

Analytical Investigation of High Rise Building under Blast Loading

P. Vinothini* and S. Elavenil

School of Mechanical and Building Sciences, VIT University, Chennai, India;
p.vinothini2014@vit.ac.in, elavenil.s@vit.ac.in

Abstract

This paper presents the dynamic response of high rise building subjected to blast loading. It is about understanding the explosion phenomena and investigating the dynamic response of a concrete frame structure by using SAP2000. Building is of 10 storey is exposed to 30kg TNT and 60kg TNT with three different standoff distances of 10m, 12.5m and 15m respectively. A non-linear three Dimensional is used for analyzing the dynamic response of a structure. In the present scenario, structures under blast loading (i.e. bomb explosion) are acting in short duration with high pressure intensity of shock wave which is outlined in section of TM-5 1300. The aim of this paper is to investigate the performance of high rise buildings under blast loading, blast phenomena and dynamic response of a concrete frame structure under blast loading by using SAP2000 software. Blasting vibration responses are simulated by using MATLAB program. The result obtained in terms of time history function, displacements and influence of the parameter considering the resistance of structure. Therefore, for decreasing the facade on surrounding buildings, moderate explosive energy is used to control the structural damages due to explosion.

Keywords: Blasting Loading, Concrete Frame Structure, Dynamic Response, Standoff Distance

1. Introduction

A structure subjected to blast load gained more importance due to accidental events or Natural events. Blasting always produces vibration waves then it can cause vibration damages to the structures. Moreover, loss of life can result due to structural failure. So, effects of blast loading on the structures, structural engineers have developed methods for designing the structures and how to analyze against blast loads. Army TM5-855-1 and Army TM5-1300 are the parameters developed by empirical method used by military engineers to predict the blast loads. The analysis of the structural elements under explosion with given charge weights and stand-off distances. 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.

Understanding the performance of high-rise building subjected to blast loading gives more importance for avoiding or control damages to structures and property under explosion. Blast resistant structures require a detailed understanding of blast phenomena, explosion and blast effects on buildings. Pressure intensities should 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 Figure 1.

2. Literature Review

¹Nitesh N Moon explained the response of simple RC columns under constant lateral blast loads and axial loads was examined. By using ANSYS, RC column was modelled with different boundary conditions and by the

*Author for correspondence

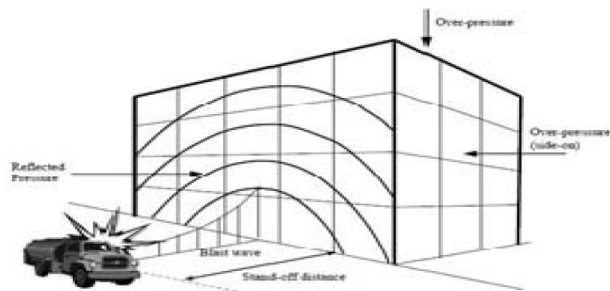


Figure 1. Blast load on building.

method of mesh less to reduce mesh distortions. A simplified triangle shape was used to find out the blast load and blast wave pressure.

²Ngyuen and Tran were described the dynamic behavior of vertical wall structures subjected to blast loading. Blast loading is simulated by the term of dynamic response in time based on some assumptions to assure physical nature of dynamic problems and it have practical applications in design of protective buildings in both civil and defence areas.

³Hrvoje Draganic described the process of determining the blast load on structures and provides a numerical example of a fictive structure exposed to this load. The blast load was analytically determined as a pressure-time history and by using SAP2000 numerical model was created. The results confirm the initial assumption that it is possible with conventional software for an explosion effects and give a preliminary assessment of the structure.

⁴Juraj Králik and Michal Baranb explained o show the approach to addressing air pressure waves from explosions using empirical formulas and compare it with numerical calculation, which is solved using the computational program AUTODYN. Simulation of blast pressure waves in the environment and its impulse loading in structure in a simple shape gives realistic results from the blast wave pressure analysis and their influence with a rigid obstacle.

⁵Kulkarnil Sambireddy explained the dynamic response of a High Rise Structure subjected to blast load. In this study it is found that the optimum model is a regular infill frame which shows the lowest value of storey drift and the structure is very good in lateral stability against blast load.

⁶Sindhura and Elavenil S described the behaviour of reinforced concrete plates subjected to explosion under blast load which occurs in a very short duration categorized as an impulsive loading by nonlinear dynamic analysis using finite element method. The results obtained

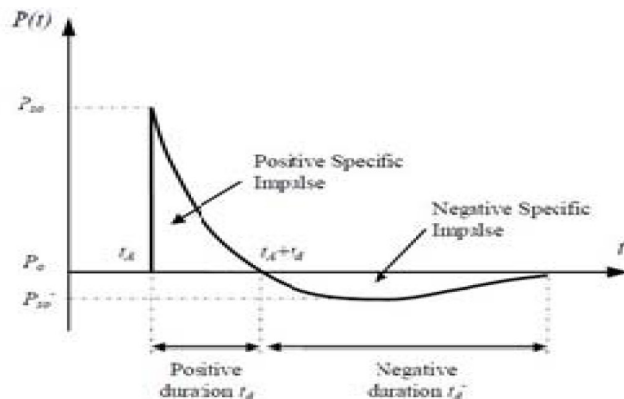


Figure 2. Blast wave pressure.

in terms of time history function and interaction of the parameters considering the nonlinear dynamic analysis of concrete plates is subjected to blast load.

3. Blast Phenomena

Generally blast load assessment is a difficult procedure with number of factors which affecting the performance of the building. Blasting produces vibration so it can cause structural damages. Blast have a close relationship with blasting distances and charge weights where the vibrations caused due to explosion and blasting distances are different. Blast always reflects as pressure. Time history function is used to express the blast phenomena and the blast wave profile is in the terms of pressure due to explosion versus time. Time is the main function for blast loading and a very small time period is essential to get stable result

Model building is created as reinforced concrete framed structure where the beams and columns were generated as framed sections and the slab was modelled as shell elements. Columns fixed support conditions applied and non-linear modal analysis (time history) was carried over in the structure by using SAP2000. Blasting vibration waves are determined in different simulation method by using MATLAB programming and blasting on standoff distance and quantity on peak acceleration. Figure 2 illustrating the blast pressure graph, where t_A is a arrival time, P_{so} is a peak overpressure and P_o is a ambient pressure under explosion. P_{so} is a peak side-on overpressure or incident peak overpressure. The pressure passes to ambient level at time t_d , and then to under pressure P_{so-} are creating a partial vacuum before returning to ambient conditions at time $t_d + t_d-$.

4. Analytical Study

The structure selected for this study is 10-storey high rise building at the height of 40m shown in Figure 3. The height of each storey is 4m. The model structure taken as reinforced concrete frame structure. The yield strength of reinforcement is 300 MPa with elastic modulus of 210 GPa. The typical beam size is 300x700mm; column size is 900 x900 mm. R.C wall is taken as infill element, the concrete infill Wall thickness is 150 mm and the slab thickness is 175mm. Design Concrete frame structure shown in Figure 4. For solving dynamic response of structural system, non-linear modal analysis is used. The deformation of the structure diagram under 30kg and 60kg explosives are illustrated in below Figure 5 and 6.

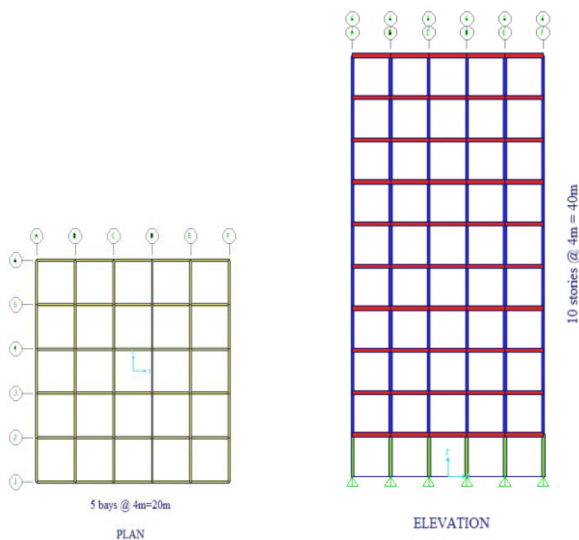


Figure 3. 10-Storey building plan and section.

5. Dynamic Response Analysis

5.1 Floor Displacement

Floor displacement and story drift are the two important factors to determine the structural damages. The size of the structure reflects the extent of the damage depends on floor displacement and storey drift subjected to blasting of 30kg and 60kg explosives. Blasting distances increases with vibration gradually decreases whereas floor displacement decreases with increase of storey drift.

Therefore, blasting dynamic response at 10 m distance is larger, and floor displacement cannot be ignored at the 12.5 and 15 m distances. The weak parts of the top story in the actual project, and the roof room and parapet should be especially strengthened in the seismic design. The floor displacements of frame structure under blasting vibration with explosive quantities of 30 and 60 kg at different distances are shown in Figure 7.

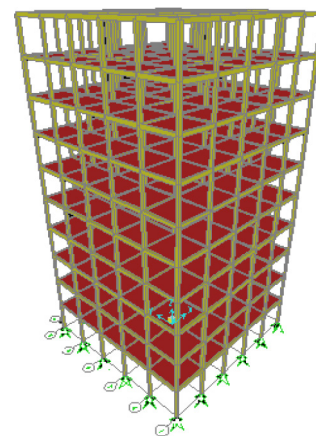


Figure 4. Concrete frame structure.

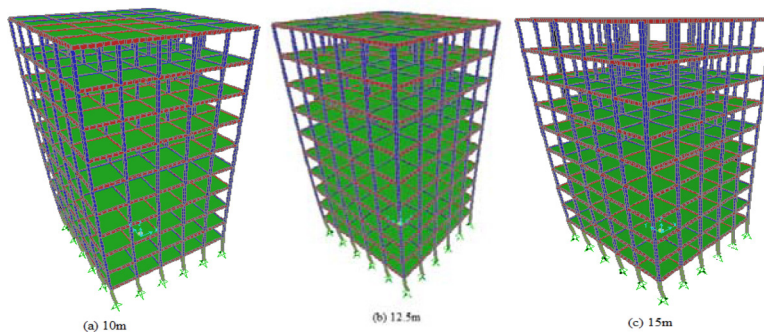


Figure 5. Deformation of structure for 30kg explosive quantity (10m,12.5m,15m).

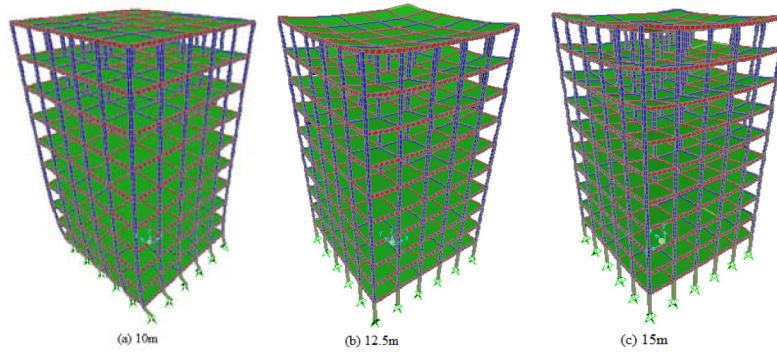


Figure 6. Deformation of structure for 60kg explosive quantity (10m,12.5m,15m).

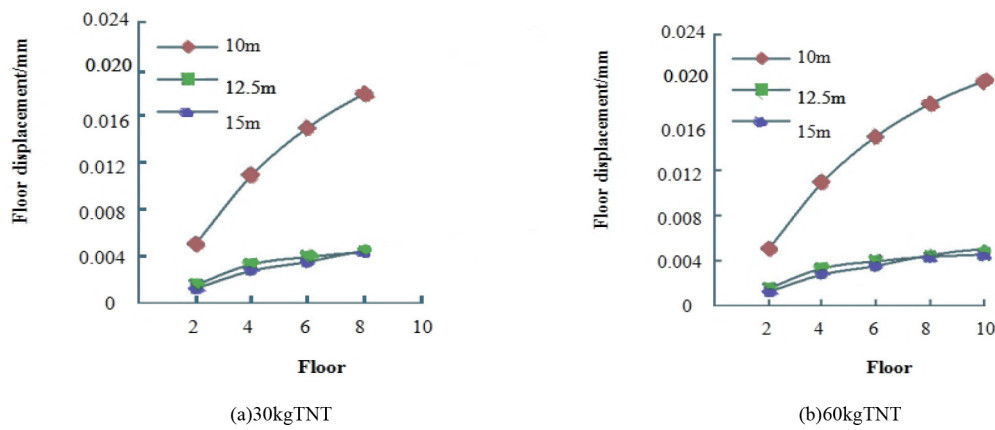


Figure 7. Floor displacement change of frame structure under explosives.

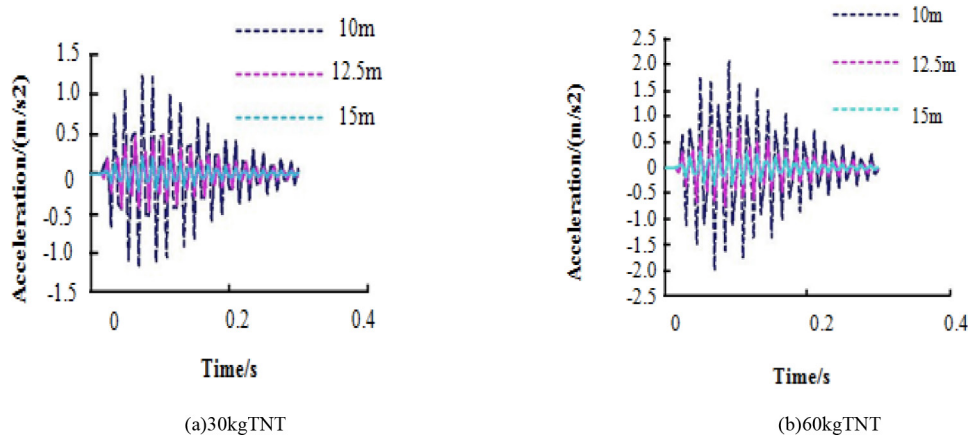


Figure 8. Acceleration response curves under explosives.

5.2 Acceleration

The response of blasting vibration increases with the increase in charge weights (explosive quantity). When the floor displacement decreases storey drift gradually

increases. Figure 8 illustrating in the case of 30kg and 60 kg explosive quantities, the acceleration of the structure at the top is at its maximum at 10 m distances. It reaches its maximum at 0.1 s under different explosion

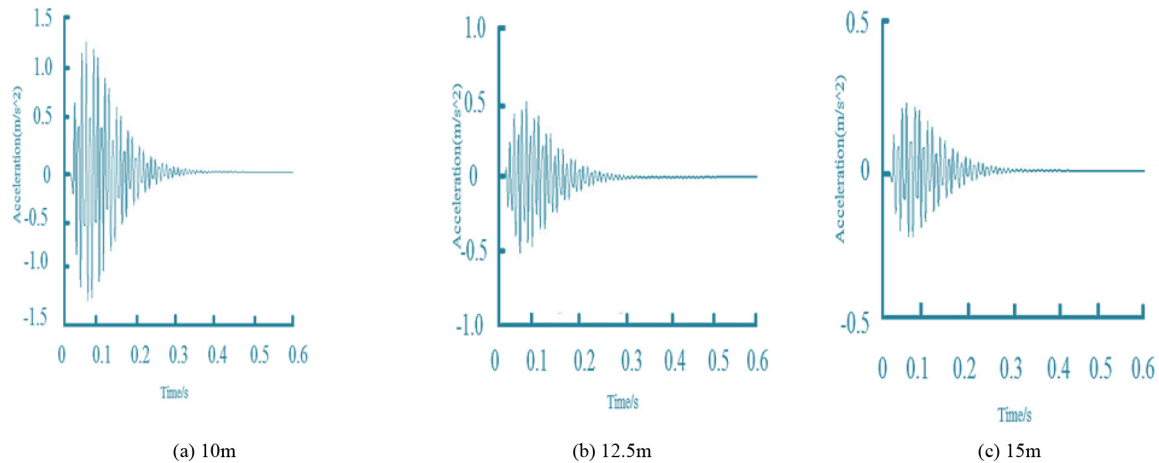


Figure 9. Blast vibration waves (30kg explosives).

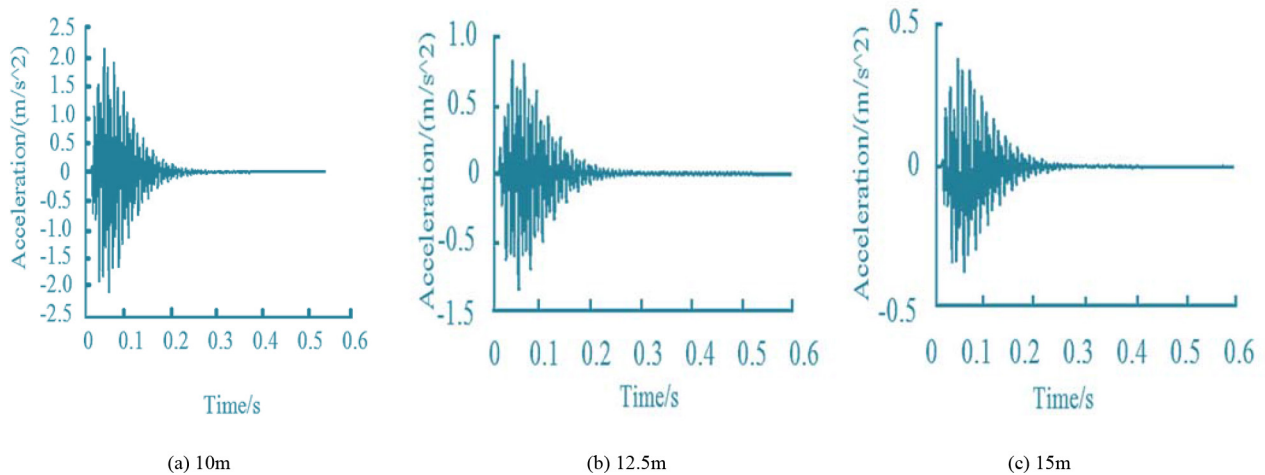


Figure 10. Blast vibration waves (60kg explosives).

and becomes zero. Maximum vibration response on the structure under explosion of blasting vibration wave is at the top obtained from the analysis. The floor displacement of a structure at 10 m distance is larger than that at 12.5 and 15 m distances in the case of 30 and 60 kg explosive quantities. Therefore, blasting dynamic response at 10 m distance is larger, and floor displacement cannot be ignored at the 12.5 and 15 m distances. The weak parts of the top story in the actual project, and the roof room and parapet should be especially strengthened in the seismic design. Figure 9 and 10 shows the blast vibration wave in terms of time versus acceleration under 30 kg and 60kg explosive charge weight.

6. Blast Wave Profile

Dynamic parameters for the blast load are front velocity, time of arrival and frequency. Table 1, 2 and 3 shows the mode shapes with respect to time and blast wave velocity along the height of the structure for the charge weight 30kg and 60kg TNT at different standoff distances. The blast always reflects as pressure. It can be converted to blast load which is applied as a point load on each node in the front face of the targeted multi story building by using the time history function. Figure 11 showing the variation of pressure at different stand-off distances by manual calculation.

Table 1. Variation of time period and frequency of the building.

STEPS	10m		12.5m		15m	
	T(S)	F(C/S)	T(S)	F(C/S)	T(S)	F(C/S)
1	0.97	1.07	0.91	1.22	0.82	2.22
2	0.93	1.13	0.87	1.29	0.80	2.25
3	0.88	1.19	0.85	1.35	0.79	2.36
4	0.83	1.21	0.72	1.39	0.74	2.49
5	0.76	1.59	0.68	1.67	0.72	2.50
6	0.60	1.59	0.62	1.70	0.66	2.51
7	0.63	1.59	0.57	1.75	0.69	2.57
8	0.58	1.65	0.54	1.82	0.58	2.87
9	0.51	1.83	0.49	1.98	0.56	2.96
10	0.47	2.56	0.46	2.43	0.51	3.24

Table 2. Blast wave velocity for charge weight 30kg TNT.

Floor	Arrival time (t _A) ms	Time of decay (t ₀)ms	Velocity (U)m/ms
Ground level at 0.00m	5.38	10.2081	1.0110
Roof level at 40.00m	67.16	24.6800	0.3801

Table 3. Blast wave velocity for charge weight 60kg TNT.

Floor	Arrival time (t _A) ms	Time of decay (t ₀)ms	Velocity (U)m/ms
Ground level at 0.00m	3.73	8.0641	0.9300
Roof level at 40.00m	49.68	17.6050	0.2551

7. Result and Discussion

It has been observed that the dynamic response of concrete frame structure is discussed under two different charge weights and centre blasting distances under blast loading. The 3-D high rise concrete frame structure (G+10) subjected to two charge weights 30 and 60 Kg TNT. The frame is simulated for two blast load combinations at 10m range of 30kg and 60Kg TNT Charge weights. Similarly 12.5m and 15m to the above charge weights are considered. Reflected positive pressure decreases when the standoff distances increases.

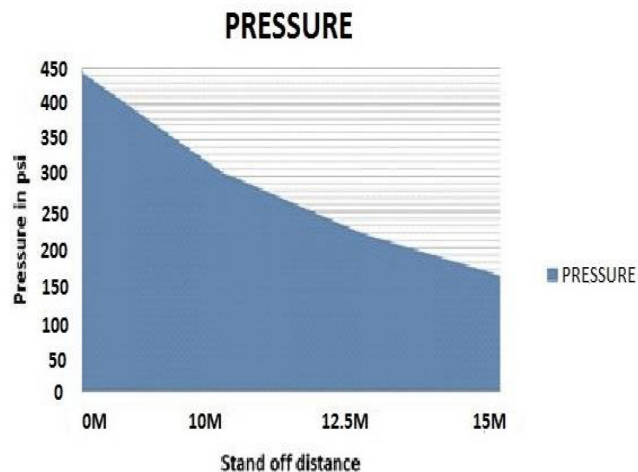


Figure 11. Variation of pressure.

8. Conclusion

The results show that the explosions near to the structure can cause damages to the surrounding buildings. Blasting over the exterior side of the structure three dimensional frame analysis gives distribution of reflected pressure is in decreasing order with the height of Structure. The structure first failure locally then distributed to entire structure, the response in the structure is more, in the case of lower ranges. Acceleration amplitude is higher in case of 60 kg charge weight than in 30 kg charge weight. So, it may cause direct effect on the structure. The pressure which in front face of the structure is low at the top is observed in the case of 10m range and more in 12.5m and 15m range under 30kg and 60kg TNT. From the above observation reflected blast wave pressure is more in the case of bottom floors, low in top floors for different charge weights. When standoff distance is larger, blasting vibrations will be smaller; standoff distance is smaller, blasting vibration will be greater under explosive blasting. Finally, blasting explosive quantities should be moderately good for selecting according to the stand-off (blasting) distances to control blasting effect to the nearby buildings.

9. References

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