Modelling the thermomechanical behaviour of high strength steel beams exposed to the fire resistance test using microplane approach.

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Abstract

The computational simulation of high strength steel structures exposed to high temperatures provides valuable insights into the failure mechanisms of buildings in case of fire. To achieve this, precise methods are essential to evaluate various changes in the stress state of the steel, cyclic loads, and non-proportional loading paths that simulate the effects of impacts, blasts, or earthquakes. Conventional constitutive models for ductile metals fall short in predicting these effects; thus, alternative models are necessary, as presented herein.
In this study, the mechanical behavior of Q690 high strength steel is first calibrated with experimental data of tensile tests under different stress states and its response at elevated temperatures is optimally fitted with experimental data of transient-state temperature tensile tests. Subsequently, the thermo-mechanical simulation is performed on a loaded beam of the same steel subjected to the fire resistance test. During the test, the specimen is subjected to a constant load and increasing temperature according to the ISO 834 fire curve. The thermo-mechanical simulations are based on the calibration of two models: (1) The microplane-J2 constitutive model (MPJ2), and (2) the microplane model for metals (MPM) that employs strain-dependent yield functions. The microplane approach effectively reproduces the average response of physical phenomena occurring on various slip planes during plastic deformation and allows for a higher predictability under complex loading conditions. The temperature dependence of mechanical behaviour and the thermal expansion are introduced based on the measured experimental data. The results represent insight into the digitalization of fire resistance tests and predictive analysis of steel structures failure under fire, and open up new strategies for more accurate predictions under complex loading scenarios.

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