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Analysis of Multi-Storey RC Building Subjected to Blast Load using Time History Method

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Abstract:- The impact of the blast load on the structure due to the increase of terrorist activities is a serious issue causing failure of the buildings and loss of life. Depending upon the location of blast within or nearby buildings the structure undergoes ravaging failure due to explosion. In the present study, G+5 storeyed building is subjected to 200, 400 and 600 kg charge weight of the blast load with a standoff distance of 20, 40 and 60m. IS:4991 – 1968 is used to determine the blast parameters. The time history analysis is carried out using ETABS 2016 software. The response of the structure is determined in terms of displacement v/s time, velocity v/s time and acceleration v/s time, storey drift, column forces and storey displacement. Depending on the source of the blast load and the charge weight of the explosive, response of the building and safe standoff distance is found. To make the building more resistible for blast load, various structural systems like shear wall and steel bracings are implemented.

Keywords:- *Blast load; Standoff distance; Charge Weight; ETABS 2016.*

I. INTRODUCTION

Due to the increase in terrorist and explosion activities and even the natural activities, their effect on the structure has become a serious issue which leads to damage of the structures, death of people and economical loss as well. An explosion is a chemical response that releases large amount of energy and hot gases consisting of loud sound and a bright flash. It occurs within a few seconds of duration resulting in release of high temperature and pressure. In many countries, considering blast effects in the structural analysis and other techniques are initiated in order to protect the structures and build environment. An explosion, depending on the occurrence of blast i.e., near or far from the structure, can cause ruinous damage to the internal or external frames of the structure. Thus, special care should be taken in designing the structures considering the blast load effect.

- *The classification of blast loads is done based on the confinement of explosives as two types;*

Confined Explosion and Unconfined Explosion. The confined explosion is further classified into three types depending on the area of confinement as Fully vented explosion, Partially vented or confined explosion and Fully confined explosion. There are three types of unconfined explosion based on the standoff distances as Air Blast, Free Air Blast and Surface Air Blast.

M.T.R Jayasinghe et al. (2010) studied the non-linear dynamic response of the tall buildings with and without setbacks. The 20 storey buildings is considered for the study which is designed for imposed load, dead load and wind load. Time history analysis is carried out using SAP 2000 for the buildings with 500kg charge weight of the blast. Storey drift, peak deflection, acceleration and bending moments are obtained. Great variations are observed in the response near the setback storey level due to the blast load. Placement of the shear wall in the face of the building effecting by the blast load improves the strength of the building decreasing the damage of the structure. Aditya C. Bhatt et al. (2013) have conducted a comparative study of four storey building subjected to both blast load and earthquake load using ETABS software. Linear time history method is carried out for the analysis. Displacement of the structure subjected to blast load is very high due to high intensity of blast load compared to the earthquake load and very high variation in different storeys. In case of structures subjected to earthquake load, displacement proportionally increases. Quantity of concrete used for EQ resisting building is 40% less than blast resisting building. Safe standoff distance and charge explosive for earthquake resistant RC building is obtained using trial and error method. Helen Santhi.M et al. (2013) have investigated the dynamic response of the space framed structure due to blast load. A type of fibre reinforced concrete (FRC) with high fibre content is used as an alternative of RCC which is SIFCON (Slurry Infiltrated Fibre Reinforced Concrete) having high strength, ductility and energy absorbing capacity. Using SAP2000 software the models are developed and time history analysis is carried out for blast load. The displacement time history response of the model with SIFCON and RCC was compared and the capacity of the SIFCON frame was observed to be better than RCC frame under blast load with the reduction in displacement of about 25 to 30%. A.V. Kulkarni and Sambireddy G, (2014) studied the response of the high rise building subjected to blast load. SAP 2000 software was used for the modelling of the building and to know the lateral stability of the building due to blast load. Two different charge weights of around 400kg and 800kg were considered with 5m and 10m standoff distances. Non-linear modal analysis was carried out to know the response of the building. The primary parameters obtained were total drift and inter-storey drift. The standoff distance and blast source point was the important parameter in the study. The building with irregular geometry showed maximum drift than the regular infill frame building. Jiji Madonna et al. (2016) have carried out the analysis of the high rise RCC building subjected to blast load. Both regular and irregular buildings are considered for the analysis with two different standoff distances and charge weight. The blast parameters are obtained using ATBlast software and the results are compared by using ETABS software. It is observed that the storey drift increases with the decrease in the standoff distance. The effect of the blast load is more in the lower storeys when compared to higher level storeys. The response of regular buildings is better than the irregular building against the blast load.

II. BLAST LOAD PHENOMENA AND INTERACTION

When the blast occurs at a location there will be a huge amount of hot gases released which is the compresses the surrounding gases and travels away from the blast source with higher velocity. The distance between the blast source point and the structure is called as the standoff distance. As the blast wave travels away from the blast source the pressure or the intensity of the wave goes on reducing and due to this the effect on the building with higher standoff distance will be less and the time duration required to reach the building is reduced. The Fig.1 shows the blast wave propagation curves depending on the pressure and distance from the explosion or the blast source.

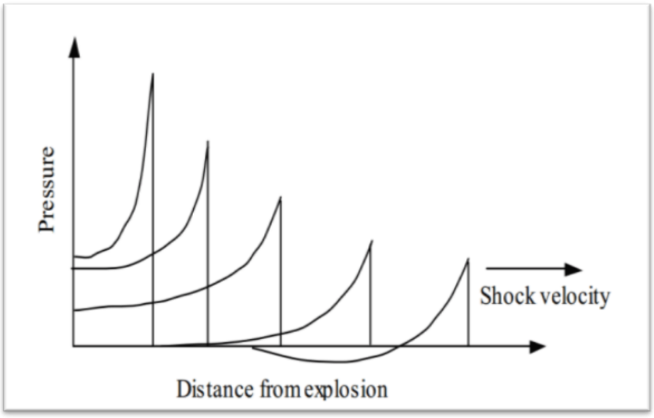

Fig. 1:- Blast Wave Propagation

A blast wave generated during an explosion spreads through the surrounding air and due to which a shock front or wave is created. This shock wave created surround the entire building subjected to blast pressure.

The factors affecting the blast load are the material type, weight of the explosive, amount of the energy released during the blast, distance between the detonation point and the structure called as standoff distance and intensity of the pressure released. The Fig.2 below shows the interaction of blast wave with the building.

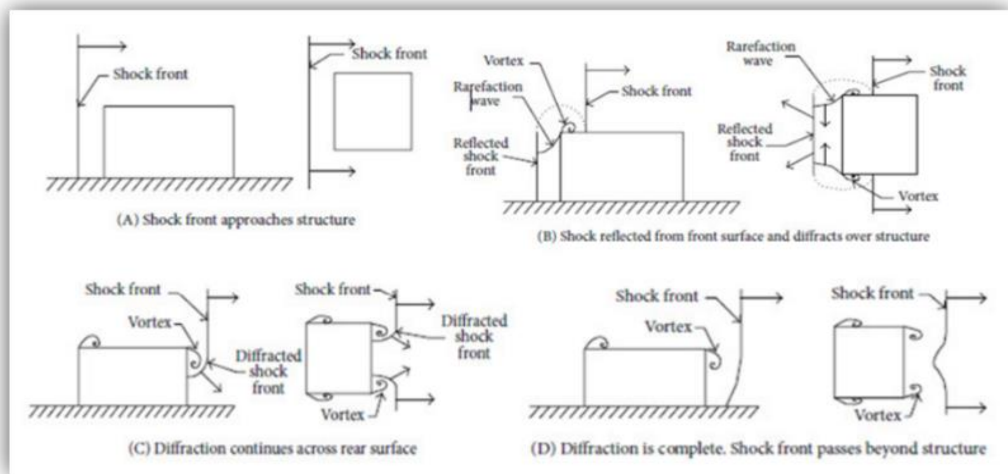

Fig. 2:- Interaction of blast wave with building

2.1 Typical Blast wave Pressure-Time history curve

Fig. 3 shows the typical blast wave pressure-time history curve. Initially, when the explosion takes place during the arrival time of the blast wave, the pressure present in the surrounding is equivalent to the Ambient pressure (Po) and then it suddenly rises to Peak pressure (Pso) in the fraction of second which is in the time (tA) when blast wave reaches the structure. To achieve the peak pressure the time required is very small and thus it is taken as zero during the design. This peak pressure is also called as side-on overpressure and it decreases with the increase in the standoff distance from the blast source. And this eventually becomes equal to the ambient pressure with time duration (tA + to + to) which is called as negative phase duration which is longer than the positive phase duration. During this negative phase duration, the building or the structure is subjected to suction forces which results in failure of façade of the building such as glass segments or windows lying outside the building. This negative phase of the curve is neglected during the design as its effect on the structure is less when compared to the positive phase of the pressure time history.

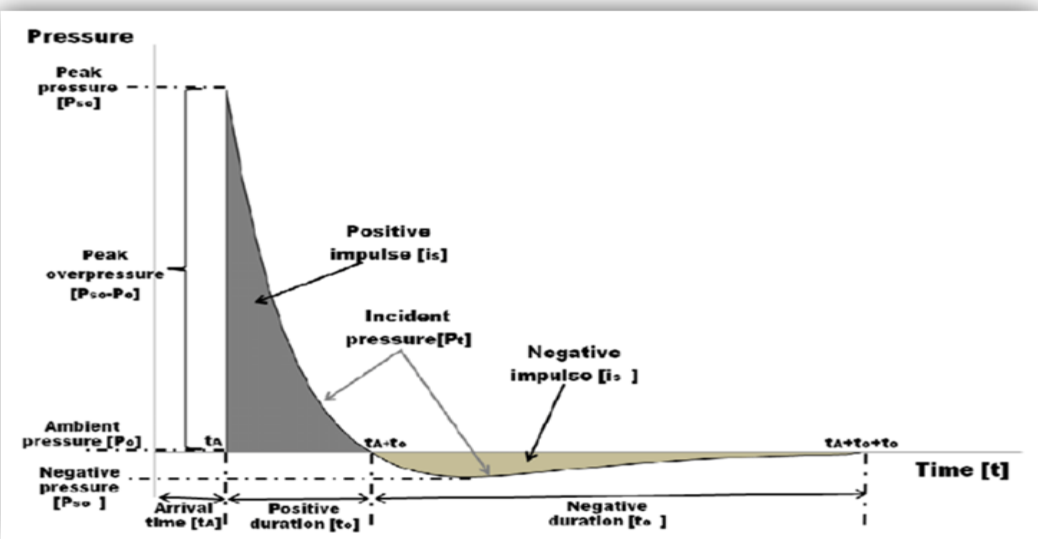

Fig. 3:- Pressure-Time History Curve

III. METHODOLOGY

In the present study, six storey RCC building is considered and is subjected to surface blast of 200kg, 400kg and 600kg charge weight of explosive. The building is having a plan dimension of 14 x 14 m with bottom storey height as 3.5m and typical storey height of 3m each. It is analyzed using ETABS software for different standoff distances of 20m, 40m and 60m from the front face of the building. The peak reflected overpressure obtained from IS:4991-1968 is multiplied with the tributary area and this blast load is applied as the joint load on the joints of the front face of the building in the 'x' direction and time history method is carried out. The safe standoff distance is determined at which the effect of blast reduces by trial and error method. The response of the building with blast source of varying distances is determined by creating different models to obtain efficient blast resistant system.

Model: X and Y direction = 4 bays, 2 bays spaced 4m and other 2 spaced 3m
Material Properties: Density of concrete = 25 kN/m3, Density of steel = 78.5 kN/m3
Grade of concrete = M30, Grade of rebar (steel) = Fe500
Sectional Properties: Beam = 300mm × 450mm, Column = 450mm × 450mm and Slab = 150mm
General loading: Live load (IS 875, part 2) = 3 kN/m2 (floor) and 1.5 kN/m2 (roof)
Floor finish load = 1 kN/m2, Water proofing (roof) = 1.5 kN/m2

The validation of the ETABS software is been carried by doing seismic analysis of the G+5 storey building taken for the study. The storey shear and base shear obtained by the end of the analysis in the software is compared with the values obtained by manual calculation and table it is seen that the ETABS software values of base shear and storey shear agree with the theoretical values with a slight marginal error of 2.02% which is acceptable. Thus, the further work of the project is carried out using ETABS 2016 software.

Fig. 4 and 5 below shows the 3D view and plan respectively of the building considered for the study.

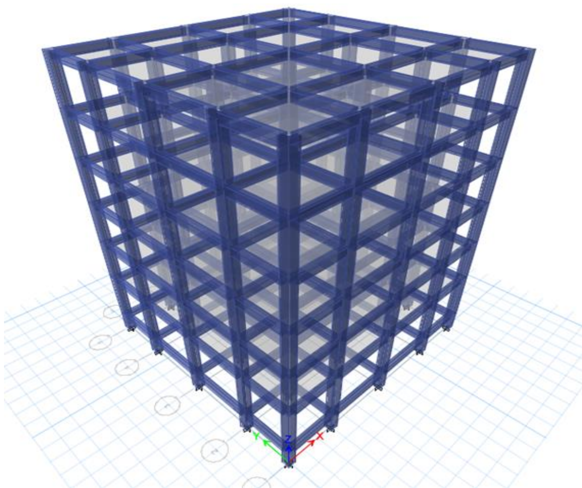

Fig. 4:- 3D view of building

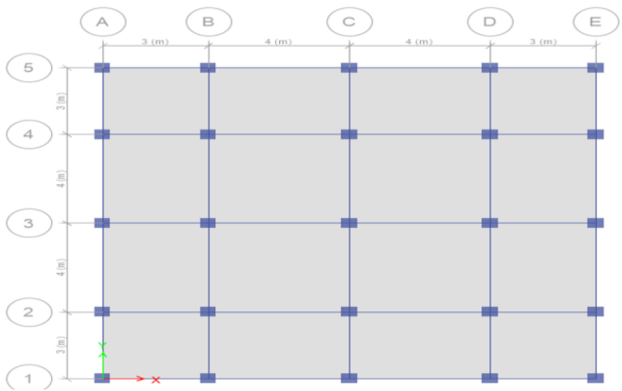

Fig. 5:- Plan of building

Joint	F.L	Z (20m)	Z (40m)	Z (60m)	P (20m)	P (40m)	P (60m)	A m^2	F (20m)	F (40m)	F (60m)
1	GL	34.2	68.4	102.6	317	73	38.8	7.00	2219	511	271.6
2 & 4		34.9	68.7	102.8	300	72.5	38.7	6.13	1839	444.4	237.2
3 & 5		36.2	69.4	103.3	271.8	71.3	38.5	2.63	714.8	187.5	101.3
1	1	34.7	68.7	102.8	305	72.5	38.7	13.0	3965	942.5	503.1
2 & 4		35.4	68.9	102.9	289	72.2	38.7	11.38	3288.8	821.6	440.4
3 & 5		36.7	69.7	103.5	264	70.8	38.5	4.88	1288.3	345.5	187.9
1	2	36.0	69.3	103.2	275	71.5	38.6	12.0	3300	858	463.2
2 & 4		36.6	69.6	103.4	265.6	71	38.5	10.5	2788.8	745.5	404.3
3 & 5		37.9	70.3	103.8	245	69.8	38.4	4.50	1102.5	314.1	172.8
1	3	37.9	70.3	103.8	245	69.8	38.4	12.0	2940	837.6	460.8
2 & 4		38.5	70.6	104.1	235.8	69.3	38.3	10.5	2475.9	727.7	402.2
3 & 5		39.7	71.3	104.6	220.7	68.1	38.1	4.50	993.15	306.5	171.5
1	4	40.3	71.6	104.8	214.5	67.6	38.1	12.0	2574	811.2	457.2
2 & 4		40.9	71.9	105.0	208.3	67.2	38.0	10.5	2187.2	705.6	399
3 & 5		42.1	72.7	105.5	195.9	65.8	37.8	4.50	881.55	296.1	170.1
1	5	43.3	73.4	105.9	183.5	64.6	37.7	12.0	2202	775.2	452.4
2 & 4		43.8	73.7	106.2	178.4	64.1	37.6	10.5	1873.2	673.1	394.8
3 & 5		44.9	74.3	106.6	167	63.1	37.5	4.50	751.5	284.0	168.8
1	6	46.6	75.4	107.4	155.3	61.4	37.2	6.00	931.8	368.4	223.2
2 & 4		47.1	75.7	107.6	152	61.0	37.1	5.25	798	320.3	194.8
3 & 5		48.1	76.3	108.0	145.4	60.2	37.0	2.25	327.2	135.5	83.3

Table 1:- Pressure and Joint load acting on the front face of the building due to explosive weight of 200kg at 20m, 40m and 60m standoff distance

Joint	F.L	Z (20m)	Z (40m)	Z (60m)	P (20m)	P (40m)	P (60m)	A m^2	F (20m)	F (40m)	F (60m)
1	GL	27.14	54.3	81.4	573	112.7	54.7	7.00	4011	788.9	382.9
2 & 4		27.7	54.6	81.6	543.4	111.4	54.6	6.13	3331	682.9	334.7
3 & 5		28.8	55.1	82.0	484.4	109.2	54.3	2.63	1274	287.2	142.8
1	1	27.6	54.5	81.6	548.8	111.8	54.6	13.0	7134.4	1453	709.8
2 & 4		28.1	54.8	81.7	521.9	110.5	54.5	11.38	5939.2	1257	620.2
3 & 5		29.1	55.3	82.1	468.3	108.4	54.2	4.88	2285.3	528.9	264.5
1	2	28.9	55.0	82.0	479	109.6	54.3	12.0	5748	1315	651.6
2 & 4		29.1	55.3	82.1	468.3	108.4	54.2	10.5	4917.2	1138	569.1
3 & 5		30.1	55.8	82.5	417.5	106.2	54	4.50	1878.8	477.9	243
1	3	30.0	55.8	82.5	420	106.2	54	12.0	5040	1274	648
2 & 4		30.5	56.1	82.6	407.5	104.9	53.9	10.5	4278.8	1101	565.9
3 & 5		31.5	56.6	83.0	382.5	102.7	53.6	4.50	1721.3	462.1	241.2
1	4	32.0	56.9	83.2	370	101.4	53.5	12.0	4440	1216	522
2 & 4		32.5	57.1	83.4	357.5	100.7	53.4	10.5	3753.8	1057	560.7
3 & 5		33.4	57.7	83.7	335.6	99.1	53.2	4.50	1510.2	445.9	239.4
1	5	34.3	58.2	84.1	314.6	97.8	52.9	12.0	3775.2	1173	634.8
2 & 4		34.8	58.5	84.3	303	97	52.7	10.5	3181.5	1018	553.4
3 & 5		35.6	59.0	84.6	284.3	95.6	52.4	4.50	1279.4	430.2	235.8
1	6	37.0	59.8	85.2	259.3	93.5	51.8	6.00	1555.8	561	310.8
2 & 4		37.4	60.1	85.4	253	92.7	51.6	5.25	1328.3	486.6	270.9
3 & 5		38.2	60.6	85.7	240.5	91.4	51.3	2.25	541.2	205.6	115.4

Table 2:- Pressure and Joint load acting on the front face of the building due to explosive weight of 400kg at 20m, 40m and 60m standoff distance

Similarly, Joint load, F acting on the building is calculated for charge weight of 600kg with 20m, 40m and 60m standoff distances.

IV. RESULTS AND DISCUSSION

The behavior of the building subjected to blast load acting on the front face of the building with various charge weight and standoff distances is discussed in this chapter. The response of the building is obtained as storey displacement, storey drift, joint displacement v/s time, joint velocity v/s time, joint acceleration v/s time and column forces. These results extracted are tabulated and discussed as shown below.

From Fig. 6 it is observed that when the blast source is nearer to the building the displacement is more. Thus, as the blast source point or standoff distance decreases and charge weight increases, the storey displacement in the building also increases.

Fig. 7 of storey drift, it is seen that the drift increases when blast source is closer to the building. Thus, it can be said that the drift is inversely proportional to the standoff distance and directly proportional to the charge weight of the blast. And it is noticed that drift is greater in lower storeys when compared to the higher storeys.

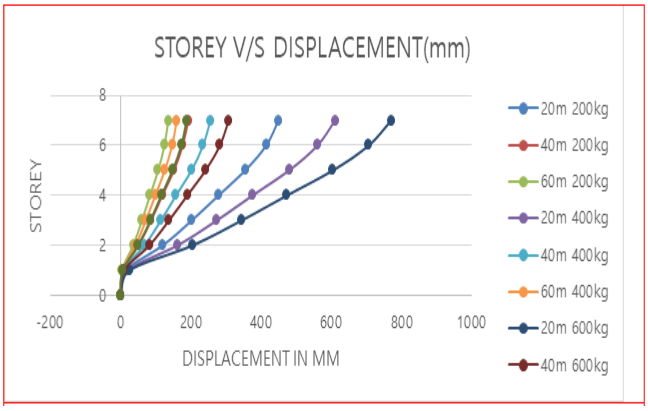

Fig. 6:- Displacement of the building along the storey

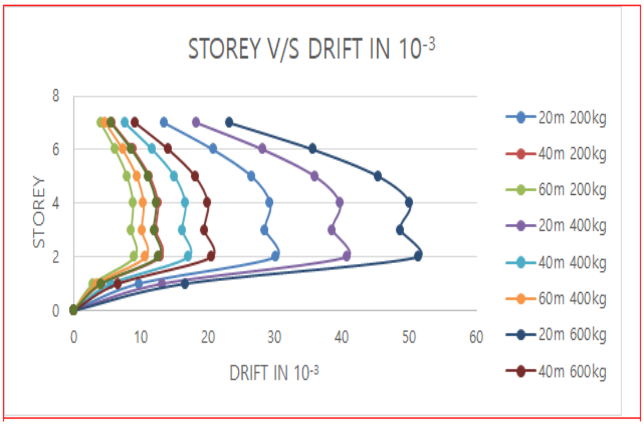

Fig. 7:- Drift of the building along the storey in 10-3

The response of the building in terms of joint displacement, velocity and acceleration is obtained when the building is subjected to the blast load of different charge weight with varying standoff distances. The following Figures 8, 9 and 10 represents the plot of joint displacement (mm) verses time (sec), joint velocity (m/sec) verses time (sec) and joint acceleration (m/sec^2) verses time (sec) respectively.

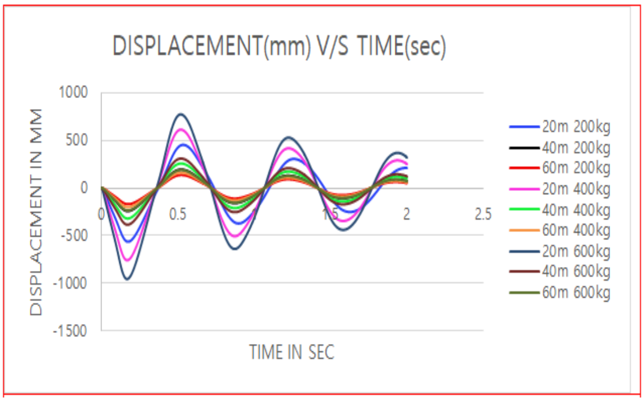

Fig. 8:- Joint Displacement(mm) v/s time(sec) plot

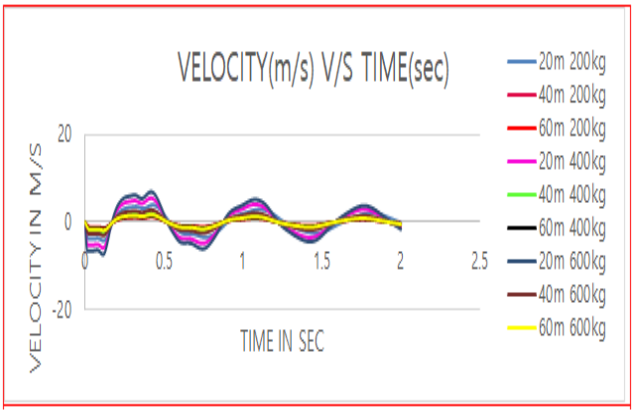

Fig. 9:- Joint Velocity(m/s) v/s time(sec) plot

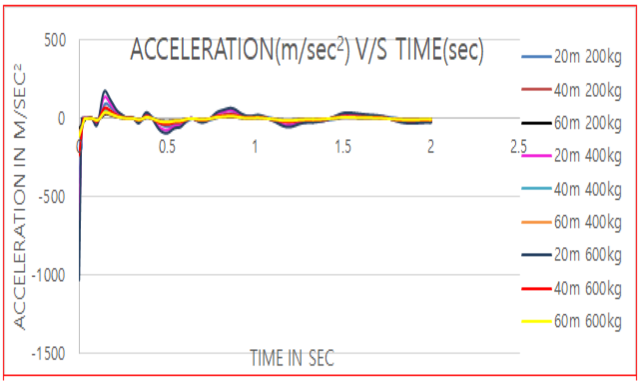

Fig. 10:- Joint Acceleration(m/s2) v/s time(sec) plot

The following table 3 shows the comparison of the above three graphs of joint displacement, velocity and acceleration with respect to time.

Response	200kg			400kg			600kg		
	20m	40m	60m	20m	40m	60m	20m	40m	60m
Displacement in mm	452.158	192.994	136.067	611.232	256.298	160.144	771.334	308.268	188.441
Velocity in m/s	3.94	1.75	1.24	5.47	2.32	1.46	6.9	2.78	1.71
Acceleration in m/s^2	96.55	43.45	30.27	139.52	57.83	36.08	176.87	69.77	42.43

Table 3:- Comparison of joint displacement, velocity and acceleration of the building subjected to various charge weight and standoff distances

In order to make the building as blast resisting structure, various structural system such as shear wall and steel bracings are provided at the corner periphery of the building.

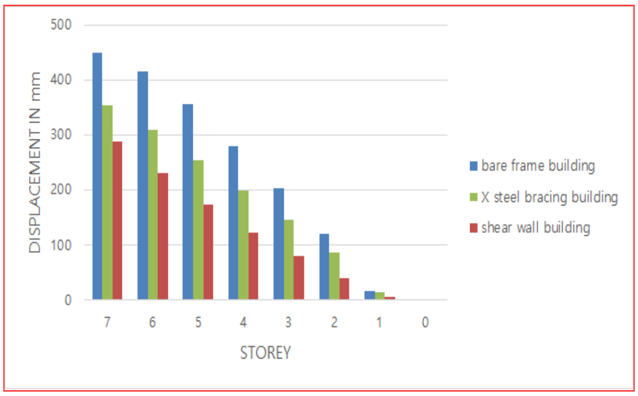

Fig. 11:- Storey displacement of bare frame building, building with corner shear wall and steel bracings

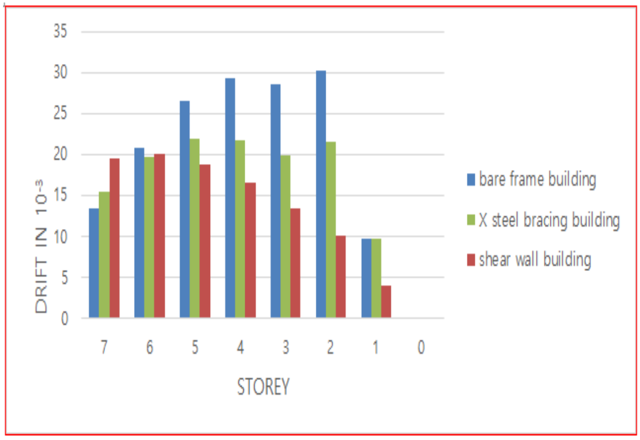

Fig. 12:- Storey Drift of bare frame building, building with corner shear wall and steel bracings

From Fig.11 and 12, it is observed that the displacement and drift in the building with shear wall and steel bracings is less than conventional bare frame building.

The building with corner shear wall reduces the displacement and drift by 53.51% and 30.04% respectively when compared with bare frame building and the building with corner X steel bracings reduces displacement and drift by 23.6% and 13% respectively when compared with bare frame building.

Thus, it can be concluded that implementation of shear wall is more effective in the building against blast load when compared with bare frame building and corner X steel bracing building.

V. CONCLUSIONS

- From the results obtained of the buildings subjected to blast load with various charge weight and standoff distances, it shows that the storey displacement, storey drift and column forces are high when blast source point is at 20m distance from front face of the building.
- The response of the building in terms of displacement and drift is more when standoff distance and charge weight of blast is less. Thus, it can be said that the response is inversely proportional to the standoff distance and charge weight.
- The safe standoff distance for the building is chosen as 60m.
- Implementation of shear wall at the corner periphery of the building reduces the storey displacement and drift by 53.51% and 30.04% respectively compared to bare frame building.
- Implementation of X steel bracings at the corner periphery of the building reduces the storey displacement and drift by 23.6% and 13% respectively compared to bare frame building.
- Thus, the building is more resistible for the blast load with shear wall and steel bracing implementation.

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