Engineering Structures 33 (2011) 3537–3545

Contents lists available at SciVerse ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

The influence of separation distance on the performance of perforated plates as a blast wave shielding technique

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ARTICLE INFO

Article history:
Received 15 April 2011
Received in revised form
14 July 2011
Accepted 15 July 2011
Available online 16 August 2011

Keywords:
Blast loading
Plastic deformation
Perforated plates
Mitigation

ABSTRACT

This article presents the results of an experimental investigation into the performance of perforated plates as a blast wave mitigation method in tunnel-like structures. Combinations of three different blockage ratios and three different separation distances (defined as the distance between the perforated plates and target plates) were used during the blast experiments to ascertain the influence of the two variables, while the charge to target plate stand-off distance was kept constant. The results were compared to those obtained during similar test work at a lower separation distance of 25 mm, and also to baseline experiments with no perforated plate at a similar stand-off distance. Results of the blast tests showed that the perforated plates with higher blockage ratios reduced the damage imparted to the target plate. This effect was more significant at the lower separation distances. Increasing the separation distance also reduced the damage for a given blockage ratio and impulse.

1. Introduction

The loading and damage arising from the detonation of explosives in a confined space is an important research issue as many explosions do not occur in free space. Silvestrini et al. [1] developed various energy concentration factors (ECFs) for different partially confined geometries including platforms, tunnels with explosions in the centre and tunnels with the explosion sited at the closed end. It was shown by Silvestrini et al. [1] that explosions in partially confined spaces led to the concentration of explosive energy that would be hundreds of times greater than in an unconfined blast. The risk of explosions in tunnels (whether due to accident or terrorist attack) is a potential hazard.

A number of authors [1–5] have reported the results from scaled experiments investigating the side-on pressures developed due to explosions within tunnel structures. The charge sizes ranged from 0.5 g PETN [2] to 16 000 kg TNT [5]. Neuwald et al. [2] reported the pressure measurements from detonating very small scale charges of PETN (0.5 and 1.0 g) within a square cross-section tube with a side length of 80 mm and a length of 3 m. Smith et al. [3] reported the work of Skjeltorp in 1968, who studied the effect of explosions within an underground ammunition storage chamber connected to a single access tunnel. Larger scale test results were reported by Ishikawa and Beppu [4] from two explosion tests involving the detonation of 100 g TNT (test 1) and 22 kg TNT (test 2) in a 188 m long straight type underground mining tunnel. The side-on blast pressure was of the order of 1 MPa for the 100 g TNT blast and 7 MPa for the 22 kg TNT blast, both recorded at a distance of 10 m from the explosive detonation. The pressure decreased by more than half in the first 30 m of propagation.

Forsen [5] reported the experimental results from the detonation of 15, 400 and 16 000 kg of high explosive in a tunnel system, alongside numerical modelling using Autodyn. Forsen [5] reported that the tunnel length and cross-section dimensions, wall roughness and area changes influenced that blast wave propagation along an underground tunnel. Silvestrini [1] plotted the measured side-on pressures reported in [2–5], among others, against the values predicted using the ECF method and found good agreement for a wide range of pressures from 10 kPa to 10 MPa [1].

Due to the great difficulty in conducting full scale blast testing in tunnel-like structures (whether subway tunnels, road tunnels, underground mining constructs or ventilation shafts), a number of authors have performed numerical modelling [5–8] and statistical analysis [1,8] to study the effect of explosions within tunnels.

Hitherto, the work has dealt with explosions within tunnel-like structures that do not have any form of mitigating system within it, although Forsen [5] commented that changes to the area of a tunnel will influence the blast wave propagation along it. To protect critical plant and personnel within tunnels, it could be desirable to employ a barrier or a blast wave disrupter system that makes use of an area change within a tunnel. Berger et al. [9] investigated using barriers to disrupt shock wave propagation in tunnel-like structures. The barrier height, inclination and quantity were varied in shock tube experiments and the effectiveness of the barrier was assessed from the pressure measured on the tunnel

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doi:10.1016/j.engstruct.2011.07.017