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Technical Report

Blast response of cracked steel box structures repaired with carbon fibre-reinforced polymer composite patch

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ABSTRACT

In this paper the blast resistance of cracked steel structures repaired with fibre-reinforced polymer (FRP) composite patch are investigated. The switch box which has been subjected to blast loading is chosen to study. The steel material is modelled using isotropic hardening model, pertaining to Von Mises yield condition with isotropic strain hardening, and strain rate-dependent dynamic yield stress based on Cowper and Symonds model. Three different cracked structures are chosen to investigate their capability in dissipating the blast loading. To improve the blast resistance, the cracked steel structures are stiffened using carbon fibre-reinforced polymer (CFRP) composite patches. The repaired patches reduce the stress field around the crack as the stress is transferred from the cracked zone to them. This situation prevents the crack from growing and extends the service life of the steel structure. It will be shown that CFRP repairing can significantly increase the blast resistance of cracked steel structures.

1. Introduction

The susceptibility of civilian buildings when exposed to explosions has been shown by the latest terrorist attacks or industrial accidents. A blast wave from explosion acting directly in a building can cause major economic and human losses. As result, the number of studies in the structural response, retrofitting and repairing of structures as increased in the last years. As experimental full-scale test are quite expensive, the need of numerical analysis took a very important role in the development of knowledge in this field.

In this paper the blast resistance of cracked steel structures repaired with carbon fibre-reinforced polymer (CFRP) composite patch are investigated. Three different cracked structures are chosen to investigate their capability in dissipating the blast loading. Experimental studies with HE (High Explosive) were conducted in steel switch boxes. The peak side-on overpressure ranged from 100 kPa to 800 kPa and the reflected pressure (pressure experienced in the side of the box that faced the charge) ranged from 320 kPa to 4 MPa. The duration of the positive phase of the blast wave were around 8 ms for the highest peak side-on overpressure and 17 ms for the lower ones [1].

Previous studies have shown several different solutions to predict the structure response to blast loading. These studies lead to satisfactory results in the prediction of the permanent deformations of structures subjected to blast loading using Single Degree of Freedom (SDOF) models [2–6]. This approach has however several limitations. With the increase of computers capacity and the constant development of software, FE (Finite Elements) method has been getting the attention of the scientific community in the past few years. Yuen et al. [7,8] studied the response of quadrangular stiffened plates subjected to uniform blast loading. They have also investigated [9] the deformation of mild steel plates subjected to large-scale explosions. According to their results the use of the Hopkinson-Cranz scaling laws have proven to be useful to evaluate pressures, time durations and impulses; and the use of proper explicit dynamic codes can lead to a reasonable agreement with experimental results.

Jama et al. [10] through numerical modelling studied square tubular steel beams subjected to transverse blast loading using LS-DYNA and concluded that these elements undergo local cross-sectional deformation followed by global beam bending deformation and highlighted the importance of the strain-rate hardening for proper detail in both local and global deformation. Nurick and co-workers [11–13] studied the influence of boundary conditions of the loading of rectangular plates subjected to localized blast loading. They showed that axial crushing of tubes sandwiched between steel panels could be used to absorb significant energy from a blast load and studied the post-failure motion of steel plates subjected to blast loading. Sabuwala et al. [14] analysed beam to column connections subjected to blast loads, showing that the TM5-1300 over-designs these elements. Krauthammer [15] proposed a model to predict the behaviour of structural concrete and structural steel connections subjected to blast loading conducting a series of numerical simulations and concluded that the current design procedures should be modified for a better

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