RESPONSE OF COMPOSITE FRAME STRUCTURES UNDER BLAST EXPLOSIONS

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Abstract -*Over the years, thanks to fast development and urbanization, cities have reworked to a bigger and advanced metropolis. Most of the medium to high-rise structures in these cities are designed to be earthquake resistant. Due to increase in accidental and intentional explosions, high-rise buildings can be subjected to those types of blast pressures. It is a real matter of concern for the designers to know how these structures would perform when exposed to accidental blast loads. This research was aimed at exploring the response of composite reinforced concrete frame structures under blast loading. Blast forces causes loss of structural integrity thanks to partial or complete collapse of structural members. This study presents the effect of blast loads on three storey composite reinforced concrete frame building. Effect of 100kg and 300kg of Tri nitro toluene (TNT) blast source which was at 30m and 20m away from the building, considered for analysis. Blast loads on the joints were calculated manually as per IS: 4991-1968. The main aim was to compare the response of the frame structures with different sections (Tee, I, C sections) based on their alignments on the basis such as storey drift, storey displacement using ETABS 2015.*

Key Words: **Blast loading, Composite frame, Standoff distance, storey drift, storey displacement.**

1. INTRODUCTION

The quick discharge of energy due to a blast is characterized by air pressure and an audible blast. The energy released is divided into two different phenomena, thermal radiation and pairing with air and ground, known as air blast and ground shock. Air blast is that the principle explanation for the spoil to a building exposed to blast loading. The conventional chemical charge is considered as sphere-shaped. The effective yield is almost double of an equal detonation high in the air. This situation gives major effects. As a consequence of the detonation, a shock wave is created in the air which moves outward in every directions. At any shock wave surface, the pressure increases instantly to top values of side-on overpressure and the dynamic pressure. The top value is affected by the size of detonation, the distance of the surface from the source. Members subjected to blast pressures resist the applied force by internal stresses developed in them as in the case of normal loads. Never the less, dynamic properties of the member itself depend upon the effective load due to blast.

Composite structure is a combination of concrete and steel sections. It is light weight in nature when compared to the conventional RCC and due to this it possess resistance to lateral loads (earthquake). By early 1960, analysis showed that concrete inclosure or wrapping can increase the load resistance of steel columns. Substantial economy in construction may be gained by employing a higher quality of concrete and introducing the composite action in style of columns. Composite construction combines the higher properties of the each i.e. concrete in compression and steel in tension and they have almost the same thermal expansion. Both steel section and concrete oppose the exterior loading by collaborating collectively through friction and chemical bond and also by the use of mechanical shear connectors in some circumstances. In this analysis, a study on composite structure is evaluated and the composite structure is analysed separately by providing different steel sections in the columns (Tee section and channel section) and a comparative study is done to determine which section provides better performance and thereby effect of blast on each framed models.

2. LITERATURE REVIEW

M.D. Geol, Dhiraj Agarwal et.al (2017), studied on the identification of critical column of a 4 storey building. The analysis was done using Staad pro and investigation was carried out by considering the load path where maximum behaviour change occur in terms of displacement, vertical reaction and axial force.

Y.A. Al-Salloum, H. Abbas et.al (2017), study on an existing structure (4 base + ground + 23 levels) was carried out. Two stage analysis was carried out using LSDYNA: (1) Local model analysis (2) Global model analysis.

Dan Nourzadeh, Jagmohan Humar et.al (2017), studied on a G+10 model, developed using OpenSEEs software. The building was then analysed for the response under two blast scenarios and a series of seismic ground motions. The major goal was to compare the global response of the building to these two types of dynamic loading. The response results showed that the inter-storey drifts generated in the building due to the blast loading significantly exceeded those caused by the design- and higher than design-basis earthquakes. Thus, it may be reasoned that the blast loads could force the structure to deform laterally with magnitudes of deformations that are similar to or higher than those under seismic action. It would therefore be necessary for the designers to check the lateral deformations and the global response of the buildings under blast loads, in the same fashion as for earthquake forces

Bijan Samali, Graeme Mckenzie et.al (2017), carried out a study on the three pressures impact on the structure and these are incident pressure (Pso), reflected pressure (Pr) and dynamic pressure (qs).The latter is that the smallest of the 3 while the remaining 2 turn out the most important pressures. The question that so arises is on which of the most important pressures to use in planning a structure against blast loadings. Examples exist worldwide on the end result of buildings not being designed to hold blast loadings that has inevitably resulted within the total collapse of the structure leading to death or injury to those unfortunate enough to be caught within the building because it folded.

Meysam Bagheri Pourasil, Yaghoub Mohammadi et.al (2017), carried out a study on a 3D model of a 7 storey building. The building was modelled using the software ABAQUS. A blast load equivalent to 1 T on TNT was simulated at a distance of 4 m from the corner of the structure. The pressure of blast at four levels of loading was applied to adjacent structural members and therefore the structural response was examined. The results indicate that the potential for progressive collapse once assumptive blast loading because the initial explanation for failure can dissent from results of common ways used for analysis of progressive collapse and in ways that ignore the initial reason for progressive collapse.

Yasser E Ibrahi, Mostafa a ismail et.al (2016), studied on a 2D model of a 4 storey building and then analysis was carried out using the software ABAQUS. The objective of the study was to identify the structural response and most vulnerable locations. Results showed that the response of the building was improved by changing the design of external column and especially by the use of concrete filled steel tube section.

Demin George, Varnitha M.S (2016), carried out a comparative study between four 3 storey building (1) Normal frame building, (2) Frame building with increased cross-section, (3)Frame building with shear wall, (4)Frame building with X shaped steel bracing. The study concluded that, by increasing column size and beam size in a structure will improve the resistance but it's not practical in most cases due to serviceability problems because large cross-section of beam and column required to resist blast loads. Imposing shear wall and steel bracing (X type) helps to resistant blast loads effectively. The steel bracing addition give good result but shear wall gives more desirable results than steel bracing, and it is economical too, compared to other methods to resist blast loads.

3. NUMERICAL ANALYSIS

A midrise building was taken for analysis with columns encased with different shapes of steel sections (I, Tee and Channel) are analysed separately. For the analysis, composite columns are provided with I, Channel and Tee section and the performance is evaluated with that of RCC. The different alignment of C sections are shown in Fig- 1-Fig- 3. For finding out the size of the columns, initially building with columns having encased I sections was modelled and the structure was analysed to find out the economical sections of beams and columns. After finding the economical section, building with Tee and channel section encased columns was modelled with corresponding economical column size obtained earlier and further analysis was carried out to find the efficiency of the buildings with new steel sections. The efficiency of the new composite buildings was analysed by comparing the response factors of composite building with steel I section. In case of composite columns, it was found that as the alignment of the column changes, the response factors of the building also changes and hence different steel sections are encased in the columns and different column orientations have been checked to determine which conFig-uration of steel sections in column give better performance.

For composite models, different conFig-urations have been evaluated as follows;

- Model 1- Section aligned 0^0 to X axis
- Model 2 - Section aligned 90^0 to X axis
- Model 3 - Section aligned 180^0 to X axis
- Model 4 - Section aligned 270^0 to X axis

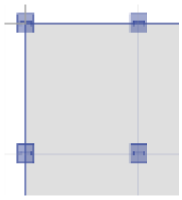

Fig- 1 C Section aligned 0^0 to X axis

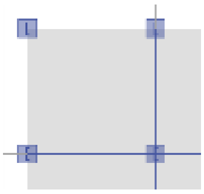

Fig- 2 C Section aligned 90^0 to X axis

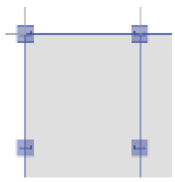

Fig- 3 C Section aligned 180^0 to X axis

The analysis was done with a G+2 building, 4 bays of 3.5m in each direction with a storey height of 3m using Etabs 2015.

The loads considered were;

- Live load = 3 kN/m^2
- Blast load acting on structure due to explosion calculated using IS: 4991 - 1968 (Reaffirmed 2003)
- Grade of concrete = M30
- Grade of reinforcing steel = Fe500
- Column size: 500 x 500mm
- Beam size: 300 x 400mm

The loading diagram is shown in the Fig- 4.

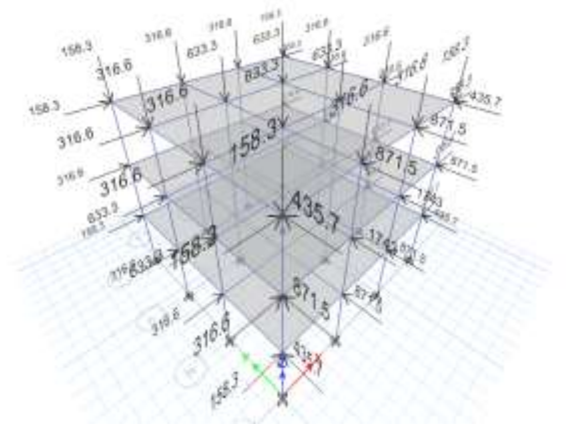

Fig- 4 Loading diagram of 100 kg at 20m.

4. RESULTS AND DISCUSSIONS

The composite building with best column conFig-uration (i.e. at 90°) as shown in Fig-ure have been analysed for storey displacement and storey drift and obtained graphs (maximum and minimum displacement based on the alignment of sections) and results are given below;

4.1 Storey Displacement Graphs

4.1.1 100 Kg at 30m of C Section

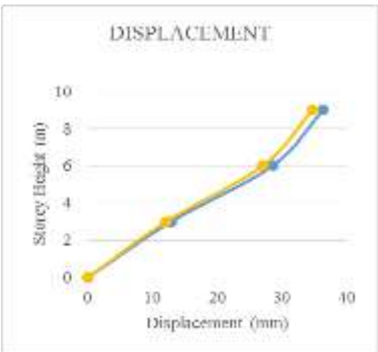

Fig- 5 Displacement of 100 Kg at 30m of C Section

4.1.2 100 Kg at 30m of I Section

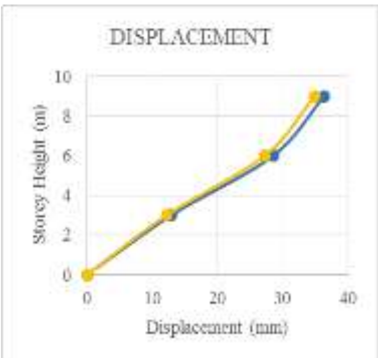

Fig- 6 Displacement of 100 Kg at 30m of I Section

4.1.3 100 Kg at 30m of T Section

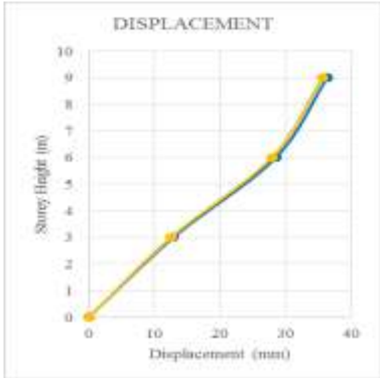

Fig- 7 Displacement of 100 Kg at 30m of T Section

4.1.4 100 Kg at 20m of C Section

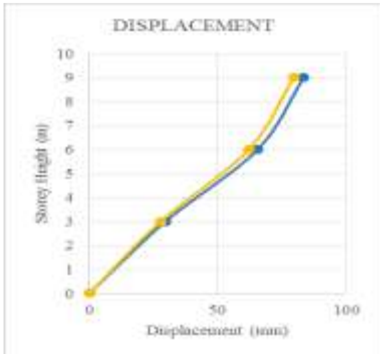

Fig- 8 Displacement of 100 Kg at 20m of C Section

4.1.5 100 Kg at 20m of I Section

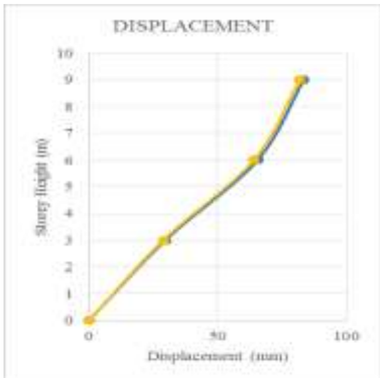

Fig- 9 Displacement of 100 Kg at 20m of I Section

4.1.6 100 Kg at 20m of T Section

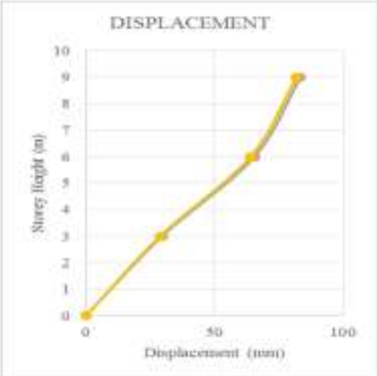

Fig- 10 Displacement of 100 Kg at 20m of T Section

4.1.7 300 Kg at 30m of C Section

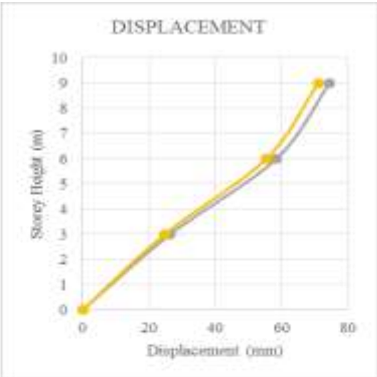

Fig- 11 Displacement of 300 Kg at 30m of C Section

4.1.8 300 Kg at 30m of I Section

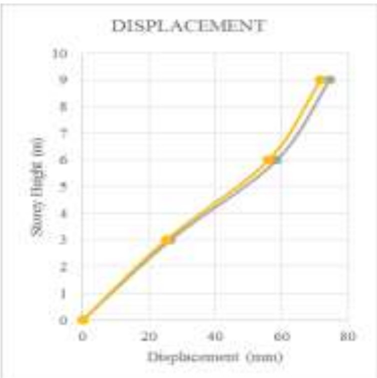

Fig- 12 Displacement of 300 Kg at 30m of I Section

4.1.9 300 Kg at 30m of T Section

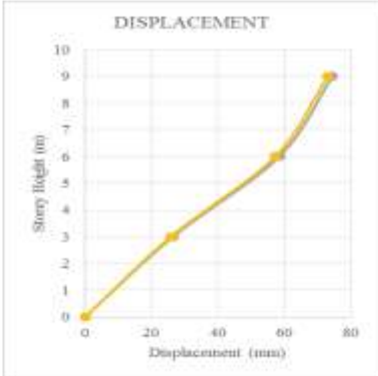

Fig- 13 Displacement of 300 Kg at 30m of T Section

4.1.10 300 Kg at 20m of C Section

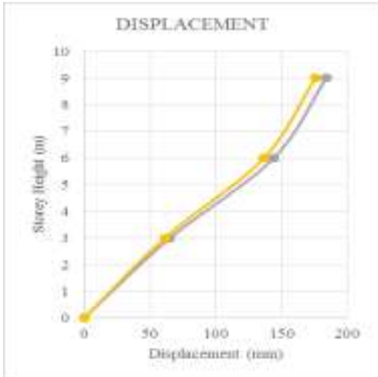

Fig- 14 Displacement of 300 Kg at 20m of C Section

4.1.11 300 Kg at 20m of I Section

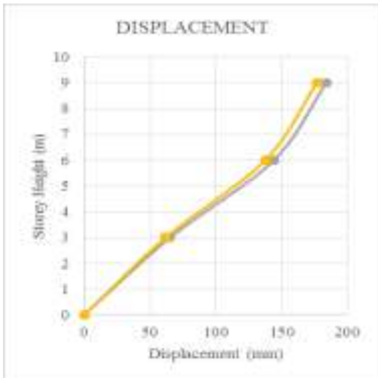

Fig- 15 Displacement of 300 Kg at 20m of I Section

4.1.12 300 Kg at 20m of T Section

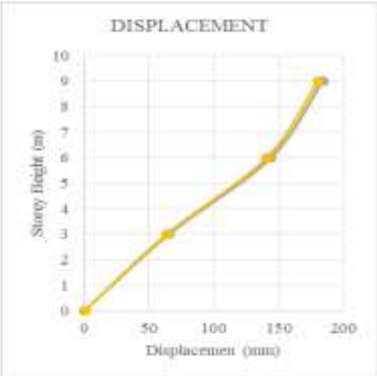

Fig- 16 Displacement of 300 Kg at 20m of T Section

4.2 STOREY DISPLACEMENT RESULTS

Table 1- Storey displacement results of different sections:

LOAD CASE	SECTIONS	STOREY DISPLACEMENT			
		0^0	90^0	180^0	270^0
CASE 1	C	36.314	34.661	36.314	34.661
	I	36.319	34.909	36.319	34.909
	T	36.327	35.644	36.327	35.644
CASE 2	C	83.388	79.591	83.388	79.591
	I	84.573	83.4	84.573	83.4
	T	83.417	81.849	83.417	81.849
CASE 3	C	74.422	71.033	74.422	71.033
	I	74.461	71.718	74.461	71.718
	T	74.448	73.049	74.448	73.049
CASE 4	C	183.985	175.609	183.985	175.609
	I	184.01	176.869	184.01	176.869
	T	184.048	180.591	184.048	180.591

4.3 Storey Drift

4.2.1 100 Kg at 30m of C Section

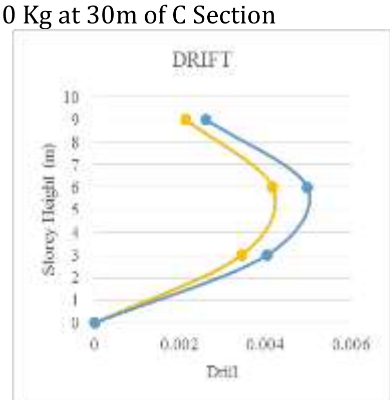

Fig- 17 Storey drift of 100 Kg at 30m of C Section

4.2.2 100 Kg at 30m of I Section

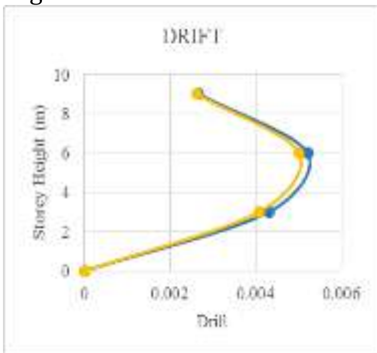

Fig- 18 Storey drift of 100 Kg at 30m of I Section

4.2.3 100 Kg at 30m of T Section

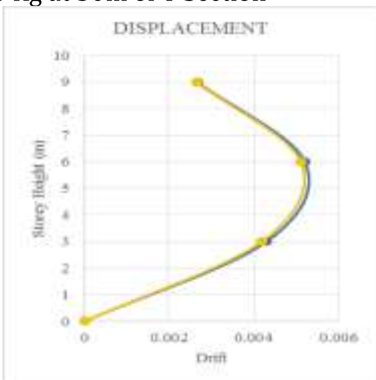

Fig- 19 Storey drift of 100 Kg at 30m of T Section

4.2.4 100 Kg at 20m of C Section

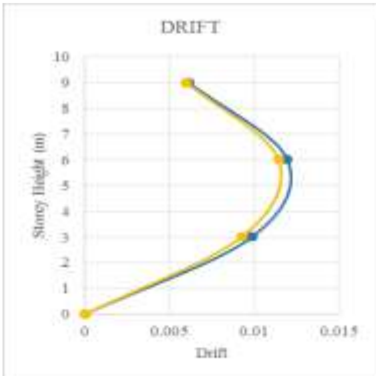

Fig- 20 Storey drift of 100 Kg at 20m of C Section

4.2.5 100 Kg at 20m of I Section

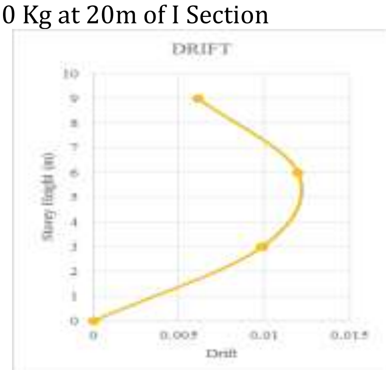

Fig- 21 Storey drift of 100 Kg at 20m of I Section

4.2.6 100 Kg at 20m of T Section

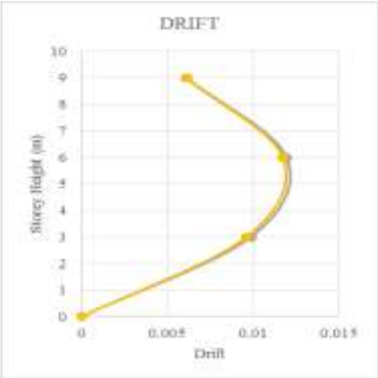

Fig- 22 Storey drift of 100 Kg at 20m of T Section

4.2.7 300 Kg at 30m of C Section

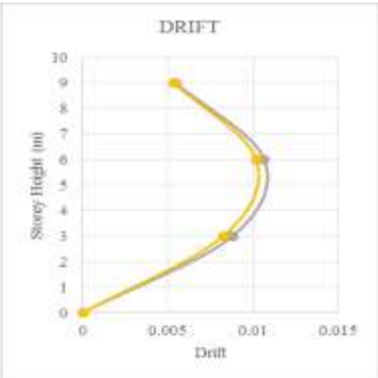

Fig- 23 Storey drift of 300 Kg at 30m of C Section

4.2.8 300 Kg at 30m of I Section

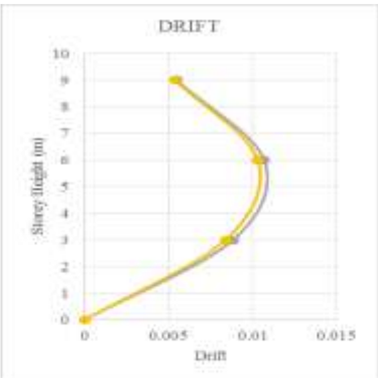

Fig- 24 Storey drift of 300 Kg at 30m of I Section

4.2.9 300 Kg at 30m of T Section

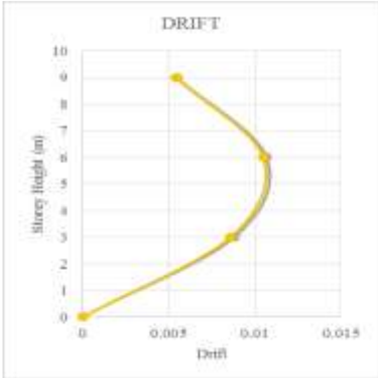

Fig- 25 Storey drift of 300 Kg at 30m of T Section

4.2.10 300 Kg at 20m of C Section

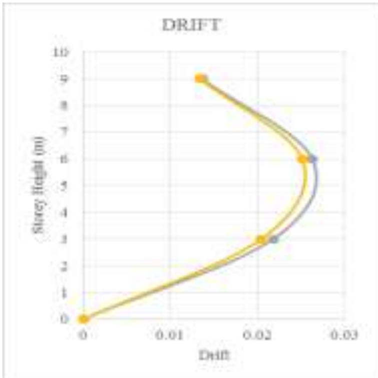

Fig- 26 Storey drift of 300 Kg at 20m of C Section

4.2.11 300 Kg at 20m of I Section

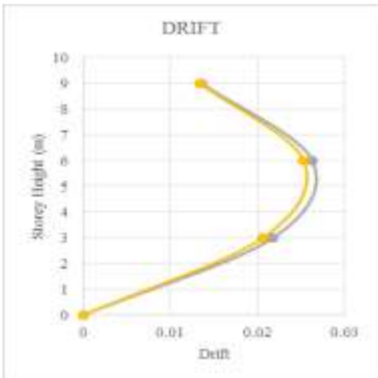

Fig- 27 Storey drift 300 Kg at 20m of I Section

4.2.12 300 Kg at 20m of T Section

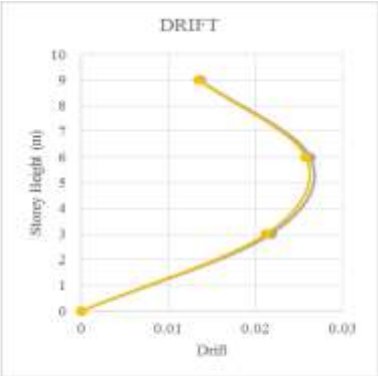

Fig- 28 Storey drift 300 Kg at 20m of T Section

4.4 STOREY DRIFT RESULTS

Table 2- Storey drift values of different sections:

LOAD CASE	SECTIONS	STOREY DRIFTS			
		0^0	90^0	180^0	270^0
CASE 1	C	0.004163	0.004974	0.004163	0.004974
	I	0.005204	0.005008	0.005204	0.005008
	T	0.005205	0.00511	0.005205	0.00511
CASE 2	C	0.01195	0.011423	0.01195	0.011423
	I	0.011974	0.011952	0.011974	0.011952
	T	0.011953	0.011736	0.011953	0.011736
CASE 3	C	0.010664	0.010194	0.010664	0.010194
	I	0.010671	0.010289	0.010671	0.010289
	T	0.010668	0.010474	0.010668	0.010474
CASE 4	C	0.026249	0.025094	0.026249	0.025094
	I	0.026255	0.025268	0.026255	0.025268
	T	0.026258	0.025781	0.026258	0.025781

From the results obtained we can conclude that;

- Max displacement obtained was 36.314mm, 36.319mm, 36.319mm and min displacements were 34.661mm, 34.909mm, 35.644mm for C section, I section and T section respectively for 100 kg TNT explosive load at 30m.
- Max displacement obtained was 83.388mm, 84.573mm, 83.417mm and min displacements were 79.591mm, 83.4mm, 81.849mm for C section, I section and T section respectively for 100 kg TNT explosive load at 20m.
- Max displacement obtained was 74.422mm, 74.461mm, 74.448mm and min displacements were 71.033mm, 71.718mm, 73.049mm for C section, I section and T section respectively for 300 kg TNT explosive load at 30m.
- Max displacement obtained was 183.985mm, 184.01mm, 184.048mm and min displacements were 175.609mm, 176.869mm, 180.591mm for C section, I section and T section respectively for 300 kg TNT explosive load at 20m.
- Max drift obtained 0.004974, 0.005204, 0.005205 and min drift were 0.004163, 0.005008, 0.00511 for C section, I section and T section respectively for 100 kg TNT explosive load at 30m.
- Max drift obtained was 0.01195, 0.011974, 0.011953 and min drift were 0.011423, 0.011952, 0.011736 for C section, I section and T section respectively for 100 kg TNT explosive load at 20m.
- Max drift obtained was 0.010664, 0.010671, 0.010668 and min drift were 0.010194, 0.010289, 0.010474 for C section, I section and T section respectively for 300 kg TNT explosive load at 30m.
- Max drift obtained was 0.026249, 0.026255, 0.026258 and min drift were 0.025094, 0.025268, 0.025781 for C section, I section and T section respectively for 300 kg TNT explosive load at 20m.

5. CONCLUSION

The study helped me to gain amble exposure to the analysis of blast building under blasting phenomena. The response of a blast building varies with respect to TNT capacity and standoff distance. The installation of steel sections is studied as a beneficial alternative for obtaining good results and in blasting condition. For the study purpose the model of blast building is generated in ETABs. The models with and without steel sections were created.

1. As the blast load increases and standoff distance decrease the displacement and storey drifts are increasing drastically in the structure.
2. The structure response depends on blast load and standoff distance values
3. Form the above results we can conclude that C section is better than I section and T section in terms of storey drift and displacement

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