Phase-field modeling of failure behavior of reinforced high performance concretes at low cycle fatigue

Mangesh Pise[1]*, Dominik Brands[1], Gregor Gebuhr[2], Steffen Anders[2], Jörg Schröder[1]

[1]Institut für Mechanik, Fakultät für Ingenieurwissenschaften, Universität Duisburg-Essen, Universitätsstraße 11, 45141 Essen, Germany, mangesh.pise@uni-due.de
[2] Chair for Construction Materials, Faculty of Architecture and Civil Engineering, Bergische Universität Wuppertal, Pauluskirchstraße 11, 42285, Wuppertal, Germany

In the recent decades great research effort has been carried out which led to more efficient and stronger concrete types, e.g. high performance concrete (HPC) and ultra-high performance concrete (UHPC). They are rapidly emerging as promising materials in construction industries worldwide. HPCs are available in wide varieties of composition which make them different from classical concrete types. For example, steel fibers and short-wire fibers are usually added to ensure ductility in HPC and in UHPC, respectively. The fiber reinforcements provide a sufficient ductility by transmitting the stresses in concrete from matrix to the fibers during fracture. These fibers contribute to the energy absorption capacity of concrete by restraining the further growth of crack. This process shows pronounced effect on the deterioration characteristics of concrete in cyclic flexural tests, see [3].

In this contribution, the aim is to investigate the influence of fiber's orientations and distribution on the overall material behavior of fiber reinforced HPCs at low cyclic fatigue. A phenomenological material model is developed by combining the superposed models of transversal isotropic elasto-plasticity, see [1] and a continuum phase-field model of fracture in elasto-plastic material, cf. [2, 4, 5]. Two different continuous stepwise linearly approximated degradation functions for the modeling of unsymmetric behavior of concrete materials in tension and in compression are considered. The numerical model is calibrated using the experimental data and by simulating the typical uniaxial cyclic tests and three-point bending beam test at low cycle for pure concrete specimens. Three-point bending beam tests at low cycle for reinforced HPCs with different fiber contents and orientations are simulated. To incorporate the different distributions and orientations of reinforced fibers different orientation distribution functions (ODF) are constructed and implemented. The degradation of residual stiffness is calculated using experimental and numerical results and compared to validate the accuracy of the numerical results, see [5, 6].

References

[1] J. P. Boehler, Applications of tensor functions in solid mechanics, CISM, 292, Springer, Vienna, 1987.

[2] M. Ambati, T. Gerasimov, L. De Lorenzis, Phase-field modeling of ductile fracture, Computational Mechanics 55 (2015) 1017–2015.

[3] K. Elsmeier, J. Hümme, N. Oneschkow and L. Lohaus, Prüftechnische Einflüsse auf das Ermüdungsverhalten hochfester feinkörninger Vergussbetone, Beton- und Stahlbetonbau 111 (2016) 233–240.

[4] C. Miehe, F. Aldakheel, and A. Raina, Phase-field modeling of ductile fracture at finite strains: A variational gradient-extended plasticity-damage theory, International Journal of Plasticity 84 (2016) 1–32.

[5] M. Pise, D. Brands, J. Schröder, G. Gebuhr, S. Anders, Phenomenological material model for damage in steel-fiber reinforced high performance concrete during low cycle fatigue, Proceedings in Applied Mathematics and Mechanics 22 (2022)

[6] G. Gebuhr, M. Pise, S. Anders, D. Brands, J. Schröder, Damage evolution of steel fiber reinforced high performance concrete in low-cycle flexural fatigue: numerical modeling and experimental validation, Materials 15 (2022) 1179.