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Blast and residual capacity analysis of reinforced concrete framed buildings

Ruwan Jayasooriya *, David P. Thambiratnam, Nimal J. Perera, Vladis Kosse

Faculty of Built Environment & Engineering, Queensland University of Technology, 2 George Street, Brisbane, GPO Box 2434, Brisbane, QLD, 4001, Australia

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ABSTRACT

Iconic and public buildings have become a universal target of bomb attacks from terrorists. Most of these buildings have been or are built without consideration for their vulnerability to such events. Planning and building control authorities have begun to recognise the risks of these events and have introduced provisions in planning guidelines for mitigation of such impact. This paper is a study of the impact of near field explosions on the structural framing system and key elements such as columns and describes the component material response. This information can be used in planning strategies to mitigate potential catastrophic and progressive collapse of the structure. Reinforced concrete framed buildings have been selected for this study. A two stage finite element modelling (FEM) and analytical technique has been used to interrogate the structural framing system and components for global stability and local residual strength capacity in the linear elastic and non-linear plastic response regimes. The first stage involved linear time history analysis carried out using SAP 2000 to verify the response of the complete framing system and its ability to restore global frame stability and to enable iterative interrogations. An explicit rigorous analysis accounting for strain rate effects of the reinforced concrete elements was carried out in stage two using LS DYNA code to investigate the non-linear response of vulnerable elements identified in the first stage. The damage mechanisms and the extent of damage have been studied using principal stress plots along with plastic strain diagrams and used to assess the residual strength capacity of key elements that can cause catastrophic failure of large sections of the building and propagate progressive collapse. Numerical analysis is based on techniques that have been established in previous research work and the models have been calibrated with similar work by others. The method used in this research work can be used for assessing vulnerability, damage and residual strength capacity of building frames and component elements subjected to near field blast events.

1. Introduction

Bomb explosions against iconic and public buildings have become hazardous due to widespread terrorist activities in various parts of the world [1]. Loss of lives and millions of dollars of property damage are the consequence following a successfully targeted bomb attack. While initial casualties are due to direct over pressure released by the explosion, falling of structural elements may extensively increase the total figure. Most buildings which are likely to be the target of a terrorist bomb have been constructed without considering their vulnerability, or their potential to mitigate the impact. However, planning and building control authorities are currently identifying the risks associated with such events in the present environment of global terrorism [2]. It is therefore important to carry out vulnerability and damage assessment of buildings subjected to blast loads to provide mitigation strategies. This paper discusses an evaluation of the response of a reinforced concrete (RC) framed building to a near field blast event. Evidence of recent blast events in major cities shows that explosion at more than 20 m distance from the buildings generally cause damages to their facades with some impact on the structural integrity. Recent examples are the Jewish Community Centre, Argentina 1994 [3], and the WTC twin tower attack, Sri Lanka, 1997 [4]. On the other hand, the near field events such as the Murrah building bombing, USA 1995 [3], the Central Bank bombing, Sri Lanka 1996 [5] and, Khobar Towers bombing, Saudi Arabia, 1996 [6] have had the potential to damage and destroy the structural integrity of the buildings. In some incidents, this has been accompanied by a large number of casualties. Recent incidents such as the Lahore city bomb blast 2009 [7] and, the Baghdad bomb blasts on foreign embassies 2010 [8] illustrate the importance of investigations of the response of building structures to a near field blast in order to protect lives and property. The work described in this paper focuses on the near field blast events that are likely to cause damage on the structural integrity of the buildings and set off catastrophic or progressive collapse.

* Corresponding author. Tel.: +61 731389946.
E-mail addresses: j.jayasooriya@qut.edu.au, ruwanjayasuriya@gmail.com (R. Jayasooriya).

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