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BLAST LOADING ON ABOVE GROUND STRUCTURES

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ABSTRACT

A bomb explosion within or immediately nearby a building can cause catastrophic damage on the building's external and internal structural frames, collapsing of walls, blowing out of large expanses of windows, and shutting down of critical life-safety systems. Loss of life and injuries to occupants can result from many causes, including direct blast-effects, structural collapse, debris impact, fire, and smoke. The indirect effects can combine to inhibit or prevent timely evacuation, thereby contributing to additional casualties.

In addition, major catastrophes resulting from gas-chemical explosions result in large dynamic loads, greater than the original design loads, of many structures. Due to the threat from such extreme loading conditions, efforts have been made during the past three decades to develop methods of structural analysis and design to resist blast loads. Studies were conducted on the behavior of structural concrete subjected to blast loads. These studies gradually enhanced the understanding of the role that structural details play in affecting the behavior. 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. This gives a comprehensive overview of the effects of explosion on structures.

A 10 storied building will be selected for computation of blast loading and its effect on the RCC framed structure. The actual effective distance from explosion (standoff distance) i.e. R is taken as 5 m, 10 m, and 15 m respectively for the equivalent TNT (Trinitrotoluene) charge weight, W = 25 Kg, 50 Kg and 75 Kg respectively. The blast pressure coming from different values charge weights of TNT are considered with different positions (standoff distances) of the blast points relative to the column. The 3D model of a column will be analyze using ETABS or STADPRO. The effect of the blast loading will be modeled in the dynamic analysis to obtain the total deflection, stress and strain in the column.

I. INTRODUCTION

An explosion is an extremely rapid release of energy in the form of light, heat, sound, and a shock wave. The shock wave consists of highly compressed air that wave-reflects off the ground surface to produce a hemispherical propagation of the wave that travels outward from the source at supersonic velocities.

Extensive studies during the last five decades have shown that short-duration high- magnitude loading conditions significantly influence structural response. Explosive loads are typically applied to structures at rates approximately 1000 times faster than earthquake- induced loads. The corresponding structural response frequencies can be much higher than those induced by conventional loads. Furthermore, short-duration dynamic loads often exhibit strong spatial and time variations, resulting in sharp stress gradients in the structures. It is known that high strain rates also affect the strength and ductility of structural materials, the bond relationships for reinforcement, the failure modes, and the structural energy absorption capabilities.

Due to different accidental or intentional events, related to important structures all over the world, explosive loads have received considerable attention in recent years. The design and construction of public buildings to provide life safety in the face of explosions is receiving renewed attention from structural engineers. Such concern arose initially in response to air attacks during World War II, it continued through the Cold War and more recently this concern has grown with the increase of terrorism worldwide. For many urban settings, the proximity to unregulated traffic brings the terrorist threat to or within the perimeter of the building.

For these structures, blast protection has the modest goal of containing damage in the immediate vicinity of the explosion and the prevention of progressive collapse. In this sense, computer programs simulations could be very valuable in testing a wide range of building types and structural details over a broad range of hypothetical events. Over the last decades considerable attention has been raised on the behaviour of engineering structures under blast or impact loading. The use of explosives by terrorist groups around the world that target civilian buildings and other structures is becoming a growing problem in modern societies. Explosive devices have become smaller in size and more powerful than some years ago, leading to increased mobility of the explosive material and larger range effects. Usually the casualties from such a detonation are not only related to instant fatalities as a consequence of the direct release of energy, but mainly to structural failures that might occur and could result in extensive life loss. civilian and government buildings, as well as areas with high people concentration (metro and train stations, means of mass transportation, stadiums etc.) are becoming potential bombing targets of terrorist groups. Since most engineering structures are vulnerable to such type of loading scenarios, a guide should be introduced to the designer in order to guarantee structural integrity even under those extreme situations.

The problem of structural resistance under explosive loads has been under investigation for many years and has been well advanced in the military community. This is also the reason that the majority of these findings are not accessible to the public and are only restricted to military use. Nevertheless, some documentation that allows the prediction of the effects of an explosive blast is available for use by design engineers. The development of a procedure that will give practical design solutions is essential for the design of new or the retrofitting of existing structures so as to be able to withstand the effects of explosive loads. The engineer needs to calculate the acting forces according to a certain blast scenario, which includes the type and weight of the used explosive, the distance from the structure and the geometry of the surrounding area and the structure itself. These forces should then be applied on the structural system at hand in order to design structural members, sections and connections that will ensure sufficient robustness of the building to survive the effects of the computed actions..

II. TERMINOLOGY

Explosion: An explosion is a sudden release of energy with a related volume expansion. The explosion will lead to an increase of light and temperature but above all a high increase of pressure. For an explosion in mid air the pressure will create a pressure wave which will advance in a spherical motion originating from the point of source. The pressure will decrease with increasing distance from the source, and hence, the distance is of utmost importance when regarding explosions. The time it takes for the pressure wave to reach the object is referred to as arrival time, ta, and is a way to relate the distance from the explosion to a certain object.

Explosion and blast phenomenon:

In general, an explosion is the result of a very rapid release of large amounts of energy within a limited space. Explosions can be categorized on the basis of their nature as physical, nuclear and chemical events.

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.

III. BLAST LOADING TYPES

As an explosive charge detonates in urban areas the surroundings, and relative placement of the explosion, effects the loading on the structures. The type of explosion that is considered in this thesis is unconfined, non-contact explosions which is external to the building structure. As Karlos et al. writes, the type is divided into three subtypes such as a) free-air bursts, b) air bursts and c) surface bursts.

The Free-air burst is an explosion detonated in the air where the blast wave propagate spherically outwards and hits the structure without prior interaction with the surrounding. This gives a load acting ontop of the structure and on the facade. The Air burst is basically the same as a free-air burst with the difference that the blast wave hits the ground first which gives rise to a Mach wave front which then impinge onto the structure. While the other two types of bursts detonates in mid-air the surface burst detonates almost at the ground surface. The blast waves from the surface burst immediately interacts with the ground and then propagates hemispherical outwards and impinge onto the structures facade [2]. The first two load types could originate from explosives like granates. The surface burst type could originate from a truck with explosives that accidentally detonates which will be used when modeling blast loads in this thesis. In Figure 1.9 the three burst types are shown.

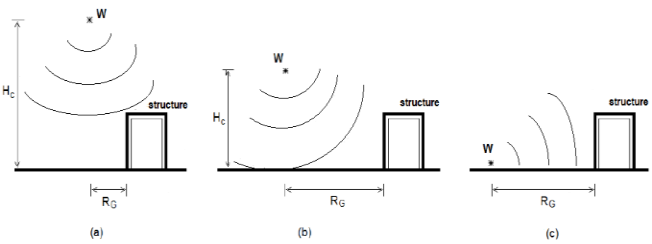

Fig.Blast loading from explosion types

IV. METHODOLOGY

The analysis of the blast loading on the structure started in 1960's. US Department of the Army, released a technical manual titled "structures to resist the effects of accidental explosions" in 1959. The revised edition of the manual TM 5-1300 (1990) most widely used by military and civilian organization for designing structures to prevent the propagation of explosion and to
provide protection for personnel and valuable equipments.
The methods available for prediction of blast effects on buildings structures are:

- Empirical (or analytical) methods
- Semi-empirical methods
- Numerical methods.

Empirical methods are essentially correlations with experimental data. Most of these approaches are limited by the extent of the underlying experimental database. The accuracy of all empirical equations diminishes as the explosive event becomes increasingly near field.
Semi-empirical methods are based on simplified models of physical phenomena. The attempt is to model the underlying important physical processes in a simplified way. These methods are dependent on extensive data and case study. The predictive accuracy is generally better than that provided by the empirical methods.

Numerical (or first-principle) methods are based on mathematical equations that describe the basic laws of physics governing a problem. These principles include conservation of mass, momentum, and energy. In addition, the physical behavior of materials is described by constitutive relationships. These models are commonly termed computational fluid dynamics (CFD) models.

The key elements are the loads produced from explosive sources, how they interact with structures and the way structures respond to them. Explosive sources include gas, high explosives, dust and nuclear materials. The basic features of the explosion and blast wave phenomena are presented along with a discussion of TNT (trinitrotoluene) equivalency and blast scaling laws. The characteristics of incident overpressure loading due to atomic weapons,
conventional high explosives and unconfined vapors cloud explosions are addressed and followed by a description of the other blast loading components associated with air flow and reflection process. 1814 kg at a stand off of 5m. As terrorist attacks may range from the small letter bomb to the gigantic truck bomb as experienced in Oklahoma City, the mechanics of a conventional explosion and their effects on a target must be addressed. Throughout the pressure-time profile, two main phases can be observed; portion above ambient is called positive phase of duration (td), while that below ambient is called negative phase of duration (td). The negative phase is of a longer duration and a lower intensity than the positive duration. As the stand-off distance increases, the duration of the positive-phase blast wave increases resulting in a lower-amplitude, longer-duration shock pulse. Charges situated extremely close to a target structure impose a highly impulsive, high intensity pressure load over a localized region of the structure; charges situated further away produce a lower-intensity, longer-duration uniform pressure distribution over the entire structure. Eventually, the entire structure is engulfed in the shock wave, with reflection and diffraction effects creating focusing and shadow zones in a complex pattern around the structure. During the negative phase, the weakened structure may be subjected to impact by debris that may cause additional damage.

V.ESTIMATION OF BLAST LOAD

For calculating horizontal net pressure due to blast on a building, it is required to find the important parameter as follow:

Scaled distance is computed by

$$Z = \frac{R}{W^{1/3}}$$

Where R is the distance from the centre of a spherical charge in meters and W is the charge mass expressed in kilograms of TNT.

Computation of Pressures:

The estimation of peak pressure due to blast based on scaled distance Z was introduced by Brode(1955)

$$Pso = \frac{6.7}{Z^3} + 1bar$$

Pso > 10bar

$$Pso = \frac{0.975}{Z} + \frac{1.455}{Z^2} + \frac{5.85}{Z^3} - 0.019bar$$

0.1 > Pso > 10bar

Newmark and Hasen introduced a relationship to calculate the maximum blast pressure (1961)

$$Pso = 6484\left(\frac{W}{R^3}\right) + 96\left(\frac{W}{R^3}\right)^{1/2} bar$$

Mills introduced another expression of the peak overpressure in KPa

$$Pso = \frac{1772}{Z^3} - \frac{114}{Z^2} + \frac{108}{Z}$$

As the blast wave propagates through the atmosphere, the air behind the shock front is moving outward at lower velocity. The velocity of the air particles, and hence the wind pressure, depends on the peak overpressure of the blast wave. This later velocity of the air is associated with the dynamic pressure, q(t). The maximum value, q(s), says, is given by

$$q(s) = \frac{5 X Pso^2}{2(Pso + 7 X P0)}$$

Or

$$q(s) = \frac{Pso^2}{(0.4 Pso + 41.2)}$$

If the blast wave encounters an obstacles perpendicular to the direction of propagation, reflection increases the overpressure to a maximum reflected pressure Pr as: P0

$$Pr = 2X Pso \left(\frac{7 X Po + 4 X Pso}{7 X Po + Pso} \right)$$

P0 = 14.7

$$Pr = 2X Pso \left(\frac{103 + 4 X Pso}{103 + Pso} \right)$$

For design purpose, reflected overpressure can be idealised by an equivalent triangular pulse of maximum peak pressure Pr and time duration td, which yields the reflected impulse (ir)

$$ir = \frac{1}{2} X Pr X td$$

Duration td is related directly to the time taken for the overpressure to be dissipated. Overpressure arising from wave reflection as the perturbation propagates to the edges of the obstacles at a velocity related to the speed of sound (Vs) in the compressed and heated air behind the wave front. Denoting the maximum distance from an edges as S (for example, the lesser of the height or half the width of a conventional building), the additional pressure due to reflection is considered to reduced from Pr-Pso to zero in time 3S/Vs, and the additional impulse to the structure evaluated on the assumption of a linear decay. After the blast wave has passed the rear corner of a prismatic obstacle, the pressure similarly propagates on to the rear face; linear build-up over duration 5S/Vs has been suggested.

For skeletal structures the effective duration of the net overpressure load is thus small, and the drag loading based on the dynamics pressure is then likely to be dominant. Conventional wind loading pressure coefficients may be used, with the conservation assumption of instantaneous build-up when the wave passes the plane of the relevant face of the building, the loads on the front and rear faces being numerically cumulative for the overall load effect on the structure.

Various formulations have been put forward for the rate of decay of the dynamic pressure loading.

Vs = 1117 X (0.0583 X Pso X 1)1/2

From Fig.(a), the positive phase duration (t01) of the overpressure Pso foe 1kiloton weapon yield is given then for estimating the value which needed using as:

t02 = t01 X (Z)1/3

The peak dynamic pressure (qs) can be determined from fig. b. With Pso, the range d1 for a 1-kiloton weapon is given. In the same fig. the same range, the peak dynamic pressure qs is given

d = d1 X (Z)1/3

The positive phase duration (t0d1) of the dynamic pressure (qs) for 1 kiloton weapon yield can be found fig. c. Thus with d1 Fig.c. yield t0d1 is given

t0d = t0d1 X (Z)1/3

Pressure on front face of building

$$tc = \frac{3S}{V_s}$$

t02 = t0d

t = tc

If Pso < 10then we can use these formula

$$Ps = Pso \text{ X } [1 - \frac{t}{t_n}] \text{ X } e^{-t/to}$$

$$Pd = Pdo \text{ X } [1 - \frac{t}{t_{nd}}] \text{ X } e^{-2t/tod}$$

Pfront = Ps + C1 X Pd

C1 = 0.85

Pressure on the rear face of building

The time td at which the shock front arrives at the back face of the building is

$$Td = \frac{L}{Vs}$$

The time tb that is required for the average pressure P back to build up to its maximum value (Pback) max is,

$$tb = \frac{5S}{Vs}$$

t = tb

t0 = t02

The value Psb of the overpressure

$$Psb = Pso \text{ X } [1 - \frac{t}{t_n}] \text{ X } e^{-t/to}$$

$$\beta = \frac{Pso}{2Po}$$

$$Pback = \frac{Psb}{2} + [1 + (1 - \beta) \text{ X } e^{-\beta}$$

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