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Damage state identification for reinforced concrete columns in uplift due to internal building detonations

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ABSTRACT

This paper details the development of a generalised damage identification procedure for reinforced concrete columns subjected to internal building detonations. With the successful application of advanced computational fluid dynamics and structural response modelling techniques, we have conducted a set of comprehensive parametric studies on reinforced concrete column failure when subjected to high-rate, coupled uplift and shear typically induced by internal explosive blast. The outputs of the parametric studies have been analysed using a multi-variable, non-linear curve fitting technique to develop the generalised damage identification procedure for columns, separately for two main internal blast conditions. The paper also presents a number of worked examples illustrating its application and significance in practice.

1. Introduction

Highlighted previously by the authors Wijesundara and Clubley [1,2], columns in internal blast environments are subjected to complex, high-rate axial and shear loads due to confinement effects and gas pressure build-up; leading to a noticeable loss of column structural integrity. With respect to the development of robust damage identification procedures for columns in such complex blast environments, it is essential to carefully take account of the effect of coupled, time-dependent uplift forces, because: (i) – these forces can significantly reduce the net axial compression force in columns, leading to pure axial tension forces [1], and (ii) – the rebound displacement of adjacent floor plates and cross girders typically induce substantial axial compression forces [3] which can easily exceed the column ultimate design capacity. General literature on internal explosive blast and the effect of consequential complex loading conditions on the integrity of primary elements currently remains inconclusive and unhelpful towards pragmatic structural design.

Literature focused towards the field of blast effects and protective structures typically encompasses research mainly targeted at the design and performance assessment of components subjected to external explosive blast [4–8]. In the context of damage state identification for columns, this results in columns that have been comprehensively assessed against only two main loading conditions: pure transient-lateral blast loads or secondly, lateral blast loads coupled with static axial compression forces. Key aspects of interest in these research studies include: (i) – the extent of localised damage, failure patterns and residual axial capacity of reinforced concrete (RC) columns [4,6] and, (ii) – the effect of close-proximity (near-field) or contact detonations on the response behaviour of RC columns [5,8]. Consistent with the nature of internal blast-induced loading conditions to a reasonable degree, multi-directional ground motions typically induced by seismic events can induce significant coupled, time-dependent axial and shear loads on columns [9]. As a consequence, the behaviour of RC columns in these circumstances has been of primary interest to many researchers [10,11], leading to the development of numerous design guidelines quantifying the effects of axial force variation [12]. Notwithstanding these advances, there exists a fundamental problem with these methodologies when applied to blast loading conditions due to the significant difference in loading rates. High explosive initiated blasts normally lead to significantly higher strain rates than those typical of seismic actions

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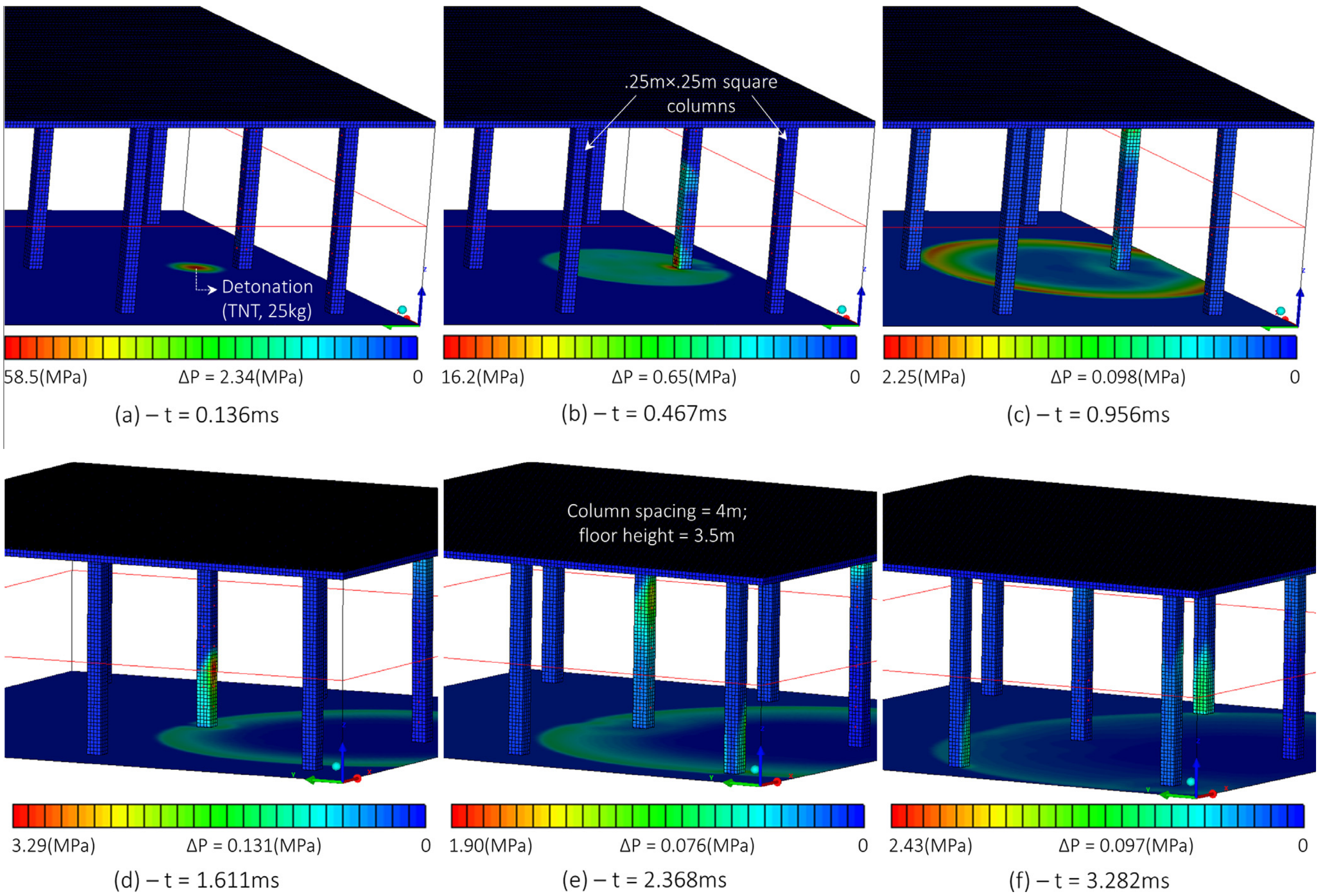

Fig. 1. CFD simulation of internal building detonation and wave propagation.

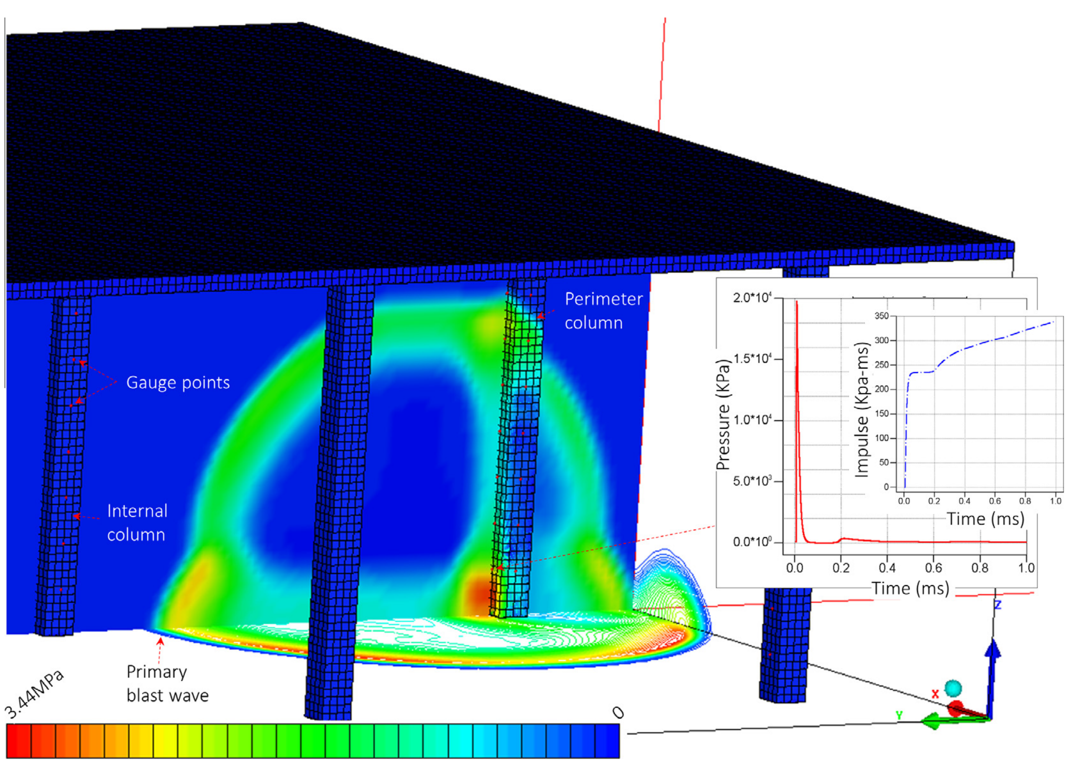

Fig. 2. Fluid-structure interaction and extracting consequential pressure histories.