Effect of the Blast Load on FRP Panels and Analysis of Resistance

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1. Introduction

Recently, blast loads have received considerable attention due to the increasing occurrences of different accidental or intentional events. Such events adversely affect different structures and relatively, their occupants. Normally, conventional structures are not designed to resist blast loads. Therefore, it is becoming increasingly important to focus on the design and retrofit of these structures against blast loads. However, one of the main challenges that face researchers is the feasibility of providing an adequate level of protection without going for designing more bunker-like structures that make people think that their lifestyle or daily routine has been changed.

Maneuverable blast walls can be one of the solutions to shield a building or other structures from blast loads. Using maneuverable structures provides a reflective surface for the blast waves and limits the strength of the load on the structure of interest. At a higher level of threat, maneuverable walls are erected around structures as a first line of defense, increasing the stand-off distance. Ease of assembly and portability are two factors that have to be taken into consideration while designing such types of walls. Zhou and Hao studied numerically the effectiveness of blast barriers for blast reduction. They found that the erection of a barrier between an explosion and a building can reduce the peak reflected pressures and impulses, which are created on the surface of a building and delay the arrival time of blast wave¹. Moveable walls with such specifications

Abstract

Background/Objectives: Fiber-reinforced polymer (FRP) sandwich panels are increasingly making their way into structural engineering applications. One of these applications is the blast mitigation. This is attributed to FRP ability of absorbing considerable amount of energy relative to their low density. Methods/Statistical Analysis: In this study, FRP sandwich panels are numerically studied using an explicit finite element code ANSYS AUTODYN. The numerical model is then validated with the experimental field tests in the literature. The inner core configurations that have been studied in the experimental field tests were formed from different orientations of the honeycomb shape. On the other hand, the conducted numerical study has proposed a new core configuration. The new core configuration is formulated from a combination of woven and honeycomb shapes. Results: Throughout this study, two performance parameters are considered; the amount of the energy absorbed by the panels and the peak deformation of the panels. Following, a parametric study has been conducted with more variations of the studied parameters to examine the enhancement of the panels' performance. Conclusion: It is found that the numerical results have shown a good agreement with the experimental measurements. Moreover, the analyses have revealed that using the proposed core configuration obviously enhances the FRP panels' behavior when subjected to blast loads.

Keywords: Blast Load, Fiber Reinforced Polymers, Finite Element Modeling, Sandwich Panels

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can be also beneficial for constructing temporary high-importance facilities such as barracks and hospitals. In addition, these temporary structures can be used in hazardous industrial fields that are vulnerable to blast such as petrochemical industry. In industrial facilities, man-made accidents can trigger explosions that are accompanied by other phenomena such as fire and impacts caused by explosion-borne missiles.

Sandwich panels are one of the best solutions for providing light-weight moveable walls. Sandwich panels are composed of upper skin, inner core and lower skin. The inner core can have several forms such as honeycomb cores, corrugated cores, truss cores, Z-cores, C-cores, I-cores or solid foam cores. Fiber Reinforced Polymer (FRP) composites have a great potential in manufacturing sandwich panels that can be used for moveable structures. The high strength-to-weight ratio, resistance to corrosion and ease of handling and fabrication are the basic advantages of FRP. For manufacturing such panels, the core stiffness is the main factor that controls the FRP sandwich panel’s behavior. Regarding the upper and lower skins, they are bonded to the core by an adhesive polymer such as epoxy resin to form the FRP panels. In the design of FRP panels, one of the factors that control the deflection of the FRP sandwich panels is the core density. It is seen that the increase in the core density increases the energy absorption, so the failure in the middle core is acceptable and, in fact, desirable. At the same time, it indicated that the delamination, core compression and fibre fracture increase the energy absorption of the sandwich panels. Concluded that using a filling material reduces the maximum deflections by more than 50%.

This paper numerically evaluates the effectiveness of a proposed FRP sandwich panel in resisting blast loads. The finite element model has been validated using the experimental tests conducted by Hoemann. Also, a parametric study has been conducted examining more variations of the studied parameters in order to achieve better enhancements for the panels resisting blast loads.

2. Numerical Model Validation

A numerical model has been simulated based on the experimental work conducted by Hoemann at Tyndall Air Force Base, Florida, where the obtained results were compared to validate the numerical model. The numerical model has been simulated using dynamic nonlinear explicit software ANSYS AUTODYN. The software is used in solving fluid dynamics equations and can be used to simulate three-dimensional blast wave propagation with multiple reflections and refraction. Figure 1 shows a schematic of the numerical model, including all blast wave characteristics that are usually associated with the explosion. Similar to the experimental investigation, the center of explosion is located at 10.7 m from the simulated panel and elevated at 1.8 m from the ground surface.

Figure 1. Schematic of the numerical model.

Figure 2 shows the pressure-time history of the experimental field test and the numerical model. In the experimental tests, four gauges were installed in the field (R1 to R4), where gauge R3 was considered as a defective gauge. In the numerical model, the peak pressure value is 1215 kPa which is close to the average pressure value of the 3 field pressure gauges. Figures 3(a) to 3(d) show the experimental and numerical deflection time histories of the four panels (W1 to W4) considered. It is worth noting that in the current analysis, the blast pressure wave is considered to be a sinusoidal wave with a peak pressure of 1215 kPa and a frequency of 200 Hz.