Mesoscale discrete model for monotonic, cyclic and fatigue loading of concrete

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The task of predicting the structural performance of concrete, including its damage and failure, is very practical one and it has led to a number of innovative models and modeling approaches. The limitations of traditional fracture mechanics to properly capture quasi-brittle behavior of concrete is one of the driving forces behind the development of advanced modeling approaches. These models must balance the incorporation of material features that dictate the concrete behavior with the computational tractability, because in the end, models should not only serve to improve scientific understanding of the underlying phenomena, but most importantly to solve practical problems. The available advanced models range from modified *continua* in which the heterogeneity is modeled via spatially varying properties to *discrete* models in which the material representation is better tied to the physical microstructure and the micromechanical phenomena that produce quasi-brittle behavior.

The last about two decades has seen a gradual rise in discrete models that use discontinuous representations of the quasi-brittle material. The particle-based discrete models resolving the mesoscale features (individual large mineral grains) seem to provide the best balance between affordable computational complexity and the amount of captured structural redistribution effects associated with inelastic effect in heterogeneous materials such as concrete. The advantage of discrete models is the possibility to use vectorial-based constitutive law for individual interfaces instead of full tensorial description needed in standard continuum-based models. The triaxial stress redistribution effects with complicated phenomena such as anisotropic damage are automatically captured by the resolution of material mesoscale with the involved interactions between material bonds described by interface-like constitutive laws, see e.g. a recent advanced damage-plastic interface model presented in [1]. The marriage of the tractable vectorial description with structural effects is the key to success in matching diverse mechanisms in a wide range of loading scenarios.

The particle-based discrete model used in the present work reproduces the material integrity via mechanical components (links) each representing the connection between a pair of two adjacent mineral grains. A phenomenological interface model is used to lump the inter-aggregate interaction into a single interface constitutive law. This constitutive model must, apart from the variety of monotonic loading scenarios, respond reasonably also under cyclic loading.

This presentation serves as promotion of a recent work [2] focused on mesoscale modeling of concrete, in which we show that a single discrete model with a properly formulated constitutive law featuring a combination of damage with plasticity is capable of reproducing experimental data obtained on concrete under: (i) monotonic loading with both proportional and non-proportional loading, (ii) cyclic loading (postcritical cycling leading to low-cycle fatigue), and (iii) fatigue loading (precritical cycling leading to high-cycle fatigue). In this way, a common approach for a general monotonic, cyclic and fatigue loading is established. The model provides the history of energy dissipation, and the detailed energy breakdown allows for the analysis of the link between the dissipation generated by the cyclic plastic activity and the crack initiation via damage.

References

[1] R. Chudoba, M. Vořechovský, M. Aguilar, A. Baktheer, Coupled sliding–decohesion–compression model for a consistent description of monotonic and fatigue behavior of material interfaces, omputer Methods in Applied Mechanics and Engineering 398 (2022) 115259 doi:10.1016/j.cma.2022.115259.

[2] M. Vořechovský, V. Sadílek, J. Eliáš, J. Mašek, J. Květoň, Mesoscale discrete model for fatigue in concrete, Computer Methods in Applied Mechanics and Engineering (under preparation).