ANALYSIS OF BLAST RESISTANT STRUCTURE

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***Abstract*: A bomb explosion nearby a building can cause catastrophic damage to the building's external and internal structural frames, collapsing of walls and shutting down of critical life-safety systems. Loss of life and injuries to occupants can result from many causes, including direct blast-effects, structural collapse, debris impact, fire, and smoke. The indirect effects can cumulate to inhibit or avert timely avoidance, thereby contributing to supplemental casualties. The main intent of this Study is to through light on the design of blast resistant buildings and to know the response of a structure when subjected to blast loads utilizing ETABS software with prominence given on different Standoff distances of the blast and incorporating different charge weights of TNT according to the IS CODE 4991. Predicated on the data and function of the building, dead loads, live loads & partition Wall loads are considered in the analysis of the building under the designations of IS 875-1987. In the present study, G+17 storied building is subjected to 200kg and 400 kg charge weight of the blast load with a standoff distance of 20, 40 and 60m. IS: 4991 – 1968 is utilized to determine the blast parameters. The response of the structure is resolute in terms of storey drift and storey displacement. Depending on the source of the blast load and the charge weight of the explosive, the response of the building and safe standoff distance is found. To make the building more resistible for blast load, different structural systems like shear wall and steel bracings are implemented.**

***Index Terms*: Blast, Blast load**

I. INTRODUCTION

These structures should be safeguarded from the blast effects, which are liable to be the targets of terrorist attacks. The dynamic replication of the structure to blast loading is intricate to analyze, because of the non- linear deportment of the material. Explosions result in sizable voluminous dynamic loads, more preponderant than the pristine design loads, for which the structures are analyzed and designed. Analyses and design of blast loading require detailed cognizance of blast and its phenomena.

In last 20 years, majority of terrorist attacks on civil buildings and structures are carried out utilizing high explosive contrivances. It is September 11, 2001 attack, which lead to transmute in focus of research in particular to analysis, design and aegis of buildings against blast. More and more research accentuation is put towards making building/structures safe against such man-made devastating attacks. The indirect effects can amalgamate to inhibit or avert timely avoidance, thereby contributing to adventitious casualties. In integration, major catastrophes resulting from gas-chemical explosions result in sizable voluminous dynamic loads, more preponderant than the pristine design loads, of many structures.

Strategies for blast protraction have become a consequential consideration for structural designers as numerical terrorist attacks perpetuate at an alarming rate. No civilian buildings can be designed to withstand the kind of extreme attack that transpired to the World Trade Centre in USA. Building owners and design professionals homogeneous, however, can take steps to better understand the potential threats and bulwark the occupants and assets in a dubious environment. The blast resistance of variants of civilian and military structures against contingent explosions and terrorist attacks is a consequential security issue. Attacks towards vulnerably susceptible structures can cause an astronomically immense number of casualties especially if total collapse occurs. Abbreviating susceptibility of subsisting and future buildings and conveyance terminals is a topic of major concern for researchers in both civil and material engineering.

Structural damages caused by blast loading are the combination of both immediate effects and consecutive hazards, among which is progressive collapse. This catastrophic failure mode occurs when the initial failure of one or several key load-carrying members causes a more widespread failure of the circumventing members what leads to consummate collapse of the whole structure. Consequently, it is of great paramount to investigate and ameliorate the replication of structures to blast loading. Compared to other construction materials, concrete is generally kenned to have a relatively high extreme blast resistance capacity. However, to ameliorate resistance against extreme blast loads, some subsisting concrete structures require supplemental retrofitting. To enhance the blast performance of concrete, two main procedures have been widely utilized. The first consists of integrating steel, carbon, or polypropylene fibres as internal reinforcement to get a fibre-reinforced concrete, and second method for minimization of damage is by for fending structure with external elements such as aluminium foam or steel sheets. One of the most subsidiary information when assessing the consequences of a blast event on a building would be the precise evaluation of dynamic replication and residual load-carrying capacity of the primary fortifying members. There has been a growing trend in the engineering community to find integrated solutions for the design of infrastructures across sundry hazards, namely, Multihazard engineering. Multihazard engineering is the search for a single design concept which can adequately consummate the authoritative ordinances of multiple hazards. Since bulwark is never an absolute concept and there is a calibre of high cost associated with a given damage level of bulwark, felicitous assessment implements must be employed to determine within plausible degree of precision the calibre of susceptibility of subsisting and incipient structures. Furthermore, in blast design, one can withal determine an acceptable level of damage that a structure can abide. Blast testing in general seems to best mimic the authentic situation of blast action on an object. It definitely can replicate with high fidelity intricate configurations and conditions that appear in a genuine situation and are profoundly arduous if not infeasible to simulate in a theoretical or a computational model. Testing naturally accounts for the authentic material comportment no matter how intricate they are, and for the authentic conditions, no matter how non-ideal they look homogeneous to, whether these are support conditions or connections with other elements or poor workmanship.

II. OBJECTIVE

- The main aim of this work is to analyze Behaviour of structure subjected to Blast loads and reduce the effects of blast load by using shear wall and steel bracings are provided to the building.
- Modelling and analysing of high rise building Models for external explosion.
- To understand the behaviour of blast of high rise building.
- To study and compare the behaviour of different building models for analysed results.
- To know the response of a structure when subjected to blast loads of different standoff distances & various charge weights.
- To knowing the response of a building when subjected to blast loadings using ETABS software as per IS Code 4991.

III. METHODOLOGY

In this analysis of 17 storey structure in ETABS, four different models are generated. The dimensional properties chosen are as below.

Table 1 Model Data

No of grid in X direction	5
No of grid in Y direction	4
Spacing of grid in X direction	5
Spacing of grid in Y direction	4
No of story	17
Story Height	3
Bottom story height	3
Location	Zone 3
Soil Type	Type II, Medium soil
Column Size	400mm*400mm
Beam Size	300mm*300mm
Slab Thickness	150mm
Live Load	2.0 KN/m²
Floor Finish	1.5 KN/m²
Brick Masonry	230mm

Different Cases for Analysis:-
TYPE 1 MODEL - Normal Building Structure
TYPE 2 MODEL - Building Structure with increased column & beam sizes. TYPE 3 MODEL - Building Structure with addition of shear walls at the corners. TYPE 4 MODEL - Building Structure with addition of steel bracing at the corners.

Case 1: Blast of 200kg explosive with standoff distance of 20 m Case 2: Blast of 200kg explosive with standoff distance of 40 m Case 3: Blast of 200kg explosive with standoff distance of 60 m Case 4: Blast of 400kg explosive with standoff distance of 20 m Case 5: Blast of 400kg explosive with standoff distance of 40 m Case 6: Blast of 400kg explosive with standoff distance of 60 m

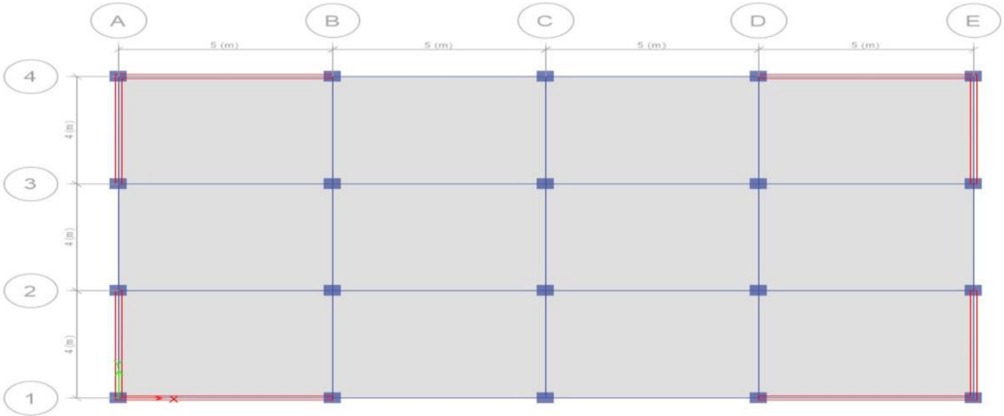

Figure 1 Plan view

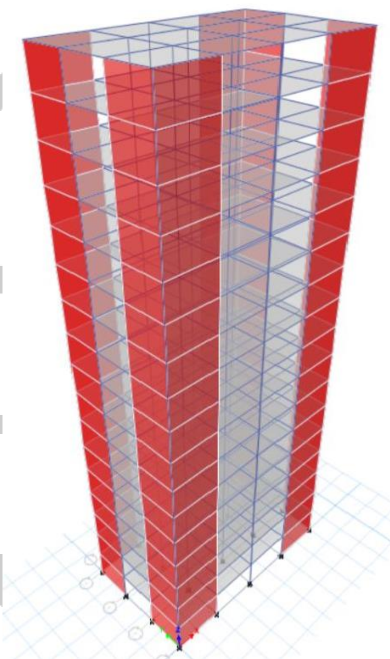

Figure 2 3-D view

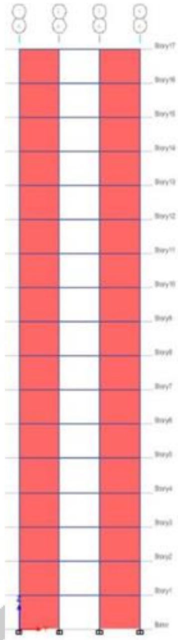

Figure 3 Elevation view

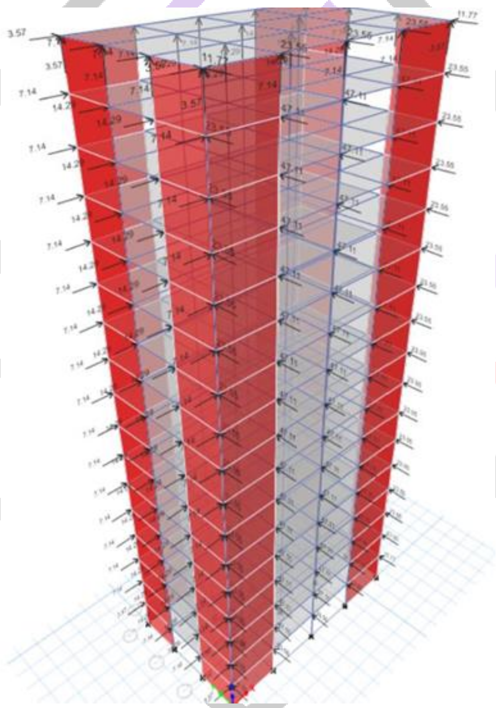

Figure 4 Blast load application

IV. LOAD CALCULATIONS

LOADS CONSIDERED IN ANALYSIS

The following loads are considered for the analysis of various phases of structure.

- Gravity loads: The intensity of dead load and live load considered in the study are given below:
- Dead loads: Dead load comprising of self-weight of members i.e. Beam, Column and Slab.
- Live load: Live load of 4 KN/m2 on floor area.
- Blast loads: IS 4991-1968 is used for blast load calculations. The maximum values of the positive side-on overpressure (Pso), reflected over pressure (Pro) and dynamic pressure (qo), as caused by the explosion of one tone explosive at various distances from the point of explosion are given in the following Table

Table 2 Blast load calculation

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Blast of (kg)	200	200	200	400	400	400
Standoff Distance (m)	20	40	60	20	40	60
Scaled Distance (m)	34.01	68.027	102.04	27.063	54.127	81.19
Pu	1	1	1	1	1	1
Pso	1.13	0.326	0.18	1.80	0.4778	0.2493
Pro	3.21	0.736	0.40	5.81	1.14	0.548
qo	0.396	0.0362	0.012	0.92	0.077	0.0215
to	25.54	38.56	45.61	20.92	34.52	41.58
td	16.85	29.09	36.22	13.36	24.70	31.92
M	1.4	1.13	1.07	1.60	1.2	1.1
a (m/s)	344	344	344	344	344	344
U	0.481	0.39	0.368	0.555	0.412	0.378
Bay Spacing (m)	4	4	4	4	4	4
H	17	17	17	17	17	17
B	15	15	15	15	15	15
L	16	16	16	16	16	16
S	7.5	7.5	7.5	7.58	7.5	7.5
Story Ht. (m)	3	3	3	3	3	3
tc	46.77	57.692	61.015	40.54	54.50	59.26
tr	62.29	76.99	81.35	54.05	72.67	79.28
For roof and sides Cd	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Pso+Cd*qo (kg/cm²)	0.97	0.311	0.175	1.432	0.477	0.24
Loads On Front Face Joints (kg/m²)						
Load On Center Joints	3852	883.44	480	6972	1368	658.44
Load On Side Joints	1926	441.72	240	3386	686	329.22
Load on Edge Joints	963	220.86	120	1743	342	164.11
Loads On Roof & Side Walls (kg/m²)						
Load On Center Joints	1458	970.32	262.8	2148	670.5	361.05
Load On Side Joints	729	485.16	131.4	1074	335.25	180.52
Load on Edge Joints	364.5	242.58	65.7	537	167.62	90.26

V. RESULTS AND DISCUSSIONS

The aim in blast resistant building design is to prevent the overall collapse of the building and fatal damages. Despite the fact that, the magnitude of the explosion and the loads caused by it cannot be anticipated perfectly, the most possible scenarios will let to find the necessary engineering and architectural solutions for it.

Storey Displacement- It is total displacement of storey with respect to ground and there is maximum permissible limit prescribed in IS codes for buildings.

Storey Drift- It is defined as ratio of displacement of two consecutive floor to height of that floor. It is very important term used for research purpose in earthquake engineering.

- The response of the structure will be plotted in terms of Height v/s Story Displacement and Height v/s Story Drift.
- Combine result of all he Models are plotted in terms of Height v/s Story Displacement and Height v/s Story Drift.

RESULTS

Table 3 Displacement comparisons of all models

laceme nt	Model 1		Model 2		Model 3		Model 4	
	0.2 T 20m	0.4 T 20m	0.2 T 20m	0.4 T 20m	0.2 T 20m	0.4 T 20m	0.2 T 20m	0.4 T 20m
51	455.058	787.274	228.287	394.608	72.237	123.587	24.829	42.444
48	450.03	780.213	225.284	390.236	67.445	115.517	23.03	39.406
45	442.484	768.891	221.162	383.958	62.584	107.323	21.22	36.344
42	431.927	752.177	215.588	375.1	57.649	98.987	19.4	33.263
39	418.249	729.814	208.425	363.377	52.634	90.497	17.577	30.17
36	401.431	701.752	199.616	348.676	47.549	81.865	15.757	27.078
33	381.481	667.999	189.143	330.954	42.412	73.121	13.951	24.004
30	358.415	628.579	177.003	310.205	37.253	64.317	12.171	20.967
27	332.252	583.528	163.204	286.44	32.116	55.524	10.43	17.992
24	303.017	532.888	147.761	259.686	27.052	46.834	8.746	15.108
21	270.739	476.707	130.702	229.991	22.127	38.362	7.137	12.346
18	235.452	415.047	112.079	197.446	17.421	30.245	5.623	9.742
15	197.205	347.994	91.996	162.237	13.023	22.641	4.228	7.337
12	156.094	275.715	70.683	124.77	9.039	15.739	2.976	5.175
9	112.393	198.699	48.654	85.959	5.591	9.751	1.896	3.304
6	67.114	118.74	27.095	47.906	2.818	4.923	1.016	1.776
3	24.288	42.995	8.763	15.502	0.881	1.544	0.369	0.648
0	0	0	0	0	0	0	0	0

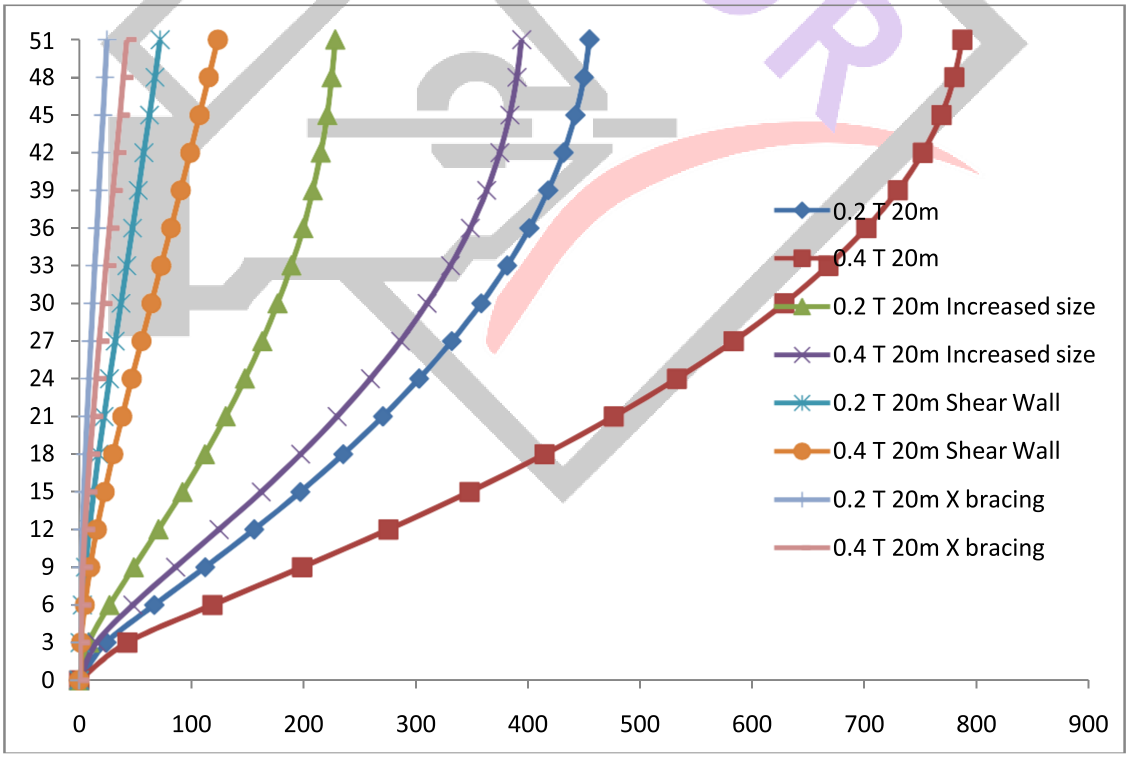

Figure 5 Displacement comparisons of all models

Table 4 Story Drift comparisons of all models

Drift	Model 1		Model 2		Model 3		Model 4	
	0.2 T 20m	0.4 T 20m	0.2 T 20m	0.4 T 20m	0.2 T 20m	0.4 T 20m	0.2 T 20m	0.4 T 20m
51	0.001676	0.002354	0.001001	0.001457	0.001597	0.00269	0.000599	0.001013
48	0.002515	0.003774	0.001374	0.002092	0.00162	0.002731	0.000604	0.001021
45	0.003519	0.005571	0.001858	0.002953	0.001645	0.002779	0.000607	0.001027
42	0.004559	0.007454	0.002388	0.003908	0.001672	0.00283	0.000608	0.001031
39	0.005606	0.009354	0.002936	0.004901	0.001695	0.002877	0.000607	0.001031
36	0.00665	0.011251	0.003491	0.005907	0.001712	0.002915	0.000602	0.001025
33	0.007689	0.01314	0.004047	0.006916	0.001719	0.002935	0.000593	0.001012
30	0.008721	0.015017	0.0046	0.007922	0.001713	0.002931	0.00058	0.000992
27	0.009745	0.01688	0.005148	0.008918	0.001688	0.002897	0.000561	0.000962
24	0.010759	0.018727	0.005686	0.009898	0.001641	0.002824	0.000536	0.000921
21	0.011762	0.020553	0.006208	0.010848	0.001569	0.002706	0.000505	0.000868
18	0.012749	0.022351	0.006694	0.011736	0.001466	0.002534	0.000465	0.000802
15	0.013704	0.024093	0.007104	0.012489	0.001328	0.002301	0.000417	0.000721
12	0.014567	0.025672	0.007343	0.012937	0.001149	0.001996	0.00036	0.000624
9	0.015093	0.026653	0.007186	0.012684	0.000924	0.001609	0.000293	0.000509
6	0.014275	0.025248	0.006111	0.010801	0.000645	0.001126	0.000216	0.000376
3	0.008096	0.014332	0.002921	0.005167	0.000294	0.000515	0.000123	0.000216
0	0	0	0	0	0	0	0	0

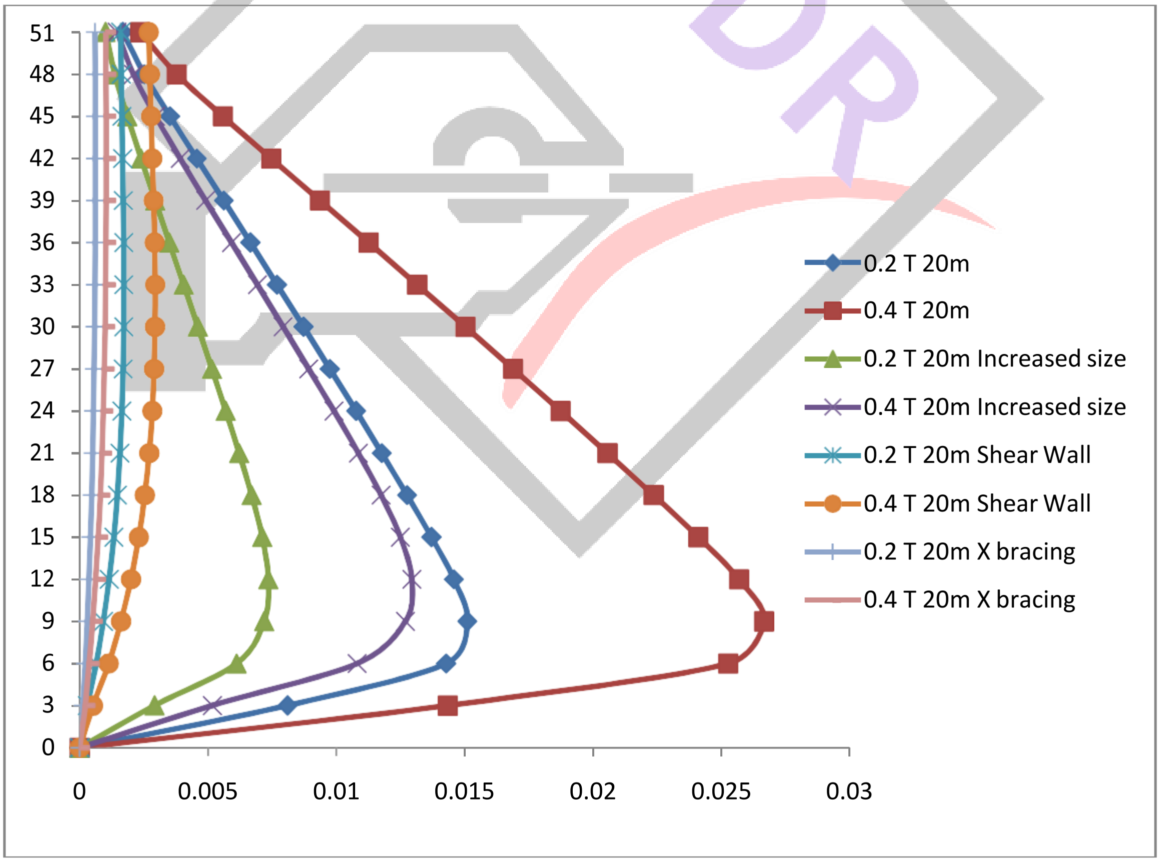

Figure 6 Story Drift comparisons of all models

- The maximum inter storey drifts are 45.27 for 200 Kg blast load from 20 m standoff distance, 79.95 is the max storey drift for 400kg blast load from 20 m standoff distance for the model 1. According to IS 1893 maximum allowable storey drift is 12 (.004* Storey height). So maximum storey drift are not satisfying IS code recommendation in **model 1**.
- For all the cases in **model 2** when we increase beam and column cross-section of structure compared to model one the maximum storey displacement are reduced by around 49.83 % , and maximum storey drift reduced by around 52.38 %.

- In **model 3**, addition of shear wall around the structure in model 1 results in reduction of maximum storey displacement by around 84 %, and max storey drift by around 94% compared to the maximum storey displacement and drift from model 1.In this model shear wall helps to decrease storey displacement effectively so that the maximum displacement and maximum story drift in this model are within the allowable max storey displacement and max story drift given by IS 1893.
- In **model 4**, addition of steel bracing around the structure helps to reduce the maximum storey displacement by around 84% and maximum storey shear by around 97% compared to maximum storey displacement and maximum storey shear from model 1.

VI. CONCLUSION

- As the blast load increases and standoff distance decreases the displacement and story drifts are increasing drastically in the structure. The blast parameters are depends on blast load and standoff distance. So the structure response depends on blast load and standoff distance values.
- By increasing column and beam size in a structure will improve the resistance but it is not practical in most cases due to serviceability problems because huge cross section of beam and column needed to resist blast loads.
- Addition of shear wall and bracing helps to resist the blast loads effectively.
- The addition of steel bracings gives good results but shear wall more desirable results than steel bracings and it is economical too compared to other methods.
- Addition of 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. A thorough comparative study could be done on structures for heavier blast loads and also by adding floors to find out the effects of blast loads in high rise structure.

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