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Inelastic deformation and failure of profiled stainless steel blast wall panels. Part I: experimental investigations

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Abstract

This three-part article presents the results of experimental, analytical and numerical studies on the response of $\frac{1}{4}$ scale stainless steel blast wall panels and connection systems. The panel design was based on a deep trough trapezoidal profile with welded angle connections top and bottom and free sides. The loading applied to the panel was a triangular pulse pressure representative of a gas explosion overpressure. The aim of this work was to investigate the influence of the connection detail on the overall performance of the panel/connection system under pulse pressure loading and to develop appropriate analytical and numerical models for correlation with the test results. Part I reports on the experimental investigations, whilst the analytical modelling considerations are examined in Part II. Finite element analysis, with ABAQUS, was used to simulate the blast wall panel behaviour and is discussed in Part III. Large permanent plastic deformations were produced in the panels without rupture, and localised buckling developed at the centre of the corrugations. The work highlights the importance of correctly modelling the support details and the variation in strength with blast direction (the blast wall panels being stronger in the design direction). The modelling approaches predict a design capacity that is 39% higher than the current design guidance predicts, as a result of modelling the supports and including membrane action.

Keywords: Blast walls; Pulse pressure loading; Buckling; Modelling; Corrugations

1. Introduction

Blast walls are used on the topsides of offshore oil and gas platforms to limit the maximum possible overpressure resulting from an explosion by controlling the size of a gas cloud build-up

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Nomenclature

δ_{max}	maximum transient mid-point displacement (mm)
δ_{perm}	permanent mid-point displacement (mm)
P	applied overpressure (bar)
P_{peak}	peak applied pressure (bar)
t_{dur}	total load duration (ms)
t_m	time to maximum applied pressure (ms)

and to reduce the impact of a potential gas explosion on the temporary refuge. Their main function is mitigation of the explosive energy and thus the walls are designed to be efficient energy absorbing systems. Blast walls in the UK are designed using guidance issued by the Fire and Blast Information Group (FABIG) and the Steel Construction Institute (SCI), known as Technical Note 5 [1] that has its basis in Eurocode 3 [2].

Current design practice is to assume a single plastic hinge formation at the ends of the blast wall (treated as a one-way member) and to ignore end effects. The capacity of the wall is therefore based on a simple bending resistance model and generally leads to conservative designs. The actual capacity of the wall to resist a dynamic event is considerably larger than the simple design estimate when considering the support construction and attachment to the primary framework. The experimental and modelling work at Liverpool has enabled a more accurate assessment of the ultimate capacity of the blast wall based on the influence of the connection detail. A reliable method of including the connection detail in the assessment of the blast response of the wall should result in improved safety through better understanding of the blast wall behaviour in an accidental gas explosion.

An extensive programme of experimental work has been performed at the University of Liverpool Impact Research Centre on $\frac{1}{4}$ scale stainless steel blast wall panels with connections subjected to pulse pressure loading to determine their various modes of failure and blast resistance beyond the design limit. The aim of the work was to investigate the influence of the connection detail on the overall performance of the panel/connection system under pulse pressure loading and to develop appropriate analytical and numerical models of the blast wall/connection system for correlation with the test results.

Previous work by Malo and co-workers [3,4] used a water chamber to apply a uniformly distributed quasi-static pressure load to duplex stainless steel corrugated panels. The corrugated ends were stiffened to prevent distortion of the end profile, and were prevented from moving in the direction of the pressure loading but simply supported in every other way. They found that modelling the support geometry led to better correlation with experiment, but were unable to test panels with connection designs typically used on offshore installations. This is the first time that an experimental study of the behaviour of blast walls made from profiled stainless steel sheet has considered a detailed investigation of the modes of failure and end effects of a ‘realistic’ support construction.

Blast loading of various flat, stiffened and corrugated panels has been studied by previous researchers [3–8] and by the blast wall manufacturers themselves, with the aim of enhancing their blast resistance capacities. However, due to the design of the experimental facilities available to