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SECURITY EVALUATION AND DESIGN OF STRUCTURES SUBJECTED TO BLAST LOADING

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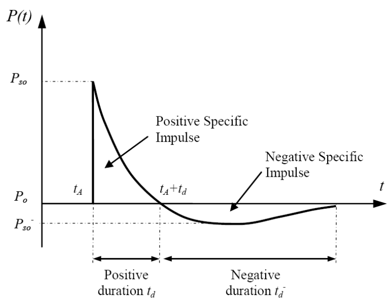
ABSTRACT

Many nations have become victims of terrorism in a grand scale. Such events have generated a considerable concern on the capacity to protect buildings and their occupants from the threat of bombing. The knowledge and understanding of the explosion phenomenon and his effects on structures may save lives and drastically reduce the damage on the structure. However, this topic is not getting the proper attention from the technical community. The aim of this work is to provide recommendations for existing structures like historical masonry monuments, and recommendations regarding the design of new structures, mainly reinforced concrete structures. Another objective is to introduce this topic at national level for future developments.

INTRODUCTION

An explosion is a sudden energy release. In an explosion the gas expands in its volume and it is forced out of the volume it occupies, as consequence, a layer of compressed air – shock wave – is formed around that gas containing most of the energy released by the explosion (Ngo et al 2007).
The shock wave increases the pressure above the atmospheric pressure – positive phase, which later decreases as the wave moves away from its source. After a certain period of time the pressure decreases below the atmospheric pressure – negative phase (Mays and Smith 2001). In Figure 1 can be seen a generic profile of a shock wave from an explosion.

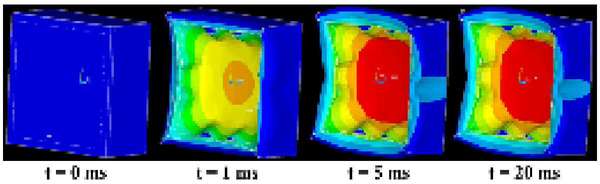


Figures 1: Generic Pressure-Time profile.

Explosions produce high strain rates, usually between $10^2 – 10^4\ s^{-1}$. The materials mechanical properties under these conditions, dynamic loading, can be very different from its properties under static conditions. Some design manuals provide ways to predict the increase factor depending on the strain rate, type of element, material and loading mechanism (TM 5-1300 1990).
Due to the effect of high strain rates and the non-linear inelastic material behaviour analysing the dynamic response of blast-loaded structures becomes a very complex problem. Computational methods in the area of blast-effects mitigation are generally divided into those used for prediction of blast loads on the structure and those for calculation of the structural response to the loads. Codes such as LS-Dyna (LS-DYNA 1997) proved themselves in previous researches capable of, with some accuracy, predict the structural response of blast loaded structures (Borvic et al 2008).

MODELLING AND ASSESSMENT OF BLAST LOADING EFFECTS – STEEL THIN-WALLED STRUCTURES

The assessment of the type and magnitude of the blast loading is one of the most important issues in this field. Using common objects presented in most of industrial buildings, such as steel switch boxes, as reference samples it is possible to establish a relation between the permanent deformation after the blast and the pressure/impulse responsible for such deformation.
Experimental work with HE (High Explosives) was conducted in steel switch boxes using different explosive masses at different distances. To model the explicit dynamic problem commercial code Ansys/LS-Dyna was used. Figure 2 represents the deformed shape time-history for an explicit simulation of the big box with the front facing the blast, using LS-Dyna.
It was possible to build Iso-deformation plots for each type of switch box (big box and small box) and each type of loading configuration (blast facing the front of the box and blast facing the side of the box) by varying the pressure and the load duration (impulse). These plots allow to relate the permanent deformation with the combination of pressure/impulse.



Figures 2: Example of explicit dynamic simulation for the big box with the front side facing the blast.

Numerical simulation to predict the blast behaviour of steel cracked box sub-structures repaired with CFRP composite patch

It was also evaluated the improvement of repairing cracked steel thin-walled structures with CFRP. The influence of the crack orientation was studied using three different orientations. Cracks were 20 mm long and centre of the crack is coincident with the centre of the side face of the switch box.
To evaluate the improvement of the CFRP repair several different simulation were made to study the influence of the patch thickness, the patch size and the orientation of the patch fibres. The CFRP patch was modelled with a layered thin-shell element type specific for explicit dynamic analysis and applied on top of the cracked zone. The contact between the FRP patch and box was modelled using a *nodes impacting surface* with a friction coefficient of 0.3 which was measured experimentally to avoid lateral movements.
It was shown that there was no significant influence in the permanent deformation when varying the crack orientation, the thickness of the CFRP patch and the orientation of the fibres. The size of the CFRP patch proved to have an significant influence in the permanent deformation, showing that an optimum patch size (leading to the minimum permanent deformation) should be found. Repairing with FRP patch can improve the behaviour of the thin steel structure almost to the point of the un-damaged one.

FUTURE WORK

Conserving the architectural heritage is now a requirement of society, given the cultural value, and an economic requirement, given the impact of tourism in our economy. These structures appear to have a higher risk due to religious reasons, political reasons (governmental headquarters) or impact on public opinion. It is intended to study one of these “high risk” structures (Gare do Oriente, Lisbon or Estação do Rossio, Lisbon) evaluating the security of this structure in terms of blast loading resistance.
Most of the recent building involves reinforced concrete structures. These types of buildings and materials are to be analysed when subjected to blast loading, considering irregularities in height and plant, and as usual in the design of new buildings, ignoring any contribution of the masonry walls.The main objective is to create guidelines on how to obtain sufficient robustness on new building in the event of explosions.

CONCLUSIONS

With this work it is intended to recommend modelling techniques for this kind of loading conditions using FE codes. The use of Finite Element Analyses (FEA) is one of the most used techniques to predict the behaviour of structures. FE software like LS-DYNA has been proved capable of, with relative accuracy, model explicit dynamic situations comparing with experimental results. Explicit dynamic simulations are still in an early stage of development as many of the modelling possibilities for the implicit analysis are not yet available for the explicit analysis. Blast loading simulating still needs to concentrate the attention of researchers in terms of the material properties for high strain-rate situations. The commercial codes should be improved too in terms of available element types and material models.

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AUTHOR BIOGRAPHIES

JOÃO M. PEREIRA was born in Braga, Portugal and went to the University of Minho, where he studied Civil Engineering and obtained his degree in 2008. He started his PhD in the same year in the field of Structural response and Blast loading. He also was in Kingston University, London as Visiting Researcher and Assistant Researcher during part of 2009/2010. His e-mail address is : `jpereira@civil.uminho.pt`.