# Blast Effects on Structures: A Critical Review

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**Abstract- The main aim of this study is to review the work already done till now on the effect of the blast loading on structures. The bomb explosion within or immediately nearby a building can cause catastrophic damage to the buildings external frames, collapsing of walls and internal structure frames. Now a days there are various terrorist activities in the world and therefore from security purpose, the structure should be design as blast proof. Many of the existing buildings which are not designed for blast loads get damaged or even fully collapsed when subjected to such impulsive loads. Loss of life and injuries to occupants can result from direct blast effects, structural collapse, impact fires, debris and smoke. However, it was found that if the structure is designed to resist the blast load impact, the cost of the structure tends to be very high. These studies gradually enhanced the understanding of the role that blast loads play in affecting the response of building. For this dynamic analysis is to be performed in order to determine the effect of the blast impact on the structure. Specially, we have to take extra care of those structures which are located in highly sensitive areas where bombarding, explosion or war are happening day by day and also the regions of high intensive earthquake zones based on codal provisions.**

**Keywords – Blast loading, time-history, SDOF (single degree of freedom), SIFCON (Slurry Infiltrated Fibre Reinforced Concrete), blast waves, explosion**

## I. INTRODUCTION

Blast loading is a short duration load of very high magnitude also called as impulsive load [1]. 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 architectural as well as structural approach. In recent years due to different accidental or intentional blasts all over the world that resulted in number of initiatives to study the resistance of structures to blast and to develop system to reduce the hazard of such attacks. Damage to the loss of life is the factor that has to be minimized if the threat of terrorist action cannot be stopped. 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 when subjected to blast loads. In RCC design, structures particularly are not designed to resist blast loads and magnitude of design loads is significantly lower than those produce by most explosions. Structures are susceptible to damage from explosion. On the other hand, this topic is of interest in military circles and important data derived from the experience and tests have been restricted to army use. Single degree of freedom models have been widely used for predicting dynamic response of concrete structures subjected to blast loading.

Examples of such cases of bombing attacks are as follows:-

- World Trade Centre in New York in 1993
- Alfred P. Murrah Federal Building in Oklahoma City in 1995
- Kenya and Dares Salaam U.S. embassies in Nairobi, Tanzania in 1998
- Khobar Towers military barracks in Dhahran.

## II. Effect On Structures

Blast effect on building structures can be classified as:

### *2.1 Primary Effects –*

Primary effects of blast loads on structures include:

i) Airburst: The blast wave causes a pressure increase of the air surrounding a building structure & also a blast wind.
ii) **Direct Ground Shock:-** An explosive which is immersed completely or partly below the ground surface will cause a ground shock. This is a horizontal vibration of the ground, similar to an earthquake but with a different frequency.
iii) **Heat:-**A part of the explosive energy is converted to heat. Building materials are weakened at increased temperature and heat can also cause fire if the temp is high enough.
iv) **Primary Fragments:-**Fragments from the explosive sources which are thrown into the air at high velocity.

### *2.2 Secondary Effects –*

Secondary effects of blast loads on structures include:

i) Secondary effects can be fragments hitting people or buildings near the explosion.
ii) They may destroy windows & glass facades & cause victims among occupants & passers-by.
iii) They are not a direct threat to the bearing structure of the building, which is usually covered by a façade.

## III. Expected Damage Levels

There are mainly three damage levels which can be classified as follows:

### *3.1 Minor Damage Levels –*

The shock wave effectively acts on the entire structure simultaneously. There is a drag force from the rapidly moving wind behind the blast wave, however the structure is massive enough to resist translation. The blast wave may break windows, exterior walls may be blown in or the columns may be damaged as shown in Figure 1.

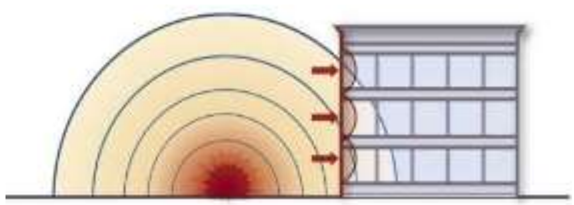

Figure 1. Blast wave with Minor Damage Level

### *3.2 Moderate Damage Levels –*

It involves a relatively large shock wave & a target much smaller than the previous case. The target is sufficiently small enough to be moved by the dynamic and drag pressure. This shock wave forces the floors in upward direction as shown in Figure 2.

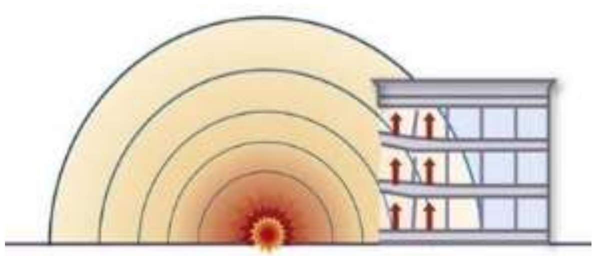

Figure 2. Blast wave with Moderate Damage Level

*3.3 Major Damage Level –*

The shock burst is too small to surround the structure simultaneously & the structure is too large to be shifted, hence instead of simultaneously loading, each component is affected in succession. This blast wave exerts downward pressure on roof and inward pressure on sides as shown in Figure 3.

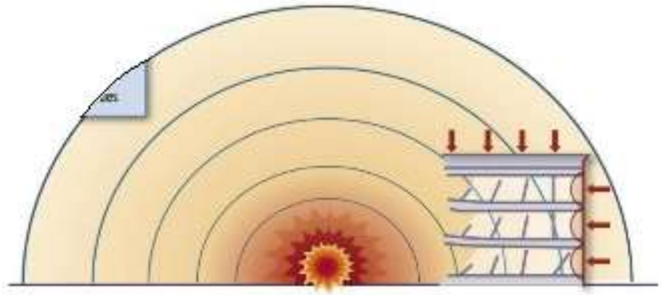

Figure 3. Blast wave with Major Damage Level

For detailing and connections to minimize or abort the damage due to blast waves, we can use special moment frames, avoid splices at plastic hinge locations, provide continuous reinforcing through joints and use hooked bars where continuous reinforcing is not possible.

## IV. Literature Review

In the past various studies have been conducted to determine the effect of blast loads on structures of which few of them have been summarized below:

**T. Ngo et al. [2]** stated that the use of vehicles bomb attacking city centres has been a sign of sledding by terrorist organizations around the whole world. A bomb explosion with in or immediately near by a building can cause catastrophic damage to the buildings external & internal structural frames. The analysis and design of structures subjected to blast loads require a detailed understanding of blast phenomena and the dynamic response of various structural elements. The indirect effects can combine to inhibit or prevent timely evacuation; thereby contributing to additional casualties. This research paper presents an extensive overview of the effects of the explosion on structure.

**J.M. Dewey [3]** studied on the properties of blast waves obtained from particles courses as well as the temperature and the sound speed found from the pressure and density, assuming the perfect gas equation of states. He also studied the effect of circular & hemispherical TNT in blast waves & determined the density throughout the flow by application of the Lagrangian maintenance of mass equation which can be used for calculating the pressure by assuming the adiabatic flow for each air elements between the shock fronts.

**A.M. Remennikov [4]** studied the method for predicting bomb blast attack on building. The building was subjected to blast loading produced by the explosion of high explosive device. Simplified analytical techniques were used for attaining conservative estimate of the blast effect on buildings. Numerical techniques including Lagrangian, Euler & FEM were used for accurate prediction of blast loads on buildings.

**Z. Koccaz et al. [5]** summarized that the increase in the number of terrorists' attacks, considerably in the last few years has shown that the effect of blast loads on building is a serious matter that should be taken into opinion in the design process. The purpose of this study is to shed light on blast resistant building design theories, the enhancement of building security against the effect of explosives in both architectural & structural design process & the design techniques that should be effectuated. Essential techniques for increasing the capacity of a building to provide protection against explosive effects is discussed both with an architectural and structural approach.

**A.T. Hussein [6]** studied on the analytical method of a Single Degree of Freedom (SDOF) system analysis subjected to blast loading. There are two types of blast wave applied for the analysis focused on displacement time history responses which form the basis for studying the behavior of single degree of freedom (SDOF) system under blast loadings. The two types of blast function are as simple pulse and bilinear pulse. The results obtained from a computer program NON-SDOF clarified the effect of type of blast wave on the behavior of the system.

**S. Ahmad et al. [7]** studied the response of 4 different RC walls with varying thickness for different explosive loads and scaled distance. Pressure sensor, accelerometers, dynamic strain amplifier, data acquisition board and strain gauges were used to measure air blast & ground shock. It was observed that air blast and ground shock pressure are important parameters for accurate analysis of structural response of structures.

**S.M. Jayashree [8]** used Slurry Infiltrated Fibre Reinforced concrete (SIFCON), a type of Fibre Reinforced Concrete with high fibre content as an alternative material to RCC and concluded that SIFCON has high energy soaking capacity, higher strength and is highly ductile.

**M.R. Wakchaure and S.T. Borole [9]** compared the response of reinforced concrete long column and short column when subjected to random blast loads. The percentage of stress in RC column for long side and short side was presented through analysis results obtained by ANSYS software. He concluded that the critical impulse for the long column case is significantly higher.

**X. Cheng et al. [10]** analysed the dynamic response of concrete frame structures under different explosive quantities and blasting distance. The main conclusion drawn was that during structural design special attention should be given to the weaker parts; strengthen the roof and parapet design since vibration response of concrete frame structure is maximum at the top under vibration wave. Blasting vibration waves were obtained using MATLAB & SAP2000 finite element software.

**A.K. Pandey et al. [11]** conducted the analysis using suitable non-linear material models till the ultimate stages. An analytical procedure for non-linear analysis using appropriate model was implemented into a finite element code DYNAIB.

**R.L. Shope [12]** studied the response of wide flange steel column subjected to constant axial load & lateral load. The finite element program ABAQUS was used to model with different circular ratio & boundary conditions. The columns with linear elastic and rotational supports were studied considering the non-uniform blast loads .The effect of strain rate and residual stresses were also examined. It was observed that for axially loaded column, there exists a critical lateral blast impulse and any applied blast impulse above that value results in the collapsing of the column before the allowable beam deflection criterion was reached. The critical impulse governs the response when the axial load is high while the beam deflection criterion governs the response when the axial load is low.

**A. Kadid et al. [13]** analysed the fully fixed stiffened plates under the effect of blast loads to determine the dynamic response of the plates with different stiffener configuration considering the effect of mesh density, time and strain rate sensitivity. They used the FEM and the CDM for the time integration of the non-linear equation of motion to obtain numerical solutions.

According to **J.A. Schmidt [14],** the US government funded extensive research in to blast analysis and protective design methods and produced a number of guidelines for its own facilities. The private division increasingly considered the similar measures, particularly for so called icon buildings. He also summarized the methods available to define an external terrorist bomb threat and estimated structural design loads and elements response using simple dynamic system models and principles.

## V.CONCLUSION

Based on the studies available in the literature, the ultimate objective is to make available the procedure for calculating the blast loads on the structures. The aim in the blast proof building design is to prevent the overall collapse of the building and damages. But it should be remembered that blast loads are unpredictable, instantaneous and extreme. It is uneconomical to design all building for blast loading. Result of non SDOF program showed the effect of type of wave on the time history analysis result & computed energy of blast load. It can also be used to study the dynamic properties of reinforcing steel & concrete under high strain rates typically produce by the blast loads .The explosion near the structure can cause catastrophic damage to the structure hence these loads should be considered in design.

The blast pressure & the corresponding displacements on the structure increase with increase in charge weight & decrease in the standoff distance .The variation of displacement along the length & width of front, rear, roof & side surface of the structure are approximately sinusoidal in nature with maximum displacements around the centre of the surface.

Two types of blast load wave, simple & bilinear pulse should be applied to study the non-linear behaviour of SDOF system. The main objective is to make available the procedure for calculating the blast loads on the structure with or without the openings & frames structure. During the architectural design of structural elements walls, flooring etc. should be considered carefully.

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