Validation of simplified models for the analysis of reinforced concrete beams exposed to gas explosions

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Abstract

This paper addresses structural performance of reinforced concrete beams in residential buildings exposed to the effects of explosions. Eighteen beams were defined and analysed with simplified models. Their flexural response was assessed assuming a system with a single degree of freedom, whereas the reaction forces were determined by applying dynamic equilibrium to the members. Simplifying assumptions therefore had to be made, particularly in connection with the resistance function. To validate those assumptions, the beams were subsequently analysed using a finite element model into which complex issues such as material non-linearity or the effect of gravitational loads on dynamically loaded beams can be adequately factored. The numerical results were found to agree closely with the simplified model predictions, particularly with respect to flexural behaviour. The reaction forces calculated differed by about 5-23 %.

Keywords: explosions, blast loading, dynamic analysis, reinforced concrete beams, SDOF systems, dynamic reaction forces, strain-rate effects, finite element analysis, numerical analysis, DIANA.

1. Introduction

The present study, part of ongoing research on the assessment of gas explosion-induced structural risk, addresses the structural performance of reinforced concrete (RC) beams in residential buildings undergoing such accidents.

A number of approaches are in place for determining internal forces and stresses in structural elements exposed to explosions, with the grounds for calculations ranging from equivalent static loads to complex, numerical simulations of the blast wave and its dynamic effects on the structure [1]. In the present study, the explosion load was represented as an idealised pressure-time function compatible with simplified model analysis. Beam flexural response was obtained assuming a single degree of freedom (SDOF) system, whereas the reaction forces were determined from the dynamic equilibrium formulation applied to the beams themselves. This type of analysis calls for reasonable hypotheses and assumptions for the simplified characterisation of both dynamic loading and structural resistance as shown, for instance, in [2].

The dynamic resistance function for the beams was deduced in the present study from simple cross-sectional moment-curvature analysis. In addition to essential issues normally dealt with in dynamic structural analysis, such as non-linear behaviour in materials or strain rate effects on their properties, the present approach also took the impact of pre-explosion gravitational loads on the beams into consideration. The simplifying hypotheses and assumptions were validated with a finite element model that factors in the many complex features of structural behaviour in beams under explosive loading. A numerical model based on a plane stress assumption was developed and its structural performance compared to test results reported in the literature. That model was subsequently used to explore the behaviour of the beams previously analysed with the simplified models.

2. Selected beams: description

The present study analysed floor beams in residential buildings exposed to the pressure generated by gas explosions, p_{ex}, acting in the same direction as gravitational load g+q (Figure 1). The survey was limited to simply supported members, for it is a conservative approach with regard to the reliability analysis [3], which lies beyond the scope of the present paper.

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