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An experimental study of the effects of degrees of confinement on the response of square mild steel plates subjected to blast loading

C. Geretto, S. Chung Kim Yuen*, G.N. Nurick

Blast Impact and Survivability Research Unit (BISRU), Department of Mechanical Engineering, University of Cape Town, Private Bag, Rondebosch 7701, South Africa

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ABSTRACT

This paper present the experimental analysis of square mild steel plates subjected to blast loads in three different degrees of confinement (free air burst, fully vented and fully confined). Varying spherical masses of explosive were detonated at a constant stand-off distance from three different thickness target plates in the three different degrees of confinement to investigate the effects of confinement as well as the effect of plate thickness on the final plate deformations. Plate deformations ranging from one to fourteen plate thickness were obtained. The experimental results show that the midpoint deflection ratio between two different thickness plates subjected to identical blasts is inversely proportional to the ratio of the plate thicknesses. Equations for predicting the final midpoint deflection of square mild steel plates subjected to blast loading in the three degrees of confinement are presented.

1. Introduction

Over the years there have numerous investigations on blast waves and their effects on structures [1–5]. Predominately these investigations focus on the response of structures subjected to one type of blast loading albeit at different magnitudes. Depending on the environment where an explosion occurs the surrounding structures will be subjected to different blast loads. In the UFC 3-340-02 (formerly TM 5-1300) design manual [6] blast loads are divided into two main categories; unconfined and confined, thereafter split into three sub-categories as listed in Table 1.

1.1. Unconfined blast loading

An unconfined blast load can be defined by a blast load acting onto a structure that is affected by the height of detonation and the stand-off distance [6,7]. No distinct limit between the categories exists and in some instances the categories may overlap [6,7]. Fig. 1 illustrates the three different unconfined blast load categories and lists some of the defining points. For unconfined blast, extensive experimental studies have been carried out to understand the large permanent ductile deformation and rupture of plates, beams and shells as a result of surface blast. The response of thin plates clamped at the outer edges and built-in plates subjected to both uniform and localised blast loading conditions has been studied for a number of years. Several authors such as Jones [8], Nurick and Martin [9,10], Zhao [11] and Rajendran and Lee [12] have presented overviews of the theoretical results using scaling analysis and experimental results on plates that are blast loaded uniformly over the entire exposed area. The results reported discuss the geometrical effects of circular, square and rectangular plates. In the past 20 years, further studies, Refs. [13–24] have been conducted on beams and plates of different geometries (circular and quadrangular) with and without stiffeners and different boundary conditions (clamped or built-in).

1.2. Confined blast loading

A confined blast refers to an explosion that occurs within or close to a structure that limits the propagation of the blast wave [6,7]. A confined blast results in more damage than the equivalent mass unconfined blast [25]. The damage depends on various geometrical parameters of the confinement vessel and explosive charge such as geometrical dimensions and shape, charge location, size and location of vents/openings as well as explosive characteristics [6,7,25]. Typically confined blast load is comprised of a short duration shock load and a long duration gas pressure load. Schematics and attributes of the different confined blast loads are presented in Fig. 2.The internal blast loading within a fully confined structure is extremely complex, thus less investigated [25]. The

* Corresponding author.
E-mail address: steeve.chungkimyuen@uct.ac.za (S. Chung Kim Yuen).

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Table 1
Categories of blast loading [6].

Unconfined blast loading	Free air burst
	Air burst
	Surface burst
Confined blast loading	Fully vented
	Partially vented
	Fully confined

complexity of the internal loading is due to the repetitive shock loading, long duration pressure loading and interaction of the blast waves at the boundaries and joint interfaces [6,7,25].

Nevertheless, numerous authors [26–28] have presented analytical solutions describing the elastic-plastic response of spherical vessels subjected to fully confined blast loads. Analytical solutions for the radial deformations of open and closed ended cylinders subjected to internal blast loading are also proposed by Duffey and Mitchell [2] and Benham and Duffey [29]. Research into explosion confinement cuboidal containers has been carried out in the aviation sector where the luggage containers are approximated as cubic containers [30–32] and in the design of bomb disposal vessels [33,34]. Yiannakopoulos et al. [35–39] and Brundage et al. [40] have reported on experiments and finite element simulations of steel cuboidal containers subjected to fully confined blasts. The pressures, final deformed shape and response of the vessel walls for both the experimental and predictions were similar.

This paper reports on the results of an investigation into the effect of degrees of confinement (free air burst, fully vented and fully confined) of a blast load on the final midpoint deflection of square mild steel monolithic target plates to address some of the unknowns in the literature. Numerical analysis and transient response of the target plates will be address in a separate paper.

2. Experimental procedure

Three series of experiments were designed and carried out to investigate the effects of three different degrees of confinement (free air burst, fully vented and fully confined) on the response of square mild steel plates subjected to blast loading. Free air bursts will henceforth be termed unconfined as it is the only type of unconfined blast load investigated. The performance of the degrees of confinement was evaluated on the final midpoint deflection of square monolithic mild steel target plates with an exposed area of 200 × 200 mm. Three different target plate thicknesses (3 mm,

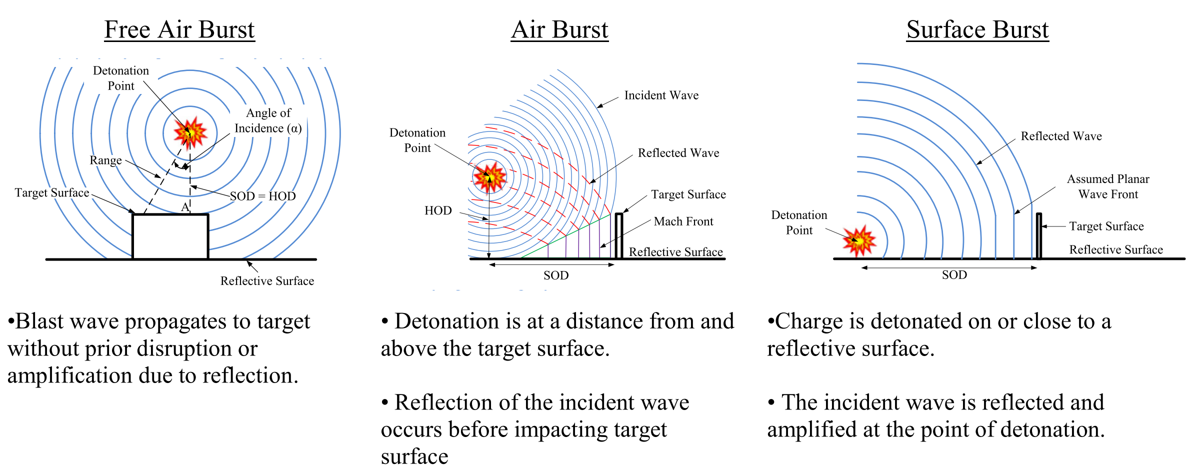

Fig. 1. Schematics illustrating different types of unconfined blast loads.

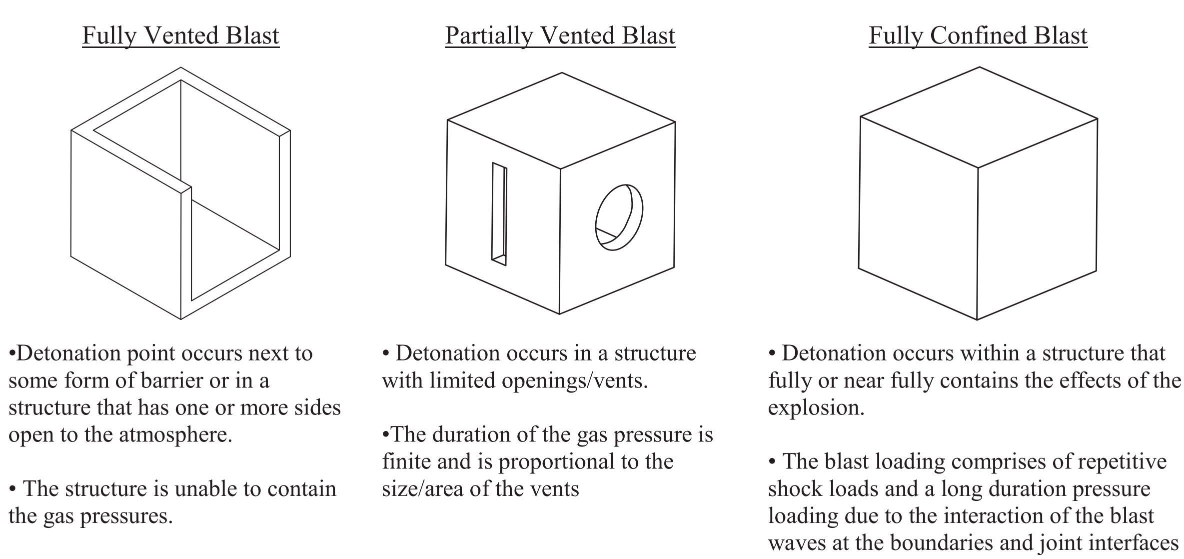

Fig. 2. Schematics illustrating different types of confined blast loads.