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Damage model calibration and application for S355 steel

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Abstract

Current demands for improved structural integrity and risk assessment involves the evaluation of alternative unloading paths, ensuring that a whole building (or a significant part of it) remains stable when subject to an unforeseen event: natural hazards (earthquakes, foundation failure, fire,…) or even terrorist attacks. The design under these conditions requires that the structural elements and, particularly in steel framed structures, the joints connecting elements are able to undergo elevated deformations without fracturing, thus providing means of energy dissipation.

The finite element method (FEM) is nowadays a widespread practice assisting in the simulation of many physics phenomenon. Looking forward to an accurate finite element simulation of steel connections up to its fracture, the implementation of a failure criterion based on continuum damage mechanics is explored in this paper. It is done by comparing the results reached from an undamaged analysis and the ones obtained from a damaged analysis using a ductile failure with "element deletion" technique to simulate the fracture. The analyses are carried out using the finite element software ABAQUS. The establishment of the fracture strain dependency to the triaxial stress state is based on the experimental evidences reached from 12 tensile coupon (S355) tests, including both notched and unnotched flat dog-bone test specimens.

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Keywords: Structural steel; Material behaviour; Damage, FE methods; Experimental tests.

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1. Introduction

Structural design solutions that can withstand the localised damaged without widespread collapse have become an important and urgent subject to study. Such design requires that the structural elements and, particularly in steel framed structures, that joints connecting elements undergo under elevated deformations without fracturing, thus providing

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means of energy dissipation. Today, the Eurocodes already provide recommendations towards a ductile design; yet, the establishment of the joints limiting rotation capacity requires costly laboratory tests. Past studies have showed that finite element modelling can be used to predict the nonlinear behaviour of joints. These numerical results were mostly used to supplement test data and give a more accurate description of the loading paths in the connecting components of the joints, Swanson et al. (2002), Girão Coelho et al., 2006 and Ribeiro et al., 2016. In order to model more realistic behaviour of materials, its complete description (including failure criteria) is required, either based on experimental procedures or numerical methods. In this respect, virtual tests carried out by means of numerical modelling are increasingly replacing some mechanical and physical tests to predict and validate their structural performance and integrity due to recent developments in software-based nonlinear finite element analysis methods, as example: Kang et al. (2015) and Liao et al. (2015). This includes the computational advances in fracture modelling. This approach represents a cost effective way of exploring new, adequate and cheaper solutions (Fig. 1).

Nomenclature

CTOD	Crack tip opening displacement
CDM	Continuum damage mechanics
FEM	Finite element method
PEEQ	Equivalent plastic strain
TRIAX	Triaxial stress state

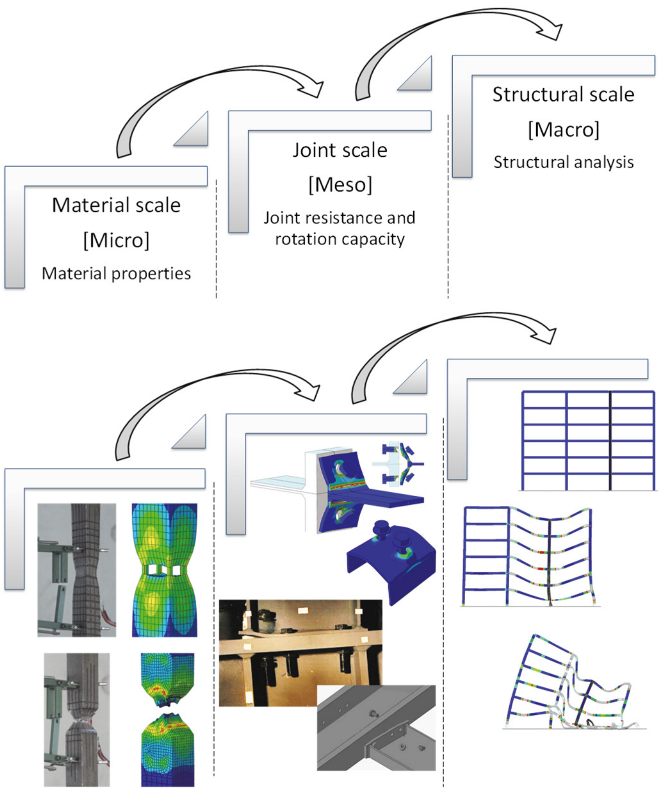

Fig. 1. Scale levels used on the design of steel structures.

Regarding the failure criteria, the use of micromechanical models based on void growth and coalescence seems like an attractive tool to evaluate conditions for ductile fracture initiation, Lemaitre (1992). These models are able to predict ductile fracture from fundamental mechanical principles, as a function of multiaxial stresses and plastic strains.