ANALYSIS OF G+6 STORY STEEL STRUCTURE UNDER BLASTING EFFECT

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Abstract: *A detailed study of the progressive collapse analysis of multi-story buildings subjected to blast loading is now required due to the severe damage to property and life caused by recent terrorist attacks on the infrastructure. Research has typically been conducted using the Alternative Path Method (APM) with sudden column removal while neglecting the ideal site for blast loading. In this thesis, 3D models of a steel building with six stories and direct blast load modelling are suggested. Additionally, the impact of blast loading has been assessed at numerous sites. Two different types of explosive events—vehicle-borne and package bomb—have been taken into consideration. By employing a numerical model of the structure created with the "STAAD PRO" SOFTWARE, the blast load is analytically computed. By using a published example of a 7-story steel building that was subjected to blast load, the numerical model is validated. The collapse of steel buildings has been postulated as a possible outcome of the finite analysis, and proposals have been made to control it. By using a published example of a 7-story steel building that was subjected to blast load, the numerical model is validated.*

Keywords: Keywords: Steel Structure, Blast, STAAD PRO, APM, Collapse, Vehicle Bomb, Package Bomb, G+6 Storey.

Introduction

General

Although it is impossible to completely stop terrorist attacks on buildings, it is possible to greatly reduce their impact by taking preventative measures and using proactive strategies. It is essential to comprehend the structure, its intended use, and any concerns posed by terrorist attacks in order to identify the strategies most likely to be effective in reducing the negative effects of the attacks. When compared to the whole lifespan costs of the building (which also include the land estimation and security checking), the cost of renovating the building for a "particular level" of assurance against terrorist threats may not be very high. A bomb blast inside or around a building can have disastrous impacts, harming and crushing interior or outside portions of the building.

The type and layout of the building, the materials used, the range of the explosive device that was found, and the charge weight all affect how much damage a bomb causes.

Case studies from various countries are examined, but they are by no means exhaustive because other explosions may occur and building sub-frameworks may sustain additional collateral damage in the future.

Explosion and Blast Phenomenon

An explosion frequently occurs when a significant amount of energy is released rapidly inside a small area. Explosions can be classified as physical, nuclear, or chemical occurrences based on their nature.

In physical event: - Energy may be released in the event of a catastrophic failure of a pressurised gas cylinder, a volcanic ejection, or even the mixing of two liquids at different temperatures.

In nuclear event: By regenerating protons and neutrons inside the inner acting cores of different atoms, energy is released from the development of those distinct atoms.

In chemical event: The primary source of energy is the quick oxidation of carbon and hydrogen atoms, which make up the fuel.

According to popular belief, there are numerous types of high explosives accessible, and because each explosive has unique detonation characteristics, each blast wave's qualities will vary. TNT is being utilised as the industry benchmark, with all values represented in terms of a TNT equivalent charge mass.

As it may be considered as a charge in terms of TNT and depending on the weight, calculation can be done, analysis and design can be done for both physical and chemical explosions. In contrast, there is no suitable methodology for analysing nuclear explosions since they emit abnormally high levels of atomic radiation when neutrons are present.

Fig 1.1 shows the different type of explosive. Explosive are classified mainly into two parts

○ High explosive

○ Low explosive

In general, low explosive is utilised in mining and fireworks, whereas high explosive is typically used in military weapons.

Primary and secondary explosives are subcategories of high explosive, whereas booster and main charges are subcategories of secondary explosive

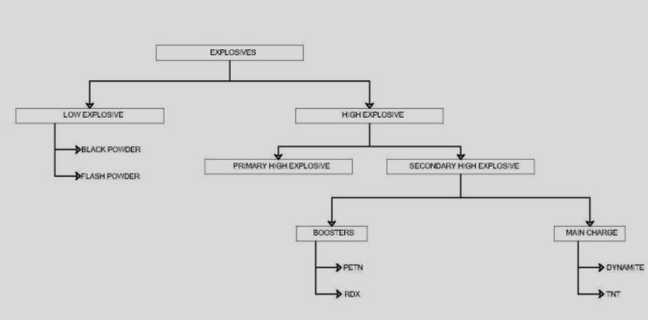


Figure 1. Type of explosive

Objective of Work

○ To analyse how a multi-story steel building responds dynamically to external and internal blast loads.

○ Investigate chain mechanism of progressive collapse if occurred.

○ Provide effective measures for reducing blast effect of structure.

○ Reliability analysis of structure against blast loads.

○ To provide effective protective measures to protect structure against blast loads.

Selection of Frame

A 7-storey steel framed building is studied under the blast loading and for different cases as discussed in scope of works.

Selection of Blast Charge

0.15 Tonne

0.25 Tonne

0.35 Tonne

Selection of Ground Zero Distance

15 metres

25 metres

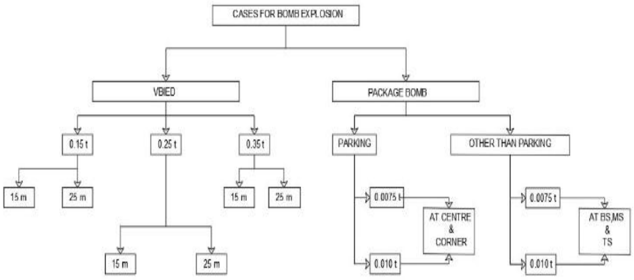


Figure. 2 Number of models to be workout

Were,

BS = Base storey

MS = Middle storey

TS = Top storey

Literature Review

Yang Ding, Xiaran Song, Hai tao zhu [1] [2017]: The purpose of this paper is to examine a study of the progressive collapse of a steel frame building with a ten-story seismic design that was attacked by a vehicle-borne explosive device. In this study, a two-step process is employed to assess the structure's propensity for collapse.

H.M. Elsanadedy, T.H. Almusallam, Y.R. Alharbi, Y.A. Al –salloum, H. Abbas [2] [2014]: In order to determine the Riyadh building's vulnerability to blast loads, this article will analyse the progressive collapse of a six-story steel frame structure. To simulate how buildings will behave under blast-generated waves, the FEA programme LS - DYNA was used. Based on the examination of a specific structural member that was subjected to blast load, a numerical model was validated. Two types of structures—one without a façade wall and the other with one—are explored in this study.

Feng Fu [3] [2012]: This study uses a 20-story steel building with a blast load at column A1 on level 12 to study the blast effect. Comparative analysis is done between the output of ABAQUS, ATBLAST, and APM (alternative path technique from GSA guideline). The nonlinear dynamic analysis approach controls the response of the structure in the ABAQUS programme. According to GSA requirements, the load is calculated as DL+0.25LL. The structure's response was documented.

Jenny Sideri, Chris Mullen, Simos Gerasimidis, George Deodatis [4] [2017]: The purpose of this article is to investigate a detailed 3D nonlinear finite element dynamic analysis of a steel frame building in order to examine the response and damage to frame members along the building's façade when confronting an external explosion. Three case studies of steel buildings with various structural systems are taken into consideration in this research.

Yang Ding, Ye Chan, Yanchao Shi [5] [2016]: The purpose of this article is to investigate the steel building after a restricted explosion caused by a blast load. To determine the internal blast load and analyse the impact of blast-related damage on the steel structure's fire defence, the software AUTODYN is used. With the use of LS-DYNA, the 10-storey NIST numerical model was developed.

ZHANG Xiuhua, DUAN Zhongdong, ZHANG Chunwei [6] [2008]: LS-DYNA was used to explore how steel frame structures gradually collapsed under the blast stress. The multi-material Langrangian and Euler algorithm was used. The propagation of blast pressure waves, structural dynamic response and deformation, and progressive collapse of a five-story steel frame structure in the case of an explosion close to the surface were all numerically simulated. For the purpose of creating pressure through the expansion of the chemical explosive's detonation product, the high explosive burning material model and the Jones Wilkens-Lee (JWL) equation of states are used.

Tapan Sabuwala, Daniel Linzell, Theodor Krauthammer [7] [2005]: This research uses ABAQUS software to investigate the behaviour of fully restrained steel connections when subjected to blast stresses. By contrasting numerical results with experimental data from the AISC Programme, the Models were validated. Models were then tested to blast loads, and their effectiveness against blast loads was evaluated using TM5-1300.

Cameron B. Ritchie, Jeffrey A. Packer, Michael V. Seica [8] [2017]: For the first time, cold-formed steel rectangular hollow sections (RHS) in flexure have been subjected to extensive far-field air-blast testing. These arena tests demonstrated the exceptional ductility and performance of cold-formed tubular steel members under heavy blast loads without any cross-sectional fractures.

Two sizes of cold-formed RHS were tested: RHS120 × 120 × 5 and RHS120 × 120 × 8.

UMESH JAMAKHANDI1, Dr. S. B. VANAKUDRE [9] [2015]: This study's goals include providing information on blast resistant building design theories, improving building security against explosive impacts during the architectural and structural design process, and recommended design methods. By doing a time history analysis in which the blast loading is applied, often utilising a triangle time function, blast analysis can be carried out in ETABS 2015.

Research Gap

It is clear from the literature analysis that no effort is done to investigate the effects of blasts on steel structures in various locations. The purpose of this study is to look into and offer practical solutions of preventing structural damage caused by blast loading at various loadings at once.

Definition [10]

01.Blast Wind [10]

It is the moving air mass alongside the overpressures coming about the pressure contrast behind the shock wave front.

02.Clearance Time [10]

It is the time in which the reflected pressure declines to the aggregates of the overpressure on the side and the drag pressure.

03.Decay Parameter [10]

It is the constant quantity of the -ve power of the exponent a governing the fall of pressure with time in pressure line curves.

04.Drag Force [10] force on a structure or structural element due to the blast load effect.

05.Ductility Ratio [10] ratio of the max deflection because of the deflection relating to elastic limit.

06.Dynamic Pressure [10]

It is the pressure effect of air mass movement called the blast wind.

07.Ground Zero [10]

It is the point on the earth surface vertically below the explosion.

08.Impulse [10]

Impulse per unit of anticipated region is the pressure time product given by the zone under the pressure time curve considered for the positive stage just unless specified.

09.Mach Number [10]

It is the ratio of the speed of the shock front propagation to the speed of sound in standard atmosphere at sea level.

Blast Load Calculation [IS 4991:1968] [10]

In view of the determinations to IS 4991:1968, blast load pressure on the building in type of a triangular load is ascertained as takes after:

Characteristic of Blast

Scaled Distance, X = D/$W^{/}$
Scaled time, t_o = Actual time /$W^{/}$
Where D = Distance of the building from ground zero
W = Explosive charge in tonne
Here assuming P_a = 1.00 kg/cm

Blast Parameters

For the estimation of scaled distance, different blast parameters are chosen from the table 1 of IS 4991:1968. These parameters are:

1. Pso = Peak side-on overpressure (kg/cm^2)
2. Po = the ambient atmospheric pressure =1kg/cm^2
3. Pro = Peak reflected overpressure (kg/cm^2)

   Pro = Pso (2+________)
4. Qo = Dynamic pressure (kg/cm^2)
5. Td = Duration of equivalent triangular pulse (Milliseconds)
6. To = Positive phase duration (Milliseconds) Td = value corresponding to X/W $^{(1/3)}$ (Milliseconds) To = value corresponding to X/W $^{(1/3)}$ (Milliseconds)

$$M = 1 + \sqrt{\frac{6Ps}{\ }}$$

Take a = 344 m/s; U = (M*a) m/milliseconds

Pressure on Building

The net pressure follows up on the front face at any time t, the reflected overpressure Pr or

(Po +Cdq), whichever is more predominant;
Where, Cd = drag coefficient given in following table
Pr = the reflected overpressure which drops from the peak value Pro to overpressure (Po+ C_d*q) in clearance time t_o given by:

For H (height), B (width), L (length) of the building, calculate S = H or B/2 (whichever is lesser)

Sr No	Shape of element	Drag coefficient	Remark
For closed rectangular structure			
1	Front vertical face	1	For above ground structure
2	Roof, rear & side face for		
	Qo= 0 to 1.8 kg /Cm^2	-0.4	
	Qo= 1.8 to 3.5kg /Cm^2	-0.3	
	Qo= 3.5 to 9.0kg /Cm^2	-0.2	
3	Front face sloping		
	4 to 1	0	For semi buried structure
	1.5 to 1	0.4	
For open, drag type structure			
4	sphere	0.1	This cover steel tubes used as column, truss etc.
5	cylinder	1.2	
6	Structural shapes	2.0	This cover flats, angles, tees
7	Rectangular projection	1.3	Cover beam projection below or above slabs

Tc = 3S/U (millisecond) > Td

Tt = L/U (millisecond) > Td

Tr = 4S/U (millisecond) > Td

Consider no pressure on back face for Tr>Td

For roof and sides, find drag coefficient from table 2,

Pressure on roof and sides=Pso+Cd*Qo (kg/cm^2), Time=Td (millisecond)

Pressure on front face = Pro (kg/cm^2), Time = Td (millisecond) The pressure is taken in the form of a triangular load.

Blast Categories

Blasts can be categorized as:

1. External Burst

2. Internal Burst

An internal blast will produce load in the form of shock or gas pressure due to the explosion's containment. Due to the outside blow, this pressure has a longer duration than the shock pressure.

It needs to be highlighted that surface structure cannot be predicted from an initial nuclear blast.

1. Free Air Burst

When an explosion occurs next to or above a defensive structure, the impact loads acting on the structure must be free air blast in order to prevent an increase of the initial shock wave between the explosive source and the defensive structure.

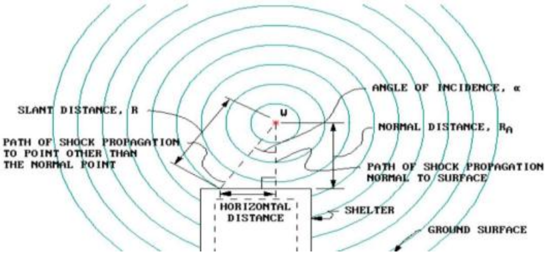


Figure 3 Free Air Burst Blast Environment

2. Air Burst

In order to cause the first shock wave to extend out from the explosion and encroach on the ground surface before reaching the defensive structure, explosions that occur over the ground surface and at a distance from it create the air burst situation. This reflected wave is the consequence of the strengthening of the incident wave by the ground surface.

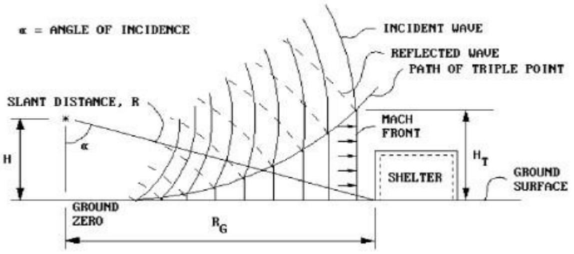


Figure 4 Air Burst Blast Impact Environment

3. Surface Burst

Surface bursts are charges that are located on or very close to the ground's surface. Contrary to an air burst, the reflected wave converges with the incident wave at the site of blast to form a single wave that is about hemispherical in shape but has a similar character to the air burst's Mach wave.

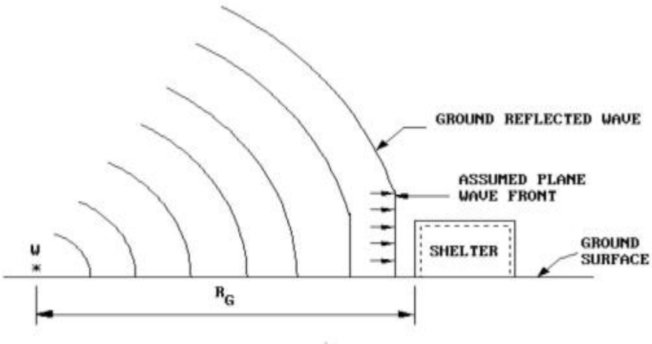


Figure 4 Surface Burst Blast Environment

Example of Common High Explosives

Based on the amount of energy released, explosives are classified as: low explosives and high explosive. Black powder is the most common example of the low explosive. Some of the common explosives are RDX (Royal Demolition Explosive), Dinitrotoluene, TNT (trinitrotoluene), Pentrinite, Pyroxilene, Dynamite, Compound B etc.

The use of TNT is generally considered as a reference. The high explosive other than TNT is expressed as the equivalent mass of TNT.

For example, equivalent TNT mass of RDX is 1.185, for Dinitrotolune it is 0.70 and for Dynamite it is 1.30. Hence, 100 Kg RDX is converted to 1.185 x 100 = 118.5 kg of TNT.

Explosive and bombs are categorized as small, medium and high or large as:

Small explosive devices – up to 10 kg of TNT.

Medium explosive devices – up to 15 kg TNT.

Large explosive device and bombs – up to 110 kg of TNT.

Very large explosive devices and bombs - up to 2600 kg of TNT.

Out of these, three cases -150 kg, 250 kg, 350kg will be studied for the blast pressure and its effects that it will create on the building.

Estimation of Blast Load Imposed on Buildings

Within a few milliseconds of the blast loading, a chemical process that is exothermic takes place. The explosive substance is converted into a highly hot, dense, high-pressure gas. The shock wave front is made up of the supersonic motion of this highly compressed air as it moves radially outward from the source.

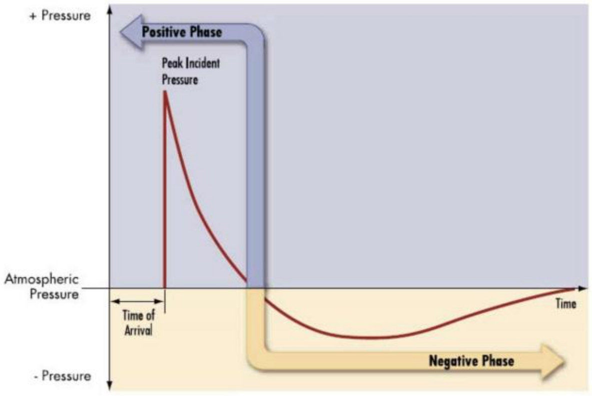


Figure 5 Shock Front Characteristics: Overpressure-Time History Indicating Sharp Initial Drop and Extended Negative Phase

Influence of Stand-Off Distance

The stand-off distance, an important factor, affects the degree of building damage. The geometric distribution of the energy in the practically hemispherical area surrounding the blast that is at or just above earth gives one the impression that the blast's intensity rapidly reduces as one walks away from it. It appears that less hardening is necessary to provide the necessary protection because the damage is likewise proportionally decreased.

Blast Load Prediction

The majority of the time, consultants employ streamlined approaches to forecast blast loads, particularly for the design of single and isolated buildings. The overpressure is supposed to reach its highest value immediately and then linearly decrement to zero over a period of time known as the duration time Td.

Mechanisms of Damage in Buildings

a) Local Damage: Individual non-structural and structural building components, such as exterior infill walls and windows, as well as floor systems (slab and girders), columns, and load-bearing/structural walls, are damaged when high-intensity air blasts are directed against the building's exposed surfaces.

(b) Global Damage due to Progressive collapse: Buildings may gradually collapse as a result of the failure of a single structural member or a small number of structural elements at a local level, creating a domino effect.

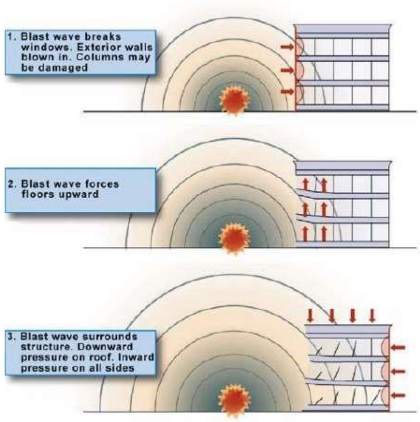


Figure 6 Sequence of Building Damage Due to A Vehicle Weapon

An internal explosion of a minor size might cause the following harm to the structure:

(a) localised damage and failure of adjacent RC and masonry walls as well as floor systems immediately below and above the explosion;

(b) Deterioration and failure of non-structural elements, such as window finishes, ducts, and partition walls;

Flying debris produced by electronics, furniture, and other things. Small internal explosions can cause severe damage, possibly resulting in progressive collapse, if they are directed directly at a key load-bearing part like a structural wall.

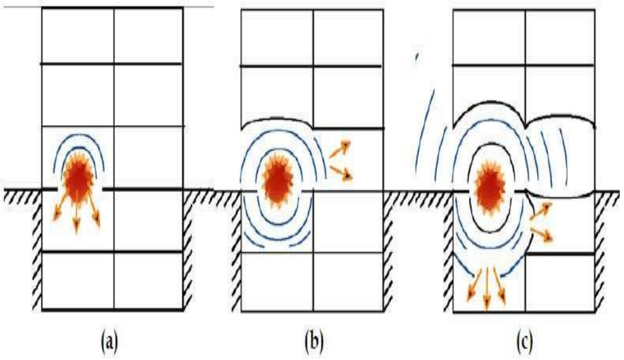


Figure.7 Sequence of Building Damage Due to An Internal Blast Within a Building: (A) Local Damage of Floor, (B) Uplift of Floor Above, And Failure of Walls Windows, and (C) Venting of Pressured Air Through the Various Levels of The Building

Selection of Steel Structure

For a present work, a G+6 storey steel structure has been selected. To evaluate the design stress, and displacement in a steel structure, it has been analysed keeping its base as fixed and providing the pinned connection for secondary beam to main beam subjecting it to various combinations of Gravity and wind loads using software STAAD Pro. From the analyses results, the critical values of stresses and displacement have been selected for design. The steel structure is designed using the Limit State Method & conforming to specification of IS: 800–2007 and IS: 875(part 3) – 2015.

Modal Specifications

Section Name	Web Data (inch)	Flange Data (inch)
columns	24.7 X 0.65	12.9 X 1.09
beams	24.3 X 0.515	9.07 X 0.875

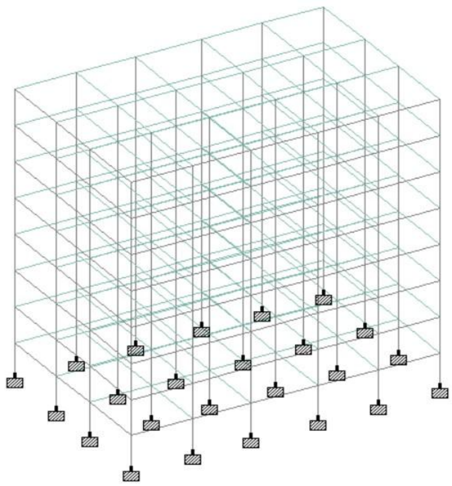


Figure 8 3D View of Steel Model

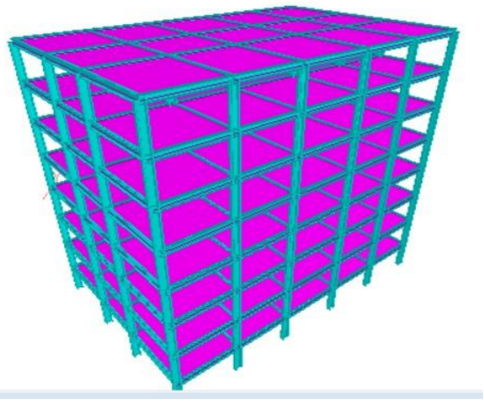


Figure 9 Plane

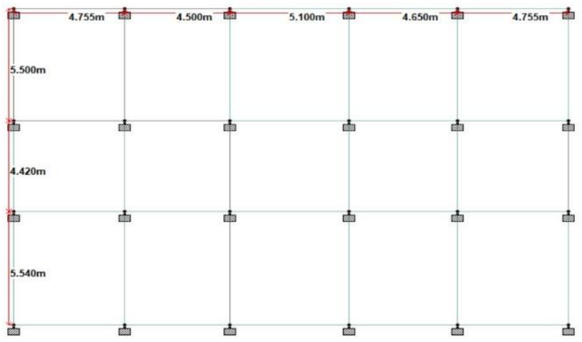


Figure 10 Y-Z Plan

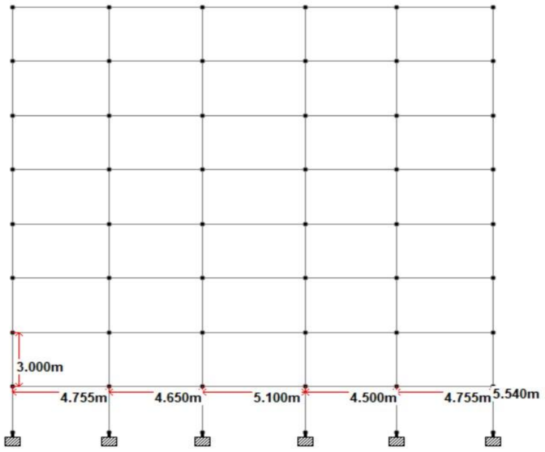


Figure 11 X-Y Plane

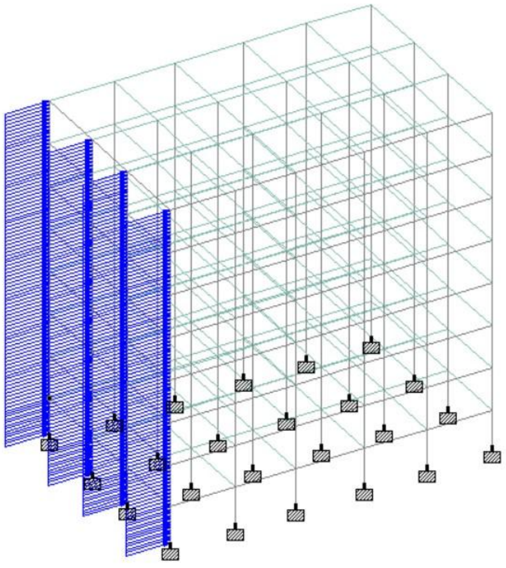


Figure 12 Blast Load Assign

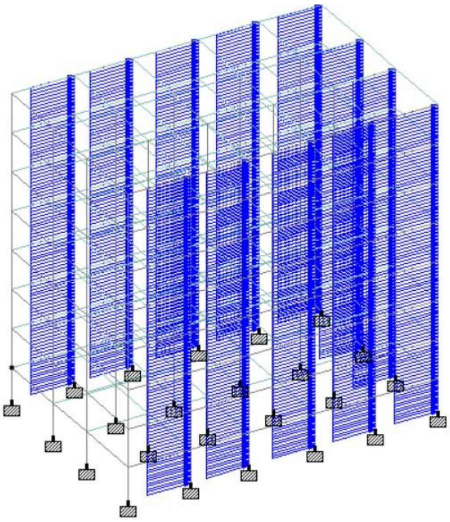


Figure 13 Internal Blast Load Assign

Load Data

In the present structural model, the loads have been assigned under the following six Categories:

1. Dead Load (DL)
2. Live Load (LL)
3. Wind Load (WL)
4. Wind load in X direction (WLX)
5. Wind load in Y direction (WLY)
6. Wind in –ve X direction (-WLX)
7. Wind in –ve Y direction (-WLY)

Calculation of Blast Load

Distance from ground zero	explosive	scaled distance,x	P_{SO}	P_{RO}	Q_O	positive phase duration T_O (millisecond)	T_O	Duration of equivalent triangular pulse T_d	M
15	0.35	22	3	11.46	2.28	9.96	9.96	7.02	1.89
					pressure on front face			11.46	kg/cm²
					pressure on rear and side face			7.56	kg/cm²

sample calculation considers standoff

distance(D): 15 m explosive charge weight (W): 0.35 tonne

Step 1 calculate the scaled distance

$X = D/W\ (1/3)$

$X = (15)/(0.35)^{(1/3)}$

$X = 21$ m

Step 2 find out peak side overpressure from IS 4991: 1998.

Step 3 find out peak reflected overpressure from IS 4991: 1998.

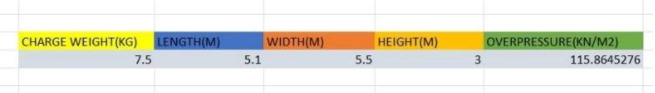
Step 4 find out dynamic pressure (Q_0) from IS 4991: 1998.

Step 5 find out positive phase duration (T_0) from IS 4991: 1998.

Step 6 find out duration of equivalent triangular pulse (T_d) from IS 4991: 1998.

Step 7 find out the match number (M) from IS 4991: 1998.

Application of internal blast load on steel structure



CHARGE WEIGHT(KG)	LENGTH(M)	WIDTH(M)	HEIGHT(M)	OVERPRESSURE(KN/M2)
7.5	5.1	5.5	3	115.8645276

The variable Apply load while approaching. The pressure calculated in chapter 3 is used to apply the external blast event. The internal blast event is calculated by the empirical equation given by **Los Alamos Scientific Laboratory** [11]

$$P = 13\ (W/V)$$

where, W = charge weight of explosion (kg)

V = confined volume of air (m^3)

P = blast overpressure (bar)

Sample calculation

Consider charge weight: 7.5 kg

Consider length of one room: 5.1 m

Consider width of one room: 5.5 m

Consider height of one room: 3 m

Step 1 calculate overpressure for internal blast

Overpressure = **13 (W/V)**

$= 13 * (15/(5.1*5.5*3))$

$= 115.86\ KN/m^2$

Result

Table 1 Displacement Data for Combination of 0.15T AT 15M WITH 0.0075T As Internal Blast

LOAD COMBINATION	DISPLACEMENT(MM)
0.15T AT 15M WITH 0.0075T AT BASE STORY	1388.016
0.15T AT 15M WITH 0.0075T AT MID STORY	1383.776
0.15T AT 15M WITH 0.0075T AT TOP STORY	1377.898

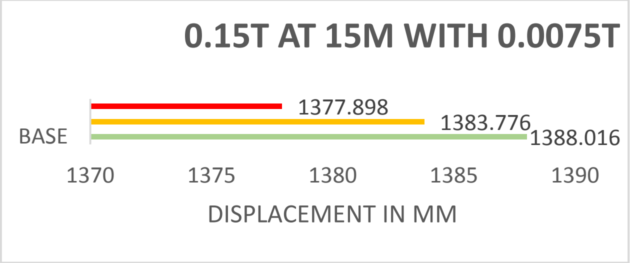


Figure 14 Displacement for Value of Combination of 0.15T AT 15M WITH 0.0075T as Internal Blast

Table 2 Displacement Data for Combination of 0.15T AT 15M WITH 0.010T as Internal Blast

LOAD COMBINATION	DISPLACEMENT(MM)
0.15T AT 15M WITH 0.010T AT BASE STORY	1387.811
0.15T AT 15M WITH 0.010T AT MID STORY	1382.146
0.15T AT 15M WITH 0.010T AT TOP STORY	1374.291

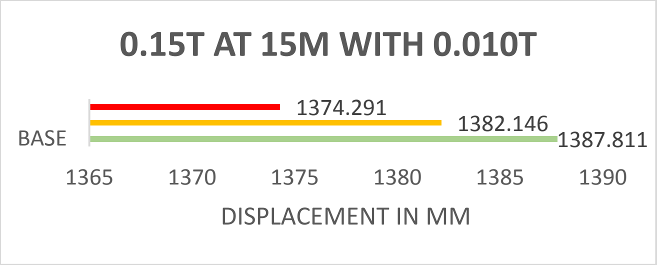


Figure 15 Displacement for Value of Combination Of 0.15T AT 15M WITH 0.010T As Internal Blast

Table 3 Displacement Data for Combination of 0.15T AT 25M WITH 0.0075T as Internal Blast

LOAD COMBINATION	DISPLACEMENT(MM)
0.15T AT 25M WITH 0.0075T AT BASE STORY	405.827
0.15T AT 25M WITH 0.0075T AT MID STORY	401.588
0.15T AT 25M WITH 0.0075T AT TOP STORY	395.71

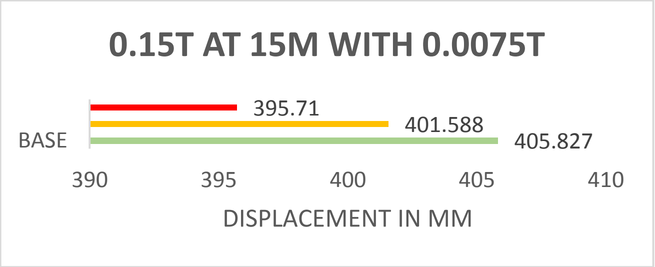


Figure 16 Displacement for Value of Combination of 0.15T AT 25M WITH 0.0075T as Internal Blast

Table 4 Displacement Data for Combination of 0.15T AT 25M WITH 0.010T as Internal Blast

LOAD COMBINATION	DISPLACEMENT(MM)
0.15T AT 25M WITH 0.010T AT BASE STORY	405.622
0.15T AT 25M WITH 0.010T AT MID STORY	399.957
0.15T AT 25M WITH 0.010T AT TOP STORY	392.104

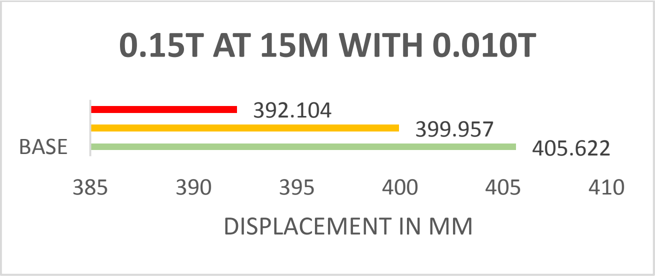


Figure 17 Displacement for Value of Combination of 0.15T AT 25M WITH 0.010T as Internal Blast

Table 5 Displacement Data for Combination of 0.25T AT 15M WITH 0.0075T as Internal Blast

LOAD COMBINATION	DISPLACEMENT(MM)
0.25T AT 15M WITH 0.0075T AT BASE STORY	2549.08
0.25T AT 15M WITH 0.0075T AT MID STORY	2544.841
0.25T AT 15M WITH 0.0075T AT TOP STORY	2538.662

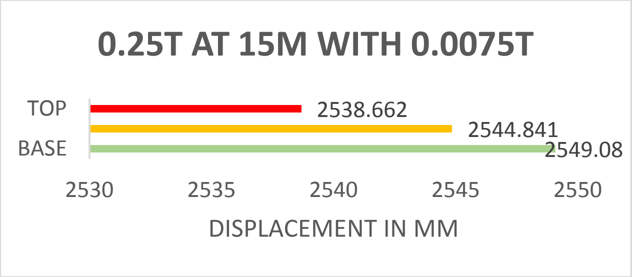


Figure 18 Displacement for Value of Combination of 0.25T AT 15M WITH 0.0075T as Internal Blast

Table 6 Displacement Data for Combination of 0.25T AT 15M WITH 0.010T as Internal Blast

LOAD COMBINATION	DISPLACEMENT(MM)
0.25T AT 15M WITH 0.010T AT BASE STORY	2548.875
0.25T AT 15M WITH 0.010T AT MID STORY	2543.21
0.25T AT 15M WITH 0.010T AT TOP STORY	2535.354

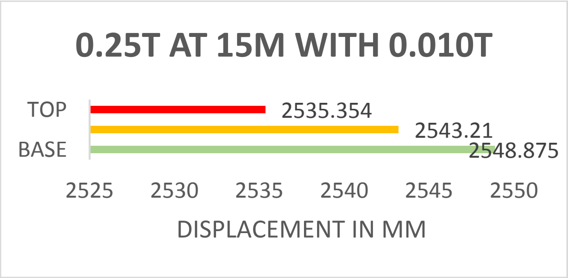


Figure 19 Displacement for Value of Combination of 0.25T AT 15M WITH 0.010T internal Blast

Table 7 Displacement Data for Combination Of 0.25T AT 25M WITH 0.0075T As Internal Blast

LOAD COMBINATION	DISPLACEMENT(MM)
0.25T AT 25M WITH 0.0075T AT BASE STORY	614.32
0.25T AT 25M WITH 0.0075T AT MID STORY	610.081
0.25T AT 25M WITH 0.0075T AT TOP STORY	604.203

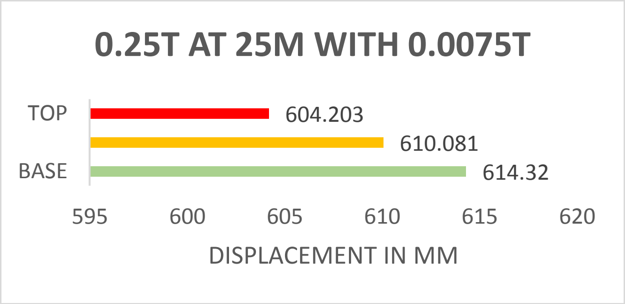


Figure 20 Displacement for Value of Combination Of 0.25T AT 25M WITH 0.0075T As Internal Blast

Table 8 Displacement data for combination of 0.25T AT 25M WITH 0.010T as internal blast

LOAD COMBINATION	DISPLACEMENT(MM)
0.25T AT 25M WITH 0.010T AT BASE STORY	614.115
0.25T AT 25M WITH 0.010T AT MID STORY	608.45
0.25T AT 25M WITH 0.010T AT TOP STORY	600.596

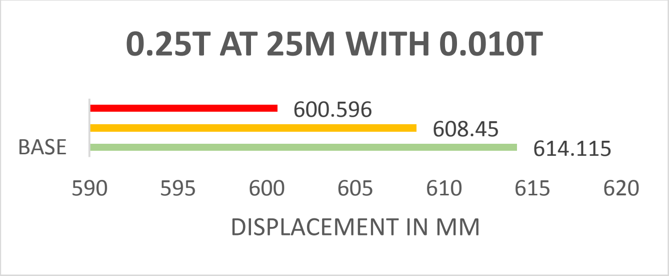


Figure 21 Displacement for Value of Combination Of 0.25T AT 25M WITH 0.010T As Internal Blast

Table 9 Displacement Data for Combination Of 0.35T AT 15M WITH 0.0075T As Internal Blast

LOAD COMBINATION	DISPLACEMENT(MM)
0.35T AT 15M WITH 0.0075T AT BASE STORY	3491.424
0.35T AT 15M WITH 0.0075T AT MID STORY	3487.185
0.35T AT 15M WITH 0.0075T AT TOP STORY	3481.305

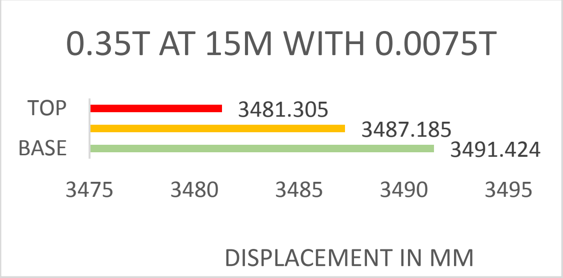


Figure 22 Displacement for Value of Combination Of 0.35T AT 15M WITH 0.0075T As Internal Blast

Table 10 Displacement Data for Combination Of 0.35T AT 15M WITH 0.010T As Internal Blast

LOAD COMBINATION	DISPLACEMENT(MM)
0.35T AT 15M WITH 0.010T AT BASE STORY	3491.219
0.35T AT 15M WITH 0.010T AT MID STORY	3485.554
0.35T AT 15M WITH 0.010T AT TOP STORY	3477.698

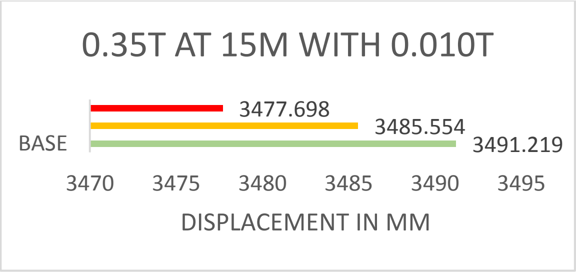


Figure 23 Displacement for Value of Combination Of 0.35T AT 15M WITH 0.010T As Internal Blast

Table 11 Displacement Data for Combination Of 0.35T AT 25M WITH 0.0075T As Internal Blast

LOAD COMBINATION	DISPLACEMENT(MM)
0.35T AT 25M WITH 0.0075T AT BASE STORY	786.024
0.35T AT 25M WITH 0.0075T AT MID STORY	781.784
0.35T AT 25M WITH 0.0075T AT TOP STORY	775.906

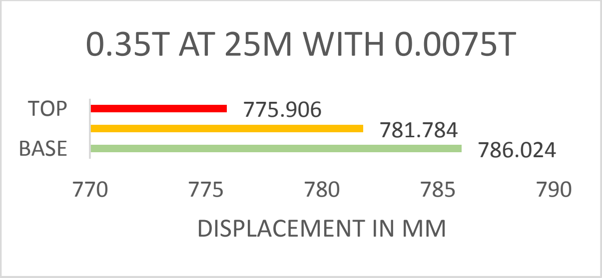


Figure 24 Displacement for Value of Combination Of 0.35T AT 25M WITH 0.0075T As Internal Blast

Table 12 Displacement Data for Combination Of 0.35T AT 25M WITH 0.010T As Internal Blast

LOAD COMBINATION	DISPLACEMENT(MM)
0.35T AT 25M WITH 0.010T AT BASE STORY	785.819
0.35T AT 25M WITH 0.010T AT MID STORY	780.154
0.35T AT 25M WITH 0.010T AT TOP STORY	772.299

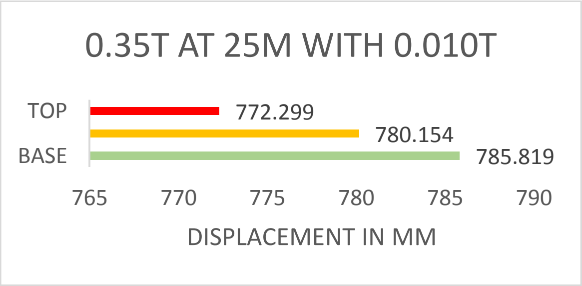


Figure 25 Displacement for Value of Combination Of 0.35T AT 25M WITH 0.010T As Internal Blast

STRESS RESULTS

Table 13 Stress Data for Combination Of 0.15T AT 15M WITH 0.0075T As Internal Blast

LOAD COMBINATION	SRESS(N/MM^2)
0.15T AT 15M WITH 0.0075T AT BASE STORY	989.05
0.15T AT 15M WITH 0.0075T AT MID STORY	986.229
0.15T AT 15M WITH 0.0075T AT TOP STORY	982.696

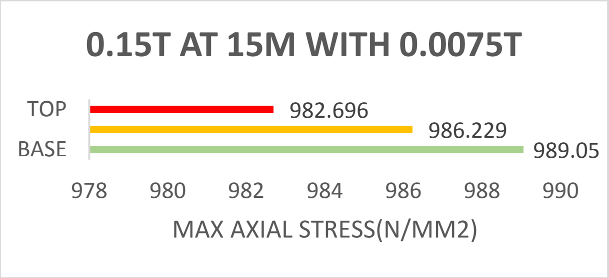


Figure 26 Stress for Value of Combination Of 0.15T AT 15M WITH 0.0075T As Internal Blast

Table 14 Stress Data for Combination Of 0.15T AT 15M WITH 0.010T As Internal Blast

LOAD COMBINATION	SRESS(N/MM^2)
0.15T AT 15M WITH 0.010T AT BASE STORY	988.933
0.15T AT 15M WITH 0.010T AT MID STORY	985.257
0.15T AT 15M WITH 0.010T AT TOP STORY	980.442

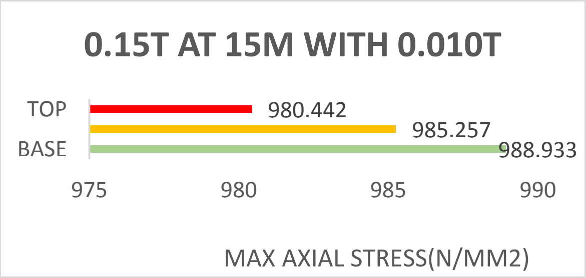


Figure 27 Stress for Value of Combination Of 0.15T AT 15M WITH 0.010T As Internal Blast

Table 15 Stress Data for Combination Of 0.15T AT 25M WITH 0.0075T As Internal Blast

LOAD COMBINATION	SRESS(N/MM^2)
0.15T AT 25M WITH 0.0075T AT BASE STORY	370.542
0.15T AT 25M WITH 0.0075T AT MID STORY	367.79
0.15T AT 25M WITH 0.0075T AT TOP STORY	364.187

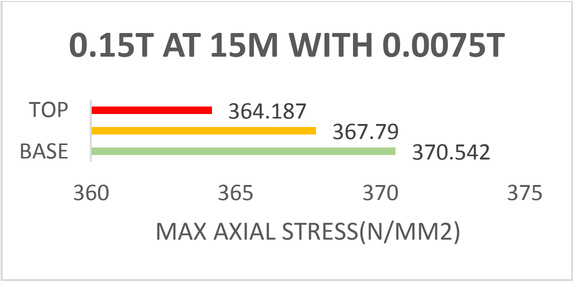


Figure 28 Stress for Value of Combination Of 0.15T AT 25M WITH 0.0075T As Internal Blast

Table 16 Stress Data for Combination Of 0.15T AT 25M WITH 0.010T As Internal Blast

LOAD COMBINATION	SRESS(N/MM^2)
0.15T AT 25M WITH 0.010T AT BASE STORY	370.425
0.15T AT 25M WITH 0.010T AT MID STORY	366.748
0.15T AT 25M WITH 0.010T AT TOP STORY	361.933

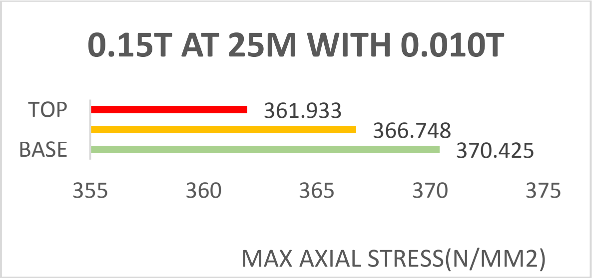


Figure 29 Stress for Value of Combination Of 0.15T AT 25M WITH 0.010T As Internal Blast

Table 17 Stress Data for Combination Of 0.25T AT 15M WITH 0.0075T As Internal Blast

LOAD COMBINATION	SRESS(N/MM²)
0.25T AT 15M WITH 0.0075T AT BASE STORY	1720.188
0.25T AT 15M WITH 0.0075T AT MID STORY	1717.437
0.25T AT 15M WITH 0.0075T AT TOP STORY	1713.833

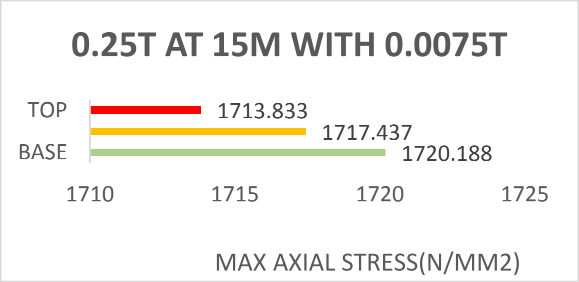


Figure 30 Stress for Value of Combination Of 0.25T AT 15M WITH 0.0075T As Internal Blast

Table 18 Stress Data for Combination Of 0.25T AT 15M WITH 0.010T As Internal Blast

LOAD COMBINATION	SRESS(N/MM²)
0.25T AT 15M WITH 0.010T AT BASE STORY	1720.071
0.25T AT 15M WITH 0.010T AT MID STORY	1716.395
0.25T AT 15M WITH 0.010T AT TOP STORY	1711.58

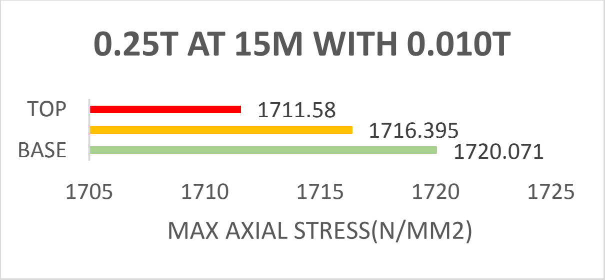


Figure 31 Stress for Value of Combination Of 0.25T AT 15M WITH 0.010T As Internal Blast

Table 19 Stress Data for Combination Of 0.25T AT 25M WITH 0.0075T As Internal Blast

LOAD COMBINATION	SRESS(N/MM²)
0.25T AT 25M WITH 0.0075T AT BASE STORY	501.838
0.25T AT 25M WITH 0.0075T AT MID STORY	499.087
0.25T AT 25M WITH 0.0075T AT TOP STORY	495.484

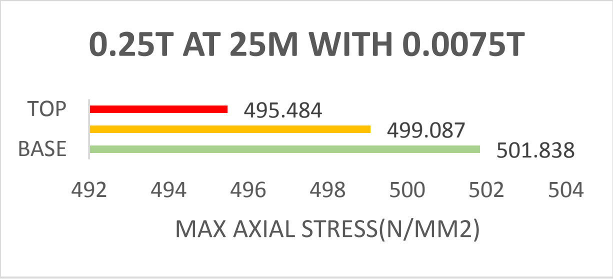


Figure 32 Stress for Value of Combination Of 0.25T AT 25M WITH 0.0075T As Internal Blast

Table 20 Stress Data for Combination Of 0.25T AT 25M WITH 0.010T As Internal Blast

LOAD COMBINATION	SRESS(N/MM²)
0.25T AT 25M WITH 0.010T AT BASE STORY	501.721
0.25T AT 25M WITH 0.010T AT MID STORY	498.045
0.25T AT 25M WITH 0.010T AT TOP STORY	493.23

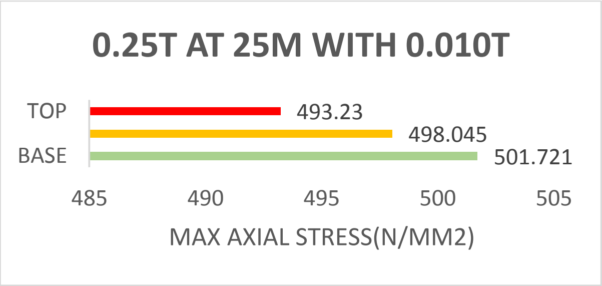


Figure 33 Stress for Value of Combination Of 0.25T AT 25M WITH 0.010T As Internal Blast

Table 21 Stress Data for Combination Of 0.35T AT 15M WITH 0.0075T As Internal Blast

LOAD COMBINATION	SRESS(N/MM^2)
0.35T AT 15M WITH 0.0075T AT BASE STORY	2313.593
0.35T AT 15M WITH 0.0075T AT MID STORY	2310.441
0.35T AT 15M WITH 0.0075T AT TOP STORY	2307.238

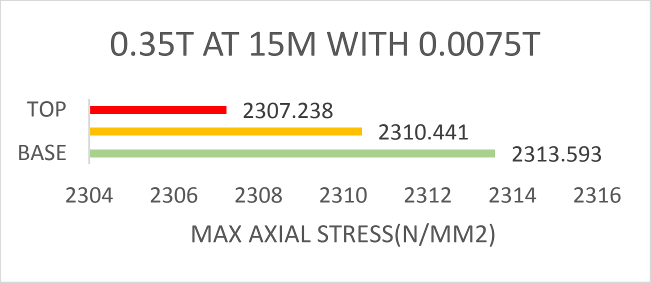


Figure 34 Stress for Value of Combination Of 0.35T AT 15M WITH 0.0075T As Internal Blast

Table 22 Stress Data for Combination Of 0.35T AT 15M WITH 0.010T As Internal Blast

LOAD COMBINATION	SRESS(N/MM^2)
0.35T AT 15M WITH 0.010T AT BASE STORY	2313.475
0.35T AT 15M WITH 0.010T AT MID STORY	2309.799
0.35T AT 15M WITH 0.010T AT TOP STORY	2304.984

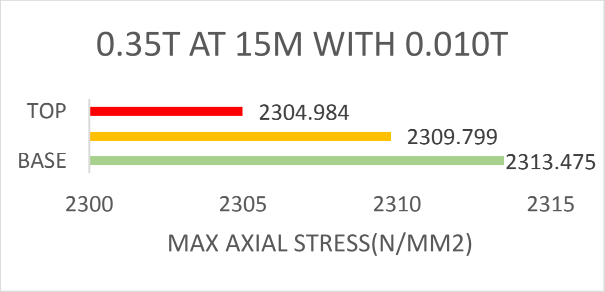


Figure 35 Stress for Value of Combination Of 0.35T AT 15M WITH 0.010T As Internal Blast

Table 23 Stress Data for Combination Of 0.35T AT 25M WITH 0.0075T As Internal Blast

LOAD COMBINATION	SRESS(N/MM^2)
0.35T AT 25M WITH 0.0075T AT BASE STORY	609.965
0.35T AT 25M WITH 0.0075T AT MID STORY	607.213
0.35T AT 25M WITH 0.0075T AT TOP STORY	603.61

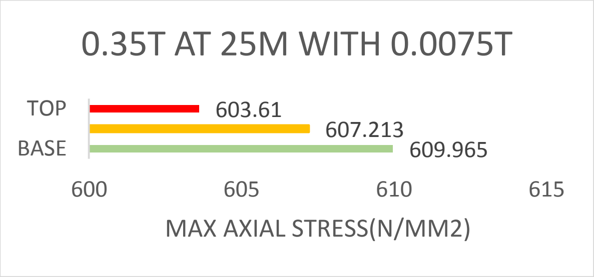


Figure 36 Stress for Value of Combination Of 0.35T AT 25M WITH 0.0075TAs Internal Blast

Table 24 Stress Data for Combination Of 0.35T AT 25M WITH 0.010T As Internal Blast

LOAD COMBINATION	SRESS(N/MM^2)
0.35T AT 25M WITH 0.010T AT BASE STORY	609.848
0.35T AT 25M WITH 0.010T AT MID STORY	606.171
0.35T AT 25M WITH 0.010T AT TOP STORY	601.357

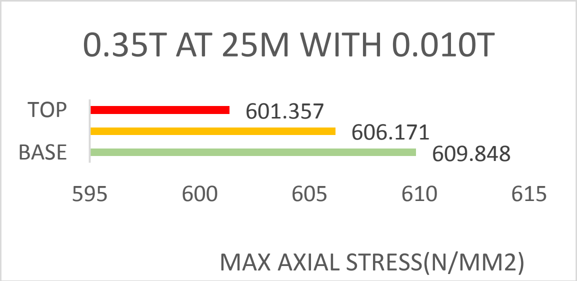


Figure 37 Stress for Value of Combination Of 0.35T AT 25M WITH 0.010T As Internal Blast

Conclusion

1. The results show that the system is considerably affected by changes in standoff distance and charge weight, respectively. However, the effectiveness of the chemical reaction cannot be predictably

determined from the actual charge weight of the explosive employed by the terrorist.

2. In order to defend a structure and keep the bomb as far away as possible, the standoff distance must be maximised as it is the essential parameter that controls the blast pressure.

3. Since the internal blast impact is more likely to occur in the top storey columns due to their reduced cross section features, the blast has a high amplitude characteristic. Therefore, all storeys should incorporate the same cross sectional features.

4. It was discovered in this investigation that the 25 m distance, which had the lowest displacement and stress values, indicated that the structure had very excellent lateral stability against blast load, as opposed to the explosion that happened at the 15 m distance, which is also logically true. The cost impact is generally increase about 16.50 % for the highest charge weight 15 m 0.35 tonne case.

5. For the 15 m 0.35 tonne case with the maximum charge weight, the volume gain is approximately 29.13%.

6. Based on the findings, it can be said that the internal explosion event is not causing a structure to collapse because of their light charge weight.

7. The conclusion derived from the results is that the largest charge weight, 15 m, with a blast event weighing 0.35 tonnes on the exterior and 0.025 tonnes on the interior, can deform the structure more than the standoff distance of 25 m.

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