NUMERICAL SIMULATION OF THE EFFECT OF BLAST AND PENETRATION ON REINFORCED CONCRETE STRUCTURES

By

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ABSTRACT

In this thesis a novel discrete meso-scale model for concrete, called Lattice Discrete Particle Model (LDPM) will be presented.

This novel approach enables the computational investigation of the mechanical behavior of concrete structures subjected to blast and projectile impact. Under these loading conditions concrete behaves non-linearly, and the material behavior is strongly influenced by the heterogeneity of the internal structure and by the associated damage localization and fracture occurring at failure. In particular fragmentation phenomena and triaxial confined behavior are predominant in this type of problems. Concrete non-linearity has been investigated by both continuum and discrete models, but at this time there is no a model able to reproduce correctly concrete behavior under fragmentation and highly confined compression. To overcome this limitation of the current state-of-the-art, the goal of this research is to formulate a model able to simulate concrete subjected to both extensive fracture and triaxial state of stress.

Herein an overview of typical discrete models for concrete will be presented. Models will be characterized considering the scale of the material heterogeneity discretization. Material discretization, kinematic and static modeling, simulated tests, advantages and disadvantages of each model, and future developments will be also discussed.

The formulation of the new approach will be then presented and explained. The model reproduces the concrete mesostructure through polyhedral cells obtained by a 3D Delaunay tetrahedralization, and a dual domain tessellation. Facets, produced by the tessellation, exchange axial and shear forces following compatibility and equilibrium equations at the discrete level. Softening behavior is reproduced only in tension and hardening only in compression. Shear reproduces both cohesion and friction. The model is able to reproduce concrete damage and failure under direct tension, mode I and mixed mode fracture as well as unconfined, confined, hydrostatic, and triaxial compression behavior.

LDPM will be calibrated and validated simulating a group of experimental tests both in compression and tension. Regarding compression: uniaxial confined and unconfined, biaxial, triaxial, and hydrostatic tests will be simulated, considering also cases of cyclic loads. Regarding tension: three point bending and splitting tests will be simulated. In every test stress-strain or force-displacement results and failure modes will be compared, with very good agreement, with the experimental results.

LDPM will be extended to simulate rate effect, and a group of experimental test simulations will be presented. Uniaxial unconfined compression and Hopkinson Bar in tension will be simulated to calibrate and validate the dynamic parameters. LDPM dynamic implementation will be used to investigate brick fragmentation, projectile impact on reinforced concrete walls, and wall subjected to blast.

Finally, conclusions will be discussed: model capabilities will be summarized, and future works will be listed.