Continuum damage mechanics model as an instrument for development of design rules for steel structures in seismic affected zones

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ABSTRACT

High strength low alloy (HSLA) steels are nowadays available as plate materials with high yield strength and excellent toughness properties. This is mainly a result of tailored metallurgical processes, such as thermo mechanical rolling as well as quench and temper processes. It can be easily argued that this advanced balance of strength and toughness could be turned into economic advantages resulting from new possibilities of lightweight engineering. However, modern HSLA steels are only rarely applied to typical structures of civil engineering. The main obstacle is the missing knowledge on limit state analysis because reliable methods to quantitatively predict damage initiation in components made of HSLA steels are still missing. As a consequence, the superior mechanical property profile may not be completely exploited, and this nearly excludes HSLA steels like S690Q, S890Q and S960Q from application.

By the design of steel constructions the resistances of the structures to cyclic loading with large strain amplitude in case of earth quake or hurricane are considered by the toughness properties of steels and stiffness of the structural elements. For better understanding the correlation of toughness properties and behaviour of steels under ULCF loading use of continuums damage mechanic approach can be helpful.

In the frame of this work, a new damage model for the prediction of ULCF failure was developed in order to predict the cyclic strain hardening and the failure behaviour of high strength structural steels. In detail, the modified Bai-Wierzbicki (MBW) model as presented by Lian [1] delivers the initial model configuration in relation to damage initiation and evolution. The plastic core of the model is given by J2 plasticity with non-linear Armstrong-Frederic [2] kinematic hardening. The damage evolution law was optimized by consideration of Ohata-Toyoda [3] effective strain concept.

The developed model was calibrated by monotonic and cyclic tests on round notched samples from S690Q steel. After calibration the model was used for analysis of toughness properties and correlation of toughness properties to the failure behaviour of material under ULCF loading. This analysis was performed under following assumptions: damage initiation locus of material model controls toughness properties of material, damage evolution law stays unchanged by monotonic and cyclic loading. The provided analysis allows better understanding of relation toughness properties and ULCF failure behaviour. In this case the material model can be used as an instrument for design rules development of steel constructions in seismic affected zones.

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