A Review Article on Blast Load And Its Effect on Structures

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Abstract - In the last few decades, the number of terrorists attacks have been increased and it has shown that the effects of blast load on buildings is a very serious matter that should be taken in to consideration in the design process. Blast load are in fact dynamic loads that need to be carefully evaluated just like earthquake and wind loads. An explosion by bomb can cause catastrophic damage on building's external and internal structural parts like structural frames, collapsing of walls, collapsing of windows and shutting down of critical life safety systems. The indirect effects can combine to inhibit or prevent timely evacuation, thus the casualties like loss of life and injuries to occupants can be minimised.The objective of this paper is to shed light on the overview of the effects of the explosion on structures and presents the work already done on the same. Due to the threat from such extreme loading conditions, efforts have been made to develop methods of structural analysis and design to resist blast loads since past two to three decades. 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. For this the dynamic analysis is done to determine the effects of blast load on structures..

Keywords - Blast loading, DLF(Dynamic Load Factor), SIFCON (slurry Infiltrated Fibre reinforced Concrete).

I INTRODUCTION

Damage to the assets, loss of life and social panic are factors that have to be minimized if the threat of terrorist action cannot be stopped. Designing the structures to be fully blast resistant is not an realistic and economical option, however current engineering and architectural knowledge can enhance the new and existing buildings to mitigate the effects of an explosion. Due to different accidental or intentional events, the behavior of structural components subjected to blast loading has been the subject of considerable research effort in recent years. Conventional structures are not designed to resist blast loads; and because the magnitudes of design loads are significantly lower than those produced by most explosions. Further, often conventional structures are susceptible to damage from explosions.

This study is very much useful which shows the work already done for design the buildings constructed for industries where chemical process is the main activity and a short description on blast loading and explosions. An increasing number of research programs on the sources of these impact loads a dynamic analysis and preventive measures are being undertaken. Just in design some areas takes into account the effects of earthquakes, hurricanes, tornadoes and extremes snow loads, likewise even explosive or blast loads has to be taken into design consideration. This does not mean design and consideration of special shelter facilities but simply the application of appropriate design techniques to ordinary buildings, so that one can achieve some degree of safety from sudden attacks.

II REVIEW OF LITERATURE

Taylor [1] (1950a), is perhaps the first person to get his work published in this area of blast waves from intense explosions. The was actually published in two parts of under the same head. The first part was written in 1941 during world war II. This paper was the first attempet to describe what mechanical effects could be expected from the explosion of an atomic bomb. The paper was declassified in 1950 and was permitted to be published. Taylor discussed an ideal problem of sudden release of energy in an infinitely concentrated form and calculated the motion and pressure of the surrounding air. He suggested that explosion result in a spherical shock wave propagating outward whose radius R can be related to the time, energy released, atmospheric density and the ratio of specific heat.

In the second part of the paper, Taylor (1950b) compared his analytical prediction of blast wave propagation to the data collected from some motion picture records of the first atomic explosion in New Mexico.

J.M. Duwey [2] (1971) studied the properties of blast wave obtained from particle trajectories. Introduced firstly, the effect of hemispherical and spherical TNT(trinitrotoluene) in the blast wave and determined the density throughout the flow by application of the Lagranian conservation of mass equation which is used for calculating the pressure by assuming the adiabatic floe for each element between shock fronts. the temperature and pressure were obtained assuming the perfect gas equation of states.

M. V. Dharaneepathy et al. [3] (1995) studied the effects of the stand-off distance on tall shells of different heights, carried out with a view to study the effect of distance (ground-zero distance) of charge on the blast response. An important task in blast-resistant design is to make a realistic prediction of the blast pressures. The distance of explosion from the structure is an important datum, governing the magnitude and duration of the blast loads. The distance, known as ‘critical ground-zero distance, at which the blast response is a maximum. This critical distance should be used as design distance, instead of any other arbitrary distance.

Alexander M. Remennikov [4](2003) studied the methods for predicting bomb blast effects on buildings. When a single building is subjected to blast loading produced by the detonation of high explosive device. Simplified analytical techniques used for obtaining conservative estimates of the blast effects on buildings. Numerical techniques including Lagrangian, Eulerian, EulerFCT, ALE, and finite element modelling used for accurate prediction of blast loads on commercial and public buildings.

H.Kit Miyamoto & Douglas P. Taylor [5] (2005) proposed a paper to evaluate the effectiveness of fluid viscous dampers(VFD) when used to control blast loading responses on lateral load resisting frames. Non dynamic force history analyses were conducted on three different types of structures :1. Conventional Special Moment Resisting Frames(SMRF), 2.SMRF with FVD and 3. Conventional concrete shear wall .

Kirk A. Marchand et al. [6] (2005) reviews the contents of American Institute of Steel Construction, Inc. for facts for steel buildings give a general science of blast effects with the help of numbers of case studies of the building which are damaged due to the blast loading i.e. Murrah Building, Oklahoma City, Khobar Towers , Dhahran, Saudi Arabia and others. Also studied the dynamic response of a steel structure to the blast loading and shows the behavior of ductile steel column and steel connections for the blast loads.

Ronald L. Shope [7] (2006) studied the response of wide flange steel columns subjected to constant axial load and lateral blast load. The finite element program ABAQUS was used to model with different slenderness ratio and boundary conditions. Non-uniform blast loads were considered. Changes in displacement time histories and plastic hinge formations resulting from varying the axial load were examined.

A.Ghani Razaqpur et al. [8] (2006) investigated the behavior of reinforced concrete panels , or slabs , retrofitted with glass fiber reinforced polymer (GFRP) composite , & subjected to blast load. Eight 1000 X 1000 X 70 mm panels were made of 40 MPa concrete & reinforced with top and bottom steel meshes. Four of the panels were used as control while the remaining four were retrofitted with adhesively bonded 500 mm wide GFRP laminate strips on both faces, one in each direction parallel to panel edges. The panels were subjected to blast loads generated by the detonation of either 22.4 Kg or 33.4 Kg ANFO explosive charge located at 3-m standoff. Blast wave characteristics , including incident & reflected pressure & impulses , as well as panel central deflection & strain in steel & on concrete/ FRP surfaces were measured. The post blast damage & mode of failure of each panel was observed , & those panels that were not completely damaged by the blast were subsequently statically tested to find residual strength . It was determined that overall the GFRP retrofitted panels performed better than the companion control panels.

T.Ngo et al. [9] (2007) presented a comprehensive overview of the effects of explosion on structures. An explanation of the nature of explosions and the mechanism of blast waves in free air is given. This paper also introduces different methods to estimate blast loads and structural response. For high-risks facilities such as public and commercial tall buildings, design considerations against extreme events (bomb blast, high velocity impact) is very important. Requirements on ductility levels also help improve the building performance under severe load conditions.

Dennis M.McCamn [10] (2007) presented a general overview of key design concept for blast resistant reinforced concrete structures. Reinforced concrete can provide substantial protection from extreme blast loading. The relatively large mass of concrete elements provides an inherent resistance to impulsive load . Structural design considerations include sizing members to provide an expected degree of deformation a& associated damage & optimizing the structure to resist & transfer blast load in a reliable manner. Proper detailing is the final critical component of the design process to insure that the structural elements have sufficient toughness to achieve the desired in elastic deformation.

Zeynep Koccaz , Faith Sutcu & Necdet Torunbalci [11] (2008) have studied blast resistant building design theory, the enhancement of building security against the effect of explosive on both architectural & structural design process & the design techniques that should be carried out. They concluded that during the architectural design, the behavior under extreme compression loading of the structural form, structural elements e.g. walls, flooring, cladding & glazing should be considered carefully.

Murat Saatcioglu et al. [12] (2009) investigated two reinforced concrete buildings and demonstrated the vulnerability of buildings to blast loads. The vulnerability, however, decreases with the implementation of seismic design & detailing requirements of current building codes

& standards . The concrete confinement requirement for earthquake resistant columns improve inelastic ductility & drift capacity significantly for protection against blast - induced damage & structural columns. The level of improvement depends on the charge distance combinations & the resulting impulse imposed on the structural elements. Seismic design & detailing required for beams also improve blast resistant , providing continuity & integrity to the structure in the event of a column loss , reducing the progressive collapse potential.

J.H.J. Kim, N.H. Yi et al. [13] (2009) estimated FRP retrofitting effect under blast loading, nine 1000 × 1000 × 150 mm RC slab specimens, which were retrofitted with carbon fiber reinforced polymer (CFRP), basalt fiber reinforced polymer (BFRP), polyurea, and CFRP with polyurea were carried out. The applied blast load was generated by the detonation of 35lbs ANFO explosive charge at 1.5m standoff. The data acquisitions not only included blast waves of incident pressure, reflected pressure and impulse but also included central deflection and strains at steel, concrete, and FRP surfaces. From this study, various externally bonded strengthened RC slabs' response induced by explosive blast wave pressure are evaluated to understand the retrofit effect. The reflected blast pressure and impulse values calculated using the ConWEP were in reasonable agreement with the experimental data. The performance of retrofitted specimens compared to control specimens when subjected to blast loads of ANFO 35 lbs has shown the retrofitted effect about 15~38% for maximum displacement.

T. Borvik et al. [14] (2009) studied the response of a steel container as closed structure under the blast loads. He used the mesh less methods based on the Lagrangian formulations to reduce mesh distortions and numerical advection errors to describe the propagation of blast load. All parts are modelled by shell element type in LS-DYNA. A methodology has been proposed for the creation of inflow properties in uncoupled and fully coupled Eulerian–Lagrangian LS-DYNA simulations of blast loaded structures.

Naury K. Birnbaum et al. [15] (2010) concentrates on various analysis method available to predict the loads from a high explosive blast on commercial buildings. Different analysis methods (analytical & numerical methods) are appropriate to different situations. Currently available analytic & numeric technique can be used to effectively assess the loadings on buildings resulting from the detonation of high explosive devices. Numerical techniques encompassing Eulerian , Lagranian , ALE & Structural representation can address different aspects of loading & response of buildings.Specialized Euler methods , such as the optimized FCT approach should be used to extained high resolution blast calculation to 10^7 cells or more super computer facilities & massively parallel processors.

Mehran Pourgholi et al. [16] (2010) reported that Selection of a proper form and capacity for a building has a great effect on the rate of the total damage of the building. The windward angels and the surrounding elements of the building may capture the shock wave and intensify the explosion effect. Wide and obtuse angels have less effect than the windward or acute ones. When using curved surfaces, convex forms are prior over concave ones. The intensity of the pressure reflected on a convex and round building surface, also, is less than the pressure reflected on flat buildings. Making use of concrete structures, compound structures, retaining wall, concrete sheeting, virtual structures and the like are some of the methods to control the threats resulted from waves and the destructive power of such dynamic loads.

Assal T. Hussein [17] (2010), presented the analytical methods of a SDOF system analysis subjected to blast loadings. Two types of blast wave applied for study the non-linear behavior of system, the analysis focused on displacement time history responses which form the basis for studying behavior of SDOF System under blast loadings. For two types of blast function simple pulse, and bilinear pulse, many parameters used for obtained time history plots, computed energy, and Hysteresis Analysis. Results of NON-SDOF program, showed the effect of type of wave on the time history analysis results, and computed energy of blast load. Many parameters used for obtained time history plots, computed energy and Hysteresis Analysis results.

Saeed Ahmad [18] (2012), has evaluated reinforced structural elements under impulsive loading by constructing different wall panels. Four reinforced walls with varying thickness were tested with varying explosive load & scaled distance. Acceleration & pressure time history at different points were recorded & empirical relationship were developed & results obtained were compared with the previous researchers.

Seema T. Borole [19](2013), discuss the comparison between long side and short side column is made and percentage of stress of Reinforced concrete column for long and short side is presented and analysis is done in ANSYS. It is concluded that the critical impulse for the long column case is significantly higher.

Subin sj.[20] (2013), the finite element package Ansys version 12 was used to model R.C.C. and masonry building subjected to blast. Blast pressure acting on each wall face and roof were calculate corresponding to charge weight and distance of building from detonation. Transient non linear analysis was is done in ansys for dynamic blast loading and response time history from ansys. A seismic loading was applied on R.C.C. building to get response of the structures and comparison is done with the blast load. Concluded that Effect of seismic loading on low rise buildings are smaller compared to blast load. But for high raised multi storied building effect of seismic loading will be larger when compared with local blast load.

It is found from the studies of literature that limited work has been done on comparative study of simple R.C.C. building and R.C.C. building with shear wall with different charge location, hence this project is under taken.

Jayshree.S.M et al. [21] (2013), investigated the dynamic response of a space framed structure due to blast load. They used Slurry Infiltrated Fiber Reinforced concrete (SIFCON) , a type of FRC with high fiber contain as an alternative material to Reinforced Cement Concrete (RCC) . Space framed models are developed & time history analysis is carried out using software package SAP 2000. The dynamic characteristics such as fundamental frequency , mode shapes are evaluated . The displacement time history response of frames with SIFCON & RCC due to blast load is compared.

Umesh Jamakhandi et al. [22] (2015), presented the general aspects of explosion process to clarify the effects of explosives on buildings. Etabs 2015 was used for analysis. It was concluded that the system affects significantly when the charge weight increases and standoff distance decreases respectively and it was found that the most optimum model is regular frame which shows the lowest value of storey drift and the structure is very good in lateral stability against blast load. therefore for economical design consideration the column size can reduce.

1.3Blast loading

Blast is actually an explosion which is a large-scale and sudden release of energy that generally generates high temperature and a large amount of gas (Baker et al. 1983). For a conventional explosive, such as trinitrotoluene (TNT), the energy release is associated with the rearrangement of its atoms, while in nuclear explosive the reaction between protons and neutrons releases the energy (Baker et al. 1983). In general, explosions can be classified into four basic types; a vapor cloud explosion, a vessel explosion, a dust explosion and a condensed phase explosion (ASCE, 1997). In a vapor cloud explosion, a flammable material, such as liquefied gases, ignites under certain conditions of pressure and temperature and may produce a fire ball. In a vessel explosion, a rapid combustion or release of energy occurs in an airtight space like a room or pressure vessel. In a dust explosion, similar to a vapor cloud explosion, a combustible material is dispersed in the air forming a flammable cloud and a flame propagates through it. Generally, explosion against structures are condensed phase explosions. High pressure and waves accompany the detonation of high explosive materials. An oxidation reaction occurs during the explosion which is called combustion. When explosive materials decompose at a rate below the speed of sound (subsonic),the combustion process is called deflagration. on the contrary, detonation, such as explosion of TNT, occurs more rapidly and produces a high intensity shock wave with the reaction rate being 4-25 times faster than the speed of sound (supersonic) (Smith and Hetherington 1994). The detonation is accompanied by large pressure up to 300 kilobar and temperature of about 3000- 4000oC. The hot gas expands forcing out the surrounding air and occupying the associated volume. As a consequence, a blast wave forms in front of this gas volume containing most of the energy released by the explosion.

1.4 Explosion as Loading

In most instances simplifications lead to conservative constructions. However, unknown factors may lead to the overestimation of the structural capacity to blast loadings. Unexpected shock wave refraction, design methods, quality of construction and materials, interaction with ground, are different for each particular structure. In order to overcome these uncertainties it is recommended that the mass of TNT equivalent is increased by 20 %. This increased value of the charge weight is called the "Effective charge weight".

1.5 Loading Categories:

Explosion loadings can be divided into two main groups according to the confinement of an explosive charge: confined and unconfined.

1.5.1 Unconfined Explosion:

The open air explosion causes a wave that spreads from the source of detonation to the structure without any wave amplification. These explosions are situated at a given distance and height away from the structure and there is a wave increase due to the reflection of the ground before it contacts the structure. The height limitations of these explosions are two to three times of the height of a one-story or two-storey structure. The explosion near the ground is an explosion occurring near or on the ground and the initial pressure is immediately increased as a result of refraction on the ground.

1.5.2 Confined Explosion:

If the explosion occurs inside the structure, the peak pressures associated with the initial wave fronts are extremely high. They are enhanced by the refraction within the structure. In addition to this, depending on the degree of confinement, high temperatures and the accumulation of gaseous products of chemical reactions in the blast would produce more pressure and increase the load duration within the structure. The combined effects of these pressures can lead to the collapse of the structure, if the structure is not designed to withstand internal pressure. Appropriate ventilation reduces strength and duration of pressure so the effect of pressure is different in structures with openings and structures without openings.

1.6 Conclusions

As any structure can not be blast proof structure, it can be blast resistant but it is not economical to design all buildings for blast loading. Public buildings, tall structures and city centers have to be designed against terrorists attacks and sudden explosions. It is recommended that guidelines on abnormal load cases and provisions on progressive collapse prevention should be included in the current Building Regulations and Design Standards. Requirements on ductility levels will also helps to improve the building performance under severe load conditions. Evaluation of DLF resulting due to blast loading under several conditions have to be included in the design procedure to get into the correct evaluation of the stress characteristics of the material under consideration.

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