0.013	0.08	0.037	0.028
Base	0	0	0	0	0	0

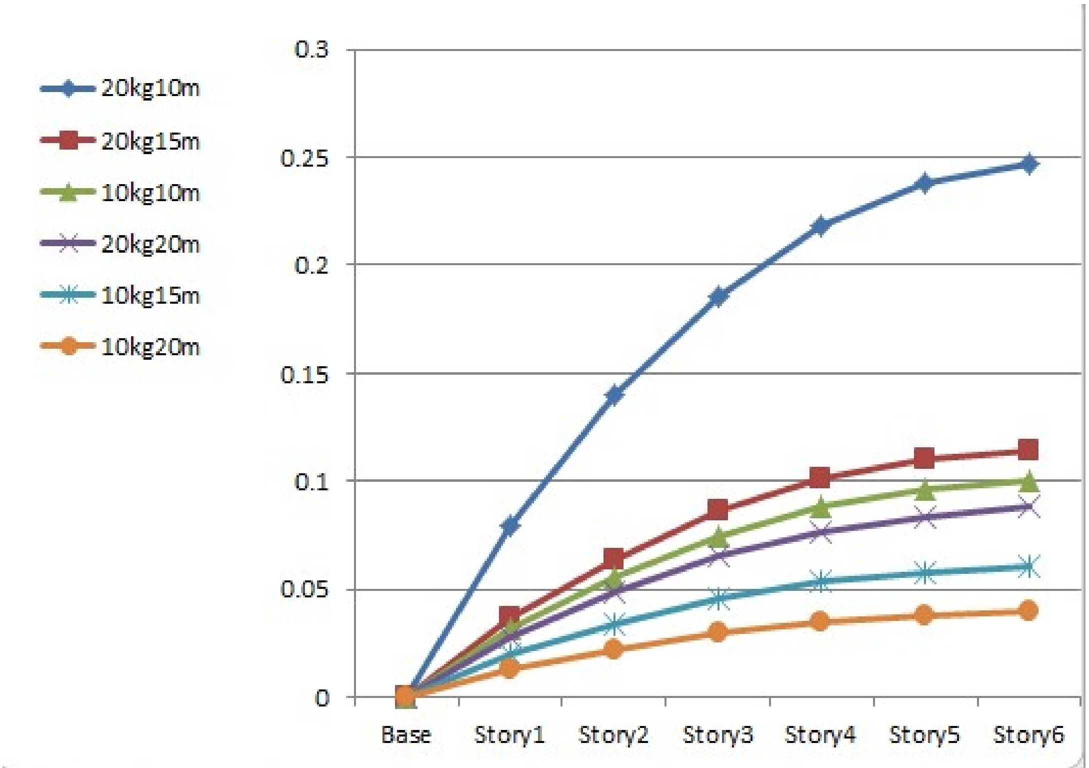

Figure: 9 Story displacement for all cases under blast loading

Story drift

Above plot shows story drift obtained from time history analysis at specified story due to blast loading in all cases. The maximum value of drift is obtained at story 3 in the X direction as shown in figure 5.5.

Table-1.5: Story drift for all cases under blast loading

STORY	**10kg10m**	**10kg15m**	**10kg20m**	**20kg10m**	**20kg15m**	**20kg2m**
Story6	0.008	0.005	0.003	0.02	0.009	0.007
Story5	0.012	0.007	0.004	0.029	0.013	0.01
Story4	0.014	0.009	0.006	0.035	0.016	0.012
Story3	0.019	0.011	0.007	0.046	0.021	0.016
Story2	0.024	0.015	0.01	0.062	0.028	0.021
Story1	0.032	0.021	0.013	0.081	0.037	0.028
Base	0	0	0	0	0	0

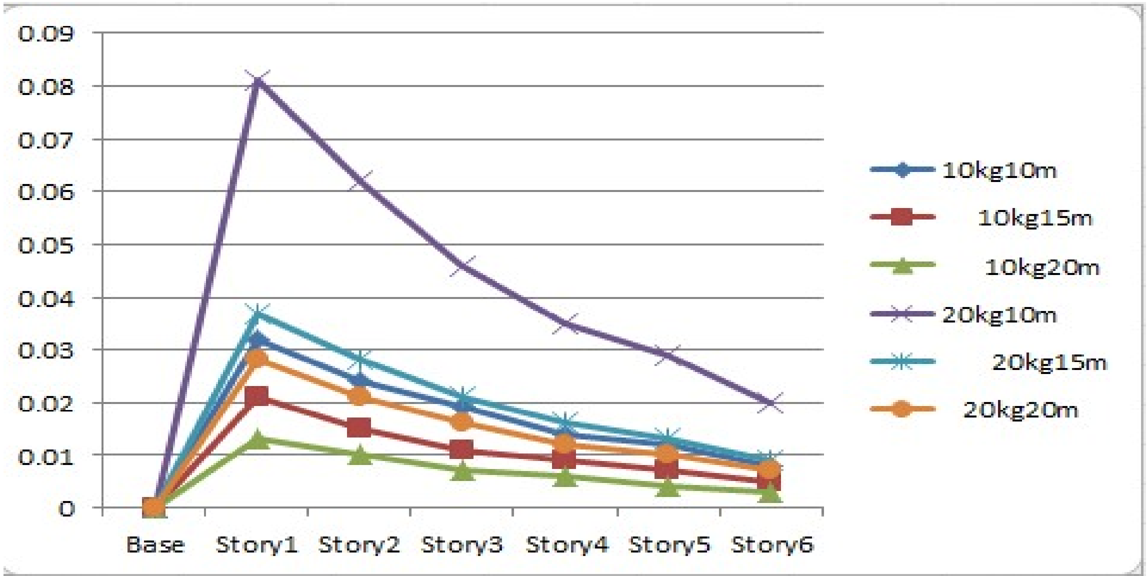

Figure: 10 Story drift for all cases under blast loading

Discussion

In these the results are compared to draw out some of the conclusions. story displacements and story drifts are compared from time history analysis.

Story displacement comparison for all cases

- From time history analysis the story displacement is high in 20kg10mts case and it is in 6th story.
- Story displacement is lowest in 10kg20mts case and it is in 1st story.

Story drifts comparison for all cases

- From time history analysis the story drift is high in 20kg10mts case and it is in 1th story.

CONCLUSION

1. Standoff distance is inversely proportion to displacements and damage. If blast happens near to the structure intensity of load will be more it will cause higher damage to the structure and vice versa. To protect the structure standoff distance and charge is the main criteria which has an

impact on the blast pressure. There is less significant effect 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. As the unit charge increases the displacement increases, displacements are higher in top storeys when compared to bottom storeys in all cases. From graphs, it's evident that as standoff distance increase storey drifts goes on decreasing and as charge weight increases storey drifts increases and Story drifts are higher in first storeys when compared with sixth storeys in all cases. 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.

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