Effect of Blast Loading on Framed Structure: A Review

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Abstract - *In the present scenario, terrorist activities are increasing day by day and they mainly target structures and crowded place. It has become very complicated to do blast assessment as it involves various parameters which cannot be calculated easily. The present paper reviews the literature related to the effect of blast loading on different structures. Various other journals were studied to understand the behavior of different structures using various charges. The study will help to better understand the behavior of RC framed structures during explosive events.*

***Key Words*: Blast loading, explosives, charges, framed structure, standoff distance**

1. INTRODUCTION

Explosive events mainly originate from terrorist attacks targeting civilian or commercial structures. However, accidental events such as explosions in storage facilities or gas explosions also occur from time to time. Hence, it is essential to estimate and predict the effects of explosions and provide designs to protect structures against the potential explosive events. Explosions generated using the redistribution of subatomic particles is considered as nuclear explosions. Therefore, a small nuclear explosion can be much more devastating than an industrial level physical explosion. Creating a nuclear explosion requires highly skilled personnel and technology hence, it is quite rare for these to be used to target civilian and commercial structures. Blast loading and its effects on a structure is influenced by a number of factors including charge weight, W location of the blast (or standoff distance), R and the geometrical configuration and orientation of the structure (or direction of the blast). Structural response will differ according to the way these factors combine. The potential threat of an explosion is random in nature making the analysis complex. Therefore, it is necessary to identify the influence of each factor in relation to the most credible event when assessing the vulnerability of structures.

1.1 Classification of Explosion

Explosions are classified into two major categories (TM5-1300 1990)

- External
- Internal

External explosions are blasts outside in an open environment while internal explosions occur inside a covered container or building. Further classification is made of

- Unconfined
- Confined
- Explosive attached to a structure.

2. LITERATURE REVIEW

Luccioni et. al. (2004) [1] carried an analytical study on the failure of RC building subjected to blast load using AUTODYN software. Then compared the numerical results with the photograph of real damage caused by explosion has been included. Assuming that 400 kg of TNT placed in the entrance hall of the building. The columns, beams and slabs are modeled with 3D solid elements that are solved with a Lagrange processor. The results show that the numerical analysis accurately reproduces the collapse of building under blast load confirming the location and magnitude of explosion. He concluded that simplifying assumptions is to be made for the structure and materials are allowable for this type of analysis.

Nelson et. al. (2004) [2] studied time-history analyses of simple cantilevered wall models. He developed capacity spectrum model for its performance of cantilevered wall under blast loads. In this study, rectangular blast walls were subject to linear elastic dynamic analyses based on the blast pressure function. The computed response behavior will be presented in the form of acceleration and displacement time-histories. The conclusion of this study is the identification of the direct relationship between corner period and the "clearing time" for the blast.

Alex M. Remennikov (2005) [3] demonstrated the importance of considering the effects of congestion between buildings on blast loading and to present numerical techniques to predict the loads on buildings in an urban environment. Blast loadings on structures have been evaluated using empirical relationships. He concerned with an accurate prediction of the effects of adjacent structures on the blast loads on a building in urban terrain using a computational fluid dynamics (CFD) code Air3D. He concluded that the use of both analytical techniques and sophisticated CFD numerical simulations can provide an effective approach to determining blast loads in an urban environment.

Ngo et. al. (2007) [4] introduced different methods to estimate blast loads and structural response. Paper presents a comprehensive overview of the effects of explosion on structures. A case study of 52 storeys has been analyzed. The structural stability and integrity of the building were assessed by considering the effects of the failure of some perimeter columns, spandrel beams and floor slabs due to blast overpressure or aircraft impact. He concluded that for high-risks facilities such as public and commercial tall buildings, a design consideration 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.

F. Zhu & G. Lu (2007) [5] reviewed the characteristics of blast loads and corresponding structural response, as well as the current advances. The numerical approaches to analyze the structure responses to blast impact were also summarized with a number of available constitutive relations of explosive charge and material properties of structures. In blast impact, structures usually undergo large plastic deformations or failure, and they absorb considerable energy. The resulting structural response is divided into three modes: (I) Large inelastic deformation; (II) Tearing (tensile failure) at or over the support; and (III) Transverse shear failure at the support. Mode I can transit to Mode II and III with the increase of impulsive loads.

L. J. van der Meer (2008) [6] has reported about the dynamic response of high-rise building structures to blast loading in general and BLEVE blast loading. A BLEVE is a type of explosion that can occur when a train wagon containing a liquefied gas is damaged. The model generated by ANSYS11.0 with beam element. The modal analysis gives the natural frequencies and mode shapes. The static analysis results in a maximum displacement of the top. The equivalent beam is reduced to a single-degree-of-freedom (SDOF) system, which is the most basic dynamic system that allows easy response calculations. BLEVE blast loading on an example building the response and pressure impulse diagram is obtained, using both a SDOF and a MDOF approach. In this, the top displacement, base moment and base shear response are compared.

Nassr et. al. (2010) [7] evaluated the dynamic response of typical W-shape steel beams. Thirteen wide flange steel specimens were field tested using live explosives. The test specimens were subjected to blast loads generated by detonation of different charge sizes, ranging from 50 to 250 kg of ANFO at standoff distances varying from 7 to 10 m. Blast wave characteristics, including incident and reflected pressures, and impulses were recorded. The mid-span deflection and strains at different locations along the steel members were measured. The results were compared with those obtained from nonlinear dynamic analysis based on a Single-Degree-of-Freedom (SDOF) model.

Assal T. Hussein (2010) [8] investigated the analytical methods of a SDOF system analysis subjected to blast loadings. The analysis focused on displacement time history responses which form the basis for studying behavior of SDOF System under blast loadings. Two types of blast load wave simple and bilinear pulse applied to study the non-linear behavior of SDOF system. Results of NON-SDOF program, showed the effect of type of wave on the time history analysis results, and computed energy of blast load.

Mohamed S. Al-Ansari (2012) [9] studied the response of buildings to blast and earthquake loadings. The numerical data was obtained using several structural models with different dimensions, shapes, and material and subjected to different blast loadings, and earthquake loads in different zones. A six story building with a 4-meter constant floor height that is subjected to a blast loading with a charge weight of 1000 kg of TNT at a standoff distance of 2 m was taken. Analysis shows that a twenty- story building, which is subjected to earthquake load in zone 5, have the same response as if it is blasted with 128 kg of TNT at a 2 m stand-off distance or 261 kg of TNT at a 10 m stand-off distance.

Jayashree et. al (2013) [10] investigated the dynamic response of a space framed structure due to blast load. An attempt has been made to use Slurry Infiltrated Fiber Reinforced Concrete (SIFCON), a type of FRC with high fiber content as an alternative material to Reinforced Cement Concrete (RCC). SIFCON has high energy absorption capacity, higher strength and it is highly ductile. Space framed models are developed and time history analysis is carried out for blast load using the software package SAP2000. The results shows that the reduction in the displacement of about 25 - 30 % is achieved using SIFCON.

Amol B. Unde (2013) [11] estimating the blast wave parameters for various charge amounts placed at various distances. The effect of TNT (trinitrotoluene) explosive on a column foundation for various amount of TNT charge at various distances is investigated for model buildings of various floors. The blast wave parameters for charge of 0.1 Tonne (T), 0.2 T, 0.4 T, & 0.6 T at distances of 30m, 35m and 40m are estimated. The load is applied in the form of time history loading at nodes of beam column junction in order to perform the dynamic analysis using finite element package Staad-pro. The blast wave parameters are calculated using IS 4991. Result shows that for buildings having less than 6 floor high tensile loads is induced due to blast. Shear force and bending moments is comparably less on the foundation of building.

J. R. Geringer et. al. (2013) [12] evaluated multi-hazard loading environments. The analysis has as major topics air-blast and structural responses. Then compares the output and results of each program against the test results to determine if the software is comparable in an effort to simplify the multi-hazard analysis process, it concluded that the peak overpressure can be measured to accuracies of 10 percent. This error band includes atmospheric conditions that may not be accounted for, errors in explosive yield, errors in gauge response, and errors in range measurements and gauge calibration errors.

Amy coffield and Hojjat adeli (2014) [13] investigated different framing systems for three seismically designed steel frame structures subjected to blast loading. The blast loads are assumed to be unconfined, free air burst detonated 15 ft. (4.572 m) from one of the center columns. The structures are modeled and analyzed using the Applied Element Method, which allows the structure to be evaluated during and through failure. Failure modes are investigated through a plastic hinge analysis and member failure comparison. The main conclusion of this research is that braced frames provide a higher level of resistance to the blast loading.

Kulkarni (2014) [14] examined the dynamic response of a High Rise Structure subjected to blast load. The lateral stability of a high rise building modeled using SAP2000. The model building was subjected to two different charge weights of 800 lbs and 1600 lbs TNT at a two different standoff distances of 5 m and 10 m. The blast loads are calculated using the methods outlined in section 5 of TM5-1300 and a nonlinear modal analysis is used for the analysis of the dynamic load of the blast. The primary performance parameters that will be used to evaluate the behavior of the building from a global perspective are the total drift and the inter-storey drift. the results shows that the first storey columns subjected to high pressure they could cause big deformation and exceed the support reaction so the columns which are close to explosion are damaged which leads to sudden loss of critical load bearing columns is lost.

Aditya Kumar et. al. (2014) [15] reviewed various loading which can occur during a blast i.e. the dynamic impact loading, varying rate concentrated loading &transverse blast loading and the methods applied to analyze those loading phenomena i.e. Single Degree of Freedom (SDOF) model, Finite Element Model (FEM) & non-linear dynamic analysis. The analysis shows that the lack of relevant code is the major concern behind the ignorance of this phenomenon while designing the structure.

M. Amini et. al. (2015) [16] developed the method to nonlinear dynamic analysis of single-degree-of-freedom (SDOF) systems under exploding loads. Newton-Raphson iterative method used to develop new formulation for solving nonlinear dynamic problems. A simple step-by-step algorithm is implemented and presented to calculate dynamic response of SDOF systems. The validity and effectiveness of the proposed method is demonstrated with two examples. Quartic B-spline time integration method gains second order of acceleration at each time-step so it benefits from high order accuracy. The numerical evaluation shows that the proposed method is a fast and simple procedure with trivial computational effort.

Amy Coffield and Hojjat Adeli (2015) [17] considered six seismically designed steel framed structures moment resisting frames (MRF), concentrically braced frames (CBF) and eccentrically braced frames (EBF) each with geometric irregularity in the plan and with a geometric irregularity in the elevation. The blast loads are assumed to be unconfined, free air burst detonated 15 ft from one of the center columns. The structures are modeled and analyzed using the Applied Element Method. Comparative analysis observing roof deflection and acceleration to determine the effect of geometric irregularity under extreme blast loading conditions. Two different blast locations are examined. Result shows that for all structural types a vertical or horizontal irregularity results in a smaller roof deflection in the order of 12–17 %. The conclusion is concentrically braced frame provides higher level of resistance to blast loading for irregular structures and geometric irregularity has an impact on the response of a structure subjected to blast loading.

Sarita Singla et. al. (2015) [18] studied the blast pressure for different TNT and standoff distance. Blast pressures for different cases are computed using correlation between blast pressure and blast scaled distance based on charts given in U.S manual. Time history loading is also obtained with parameters of reflected total over pressure and duration of positive phase of blast. The result shows that as the distance increases from the building, blast pressure reduces.

3. CONCLUSIONS

Based on the studies of different researchers on blast loading behavior, following conclusions has been drawn:

- As the standoff distance increases the magnitude of blast pressure increases.
- Blast pressure and blast scaled distance is inversely proportional.
- Blast pressure increases as weight of blast increases and blast pressure decreases when standoff distance increases.
- The variation of force in the structural members is such that the blast force must be considered in the analysis.
- As the distance from the charge increases the peak of positive phase decreases and also the time of arrival increases.

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