PREDICTION OF BLAST LOADING AND ITS IMPACT ON BUILDINGS

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***Abstract*—This paper presents the dynamic response of multi storeyed building subjected to load permiting from blast. It is about understanding the explosion phenomena and investigating the dynamic response of a concrete frame structure by using structural software. Building modal considered here is 5 storey building exposed to 1000kg TNT with three different standoff distances of 10 m. A linear and non-linear three Dimensional frame is used for analysing the dynamic response of a structure. In the present scenario, structures under blast loading (i.e. bomb explosion) are acting for short duration with high pressure intensity of shock wave which is outlined in section of TM-5 1300(UFC 3-340-02). The aim of this work is to investigate the performance of multi storey buildings under blast loading, and the dynamic response of a concrete frame structure under blast loading by using structural software. The result obtained in terms of time history function, displacementsconsidering the resistance of structure is compered. It is noticed that shear wallup-tosecond floor (40% height) is effective in reducing the displacement and further it can resist more base shear.**

***IndexTerms*—blast loading, acceleration, displacement, shear wall, pressure-time history, base shear**

I. INTRODUCTION

Over the last few decades considerable attention has been raised on the behaviour of engineering structures under blast or impact loading. The use of explosives by terrorist groups around the world that target civilian buildings and other structures is becoming a growing problem in modern societies. Explosive devices have become smaller in size and more powerful than some years ago, leading to increased mobility of the explosive material and larger range effects. Usually the casualties from such a detonation are not only related to instant fatalities as a consequence of the direct release of energy, but mainly to structural failures that might occur and could result in extensive life loss. Famous examples of such cases are the bombing attacks at the World Trade Center in 1993 and on the Alfred P. Murrah Federal Building in Oklahoma City in 1995. In both of these incidents, structural failure, including glass breakage, resulted in far more victims and injuries than the blast wave itself. After the events of the 11th September 2001 that led to the collapse of the World Trade Center in New York it was realized that civilian and government buildings, as well as areas with high people concentration (metro and train stations, means of mass transportation, stadiums etc.) are becoming potential bombing targets of terrorist groups. Since most engineering structures are vulnerable to such type of loading scenarios, a guide should be introduced to the designer in order to guarantee structural integrity even under those extreme situations. The problem of structural resistance under explosive loads has been under investigation for many years and has been well advanced in the military community. This is also the reason that the majority of these findings are not accessible to the public and are only restricted to military use. Nevertheless, some documentation that allows the prediction of the effects of an explosive blast is available for use by design engineers. The Eurocode EN 1991-1-7 [1]makes reference to the case of accidental loads and explosions, but it is mainly focused on impact actions, such as collisions from trucks, trains, ships, helicopters or any other vehicle in general. Reference is also made to gas explosions that take place in enclosed spaces but an overall approach for design under blast external loads is still missing. Some design strategies are also recommended aiming to ensure increased robustness in building structures that are to endure localized failure. However, no guidelines are provided in EN 1991-1-7 for the calculation of external blast induced loads.

II. BLAST WAVE PRESSURE – TIME HISTORY

Figure 1 shows the idealised profile of the pressure in relation to time for the case of a free air blast wave, which reaches a point at a certain distance from the detonation. The pressure surrounding the element is initially equal to the ambient pressure P_o, and it undergoes an instantaneous increase to a peak pressure P_{so} at the arrival time t_A, when the shock front reaches that point. The time needed for the pressure to reach its peak value is very small and for design purposes it is assumed to be equal to zero. The peak pressure P_{so} is also known as side-on overpressure or peak overpressure. The value of the peak overpressure as well as the velocity of propagation of the shock wave decrease with increasing distance from the detonation center. After its peak value,

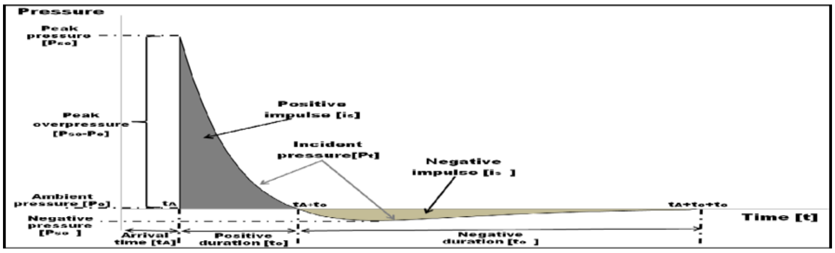


Figure 1: Ideal blast wave's pressure time history

The pressure decreases with an exponential rate until it reaches the ambient pressure at, t_A+t_o, to being called the positive phase duration. After the positive phase of the pressure-time diagram, the pressure becomes smaller (referred to as negative) than the ambient value, and finally returns to it. The negative phase is longer than the positive one, its minimum pressure value is denoted as P_{so}^- and its duration as t_o^-. During this phase the structures are subjected to suction forces, which is the reason why sometimes during blast loading glass fragments from failures of facades are found outside a building instead in its interior.

III. DESCRIPTION OF BUILDING

The structure selected for this study is 5-muilti storey building at the height of 16m shown in Figure 2. The base floor height is 4m and remaining of each storey is 3m. A Five story RC building in Zone V on medium soil was analyzed and the displacement and acceleration with and without Blast loading of the structure due to different load combination were obtained. Blast loading analysis was performed using.

A. (G+4) BUILDING INFORMATION

- Size of column = (0.45×0.45) m.
- Size of beam = (0.4×0.3) m.
- Grade of concrete = M25.
- Grade of steel = Fe 415. (For RCC structure).
- Shear wall thickness = 0.23 m.
- Slab thickness = 0.15 m
- Three bays in X and Y direction of 5m.
- Structure is G+4; Ground floor height is 4 m and other of 3 m.
- Used 1000 kg TNT blast at 10 m from building.

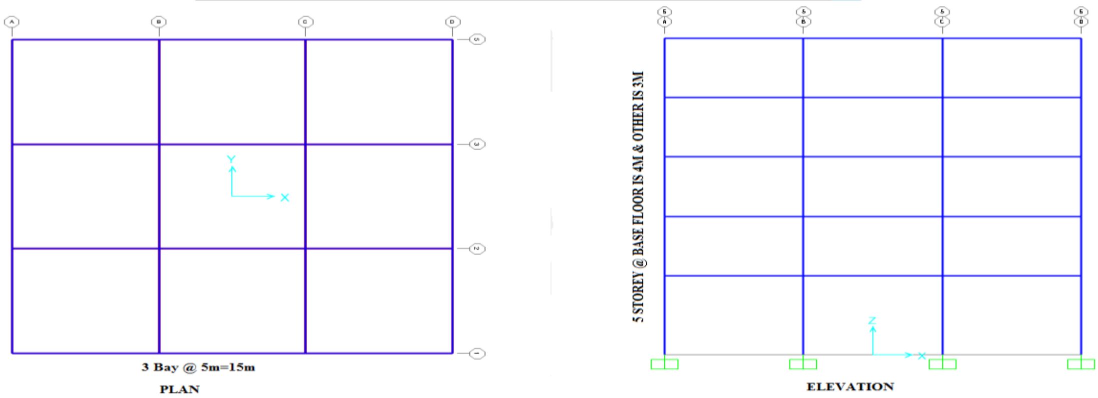


Figure 2. Plan and Elevation (G+4) Building

B. CALCULATION STEPS OF STRUCTURAL BLAST LOADING

For calculating the blast loading on the structural surfaces the following steps are necessary:
Step 1: Determine the weight of the charge, W, charge distance of the structure, R_G, charge height,H_C (for explosions in air) and structural dimensions.
Step 2: Apply safety factor of 20 %.
Step 3: Select several points on the structure (front facade, roof, side and rear surface) and determine the explosion parameters for each selected point.
For the explosion near the ground:
a) Determine the scaled charge distance:

$$Z_G = \frac{R_G}{W^{1/3}}$$

b) Determine the explosion's parameters using Fig. 3 for the calculated scaled distance Z_G and read:
– peak initial positive overpressure P_{so}
– wave front speed U
– scaled initial positive impulse $i_s/W^{1/3}$
– scaled length of the positive phase $t_o/W^{1/3}$
– scaled value of the wave arrival $t_A/W^{1/3}$
Multiply the scaled value with the value of $W^{1/3}$ in order to obtain the absolute values.

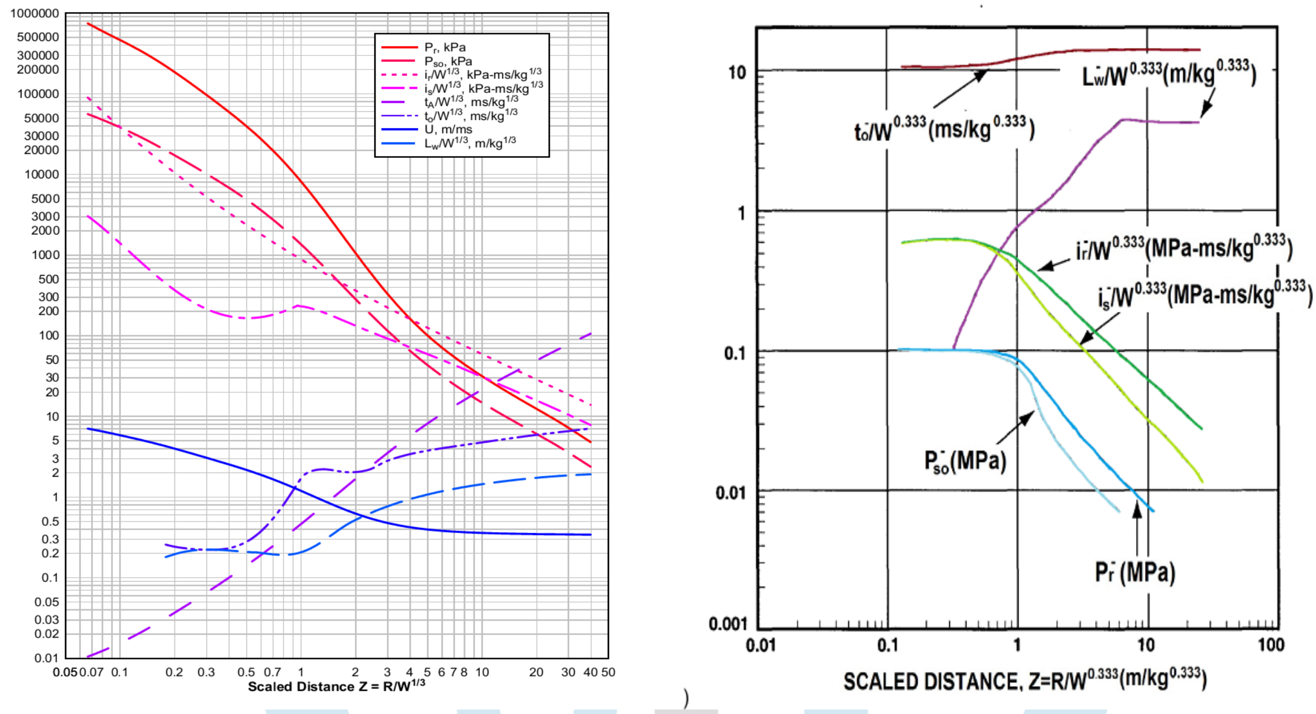


Figure 3. Calculating the blast loading parameter

IV. NUMERICAL EXPERIMENT

As a case study five story frame structure with above description.The blast of 1000 kg TNT is applied at 10 m distance. The detailed calculation of the blast wave parameter of the blast loading on each floor is given below,

TABLE I
For 1000kg TNT

Floor. No.	Scale distance, Z m/kg$^{1/3}$	Positive Pressure, Pr kPa	Time of arrival, T_A Ms	Positive Phase, t_o Ms	Negative Pressure, P kPa	Negative Phase, T Ms
G	1.08	6650	5.35	20	81.5	124.9
1	1.22	4658.7	6.74	21.8	74	127.3
2	1.41	3021.7	8.86	22	63.2	130.4
3	1.64	1929.6	11.70	20.9	51.8	133.5
4	1.89	1259.9	15.21	20.4	44.3	134.5

A. Blast Loading

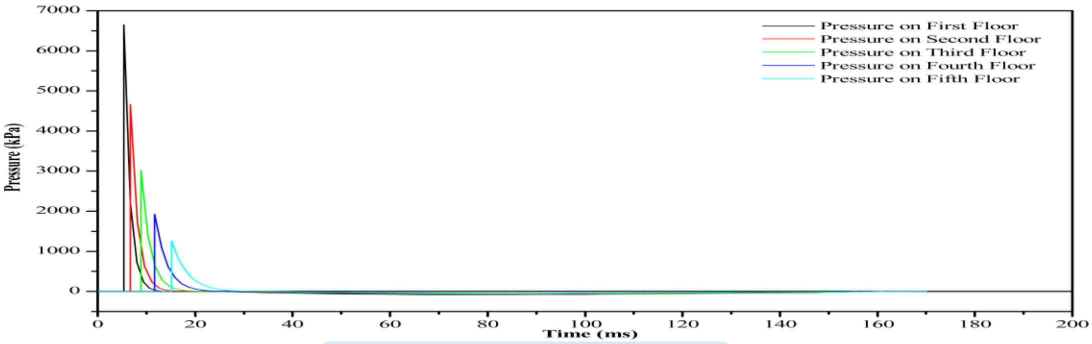


Figure 4.Blast is conducted 10 m away from structure of 1000 Kg TNT intensity

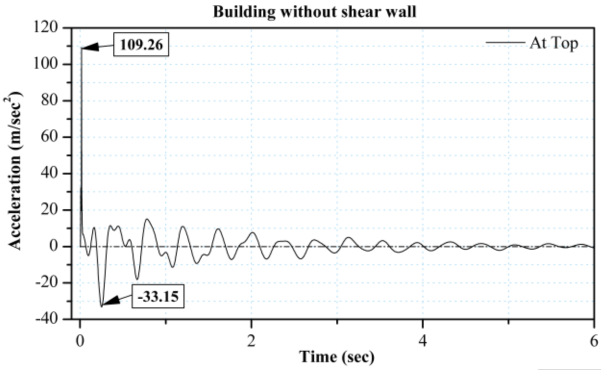
B. Shear Wall Position

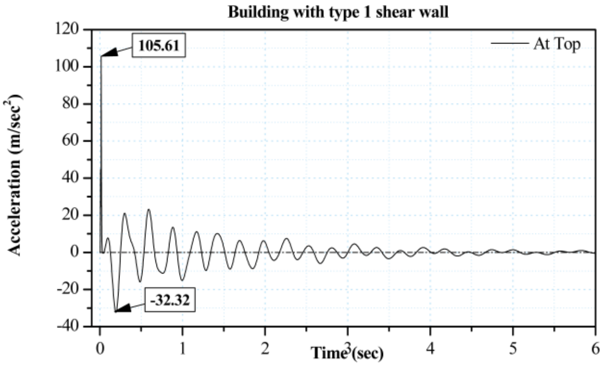
TABLE 2

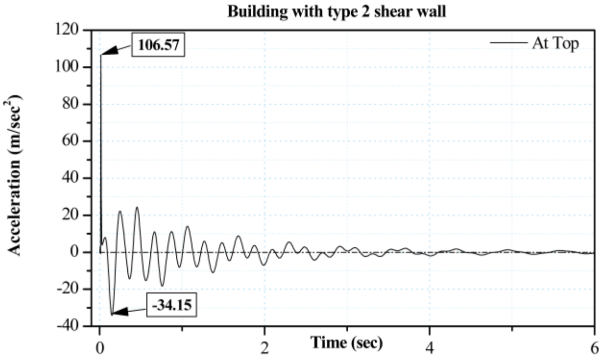
Notation	Floors	Location on Floor
Shear Wall 1	G	All side walls
Shear Wall 2	G, G+1	All side walls
Shear Wall 3	G, G+1, G+2	All side walls
Shear Wall 4	G, G+1, G+2, G+3	All side walls
Shear Wall 5	G, G+1, G+2, G+3,G+4	All side walls
Shear Wall 6	G, G+1, G+2, G+3,G+4	All four corner walls
Shear Wall 7	G, G+1, G+2, G+3,G+4	All center walls

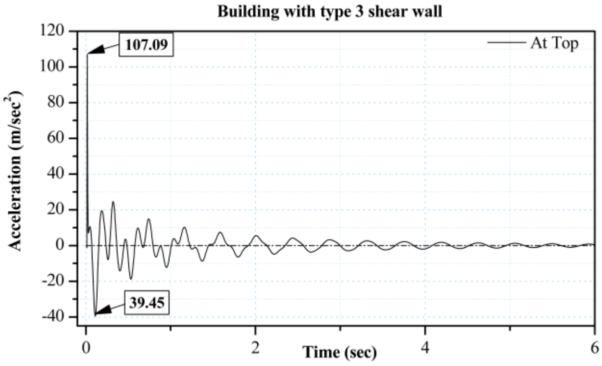
V. RESULT

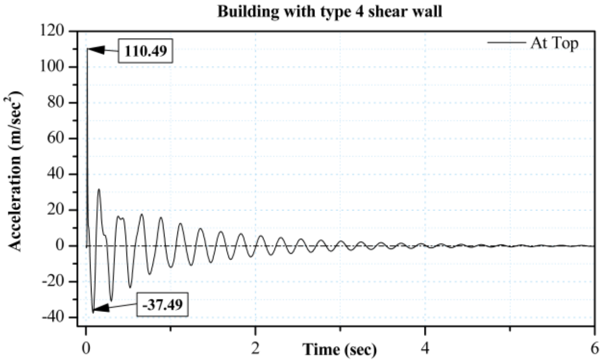
- **Acceleration**

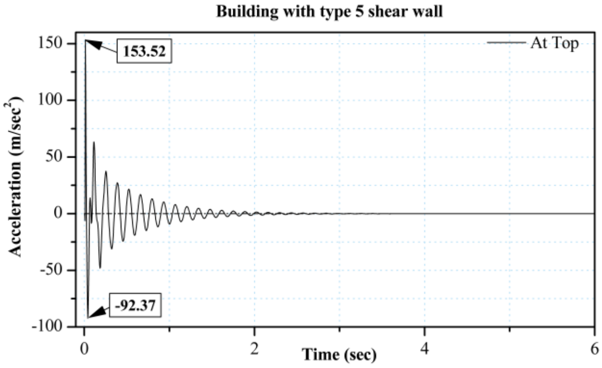


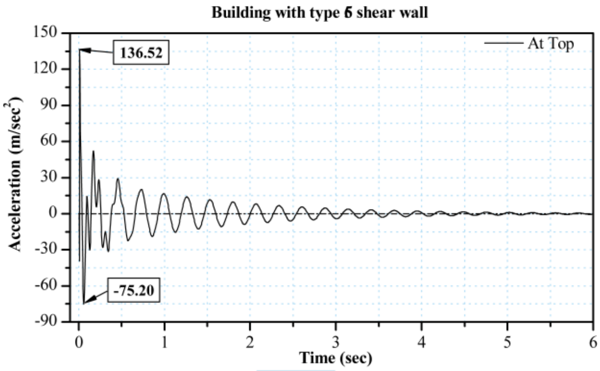


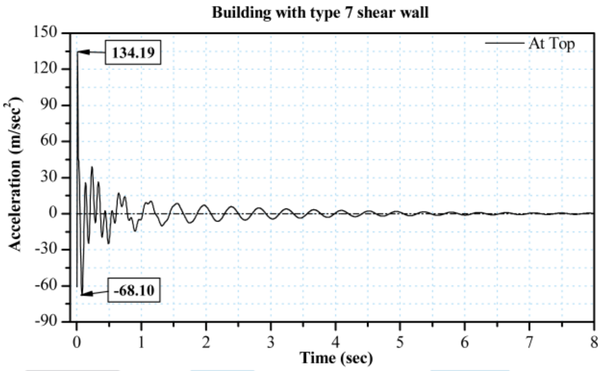




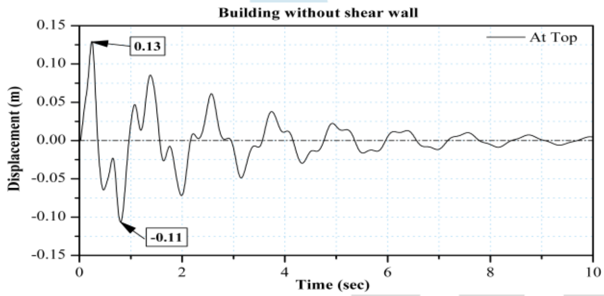


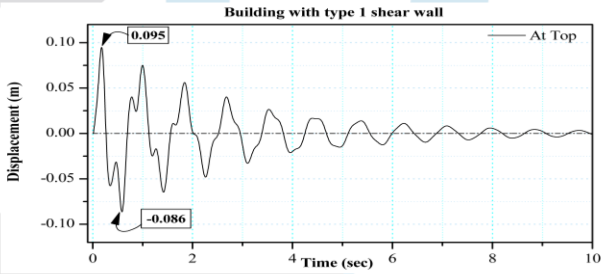


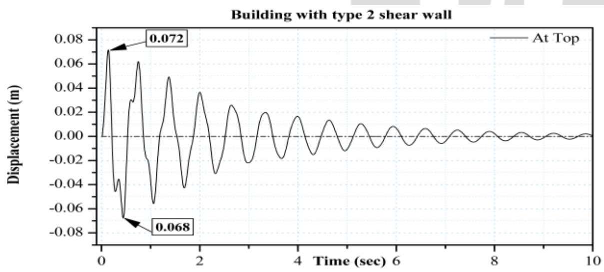


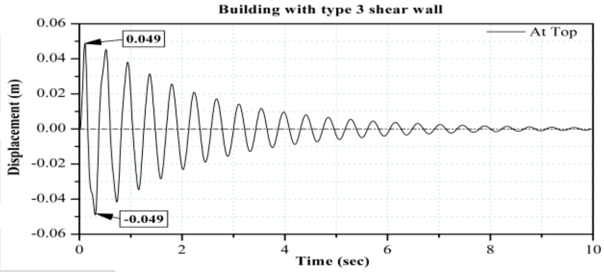


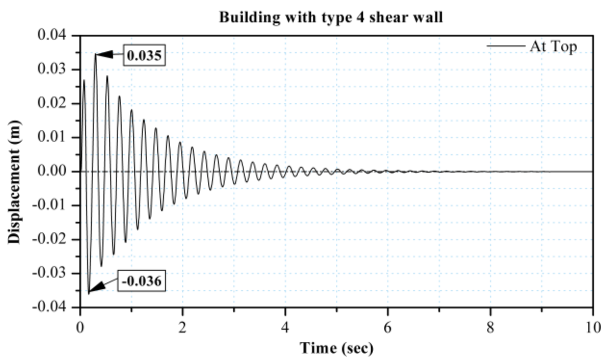
- **Displacement**

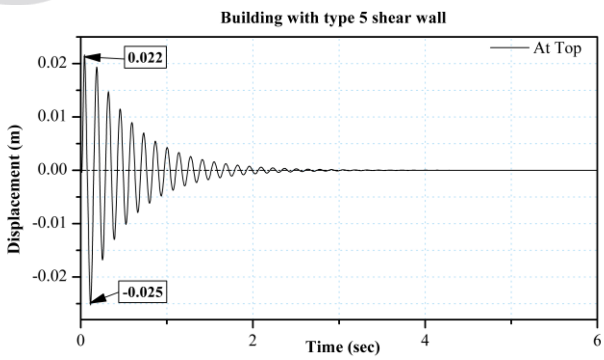


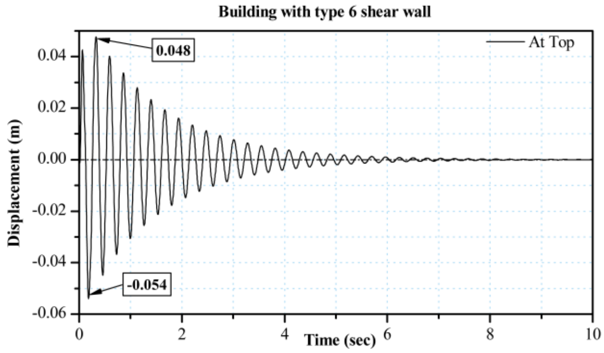


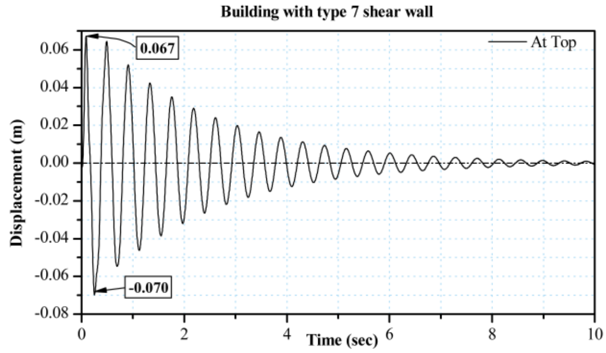




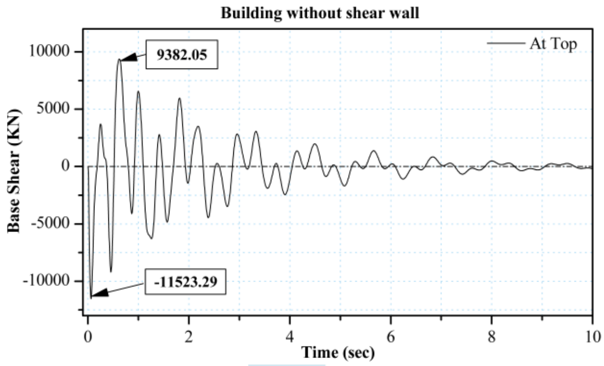


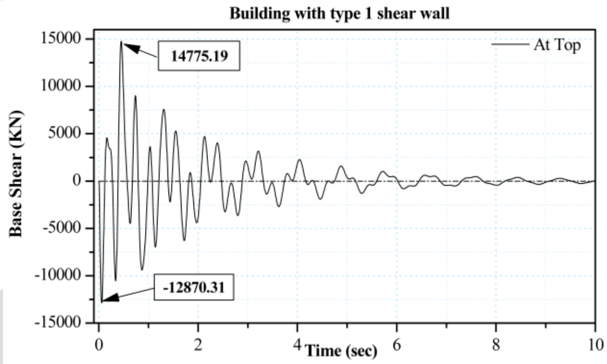


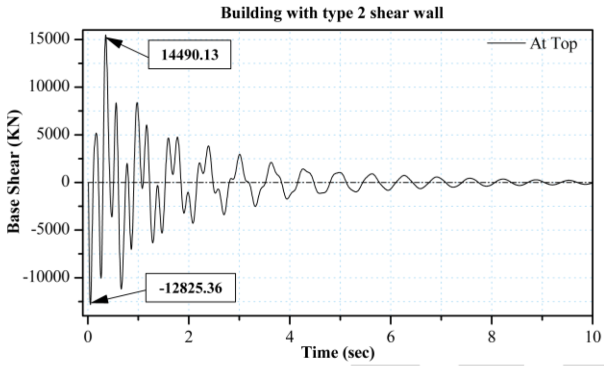

Building with type 6 shear wall
At Top
0.048
-0.054
Displacement (m)
Time (sec)

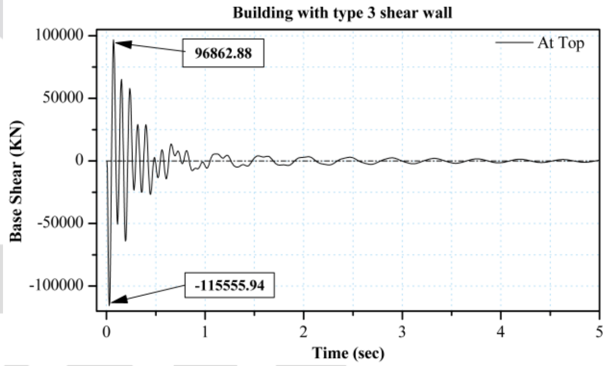

Building with type 7 shear wall
At Top
0.067
-0.070
Displacement (m)
Time (sec)

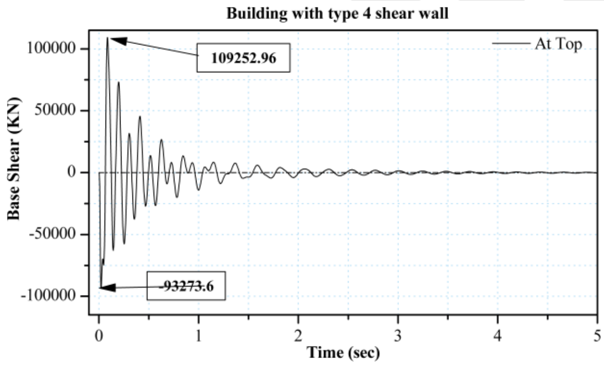
- **Base Shear**

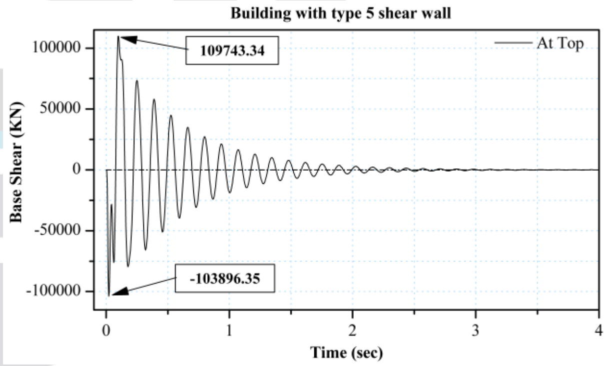

Building without shear wall
At Top
9382.05
-11523.29
Base Shear (KN)
Time (sec)

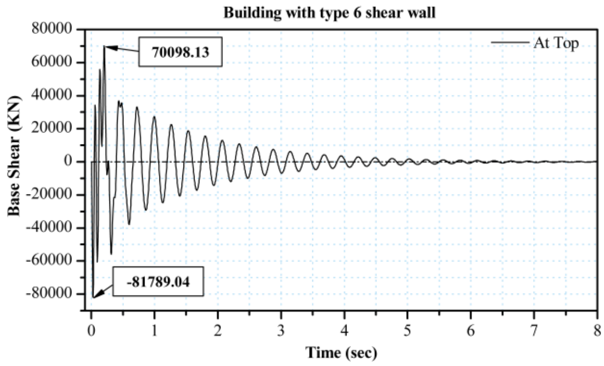

Building with type 1 shear wall
At Top
14775.19
-12870.31
Base Shear (KN)
Time (sec)

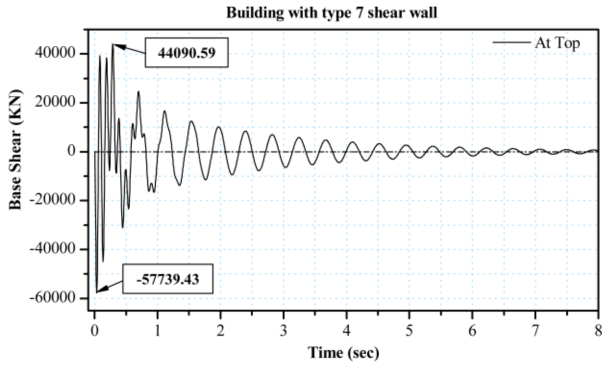

Building with type 2 shear wall
At Top
14490.13
-12825.36
Base Shear (KN)
Time (sec)


Building with type 3 shear wall
At Top
96862.88
-115555.94
Base Shear (KN)
Time (sec)


Building with type 4 shear wall
At Top
109252.96
-93273.6
Base Shear (KN)
Time (sec)


Building with type 5 shear wall
At Top
109743.34
-103896.35
Base Shear (KN)
Time (sec)



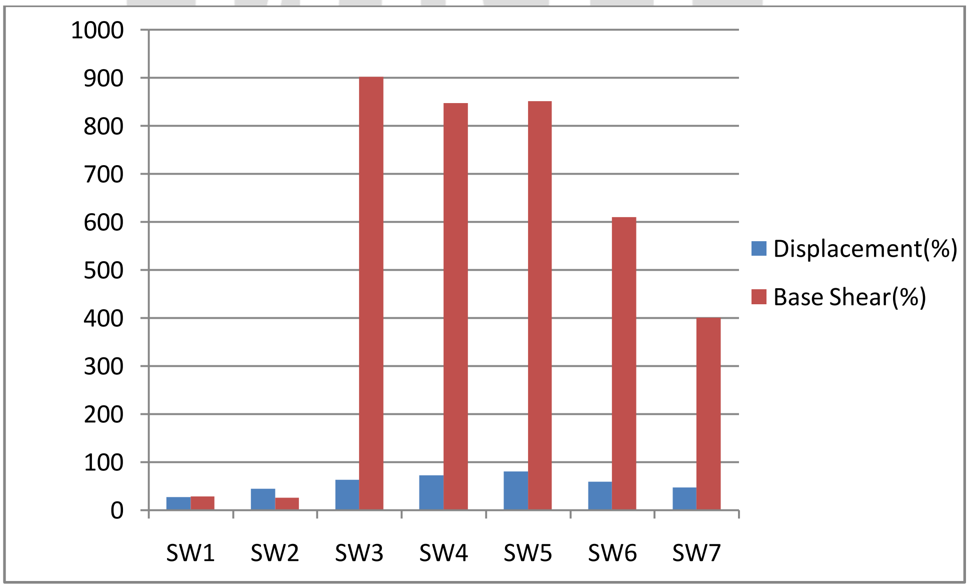


- **Comparison of displacement and base shear without shear wall and with shear wall**

TABLE 3

Sr. No.	Modelled description	Maximum displacement (m)	Decrease in displacement (%)	Maximum Base Shear (KN)	Increase in base shear (%)
1	Building without shear wall	0.13	Nil	11523.29	Nil
2	Shear Wall 1	0.095	26.92	14775.19	28.22
3	Shear Wall 2	0.072	44.62	14490.13	25.75
4	Shear Wall 3	0.049	62.31	115555.94	902.8
5	Shear Wall 4	0.036	72.31	109252.96	848.11
6	Shear Wall 5	0.025	80.77	109743.34	852.36
7	Shear Wall 6	0.054	58.46	81789.04	609.77
8	Shear Wall 7	0.07	46.15	57739.43	401.07

Table no. 4 Shear wall position graph (%)



VI. CONCLUSION

The structure first failure locally then distributed to entire structure, the response in the structure is more, in the case of lower ranges. Acceleration is higher in case of 1000 kg charge weight than in 500 kg charge weight. So, it may cause direct effect on the structure. The pressure which in front face of the structure is low at the top is observed in the case of 10m range under 500kg and 1000kg TNT.

Best position of shear wall is Shear Wall 2 (SW2), because in which displacement is decreases 43% by increasing base shear 26 %. As compared to others this effective combination of displacement and base shear.

The result obtained in terms of time history function, displacements considering the resistance of structure is compared. It is noticed that shear wall upto second floor (40% height) is effective in reducing the displacement and further it can resist more base shear.

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