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ScienceDirect

Procedia Engineering 210 (2017) 306–311

Procedia Engineering

www.elsevier.com/locate/procedia

6th International Workshop on Performance, Protection & Strengthening of Structures under Extreme Loading, PROTECT2017, 11-12 December 2017, Guangzhou (Canton), China

Effects of fragments impact on reinforced concrete protective elements

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Abstract

A common type of extreme loading on structures includes combination of blast and fragments impact. Because of the complex nature of this combined load design and verification procedures of protective structures usually decouple the effects of overpressure and of the fragmentation impact. Although it has been shown that the simple addition of the separate actions of the fragments and the blast inflicts lower damage than that caused by their combined loading, the synergistic effect of blast and fragments has yet to be investigated. Studies of reinforced concrete (RC) protective structures have shown that the main cause of increased damage to a structure, which is exposed to blast and fragments, is the fragments penetration that in many cases occurs first. To investigate the combined effect of blast and fragments impact, field tests were performed, of full-scale RC T-walls, which were subjected to the action of a detonated cylindrical cased charge that produced blast and fragments impact. The impacted specimens were then sawed at their bases and the remaining damaged plates were tested in the laboratory under 3-point loading setups. The aim of these tests was to study the fragments penetration effects on the residual mechanical properties of a damaged wall. The paper presents initial results of these static tests of the damaged, as well as control, undamaged specimens.

Keywords: Combined loading; Cased charge; Blast and fragments; Reinforced concrete protective structures.

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1877-7058
10.1016/j.proeng.2017.11.081

1. Introduction

One type of extreme loading on structures is the combination of blast and fragments impact from a cased charge detonation. The fragments are commonly considered for penetration analysis of a single 'design fragment' [1], while the blast is considered for the global analysis of the structural element. The global consideration of the fragments loading is usually ignored [1] or treated in a simplified manner, such as uniform loading [2]. Yet, there is a synergistic effect of the combined loading of blast and fragments loading [2–5], which is expressed by an increased damage and dynamic response. Thus, the fragments loading should be taken into account also for a dynamic global analysis of an element, which is exposed to this combined loading.

Test series were conducted by the Swedish Defence Research Agency [6,7], in which small-scale plates were exposed to detonation of explosives with spherical pre-formed fragments. After the blast tests, the plates were tested under quasi-static tests to investigate their mechanical properties. They assumed that the fragments reach the structure before the blat wave does and thus, a pre-damaged structure should be considered for the global dynamic analysis due to the blast load. It was found that the damaged plates capacity was lower than that of the undamaged plates, as expected. Nystrom and Gyltoft [2] dealt with this issue by numerical simulations and showed that when considering both the blast and fragments loading, there is an increased damage due to the fragments penetration, which leads to enlarged damage and dynamic deflections.

This paper presents a study of RC plate specimens, which had been exposed to blast and fragments impact from detonated charges in preceding field tests. These specimens were then tested in laboratory three-point-bending static experiments, to examine their residual mechanical properties. Control, undamaged specimens that were not tested in the field and a specimen that was exposed only to blast (without fragmentation) were tested as well.

The paper presents initial results of the static laboratory tests and their implications on the effects of fragmentation impact on the structural properties of the RC specimens that were tested.

Nomenclature

A_s	Reinforcement cross-sectional area
C	Compressive force
F_{max}	Maximum load
$F_{undamaged}$	Maximum load of the undamaged specimen
L	Span length
M_{max}	Maximum bending moment
T	Tension force
b	Section width
d_s	Distance from the section bottom to the reinforcement
f_c	Concrete compressive strength
f_s	Steel stress
h	Effective section height
x	Stress block height

2. Laboratory Quasi-static tests

2.1. Static tests setup and instrumentations

Full scale RC T-wall specimens were exposed in field tests (that were performed by the authors) to blast and fragments impact from detonated cylindrical charges [8]. The metal casing of the charges was ruptured into a large number of fragments, which reached the T-walls before the blast wave did, as indicated by high-speed camera records and pressure gauges that were set in the free field. In one of the tests, a single T-wall was placed against the same charge without a casing. Since part of the explosion energy in a cased charge is dissipated through the expansion and rupture of the casing [9], the blast pressure in this test (with the bare charge) was higher. However,