The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5 – 9 June 2022, Oslo, Norway

Numerical and experimental investigations of high-performance fiber-reinforced concrete under cyclic tensile loading

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Key Words: *SFRC, tensile loading, controlled crack opening test, cohesive zone model, crack-closure model, discrete fiber, bond-slip law*

Increasing requirements in slender design, material savings, and improved durability attract more and more interest in high-performance concretes, often reinforced by fibers to improve material characteristics further. It is, however, still a challenge to simulate the behavior of such complex material accurately and reliably, especially under cyclic loading conditions. This work aims to develop the finite element model in the context of the cohesive zone theory to model short-fiber-reinforced high-performance concretes. To this end, concrete cracking and crack closure are modeled utilizing zero-thickness cohesive interface elements, and steel fibers are modeled individually via Bernoulli beam elements. Special attention is devoted to bond elements connecting steel fibers and concrete. The bond between fibers and concrete is modeled using elastoplastic bond-slip law calibrated based on single fiber-pullout experiments.

The model was applied to investigate the behavior of fiber-reinforced high-performance concrete under cyclic loading. To this end, the displacement-controlled crack opening tests and numerical simulations thereof were carried out on notched prismatic high-performance concrete specimens reinforced by short steel fibers (~1% vol.). Experiments have shown, and the numerical simulations have confirmed, that the inclusion of short steel fibers did not significantly affect the ultimate strength; however, it notably increased the post-cracking ductility of the material. Finally, the unloading/reloading behavior was examined. The unloading stiffness was always stable, and the hysteresis loops due to unloading/reloading were very small even for significant crack openings, indicating that the residual strength comes primarily from fibers carrying the load.