Investigation of Failure Mechanisms in High Strength Concrete using 3D-XFEM

Rohan Patel, Stefan Löhnert
Institute of Mechanics and Shell Structures
Technical University Dresden, Germany

High strength concrete, has a significantly different and denser micro-structure compared to normal strength concrete. The properties of the micro-structure which ultimately depends on the manufacturing process, has remarkable influence on overall material behavior. The optimized cementitious materials and binding agents used as ingredients for high strength concrete cement paste are subjected to self-desiccation during the hydration process which leads to shrinkage [1]. This shrinkage process is susceptible to cause micro-cracks potentially leading to a weakened material. Due to the importance of high strength concrete as a modern building material and due to the significant effort to experimentally test different compositions of high strength concrete especially for the prediction of the life time of the concrete under cyclic loads, a computational model for the development of cracks within the microstructure is developed in this work. In order to obtain realistic results, the microstructural geometry used for the simulation model is obtained by means of computer tomography (mirco-CT) scans of concrete samples.

To this end, the discrete crack and its propagation within the micro-structure is simulated using the extended finite element method (XFEM) [2] including inertia effects in 3D in combination with level set techniques. The level set method is useful to track the position of the crack inside the solution domain. The need for a crack propagation criterion for the XFEM is met by a coupled damage model. When a local damage model is used, it exhibits high spurious mesh dependency. Those pathological effects are overcome by a coupled gradient enhanced damage model also simulated using the XFEM. The gradient enhanced damage values are used as propagation criterion as well as for the determination of the crack propagation direction. Once the crack propagates, the update of the crack surface geometry is performed using an advance algorithm for the level sets [3].

References

[1] Wiegrink, Karl and Marikunte, Shashidhara and Shah, Surendra P, Shrinkage cracking of high-strength concrete *Materials Journal*; vol: 93 - Num: 5; Pages: 409–415; Year: 1996

[2] Belytschko, Ted and Black, Tom. Elastic crack growth in finite elements with minimal remeshing *International journal for numerical methods in engineering*, vol: 45 - Num: 5, 601–620, 1999

[3] Beese, Steffen and Loehnert, Stefan and Wriggers, Peter. Modeling of fracture in polycrystalline materials *sema simai springer series, Advances in Discretization Methods*, 79–102, 2016.