

# Comparative Study of Blast Load on Different Buildings

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**Abstract** - In recent decades frequency of terrorist attacks is increased, due to these attacks some important public and private structures should design to resist blast load. Because of explosion severe damage may occur to structural members which may cause sudden collapse of whole structure or progressive collapse of structure. Conventional structures are not designed for such loads. Most of the structure fail to resist blast load. To avoid such effects on structure various methods are developed to analyze and design to resist such loads. To design blast resistance structure detailed study of blast phenomenon and its adverse effects on different structural members is required. Response of blast load on eight storey RCC building with different configuration examined in this study. Effect of 400kg explosive and 30m standoff distance is taken in consideration. From these parameters blast load calculated analytically as per IS 4991:1968 and applied as pressure time history on model which was created in ETABS v.17. Their response in term of peak displacement, storey displacement are calculated and compared.

**Key Words:** Blast load, charge weight, time history, ETABS v17

## 1. INTRODUCTION

Explosion term is used to describe such a situation in which there is rapid release of energy in large scale. Due to detonation of physical, nuclear, chemical explosives. Blast occurred near public building, crowded place etc. causes severe damage and loss of life. The quick effects of blast are blast wave which propagates through surrounding atmosphere, fragments generated from explosive and shock wave generated from explosive. Blast wave propagate through air with decreasing speed but with more than that of speed of sound. To design structure which can resist blast load is require to analyze effect of explosions. For this it requires combination of different specialist, experimental tests and set up and tools to analyze.

### 1.1 Blast wave characteristics

Explosion consist of release of energy, which lasts for milliseconds and creates very high temperature and pressure because of expansion of hot gases [6]. The expansion of gases produces wave type propagation in surrounding media as in spherical form and blast wave is produced because hot gases compresses the air. Blast wave reaches to its peak pressure than surrounding ambient air pressure. The energy of blast

wave decreases as the wave moves away from source of explosion [3].

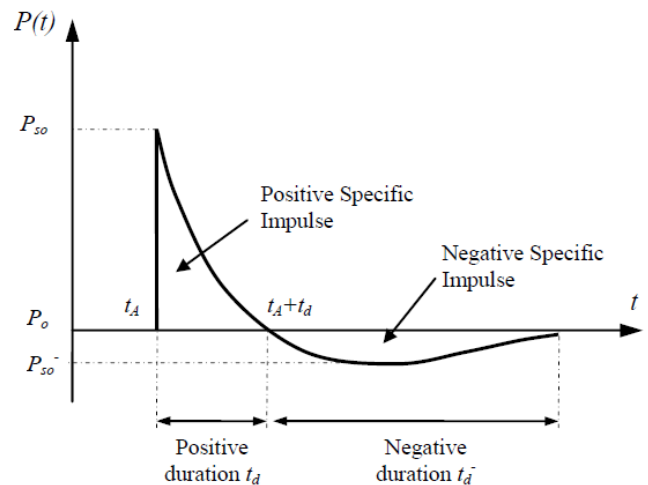
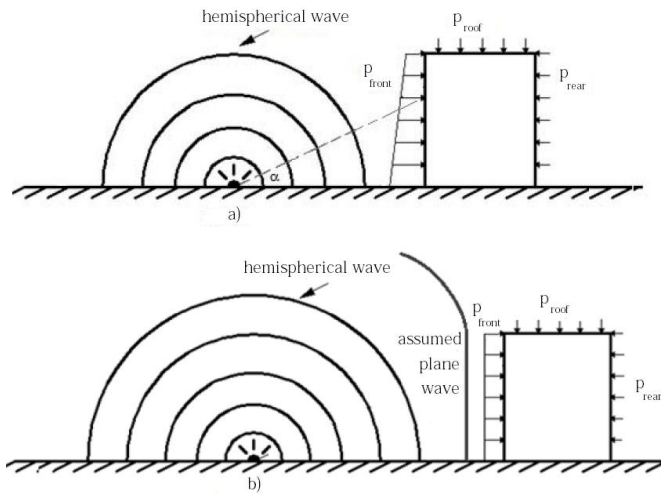


Fig.-1: Pressure time history of Blast wave

After the peak value of wave decreases at exponential rate until it reaches ambient air pressure called as positive phase. After the positive phase the pressure decreases and goes below ambient pressure which is negative phase and finally it returns to the ambient air pressure [2]. During negative phase structure subjected to suction forces. Generally, effect of negative phase of wave not taken into consideration while designing because damage occurred to structural member is mainly due to positive phase. Pressure produced by negative phase is very less as compared to positive phase [7].

### 1.2 Blast wave loading

Loading of blast wave can be classified as unconfined and non-contact explosions which are outside of building. Its subtype as free air burst, air burst and surface air burst [6]. In free air burst explosion occur in air and wave propagate as spherical and hits the structure without any contact with surrounding. This causes loading on roof of structure. Air burst is basically similar to free air burst but in this blast, wave first interact with ground then this gives rise to Mach front which affects to structure.



**Fig-2:** a) Blast load at close distance b) Blast load at sufficient distance

In surface burst explosion occurred at surface near building which gives rise to direct interaction of blast wave onto the structure. In this study surface burst loading was considered.

**2. METHODOLOGY**

For the comparative study of blast loading on different building configuration a plan dimension of 25m x 35m was modeled in ETABS. Table 1 represent the description of model.

**Table -1:** Description of model

Total floors	G + 7
Total building height	24m
Number of bays in X direction	5
Number of bays in Y direction	7
Width of bays in X direction	5m
Width of bays in Y direction	5m
Height of each storey	3m
Column dimension	450mm x 450mm
Beam dimension	230mm x 450mm
Slab thickness	125mm
Shear wall thickness	200mm

The structure subjected to blast load having explosive weight 400kg and standoff distance(R) 30m. For the comparative study different cases considered, for blast loading explosive weight and standoff distance keep unchanged. Cases are as follows:

- Case 1:** Response of building under blast load for bare frame
- Case 2:** Response of building under blast load having shear wall at center of periphery.

**Case 3:** Response of building having shear wall of 2.5m at each corner.

**Case 4:** Response of building having shear wall at 3 sides.

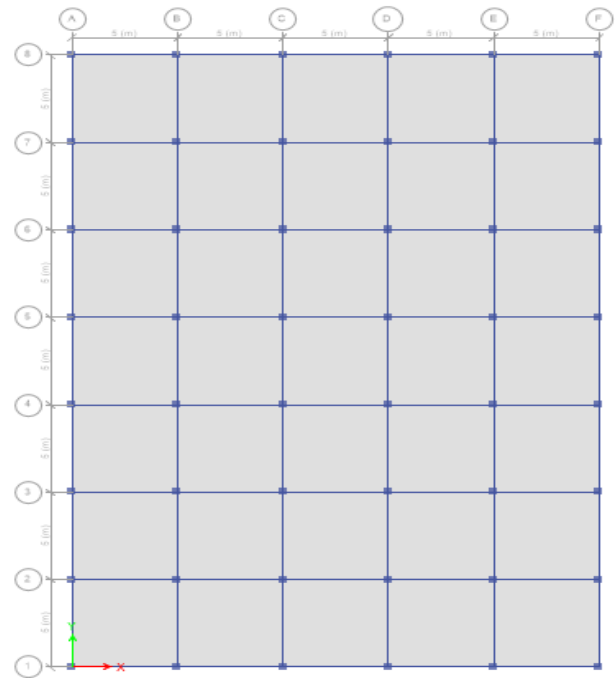
**Case 5:** Response of building having one shear wall at blast facing side.

**Case 6:** response of building having shear walls at core.

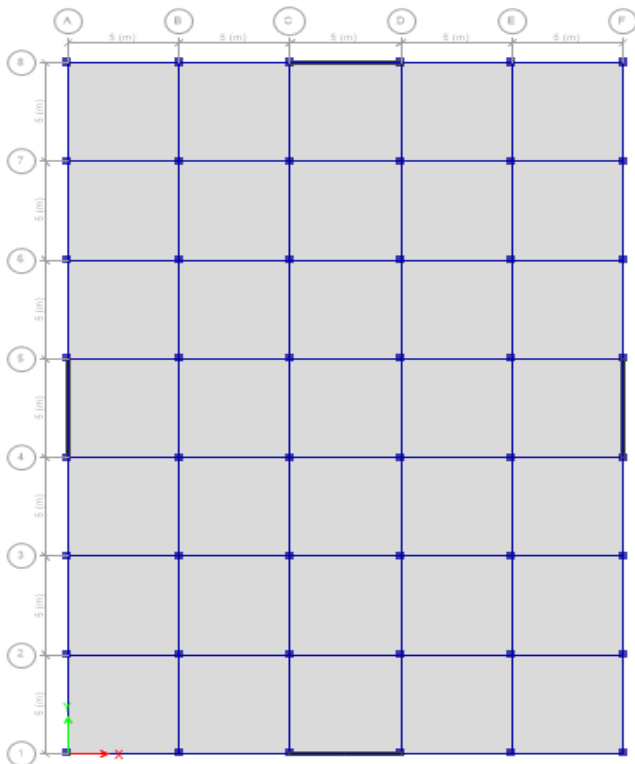
**Case 7:** Response of building having brick infill at above 6 floors. First 2 floors keep as it is.

**Case 8:** Response of building having brick infill at two sides.

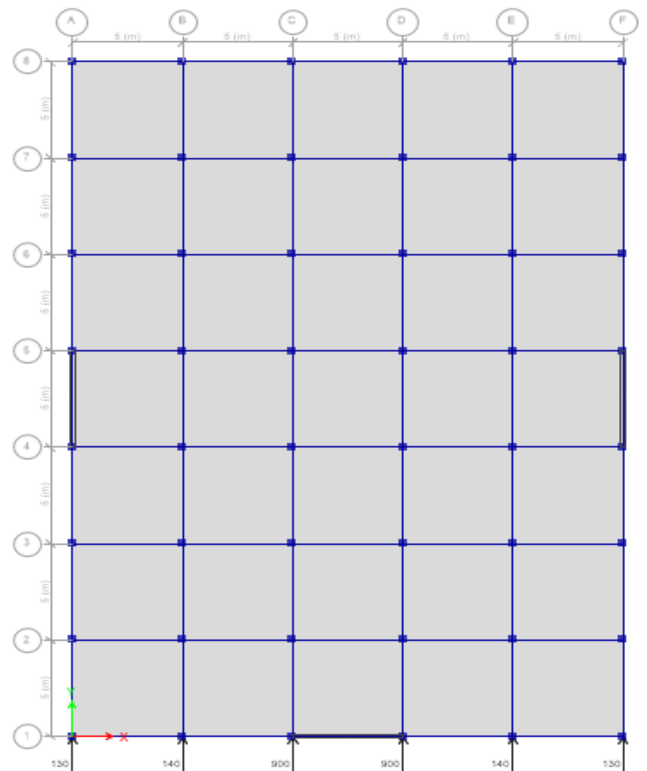
For all cases blast loading was applied on first 25m side and then on 35m side. From this comparison can be made between two directions. For different case there will be different results.



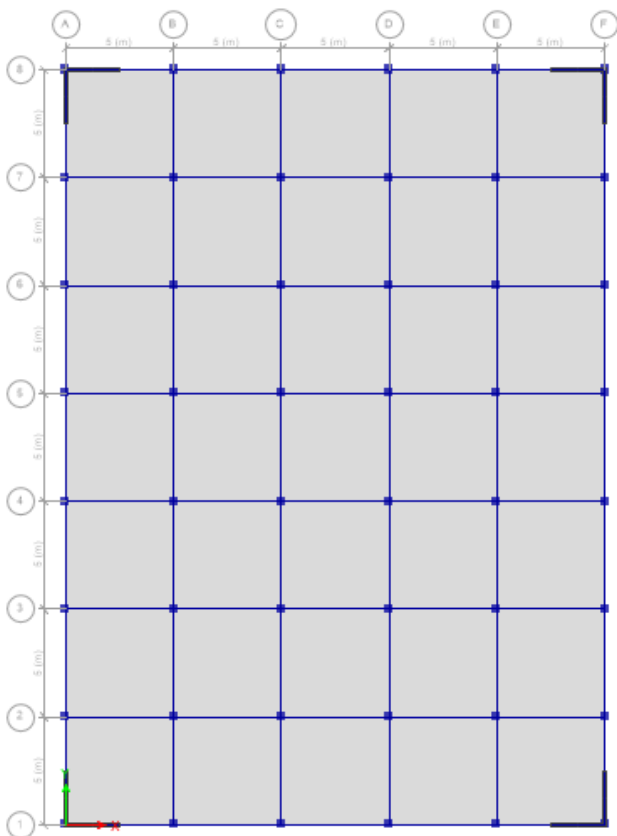
**Fig-3:** Case 1: Plan view for bare frame



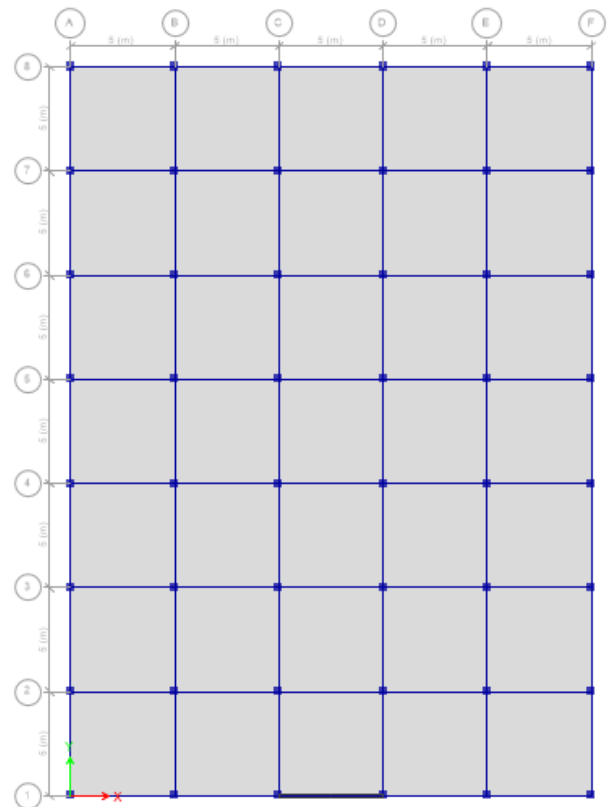
**Fig-4:** Case 2: Plan view of shear wall at middle of periphery



**Fig-6:** Case 4: plan view of 3 side shear wall at middle of periphery having blast load applied at 25m side



**Fig-5:** Case 3: Plan view of shear wall at corner



**Fig-7:** Case 5: Plan view of Shear wall on one side

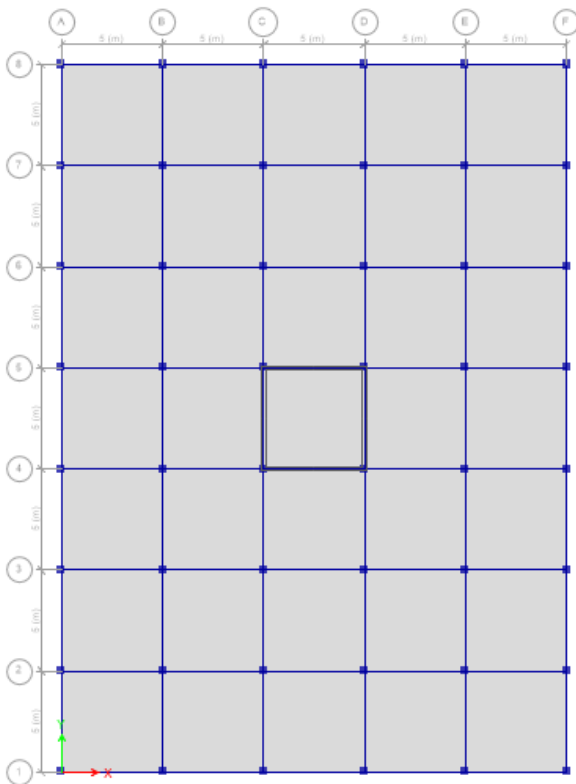


Fig.-8: Case 6: Plan view of shear wall at core

Table 2: Joint loads for bare frame acting on 35m side

Floor	Node	R (m)	Z (m)	P <sub>ro</sub> (kN/m <sup>2</sup> )	A <sub>T</sub> (m <sup>2</sup> )	F (kN)
GF	4 & 5	30.25	41.04	202.95	2.4	487.09
	3 & 6	31.06	42.14	191.81	2.4	460.36
	2 & 7	32.64	44.28	170.8	2.4	408.20
	1 & 8	34.85	47.28	147.90	1.2	177.48
1	4 & 5	30.7	41.65	196.76	2.4	472.24
	3 & 6	31.5	42.73	185.76	2.4	445.83
	2 & 7	33.05	44.84	164.44	24.	394.67
	1 & 8	35.24	47.81	144.44	1.2	173.33
2	4 & 5	31.42	42.63	186.86	2.4	448.47
	3 & 6	32.2	43.68	176.13	2.4	422.73
	2 & 7	33.72	45.75	157.93	2.4	379.04
	1 & 8	35.88	48.68	139.21	1.2	167.05
3	4 & 5	32.41	43.93	173.24	2.4	415.79
	3 & 6	33.17	45.00	162.81	2.4	390.75
	2 & 7	34.64	46.99	149.77	2.4	359.44
	1 & 8	36.74	49.84	132.34	1.2	158.81
4	4 & 5	33.63	45.62	158.73	2.4	380.95
	3 & 6	34.37	46.63	152.16	2.4	365.19
	2 & 7	35.8	48.57	139.85	2.4	335.64
	1 & 8	37.83	51.32	124.06	1.2	148.88
5	4 & 5	35.07	47.58	145.95	2.4	350.29
	3 & 6	35.77	48.53	140.09	2.4	336.31
	2 & 7	37.14	50.39	129.15	2.4	309.96
	1 & 8	39.11	53.06	116.11	1.2	139.34
6	4 & 5	36.7	49.79	132.66	2.4	318.39
	3 & 6	37.38	50.71	127.23	2.4	305.36
	2 & 7	38.69	52.49	118.72	2.4	284.94
	1 & 8	40.58	55.05	107.33	1.2	128.80
7	4 & 5	38.5	52.23	119.90	2.4	143.88
	3 & 6	39.14	53.10	115.93	2.4	139.11
	2 & 7	40.39	54.10	108.15	2.4	130.11
	1 & 8	42.2	57.25	98.40	1.2	118.09

### 3. CALCULATION FOR BLAST WAVE LOADING

Explosive weight taken as 400kg and its standoff distance taken as 30m. loading of blast wave on building is calculated as per IS 4991:1968. To get accurate blast load analysis load must be applied to each node on which blast wave facing based on tributary area of that node the standoff distance from source and incident angle of wave on that wave. For saving time in analysis incident angle of blast wave taken as perpendicular to structure and blast load acts simultaneously at each node. Tributary area (A<sub>T</sub>) of joint load is different for different cases. It was assumed that explosion occurred at middle of central bay of periphery. Blast load calculated for each joint from source of explosion only. Explosion occurred at 30m from building on the surface.

Magnitude of blast loading decreases as we move for upper storey. So clearly blast loading is depends on standoff distance, load will be greater as source of detonation comes closer and decreases when source moves away. The distance from each joint to source is calculated by using Pythagoras theorem. While modelling base support provided as fixed and rigid diaphragm is provided to all floors.

The pressure diagram for 400kg explosive and 30m standoff distance according to IS 4991:1968 as follows:

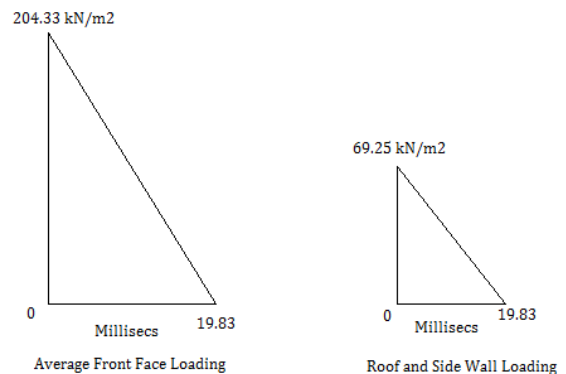
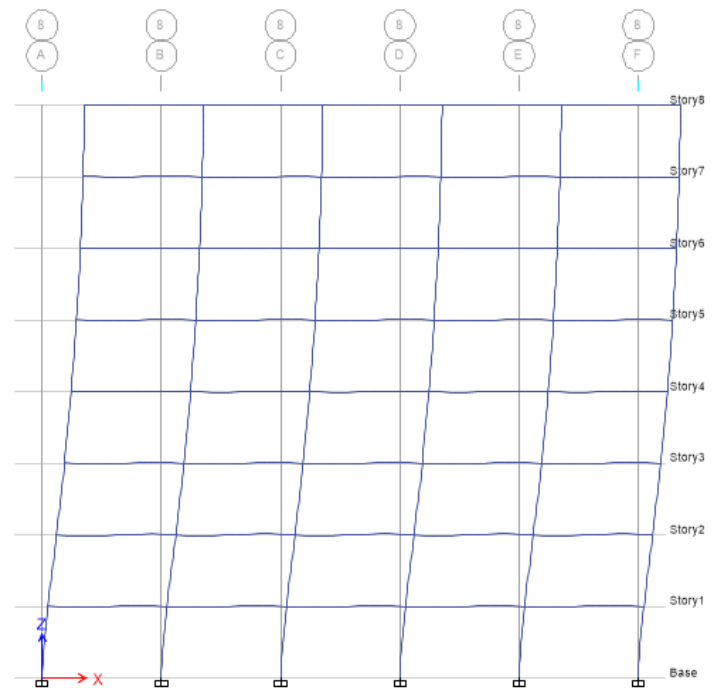


Fig.-9: Pressure diagram of blast wave

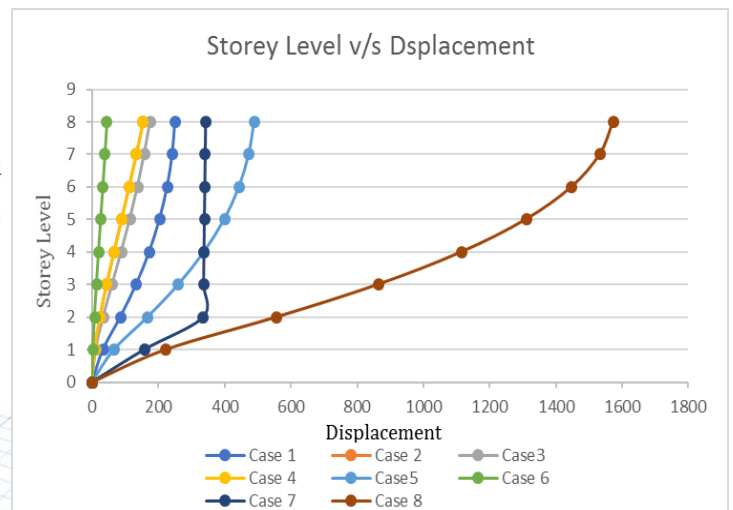
**Table 3:** joint load for shear wall on 3 sides on 25m side

Floor	Node	R (m)	Z (m)	P <sub>ro</sub> (kN/m <sup>2</sup> )	A <sub>r</sub> (m <sup>2</sup> )	F (kN)
GF	3 & 4	30.25	41.04	202.95	7.5	1523
	2 & 5	31.06	42.14	191.81	2.4	461
	1 & 6	32.64	44.28	170.08	1.2	205
1	3 & 4	30.7	41.65	196.76	7.5	1476
	2 & 5	31.5	42.73	185.76	2.4	446
	1 & 6	33.05	44.84	164.44	1.2	198
2	3 & 4	31.42	42.63	186.86	7.5	1402
	2 & 5	32.2	43.68	176.13	2.4	423
	1 & 6	33.72	45.75	157.93	1.2	190
3	3 & 4	32.41	43.93	173.24	7.5	1300
	2 & 5	33.17	45.00	162.81	2.4	391
	1 & 6	34.64	46.99	149.77	1.2	180
4	3 & 4	33.63	45.62	158.73	7.5	1191
	2 & 5	34.37	46.63	152.16	2.4	366
	1 & 6	35.8	48.57	139.85	1.2	168
5	3 & 4	35.07	47.58	145.95	7.5	1095
	2 & 5	35.77	48.53	140.09	2.4	337
	1 & 6	37.14	50.39	129.15	1.2	155
6	3 & 4	36.7	49.79	132.66	7.5	995
	2 & 5	37.38	50.71	127.23	2.4	306
	1 & 6	38.69	52.49	118.72	1.2	143
7	3 & 4	38.5	52.23	119.90	7.5	900
	2 & 5	39.14	53.10	115.93	1.2	140
	1 & 6	40.39	54.10	108.42	1.2	130

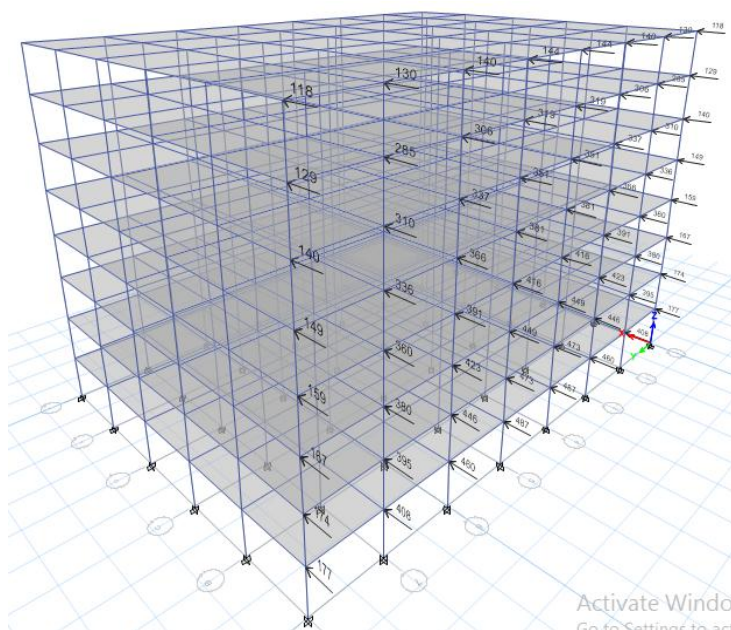


**Fig.-11:** Elevated view of bare frame deflected due to blast loading facing on 35m side

#### 4. RESULTS AND DISCUSSION



**Chart 1:** Storey displacement due to blast loading on 25m side



**Fig.-10:** Blast loading facing 35m side of bare frame

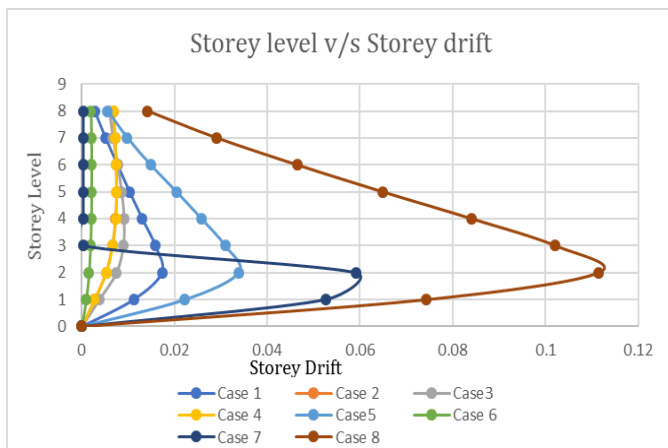


Chart 2: Storey drift due to blast loading on 25m side



Chart 3: Storey displacement due to blast loading on 35m side

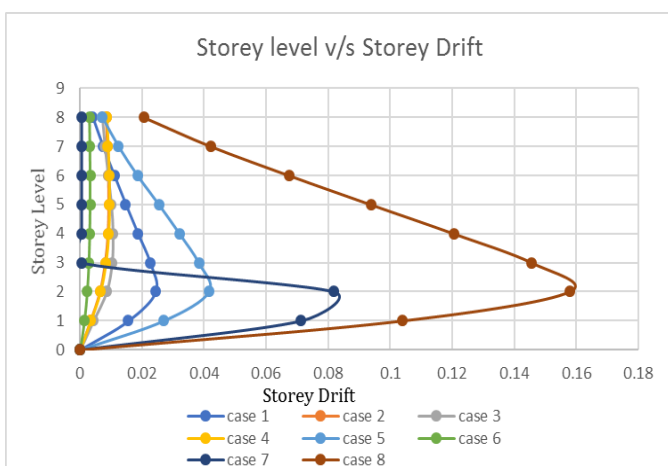


Chart 4: Storey drift due to blast loading on 35m side

Table 4: Members failed during Design

Case No.	Total no. of column	No. of column failed due to blast on 25m side	No. of column failed due to blast on 35m side
1	384	24	24
2	384	16	16
3	384	20	20
4	384	18	18
5	384	22	22
6	384	12	12
7	384	20	20
8	384	16	12

From the above results we know that as the area facing blast load increases the magnitude of blast wave increases. Chart 1 shows displacement behavior of building under blast loading, in which case 2 and case 4 coincides because their displacement is same even though there is difference in shear wall location. This proves shear wall provided at opposite side is of no use. The minimum displacement is of case 6 means model having shear wall provided at core having blast loading on 25m side is 44mm. Its displacement is minimum because shear wall at core provides rigidity to building and when exposed to blast the structure acts as a whole. The maximum displacement is of case 8 means model having brick infill at two opposite sides is 1573mm because exposed area is much more than bare frame. Chart 2 shows relation between drift and storey level due to blast loading. From the graph is clear that storey drift increases when source of detonation is close to structure, in graph first 2-3 floors showing more drift because source is much closer to them than any other. Storey drift is inversely proportional to standoff distance. Minimum drift is for case 7 which is 0.00042mm at top because this model contains brick infill at top 6 floors and bare at first two floors, top 6 floors act as rigid. Maximum drift occurs in case 8 because exposed area is large as compared to other cases.

Chart 3 shows relation between storey level and displacement when blast facing 35m side of building. According to result it was clear that there is major role played by exposed area. Here exposed area is much more than previous models; hence displacement is also more than previous models. Minimum displacement occurred at case 6 having shear wall at core is 68mm which is approximately 64 % higher than blast loading on 25m side. This also proves role of area in blast analysis. Maximum displacement observed in case 8 which is 2244mm because increase in exposed area. Chart 4 shows behavior of storey level and drift when blast loading on 35m side. Minimum drift at top for case 7 which is 0.000643mm and maximum for case 8 is 0.1578 at second floor because maximum blast loading occurs at first 2-3 floors.

The permissible limit for displacement is 4mm/m height of building. According to models total building height is 24m that means permissible limit for displacement is 96mm. All models fail in displacement criterion except shear walls provided at core which gives stability to building. Permissible limit for storey drift according to IS1893(part1):2016 is 0.004 times the storey height which is 12, all models are safe in drift criterion. While design in all models some of the column member fail. The location of these columns is mostly at ground floor. Because magnitude of blast loading is higher at ground floor and it decreases as move upwards. To make building blast resistant member sizes should be increased.

## 5. CONCLUSIONS

By considering literature available and results made from this thesis the following conclusions were made:

1. Magnitude of blast load increases as source of explosion close to structure and decreases as source moves away.
2. The displacement increases as the exposed area to blast loading increases. Area plays major role in blast load analysis.
3. Effect of blast load decreases due to provision of shear wall. Shear wall provides stability to building. When explosion occurs whole building acts as a rigid structure and abnormal effects on building reduces.
4. Location of shear wall in building also affects the overall behavior during analysis
5. Provision of shear wall on one side where blast load acting will not help to reduce blast effects.
6. Providing shear wall on 3 sides while blast analysis does not make any difference in displacement or drift. Thus, shear wall opposite to side facing blast load is of no use. But no one knows where will explosion take place so provision of shear wall at similar location will be beneficial always.
7. Provision of shear wall in core of building is very effective than any other location.
8. Buildings having no brick infill at first 1-2 floors are subjected to large displacement because upper floors act as a rigid structure and below floors may fail and that leads to progressive collapse of whole structure.

No one can predict when explosion takes place, how much quantity of explosive may use or how much is stand off distance. While designing building blast analysis should take into consideration to reduce losses. Shear wall should provide on effective location similarly. Provision of shear wall in building is also effective in seismic analysis.

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