RESPONSE OF A RECTANGULAR REINFORCED CONCRETE STRUCTURE WITH AND WITHOUT SHEAR WALLS UNDER BLAST LOADINGS

Kanchan Pujari[1], Prof. D.H. Tupe[2], Prof. Dr. G.R. Gandhe[3]

[1]*P.G. Student, Civil Engineering Department, Deogiri Institute of Engineering and Management Studies.*
[2]*Assistant professor, Civil Engineering Department, Deogiri Institute of Engineering and Management Studies.*
[3]*Proffessor, civil Engineering Department, Deogiri Institute of Engineering and management studies*

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Abstract- *Over the last few decades' attention has increased about the behavior of various civil structures under blast and impact loading conditions due to the increased vulnerability of terrorist attacks. The problem of structural resistance under blast loading conditions has been under investigation and has been well advanced in western countries. In this research work, the performance of a building under blast load on the bare frame and performance of the same building integrated with shear walls under blast loads has been analysed. The models were prepared on the structural analysis software SAP-2000. The results of the same studyhave been mapped*

Key Words: Blast Loads, Earthquake loads, Non Linear analysis, SAP-2000, Time History Analysis.

1. INTRODUCTION

Over the last decades, considerable attention has been raised on the behaviour of engineering structures under blast or impact loading. The use of explosives by terrorist groups around the world that target civilian buildings and other structures is becoming a growing problem in modern societies. Explosive devices have become smaller in size and more powerful than some years ago, leading to increased mobility of the explosive material and larger range effects. Usually the casualties from such a detonation are not only related to instant fatalities as a consequence of the direct release of energy, but mainly to structural failures that might occur and could result in extensive life loss. Many examples such as World trade centre bombings, London bombings, Paris incident, have created more concerns regarding blasts.

Due to the wide increase in such incidents there has been increase in the studies regarding blast resistant designs of buildings or other such civil structures destruction of which may endanger loss of lives. The literatures has suggested that if a building is designed to resist some lateral governing forces such as earthquakes, the same structure with EQ resistance can withstand some amount of Blast loads too [1].

The work in this research lies on the same line. In this research the models prepared were firstly made earthquake resistant then blast loads were applied on the structure. The structures were then integrated with RC shear walls and then blast load was applied and the models were analysed. The response of the building under the blast load was checked.

- Blast Phenomenon

Blast overpressure is expressed relative to ambient condition (P0) rather than the absolute pressure. Fig. 1 shows the typical blast-induced pressure wave profile produced from the ideal detonation, along with the different loadings in relation with amplitude and frequency that govern the design of any structural component. An ideal blast wave representation and its characteristics are a function of the distance of a structure to the centre of the charge, R, and time, t. The peak pressure is known as peak positive overpressure, Ppos. A negative phase follows, in which the pressure is lower than ambient pressure, known as under- pressure, Pneg. The durations of peak positive overpressure and under pressure are known as positive (Tpos) and negative (Tneg) duration, respectively. However, for simplicity in the analysis, a triangular blast load profile is generally applied as shown in Fig. 1, neglecting the negative phase. For relatively thinner components that are flexible, however, the negative phase should also be modelled. It can be noted from Fig. 1 that blast loading is associated with very high magnitude and frequency; hence it needs special attention.

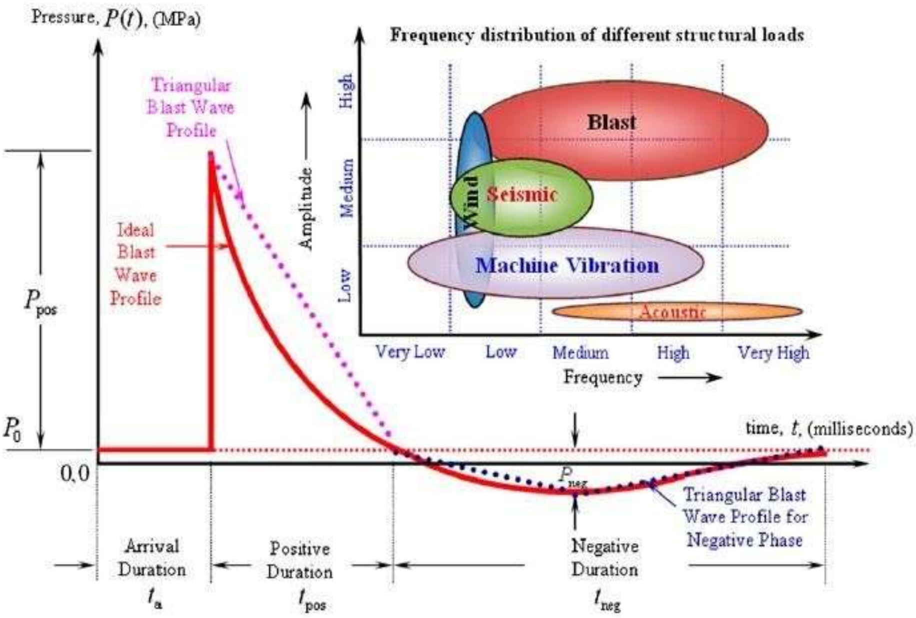

Figure 1: Blast Phenomenon

2. LITERATURE REVIEW

Zubair I. et al [1] did an investigation on Performance of Earthquake Resistant RCC Frame Structure under Blast Explosions. For this study, an earthquake resistant structure according to International building code (IBC 2009) and ACI

318-11 was analysed. To study the response of the structure, various standoff distances and various explosion charge weights were considered. Standoff distances such a 4 to 16 m and explosive charge weights were 50 kg, 100kg, 200kg and 500 kg were studied. The main focus of the study was to find out safe standoff distance for the earthquake resistant building. In this analysis, the various parameters also checked such as Earthquake resistant vs Non Earthquake Resistant structures, Effect of Location of Blast – Short *vs* Long Span, Effect of Concrete Strength, and Effect of Height of Structure. The study concluded that for avoiding column failure due to an explosion on an earthquake resistant building the distance should be 6 to 12 m required. Also, the capacity of earthquake resistant structure had a better capacity to resist blast loads. In order to a non- earthquake resistant structure, the blast load effect only minimised by increasing standoff distances. High strength concrete performs well in shear and moment capacities of beam and column .also the blast -load had less effect on the longer span to the shorter span.

Ganavi S. et al [2] studied the behaviour of frame structure subjected to an explosion on the ground. In this research, a RCC building of G+4 storey subjected to a 100 kg TNT was considered. For the positive phase parameters of explosive load at various standoff distances were determined from the UFC 3-340-02. The study performed based on linear static analysis by using ETABS 2015. The study focused on the parameters such as storey Drift, column forces and beam forces, also the displacement of the building. It concluded that when the source is nearer to the building pressure was high and it reduces when the source is away from building it means as the standoff distance increases pressure decreases. Storey drift decreased as the height of the building increased. Column forces were greater as the less standoff distance was there and when the standoff distance was more column forces were less. Also in beam the shear forces and bending moment's decreases with increase in standoff distances. The safe standoff distance was found to be 80m.

Aditya C. et al [3] studied the comparative response of structures subjected to blast and earthquake loading. The structure having G+3 storey subjected to earthquake load and blast load were analysed by using ETABS. The building was subjected to a blast load of 0.1tonne TNT at a standoff distance of 21 m on a ground. Various parameters were studied in this research such as maximum storey displacement, storey drift. The calculations of blast loading were based on IS 4991-1968. Four cases were considered such as Blast EQ Section i.e. blast load applied on the building which is designed for earthquake resistant Blast Revised Section, EQ section i.e. only for earthquake loading and EQ Section Safe In Blast i.e. maximum charge weight obtained to make the earthquake resistant building safe during blast. The study concluded that the displacement is higher comparatively than the earthquake, the storey drift is permissible in the earthquake load but it exceeds when the blast load is applied, the material required for blast resistant building is 40% more than the earthquake resistant building. The safe standoff distance concluded is 31.5 for a 0.1tonne TNT

Mohammed Alias Yusuf et al [4] did an investigation on the simulation of reinforced concrete blast wall subjected to air blast loading. In this, a 5 kg of TNT at a standoff distance of 2 m was considered to apply a load on a RC blast wall was designed. The dimensions of the RC blast wall were 4500 mm of height and 250 mm of thickness. An air blast loading was considered to simulate a RC blast wall by using AUTODYN 3D hydro-code software. Different charge weights were considered such as 50 kg for motorcycle, 400 kg for car, 5 kg for hand carried bomb, and 1500 kg of TNT in a van. The blast wall was designed on the basis of TM5-1300: structure to resist the accidental explosion. This theory concluded that if the 50 kg and below 50 kg TNT was applied on a blast wall it is safe and above 400 kg of TNT the blast wall will completely damage. Also, the blast wall is not constructed for the complete protection to the structure but at least to prevent severe damages, and to minimize injuries and loss of life. One more conclusion is that by using AUTODYN software it helps in finding the correct impact of load on the structure without having any practical test, also helps in the proper evaluation of threats.

B .M. Luccioni et al [5] presented work on the analysis of building collapse under blast load. In this research, all the process included in blast i.e. from the detonation of the explosive charge weight till the complete collapse of the building and also the propagation of blast wave and its interaction with the building were considered. Hydro-code was used for analysis. The actual building which had a blast attack on it and the numerical simulation of another building was compared and checked the results. In this research for numerical simulation explosive load of 400 kg of TNT at a standoff distance of 1 m above the ground, 1 m inside the entrance hall and 1 m from the right side of the structure were considered. This theory concludes that the numerical results of simulation of building and the actual results of a real damaged building in the blast are correlated with each other and this is the best way to analyse the structure if blast attack occurs on the structure.

Quazi Kashif and Mahavir Varma [6] did an investigation on the effect of blast on G+4 RCC frame structure. In this research, the effect of blast on a five storey building at a 30m standoff distance having 100 kg and 500 kg of TNT were considered. The blast load calculations were done according to IS 4991-1968 with non-linear direct integration and time history analysis. For this a finite element programme SAP 2000 was used after determining the blast load analytically as a pressure –time history. The response of building under the effect in inter-storey drift, acceleration, deflections, velocity was compared. The results came out to be variation in displacement were non-uniform along with the height of structure also for minimum standoff distance the building reached to collapse point, plastic hinges were developed in all beams and columns. So the analysis of blast needs to carry out as the terrorist activities are taken into consideration.

Naveen kumar Khatavkar, et al [7] did investigation on the response of high rise structures subjected to blast loads. In this research two high rise structures, one is open RC frame structure and closed structure was analysed by using ETABS. The various standoff distances were checked such as 30 m, 50 m, 70 m, 90 m, 110 m, and 150 m. The 2 models were created using ETABS. The first model has 30 stories with peripheral shear wall and another model has a shear wall at the centre. Both the models were analysed for blast load of 10KN using time triangular function. The analysis was done on the basis of various parameters such as von misses stresses, storey acceleration, storey drift, storey displacement. After the analysis, it was found that the critical distance or the minimum distance at which structure is damaged severely at 70 m for closed structure and 90 m for open structure.

3. SYSTEM DEVELOPMENT

For the analysis purpose a 10 storied RCC building was considered. The modelling of the building was developed in the finite element program SAP-2000. The building was a rectangular building with plan dimensions 30m X 21m. The material properties and other specifications of the buildings are stated under table 1, 2 and 3.

Table 1: Material Properties

1.	Grade of concrete	M35
2.	Grade of reinforcing steel	Fe 500
3.	Density of concrete	25 KN/m^3
4.	Density of brick masonry	19 KN/m^3
5.	Damping ratio	5%

Table 2: Building Specifications

1.	Plan Type	rectangular
2.	Plan Dimensions	(30 X 21) m
3.	No. of bays along X/Y	10 / 7
4.	Width of each bay	3.0 m
5.	Height of the structure	30 m
6.	Height of each storey	3.0 m
7.	Thickness of Slabs	150 mm
8.	Internal / External Wall thickness	150 mm
9.	Depth of footings	3 m
10.	Zone (IS-1893)	IV (severe)
11.	Importance factor	1.0
12.	Response reduction factor	5.0
13.	Site soil type	Medium (II)

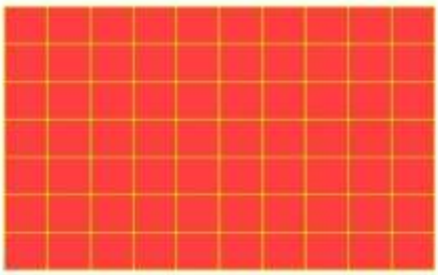

Figure 2: Typical Plan of Bare Frame

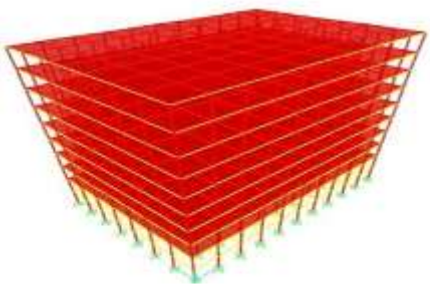

Figure 3: 3D-Extruded View of Bare Frame

4. METHODOLOGY

For this research a 0.1 Tonne TNT explosion was considered with a stand-off distance of 30 m. As per the various literatures studied the blast loads are most suitably indicated using Time History loadings [3]. The peak pressure values were calculated according to IS-4991 (1968). The pressures then were applied on the structural elements such as columns and beams which were facing towards the blast on the front and either sides of the building.

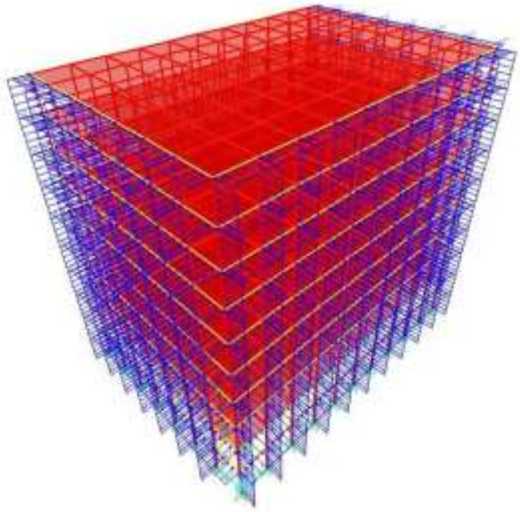

Figure 4: Blast Load Applied in the form of UDL

5. BL Calculations (IS-4991)

For 0.1 Tonne TNT at 30 m stand-off distance, the various parameters have been considered as stated below:

- Scaled Distance (X) = 64.63 m
- Peak Side Overpressure (P_{so}) = 0.353 kg/cm^2
- Mach No. (M) = 1.144
- Positive Phase Duration (T0) = 17.52 Mil. Sec.
- Eq. Trian.Pulse Duration (Td) = 13.16 Mil. Sec.
- Dynamic Pressure ratio T0/Td = 0.041
- Peak Reflected Overpressure Ratio = 0.792

All the above calculations have been done according to table no.1, IS-4991. All the pressure values are extracted for the idealised positive phase only. Negative Phase pressure was neglected. Non Linear THA has been performed using Finite element program SAP-2000. The Number of steps was considered to be 1500 with a step size as 0.01.

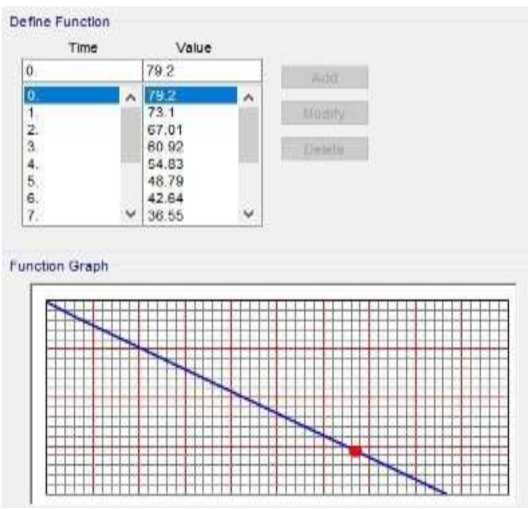

Figure 5: Front Face Pressure of Explosion

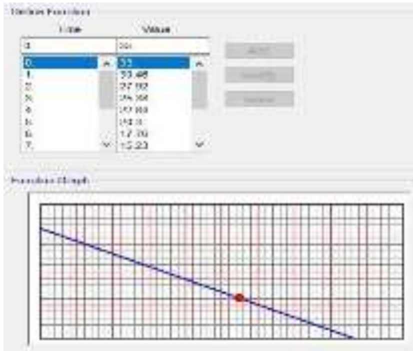

Figure 6: Side Face Pressure of Explosion

6. RESULTS & DISCUSSION.

- **Bending Moments in the Columns:**

After applying the blast loads on both the structural models, various results were extracted one of which was the bending moments in the columns which were subjected to blast loads. It can be seen from the below table that the bending moment in the bare frame with blast loads was considerably greater, after application of shear walls in the models the bending moment reduced up to 36%. The bending moments due to earthquake were quite smaller than that of blast loads, which means even if the buildings are designed to resist EQ loads there is a lot of difference in the capacity required to resist the Blast or any impact loads caused due to such incidents.

Table 3: Maximum Bending Moments in the Columns

Max BM for BF+EQ	Max BM for BF+BL	Max BM for SWF+BL

- **Maximum Displacements:**

The displacements of the structure were checked for all the three models. The first models displacement was carried out for only earthquake loadings. The second model was designed to earthquake resistant and blast load was applied and its displacements were checked. In the third model the structure was infilled with shear walls on the exterior faces and displacement results for it was checked. Fig. 8 shows the comparison of displacements of various stories with respect to the type of loadings applied on the specified structures. It can be seen from the fig.7, that the displacements of the stories for the structure with only earthquake loads is very less. Secondly it is observed that when a structure is applied with blast load caused due to 200 kg TNT at 30 m stand-off distance, the structure shows much greater displacements. Lastly the structures were coupled with a shear wall of 230 mm thickness and M35 grade of concrete. It was seen that due to the application of shear walls in the structures the displacement reduced to a considerable extent.

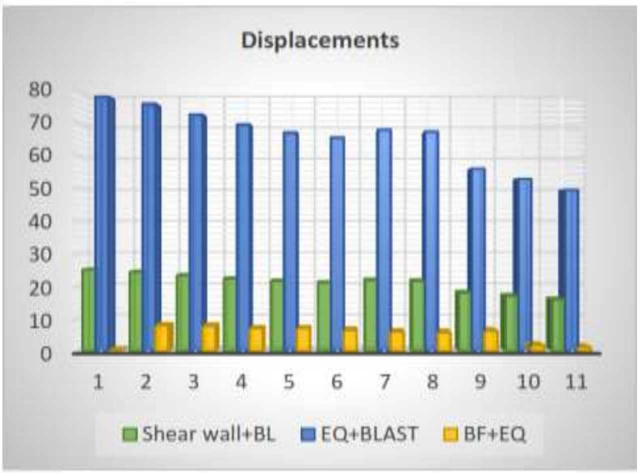

Figure 7: Comparison of Maximum Displacements

- **Acceleration vs Time functions:**

The other results which were compared were the function of acceleration of the structure with respect to time. The figures below shows the various functions for various models.

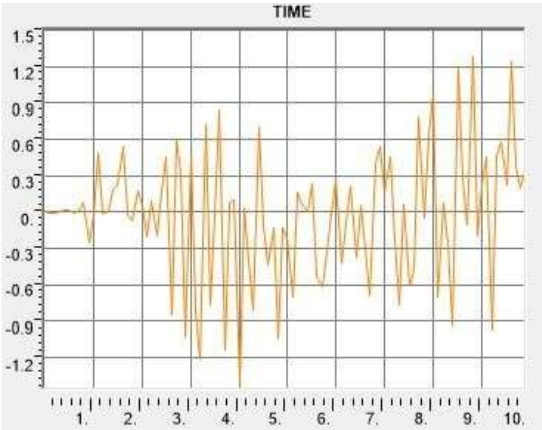

Figure 8: Acceleration for EQ loads

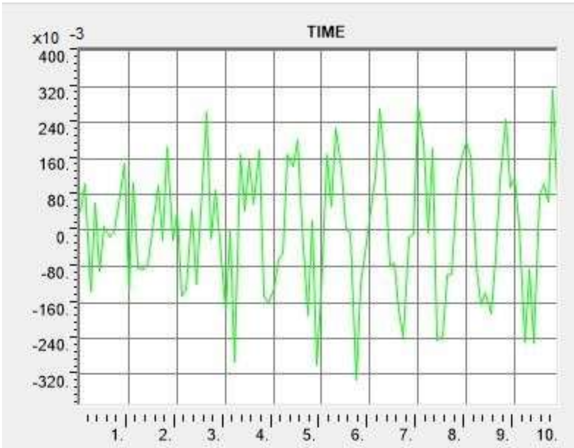

Figure 9: Acceleration for Bare frame with Blast Loads

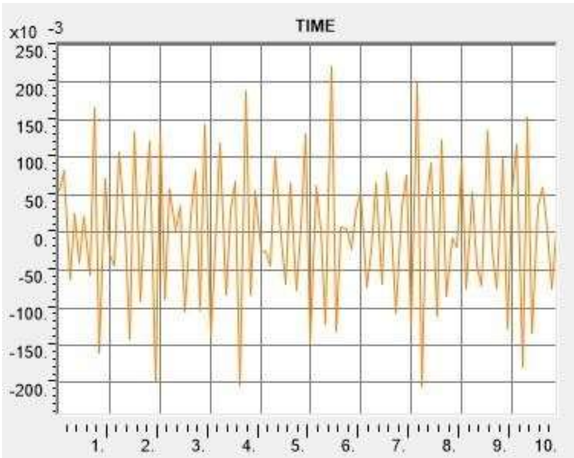

Figure 10: Acceleration for Shear wall Infilled frame with blast loads

The acceleration due to blast loads proved to be more fatal than that of earthquake loads. By the application of infilled shear walls the acceleration was improved to some extent.

7. CONCLUSIONS.

- It was observed that there is nearly no similarity between the response of the structure under EQ loadings and Blast Loadings.
- The bending moments found in columns for bare frames with blast loads was very high and critical. After the installation of shear walls the BM reduced up to 36%.
- It was also concluded that even if the building is designed to resist a considerable magnitude of EQ, the structure still needs to be enhanced a lot so as to resist the blast loadings.
- From the comparison of displacements it can be seen that the displacements for EQ loadings were quite small, which were increased to a large values. By the installation of shear walls in the structure to resist blast loads the displacements can be reduced by 60-85%.
- Lastly it was concluded that if a structure designed for EQR and applied with 200 kg TNT at a stand-off distance of 30 m is applied the structure will not be able to perform well.

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