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A Review on Blast Resistant Structures

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ABSTRACT

The main aim of this study is to review the work already done till now on the effect of blast loading on structures. Nowadays, there are various terrorist activities in the world and therefore for the security the structure should be design as a blast proof. But this is uneconomical in middle society point of view. But in case of public building like Industrial building, shopping mall etc. are possible to deign as blast proof structure. These types of attacks are exceptional cases which is not man-made disasters. Blast loads are in generally in the type of dynamic loads that need to be carefully calculated just like earthquake and wind loads and design also made for that structure considering a blast loading. . If the structures is designed to resist the blast load impact the cost of the structure tends to be very high. Specially, we have to take extra care of that structure which are located in highly sensitive area where bombarding, explosion or wars are happened day by day also the region of high intensity earthquake zone based on codal criteria. The objective of this study is to shed light on blast resistant building design theories, the enhancement of building security against the effects of explosives in structural design process and the design techniques that should be carried out. The paper includes information about explosives, blast loading parameters and enhancements for blast resistant building design with an structural approach.

Keywords: Blast Wave, Bomb Blast, Blast Design, Explosion

I. INTRODUCTION

Blast loading is a short duration load also called impulsive loading. Mathematically blast loading is treated as triangular loading. The paper includes information about explosives, blast loading parameters and enhancements for blast resistant building design with both an architectural and structural approach. Damage to the loss of life is factors that have to be minimized if the threat of terrorist action cannot be stopped. This paper gives guidelines measures for overcoming the effects of explosions, therefore providing protection for human, structure. Ductile elements, such as steel and reinforced concrete, can absorb a significant amount of strain energy, whereas brittle elements, such as timber, masonry, and monolithic glass, fail abruptly. In the investigation of the dynamic response of a building structure to bomb blast. In the IS 4991-1968 codes these types of loads are not dealt with and they need further elaboration as the engineers have no guidelines on how to design or evaluate structures for the blast phenomenon for which a detailed understanding is required as well as that of the dynamic response of various structural elements.

There are no guidelines on such topics are given in Indian standard code also. On the other hand, this topic is the interesting one in military circles and important data derived from the experience and tests have been restricted to army use.

Nevertheless, a number of publications are available in the public domain and published by the US agencies. In this paper we have explored the available literature on blast loads, explained special problems in defining these loads and explored the possibility of vulnerability assessment and risk overcoming of structures with standard structural analysis software with limited non-linear capabilities. In the past few decades considerable importance has been given to problems of blast and earthquake. The earthquake problem is old, but most of the knowledge on this subject has been accumulated during the past fifty years but in case of blast loading this condition is different.

Disasters such as the terrorist bombings of the November 13, 2015 Paris attacks were a series of coordinated terrorist attacks in Paris and its northern suburb, Mumbai 26/11 terrorist attack, Kenya and Dares Salaam U.S. embassies in Nairobi, Tanzania in 1998, the Khobar Towers military barracks in Dhahran, Saudi Arabia in 1996, and the World Trade Center in New York in 1993 have demonstrated the need for a thorough examination of the behavior of columns subjected to blast loads. It is shown that, with the present knowledge and common software, it is possible to perform the analysis of structures exposed to blast loads and to evaluate their response.

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.

How Blast Loads are different from Seismic Loads

Generally, it is not possible to design the structure both by seismic proof and blast proof at the same time like for a wind load also. Therefore, we have to consider blast load and earthquake load are to be separately and there analysis methods are also different. For blast proof structure IS4391-1968 and for seismic proof structure IS1893-2002(Part-I) are used. Blast loads are applied over a short period of time than seismic loads. Thus, material strain rate effects become critical and must be accounted for in predicting connection performance for short duration loadings such as blast. Also, blast loads generally will be applied to a structure non uniformly.

In case of blast load intensity is very high in particular small region for fraction of seconds as compare to that of seismic force.

II. METHODOLOGY

MATERIALS USED IN RECENT CONSTRUCTION TRENDS:

In every few years there's a change in different construction strategies in architectural, structural, environmental, economical, blast resistant etc. So likewise there's respective change in the construction materials. There are several variety of material are used in the recent construction works which are as follows the general categories of construction materials.

1. Polymer Fiber Concrete
2. Laminated Glass
3. Tempered Glass
4. Indestructible Plastic
5. Blast-Proof Fabric
6. Bomb-Proof Wallpaper
7. Zetix Fabric
8. Dura Steel.
9. Bomb Proof Wallpaper etc.

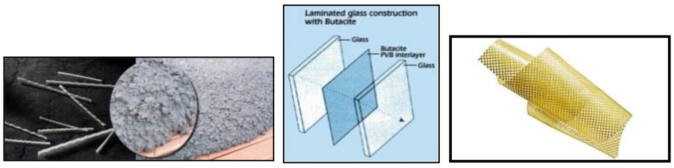

Fig.1 Blast Resisting Materials

BASIC PRINCIPLE OF BLAST EFFECT:

There are ways to blast happen which will differential the working of severity to effect on any construct structure. So what happen is every blast will generate blast wave that will propagate from blast point to nearby structures as we see in this figure, it will reflect from the ground in the air and collide through the building structure in a phase of Mach stem.

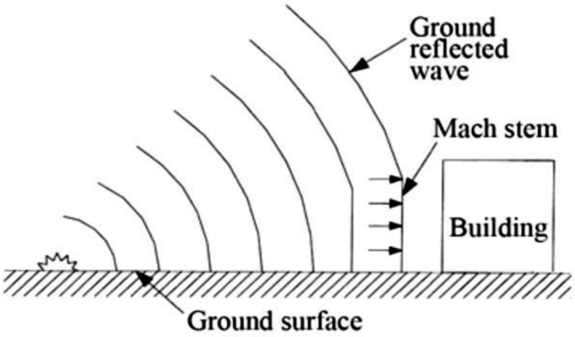

Fig.2 Propagation of Blast Wave

After that what we get by this explosive effect on structure is find the general blast wave pressure-time history, which as shown.

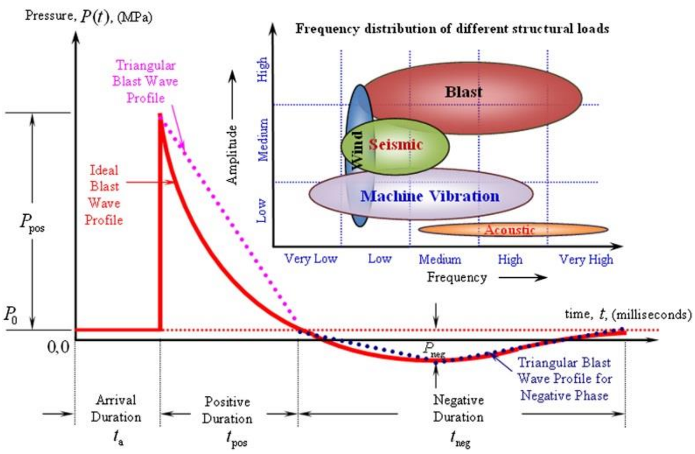

Fig.3 Blast Wave vs. Pressure Time

Effects on Structures

Blast effects on building structures can be classified as primary effects and secondary effects. Primary effects include

1. Air blast: The blast wave causes a pressure increase of the air surrounding a building structure and also a blast wind.

2. Direct Ground Shock: An explosive which is buried completely or partly below the ground surface will cause a ground shock. This is a horizontal (and vertical, depending on the location of the explosion with regard to the structural foundation) vibration of the ground, similar to an earthquake but with a different frequency.

3. Heat: A part of the explosive energy is converted to heat. Building materials are weakened at increased temperature. Heat can cause fire if the temperature is high enough.

4. Primary Fragments: Fragments from the explosive source which are thrown into the air at high velocity (for example wall fragments of an exploded gas tank). Secondary effects can be fragments hitting people or buildings near the explosion. They are not a direct threat to the bearing structure of the building, which is usually covered by a facade. However, they may destroy windows and glass facades and cause victims among inhabitants and passers-by.

Calculation of Blast Loading on Structures

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 IS:4991-1968 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.

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

Scaled distance 'X' = Z/W1/3

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 P_{so}.

b) Peak reflected overpressure P_{ro}.

c) Dynamic pressure q_o.

d) Mach number M.

e) Positive phase duration to milliseconds (millisecond).

f) Duration of equivalent triangular pulse t_d 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 P_r or (P_{so}+ $C_d.q_o$).

Where,

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

P_r = Reflected overpressure which decrease from Pro to overpressure in

Clearance time t_c.

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

i) Clearance time (t_c) = 3S/U

ii) Travel time of shock wave from front face to rear face i.e. transit time (t_t) = L/U

iii) Pressure rise time on back face (t_r) = 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.

$$=\sqrt{(1+\frac{6Pso}{7Pa})}$$

Decay of pressure with time is given by

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

q = qo (1 - t/t_o)^2 $e^{-\frac{2\alpha t}{to}}$

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/m2 on floor area.

Blast loads

IS 4991-1968 is used for blast load calculations. The maximum values of the positive side-on overpressure (**P_{so}**), reflected over pressure (**P_{ro}**) and dynamic pressure (**q_o**), 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_o**, and the equivalent time duration of positive phase **t_d** are given in Table 1.

Table.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

III. RESULTS AND DISCUSSION

Column

Design critical columns to be able to span two stories, in the event that lateral bracing is lost, particularly when using a weak beam approach.

1. Good practice is to ensure that column longitudinal reinforcement does not exceed six percent of the gross area, which also serves to avoid congestion in the splice zones?
2. Provide closely spaced ties or spirals along the entire column height when air blast loads are Non-uniform.
3. Provide closely spaced hoops for adequate confinement of concrete. This increases the Capacity of the concrete in compression and helps prevent buckling of the longitudinal bars after the concrete crushes.
4. Provide spacing of closed-hoop confinement reinforcement at column hinge regions to Comply with ACI 21.4.4.4.

Beams and Slabs

1. Balanced design often leads to a strong column–weak beam approach, with the intent that beam failure is preferable to column failure.
2. Provide sufficient shear transfer to floor slabs so that directly applied blast loads can be resisted by the diaphragms rather than weak axis beam bending.
3. Transfer girders should be avoided in regions identified as having a high blast threat.
4. Provide spacing of closed hoop confinement reinforcement at beam hinge regions and at lap splice regions based on the smallest of the following
   a) Beam effective depth / 4
   b) 8*diameter of longitudinal bars
   c) 300mm
5. Ensure that both top and bottom longitudinal reinforcing are continuous throughout the length of beams and slabs.
6. Provide confinement reinforcement at areas outside of hinge and splice regions at a spacing no more than half the beam effective depth (ACI 21.3.3.4).
7. Design lap splices as tension splices, locate them outside of plastic hinge regions (see ACI 318, section 21.4.3.), and stagger them.

IV. CONCLUSION

The objective of this study is to shed light on blast resistant building design theories, the enhancement of building security against the effects of explosives in both architectural and structural design process and the design techniques that should be carried out. Blast resistant building design provides structural integrity and acceptable levels of safety for buildings. Firstly, explosives and explosion types have been explained briefly. In addition, the general aspects of explosion process have been presented to clarify the effects of explosives on buildings. To have a better understanding of explosives and characteristics of explosions will enable us to make blast resistant building design much more efficiently.

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