

Research Article

# Dynamic Analysis of RCC Frame Structure subjected to Blast Loading without Infilled Wall in Multi Storey Building

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## Abstract

Now a day's all world is facing a major problem from terrorist. And all the new important building should be design as anti terrorist resistance building. so bomb blast cause catastrophic effect on building and cause major effect on structure as well as human being and loss of life which is non recoverable. So for designing we required to analysis the loading of bomb blast on structure so in this paper we have analysis a 100 kg of explosive effect on building in software Stadd-Pro .Dynamic Analysis is done by time history method and by using IS code 4991-1968 to find different parameters

**Keywords:** Bomb Blast, Time History, Stadd Pro., Blast Wave.

## Introduction

In the past few decades, danger of explosion damage to a structure is increased as a result of increase in number and intensity of terrorist activities all over the world. Generally structures are not designed for blast load due to the reason that the magnitude of load caused by blast is huge and the cost of design and construction is much higher. As a result, the structure is susceptible to damage from blast load. Recent past blast incidents in the country trigger the minds of developers, architects and structural engineers to find solutions to protect the life of human-being and structures from blast disasters i.e. from sudden impact.

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.

The earthquake problem is rather old, but most of the knowledge on this subject has been accumulated during the past decades. The blast problem is rather new, information for the development in this field is mostly made available through the publications of the Indian researchers, Army Corps of Engineers, Naval Facilities Engineering Command, Air Force Civil Engineering Support Agency and the other

government/public offices and institutes. The guidelines for the blast loading are published in Indian code IS 4991-1968.

## Characteristics of Explosions

In general, an explosion is result of very rapid release of energy within a limited space which 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.

**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-glycerin that is compressed in to a cylindrical shape and warped in papers.

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### Basic parameters of explosion

Use of the TNT (Trinitrotoluene) as a reference for determining the scaled distance X, is universal. 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 1.1

**Table 1.1** Conversion factors for explosives

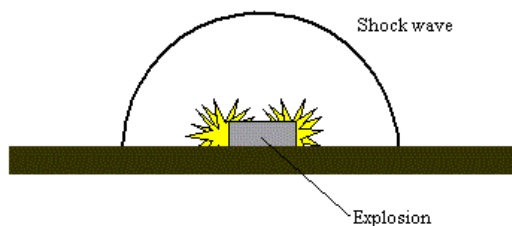
Explosive	Specific Energy $Q_x$ in Kj/Kg	TNT equivalent $Q_x/Q_{TNT}$
Compound B (60 % RDX, 40 % TNT)	5190	1.148
HMX	5680	1.256
Nitro-glycerin (liquid)	6700	1.481
TNT	4520	1
Explosive gelatine (91 % nitro-glycerine, 7.9 % nitrocellulose, 0.9 % antracid, 0.2 % water)	4520	1
60 % Nitro-glycerine dynamite	2710	0.6
Semtex	5660	1.25
C4	6057	1.34

### Blast waves

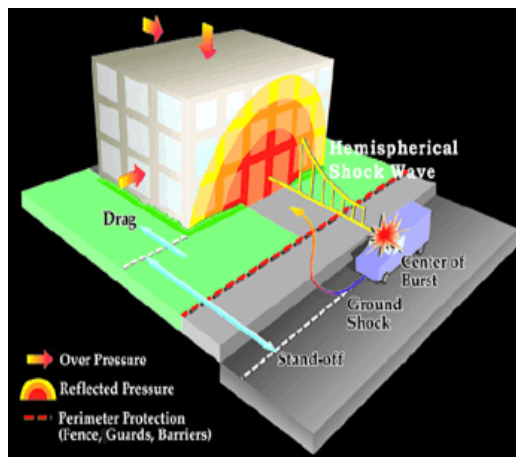
Blast wave is an area of pressure expanding supersonically outward from an explosive core. It has a leading shock front of compressed gases. The blast wave is followed by a blast wind of negative pressure, which sucks items back in towards the center. If a strong gas explosion occurs inside a process area or in a compartment, the surrounding area will be subjected to blast wave. The magnitude of blast wave depends on:

- Source
- Distance from explosion

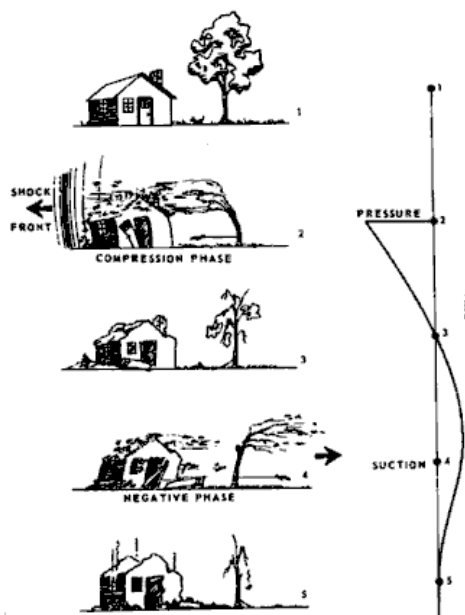
The detonation of a condensed high explosive generates gasses under pressure up to 300 kilo bar and a temperature of about 3000-4000 oc . the hot gas expands forcing out the volume it occupies



**Fig 1.1** Free Field Blast



**Fig 1.2** Blast loads on building



**Fig 1.3** variation of blast effect associated with positive and negative phase

The threat for a conventional bomb is defined by two equally important components, the bomb size or charge weight W and the standoff distance Z between the blast source and the target. The peak incident overpressure  $P_{so}$  is amplified by a reflection factor as the shock wave encounters an object or structure in its path. There reflection factors are typically greatest for normal incidence. Reflection factor depends on the intensity of shock wave and for large explosives at normal incident pressures by as much as an order of magnitude.

The pressure-time profile, two main phases can be observed; part above ambient pressure is called duration of positive phase to while below the ambient is called negative phase duration. Negative phase is of longer duration and a lower intensity then the positive duration. As the standoff distance increases, the duration of positive phase blast increases resulting in a lower-amplitude and longer-duration shock pulse.

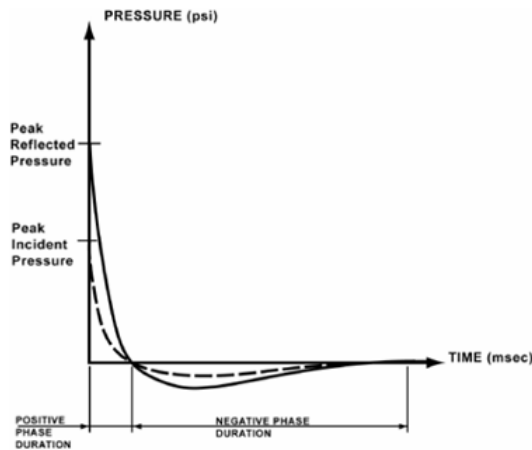


Fig. 1.5 Blast pressure with time (IS 4991-1968)

During negative phase weakened structure may be subjected to impact by debris that may cause additional damage. If exterior building walls are capable of resisting the blast load, the shock front wave penetrates through window and door openings, subjecting the floors, ceiling, walls, contents and people to sudden pressures and fragments from shattered windows, doors, etc. The components not capable of resisting the waves will fracture and be further fragmented and moved by the dynamic pressure that immediately follows the shock front.

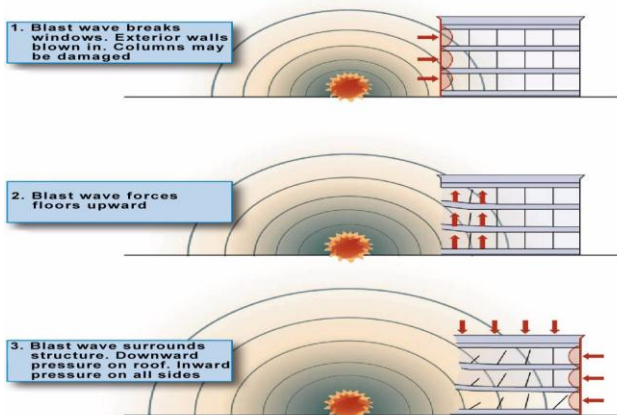


Fig. 1.6 Blast pressure on building

**Calculation of blast loading**

A six storey R C frame structure has been chosen for investigating the effect of blast loads. In this present study, effect of charge weights 100 kg, has been studied as follows:

- Standoff distance = 30 m
- Charge weight - 100 kg

**Calculation of blast parameters**

Calculation of blast parameters produced by the explosion shock front waves such as Peak reflected overpressure, Dynamic pressure, Peak side-on

pressure on structure as per IS:4991-1968 are as follows.

**Step 1:** Determine the explosive weight as equivalent to TNT weight 'W' in tonnes 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.

i) Calculate the scaled distance 'X' as per scaling law.

$$\text{Scaled distance 'X'} = Z/W^{1/3}$$

ii) Determine the explosion's parameters using Table 1 of IS:4991-1968 for above calculated scaled distance 'X' and read the values.

- a) Peak side-on overpressure Pso.
- b) Peak reflected overpressure Pro.
- c) Dynamic pressure qo.
- d) Mach number M.
- e) Positive phase duration to milliseconds (millisecond).
- f) Duration of equivalent triangular pulse td milliseconds (millisecond).

The values scaled times to and td obtained from the Table 1 of code IS: 4991-1968 for scaled distance 'X' are multiplied by to obtain the absolute values for actual explosion of W tones charge weight.

**Step 6:** Net pressure acting on the front face of the structure at any time 't' is maximum of Pr or (Pso + Cd.qo).

where

Cd = Value of drag coefficient given in Table 2 of IS:4991-1968.

Pr = Reflected overpressure which decrease from Pro to overpressure in clearance time tc.

**Step 7:** Pressure on rear face is depends on time intervals are as follows.

- i) Clearance time (tc) = 3S/U
- ii) Travel time of shock wave from front face to rear face i.e transit time (tt) = L/U
- iii) Pressure rise time on back face (tr) = 4S/U

where

S = Height 'H' or half of the width 'B/2' whichever is less

U = Shock front velocity = M.a

a = velocity of sound in air may be taken as 344 m/sec at mean sea level at 20 °C.

M = Mach number of the incident pulse.

$$= \sqrt{\left(1 + \frac{6P_{so}}{7Pa}\right)}$$

Decay of pressure with time is given by

$$P_s = P_{so} (1 - t/t_0) e^{-\frac{at}{t_0}}$$

$$q = q_0 (1 - t/t_0)^2 e^{-\frac{2at}{t_0}}$$

If pressure rise time is more than duration of equivalent triangular pulse, there will be no pressure on rear face of the structure.

i.e.  $\{t_r > t_d\}$ ; no pressure on rear face

### Loads considered in the analysis

The following loads are considered for the analysis of various phases of structure.

### Gravity loads

The intensity of dead load and live load considered in the study are given below:

#### Dead loads

Dead load comprising of self-weight of members i.e. Beam, Column and Slab and infill walls.

#### Live load

Live load of 4 kN/m<sup>2</sup> on floor area.

#### Blast loads

IS 4991-1968 is used for blast load calculations. The maximum values of the positive side-on overpressure (**P<sub>so</sub>**), reflected over pressure (**Pro**) and dynamic pressure (**q<sub>o</sub>**), as caused by the explosion of one tonne explosive at various distances from the point of explosion, are given in Table 1. And also the duration of the positive phase of the blast **t<sub>o</sub>**, and the equivalent time duration of positive phase **t<sub>d</sub>** are given in Table 1.

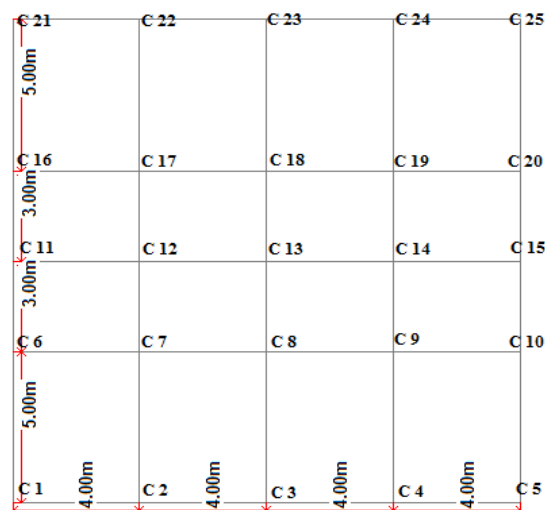
### Description of building

A six storey RC frame building with 18.0 m height situated in seismic zone IV has been considered for the purpose of present study.

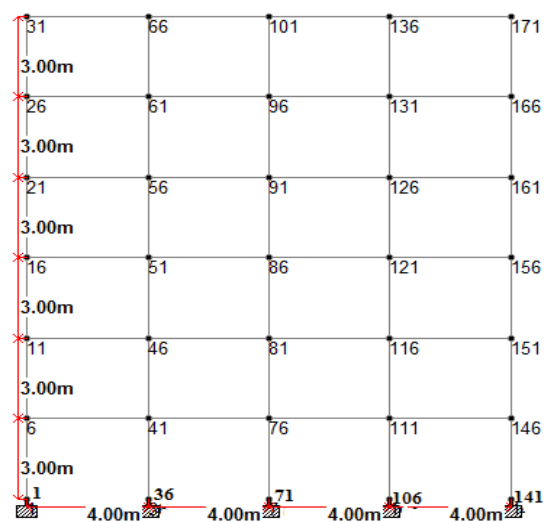
- (i) Floor to floor height = 3.0 m
- (ii) Thickness of masonry infill walls = 230 mm
- (iii) Size of Columns = 500 mm × 500 mm
- (iv) Size of Beam = 450 mm × 500 mm
- (v) Thickness of slab = 150 mm

### Properties of RCC

- (i) Characteristic compressive strength ( $f_{ck}$ ) = 20 MPa
- (ii) Poisson Ratio = 0.2
- (iii) Density = 25 kN/m<sup>3</sup>
- (iv) Modulus of Elasticity ( $E$ ) =  $5000\sqrt{f_{ck}} = 22360.67$  MPa
- (v) Damping = 0.05



Plan of building



Elevation of building

### Blast pressure parameters (AS PER IS:4991-1968)

Charge weight (TNT)  $W = 100$  Kg or 0.1 Tonne  
Scaled distance 'X' =  $X = Z/W^{1/3} = X = 30/0.1^{1/3} = 64.65$  m/tonne<sup>1/3</sup>

So values of  $t_o$  and  $t_d$  from Table 1 of IS:4991-1968  
 $t_o = 37.71 \times 0.1^{1/3} = 17.5$  milliseconds  
 $t_d = 28.32 \times 0.1^{1/3} = 13.15$  milliseconds

#### Pressure on rear face

$S = H$  or  $B/2$  (whichever is less) = 8 m.

$U = M \cdot a = 1.1369 \times 344 = 391.09$  where  $\{M = 1.1369, a = 344 \text{ m/sec}\}$

Clearance time  $t_c = 3S/U$   
 $= 3 \times 8 / 391.09 = 0.06136 \text{ sec} = 61.36 \text{ milliseconds}$

Transit time  $t_t = L/U$   
 $= 16 / 391.09 = 0.0409 \text{ sec} = 40.9 \text{ milliseconds}$

Pressure rise time  $t_r = 4S/U$   
 $= 4 \times 8 / 391.09 = 0.08181 \text{ sec} = 81.81 \text{ milliseconds}$

Here  $t_c > t_d$ ,  $t_t > t_d$  and  $t_r > t_d$

As  $t_r > t_d$  no pressure on rear face.

**Pressure on front face**

node	X	to ms	td	to+td	pso	pro KN/m2	A m2	force KN
1	66.89	17.77	13.42	31.18	33.41	75.51	3.0	226.54
36	65.21	17.57	13.23	30.80	34.79	79.12	6.0	474.72
71	64.63	17.50	13.15	30.65	35.37	80.65	6.0	483.87
106	65.21	17.57	13.23	30.80	34.79	79.12	6.0	474.72
141	66.89	17.77	13.42	31.18	33.41	75.51	3.0	226.54
6	67.20	17.80	13.44	31.24	33.20	74.99	6.0	449.97
41	65.52	17.61	13.28	30.88	34.48	78.27	12	939.21
76	64.96	17.54	13.19	30.73	35.04	79.79	12	957.43
111	65.52	17.61	13.28	30.88	34.48	78.27	12	939.21
146	67.20	17.80	13.44	31.24	33.20	74.99	6.0	449.97
11	68.13	17.91	13.51	31.42	32.58	73.45	6.0	440.71
46	66.47	17.72	13.39	31.10	33.68	76.21	12	914.52
81	65.91	17.65	13.34	30.99	34.09	77.23	12	926.78
116	66.47	17.72	13.39	31.10	33.68	76.21	12	914.52
151	68.13	17.91	13.51	31.42	32.58	73.45	6.0	440.71
16	69.65	18.09	13.64	31.73	31.57	70.92	6.0	425.55
51	68.03	17.90	13.50	31.40	32.65	73.62	12.	883.46
86	67.48	17.84	13.46	31.30	33.01	74.54	12.	894.42
121	68.03	17.90	13.50	31.40	32.65	73.62	12	883.46
156	69.65	18.09	13.64	31.73	31.57	70.92	6.0	425.55
21	71.71	18.33	13.84	32.17	30.19	67.48	6.0	404.86
56	70.14	18.15	13.69	31.83	31.24	70.09	12	841.13
91	69.61	18.09	13.64	31.72	31.59	70.98	12	851.76
126	70.14	18.15	13.69	31.83	31.24	70.09	12	841.13
161	71.71	18.33	13.84	32.17	30.19	67.48	6.0	404.86
26	74.29	18.74	14.16	32.90	28.47	63.19	6.0	379.11
61	72.77	18.49	13.97	32.46	29.48	65.71	12.	788.52
96	72.26	18.41	13.90	32.30	29.83	66.56	12.	798.76
131	72.77	18.49	13.97	32.46	29.48	65.71	12.	788.52
166	74.29	18.74	14.16	32.90	28.47	63.19	6.0	379.11
31	77.32	18.93	14.66	33.59	26.45	58.91	3.0	176.72
66	75.87	18.88	14.41	33.29	27.42	60.85	6.0	365.08
106	75.37	18.87	14.32	33.19	27.75	61.5	6.0	369.00
136	75.87	18.88	14.41	33.29	27.42	60.8	6.0	365.08
171	77.32	18.93	14.66	33.59	26.45	58.9	3.0	176.72

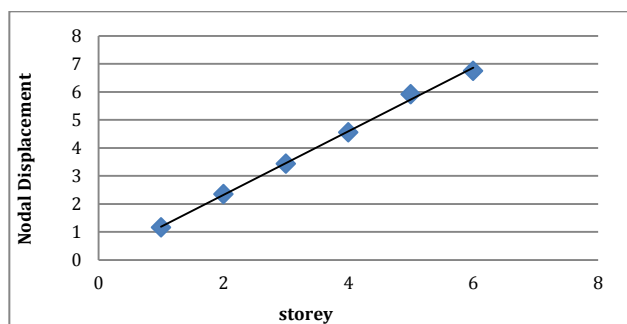
<b>Maximum nodal displacements, velocity and acceleration</b>			
Standoff distance = 30m, Charge weight = 100 kg			
Storey	Maximum nodal displacement (mm)	Maximum nodal displacement (mm/sec)	Maximum acceleration m/sec2
1	1.16	42.9	4.56
2	2.34	72.6	7.47
3	3.43	71.2	6.75
4	4.55	68	5.15
5	5.91	66.1	4.86
6	6.75	75.1	5.32

<b>Maximum shear force, axial force and moment in beams parallel to z direction</b>			
Storeys	Maximum shear-force FY (kN)	Maximum axial force FX (kN)	Maximum moment MZ (kN-m)
1	28.41	16.92	23.75
2	29.38	19.66	25.81
3	29.84	22.33	26.64
4	30.06	24.89	27.07
5	30.05	26.67	26.95
6	13.68	27.39	13.1

Maximum shear force, axial force and moment in exterior column C-1					
Standoff distance = 30 m, Charge weight = 100 kg					
Storey	Max shear force FX (kN)	Max shear force FZ (kN)	Max axial force FY (kN)	Maximum moment MX (kN-m)	Max moment MZ (kN-m)
1	26.95	0.68	674.79	3.78	53.76
2	12.86	3.63	561.94	5.8	22.62
3	13.4	4.19	444.02	6.42	21.99
4	13.04	4.97	323.76	7.68	20.92
5	14.54	5.56	202.11	8.76	24.87
6	7.68	6.33	80.29	9.73	12.99

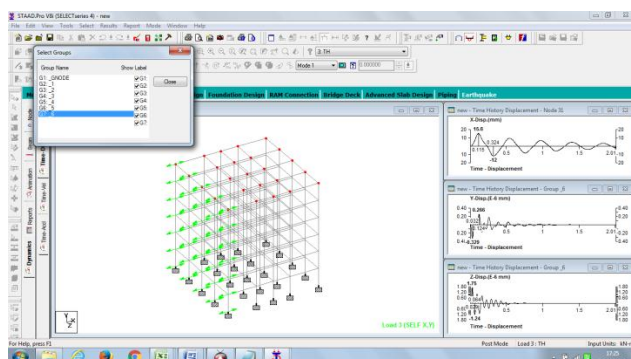
Maximum shear force, axial force and moment in exterior column C -13					
Standoff distance = 30 m, Charge weight = 100 kg					
Storey	Max shear force FX (kN)	Max shear force FZ(kN)	Max axial force FY (kN)	Maximum moment MX (kN-m)	Max moment MZ (kN-m)
1	39.88	4.3	864.9	7.57	67.52
2	32.03	3.16	721.36	4.92	48.43
3	31.22	2.43	571.99	3.87	47.61
4	32.21	1.79	419.94	2.91	49.21
5	32.71	1.15	265.93	1.51	50.81
6	17.11	0.57	111.43	1.04	29.25

Graph

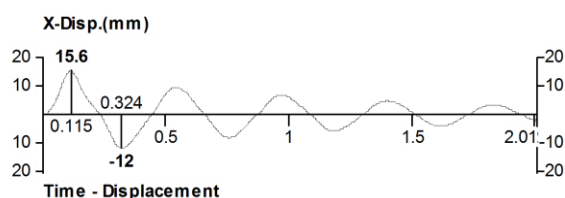


Maximum nodal displacement

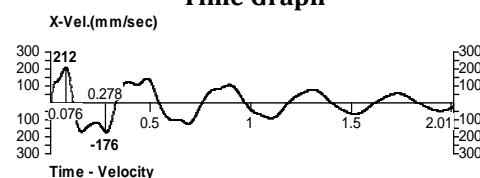
Stadd Pro Model Time History Analysis



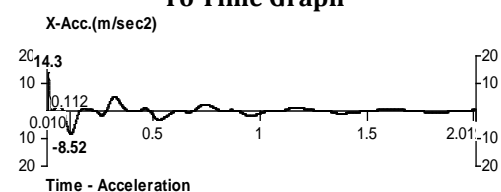
Average Displacement In X Direction With Respect To Time Graph



Average Velocity In X Direction With Respect To Time Graph



Average Acceleration In X Direction With Respect To Time Graph



Conclusions

In this paper modeling of multistoried building G+5 building is being analysis in which we have concluded

- 1) Effect of peak static pressure and reflected overpressure was more at ground store then upper store varies linearly
- 2) Blast wave take millisecond to reach the building from the side of explosion and affect the building

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