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Analysis of High Rise G+10 Steel and R.C.C Building Subjected to Blast Loading

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Abstract: The structures subjected to blast loading gained more importance due to demolition of buildings that are constructed against rules, accidental events, natural events and terrorist attacks. An explosion is a rapid chemical reaction takes place in few milliseconds and occurs in the form of shock wave. This paper presents blast analysis of Steel and R.C.C structures subjected to blast loading with different blast intensities (charge weight) and different standoff distances. Blast loading and its effects on the structure is influenced by various factors which includes charge weight, standoff distance, geometrical configuration and orientation of structure. Models are analysed by linear dynamic analysis (Elastic Time History) using ETABS V18.0.0 subjected to blast loading. The objective of the present work is to check the dynamic response of high rise G+10 Steel and R.C.C structures by time history analysis in terms of maximum base shear and variation of axial forces subjected to different charge weight and standoff distances.

Keywords: Blast loading, Shock wave front, Overpressure, Dynamic pressure, Charge weight, Standoff distance.

I. INTRODUCTION

In recent years, the analysis of blast loading gained more importance due to demolition of buildings that are constructed against rules, accidental events, natural events and terrorist attacks which causes loss lives and severe damage to the structures. Due to this, an attention has been increased to design the structures to resist against blast loads. Terrorists attacks the building using cars as it is difficult to carry the heavy explosive material as shown in Figure i When the explosion takes place hot gases are generated and occupy the surrounding space, which results in the wave propagation through space that is transmitted spherically or hemi spherically through a surrounding medium. 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.

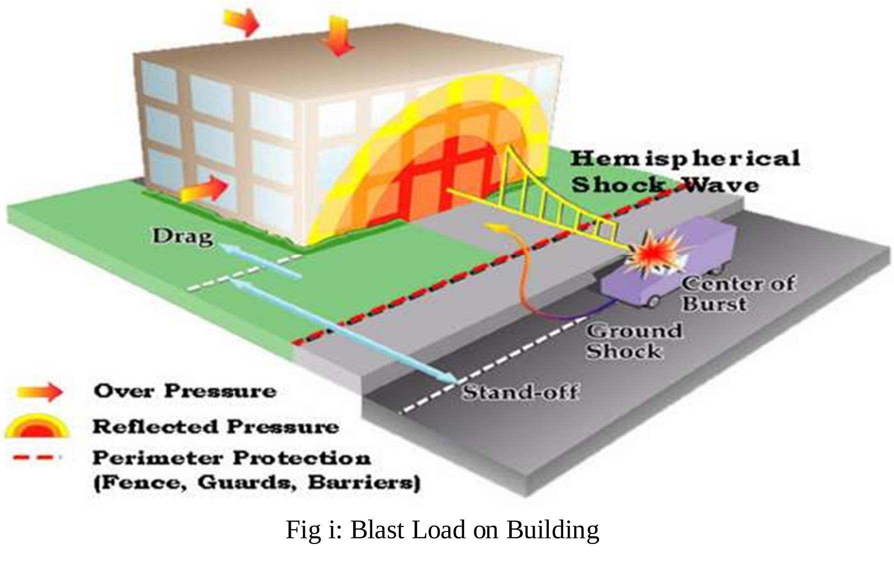

Fig i: Blast Load on Building

An Explosion is defined as a rapid chemical reaction that occurs in the few milliseconds resulting in the very fast release of energy and hot gases into the surrounding atmosphere. TNT, (Trinitrotoluene), which is one of the most stable high explosives for the analysis of blast loading.

A. Blast Phenomena

The blast effects of an explosion are in the form of a shock wave composed of a high intensity shock front which expands outward from the surface of the explosive into the adjoining air. As the wave expands, it decays in strength, lengthens in duration and decreases in velocity. 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. As the shock front continues to expand and reach greater distances, the incident pressure at the front decreases, and the duration of the pressure increases as shown in Figure ii. Also as the shock wave expands radially outward, the velocity of the shock front decreases. The dynamic pressure is an actual pressure and is a measure of the kinetic energy of a certain volume of air behind the shock front. If the air is moving the dynamic pressure is positive and if the air is not moving the dynamic pressure is zero.

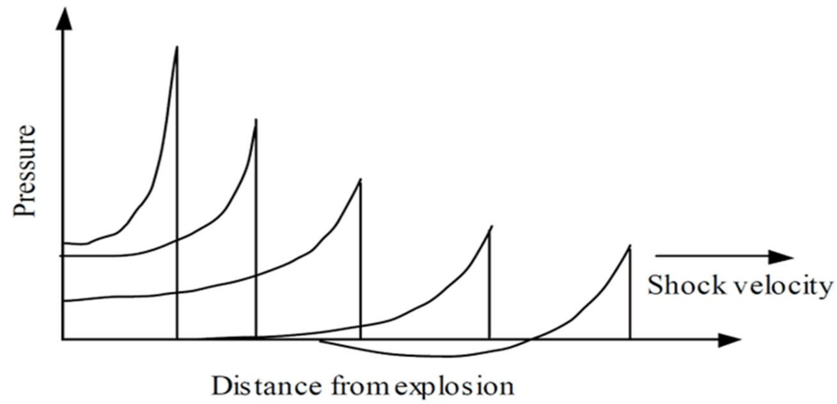

Fig ii: Blast Wave Propagation

B. Blast Load Characteristics

For blast analysis of both steel and R.C.C structural models the design blast loading are calculated as per recommendations of IS: 4991-1968 titled "Criteria for Blast Resistant Design of Structures for Explosions above Ground". The code specifies criteria's for the structure to be called as blast resistant structure. The parameters considered for generation of design blast loading are charge weight, standoff distance and other parameters of shockwave. The blast load is estimated as a plot of pressure as a function of time duration for a specified charge weight and standoff distances.

C. Scope of the Project

The response of the structural systems subjected to blast loading is being studied and still many uncertainties exist. In order to understand and evaluate the performance of high raised Steel and R.C.C structural systems under different charge weights and different standoff distances. Critical design parameter like the dynamic nature of blast loading, design philosophy to be adopted is not well studied. A series of tests simulating various field conditions needs to be carried out in this regard. With this background, in this project work, it is aimed to study the procedure to calculate or estimate blast loading, response of steel and R.C.C structural systems applied to blast loading of different intensities and different standoff distances.

II. MODELING DETAILS

A. General Considerations

Determination of blast loading for different charge weights and standoff distances and then converting the same into pressure time history for blast analysis by linear dynamic analysis (Elastic Time History) using ETABS V18.0.0 software. Blast analysis of these structures are carried out to evaluate its performance under blast loading. Performance is measured in terms of maximum base shear and column forces. Further, with different blast intensities i.e., for 300Kg, 400Kg and 500Kg charge weights and 5m, 10m and 15m standoff distances, the analysis is repeated on both the steel structure and R.C.C structure and its performance with different blast intensities is studied and compared.

1) For both Steel and R.C.C structures an eleven storied building (G+10) is considered for the study having the plan dimensions of 25m X 20m with each story height considered as 3m. The building is having 5 bays in X direction with the bay spacing of 5m and 4 bays in Y direction with the bay spacing of 5m. And bracings are provided using ISMB-250 I-Section for both Steel and R.C.C structures.

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2) Calculations of blast loads and pressure time is history is same for both the Steel and R.C.C structures. But while doing the analysis in the ETABS software the modelling of Steel and R.C.C structures are done separately and blast loading is applied for obtained pressure time history and analysis is carried out.
3) In this thesis, it is aimed to outline the procedure to estimate or generate the blast pressure-time history for Steel and R.C.C structures for different charge weights and standoff distances and analyze the structure to find the response in terms of maximum base shear and column forces.

   Table i gives the detailed description of the steel structural system considered for the study and material specification of the structure. The steel profiles or sections are adopted as per Indian standard.

Table I: Dimensions and Properties Considered for Steel structures

No.	Item	Specification
1.	Material	Structural steel
2.	No. of stories	11
3.	No. of bay in X direction	5
4.	No. of bay in Y direction	4
5.	Bay spacing in X direction	5
6.	Bay spacing in Y direction	5
7.	Modulus of elasticity	$2*10^5$
8.	Density of Steel	7850 Kg/cm^3
9.	Poisson's ratio	0.3
10.	Grade of steel	Fe 350

The below figures iii and iv shows the floor plan and elevation with the section properties of steel structures which is modeled using ETABS software.

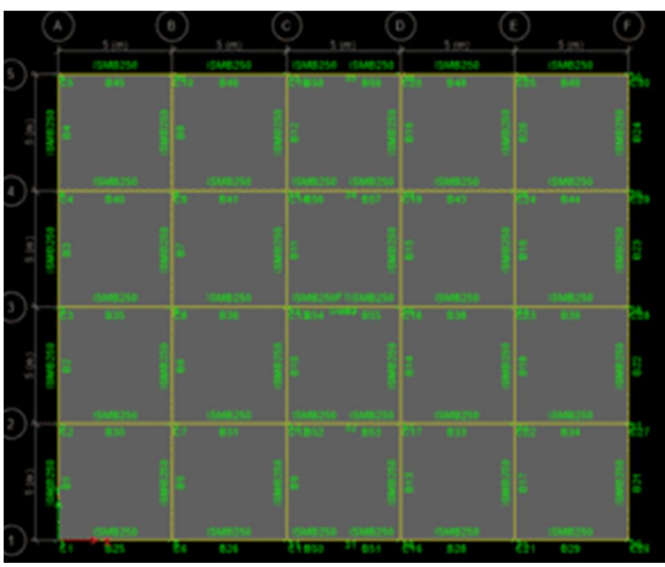

Fig iii: Floor plan with section properties of steel structures

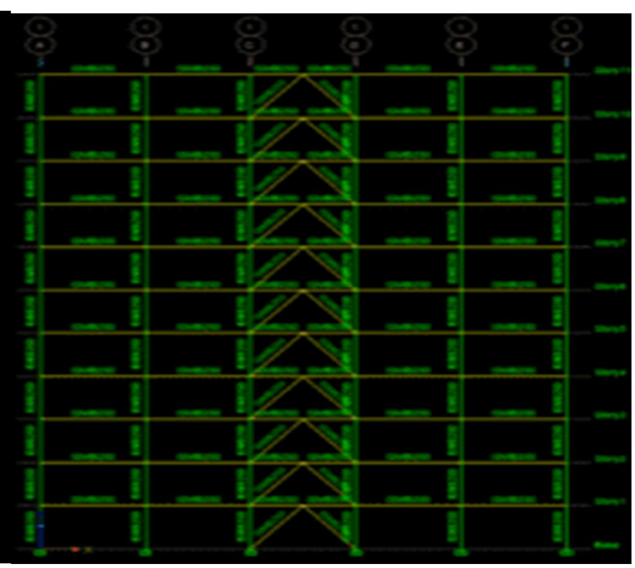

Fig iv: Elevation with section properties of steel structures

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Table ii gives the detailed description of the R.C.C structural system considered for the study. The Geometrical and material specification of the structure is tabulated below. The grade of concrete used is m30 and grade of steel is Fe550.

Table ii: Dimensions and Properties Considered for R.C.C structures

No.	Item	Specification
1.	Material	M30 grade concrete
2.	No, of stories	11
3.	No. of bay in X direction	5
4.	No. of bay in Y direction	4
5.	Bay spacing in X direction	5
6.	Bay spacing in Y direction	5
7.	Grade of steel	Fe 550
8.	Beam size	300*450 mm
9.	Column size	200*600 mm
10.	Slab thickness	150 mm
11.	Modulus of elasticity	$2*10^5$
12.	Density of concrete	2500 Kg/cm^3
13.	Poisson’s ratio	0.3
14.	Live load	3 KN/m^2

The below figures v and vi shows the floor plan and elevation with the section properties of R.C.C structures which is modeled using ETABS software.

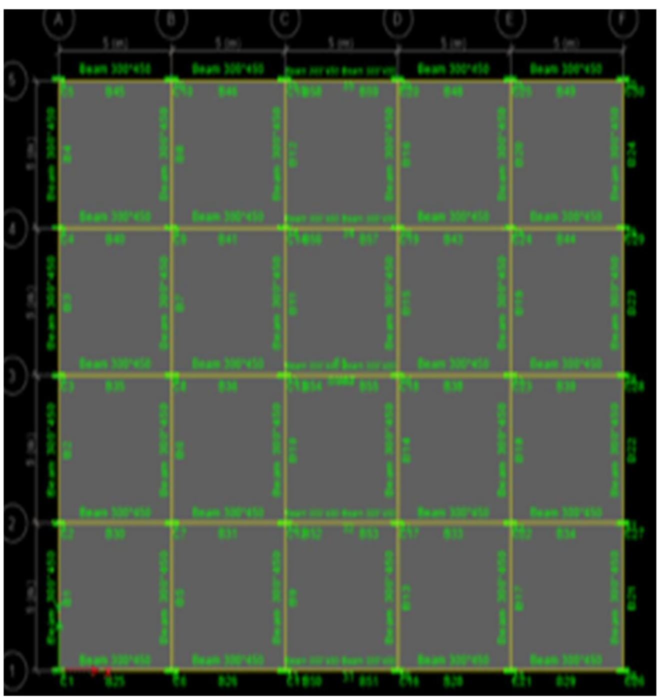


Fig v: Floor plan with section properties of R.C.C structures

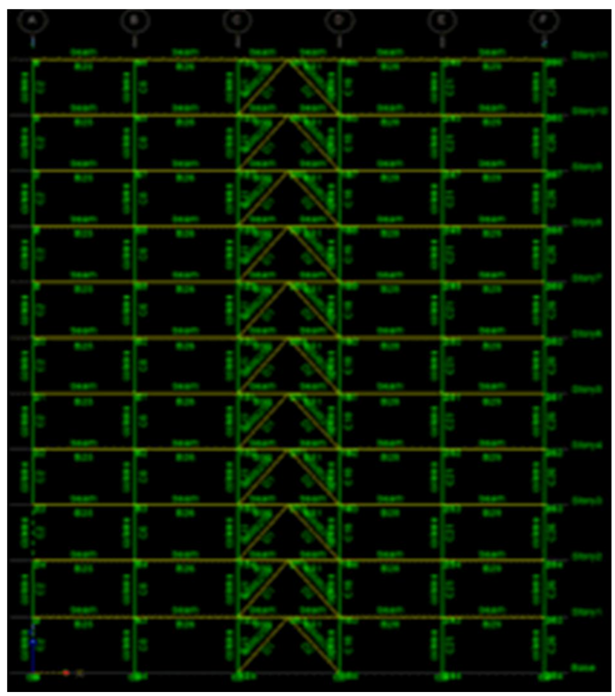


Fig vi: Elevation with section properties of R.C.C structures

III. RESULTS AND DISCUSSIONS

Based on the criteria's that amount of charge weight applied on the structure for both Steel and R.C.C structures i.e., 300Kg, 400Kg, and 500Kg and different standoff distances i.e., 5m, 10m and 15m. The response of base shear and axial forces are obtained and are shown in below tables and graphs.

A. Steel Structure Results.

1) Base Shear

Table iii: Max Base Shear from ETABS in X and Y Direction for 5m Standoff Distance

Model	Base Shear in (kN)	
	X Direction	Y Direction
0.3 MTonne Charge weight	21153.06	2517.16
0.4 MTonne Charge weight	22187.71	2620.46
0.5 MTonne Charge weight	22916.08	2693.44

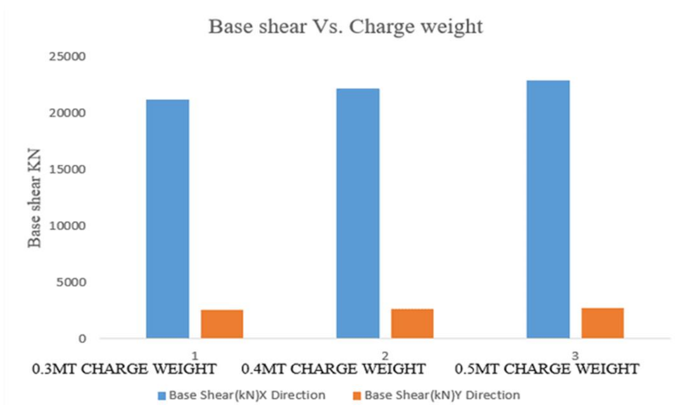


Fig vii: Max Base Shear vs. Charge Weight

Table iv: Max Base Shear from ETABS in X and Y Direction for 10m Standoff Distance

Model	Base Shear in (kN)	
	X Direction	Y Direction
0.3 MTonne Charge weight	9827.93	1385.82
0.4 MTonne Charge weight	11981.80	1601.28
0.5 MTonne Charge weight	13437.97	1746.57

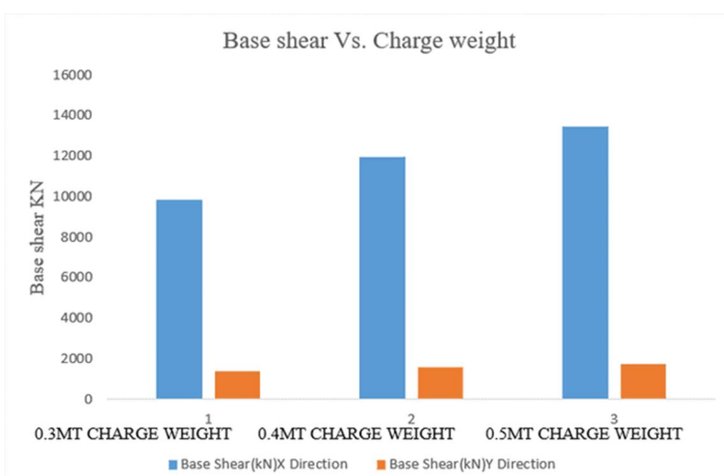


Fig viii: Max Base Shear vs. Charge Weight

Table v: Max Base Shear from ETABS in X and Y Direction for 15m Standoff Distance

Model	Base Shear in (kN)	
	X Direction	Y Direction
0.3 MTonne Charge weight	2565.76	529.66
0.4 MTonne Charge weight	3543.72	516.91
0.5 MTonne Charge weight	4637.78	850.49

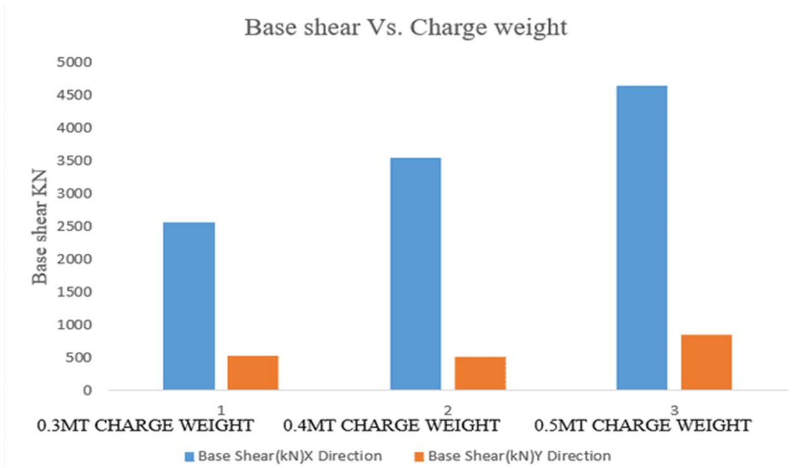


Fig ix: Max Base Shear vs. Charge Weight

As observed from the results, for steel structures, the base shear increases in direct proportion with increase in charge weight or blast intensity and decrease with the increase in standoff distances.

2) Column Forces

Table vi: Max Column Forces from ETABS for 5m Standoff Distance

Column	Forces	Load Case	0.3Tonne Charge weight	0.4Tonne Charge weight	0.5Tonne Charge weight
C8	P (kN)	Blast(Front Face)	781.37	1238.54	1934.26
C14	P(kN)	Blast(Front Face)	518.53	957.16	1334.48
C21	P(kN)	Blast(Front Face)	65.82	215.86	332.18

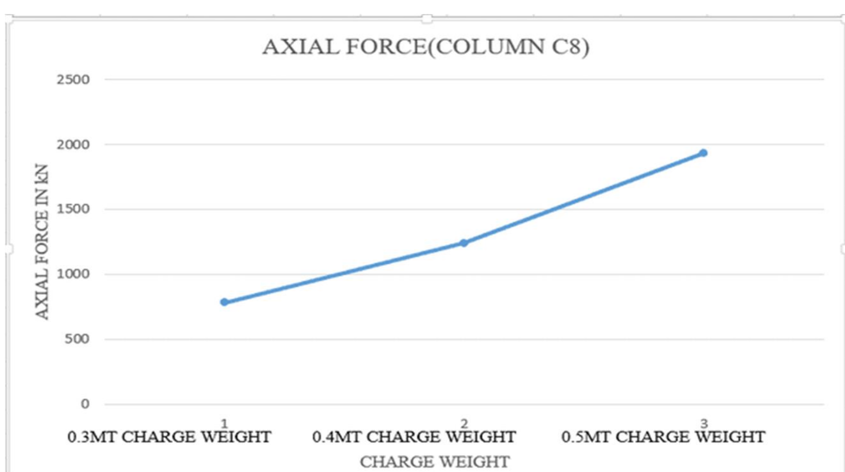


Fig x: Axial Force in Columns Vs. Blast Intensity

Table vii: Max Column Forces from ETABS for 10m Standoff Distance

Column	Forces	Load Case	0.3Tonne Charge weight	0.4Tonne Charge weight	0.5Tonne Charge weight
C10	P (kN)	Blast(Front Face)	571.21	1082.79	1722.26
C17	P(kN)	Blast(Front Face)	472.34	772.16	1117.28
C23	P(kN)	Blast(Front Face)	116.28	347.54	497.59

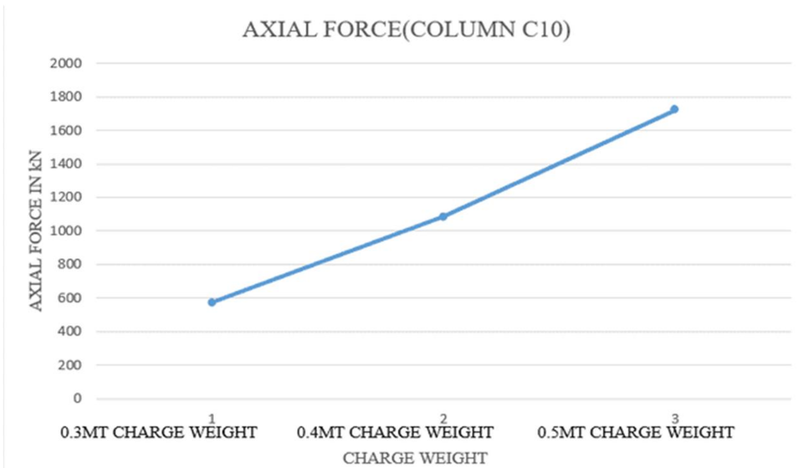


Fig xi: Axial Force in Columns Vs. Blast Intensity

Table viii: Max Column Forces from ETABS for 15m Standoff Distance

Column	Forces	Load Case	0.3Tonne Charge weight	0.4Tonne Charge weight	0.5Tonne Charge weight
C11	P (kN)	Blast(Front Face)	357.28	956.14	1800.17
C14	P(kN)	Blast(Front Face)	162.46	755.78	1163.25
C16	P(kN)	Blast(Front Face)	97.56	214.53	432.87

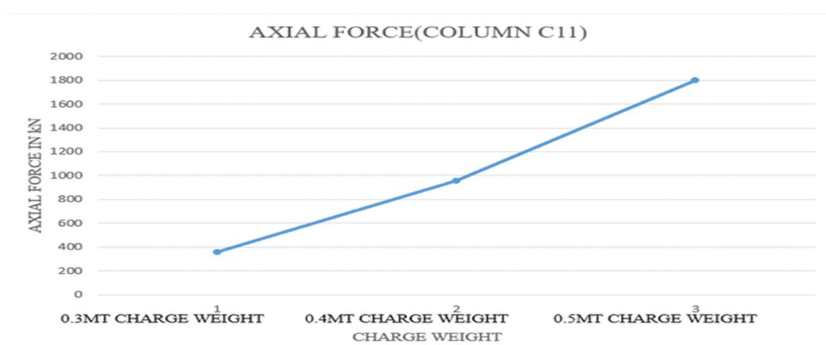


Fig xii: Axial Force in Columns Vs. Blast Intensity

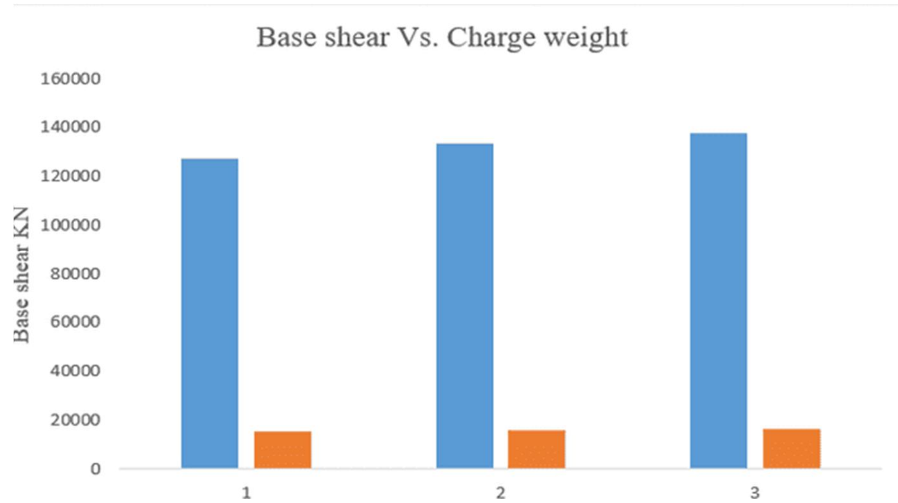
The column forces for Steel structures are sorted and tabulated above in tables vi, vii and viii are, maximum axial force of ground story columns. And the following graphs show the variation of design forces in the columns of ground story, as the blast load intensity increased, the axil forces also increased significantly and with the increase in standoff distances the axial forces decreases.

B. R.C.C Structure Results

1) Base Shear

Table ix: Max Base Shear from ETABS in X and Y-Direction for 5m Standoff Distance

Model	Base Shear in (kN)	
	X Direction	Y Direction
0.3 Tonne Charge weight	127282.06	15146.29
0.4 Tonne Charge weight	133507.47	15767.84
0.5 Tonne Charge weight	137890.51	16206.99



Figxiii: Max Base Shear vs. Charge Weight

Table x: Max Base Shear from ETABS in X and Y-Direction for 10m Standoff Distance

Model	Base Shear in (kN)	
	X Direction	Y Direction
0.3 Tonne Charge weight	59136.55	8338.75
0.4 Tonne Charge weight	72096.82	9635.26
0.5 Tonne Charge weight	80858.90	10509.84

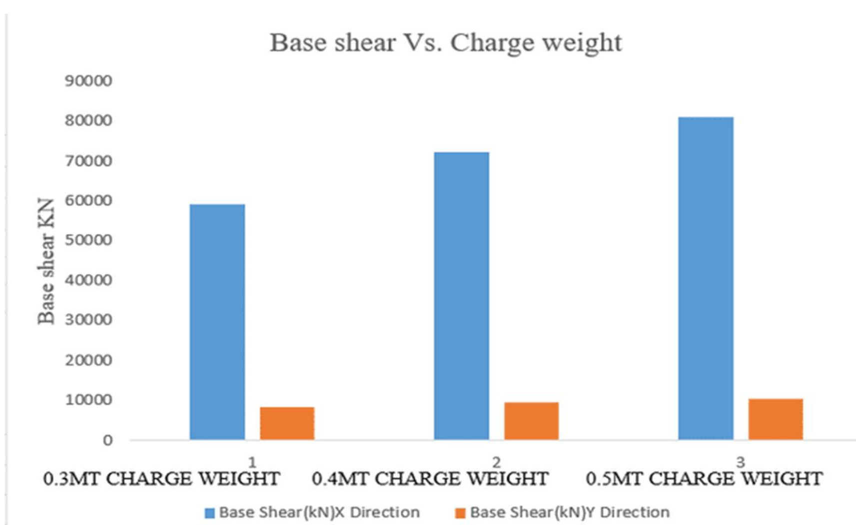


Fig xiv: Max Base Shear vs. Charge Weight

Table xi: Max Base Shear from ETABS in X and Y-Direction for 15m Standoff Distance

Model	Base Shear in (kN)	
	X Direction	Y Direction
0.3 Tonne Charge weight	15438.68	3187.11
0.4 Tonne Charge weight	21323.27	3842.45
0.5 Tonne Charge weight	27906.46	5117.58

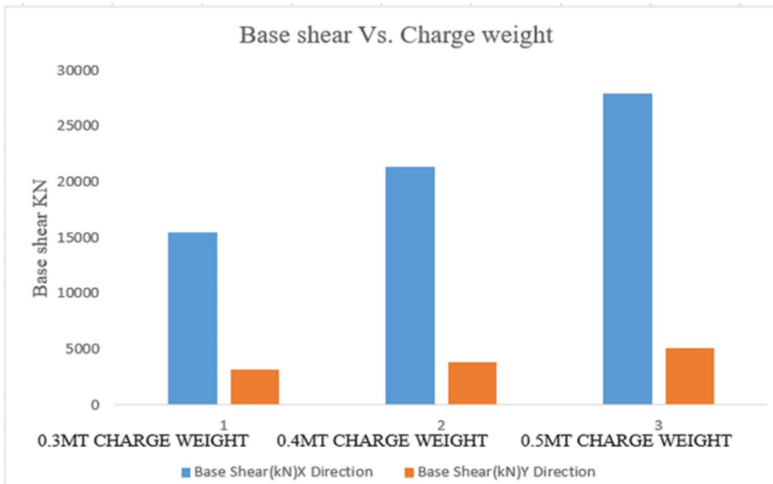


Fig xv: Max Base Shear vs. Charge Weight

As observed from the results, for R.C.C structures, the base shear increases in direct proportion with increase in charge weight or blast intensity and decrease with the increase in standoff distances.

Table xii: Max Column Forces from ETABS for 5m Standoff Distance

Column	Forces	Load Case	0.3Tonne Charge weight	0.4Tonne Charge weight	0.5Tonne Charge weight
C6	P (kN)	Blast(Front Face)	1162.74	2747.08	3688.52
C11	P(kN)	Blast(Front Face)	937.96	1941.23	2339.86
C17	P(kN)	Blast(Front Face)	174.25	415.39	498.07

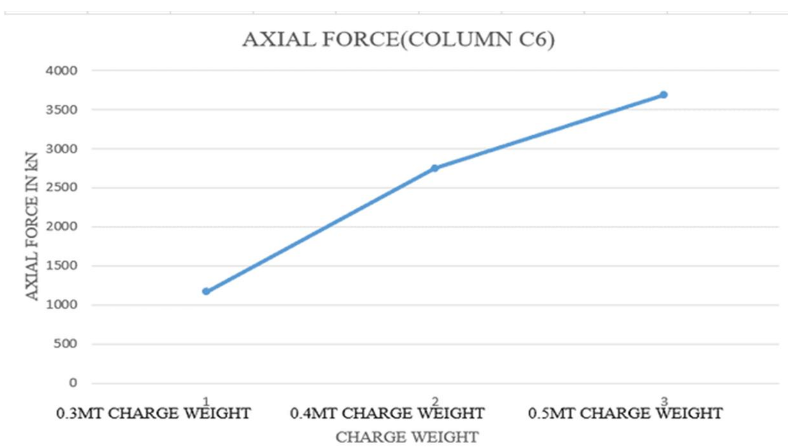


Fig xvi: Axial Force in Columns Vs. Blast Intensity

Table xiii: Max Column Forces from ETABS for 10m Standoff Distance

Column	Forces	Load Case	0.3Tonne Charge weight	0.4Tonne Charge weight	0.5Tonne Charge weight
C12	P (kN)	Blast(Front Face)	1074.42	1866.74	3421.74
C15	P(kN)	Blast(Front Face)	821.04	1732.19	2144.22
C24	P(kN)	Blast(Front Face)	322.56	694.08	1013.23

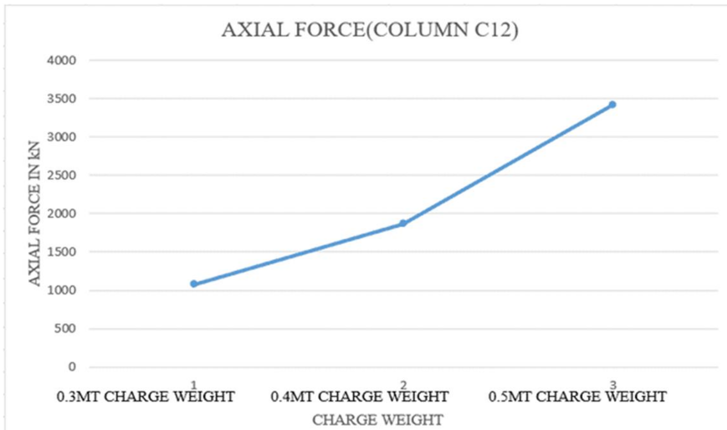


Fig xvii: Axial Force in Columns Vs. Blast Intensity

Table xiv: Max Column Forces from ETABS for 15m Standoff Distance

Column	Forces	Load Case	0.3Tonne Charge weight	0.4Tonne Charge weight	0.5Tonne Charge weight
C9	P (kN)	Blast(Front Face)	775.83	1890.28	3411.20
C15	P(kN)	Blast(Front Face)	397.94	1511.56	2326.51
C24	P(kN)	Blast(Front Face)	212.81	436.99	871.24

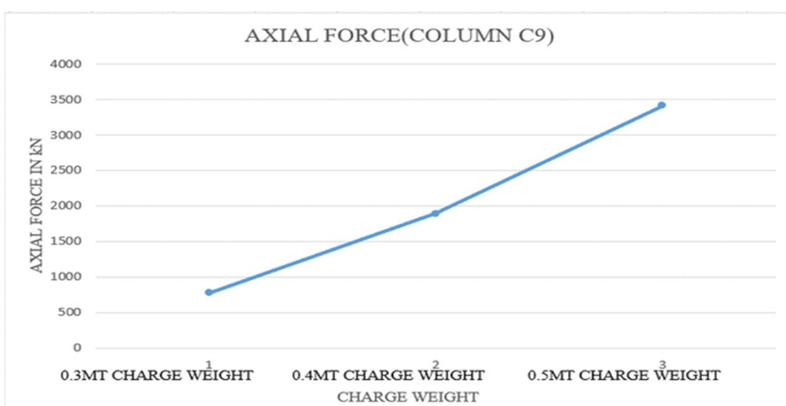


Fig xviii: Axial Force in Columns Vs. Blast Intensity

The column forces for R.C.C structures are sorted and tabulated above in tables 3.4, 3.5, and 3.6 are, maximum axial force of ground storey columns. And the following graphs show the variation of design forces in the columns of ground story, as the blast load intensity increased, the axil forces also increased significantly and with the increase in standoff distances the axial forces decreases.

IV. CONCLUSIONS

A. Analysis and design of steel and R.C.C structures is carried out using linear dynamic analysis (Elastic Time History Analysis) for the blast loading of different intensities and different standoff distances. Results of the analysis and design, are mainly maximum base shear, and column forces.

B. The maximum base shear and the axial forces increased linearly as the blast loading is increased and standoff distance is decreased, the base shear causing increases the design forces of the columns. In the event of blast, the columns of the structure fail severely causing complete collapse.

C. In blast resistant design of structures, it is very important to consider and ascertain, the blast parameters, which are justifiable, according to the standard specifications, and with reasoning of statistics and probability. Otherwise, it will lead to either ‘under design’ or the uneconomical design of structure.

D. By this analysis we can know that blast loading and its effects and its effects on a structure is influenced by a number of factors including charge weight, location of blast(standoff distance), geometrical configuration and orientation of the structure(or direction of blast). Structural response will differ according to the way these factors combine.

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