BEHAVIOUR ASSESSMENT UNDER IMPULSIVE LOADING FOR STRUCTURES OF DIFFERENT HEIGHTS

Ankita Mazumdar

B.E.(Civil Engineering)

DayanandaSagar College of Engineering, Bengaluru, India

ABSTRACT

In recent years, there have been many terrorists' attacks in India as well as in other parts of the world. Such attacks are unpredictable and can cause very severe damages to buildings as well as to the citizens of the country. In such cases, the blast loading analysis on the structures comes into picture. Blast load is nothing but the sudden explosions that occur due to terrorists' attacks or due to some natural phenomena, which leads to damage and destruction of structures if at all the explosions are taking place near or in the premises of the structures. Such blasts cause catastrophic damages to structures which leads to dismantling of structures, shattering of windows or cladding etc. Due to the damages caused by such unpredictable situations, the structures should be designed to resist the blast loads. The design of structures to resist blast loads may be uneconomical but in the long run it proves to be a smart decision for the structures. The objective of this study on blast load analysis is to have knowledge of the effect of the blast loads on the structures of various heights and design the structures accordingly in the future. As the design philosophy for such structures may be costly compared to normal structures so, more care must be taken for the structures which are located in the vicinity of earthquake prone areas or the areas where bombarding, explosions etc. are more common. The codebook used for the design of structures for blast loads is "TM 5-1300- Structures to Resist the Effects of Accidental Explosions, (U.S. Departments of the Army, Navy, and Air Force, 1990)"or UFC 3-340-02[1]. However, Indian Standard code IS: 4991 - 1968 "Criteria for Blast Resistant Design of Structures for Explosions above Ground" is also available. The software used for the analysis of the structures and modelling is SAP2000.

Keywords : Blast loads/ Impulsive loads; progressive height; charge weight; stand-off distance

1 INTRODUCTION

The blast loading or the impulsive loading is defined as the type of load which is acting on the structures in case of some natural disasters like earthquakes, volcanic eruptions etc. or of some man-made disasters like terrorists' attacks, blasts etc. The loads that occur in the structures are in the form of waves which are originated due to the sudden vibrations or blasts. The blast effects can be more or less disastrous depending on the intensity of the blasts. Disasters like Manchester Arena bombing, UK, 22nd May 2017, terrorist attacks in Paris and Mumbai 26th November 2008 proves the need for the design of blast resistant structures to overcome such hazards.

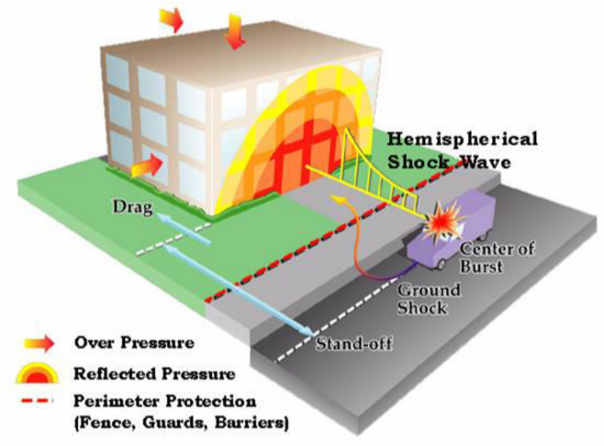

Figure 1.1: Blast Load Effect

(Source: Google image)

Figure 1.1 shows the blast effects caused on the structure due to the explosions caused in the nearby parked vehicle. The shock waves that originate from the blast are in hemispherical shape. There are two types of pressure that is created due to the blast: overpressure and reflected pressure. The overpressure is the one which is created by the blast in the form of shock wave over or above the normal atmospheric pressure. The reflected pressure is the one which is in the shape of hemisphere or the wave front which is created by the shock wave. The major parameters that play an important role in blast load analysis are height of the structure, stand-off distance and charge weight. The first parameter, i.e., height of the structure as in the common term is the height of the building taken from the ground. The second parameter, i.e., the stand-off distance is defined as the horizontal distance between the structure and the origin point of the blast. The third parameter, i.e., the charge weight is defined as the quantity of material present in the charge or explosion. The charge weight is expressed as an equivalent weight of Trinitrotoluene (TNT) which is the basic and most common explosive used. Some of the other explosives are RDX, barium nitrate, lead nitrate, PETN etc.

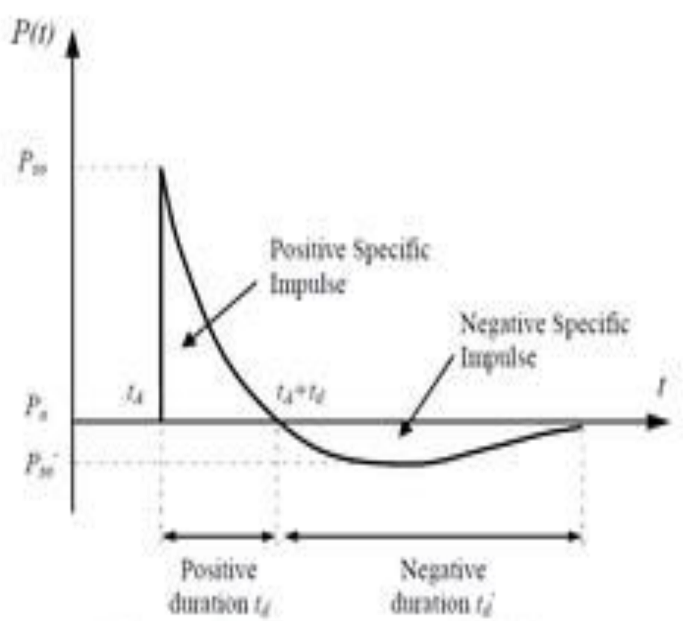

Figure 1.2 : Blast Wave Pressure – Time History Graph
(Source : Google images)

Figure 1.2 shows blast wave pressure – time history graph. In this graph, there are two phases of durations which are shown: positive duration and negative duration. When the blast takes place, a shock wave is created with a maximum pressure of (P_{so}) which is the peak side on overpressure at the arrival time(t_A). With the passing time, the pressure decays in strength until it reaches ambient pressure(P_o) at (t_A+t_d) where t_d denotes 'Positive phase duration'. Following the positive phase duration comes the 'Negative phase duration' where the pressure reaches below the atmospheric pressure(P_o). Finally the pressure reaches its ambient value(P_o).

2 PROBLEM DEFINITION

To carry out the analysis in SAP2000, a6 storied and 8 storied reinforced concrete framed structure is considered with 2 spans of 6 m and 4 bays (2 bays of 7 m at the extremity and 2 bays of 5 m in the middle) as shown in Figure 2.1. The first story height is 4 m and all the other levels are 3 m high each[11]. Dimensions of the columns are 600 mm x 600 mm, the reinforcement is 4 numbers of 25 mm diameter.Dimensions of the perimeter beams are 250mm x550 mm and 300 mm x 700mm for the central beams. Thickness of the slab is 150mm.The concrete compressive strength at 28 days is 30 MPa with elastic modulus of 32.5 GPa. The yield strength of reinforcement is 300 MPawith elastic modulus of 210 GPa[11].

With the above mentioned details, a model is generated in the software SAP2000. The six story building is modelled as framed structure. The beams and columns are generated as framed sections and the slab is modelled as shell elements. Fixed support condition is applied for columns. Non-linear modal analysis is carried out in the present study. Time history function is the main aspect to investigate the dynamic response of a structure as time is a major domain in blast. A very small time period is essential to get stable results. The details are taken from literature[11].

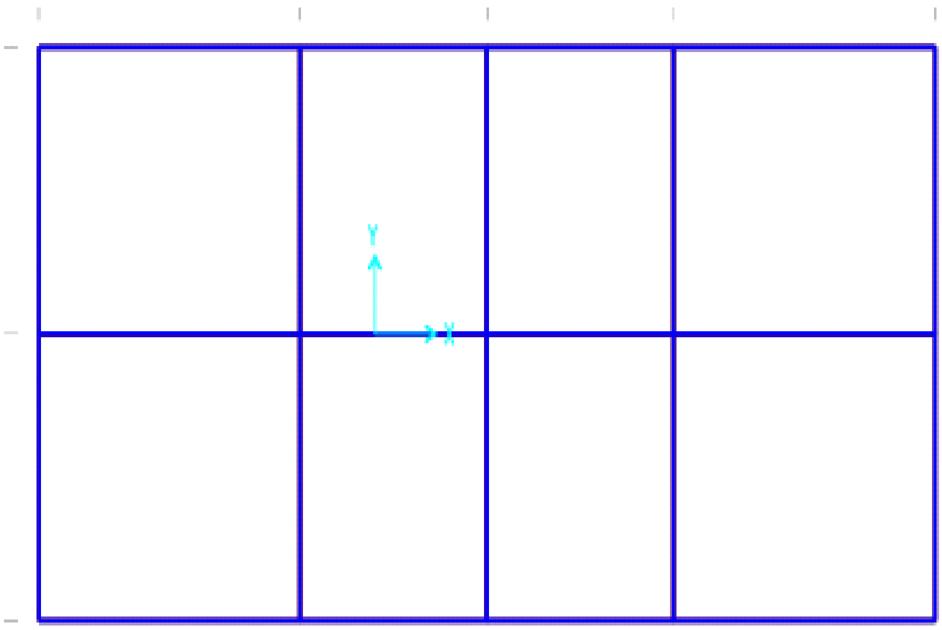

Figure 2.1: Typical Floor Plan Of The Modelled Structure

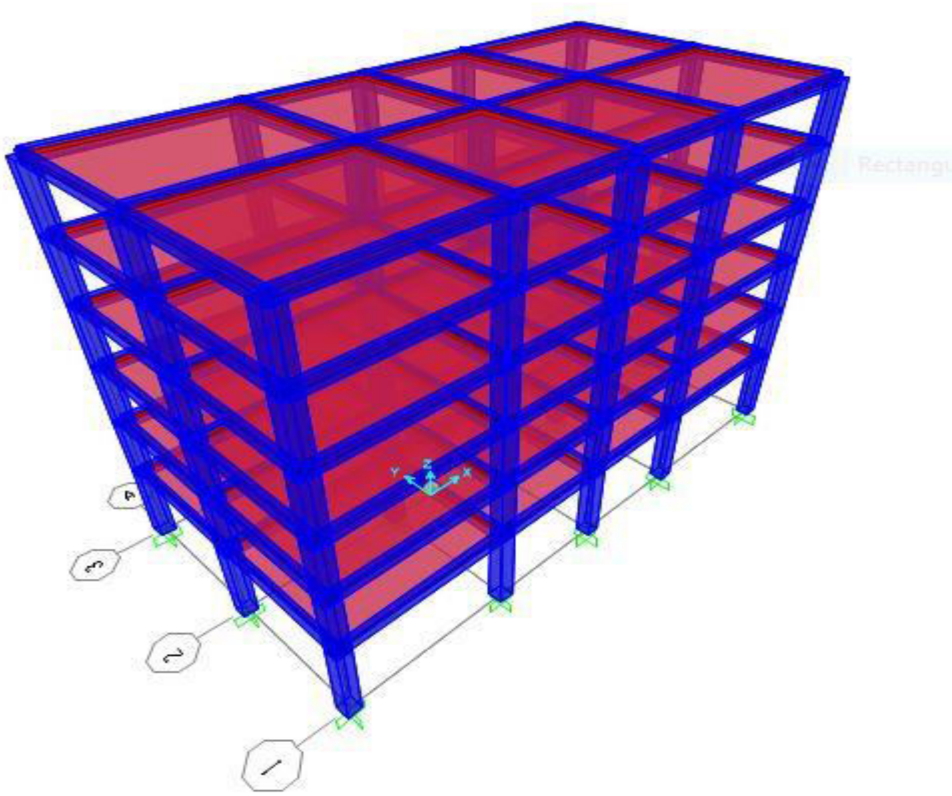

Figure 2.2: 3D View Of 6 Floor Building

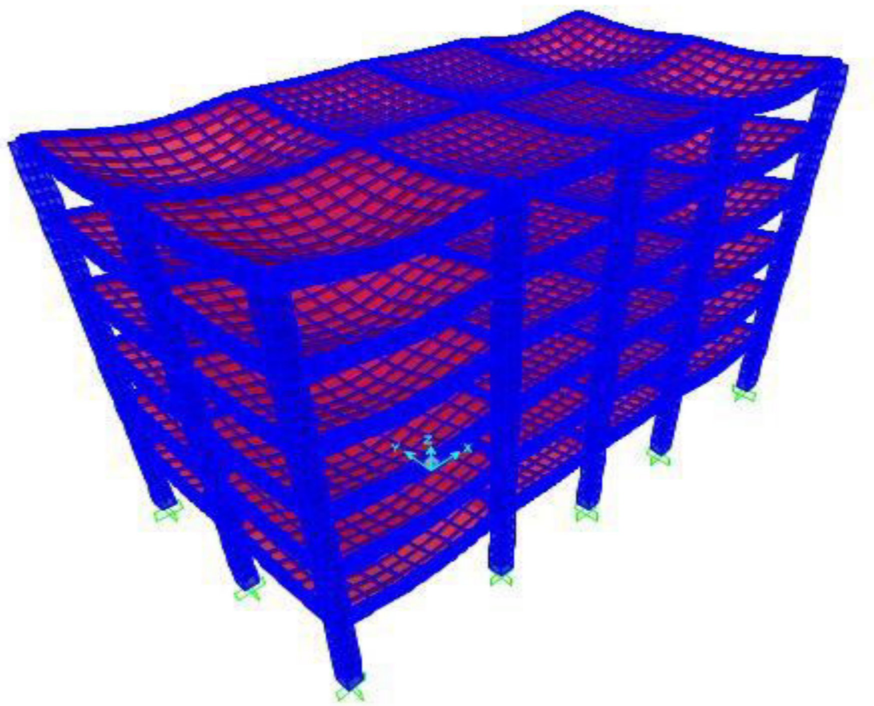

Figure 2.3: Deformation Of Building Under Combination Of Loads

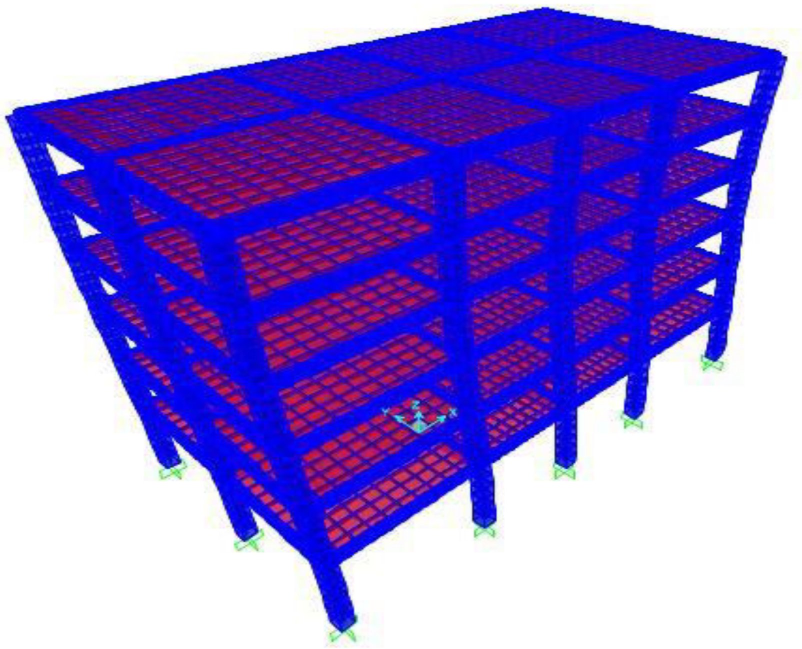

Figure 2.4: Deformation Of Building Under Blast Load

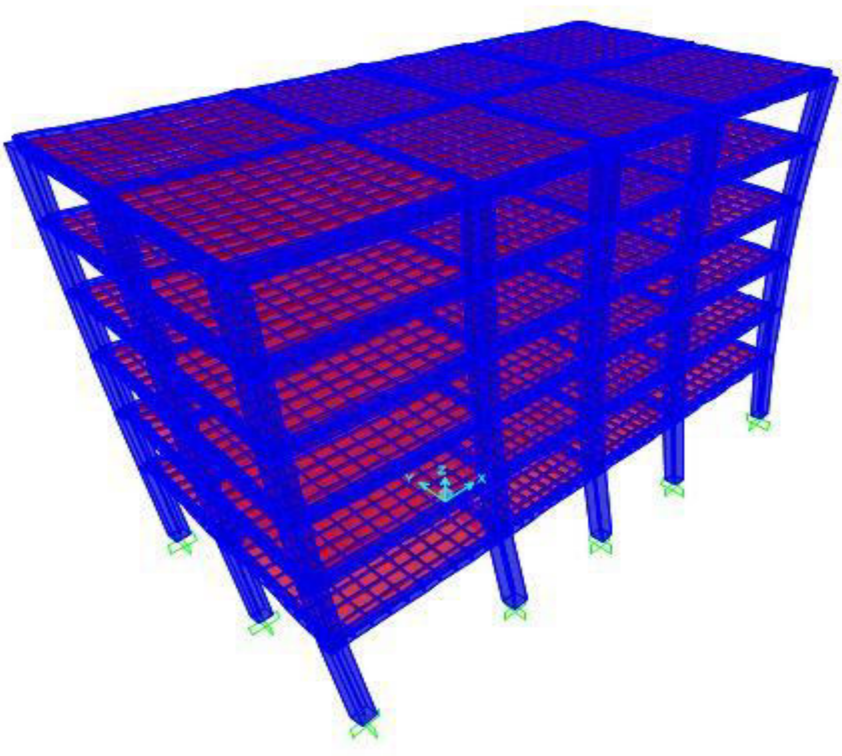

Figure 2.4: Deformation Of Building Under Combination Of Blast, Dead And Live Loads

3 MODELLING AND ANALYSIS

Following are the models created in SAP2000 for the blast load analysis of structures of different heights:

MODEL 1: A 6 story structure having a charge weight of 500 Kg TNT placed at a stand-off distance of 4m on the longer edge of the building

MODEL 2: A 8 story structure having a charge weight of 500 Kg TNT placed at a stand-off distance of 4m on the longer edge of the building

MODEL 3: A 6 story structure having a charge weight of 500 Kg TNT placed at a stand-off distance of 4m on the shorter edge of the building

MODEL 4: A 8 story structure having a charge weight of 500 Kg TNT placed at a stand-off distance of 4m on the longer edge of the building

Table 3.1: Variation of blast pressure along the 6 floor height of the structure for the 500 Kg TNT placed at 4m stand-off distanceon longer side of the building

bay	story	R(ft)	α(deg)	Arrival time (T_a)(ms)	Load duration time (T_d)(ms)	Pressure (p_{si})	Load (kN)
1.	1	41.63	9.068	8.78	3.50	232	11189
	2	44.045	24.185	10.9772	4.0656	162	5860
	4	53.93	44.39	17.56	4.95	93	3364
	5	60.69	51.60	19.75	6.49	57.5	2080
	6	68.20	57.325	27.443	8.2182	37.4	1353

Table 3.2: Variation of blast pressure along the 8 floor height of the structure for the 500 Kg TNT placed at 4m stand-off distance on longer side of the building

Bay	Story	R(ft)	α(deg)	Arrival time (T_a)(ms)	Load duration time (T_d)(ms)	Pressure (p_{si})	Load (kN)
1.	1	41.63	9.068	8.78	3.50	232	11189
	2	44.045	24.185	10.9772	4.0656	162	5860
	3	48.244	35.31	15.37	3.73	112	4051
	4	53.93	44.39	17.56	4.95	93	3364
	5	60.69	51.60	19.75	6.49	57.5	2080
	6	68.20	57.325	27.443	8.2182	37.4	1353
	7	79.002	58.35	32.931	11.821	26	940
	8	87.532	61.74	37.321	11.55	22.8	825

4 RESULTS AND DISCUSSION

Table 4.1: Lateral displacement results for different story structure with a 500 Kg TNT placed at 4m stand-off distance

story	Lateral displacement in mm	
	6 floor	8 floor
0	0.0	0.0
1	10.2	15.0
2	23.0	21.5
3	36.3	27.3
4	45.0	28.0
5	47.0	21.0
6	45.5	12.7
7	-	8.7
8	-	8.5

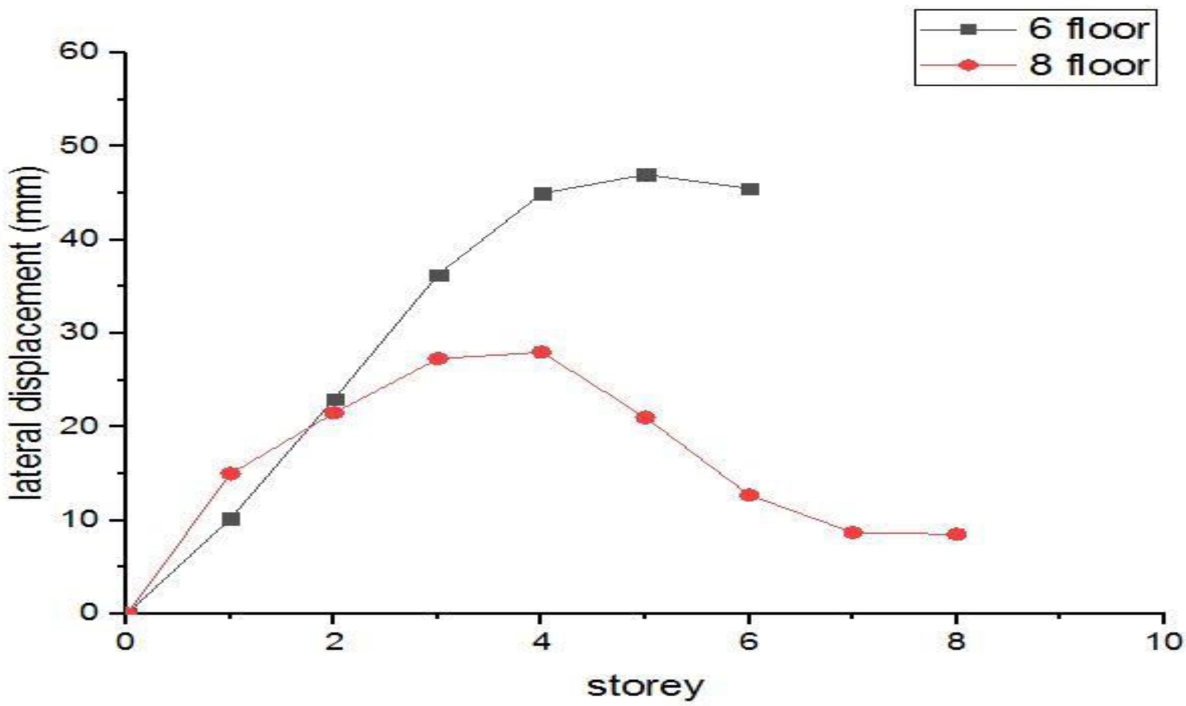

Figure 4.1: Lateral Displacement results for different "W" placed at "R" of 4m

Table 4.2: Inter story drift results for different "W" placed at 4m stand-off distance

story	Inter story drift in mm	
	6 floor	8 floor
0	0.0	0.0
1	10.2	15.5
2	12.8	6.5
3	13.2	5.5
4	8.8	0.7
5	2.3	7.0
6	1.5	8.3
7	-	4.2
8	-	0.3

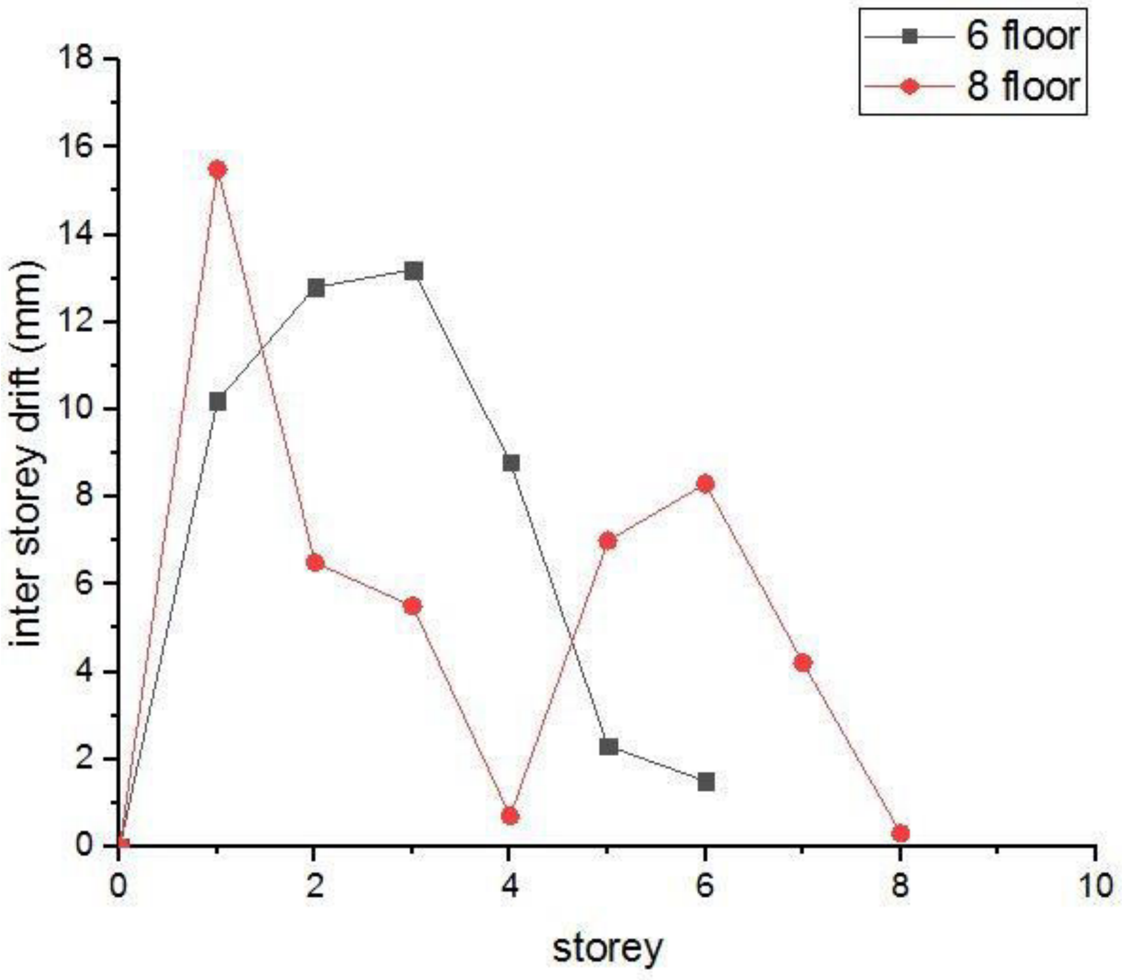

Figure 4.2: Inter story drift results for different "W" placed at "R" of 4m

5 CONCLUSIONS

- From Table 3 ,the maximum lateral displacements are 47.0mm for 6 story and 28.0mm for 8 story building with charge weight "W" of 500 Kg TNT respectively placed at 4m stand-off distance. As per IS1893 ,the allowable maximum lateral displacement is 38mm (i.e., H/500) for 6 story with 500 kg charge weight while for 8 story the allowable maximum lateral displacement is 50mm (i.e., H/500) for 500 kg charge weight. So, the maximum lateral displacement is satisfying for 8 story building but not for 6 story building.
- From Table 4,the maximum inter story drifts are 13.2mm for 6 story and 15.5mm for 8 story with charge weight "W" of 500 Kg TNT respectively placed at 4m stand-off distance. As per IS1893 the allowable maximum Inter story drift is 16mm (i.e., 0.004xh). So, the maximum story drifts are satisfying for both 6 and 8 story buildings as per the IS code provisions.

REFERENCES

[1] H. Draganić and V. Sigmund, "Blast loading on structures," *Teh. Vjesn.*, vol. 19, no. 3, pp. 643–652, 2012.

[2] "Blast Proof Occupied Buildings 1 1," pp. 1–25.

[3] N. Anandavalli *et al.*, "Behaviour of a blast loaded laced reinforced concrete structure," *Def. Sci. J.*, vol. 62, no. 5, pp. 284–289, 2012.

[4] U. Jamakhandi and S. B. Vanakudre, "Design and Analysis of Blast Load on Structures," *Int. Res. J. Eng. Technol.*, vol. 2, no. 7, pp. 745–747, 2015.

[5] J. H. J. Kim, N. H. Yi, I. S. Oh, and H. S. Lee, "Blast loading response of ultra high performance concrete and reactive powder concrete slabs coefficient ages," 2010.

[6] a. J. Watson, "Blast effects on buildings," *Eng. Struct.*, vol. 20, no. 9, p. 857, 1998.

[7] Z. Koccaz, F. Sutcu, and N. Torunbalci, "Architectural and Structural Design for Blast Resistant Buildings," *14 World Conf. Earthq. Eng.*, no. Figure 1, p. 8, 2008.

[8] A. Ghani Razaqpur, A. Tolba, and E. Contestabile, "Blast loading response of reinforced concrete panels reinforced with externally bonded GFRP laminates," *Compos. Part B Eng.*, vol. 38, no. 5–6, pp. 535–546, 2007.

[9] "Damage evaluation of a reinforced concrete containment shell subjected to blast loading.pdf." .

[10] C. Napoca, "Assessment of the Potential for Progressive Collapse in RC Frames," vol. 1, no. 9, 2007.

[11] C. Engineering, V. Akella, and C. Engineering, "Dynamic Response of a Multi-story building under Blast load."