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Comparative Study of Response of Structures Subjected To Blast and Earthquake Loading

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ABSTRACT
The increase in the number of terrorist attacks especially in the last few years has shown that the effect of blast load on building is a serious challenge that should be taken in to consideration for designing of structures. This type of loading damages the structures, externally as well as internally. Hence the blast load should be considered with same importance as earthquake load. The present study includes the comparative performance of G+3 storey building subjected to blast and earthquake loading using ETABS. For four storey building using different input parameters like charge explosive, stand-off distance and layout of building the blast pressure are conducted and linear time history analysis is carried out. Comparative study for blast and earthquake loading is carried out for different parameters like maximum storey displacement, storey drift and quantity of materials. Safe charge explosive and safe stand-off distance are obtained for the RCC structure with the sections of structural elements same as per the requirement for earthquake resistance. Displacement is higher for the blast loading as compared to earthquake loading and very high for the storey at which blast load is applied. Quantity of concrete is 40 percentages higher for blast resistant building than the earthquake resistant building.
Keywords: blast, earthquake, explosion, charge weight, safe stand-off distance

I. INTRODUCTION

Protecting civilian buildings from the threat of terrorist activities is one of the most essential challenges for structural engineers. Events of the past decades have greatly increased the attentiveness of structural designers about the threat of terrorist attacks using explosive devices. Extensive research into structural analysis considering blast effects and techniques to protect buildings has been initiated in many countries to build up methods for protecting critical infrastructure and the built environment. There are a number of means available to prevent a booming terrorist attack on a building [3]. Structures analysed for blast loads are subjected to entirely different types of load than that considered in conventional design. Here structures are subjected to quickly moving shock wave which may exert pressures many times greater than those experienced under the greatest of hurricanes. However, in blast phenomenon, the peak intensity lasts for a very small duration only [1]. The blast can generally categorize as external and internal blast. External blast can further recognized as surface burst or air burst.

An explosion which is located at a distance from and above the structure is known as air burst explosion, while surface blast will occur when detonation is situated close to or on the ground. An internal or confined explosion will produce shock loads or, gas pressure loads from the confinement of the products of the explosion. This pressure has a long duration in comparison to that of the shock pressure, due to external explosion. Due to highly uncertainty in predicting blast loads, it is difficult to construct blast proof building. But various structural and non-structural precautions can be taken to minimize structural damage and physical injuries [5].

Shallan et al. [3] showed that the effect of blast load decrease with increasing the standoff distance from the building and with variation of the aspect ratios of the buildings there is no variation in the displacement of the column in the face of the blast load but with increasing the aspect ratio the effect of blast load decrease in other element in the building. Kashif and Varma (2015) [1]analysed a five storey RCC symmetric building for blast load for 100 kg and 500 kg of Tri-Nitro-Toluene placed at 30 m distance from point of explosion. It was concluded that building was not behaving as a cantilever structure under blast load, which is different from the earthquake and wind. Results of the performance level of building, maximum displacement , plastic hinges locations were defined and compared for both 100 kg and 500 kg TNT explosives.

Based on the literature review carried out, it is observed that some researchers have investigated the effect of blast load on structures. However there is a need for detail parametric investigation in this area. Following are the main objective of the present study. i) To obtain the response of multi storied structures under blast and earthquake loading. ii) To obtain the safe standoff distance for multi storied building which is safe in earthquake.

1.1 Blast Load And Earthquake Load

Similarities and differences between seismic and blast loading are noticeable. Both of these loads are dynamic loads and they produce dynamic structural response. The structural behavior in response to these loads is inelastic as well. The focus of structural design against these loads is on life safety as opposed to preventing structural damage. Differences between blast and seismic loading are presented in Figure 1. [7]

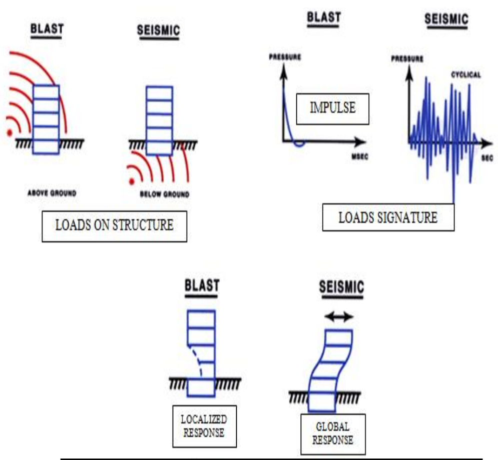


Figure 1: BLAST AND SEISMIC WAVES

II. NUMERICAL STUDY

In the numerical study carried out herein, the G + 3 storied RCC building is considered.. Figure 2 shows the plan and 3D view of the building considered. Table 1 represents the physical properties and input parameters of the considered building. The analysis and design is carried out in ETABS software.

Table 1: PROPERTIES OF BUILDING

Sr. No.	Parameter	Value
1	Height of the story	3.5 m
2	Span of each bay	5 m
3	Plan dimension of building	15 m x 15 m
4	Number of storey	G+3
5	Grade of concrete	M25
6	Height of plinth	1.5 m
7	Zone	V
8	Importance factor	1
9	Soil type	Medium

For G+3 storied RCC building, both blast and earthquake loading are applied. Comparative study has been carried out for the same for different criteria like storey displacement, storey drift and quantity of concrete. For the earthquake resistant building, calculation of both safe charge-explosive and safe stand-off distance have been carried out

2.1 Methodology

First of all consider the buildings subjected to a blast equivalent in yield to some tonne of TNT at a certain standoff distance. For the dynamic analysis of structures, the blast effects are most conveniently represented by a loading-time history which is applied to the structural members as transient loading. The magnitude and the pressure-time history of the blast load is calculated as per IS 4991-1968. Then pressure calculated is applied as UDL on column. Linear time history analysis is carried out and the response of structure is obtained subjected to blast loading.

2.2 Blast Load Calculation as per the IS 4991:1968.

For the study carried out herein explosive of 0.1 tonne TNT equivalent is considered. Building is situated 21 m from the ground zero. Analysis of the same building is carried out for Blast load combinations. Table 2 shows the blast parameters for 0.1 Tonne TNT and 21 m stand-off distance. Table 3 reprents the load combination considered in the present study.

2.2.1 Characteristics of the blast load

Scaled distance = $21/(0.1)^{(1/3)}$ = 45.243 m

Assuming p_a = 1 kg/cm² (From IS 4991:1968, Table: 1)

Table 2 : BLAST PARAMETERS FOR 0.1 TONNE TNT AND 21 M STAND-OFF DISTANCE

Distance	Pick side on over pressure ratio (kg/cm²) (p_{s0})	Positive phase duration (millisecond) (t_0)	Duration of equivalent triangular pulse (millisecond) (t_{d0})	Dynamic pressure ratio (kg/cm²) (q_0)	Peak reflected over pressure ratio (kg/cm²) (p_{r0})
45.243	0.66	31.25	21.6	0.142	1.66

q_0 = 0.142 kg/cm^2
t_0 =31.25 * (0.1) $^{0.33}$ = 14.505 milliseconds
t_d =21.6 * (0.1) $^{0.33}$ = 10.026 milliseconds
M = 1.25

a = 344 m/s
U = 0.43 m/milliseconds

2.2.2 Blast Pressure on the building

S is lesser of H or B/2 = 7 m
t_c = 3S/U = 10.026 milliseconds
t_t = l/U = 34.884 milliseconds
t_r = 4S/U = 65.116 milliseconds
As $t_r > t_d$ there is no pressure on back face
For roof & sides (from IS 4991:1968 Table 2)
For front face C_d = 1
For roof and side face C_d = -0.4
$p_{s0} + C_{dq0}$ = 59.15 kN/m²

Table 3 : LOAD COMBINATIONS FOR EARTHQUAKE AND BLAST LOAD

EARTHQUAKE	BLAST
1.5*DL+1.5*LL	1.5*DL+1.5*LL
1.2*DL+1.2*LL±1.2*EQX±1 .2*EQY	1.2*DL+1.2*LL+ 1*BL
1.5*DL+±1.5*EQX±1.5*EQ Y	1.5*DL+1*BL
0.9*DL+±1.5*EQX±1.5*EQ Y	0.9*DL+1*BL

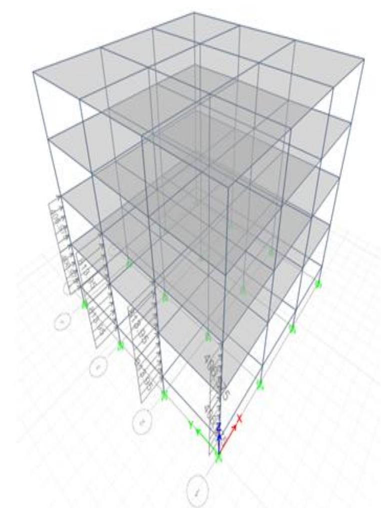
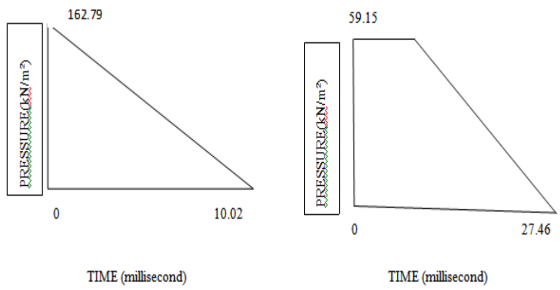


Figure 3: BLAST LOAD APLLIED AS UDL AT FRONT FACE

Figure 3 shows the isometric view of the building in which blast load is applied as udl to the column. Figure 4 shows the pressure-time diagram for the front and side faces for the considered blast loading. For the earthquake loading linear static analysis is considered.



FRONT FACE ROOF AND SIDE FACE

Figure 4: VARIATION OF BLAST PRESSURE AGAINST TIME

2.3 Comparative Study of G+3 Storied Building For Blast And Earthquake Loading

2.3.1 Displacement Comparison

Figure 5 shows the storey displacement for blast and earthquake loading. Total four cases are discussed here. 'BLAST-EQ SECTION' means, the blast load is applied in the building which is designed for Earthquake resistance. 'BLAST-REVISED SECTION' means the section provided are revised based on the representation of blast resistance, In this case, 0.1 Tonne TNT is considered. The third case of 'EQ-section', the sections are designed only for earthquake loading. In the last case of 'EQ SECTION SAFE IN BLAT', the maximum charge weight is obtained to make the earthquake resistant building safe during blast. The charge weight for each case in mentioned in the bracket From the figure 5, it is observed that the storey displacement for blast loading is higher than the same for earthquake and at level 1st and 2nd storey displacements are higher in comparison to other storey level. But in case of Earthquake load the displacement is proportionally increasing.

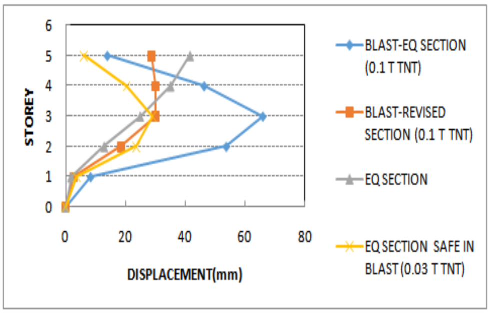


Figure 5: COMPARISON OF DISPLACEMENT

2.3.2 Storey Drift Comparison

As far as the structural as well as non structural safety of building in terms of functional aspect is concerned the storey drift is a critical parameter. Figure 6 shows the storey drift for blast and earthquake loading. From the figure 6 it is observed that for the earthquake load, the storey drift comes out to be within permissible limit specified by code. Whereas, in the case of blast load the storey drift exceeds than the permissible limit specially on the storeys where blast is applied.

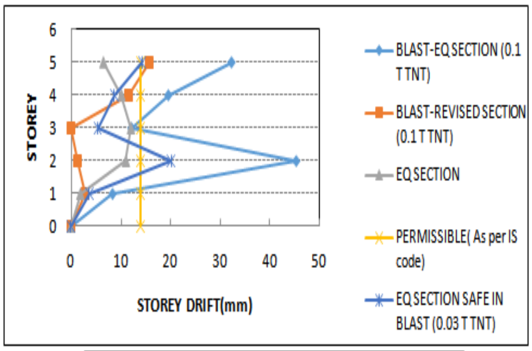


Figure6: COMPMARISON OF STOREY DRIFT

2.4 Quantity of Material

Table 4 shows the size of the optimum sections which are designed for blast resistant and earthquake resistant building. From the table 4 it is observed that the blast resisting building is having mostly same size of beams but size of columns is much more up to the plinth and at the level where blast load applied. Table 5 represent the difference of quantity of concrete between blast resistant and earthquake resistant. From the table 5 it is observed that the quantity of concrete for the blast resistant building is 40 percentage higher than the earthquake resistant building as higher section are required for blast case.

Table 4: OPTIMUM DESIGN SECTIONS FOR BLAST AND EARTHQUAKE LOADING

TYPE OF ELEMENT	SECTION SIZE	
	FOR BLAST	FOR EARTHQUAKE
BEAM	(mm)	(mm)
PLINTH BEAM	400×400	300×300
ALL OTHER BEAM	280×510	280×510
COLUMN		
UP TO PLINTH LEVEL	8 Nos.-600×600 & 8 Nos.-800×800	500×500
GROUND FLOOR	8 Nos.-600×600 & 8 Nos.-800×800	500×500
FIRST FLOOR	4 Nos.-500×500 & 4 Nos.-600×600& 8 Nos.-800×800	450×450
SECOND FLOOR	8 Nos.-500×500 & 8 Nos.-600×600	450×450
THIRD FLOOR	8 Nos.-500×500 & 8 Nos.-600×600	450×450

Table 5: DIFFERENCE IN VOLUME OF CONCRETE

LOADING	VOLUME OF CONCRETE (m^3)
EARTHQUAKE	154.112
BLAST	214.852
PERCENTAGE DIFFERENCE	**39.41 %**

2.4 Safe Charge explosive and Safe Stand-Off Distance Calculations

Safe charge explosive and safe stand-off distance for earthquake resistant RCC building is obtained by trial and error method. The safe charge explosive and safe stand-off distance are obtained as 0.03 tonne TNT and 31.5 meter respectively.

III. CONCLUSIONS

Behaviour of structures subjected to blast load as compared to earthquake load is significantly different as the blast pressure is of very high intensity which is applied in milliseconds in form of impact load. Based on the numerical study carried out herein the following major conclusions are drawn.

- In blast, the storey displacement is higher than the same for earthquake and at 1st and 2nd storey, displacements are higher in comparison to other storey level. But in case of earthquake load, the displacement is proportionally increasing.
- As far as the structural as well as non structural safety of building in terms of functional aspect is concerned, the storey drift is a critical parameter. For earthquake load, the storey drift comes out to be within permissible limit specified by code. Whereas in the case of blast load, the storey drift exceeds than the permissible limit specially on the storeys where blast is applied.
- Quantity of concrete for blast resistant building is around 40 % higher than the earthquake resistant building.
- Safe charge explosive of 0.03 Tonne TNT is obtained for the RCC structure with the sections of structural elements same as per the requirement for earthquake resistance.
- For the earthquake resistant RCC building, the safe stand-off distance is 31.5 m for the charge weight of 0.1 Tonne TNT.

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