THE STUDY OF EFFECT OF BLAST LOAD ON MULTI-STOREY BUILDING BY USING TIME HISTORY METHOD

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Abstract – *Due to increase in terrorist activities resulting in impact of blast load on the structure is a serious issue which may cause failure of buildings, collapse and loss of life. Due to explosion leads to catastrophic failure on the buildings depending on the presence of blast within or immediately nearby buildings. In the present study, G+4 storey RCC building is subjected 100, 300 and 500kg charge weight of blast load with a standoff distance 30, 40 and 50m. The blast parameters such as peak reflected over pressure, positive phase duration are determined by IS: 4991-1968. The nonlinear time history analysis is carried out by using ETABS 2016. 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, beam forces, column forces and storey displacement. When the blast source is nearer and charge weight of the explosive is more in such case the building was found to be very critical.*

Key Words: *Blast load, Standoff distance, Charge weight, ETABS 2016*

1. INTRODUCTION

An explosion is a chemical reaction and quick release of stored energy consists of bright flash and a loud noise, it takes place within a few seconds which results in very high release of temperature and pressure. The terrorists activities such as bomb blasts on the Murrah Fedral building which is located in Oklahama city (1995) with a magnitude of blast load of 33.1 tonne of TNT, the building of World Trade Centre located in New York (1993) with a magnitude of blast load of 0.6 ton of TNT and the building of US Embassies located in Nairobi (1998) these incidents shows the inevitability of detailed analysis of performance of structures subjected to explosion and also to find the safety for the life of the people and structures from the explosions. After the effect on the WTC on September 11th 2001, it was understood that the metropolitan cities where the population will be high there the terrorist activities will be more. Due to the explosion in and around the structure causes disasters damage such as collapse of internal and external load bearing frames, blowing out of large expanse of windows, debris impact, fire, smoke etc., Thus it is very essential to consider the phenomenon of blast and its effect while designing of structure.

Quazi Kashif et.al 2014[7] carried the study on effect of blast on RCC building. In this study reinforced concrete building G+4 storeys having symmetrical structure 4m of 3 bays along both in x and y direction and height of the storey kept as 3m each. It is subjected to blast load of 100kg and 500kg at a stand-off distance of 30m. Here by using IS: 4991-1968 blast load is computed and nonlinear dynamic analysis is conducted by using SAP-2000. From the dynamic nonlinear analysis results it is observed that variation of displacement is non uniform along different storey level of the building. And also observed that the performance of the building is more when explosive of 100kg at a 30m standoff distance than compared to an explosive of 500kg at a 30m standoff distance. Blast analysis and design should be carried for the important structures keeping in view of terrorist activities in the current scenario. Aditya C. Bhatt et.al 2016[1] conducted the study on effect of blast load on building considering the surface explosion and compared with the earthquake load. In this study RCC building of G+3 storey 100kg of explosive 21m standoff distance is considered for the analysis. For the structural dynamic analysis. As per IS: 4991-1968 magnitude of load and positive phase time duration due to blast is calculated. Form the results it is observed that due to blasts the storey displacement is more than the same for earth quake and displacements in storey 1st and 2nd is higher when compared with the other storey level. Whereas in earthquake load displacement increases proportionally. Storey drift is a critical parameter, for earth quake storey drifts comes out to be well within permissible limit as code specified whereas in the case of blast load especially on the storeys where blast load is applied exceeds the permissible limit. Here quantity of concrete required for blast resistant building is around 40% more than the earth quake resistant building. The safe standoff distance is 31.5m for charge weight of 0.1 tonne TNT for the earth quake resistant building. Osman Shallan et.al 2014[6] carried the study on response of building structures to blast properties. FE package AUTODYNE is used to know behavior of the structure. In this study effect of blast load is considered for 3 types of buildings. In the first building it consists of two storey having an Aspect Ratio of 0.5 (D=6m, L=3m) & standoff distance is taken as 1.5,3,6 & 9m. In the second building it consists of two storey having an Aspect Ratio of 1(D=6m, L=6m) & standoff distance is taken as above. And for the third building it consists of two storey having an Aspect Ratio of 1.5 (D=6m, L=9m) & standoff distance is taken as above. In the results the Temperature, Reflected over pressure at different points of building increases due to decrease in standoff distance. At standoff distance 1.5m from the blast load it causes total failure of the column in face of the blast load and due to failure fragments move 1.6m away from column. Due to the variation in Aspect Ratio there is no variation in the displacement of the columns. Muhammed

Hasil et.al 2016[5] conducted the study of response of blast load on RC building. In this study he considered four different models using ETABS 2016 such as Shear wall and steel bracings. Dimensions of the building taken as 3.5m width of 4 bay in both the direction. In the results we observe that the distance between the detonation points from the building decreases the value of blast load increases therefore the response of the structure is mainly dependent on standoff distance. To improve the blast resistance of the column and beam size needed to be increase but in practical it is not possible because of serviceability problems since it requires huge cross section to with stand the blast loads. By providing shear wall to the building helps to resists the blast load very effectively than providing the steel bracings and also it is very economical when compared to other methods. Jayshree S. M. et.al 2013[3] carried out the study of dynamic behavior of space framed building due to the explosion load. SIFCON (Slurry Infiltrated Fiber reinforced Concrete) is used, it can be considered as a replacement of RCC as it is a fiber. Since SIFCON has more energy, high capacity of energy absorption and high ductility. The model is generated and nonlinear time history is done using SAP 2000. In the results it is seen that SIFCON frame has better overall dynamic response than that of RCC frame. The displacement is reduced to about 25-30% is obtained in SIFCON frame hence capacity of the SIFCON against blast load is more than that of conventional RCC.

By the department of army in 1960's started an analytical study of structures subject to blast. A technical guide was released by Department of United States army in the year 1959 and later this manual was revised in the year 1990 as technical manual 5-1300 at it was used for the designing structures by the civilian association and military association to avoid the explosive wave propagation, to protect valuable equipment and people life.

2. CLASSIFICATION OF EXPLOSION

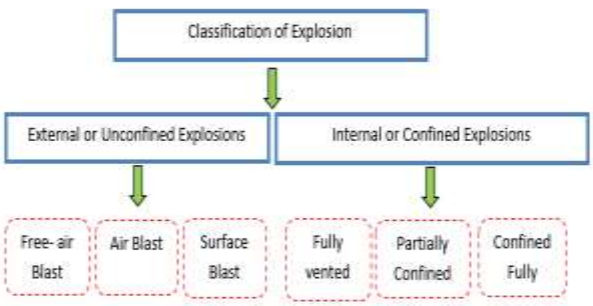

Figure -1: Different types of explosion

3. BLAST LOAD PHENOMENA AND INTERACTION

During blast, an enormous amount of energy in the form of hot gases is released which causes condensation or compression of surrounding gases results in expansion of gases released. This compressed or condensed air is called as blast wave which travels away from the point of blast source (detonation point). As the distance from the point of blast increases the intensity of pressure decreases and time required to reach the building increases. In the fig 2 shows the phenomenon blast wave propagation.

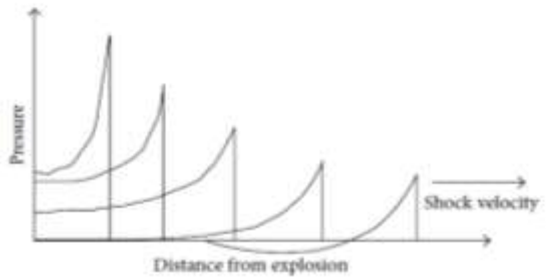

Figure -2: Phenomenon of blast wave propagation

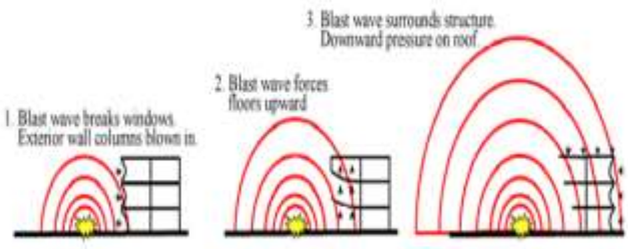

Figure -3: Blast wave interaction

During an explosion, the blast wave generated will spread through the surrounding air and as a result shock front or a wave is formed. The shock front will surround the entire building or structure due this entire structure is subjected to blast pressure. The factors influencing the effect of blast load are Explosives i.e., material type, explosive weight and the amount of energy released during blast, Standoff distances i.e., the relative distance between the structure and the source of blast and Intensity of Pressure.

4. CHARACTERISTICS OF IDEAL BLAST WAVE AND PRESSURE TIME HISTORY CURVE

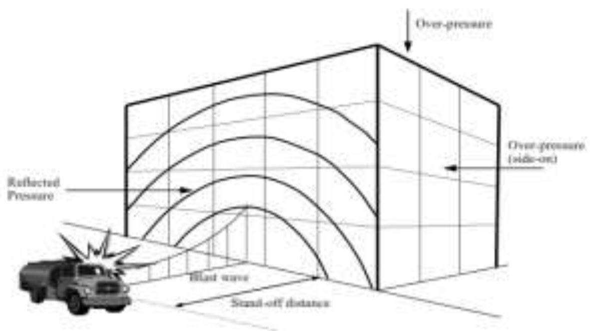

Figure -4: Blast loads on building

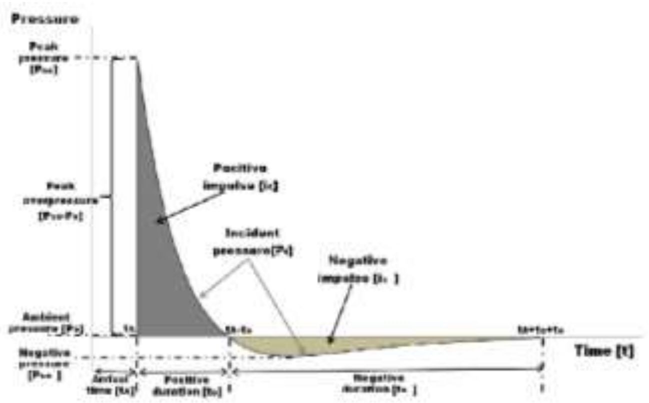

Figure -5: Pressure time history curve

Fig 5 gives the idealized curve (Pressure v/s time) occurred during open air blast arrived at a particular distance from the source of blast. Initially, pressure which is present at the surrounding of the structure is equivalent to ambient pressure (P_o) and then it suddenly rises to peak pressure (P_{so}) at an instance (t_A) when the blast wave reaches the point. The time required to achieve peak pressure is very small and hence, it is considered as zero during design. The peak pressure is also stated as side on over pressure. The velocity and side on overpressure of shock wave decreases with increase in standoff distance from the point of blast. Later, it is found that peak over pressure will decreases exponentially with time and reaches ambient pressure at a time equal to $t_A+t_o+t_o$ and this referred as negative phase duration. The negative phase duration is longer than positive phase duration. During negative phase, the structures are subjected to suction forces which results in failure of glass fragments lying outside the building i.e., failure of facades. For the design purpose, negative phase of ideal curve is neglected because the impact on the integrity of the structure is less when compared to positive phase of the pressure time history.

5. METHODOLOGY

In the current study, G+4 storey RCC building subjected to surface blast of 100,300 and 500kg charge weight of explosive having a plan dimension of 18m X 18m with bottom storey height as 3.5m and remaining all storey heights as 3m each is considered for the study. The building is analyzed for different standoff distance of 30, 40 and 50m from the front face of the building using ETABS 2016. The blast load parameters are computed as per IS: 4991-1968 and the blast load is multiplied with its tributary area and these pressures are applied as a joint load on the front face of the building i.e. in the direction of 'x' and pressure time history method is carried out.

Table -1: Description of model

Plan	18m X 18m
X- Direction	4 bays, 2bays spaced 4m and other 2 spaced 5m.
Y- Direction	4 bays, 2bays spaced 4m and other 2 spaced 5m.
Number of storeys	G+4
Height of bottom storey	3.5m
Height of other storey	3m
Column	300mm X 450mm
Beam	300mm X 450mm

Table -2: Properties of material considered

Grade of concrete	M25
Grade of rebar	Fe500
Density of concrete	25 kN/m³
Density of steel	78.5kN/m³
Poisson's Ratio	0.2

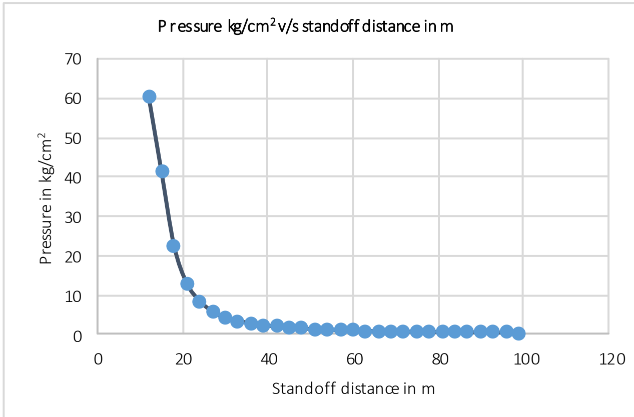

Figure -6: Graph showing Pressure in kg/cm² v/s standoff distance in m

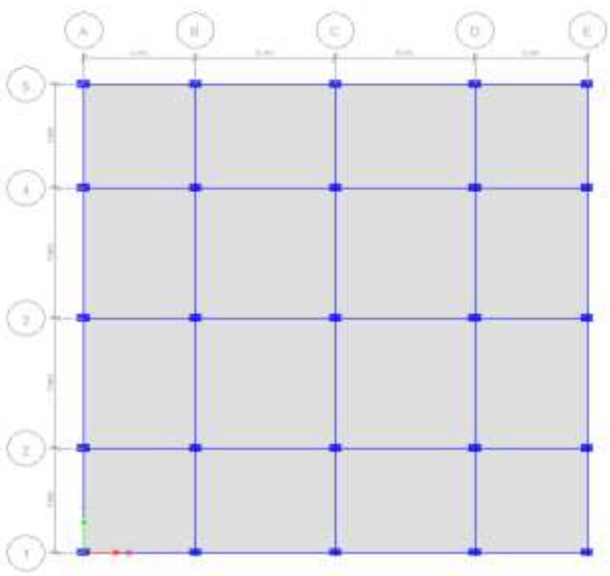

Figure -7: Plan view of model

Table -3: Pressure and the joint load acting on the front face of the building acting at 30m at a charge weight of 100kg

Joint	FL	R in m	Z in m	P in kN/m2	A in m2	F in kN
1	GL	30.00	64.6	80.6	8.8	706
2 & 4		30.41	65.5	78.3	7.9	616
3 & 5		31.32	67.5	74.5	3.5	261
1	1	30.20	65.1	79.5	16.3	1291
2 & 4		30.61	66.0	77.1	14.6	1128
3 & 5		31.52	67.9	73.8	6.5	480
1	2	30.70	66.1	76.8	15.0	1152
2 & 4		31.10	67.0	75.3	13.5	1017
3 & 5		31.99	68.9	72.1	6.0	433
1	3	31.47	67.8	74.0	15.0	1110
2 & 4		31.86	68.6	72.6	13.5	980
3 & 5		32.73	70.5	69.5	6.0	417
1	4	32.50	70.0	70.3	15.0	1055
2 & 4		32.88	70.8	68.9	13.5	931
3 & 5		33.72	72.7	65.9	6.0	395
1	5	33.77	72.8	65.7	7.5	493
2 & 4		34.14	73.5	64.4	6.8	435
3 & 5		34.95	75.3	61.6	3.0	185

Table -4: Pressure and the joint load acting on the front face of the building acting at 40m at a charge weight of 100kg

Joint	FL	R in m	Z in m	P in kN/m2	A in m2	F in kN
1	GL	40.31	86.2	50.8	8.8	445
2 & 4		41.00	86.8	50.2	7.9	395
3 & 5		40.15	88.3	48.7	3.5	170
1	1	40.46	86.5	50.5	16.3	821
2 & 4		41.15	87.2	49.8	14.6	729
3 & 5		40.52	88.7	48.3	6.5	314
1	2	40.83	87.3	49.7	15.0	745
2 & 4		41.51	88.0	49.0	13.5	662
3 & 5		41.11	89.4	47.6	6.0	285
1	3	41.42	88.6	48.4	15.0	726
2 & 4		42.09	89.2	47.8	13.5	645
3 & 5		41.91	90.7	46.1	6.0	277
1	4	42.20	90.3	46.6	15.0	699
2 & 4		42.86	90.9	45.8	13.5	618
3 & 5		42.90	92.3	43.9	6.0	263
1	5	43.19	92.4	43.8	7.5	328
2 & 4		43.83	93.0	43.0	6.8	290
3 & 5		46.91	94.4	42.0	3.0	126

Table 5: Pressure and the joint load acting on the front face of the building acting at 50m at a charge weight of 100kg

Joint	FL	R in m	Z in m	P in kN/m2	A in m2	F in kN
1	GL	50.25	107.7	37.1	8.8	325
2 & 4		50.80	108.3	36.9	7.9	291
3 & 5		50.09	109.5	36.5	3.5	128
1	1	50.34	107.9	37.0	16.3	602
2 & 4		50.89	108.5	36.8	14.6	539
3 & 5		50.36	109.6	36.5	6.5	237
1	2	50.61	108.5	36.8	15.0	553
2 & 4		51.16	109.0	36.7	13.5	495
3 & 5		50.80	110.2	36.3	6.0	218
1	3	51.05	109.5	36.5	15.0	548
2 & 4		51.59	110.0	36.3	13.5	491
3 & 5		51.42	111.2	35.9	6.0	216
1	4	51.66	110.8	36.1	15.0	541
2 & 4		52.20	111.3	35.9	13.5	485
3 & 5		52.20	112.5	35.5	6.0	213
1	5	52.44	112.5	35.5	7.5	266
2 & 4		52.97	113.0	35.3	6.8	239
3 & 5		55.46	114.1	35.0	3.0	105

Similarly for 300 and 500kg charge weight of explosive with a standoff distance 30, 40 and 50m pressure and the joint load acting on the front face of the building is calculated.

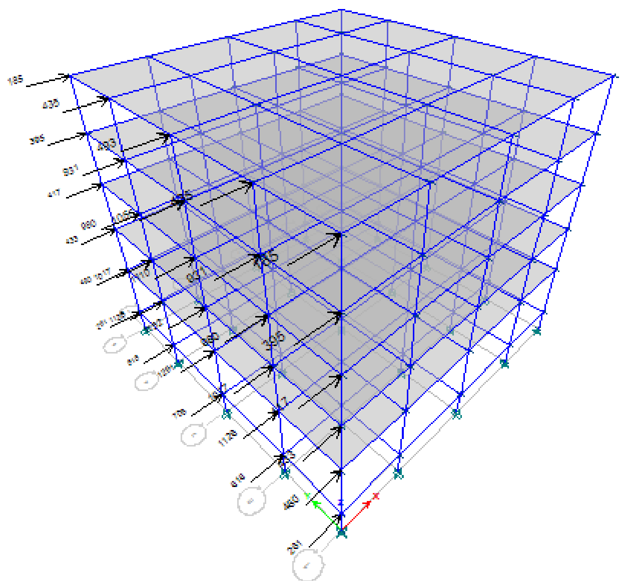

Figure -8: Blast Load applied as joint load when the 100kg blast located at a standoff distance of 30m.

6. RESULTS AND DISCUSSIONS

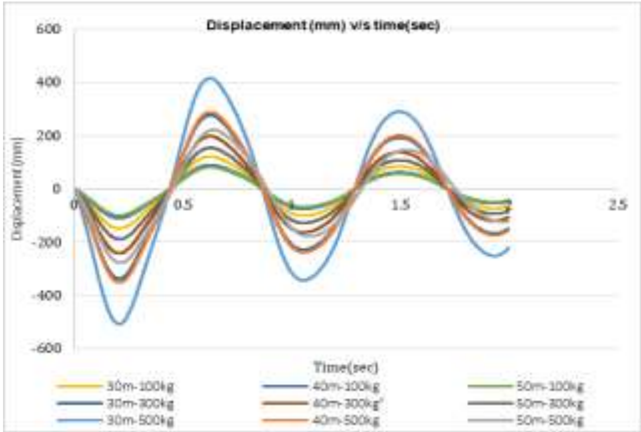

Figure -9: Comparison of displacement v/s time for various cases of standoff distances with varying charge weight of explosive.

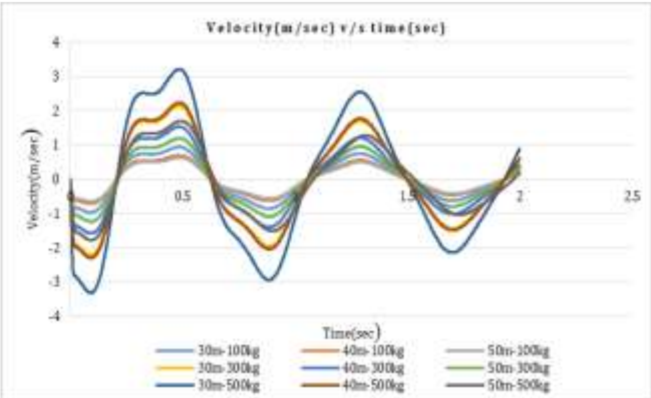

Figure -10: Comparison of velocity v/s time for various cases of standoff distances with varying charge weight of explosive.

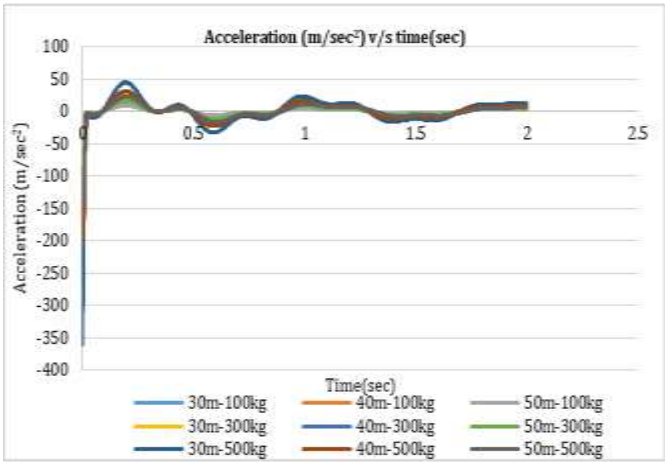

Figure -11: Comparison of displacement v/s time for various cases of standoff distances with varying charge weight of explosive.

Table -6: Response for 100kg of Charge weight of explosive

Response	Standoff Distance		
	30m	40m	50m
Displacement mm	121.89	90.16	82.35
Velocity m/sec	0.96	0.71	0.46
Acceleration m/sec2	120.4	78.56	51.84

Table -7: Response for 300kg of Charge weight of explosive

Response	Standoff Distance		
	30m	40m	50m
Displacement mm	280.00	198.39	154.75
Velocity m/sec	2.2	1.57	1.22
Acceleration m/sec2	247.85	145.38	99.23

Table -8: Response for 500kg of Charge weight of explosive

Response	Standoff Distance		
	30m	40m	50m
Displacement mm	416.66	287.83	223.47
Velocity m/sec	3.3	2.29	1.78
Acceleration m/sec2	360.39	202.33	134.15

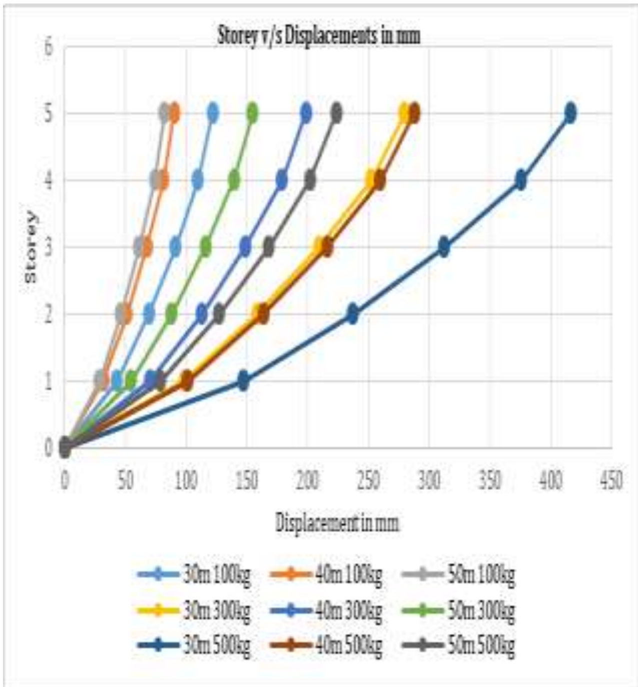

Figure -12: Comparison of displacement along the storey for various cases of standoff distances with varying charge weight of explosive

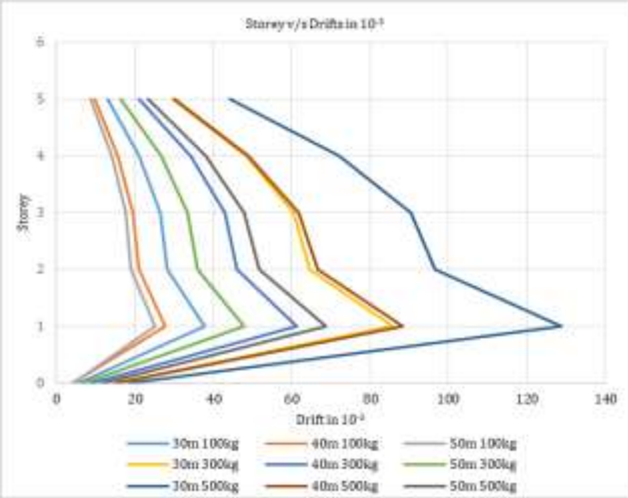

Figure 13: Comparison of storey drifts for various charge weight and for various standoff distance

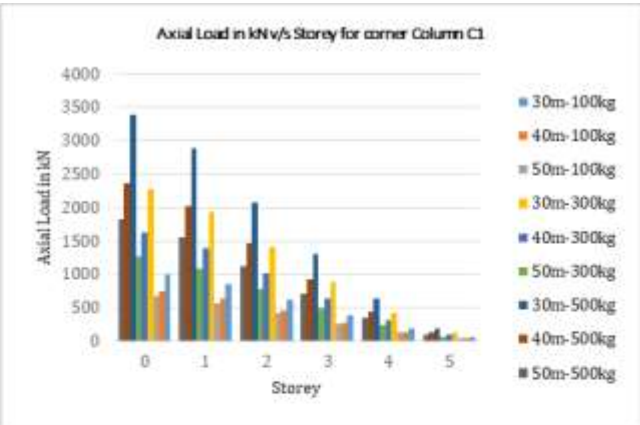

Figure -14: Variation of axial load at corner column for various cases of standoff distance and charge weight

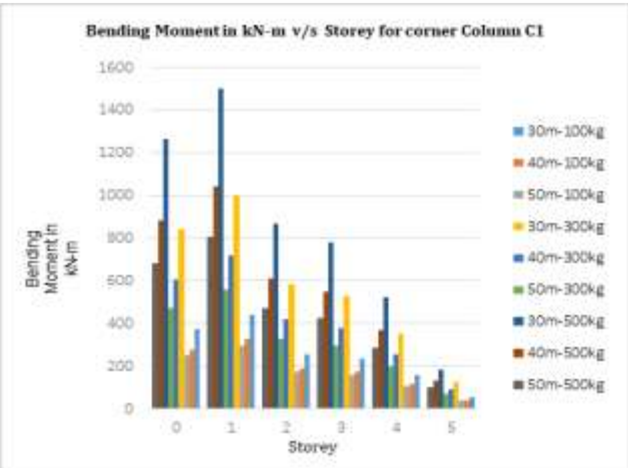

Figure -15: Variation of bending moment at corner column for various cases of standoff distance and charge weight

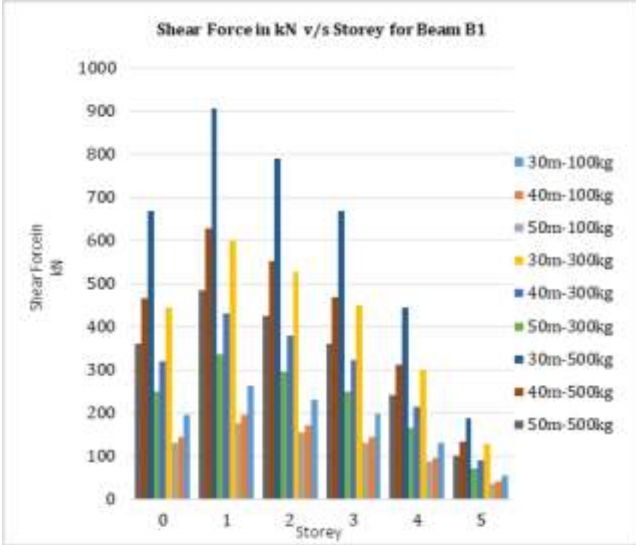

Figure -16: Variation of shear force at edge beam for various cases of standoff distance and charge weight.

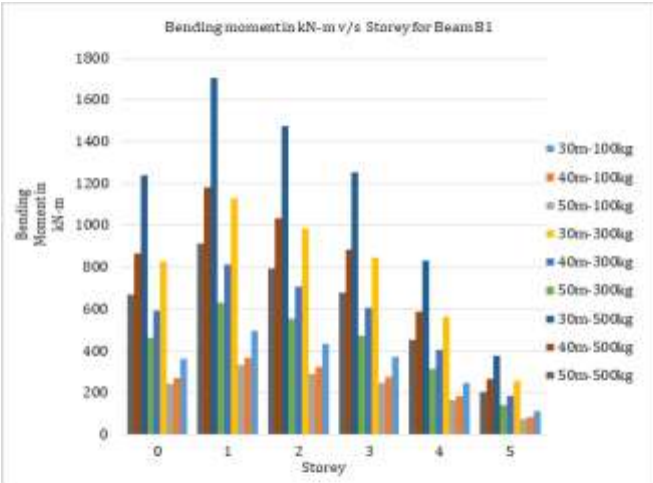

Figure -17: Variation of bending moment for intermediate beam for various cases of standoff distance and charge weight.

It is observed that the displacement increases when the source of explosion is nearer to the building and it decreases with increase in standoff distance. Thus, displacement of building increases with detonation point and target point decreases. Fig 12 shows the graph of displacement along the height of the building for various charge weight of explosive and different location of blast source.

It is observed that drift increases when blast is closer to the building, while it is less as the blast source is far away from the building. Thus drift is inversely proportional to stand off distance i.e., drift increases with decrease in standoff distance and also drift is directly proportional to charge weight i.e., drift increases with increase in charge weight and vice versa. It is also observed that drift is higher in lower storey when compared to upper storey because blast source is nearer to the lower storey. Fig 13 shows the graph of drift along the height of the building for various charge weight of explosive and different location of source of blast.

Fig 14 shows the axial load acting on the corner columns of the building subjected to blast load with varying standoff distance from the front face of the building. It is observed that the axial load gradually decreases as the storey height increases. The axial load at the top storey 56.49kN and it is increased to 997.73kN at first storey. Also, the axial load of column decreases as the source of explosion is away from the building and also decreases with decrease in the charge weight of explosive. The axial load at top storey when the blast source is at a distance of 30m is 56.493kN while it is decreased to 37.80kN when the source of blast is at a distance of 50m. The axial load of 188.9kN at 500kg of charge weight with a standoff distance of 30m it decreases to 56.49kN at 100kg of charge weight when the blast source is at a distance of 30 m (top storey).

Fig 15 shows bending moment acting on the corner columns of the building subjected to blast load with varying standoff distance from the front face of the building. It is observed that the bending moment gradually decreases as the storey height increases. The bending moment at the top storey 54.88kN and it is increased to 440.57kN at first storey. Also, the bending moment of column decreases as the source of explosion is away from the building and also decreases with decrease in the charge weight of explosive. The bending moment at top storey when the blast source is at a distance of 30m is 54.88kN while it is decreased to 36.72kN when the source of blast is at a distance of 50m. The bending moment of 182.82kN at 500kg of charge weight with a standoff distance of 30m it decreases to 54.88kN at 100kg of charge weight when the blast source is at a distance of 30 m (top storey).

Fig 16 shows shear force acting on the edge beam of the building subjected to blast load with varying standoff distance from the front face of the building. It is observed that the shear force gradually decreases as the storey height increases. The shear force at the top storey 56.46kN and it is increased to 264.97kN at first storey. Also, the shear force of beam decreases as the source of explosion is away from the building and also decreases with decrease in the charge weight of explosive. The shear force at top storey when the blast source is at a distance of 30m is 56.46kN while it is decreased to 37.78kN when the source of blast is at a distance of 50m. The shear force of 188.84kN at 500kg of charge weight with a standoff distance of 30m it decreases to 56.46kN at 100kg of charge weight when the blast source is at a distance of 30 m (top storey).

Fig 17 shows bending moment acting on the edge beam of the building subjected to blast load with varying standoff distance from the front face of the building. It is observed that the bending moment gradually decreases as the storey height increases. The bending moment at the top storey 112.49kN and it is increased to 498.35kN at first storey. Also, the bending moment of beam decreases as the source of explosion is away from the building and also decreases with decrease in the charge weight of explosive. The bending moment at top storey when the blast source is at a distance of 30m is 112.49kN while it is decreased to 75.27kN when the source of blast is at a distance of 50m. The bending moment of 376.41kN at 500kg of charge weight with a standoff distance of 30m it decreases to 112.49kN at 100kg of charge weight when the blast source is at a distance of 30 m (top storey).

7. CONCLUSIONS

1. The pressure is less when the point of detonation is far away from the building, at a distance of 30m from the front face of the building pressure is high.
2. The pressure decreases exponentially as the standoff distance increases. The pressure is inversely proportional to detonation point. The pressure beyond 30m is reduced to 54% when the standoff distance is 50m.
3. The safe standoff distance for building chosen is 50m.
4. The pressure decreases exponentially as the charge weight of the explosive decreases. The pressure is directly proportional to charge weight of explosive. The pressure beyond 500kg is reduced 67.3% when the charge weight of explosive is 100kg.
5. Displacement v/s time, Velocity v/s time and Acceleration v/s time increases as the standoff distance is less and weight of the explosive is more.
6. Column forces (Axial load and Bending Moment) and Beam forces (Bending Moment and Shear Force) increases when charge weight of explosive is more and decreases when standoff distance is less.

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