Multi-Scale Simulation and Numerical Modelling of Reinforced Concrete Slabs Subjected to Blast Loading

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Blast loading with high pressure intensity propagates within a fraction of second after an explosion. Depending on the amount of energy and wave velocity released, blast loading is highly likely to cause substantial structural damage and leads to a total failure. Taking into account various interests and requirements in the protective structures, the investigation of damage behaviour and structural responses due to this extreme condition is therefore vital. The main objective of the present research is to numerically investigate the damage behaviour and structural responses of reinforced concrete slabs under blast loading with and without protection of ceramic composite layer. The scabbing, spalling and shear plugs are of particular interest, with special attention paid to the progressive fracture and its associated wave velocity. Three major modelling aspects are given the most attention in term of blast loading, materials and fracture modelling. The interaction between non-uniform blast loading and reinforced concrete slabs is modelled using the 3D ELFEN program. The finite element method is incorporated with a crack rotating approach and discrete element to model the fracture onset and the dynamic post-failures. In the modelling, a mapping method has been employed to define blast pressure due to incompatibility of the Jones-Wilkins-Lee method with all compressible material models. The blast pressure is determined based on cumulative loads on the incident overpressure, the reflected overpressure and the dynamic windblast. The calculated blast pressure is compared with that obtained from the US Army standard, TM5-1300/UFC03-340. The Mohr-Coulomb and Von-Mises criteria are applied for material properties of the concrete and steel reinforcement respectively. Since the Mohr-Coulomb criterion in concrete can only produce continuum failure, the Rankine with fracture model is introduced to control tensile failure. Meanwhile, a multi-scale simulation is applied to overcome the lack of constitutive material model for the ceramic composite layer. The multi-scale simulation is based on the periodic boundary displacement fluctuation condition, employing a unit cell of ceramic composite with biaxial loading and a nonlinear anisotropic brittle model. The comparison between numerical and experimental results shows a favourable agreement and gives a reliable prediction on the damage behaviour and structural responses. The fracture and post-failures are still ambiguous and need for further investigation.