Abstract

Concrete is a random heterogeneous material at the micro and meso-scales. The coarse aggregate structure of concrete is a major source of its heterogeneity, since both aggregate shape and size are subject to random variations. Previous researchers have studied the effect of aggregate geometry on the macro properties of fresh and hardened concrete. However most of the studies have been experimental. To supplement the understanding gained from experiments, particle based models can be used to simulate the meso-structure of concrete. Such studies can shed light on complex meso-scale interactions and help design concretes with improved properties. In this thesis, the discrete element method (DEM) has been used to study the meso-scale behaviour of concrete.

Analysis of particle geometry to generate particles with shape and size that are as close as possible to that of actual aggregates is a pre-requisite for the study. Simulation of the casting process to generate specimens with realistic particle configurations is another requirement. A unified meso-scale constitutive model that can model the behaviour of both unconfined and confined concrete is then developed. The calibrated and validated model is used to investigate the behaviour of concrete under uniaxial and triaxial compression.

The force applied to a concrete specimen is transmitted by the particles through patterns of force-chains, also known as the fabric .Aggregates play a critical role in determining the structure of the fabric. A major goal of the thesis is to understand how the fabric affects the macro response in unconfined concrete, and in passively confined concrete. In order to do so, stress-fabric and strain-fabric relations are derived for cohesive granular materials.

Tensile failure in notched and un-notched specimens, when subjected to direct tension as well as flexural loads, is examined next. The role of material fabric in determining the strength, crack propagation and geometry of the fracture process zone (FPZ) is studied. This is another major focus of the thesis.

Keywords: meso-geometry, material fabric, stress-fabric relation, discrete element analysis