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Dynamic Behaviour of Frame Structure Subjected To Blast Loadings

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Abstract: The terrorist activities and threats have become growing problem now a day all over the world. A bomb explosion within or immediately nearby a building can cause catastrophic damage on the building's external frames, collapsing of walls and internal structural frames. Many of the existing buildings which are not designed for blast loads get damaged or even fully collapsed when subjected to such loadings. Therefore explosive load or blast load are important for designing structure. In present study a five story rc frame structure has been chosen for investigating the effects of blast loads. The blast load parameters are determined by adopting wave scaling laws given in u.s army technical manual unified facilities criteria structures to resist the effects of accidental explosions (ufc3-340-02) and dynamic analysis is performed using staad pro in order to determine the effects of blast impact on the structures.

Keywords: Blast load, Time history analysis, Staad pro, dynamic analysis, Framed structure.

I. INTRODUCTION

The term blast is commonly used to describe any situation in which the rapid release of energy occurs from a chemical, mechanical or nuclear source. However, from the point of view of the effects of explosions upon structural systems, there exists a set of fundamental characteristics which must be defined and considered, irrespective of the source. Explosions occurring in urban areas or close to facilities such as buildings and protective structures may cause tremendous damage and loss of life. The immediate effects of such explosions are blast overpressures propagating through the atmosphere, fragments generated by the explosion and ground shock loads resulting from the energy imparted to the ground.
Special importance has been given to blast loads on landmark structures, such as high rise buildings in metropolitan cities; the explosion of explosives (Bombs, trinitrotoluene TNT, etc.) inside and around buildings can cause catastrophic impacts on the structural integrity of the building, such as damage to the external and internal structural frames and collapse of walls. Moreover, loss of life can result from the collapse of the structure.

Due to different accidental or intentional events, the behaviour of structural components subjected to blast loading has been the subject of considerable research effort in recent years. Conventional buildings are constructed quite differently than hardened military structures and as such are generally quite vulnerable to blast and ballistic threats. Conventional structures, particularly that above grade, normally are not designed to resist blast loads; and because the magnitudes of design loads are significantly lower than those produced by most explosions, conventional structures are susceptible to damage from explosions. In order to design structures which are able to withstand explosions it is necessary to first quantify the effects of such explosions. Typically, it takes a combination of specialist expertise, experimental tests, and analysis tools to properly quantify the effects. With this in mind, developers, architects and engineers increasingly are seeking solutions for potential blast situations, to protect building occupants and the stuctures.

Characteristics of Explosions

In general, an explosion is result of very rapid release of energy within a limited space occurs from chemical, mechanical and nuclear sources. Explosions can be categorized on the basis of their nature as physical, nuclear and chemical event.

In physical explosion: Energy may be released from the catastrophic failure of a cylinder of a compressed gas, volcanic eruption or even mixing of two liquid at different temperature.

In nuclear explosion: Energy is released from the formation of different atomic nuclei by the redistribution of the protons and neutrons within the inner acting nuclei.

In chemical explosion: The rapid oxidation of the fuel elements (carbon and hydrogen atoms) is the main source of energy.

The principal mechanisms deriving an explosion are significantly different, depending upon the source. However, from the point of view of the effects of explosions upon structural systems, there exists a set of fundamental characteristics which must be defined and considered, irrespective of the source.

Explosives can be classified according to their rates of burning i.e. low explosive burns and high explosive burns, solid explosives are mainly high explosives. They can also be classified on the basis of their sensitivity of ignition as primary or secondary explosives. Materials such as mercury fulminate and lead azides are primary explosives. Secondary explosives when explode create blast (shock) waves which can result in widespread damage to surroundings. Examples include trinitrotoluene (TNT) and ammonium nitrate/fuel oil (AN/FO) [Ngo et al.].

Low explosives: Items those are capable of exploding but whose primary function is not act as explosives includes natural gas, liquid fuels such as gasoline etc. It is usually mixture of combustible substances and oxidants those decomposes rapidly.

High explosives: These are normally employed to explode in mining and military warheads. These compounds detonate at a rate ranging from 3 to 9 m/s. These are usually nitrate products such as toluene, phenol, pentaerythritol, amines and glycerine.

Trinitrotoluene (TNT): It a solid chemical compound of yellowish in color. This is best known as useful explosive material with convenient handling properties.

The explosive yields of TNT are considered as the standard measure of the strength of bombs and other explosives. It is common misconception that dynamite and TNT are same or dynamite contains TNT. In actual fact, TNT is a specific chemical compound and dynamite is an absorbent mixture soaked in nitro-glycerine that is compressed in to a cylindrical shape and warped in papers.

Basic parameters of explosion

Use of the TNT (Trinitrotoluene) as a reference for determining the scaled distance X is universal.

Table 1Conversion Factors for Explosives

Explosive	Specific Energy, Q_x kJ/kg	TNT equivalent Q_x/Q_{TNT}
Compound B(60 % RDX,40 % TNT)	5190	1.148
HMX	5680	1.256
Nitro-glycerine (Liquid)	6700	1.481
TNT	4520	1.000
Explosive gelatin (91 % nitro-glycerine,7.9 % nitrocellulose, 0.9 % antacid, 0.2 % water)	4520	1.000
60 % Nitro-glycerine dynamite	2710	0.600
semtex	5660	1.250
C4	6057	1.340

The first step in quantifying the explosive wave from a source other than the TNT, is to convert the charge mass into an equivalent mass of the TNT. It is performed so that the charge mass of explosive is multiplied by the conversion factor based on the specific energy of the charge and the TNT. Specific energy of different explosive types and their conversion factors to that of the TNT are given in Table

Classification of blast

There are different types of explosion nuclear, physical and chemical. Chemical explosives are the most common artificial explosives that can occur accidentally or may cause by the terrorist attacks. Chemical explosives are generally liquids or in consolidated solid forms.

The type of burst mainly classified as
(a) Air burst
(b) High altitude burst
(c) Under water burst
(d) Underground burst
(e) Surface burst

Prediction of Blast Pressure

Blast wave parameters for conventional high explosive materials have been the focus of a number of studies during the 1950's and 1960's. Estimations of peak overpressure due to spherical blast based on scaled distance $Z = \frac{R}{W^{\frac{1}{3}}}$ was introduced by Brode (1955) as:

$$Pso = \frac{6.7}{Z^3} + 1bar\ (Pso > 10\ bar)$$

$$Pso = \frac{0.975}{Z} + \frac{1.455}{Z^2} + \frac{5.85}{Z^3} - 0.019\ (0.1 < Pso > 10bar)$$

Newmark and Hansen (1961) introduced a relationship to calculate the maximum blast overpressure, Pso, in bars, for a high explosive charge detonates at the ground surface as:

$$Pso = \frac{6784W}{R^3} + \frac{93(W)^{\frac{1}{2}}}{R^3}$$

Another expression of the peak overpressure in kPa is introduced by Mills (1987), in which W is expressed as the equivalent charge weight in kilo- grams of TNT and Z is the scaled distance.

$$Pso = \frac{1772}{Z3} - \frac{114}{Z2} + \frac{108}{Z}$$

As the blast wave propagates through the atmosphere, the air behind the shock front is moving outward at lower velocity. The velocity of the air particles, and hence the wind pressure, depends on the peak overpressure of the blast wave. This later velocity of the air is associated with the dynamic pressure, q(t). The maximum value qs say, is given by,

$$qs = \frac{5Pso^2}{2(Pso + 7Po)}$$

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If the blast wave encounters an obstacle perpendicular to the direction of propagation, reflection increases the overpressure to a maximum reflected pressure Pr as,

$$Pr = 2Pso\left\{\frac{7Po + 4PSo}{7Po + Pso}\right\}$$

Complexity in the analysis of dynamic response of blast-loaded structures involves the effect of high strain, the non-linear inelastic material behaviour, the uncertainties in the blast load calculations and the time-dependent deformations. Therefore, to simplify the analysis, a number of assumptions related to it and the loads has been proposed and widely adopted. To establish general principles of this analysis, the structure is idealized as a single degree of freedom (SDOF) system and the relationship between the positive duration of the blast load and the natural period of vibration of the structure is established. This leads to blast load idealization and simplifies the classification of the blast loading.

CALCULATION OF BLAST PARAMETERS

Calculation of blast parameters produced by the explosion sock front waves such as Peak reflected overpressure, Dynamic pressure, Peak side-on pressure on structure as per unified facilities criteria **UFC**-3-340-02(2008) (structures to resist the effects of accidental explosions) are as follows.

Step 1: Determine the explosive weight as equivalent to TNT weight 'W' in tones which is used as charge.

Step 2: Determine the Standoff distance / actual distance 'Z' of the point measured from ground zero to the point under consideration.

Step 3: Determine the charge height at which it is placed above the ground surface.

Step 4: Determine the structural dimensions.

Step 5: Select different points on the structure (front face, roof, side and rear face) and calculate the explosion parameters for each selected point.
Calculate the scaled distance 'X' as per scaling law.

$$\text{Scaled Distance } (Z) = \frac{R}{W^{\frac{1}{3}}}$$

Determine the explosion's parameters using Chart for above calculated scaled distance 'X' and read the values.Charts for predicting blast pressures and blast durations given by UFC 3-340-02 (2008)

Dynamic Loading on Structures

A five storied building has been chosen for computation of blast loading and its effect on the framed structure. The present work has been divided into three Phases. In the Phase I, II and III, the actual effective distance from explosion (standoff distance) i.e. R is taken as 5 m, 10 m, and 15 m respectively for the equivalent TNT charge weight, W = 25 Kg, 50 Kg and 75 Kg respectively.

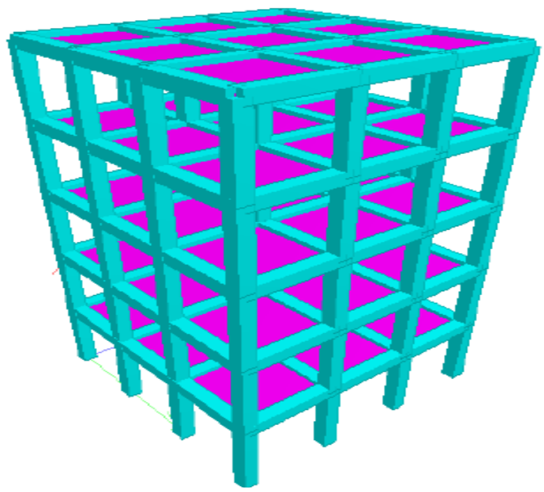
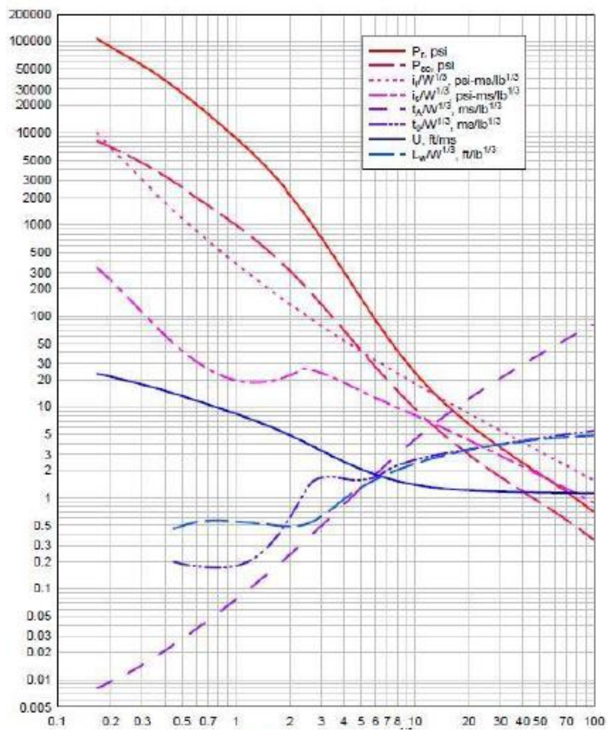


Fig-1 View of model in staad Pro



Scale distance $\left(Z = \frac{R}{W^{\frac{1}{3}}}\right)$

Fig-2 Positive phase shock wave parameters for a hemispherical TNT explosion on the surface at sea level

Blast Parameters (As Per Ufc 3-340-02)

Charge Weight, W= 25 kg or 55.12 lbs
Stand-off distance at ground level, R = 5 m or 16.4 ft
Factor of safety = 1.2
W' = 1.2 x 55.12 = 66.138 lbs

Scaled Distance $\left(Z = \frac{R}{W^{\frac{1}{3}}}\right)$ = 4.06 ft/lb1/3 For Z = 4.06 ft/lb1/3, (Refer Fig.1)

Peak Reflected Overpressure Pr = 290 psi Peak static pressure Pso = 70 psi

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tA/ W1/3 = 0.85
Arrival Time ta= 3.43 ms to/ W1/3 = 1.7
Duration of positive blast wave to = 6.88 ms
Duration of positive blast wave tO = 6.88 ms

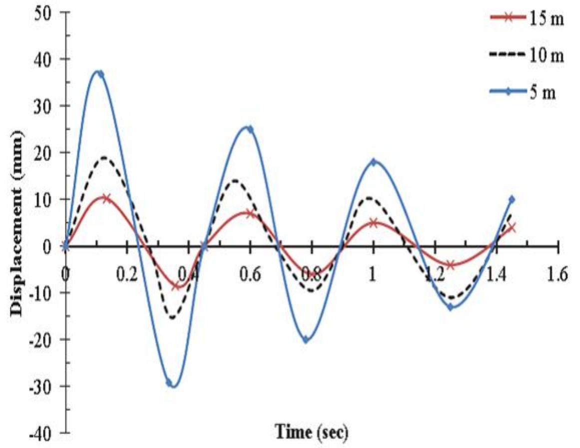

Fig-3 Variation Of Maximum Nodal Displacement At Top Storey With Time

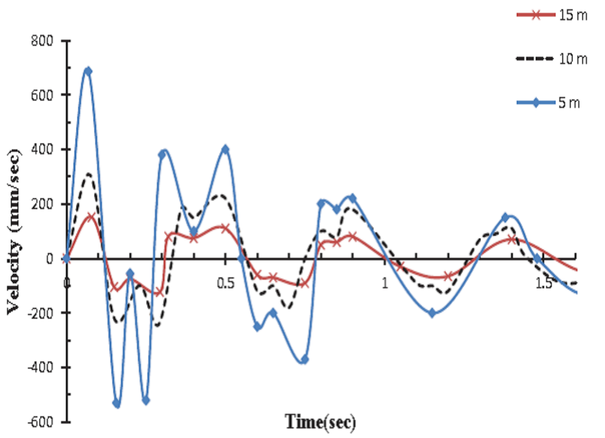

Fig-4 Variation Of Maximum Velocity At Top Storey With Time

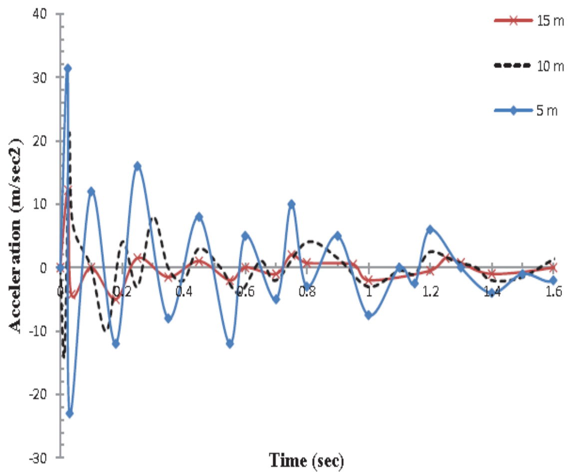

Fig-5 Variation Of Maximum Acceleration At Second Storey With Time

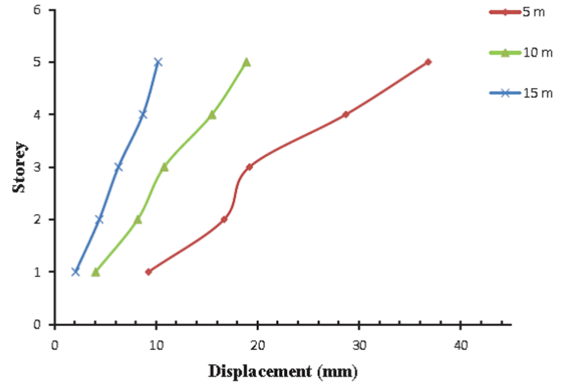

Fig-6 Maximum nodal displacement along storey level

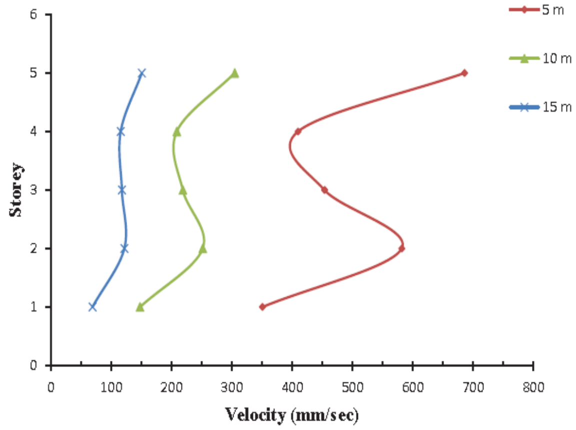

Fig-7 Maximum velocity along storey level

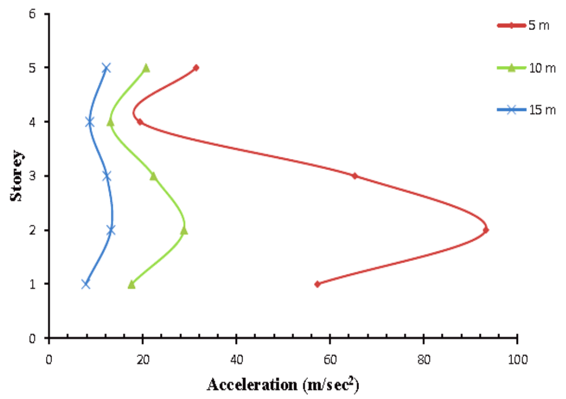

Fig-8 Maximum Acceleration Along Storey Level

CONCLUSIONS

Blast load parameters are calculated and simulated on a model building using staad pro for the dynamic analysis of structures, for various blast weight and different standoff distance. The following conclusions are drawn from this study.

1) Peak Reflected Overpressure Pro is increases with increase in the weight of blast and decreases as increase in standoff distance.
2) Blast pressure is inversely proportional to blast scaled distance.

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3) Effect of peak Reflected over pressure is reduces as we move from ground story to upper story.
4) Blast wave reaches to the structure in milli seconds from site of explosion and affect the building.
5) The maximum nodal displacement, the maximum velocity and the maximum acceleration decreases as standoff distance increases.
6) The maximum moment MX for beams and column decreases as standoff distance increases.
7) The maximum shear force for beams FZ decreases as standoff distance increases.

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