Behaviour of Prestressed Building Under Blast Loading Using Sap 2000

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Abstract- *This paper presents the dynamic response of high rise building subjected to blast loading. It is about understanding the explosion phenomena and investigating the dynamic response of a concrete frame structure by using SAP2000. Building is of 12 storey is exposed to 30kg TNT and 60kg TNT with three different standoff distances of 10m, 12.5m and 15m respectively. A non-linear three Dimensional is used for analyzing the dynamic response of a structure. In the present scenario, structures under blast loading (i.e. bomb explosion) are acting in short duration with high pressure intensity of shock wave which is outlined in section of TM-5 1300.The aim of this paper is to investigate the performance of high rise buildings under blast loading, blast phenomena and dynamic response of a concrete frame structure under blast loading by using SAP2000 software. The result obtained in terms of time history function, displacements and influence of the parameter considering the resistance of structure. Therefore, for decreasing the facade on surrounding buildings, moderate explosive energy is used to control the structural damages due to explosion.*

Keywords- Blasting Loading, Concrete Frame Structure, Dynamic Response, Standoff Distance, SAP 2000.

I. INTRODUCTION

1.1 General

Over the last few decades considerable attention has been raised on the behavior 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 that’s are few years ago, so it leads to increased mobility of the explosive material and also 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.

Blasts that result from bomb explosions have become a new threat to buildings designed for normal static loads. Under blast loading, buildings are subjected to the loads that are quite different from those governing their primary design in both magnitude and direction. Thus, a better understanding of the behaviour of buildings under blast loads is of prime importance, because there are many buildings that may be under threat of blast loading although not originally designed for the same. 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. Famous examples of such cases are the bombing attacks at the World Trade Center in 1993 and Alfred P. Murrah Federal Building in Oklahoma City in 1995.

II. OBJECTIVES

a) To perform non-linear analysis of prestress building subjected to blast load by time history method.
b) To analyze response of building for different arrival time of blast wave.
c) To study effect of various blast load at 30 m blast standoff distance for low rise, medium rise and high rise Pre-stressed building.
d) To compare response of building for blast load of steel structure with and without shear wall in terms of displacement, velocity and acceleration.
e) To check effect of in fill walls and dampers for distance for low rise, medium rise and high rise Pre-stressed building subjected to blast load.

III. LITERATURE REVIEW

The analysis of the blast loading on the structure started in 1960‘s. US Department of the Army, released a technical manual titled - structures to resist the effects of accidental explosions‖ in 1959. The revised edition of the manual TM 5-1300 (1990) most widely used by military and civilian organization for designing structures to prevent the propagation of explosion and to provide protection for personnel and valuable equipments. Also, IS code 4991:1968 can be used for blast resistant designing purposes.

M. V. Dharaneepathy et al. (1995) studied the effects of the stand-off distance on tall shells of different heights, carried out with a view to study the effect of distance (ground-zero distance) of charge on the blast response. An important task in blast-resistant design is to make a realistic prediction of the blast pressures. The distance of explosion from the structure is an important datum, governing the magnitude and duration of the blast loads. The distance, known as ‗critical ground-zero distance.

Jayatilake et al. (2007) proposed response of tall buildings with symmetric setbacks under blast loading. This study explores three-dimensional nonlinear dynamic responses of typical tall buildings with and without setbacks under blast loading. The influence of the setbacks on the lateral load response due to blasts in terms of peak deflections, accelerations, inter storey drift and bending moments at critical locations were investigated.

T. Ngo, et al. (2007) for their study on ―Blast loading and Blast Effects on Structures gives an overview on the analysis and design of structures subjected to blast loads phenomenon for understanding the blast loads and dynamic response of various structural elements. This study helps for the design consideration against extreme events such as bomb blast, high velocity impacts.

Draganic and Sigmund (2012) have shown effect of blast loading on structures. The paper describes the process of determining the blast load on structures and provides a numerical example of a fictive structure exposed to this load. The blast load was analytically determined as a pressure-time history and numerical model of the structure was created in SAP2000.

Sarita Singla et al. (2015) proposed dynamic response of a space framed structure subjected to blast load‘. Blast pressures for different cases are computed using correlation between blast pressure and blast scaled distance based on charts given in U.S manual. Time history loading is also obtained with parameters of reflected total over pressure and duration of positive phase.

IV. BACKGROUND

Analysis of structures under blast load requires a good understanding of the blast phenomenon and a dynamic response of structural elements.

1. Explosions and blast phenomenon

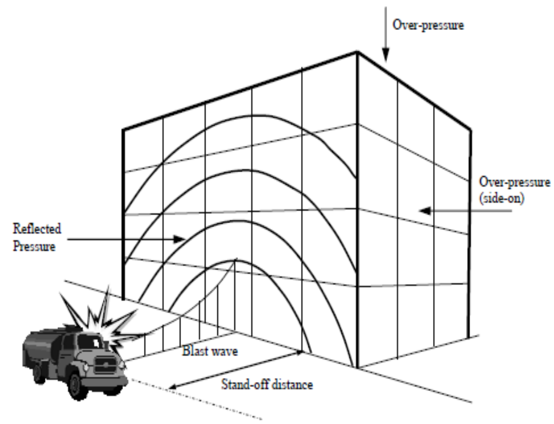


Fig. 1 Blast loading over a building structure

An explosion can be defined as a very fast chemical reaction involving a solid, dust or gas, during which a rapid release of hot gases and energy takes place. The phenomenon lasts only some milliseconds and it results in the production of very high temperatures and pressures. During detonation the hot gases that are produced expand in order to occupy the available space, leading to wave type propagation through space that is transmitted spherically through an unbounded surrounding medium. Along with the produced gases, the air around the blast (for air blasts) also expands and its molecules pile-up, resulting in what is known as a blast wave and shock front.

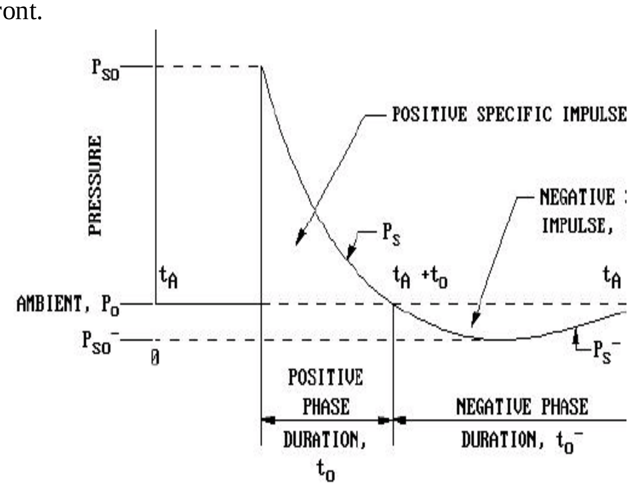


Fig.No.2 Ideal blast wave’s pressure time history

The following form of Friedlander’s equation has been proposed, and is widely used to describe this rate of decrease in pressure values:

$$P_s(t) = P_{so}\left(1 - \frac{t}{t_o}\right)e^{-b\frac{t}{t_o}}$$

Where , Pso is the peak overpressure,
to is the positive phase duration,
b is a decay coefficient of the waveform and
t is the time elapsed, measured from the instant of blast arrival.

2. Explosion and types of explosion

There are three types of blast loading according to position of charge which are;-

2.1) Unconfined explosions

There are three types of unconfined explosion which are:-

(a) Free-air bursts: The explosive charge is detonated in the air, the blast waves propagate spherically outwards and impinge directly onto the structure without prior interaction with other obstacles or the ground.
(b) Air bursts: The explosive charge is detonated in the air, the blast waves propagate spherically outwards and impinge onto the structure after having interacted first with the ground; a Mach wave front is created.
(c) Surface bursts: The explosive charge is detonated almost at ground surface, the blast waves immediately interact locally with the ground and they next propagate hemispherical outwards and impinge onto the structure.

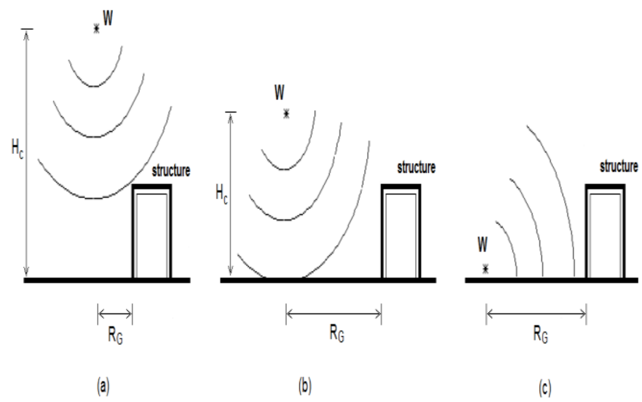


Figure 3: Types of external explosions and blast loadings; (a) Free-air bursts, (b) Air bursts, and (c) Surface bursts.

As shown in figure 3 the height Hc above ground, where the detonation of a charge W occurs, and on the horizontal distance RG between the projection of the explosive to the ground and the structure.

2.1) Confined explosions:-

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.

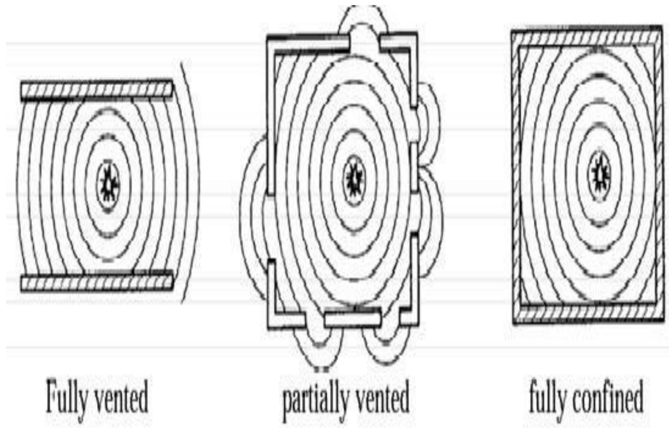


Fig.4 Fully vented, Partially Vented and Fully Confined

3. Shock Waves or Blast Waves

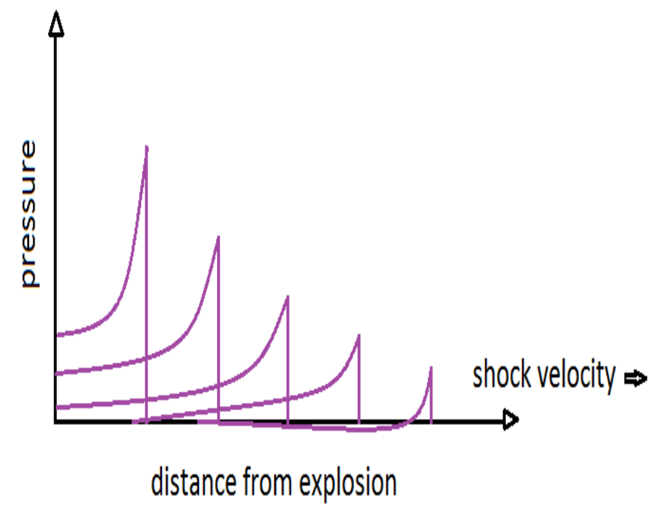


Figure 5 Blast wave propagation

From the figure 5 it can be concluded that if the explosive source is spherical, the resulting shock wave will be spherical, since its surface is continually increasing, the energy per unit area continually decreases.

Consequently, as the shock wave travels outward from the charge, the pressure in the front of the wave, steadily decreases. At great distances from the charge, the peak pressure is infinitesimal, and the wave can be treated as a sound wave. Behind the shock wave front, the pressure in the wave decreases from its initial peak value.

4. Blast effects on building

Buildings experience the effects of explosions in several stages:

1. The initial blast wave typically shatters windows and causes other damage to the building facade. It also exerts pressure on the roof and walls that are not directly facing the blast, sometimes damaging them as well.

2. In the second stage, the blast wave enters the building and exerts pressure on the structure. When directed upward, this pressure may be extremely damaging to slabs and columns because it acts counter to the design used to resist gravity loads.

V. ANALITICAL INVESTIGATION

Time History Analysis

Time-history analysis is used to determine the dynamic response of a structure to arbitrary loading. The dynamic equilibrium equations to be solved are given by,

$$Ku(t) + C\dot{u}(t) + M\ddot{u}(t) = r(t)$$

where, K is the stiffness matrix, C is the proportional damping matrix, M is the diagonal mass matrix, u, $\dot{u}$ and $\ddot{u}$ are the relative displacements, velocities, and acceleration with respect to the ground, and r is the applied load. If the load includes ground acceleration, the displacements, velocities, and accelerations are relative to this ground motion.

Any number of time- history load Cases can be defined. Each time-history case can differ in the load applied and in the type of analysis to be performed. There are several options that determine the type of time-history analysis to be performed: 1) Linear vs. Nonlinear 2) Modal vs. Direct-integration: These are two different solution methods, each with advantages and disadvantages. Under ideal circumstances, both methods should yield the same results to a given problem. 3) Transient vs. Periodic: Transient analysis considers the applied load as a one-time event, with a beginning and end. Periodic analysis considers the load to repeat indefinitely, with all transient response damped out. Periodic analysis is only available for linear modal time-history analysis.

For most real structures which contain stiff elements, a very small time step is required to obtain a stable solution. Reducing the integration time step will increase the accuracy, and generally a time step size which is less than 0.01 times the dominating period is selected.

To get consistent results for the 3D building models, the time step had to be reduced to 0.001s. The non-linear direct integration time history analyses are run for a duration of 2 s with 2000 time steps for all the buildings, and encompassed one cycle of structural response.

VI. PROBLEM STATEMENT

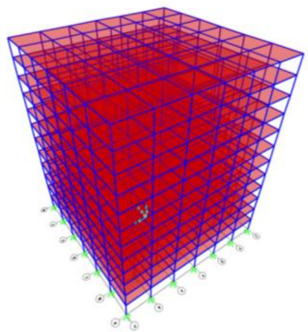
The example of commercial pre-stressed G +12 building and its elements are shown in plan, having Floor to floor height 3.2 m, internal walls are 230mm thick, Internal walls 230 mm thick Materials used for the columns and beams is Reinforced concrete M30, Rebar Steel Fe-415.Structure is subjected to Dead loads for Slab 25 D KN/m^2 (D is depth of slab in meter.) Floor finish load for slab 1.0 KN/m^2, Live load of 2 KN/m^2 .Slab thickness 125 mm. Elastic modulus of concrete 27386.12KN/m^2. Size of beams 600 mm X 600mm ,Size of columns 600 mm X 600mm,.Prestressed load of 1800KN. Tendon of 12/7 fressinet cable ,Eccentricity 50 mm. Grade of Tendon 1600 MPA, Density ofconcrete25 KN/m^3, Density of brick masonry is 20 KN/$m^{3.}$ Prepare a model for pre-stressed building using SAP 2000 software and analyze the blast loading on structure.

GIVEN DATA:-

1) Type of Building Pre-stressed Structure
2) Number of storey 12storey
3) Plan size 30 m X 30 m
4) Floor to floor height: 3.2 m.
5) Internal walls 230 mm thick
6) Materials-
Reinforced concrete for the columns and beams Concrete M30, Rebar Steel Fe-415

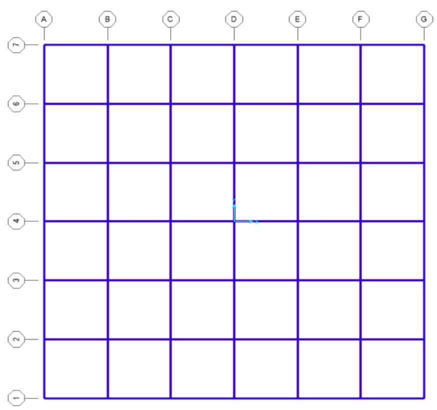
7) Loads:
a) Dead load -
i) Slab: 25 D KN/m^2
D is depth of slab in m
ii) Floor finish 1.0 KN/m^2
b) Live load - 2 KN/m^2
8) Slab thickness 125 mm
9) Elastic modulus of concrete 27386.12KN/m^2

10) Size of beams 600 mm X 600 mm
11) Size of columns 600 mm X 600 mm
12) Density of concrete 25 KN/m^3
13) Density of brick masonry 20 KN/m^3
14) Pre-stressed load 1800KN
15) Tendon 12/7 fressinet cable
16) Eccentricity 50 mm
17) Grade of Tendon 1600 MPA



ELEVATION (G+12)

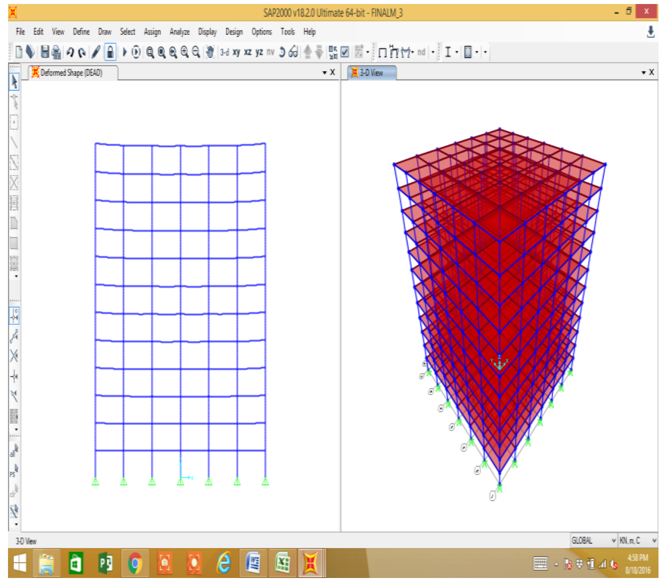
MODEL NO.1	G+12 RCC BARE FRAME
MODEL NO.2	G+12 PSC BARE FRAME
MODEL NO.3	G+12 PSC BARE FRAME+18m infill
MODEL NO.4	G+12 PSC BARE FRAME+36m infill



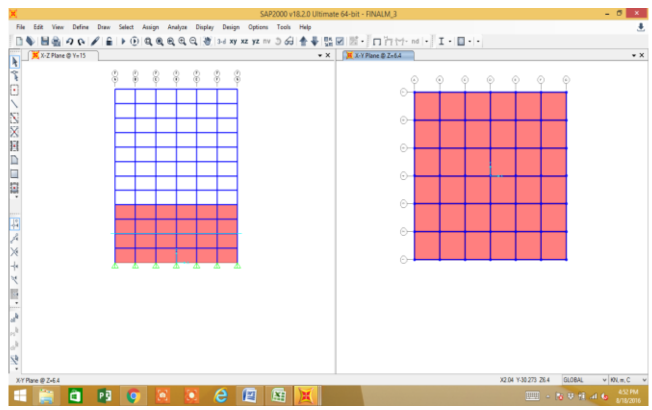
PLAN (30M X 30M)

VII. RESULT AND DISCUSSION

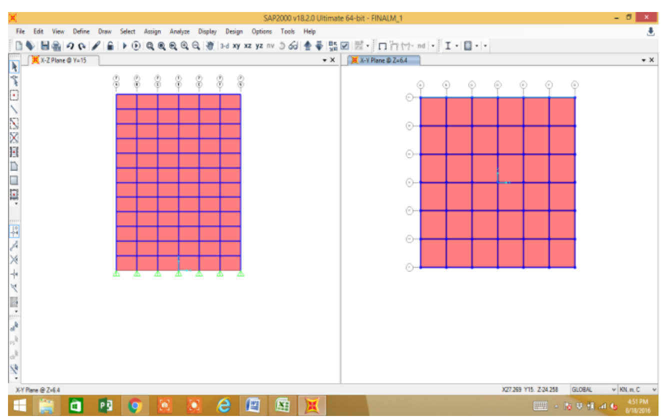
The following models are proposed for blast load analysis of 100kg TNT and 30m stand-off distance.



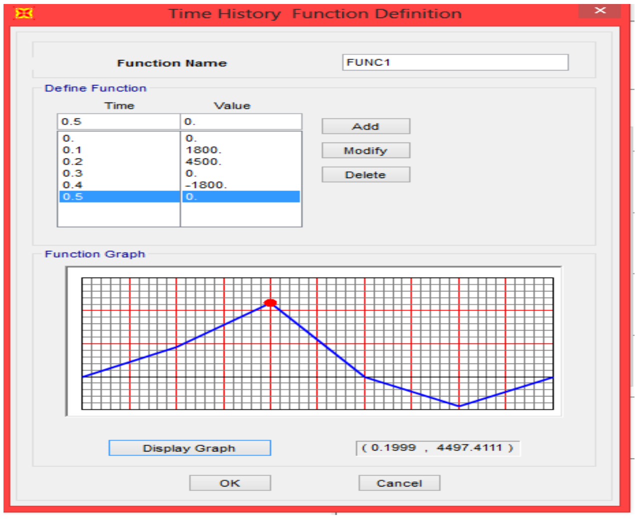
MODEL 1 & 2



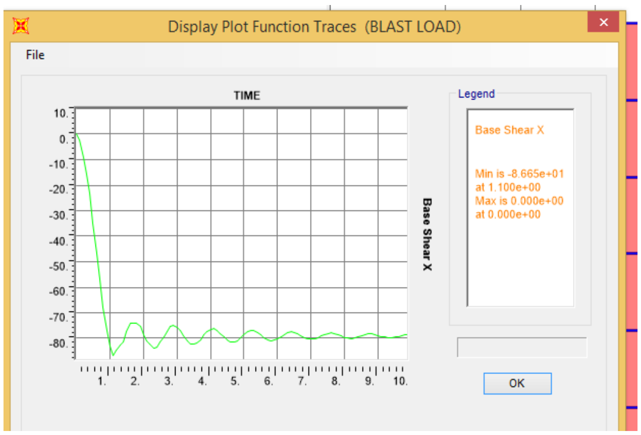
MODEL 3



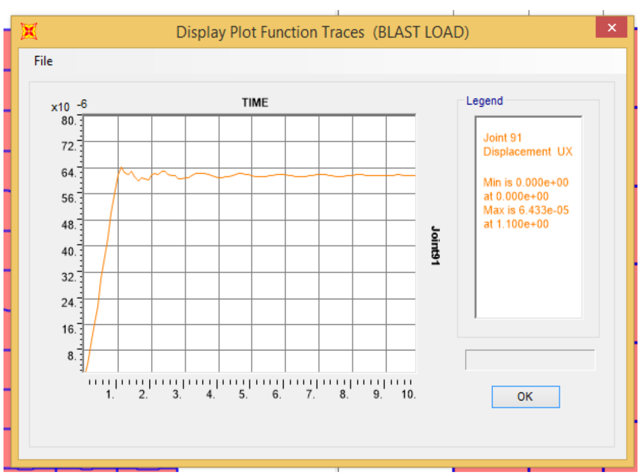
MODEL 4



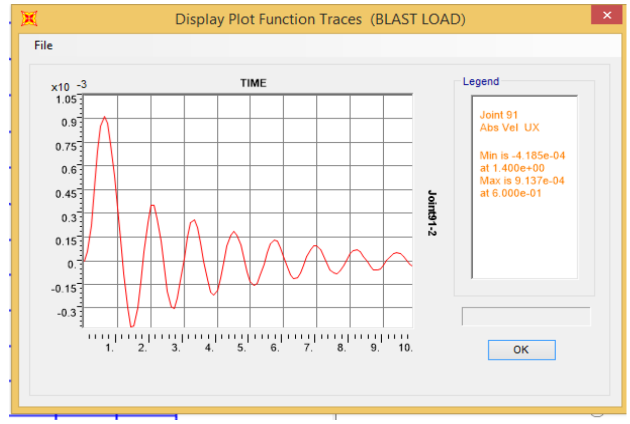
GRAPH OF FORCE VS TIME



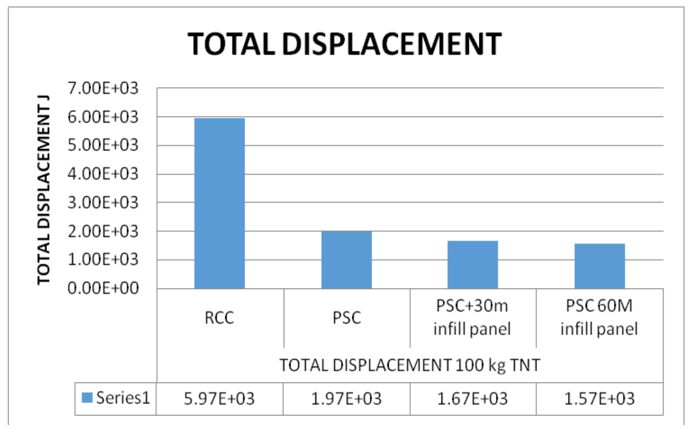
BASE SHEAR



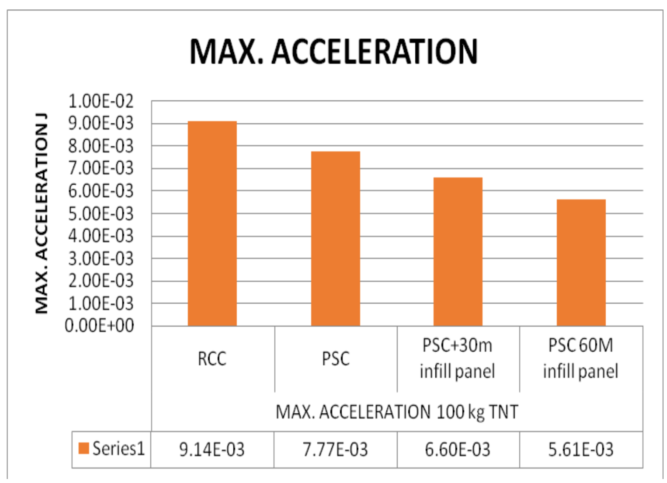
MAIMUM DISPLACEMENT



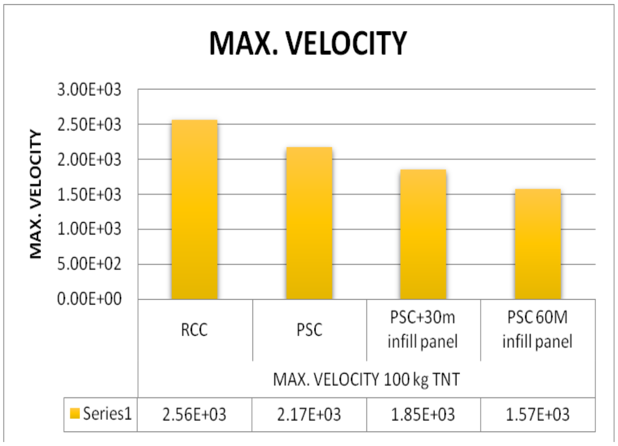
MAXIMUM VELOCITY



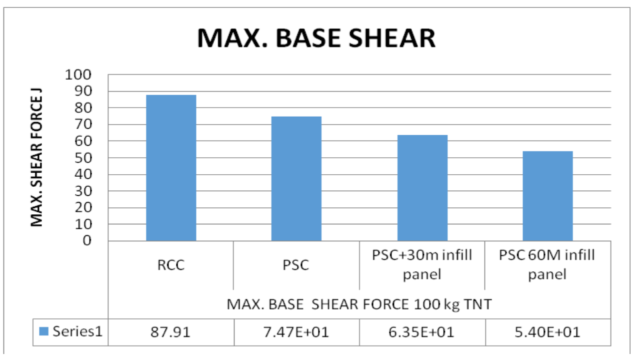
TOTAL DISPLACEMENT



MAXIMUM ACCELERATION



MAXIMUM VELOCITY



MAXIMUM BASE SHEAR

VIII. CONCLUSION

1. For G+12 100 kg TNT, due to infill there is20.82%, 16.10% &7.83% reduction in displacement, velocity and acceleration respectively.
2. For G+12 200 kg TNT, due to infill there is 24.96%, 12.87% &3.03% reduction in displacement, velocity and acceleration respectively.
3. For G+12 300 kg TNT, due to infill there is 24.44%, 11.6% &1.558% reduction in displacement, velocity and acceleration respectively.
4. For G+12 400 kg TNT, due to infill there is 24.186%, 11.24% &1.51% reduction in displacement, velocity and acceleration respectively.
5. Plastic hinges are formed in all models and are found below collapse level.
6. In soft storey building plastic hinge are formed at ground floor and first floor. But in bare frame plastic hinges are formed in almost all floors. It shows walls have higher resistance to blast load and it also define weak storey of building. .
7. Blast can create significant effect on building.so, it's necessary to design important structure for blast load.

IX. FUTURE WORK

Research Study on blast loading over a structure have been growing rapidly. The prediction models are quickly becoming more advanced as technology improves. The high demand for blast load analysis for a buildings is creating opportunities for research and development. Focused efforts will lead to finding better techniques for blast load predictions. As improved methods are discovered and implemented, people will have to continuously look for the most cost effective ways to adequately withstand the blast to be expected. So that the damage to the important buildings and human beings should be minimized.

X. ACKNOWLEDGEMENT

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REFERENCES

[1] IS 4991 ‘‘Criteria For Blast Resistant Design Of Structures For Explosions Above Ground” (1968).
[2] Quazi Kashif, Dr. M. B. Varma, “Effect of Blast on G+4 RCC Frame Structure” .
[3] S.M. Jayashree, R. R. Bharatwaj, S. M Helen, “Dynamic Response of A Space Framed Structure Subjected To Blast Load”, International Journal of Civil And Structural Engineering Volume 4, No 1, 2013.
[4] I.N. Jayatilake, W.P.S. Dias, M.T.R. Jayasinghe and D.P. Thambiratnam, “Response Of Tall Buildings With Symmetric Setbacks Under Blast Loading.”
[5] M. V. Dharaneepathy, M. N. Keshava Raot and A. R. Santhakumarzf, “Critical Distance for Blast-resistant Design.
[6] Ngo T, Mendis P, Gupta A, Ramsay J (2007) “Blast loading and blast effects on structures”, EJSE 7:76–91 (special issue: loading on structures).
[7] Paz M, Leigh W (2007) “Structural dynamics theory and computation”, 5nd edn.
[8] Qureshi A L, Madhekar S N (2015) “Response of 45 Storey High Rise RCC Building Under Blast Load”, Advances in structural engineering, Springer India.
[9] SAP (2000) Integrated finite element analysis & design of structures. Computers and Structures, Inc., Berkeley.
[10] Singla S, Singla P, Singla A (2015) “Computation of Blast Loading for A Multi Storied Framed Building” IJRET Volume: 04 Issue: 02.