Analysis Reinforced Concrete Structure Subjected to External Surface Blast Load

Mohammed Moinuddin[1], Kiran K. K.[2]

[1]Student, Dept, of Civil Engineering, SJBIT, Karnataka, India
[2]Asst. Professor, Dept, of Civil Engineering, SJBIT, Karnataka, India

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Abstract - In the recent years the iconic and public buildings have been the target of terrorist. Due to increase in technology the terrorist are coming up with high intensities of blasts. Arising problematic situation all over the world are bomb blast and threats. The safety of the human life against these attacks includes forecast, avoidance and variation of such events. In recent years, design and analysis of such impulsive loads subjected to structures are studied in detail to find out the performance of the structural elements subjected to sudden type of loading. It is given more importance due to the effect which is caused by blast due to high magnitude, sometimes blast may be even accidental. Thus it is necessary to understand the effect of blast on the structure and behaviour of structural elements due the load.

In present study, a seven storey reinforced concrete structure with and without bracing is considered, which is subjected to blast load of 100Kg RDX with stand off distance varying of 10m each, from 10m to 60m. The structure is analysed using SAP 2000. The blast loads is calculated using the code UFC 3-340-02. The lateral stability of the structure gives the clear effects of load on the structure. Based on the results, the effect of blast load is higher when the detonation point is closer to structure. The resistance of structure is seen when bracings are added to the structure. The structure is efficient when bracings are added to it.

***Key Words*: Displacement, Storey drift, SAP 2000, UFC 3-340-02, Bracing**

1.INTRODUCTION

The majorly increasing problem in the whole world is due to terrorist attacks on the public buildings which not only causes fatality but also leads to huge damage on the economy of the country. In the recent years, main importance is been given to problems of spontaneous loading such as blast loads or impact loads and earthquake loads. The behaviour of the structural components such as beams, columns and slabs are mainly subjected to this type of loading from different accidental or intentional events, predominantly blast loading has been the subject of significant research effort in the past years. In addition, the terrorists are using new chemicals and technology to increase the impact or effect of detonation of charge on the concerned area. However, the threats caused by blast cannot be found accurately but loads can be calculated to find out effect on the structure, and various safety measures can be taken into consideration. The explosion of bombs in and around buildings can cause huge effects on the structural elements, and also the interior and exterior of the structure which may cause huge effect to human life or with the igniting materials the pressure can be increased. Many structures have become target of bomb explosion attacks in the last decades. Some terrorist groups have targeted famous buildings around the globe. The cases of those attacks proved the exposure of buildings to explosion. Proofs of recent terrorists attacks such as Jewish community centre - Argentina in the year 1994, Manchester – Arena in the year 2017, Khobar towers - Saudi Arabia in the year 1996, World trade centre - USA 9/11 in the year 2001, etc. had the potential to cause huge damage to life and structure based on the type of charge been used. Thus finding out the response of a structure subjected to blast load is very important and it is also necessary to minimize the effect of blast load on structure which not only leads to safety of structure but also reduces the deaths and major effects which may occur due to collapse of a structure. As there is increasing demand for higher safety of structures due to terrorist attacks, finding out the responses of structural elements such as beam, column, slab, etc is much more necessary to attain safety.

The type of explosions can be of different types, such as gas chemical explosion, accidental explosion, aerial blast, surface blast, etc. This type of attack can even cause failing or collapsing of structure. It is therefore much more important to carry out safety measures and damage evaluation of structures subjected to blast load. The behaviour of structure, analysis and design of structures subjected to blast load were crucially studied in the 20th century. However data related to blast effect is challenging due to inter-dependent factors. Blast load differs from normal loads such as, earthquake and wind loads due to very short time and high amplitude. Therefore, it becomes highly complicated to find the effect of blast onto the structure and its behaviour.

Several technical manuals has been introduced for blast-resistant design by U.S. Department of army. The majorly accepted design manual is UFC 3-340-02. Indian manual is IS: 4991 - 1968 Criteria For Blast Resistant Design Of Structures

For Explosions Above Ground. However it's almost uneconomical to find out the experimental results for multi storey RC structure due high cost. Therefore numerical tools such as FEM has become the major tool for analysis of blast. Therefore analysis of RC-structure subjected to blast load requires complete knowledge of blast parameters and dynamic responses such as displacements of various structural members.

2.BLAST LOADING

Blast load is a rapid release of stored potential energy with a very bright flash, part of energy is released as thermal radiation & a part of it is coupled in the air such as air blast & also into the soil such as ground waves or surface blast. The effect of load of an explosion are in the form of shock or sudden impact wave. Which are composed of very high magnitudes. These waves expands from the source of origin to surrounding region in the outward direction. As the waves are expanded in the outward region, the strength of waves is reduced due to the distance travelled by the wave. An explosion can be defined as a huge quantity of energy released within few milli-seconds.

Figure 1 shows blast wave & amplitude – frequency relations of structural loadings produced from charge. The blast wave characteristics are truly dependent on distance of structure (standoff distance) from the centre of charge (w) with time (t).

The peak positive pressure (P_{os}) is known as peak pressure or maximum pressure, ambient air pressure (Po), as we can see from the figure 1 Po is zero at arrival time (ta), there is a sudden increase in peak positive pressure (P_{os}) at positive time (t_{pos}) this is called peak positive over pressure. As the duration increases negative pressure occurs at a negative time (t_{neg}) this is called under pressure (P_{neg}) here pressure is lesser than ambient pressure (P_o).

For the simplicity in the analysis process, only positive peak pressure (P_{os}) is considered by neglecting under pressure (P_{neg}). A triangular blast load profile is used for peak positive pressure (P_{os}) for a positive duration (t_{pos}) as shown in figure 1.

Also we can see from figure 1 blast load is very high in amplitude compared to other loads such as earthquake load, wind load, machine loads etc. hence blast load needs an attention in the analysis process of the structure for important buildings.

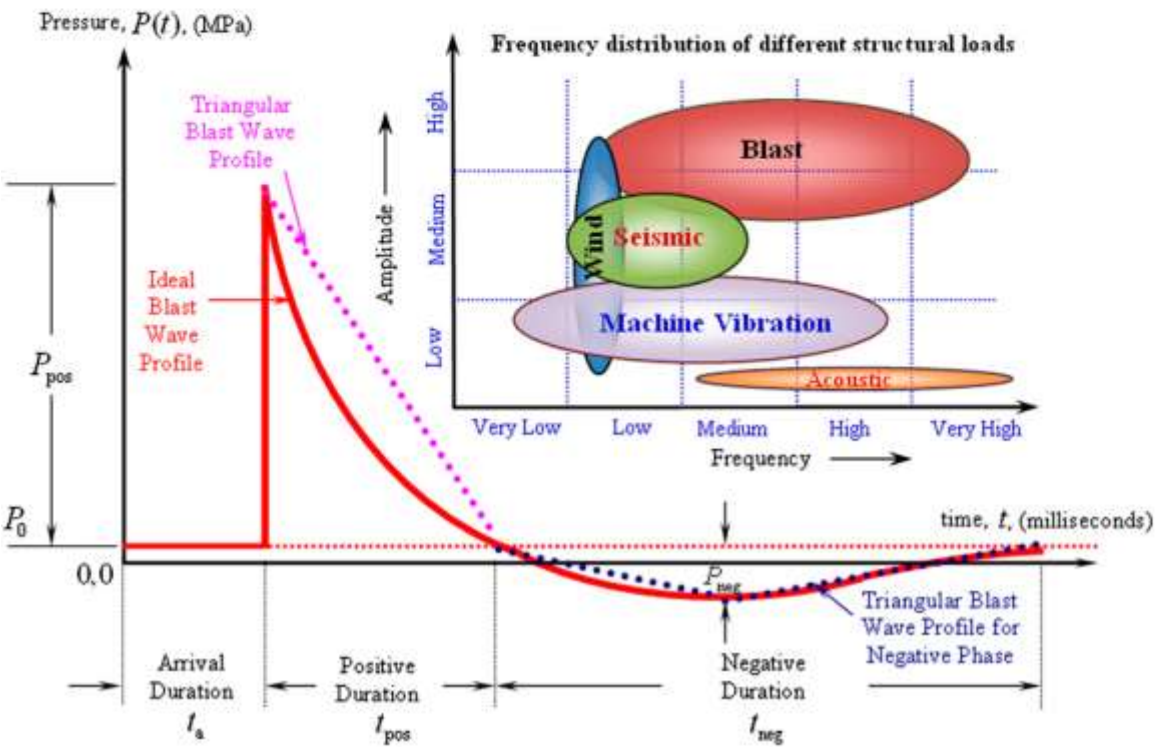

Figure - 1: Amplitude vs frequency & Blast Wave

3.OBJECTIVES

Analyzing G+6 storey structure with bracing and without bracing. Finding the blast load and its parameters for the selected structure. To find the displacements and drift of the structure and to check well within permissible limits. Cases considered are for 100 Kg RDX for stand-off distance at 10m, 20m, 30m, 40m, 50m and 60m for RC structure with braces and without braces.

4.METHODOLOGY

G+6 storey Reinforced structure is considered. 5.5m each bay in X direction and 4m each bay in Y direction. Each storey height of 3.5m. Therefore the dimension of building is 22m in X direction, 16m in Y direction and 24.5m in Z direction. Figure 2 shows the plan of the building. Using M30 concrete and Fe-415 steel. Sizes of structural members such as beam is 250mmX450mm, column is 350mmX450mm, slab thickness is 150mm, thickness of wall is 230mm and bracings used were ISMB450. The loads considered is Live load 3kN/m^2, Floor finishes 1.67kN/m^2, Wall load as 14.14kN/m^2. Braces are provided is X-Z and Y-Z direction throughout in outer periphery.
Modelling was carried out in SAP 2000. The charge considered is 100Kg RDX and calculation of blast-load parameters were based on UFC 3-340-02 manual. Calculation of blast load parameter is given below.
Scaled distance is found by using formula $Z_G = R_G / W^{(1/3)}$. For the scaled distance and charge weight the Peak over pressure, Arrival time, Positive phase duration and Positive incident impulse is found out using manual. Also the front wall reflected pressure, impulse, loading is found out for positive phase. The pressure found out is converted to point load by dividing the area and applied to the front face of the building as shown in figure 3.

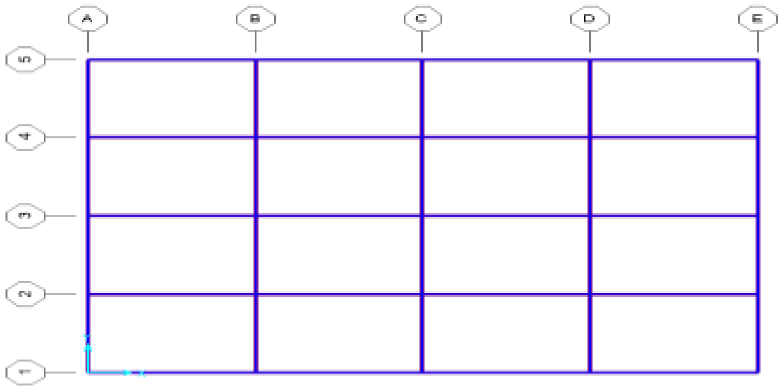

Figure - 2: X – Y Plan

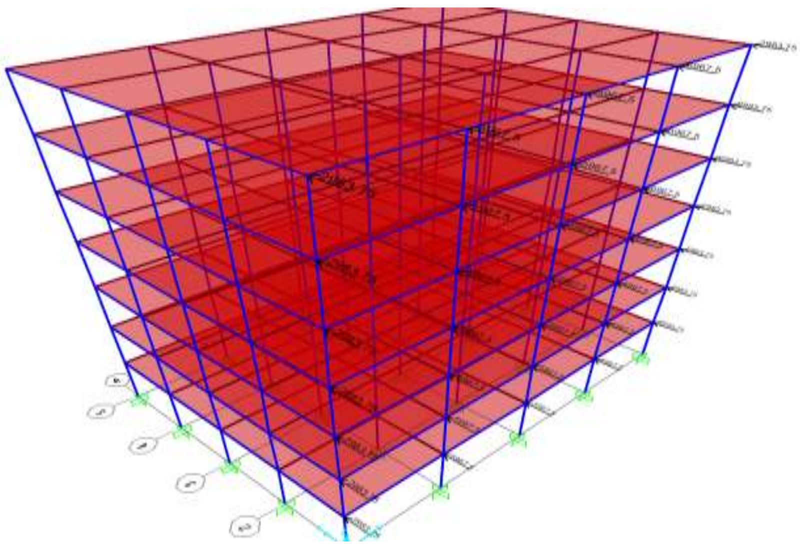

Figure - 3: Application of Blast load at the nodes

5.RESULTS AND DISCUSSION

Table 2 gives the different blast loads for different stand off distances and figure 4 shows the variation of blast load as the distance increases.

Table -2: Blast load at different stand-off distance

STANDOFF DISTANCE m	LOAD kN
10	2983.75
20	407.85
30	226.14
40	125.99
50	76.9
60	69.96

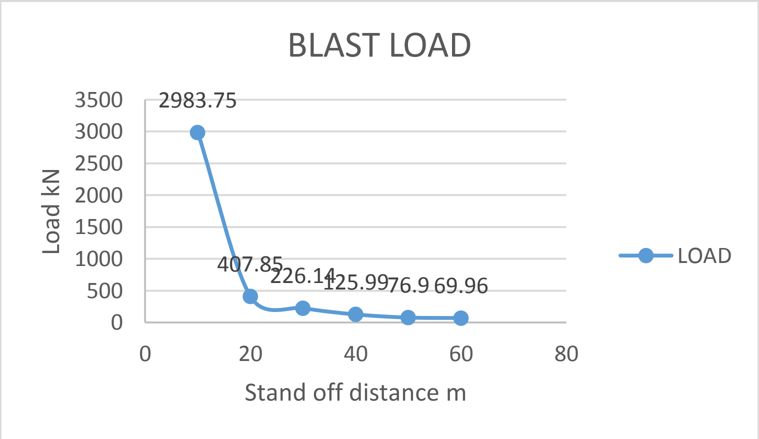

Figure - 3: Variation of blast load vs stand-off distance

G+6 Storey Reinforced concrete structure with bracing and without bracing for 100Kg RDX at 10m:

Table -3: Displacement and Storey drift

DISPLACEMENT				**STOREY DRIFT 10^{-3}**	
FLOOR	**JOINT**	**WITHOUT BRACING (m)**	**BRACING (m)**	**WITHOUT BRACING**	**BRACING**
BASE	0	0	0	0	0
GROUND FLOOR	1	0.454753	0.051411	0.129929	0.014689
STOREY 1	2	1.086794	0.103506	0.180583	0.014884
STOREY 2	3	1.651712	0.152481	0.161405	0.013993
STOREY 3	4	2.113843	0.197061	0.132037	0.012737
STOREY 4	5	2.467126	0.235974	0.100938	0.011118
STOREY 5	6	2.710576	0.268428	0.069557	0.009273
STOREY 6	7	2.850071	0.294102	0.039856	0.007335

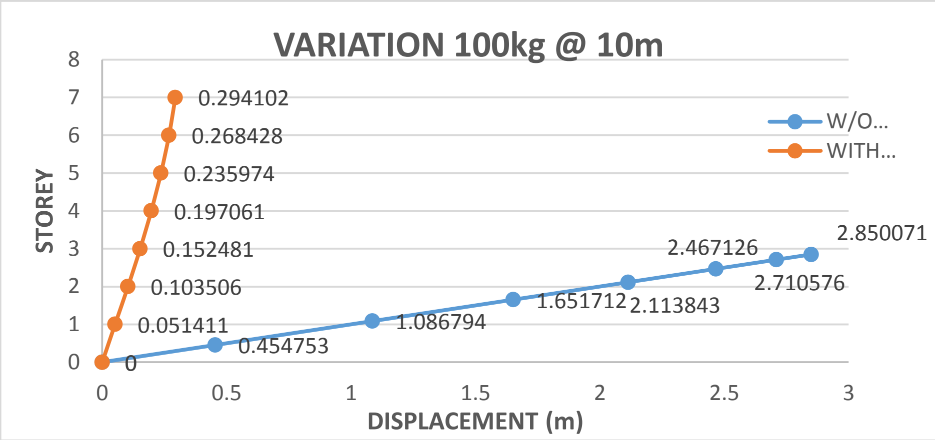

Figure - 4: Variation of Displacement for 100Kg RDX at 10m Stand-off distance, with bracing and without bracing

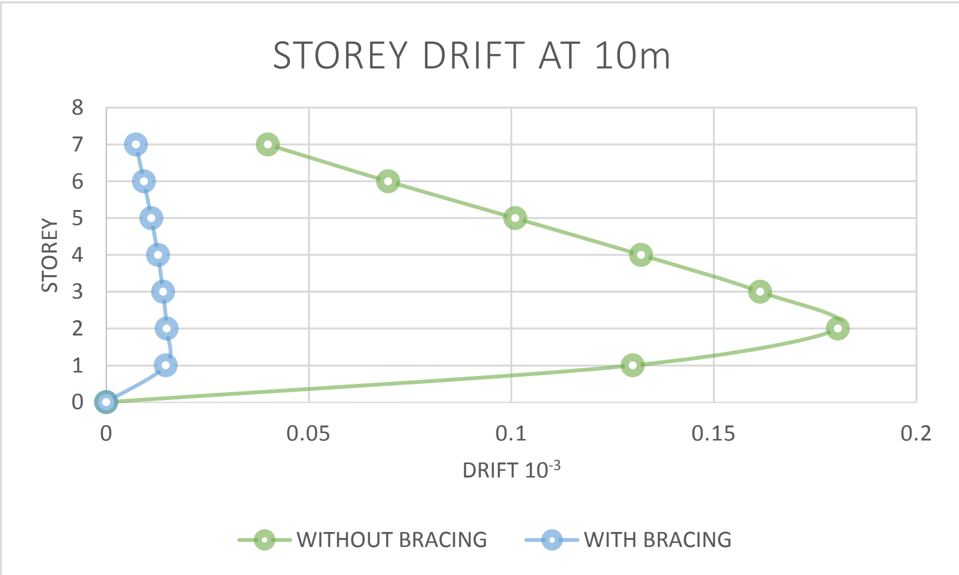

Figure - 5: Variation of Storey Drift for 100Kg RDX at 10m Stand-off distance, with bracing and without bracing.

Similar procedure was carried out for 20m, 30m, 40m, 50, and 60m. The drift results are shown in the below figures.

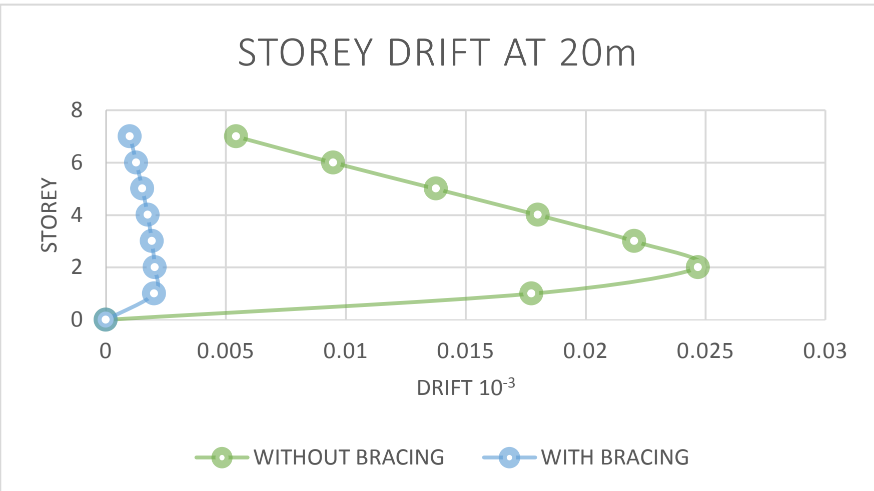

Figure – 6: Variation of Storey Drift for 100Kg RDX at 20m Stand-off distance, with bracing and without bracing

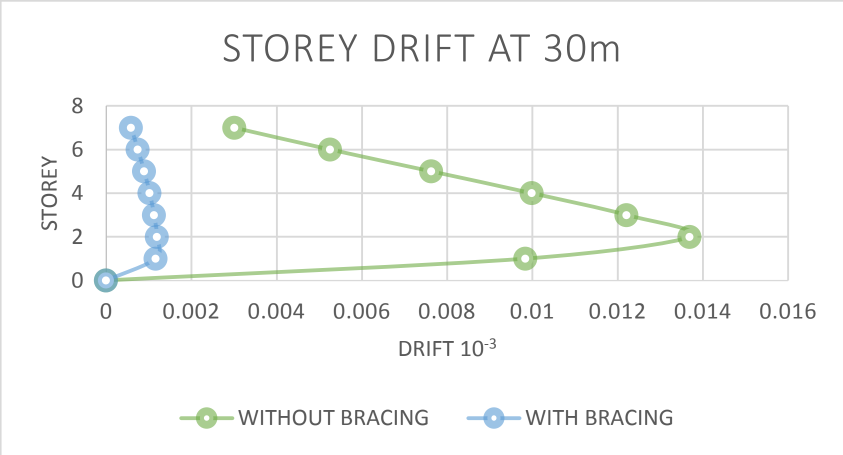

Figure - 7: Variation of Storey Drift for 100Kg RDX at 30m Stand-off distance, with bracing and without bracing

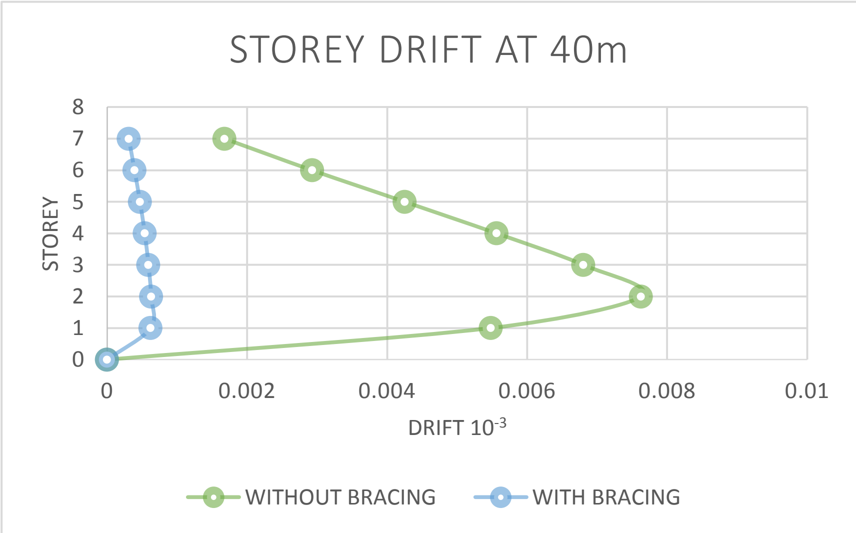

Figure - 8: Variation of Storey Drift for 100Kg RDX at 40m Stand-off distance, with bracing and without bracing

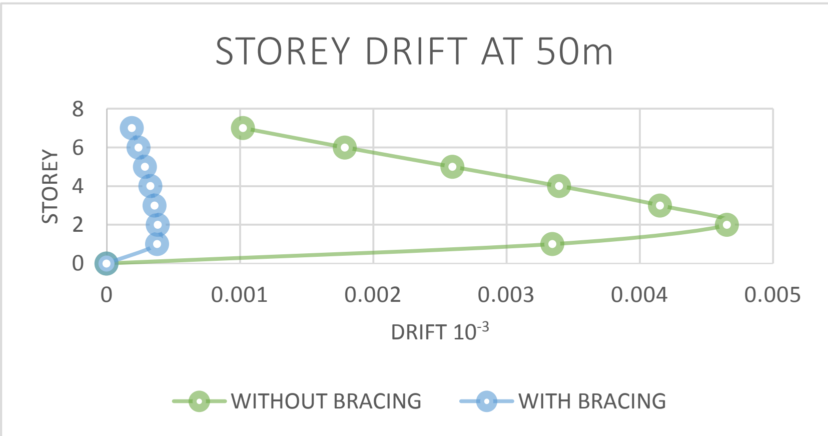

Figure - 9: Variation of Storey Drift for 100Kg RDX at 50m Stand-off distance, with bracing and without bracing

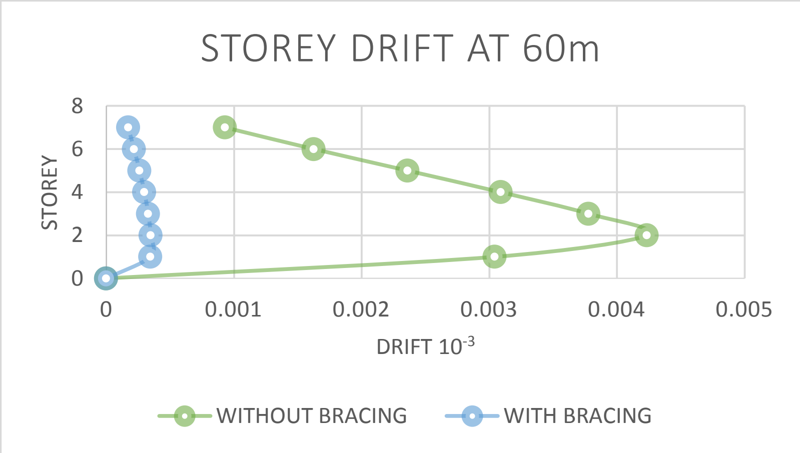

Figure - 10: Variation of Storey Drift for 100Kg RDX at 60m Stand-off distance, with bracing and without bracing

Figure 3 shows that as the stand-off distance increases blast load decreases. Table 3 gives the values of displacements and drifts for 100Kg RDX at 10m stand-off distance, we can see clearly from the figure 4 and figure 5 that the displacement and storey drift decreases when braces are added to the structure. Also for the cases from 20m to 60m shows the variation of drift of the structure with bracing and without bracing from figure 6 to figure 10. It is also seen that when the stand-off distance increases the drift value is very less. It is also seen that the safe stand-off distance for the structures with braces is achieved at 30m stand-off distance where as the structure without bracing was even failing at 60m stand-off distance.

8.CONCLUSIONS

- Determination of blast load describes for the selected cases that as the stand of distance increases the blast load decreases.
- If the standoff distance is very close to the structure, then the displacements and storey drifts are high.
- Storey drifts were high at lower storey that describes the effect of blast load is more due to nearer the detonation point.
- When bracings are added to the structure, the displacements and storey drift reduces to very high percentage. The failure of structural members are reduced very highly.
- When bracings are added it was seen that for 20m stand-off distance the obtained storey drift was 2.032mm which is well within permissible limits that is 14mm for the selected structure. Hence we can say that the safe stand-off distance for structures with bracing is for 20m.
- The value of drift is maximum at second storey in normal structure and at first storey when braces are added this may be probably due to increase in moment of inertia of the structure
- From over-all it is concluded that the structures with bracings shows high resistance to structure.

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