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SECURITY EVALUATION AND DESIGN OF STRUCTURES SUBJECTED TO BLAST LOADING

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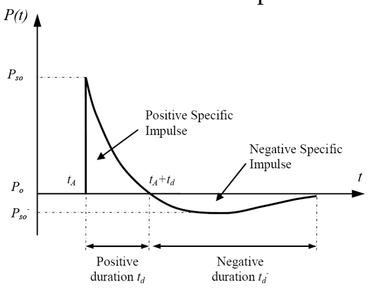
INTRODUCTION

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.

An explosion is a sudden energy release. A shock wave is created and it 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}(TM5-1300 1990). The materials mechanical properties under these conditions, dynamic loading, can be very different from its properties under static conditions. Due to this effect and the non-linear inelastic material behaviour, analysing the dynamic response of blast-loaded structures becomes a very complex problem. Codes such as LS-Dyna proved themselves in previous researches capable of, with some accuracy, predict the structural response of blast loaded structures. However calibration of these models via comparison with experimental work is still required due to the very early stage of development in this field.

POST-DISASTER SCENARIO EVALUATION

With collaboration with Kingston University, London, UK and British Petroleum, UK it was developed a method to estimate overpressures and impulses at post-disaster scenarios by relating the these elements to the deformation of small, simple and deformable object common on industrial sites. This was carried out as part of the Buncefield Major Incident Investigation.

A large campaign of experimental work using hydraulic testing, gas explosions and HE (High explosive) explosions on steel junction boxes was carried out in order to properly calibrate the numerical models (Steel Construction Institute 2009). To model the explicit dynamic problem commercial code Ansys/LS-Dyna was used.

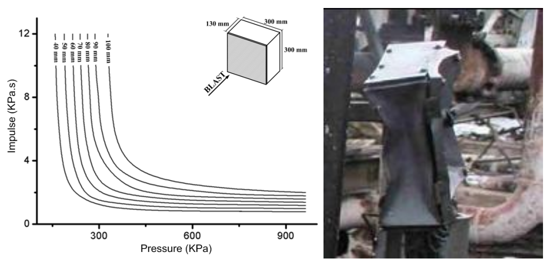


Figure 2: left) Example of developed P-I diagram; right) Example of crushed steel box at Buncefield.

With the numerical model calibrated with the experimental results it was possible to build iso-damage curves in the form of P-I (Pressure-Impulse) diagrams (Figure 2, left). These diagrams are able to relate pressure, impulse and deformation. These tools can be used to estimate the level of damage in the event of an explosion or to estimate the overpressures and impulses responsible for a specific level of damage in a post-disaster scenario, such as Buncefield. Figure 2 (right) shows one of the crushed boxes at Buncefield.

MATERIAL PROPERTIES AT ELEVATED STRAIN RATES

The materials mechanical properties under these conditions, dynamic loading, can be very different from its properties under static conditions. Tests have been started in order to investigate the properties of masonry under these high strain rates. In Figure 3 can be seen the test scheme wich consist in a Drop Weight (DW) tower with a hammer hitting on the testing specimen. The load is acquired via a load cell at the bottom of the specimen and the displacement is acquired via high speed video.

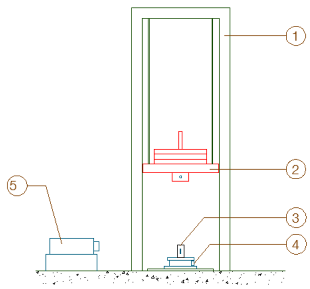


Figure 3: DW scheme; 1) drop tower; 2) hammer with accelerometer; 3) testing specimen; 4) load cell; 5) high speed video.

BLAST LOADED RESPONSE OF MASONRY IN-FILL WALLS

Minimizing the risks of injuries and fatalities as well as the risks of progressive collapse should be the main objective of the developed technologies in strengthening a structure against explosions. Masonry in-fill walls are responsible for a great number of injuries and fatalities due to their fragile behaviour and the build-up of debris thrown in the occupied space. Experimental and numerical work has started in order to investigate possible strengthening techniques to be applied to these elements. In collaboration with LEDAP (Laboratório de Energética e Detónica) a test apparatus was developed to be applied to real sized masonry in-fill walls using military grade explosives.

RISK ASSESSMENT AND SECURITY EVALUATION

In collaboration with REFER it was selected and adapted a methodology of risk assessment due to terrorism to be applied to all the REFER structure. A nationwide map of the various level of risk due to terrorism in a public transport network is an important tool from the security and prevention point of view. From the resulting of the first step, one of the highest risk structures will be selected for a security evaluation from the explosions point of view using numerical modelling.

CONCLUSIONS

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. Studying different aspects such as material properties, structural strengthening, risk assessment and security evaluation. Another objective is to introduce this topic at national level for future developments.

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AUTHOR BIOGRAPHY

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 2009/2010. His e-mail address is: `jpereira@civil.uminho.pt`.