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Inelastic finite element analysis of lateral buckling for beam structures

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Abstract

The inelastic lateral–torsional buckling resistance of real I-beam loaded by uniform moment was the subject of parametric studies using nonlinear finite elements, covering various initial imperfections as initial axis curvature, material properties, residual stress, etc. The ANSYS software package was used. The finite element SOLID185 was applied to study the inelastic failures of beams. The finite element analysis considers both geometrical and material nonlinearities. The static inelastic resistance was calculated for various beam lengths, and compared with elastic resistance and with resistances based on the Eurocode buckling curves.

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Keywords: beam, inelastic stability, finite element, buckling, steel, imperfection, reliability, sensitivity.

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1. Introduction

The European buckling curves are based on large experimental and parametric measurement programs as well as on analytical, numerical and probabilistic investigations. Numerical verification of Eurocode buckling curves is constantly the topic [1]. The theory of thin-walled beams as developed by Vlasov [2] was used in numerous calculations aimed at the reliability study of thin-walled beams [3-5]. Analytic approaches enable a transparent insight into the beam behaviour, nevertheless, only a limited number of imperfections can be taken into consideration [6,7]. Initial imperfections such as residual stress may reduce the buckling strength of a steel member. Modern calculation models based on the finite element method (FEM) enable to take into account all the unavoidable initial imperfections [8,9]. FEM makes possible to study many modes of failures and instability of the beams. The stability problems of the beams with imperfections such as geometrical and material imperfections with

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residual stress should be investigated with use of both geometrical and material nonlinear solutions. Inelastic analysis should be applied especially if residual stress is present, and its values are significant.

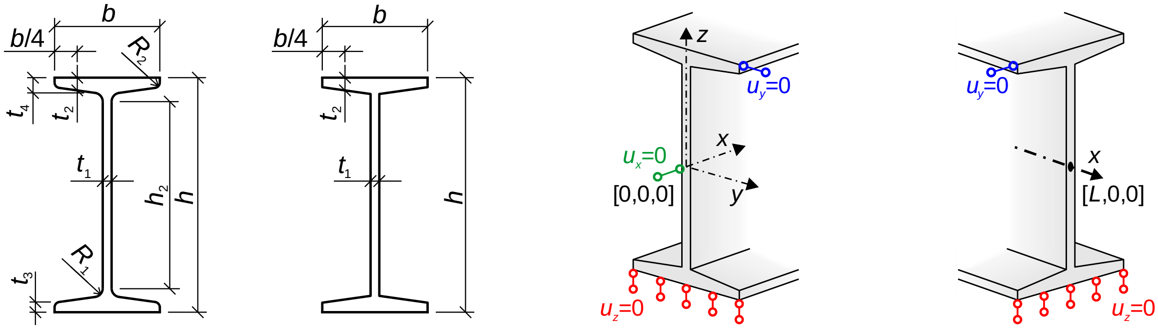
In general, the computer modelling of stability loss of the real beam is a very complex problem, for the solution of which, large knowledge must be broadly applied to. The more is FEM advanced, the more information must be assigned to model inputs. Large information on materials, and on geometrical imperfections was investigated into by experimental programmes [10,11], and was used in many reliability studies [12,13]. The size and shape of residual stress are permanently the topics of discussions concerning the stochastic character of this quantity [7,14]. The subject of the present paper is the inelastic lateral–torsional buckling (LTB) static resistance of real I-beam loaded by uniform moment.

2. Calculation models

Inelastic failures of the beam are analysed by means of the finite element SOLID185. The objective is to model the real beam, and to calculate its static resistance so, as if the real loading test were carried out in the laboratory. The advanced geometrical and material nonlinear calculation model is a powerful instrument for a very accurate calculation of static resistance of the beam.

2.1. Geometrical Imperfections and Boundary Conditions

The cross-section geometry characteristics of double-symmetric hot-rolled beam I200 of steel grade 235 are shown in the Fig. 1. Important geometrical sectional characteristics are h, b, t_1, t_2 and R_1 and R_2.



(a) (b) (c)

Fig. 1. Hot-rolled beam I200: (a) real cross-section, (b) idealized cross-section, (c) boundary conditions.

The beam is considered as simply supported and loaded at equal bending moment of opposite ends. The initial geometrical imperfection of beams is considered according to the first eigenmode of LTB. It consists of initial displacement of axis v_0 and of initial rotation of cross-sections φ_0. These imperfections are considered to be affine to the final shape as the functions sinus, v_0 being the curvature of the beam axis in the direction of major axis, i.e., in plane xy, and φ_0, rotation of cross-sections along the beam length L, see Fig. 2.

$$v_0 = a_{v0}\sin\left(\frac{\pi\, x}{L}\right), \quad \varphi_0 = a_{\varphi 0}\sin\left(\frac{\pi\, x}{L}\right) \tag{1}$$

If the beam is curved according to the first eigenmode, thus the amplitudes a_0 and $a_{\varphi 0}$ are:

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