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Basics of Blast Loading and its Effects on Structures: A Review

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ABSTRACT

Terrorists frequently target iconic and prominent structures, resulting in huge numbers of victims and considerable physical damage. Recently, an exterior bombardment of a block of flats with reinforced concrete frames took place. Explosive charges can cause catastrophic damage to the lower floors of a building, leading to the collapse of all or part of the structure. The analysis of the unbalanced and gradual collapse of a structure requires the identification of critical areas of early impact and the height, width, and depth of the detonated building, as well as the structural response.A bomb detonating under or near any structure may produce disastrous destruction to the exterior and interior of the building, the collapse of walls, the explosion of large windows, and the disruption of critical safety systems.

Keywords:Blast load: Blast wave: Dynamic response: framed structure

1. Introduction

The concerns about explosives and earthquakes have received a lot of attention in recent decades. Although the earthquake problem is not new, the majority of information on the subject has just been acquired in the last 50 years. The problem of blasting in any building is very new, and most information regarding developments in this sector comes from the Army Corps of Engineers, the department of defence, the United States Air Force, and other government agencies and public institutes. The Massachusetts Institute of Technology, the University of Illinois, as well as different institute or organization related to engineering is responsible for most of the work. The mode of building elements on which blast load is acting is the focus of substantial scientific fraternity in coming days due to various accidental or purposeful incidents. Conventional buildings, particularly those above ground, are typically not built to withstand shock wave; this is due to the reason that the design loads are typically lesser than that developed by major blast, so these building are vulnerable to damage due to explosion. Every engineers, architects, and developers always keep these things in their mind and increasingly looking for methods to safeguard both inhabitants and infrastructure in the event of a bomb.

The structural engineers are showing more devotion to the better design and construction of any structures to offer suitable protection against explosions. A large-scale, quick, and unexpected release of energy is defined as an explosion. Explosions are classified as physical, nuclear, or chemical occurrences depending on their nature. The catastrophic breakdown of a cylinder of pressurised gas, volcanic eruptions, or simply the mixing of two liquids at different temperatures can all result in physical explosions (Meena and Ramana 2021). In case of nuclear explosion some energy is formed due to production of various atomic nuclei by inter change in neutrons and protons inside the interrelating nuclei, whereas in chemical explosions, energy is generated from the fast oxidation of fuel materials. Explosive materials are classed as solids, liquids, or gases

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depending on their physical condition. Solid explosives are mostly heavy explosives with well-known explosion effects. They can also be categorised as secondary or main explosives depending on their susceptibility to ignition. Simple ignition via a spark, flame, or collision can readily explode the latter.

The complexities of analyzing the dynamic response of structures under explosion loading include high rates of deformation, nonlinear elasticity of the material, uncertainty in the calculations of explosion loading, and time-dependent deformations. Therefore, to facilitate the analysis, several hypotheses regarding the structure and response to the task have been planned and generally acknowledged. To develop the principle of this work, any structure is considered as a system with a single degree of freedom (SDOF), where the relationship in between the breath load and the time period of oscillation. The simplest sampling of the transition problem is to use the SDOF method. A real structure can be replaced by an equivalent system of a concentrated mass and a zero-gravity arc, which represents the resistance to deformation of the structure. Such an ideal system is shown in Fig. 1.

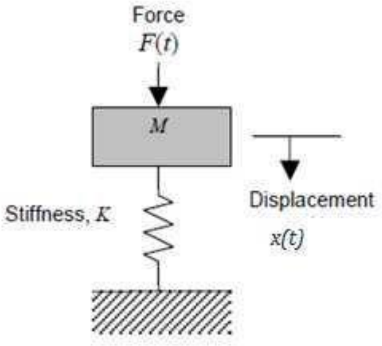

Fig. 1 - Elastic single degree of freedom (SDOF) system

2. Literature Review

The main mechanism of change in the direction of an explosion depends largely on the source. However, several key features need to be identified and considered in terms of the impact of an explosion on a structural system. Explosives can be divided into low explosives and high explosives, depending on the rate of fire, and solid explosives. It is categorised as primary or secondary explosives in terms of sensitivity to flammability. Substances like mercury flash and lead azide are the main blasting charge. Other blasts can cause shock waves (shock) which can cause enormous damage to the environment when detonated (Ngo et al., 2007).

Research focuses on the prediction of explosive loads, the behavior of materials at high loads, structural responses to shock loads, and protection and recovery actions (Morales-Alonso et al., 2011). Structural damage caused by explosive charges has an immediate impact and many hazards, including a forced fall. This catastrophic mode of failure develop at the initial stage of failure of one or more major load-bearing components results in more extensive destruction of the surrounding components, leading to the widespreadcollapse of the entire building (Arlery et al., 2001). It is therefore important to study and enhance the response of building due to explosive charges.

A model proposed by Held 1983 and another model by Brode 1955 predicts the maximum and minimum value of free air-burst and surface burst at the scale distance (Z) in the selected range of 4.353 to 1.830. A similar model was developed by other researchers like Badshah 2017 as well as Kinney and Graham 1985 who found somehow the same value within the region of large-scale distance. The outcomes of free air and surface burst are mostly spread over a small area. Also, the results of the surface explosion test are less dispersed than the results of the empty air explosion test. The scattering of the model reflects the poor study of the near field explosion charge and the variability of the explosion model behavior in the near field scenario.

Detailed information on building explosion analysis is not readily available or published for security reasons. Identifying the vulnerabilities of multi-storey buildings with RC frames and assessing their potential damage with current resources is very limited. Therefore, it is important to study in detail the nature and likelihood of the gradual collapse of apartment buildings (Knight and Whiton 2006).The information gathered from real accidents and the knowledge obtained from various research, including blast testing, may be used to enhance measurement and tools used for design, also design standards and recommendations for construction of either new building or retrofit the old one (Yankelevsky et al., 2013).

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3. Methodology

As storms spread, buildings and people move and collapse. Thus, the explosion spread throughout the building. All parameters of an explosion depend mainly on the magnitude of released energy during the explosion and forming shock wave, also depends on distance from the centre of explosion.The law of scale provides a parametric correlation between a given explosion and the standard load of an object. After the blast wave passes through the back edge of the prism barrier, the pressure propagates back in the same way, and it is proposed in a linear function in terms of 5S/Us. Several conclusions have been proposed regarding the decomposition rate of dynamic compression loads. Parabolic damping in time equal to the total duration of the positive overpressure is a practical approximation. Several studies in the 1950s and 1960s focused on blast wave parameters for conventional high-explosive materials. The speed of the air particles and the resulting wind pressure depends on the maximum overvoltage pressure.

This subsequent air velocity is related to the dynamic pressure q (t). Due to an internal explosion, complex compression load profiles may occur as a result of the two loading phases. The first result of an explosion is a reflection of excess pressure, which causes reflection due to the limitations offered by the structure. Depending on the impact, the target structure can be described as either ventilated or unventilated. The latter must be more resistant to resistance to certain explosions than ventilation structures in which part of the explosive energy is dissipated by breaking windows or fragile partitions.Explosion hazard calculation methods are generally divided into methods for predicting explosive loads on structures and methods for calculating structural responses to loads. Explosion prediction and structural response programs use the first major and semi-empirical methods. Taking into account the movement of the structure when calculating the explosion, it is possible to predict more precisely the pressure caused by the movement of the structure and the failure.

3.1. Calculation of Blast Loading

There are several reports and methods for determining the value of pressure at a certain explosion distance. All proposed reports include the calculation of a scaled distance based on the mass of the explosion and the effective distance calculated from the centre of the explosion. Kinney and Graham proposed a formula based on chemical explosions in 1985. It is described by the following equation and is widely used in computer calculations,

$$P_{so} = P_o \frac{808\left[1+\left(\frac{Z}{4.5}\right)^2\right]}{\left\{\left[1+\left(\frac{Z}{0.048}\right)^2\right]\left[1+\left(\frac{Z}{0.32}\right)^2\right]\left[1+\left(\frac{Z}{1.35}\right)^2\right]\right\}^{0.5}}$$

Where Z is nothing but scaled distance whereas, P_O is the ambient pressure. Scaled distance (Z) can find out using the equation:

$$Z = \frac{R}{\sqrt[3]{W}}$$

Where R (m) is the distance measured from the origin of the explosion to the required point and W is the mass (in kg) of the blast.

Other reports of maximum overpressure (P_{so}) for a spherical explosion include the Brod 1955 report presented in the equation. Out of these two equations, one is valid for Pso greater than 10 whereas the other is Pso in between 0.1 and 10 bar. First measure the value of Z then determines Pso in a bar using the below equations:

$$P_{so} = \begin{cases} \dfrac{6.7}{Z^3} + 1 & , for \quad P_{so} > 10\,bar \\ \dfrac{0.975}{Z} + \dfrac{1.455}{Z^2} + \dfrac{5.85}{Z^3} - 0.019 & , for \quad 0.1 < P_{so} < 10\,bar \end{cases}$$

So in general various steps involved in this process are:

- Calculate the weight of the explosive in terms of equivalent weight of TNT.
- Now measure standoff or actual distance for the point taken from zero level in the ground to point of interest.
- Find out the height of the explosive where it is kept on the ground.
- Measure all the dimensions of building components required for post-processing.
- Identify various points at each building component on the structure and determine the different parameters for explosion at each identified point. Measure the value of scale distance (Z) using below equation:

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

- Also, calculate different parameters used in blasting with the help of the chart provided corresponding to scaled distance (Z). The chart proposed by UFC 3-340-02 (2008) is used to predict the blast pressure.

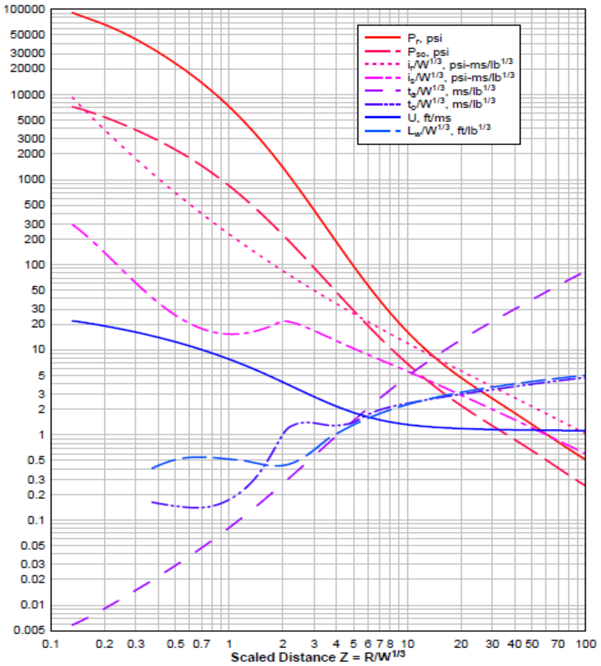

Fig. 2 - Different parameters in the blasting corresponding to scaled distance (Z) (Unified Facilities Criteria 2008)

4. Conclusions

In this study, technical information was collected, applied and presented in the form of explosion formulas, graphs and diagrams to calculate the external explosion load to be taken into account in the explosion-proof design of the structure. The method of blast load prediction recommended by UFC 3-340-02 2008 was used for the determination of blast loads over the method prescribed by IS 4491-1968 due to the prevailing inaccuracy and confusion in the latter method that led to uneconomic design. Thus in-depth method to quantify the blast load affecting a building has been discussed and a method to apply this dynamic load on a structure in ETABS has also been recommended in this study. To accurately analyze the structural response to the explosion of the surrounding surface and the deterioration of the structure, both the air blast pressure and blast wave must be taken into account.

This method can be used to assess the response of concrete paving structures to the severity of the explosion and cracks. For high-risk installations, such as high-rise public and commercial buildings, it is important to consider design for extreme conditions. It is recommended that the guidelines be reflected to prevent abnormal loads and the gradual deterioration of existing building codes and design standards. The requirement for flexibility also helps to improve the performance of the building at high loads. It is impossible to protect the surfaces of structures exposed to direct explosive pressure. However, the explosion pressure can be tolerated by increasing the distance from the explosion point.

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