Comparative Study of Effect of Underground and Above ground Explosion on RC Structure

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Abstract*;* *As the terrorist attacks and mining activity is increasing in the recent years, it made an engineer to consider the blast loads caused by such activities in designing the RC structure without causing much damage to life and structure. The aim of the study is to compare the effect of underground and above ground explosion on a RC structure. Time history analysis is carried out using ETABS software for charge weight of 500Kg, 1000Kg, 1500Kg at standoff distance of 20m, 25m, 30m. The study concludes that the effect of above ground explosion is more than underground explosion on RC structure. The structural response such as storey drift, storey displacement and storey shear increase for above ground explosion when compared to underground explosion for the same charge weight and standoff distance. It also shows that the above responses increase for increasing charge weight and decreasing standoff distance for both above ground and underground explosion.*

Keywords*:* Underground explosion, Above ground explosion, Blast load, Time history analysis.

1. INTRODUCTION

Due to increase in the terrorist attacks and mining activity for the extraction of ores, stones, etc., the consideration of effects of blast load on a structure plays the vital role in designing of the structure. Unlike seismic and wind loads, blast loads are a short duration phenomenon. Though, a blast occurs for milliseconds, it is capable of causing hazardous damage to structures and human life. The threats from such extreme loading conditions urge efforts to develop methods of structural analysis and design to resist blast load. In India, the blast-resistant design of structures is categorized as explosion above ground IS 4991 and underground blasts IS 6922. In addition, different international codes and regulations provide guidelines to mitigate blast-induced effects on structures. The chief intension of the study is to compare the effects of underground blasting and above ground blasting on a RC structure. To know the response of structure under the blast load with significance given on various standoff distances of the blast and considering various charge weights of TNT according to IS 4991 and IS 6922 using ETABS software.

2. BLAST LOAD

A Blast load is the load applied to a structure or object from a blast wave, which is described by the combination of overpressure and either impulse or duration that causes catastrophic damage to the building both externally and internally. Blast loading can be caused by above ground explosion and underground explosion.

2.1 Above ground explosion

In the above ground explosion there are 3 kinds of explosions which are unconfined explosions, confined explosions and explosions caused by explosives attached to the structure. Unconfined explosions can occur as an air-burst or a surface burst. Figure 1 shows the air burst explosion, in which detonation of the high explosive occurs above the ground level and intermediate amplification of the wave caused by ground reflections occurs prior to the arrival of the initial blast wave at a building as the shock wave continues to propagate outwards along the ground surface, a front commonly called a Mach stem is formed by the interaction of the initial wave and the reflected wave. However a surface burst explosion as shown in figure 2 occurs when the detonation occurs close to or on the ground surface. The initial shock wave is reflected and amplified by the ground surface to produce a reflected wave. Unlike the air burst, the reflected wave merges with the incident wave at the point of detonation and forms a single wave. In the majority of cases, terrorist activity occurs in built-up areas of cities, where devices are placed on or very near the ground surface. As shown in figure 3, when an explosion occurs within a building, the pressures associated with the initial shock front will be high and therefore will be amplified by their reflections within the building. This type of explosion is called a confined explosion. In addition and depending on the degree of confinement, the effects of the high temperatures and accumulation of gaseous products produced by the chemical reaction involved in the explosion will cause additional pressures and increase the load duration within the structure. Depending on the extent of venting, various types of confined explosions are possible. If detonating explosive is in contact with a structural component, e.g. a column, the arrival of the detonation wave at the surface of the explosive will generate intense stress waves in the material and resulting crushing of the material. Except that an explosive in contact with a structure produces similar effects to those of unconfined or confined explosions.

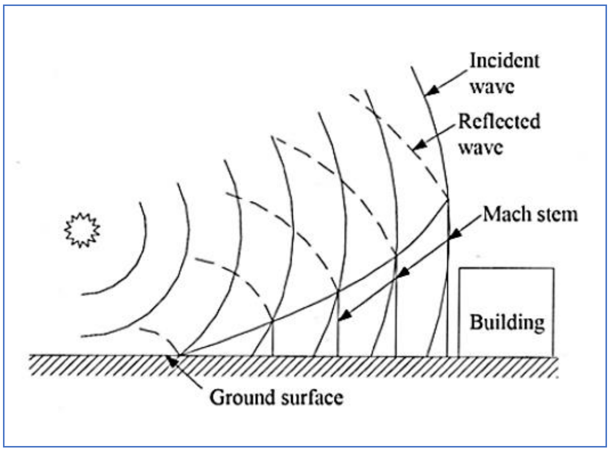

Figure 1. Air burst explosion

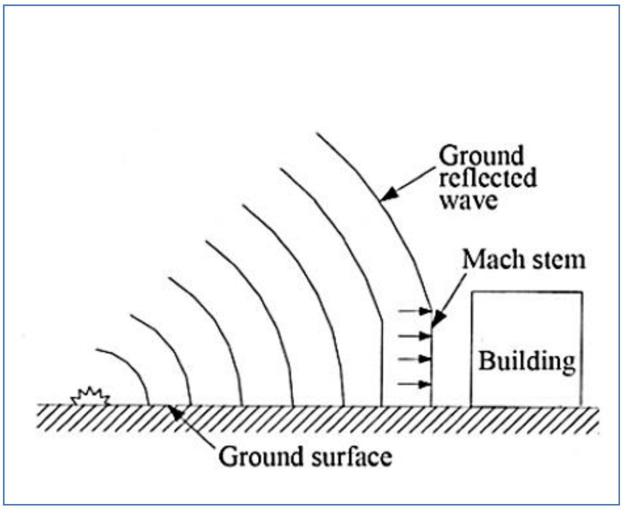

Figure 2. Surface burst explosion

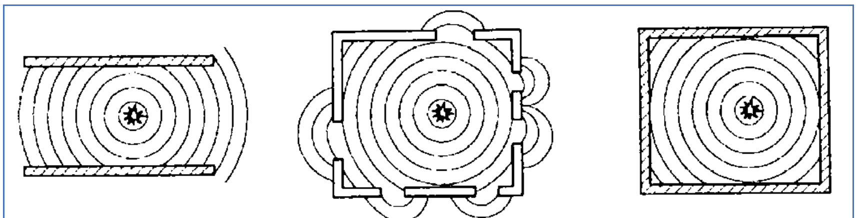

Figure 3. Confined explosion

2.2 Under ground explosion

Damage patterns due to underground explosions:

Figure 4 shows five principle scenarios for structural damage caused by shallow underground explosions

1. flying debris of dispersed soil material
2. cratering and soil rupture
3. air blast and forced vibrations
4. foundation-induced excitation of the structure to vibrations
5. inadmissible inclination of foundations due to subsidence

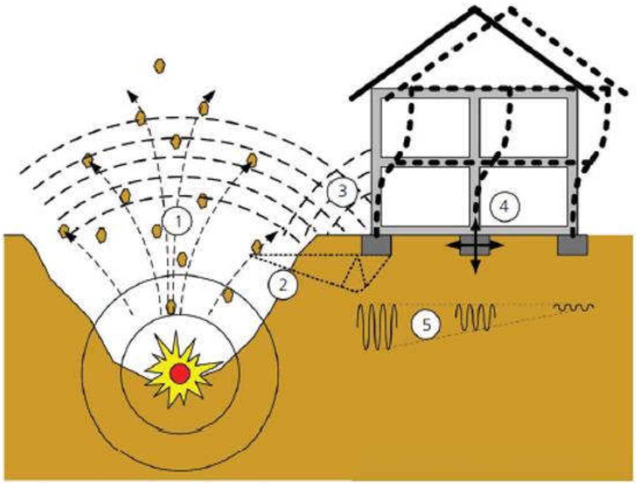

Figure 4. Damage patterns due to underground explosion

2.3 Propagation of Blast wave

Blast waves propagate at supersonic speeds and reflected as they meet objects. As the blast wave continues to expand away from the source of the explosion its intensity diminishes and its effect on the objects is also reduced. However, within tunnels or enclosed passages, the blast wave will travel with very little diminution. Close to the source of explosion the blast wave is formed and violently hot and expanding gases will exert intense loads which are difficult to quantify precisely. Once the blast wave has formed and propagating away from the source, it is convenient to separate out the different types of loading experienced by the surrounding objects. Three effects have been identified in three categories. The effect rapidly compressing the surrounding air is called “air shock wave”. The air pressure and air movement effect due to the accumulation of gases from the explosion chemical reactions is called “dynamic pressure” and the effect rapidly compressing the ground is called “ground shock wave”. Figure 5 explains that the air shock wave produces an instantaneous increase in pressure above the ambient atmospheric pressure at a point some distance from the source. This is commonly referred to as overpressure. As a consequence, a pressure differential is generated between the combustion gases and the atmosphere, causing a reversal in the direction of flow, back towards the centre of the explosion, known as a negative pressure phase. This is a negative pressure relative to atmospheric, rather than absolute negative pressure. Equilibrium is reached when the air is returned to its original state.

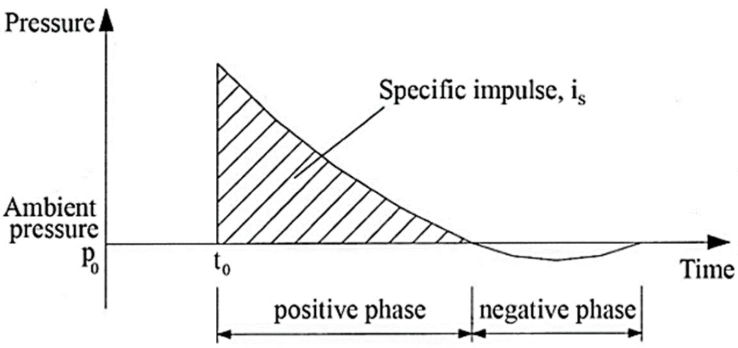

Figure 5. Shock Wave Produced by Blast

3. OBJECTIVE

1. The motto of the study is to get an idea of blast phenomenon for above ground and underground explosion.
2. To understand the response of RC regular structure when subjected to blast loadings for above ground and underground explosion using ETABS software as per IS code 4991 and IS code 6922.
3. To understand the results of the analysis of structures for different parameters such as,
   - Maximum Storey drift
   - Maximum Storey displacement
   - Storey shear

4.METHODOLOGY

In this study the ten storey RC regular structure is considered and are then subjected to blast load due to above ground and underground explosion of charge weight 500kg, 1000kg, and 1500kg at standoff distance of 20m, 25m, and 30m. The blast load is calculated as per IS 4991 and IS 6922 code provision. The modelling and nonlinear dynamic analysis (time history analysis) is carried out using ETABS software. And then the effects of above loading is analysed and compared.

5.Modelling in ETABS

A G+9 storey prototype mathematical model is created. Material and sectional properties are defined for structural members such as slabs, beams, columns and assigned the same. The dead load and live load is calculated as per IS 875 part 1 and IS 875 part 2 respectively and assigned the same. Blast load is applied to the structure using time history function and analysed using nonlinear direct integration method.

6.Model Description

6.1 Different modal conditions with different load cases

Model: Regular 10 storied frame structure

i. Blast load of 500 kg at a standoff distance of 20m.
ii. Blast load of 1000 kg at a standoff distance of 20m.
iii. Blast load of 1500 kg at a standoff distance of 20m.
iv. Blast load of 500 kg at a standoff distance of 25m.
v. Blast load of 1000 kg at a standoff distance of 25m.
vi. Blast load of 1500 kg at a standoff distance of 25m.
vii. Blast load of 500 kg at a standoff distance of 30m.
viii. Blast load of 1000 kg at a standoff distance of 30m.
ix. Blast load of 1500 kg at a standoff distance of 30m.

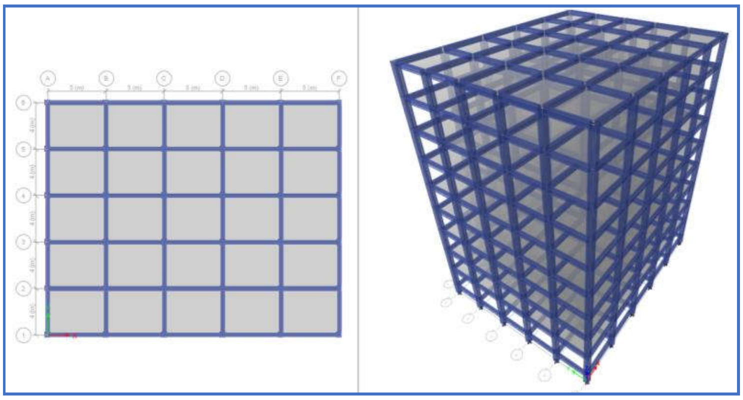

Figure 6. Plan and 3D view of ETABS model

Number of Stories	G+9
Plan Size	25mx20m
Floor to Floor Height	3.2m
Size of Beam	300mmX450mm
Size of Column	500mmX500mm
No of bays X – direction Y – direction	 5 bays of 5m spacing 5 bays of 4m spacing
Thickness of Slab	150mm
Grade of Concrete(fck) Columns Beams and Slabs	 M30 M20
Grade of Rebar (fy)	Fe 500
Live load	3 KN/m^2
Floor Finish	1.5 KN/m^2
Wall load	12.8 KN/m
Siesmic Zone	**IV**
Response Reduction Factor	5
Soil Type	Hard rock

7 BLAST LOAD CALCULATIONS

7.1 Blast load calculation for above ground explosion

The following Stand-off Distance (R) and Weight of the Explosive (W)
One important parameter in determining the intensity of the blast load is the location of the explosive or stand-off distance from the structure and another important parameter is the weight of explosive

Scaled distance (x) = $\frac{R}{W^{\wedge}\left(\frac{1}{3}\right)}$

From IS 4991: 1968 table 1 we obtain,

1) Ambient air pressure (P_a) Kg/cm^2
2) Peak side on over pressure (P_{so}) Kg/cm^2
3) Peak reflected over pressure (P_{ro}) Kg/cm^2
4) Duration of equivalent triangular pulse (t_d) milliseconds
5) Dynamic pressure (q_o) Kg/cm^2

Actual duration (t_d) = scaled duration (t_d) x $W^{(1/3)}$

7.2 Blast load calculation for below ground explosion

From IS 6922: 1973

Ground particle velocity, v = $K_1\left(\frac{Q^{2/3}}{R}\right)^{1.25}$

Ground acceleration, a = $gK_2\frac{Q^{0.83}}{R^2}$

Delay time, $t_d = \frac{R}{C}$

Where,
K_1 = constant taken as 1400 for hard rocks
K_2 = constant taken as 6 for hard rocks
Q = charge weight in kg
R = distance of structure from blast point in m
g = acceleration due to gravity in cm/s^2
C = longitudinal seismic wave velocity in m/s

7.Results and Discussions

The results of both underground (UG) and above ground (AG) explosion for 500Kg, 1000Kg, 1500Kg charge weight at standoff distance of 20m, 25m, 30m each are obtained using ETABS software and reported the same. The parameters considered are storey drift, storey displacement and storey shear. The obtained data from these graphs clearly illustrates that the effect of above ground explosion is more when compared to under ground explosion on a RCC structure. The storey drift for all the three charge weight is maximum at storey three for both UG and AG explosion. The storey displacement is maximum at top storey and storey shear is maximum at bottom storey for all the cases.

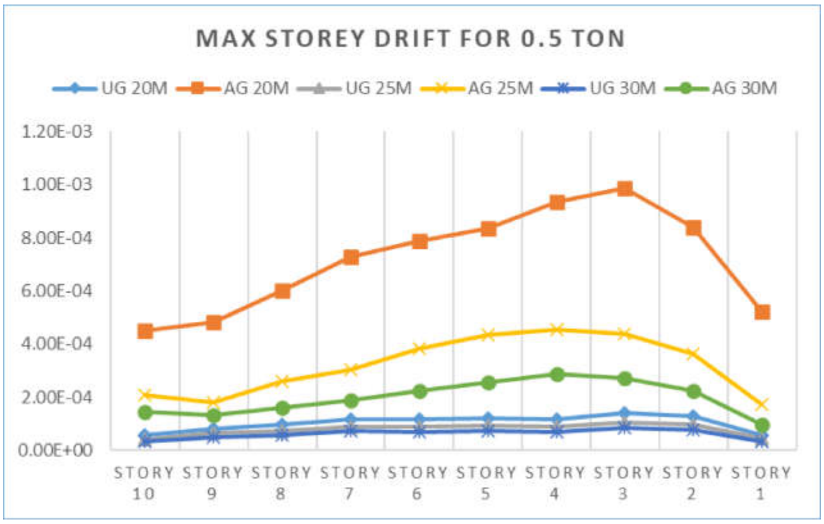

Figure 7. Storey drift for 500Kg

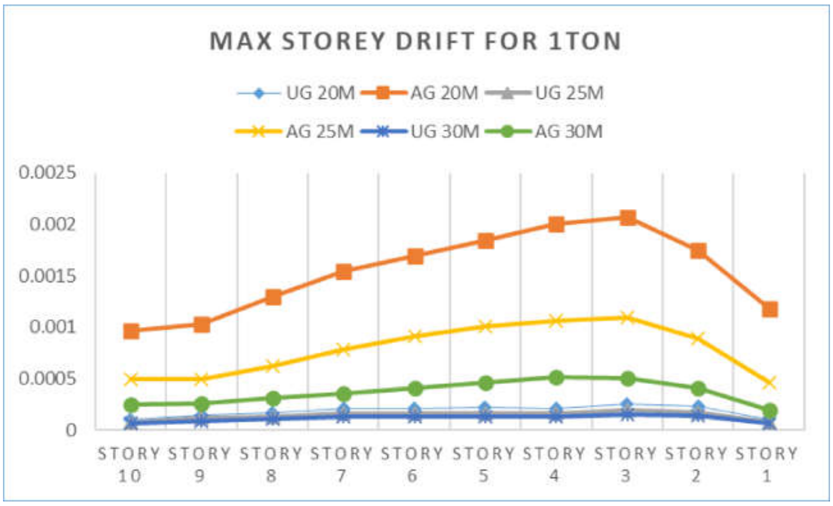

Figure 8. Storey drift for 1000Kg

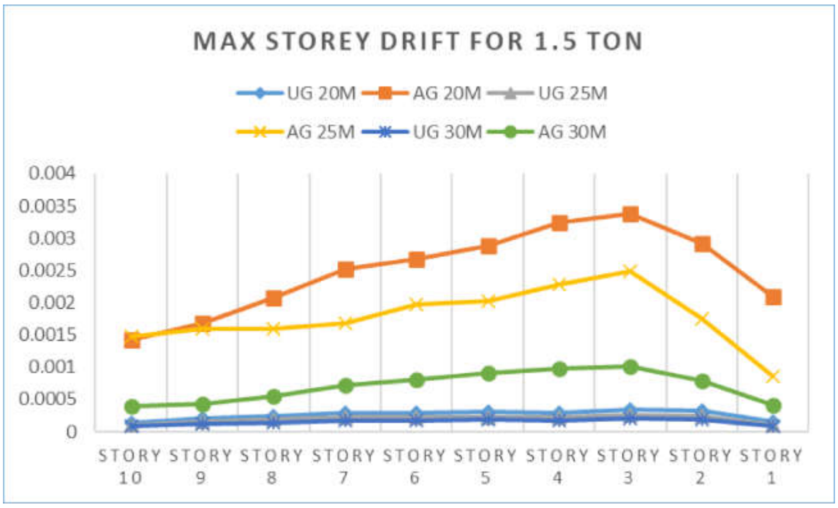

Figure 9. Storey drift for 1500Kg

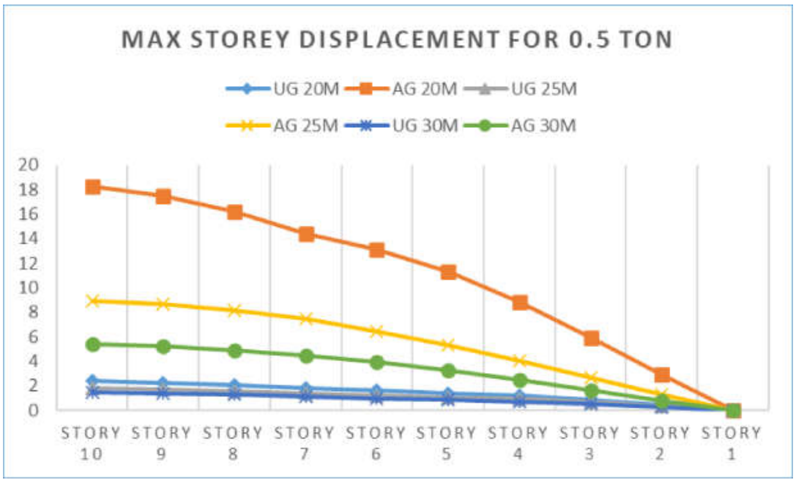

Figure 10. Storey displacement for 500Kg

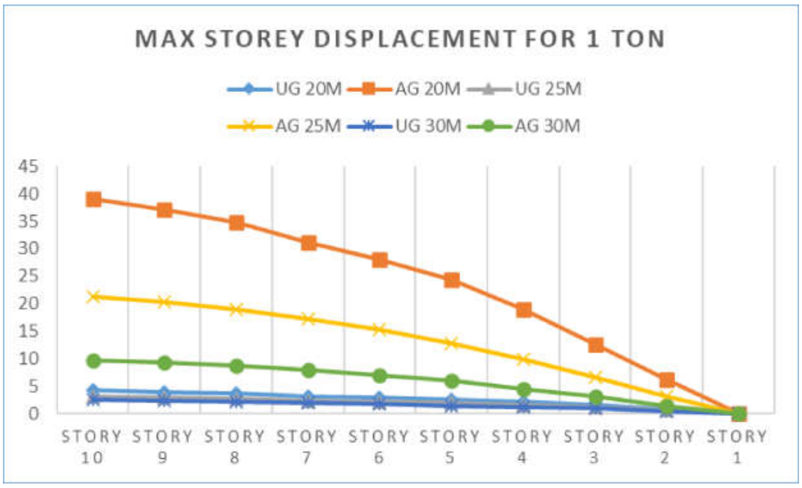

Figure 11. Storey displacement for 1000Kg

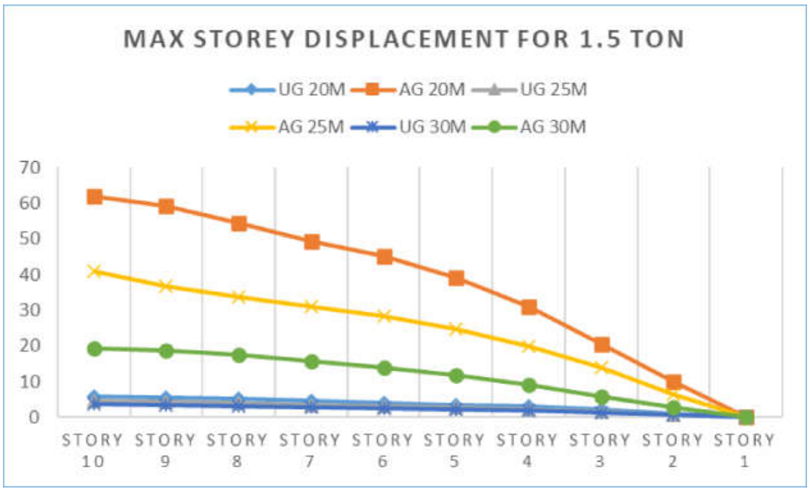

Figure 12. Storey displacement for 1500Kg

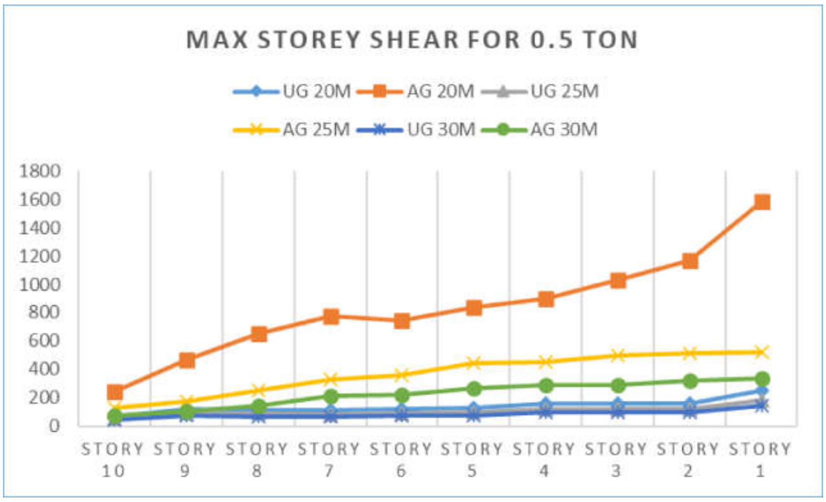

Figure 13. Storey shear for 500Kg

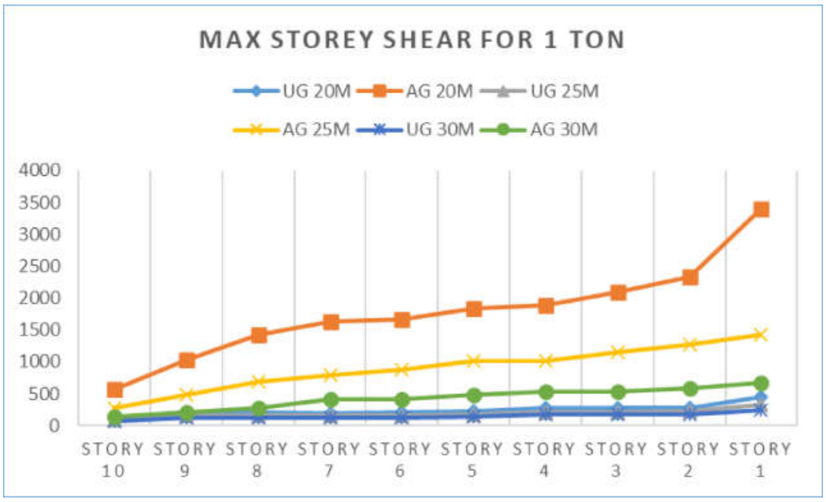

Figure 14. Storey shear for 1000Kg

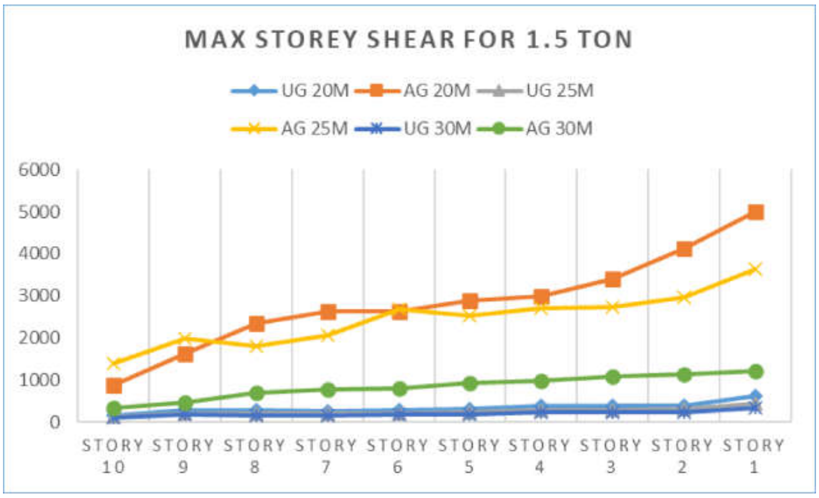

Figure 15. Storey shear for 1500Kg

The acquired data shows that the storey drift of AG explosion increases by 70% to 90% when compared to UG explosion. Storey displacement increases by 65% to 95% and storey shear increases by 45% to 85%. The obtained results conclude that as the charge weight increases and standoff distance decreases the effect of blast load increases for both UG and AG explosion.

8.Conclusion

The RC structures are prone to more damage caused by blast load when compared to earthquake and wind load due to its high temperature, high over pressure, large particle velocity, and low detonation time or delay time. A bomb explosion above the ground and/or the mining activity which includes explosion below the ground level in the vicinity of a building have capacity to cause damage to the structural frame and to the infill material of the building and resulting in the blowing out of windows, collapse of walls with the evolution fire, heat & smoke. It also results in shutting down of essential life safety systems, causing injuries & loss of life to the inhabitants.

The present study shows that the structural response such as storey drift, storey displacement and storey shear is more for AG explosion when compared to UG explosion for the same charge weight and standoff distance. It increases by almost 70% to 90%. And also the study concludes that the damage and structural response of a RC structure increases when the charge weight of explosion increases and standoff distance decreases for both AG explosion and UG explosion.

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