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FEM Modelling of Lateral-Torsional Buckling using Shell and Solid Elements

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Abstract

The paper describes two methods of FEM modelling of I-section beams loaded by bending moments. Series of random realizations with initial imperfections following the first eigenmode of lateral-torsional buckling were created. Two independent FEM software products were used for analyses of resistance. At the end the difference and correlation between the results as well as advantages and disadvantages of both methods are discussed.

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Keywords: Imperfection; Beam; Steel; Lateral-torsional buckling; FE modelling; Stability

1. Introduction

The aim of the paper is to carry out a stochastic analysis of load-carrying capacity of steel beams subjected to bending. A series of simply supported IPE200 beams are analyzed with respect to lateral-torsional buckling, which is a stability phenomenon that occurs when an unrestrained member is subjected to moment loads. The analysis is carried out by using geometrically and materially nonlinear imperfect analyses (GMNIA) so the effects of all initial imperfections can be taken into account.

Two ways of modelling and carrying out the analysis of load-carrying capacity were chosen at both universities, the Czech one and the Danish one, respectively. The paper also compares the results from both working places and

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point out to the advantages and disadvantages of both approaches. The first and the second method use shell model in Abaqus software and solid model in Ansys software, respectively. Therefore, the model differences concern boundary conditions and ways of loading as well. Material model, residual stress distribution and initial geometrical imperfections are considered the same in both cases.

The analyses are performed for three values of non-dimensional slenderness: 0.3, 0.6 and 1.2. Initial random material characteristics and cross-section dimensions were generated using the Latin Hypercube Sampling method and they were identical for each slenderness. The geometrical imperfection has been $e_0 = L/1000$, a choice based on recommendations from [1] and practice used in developing the Eurocode buckling curves [2].

2. Computational model description

FE research was carried out for models of steel beams of the European double symmetric hot-rolled profile IPE200. Beams are simply supported with fork-end boundary conditions and they are loaded by bending moments M on both ends. This represents a case of pure bending.

2.1. Initial geometrical imperfection

The initial out-of-straightness imperfection is designed according to the first eigenmode of buckling. Thus, the initial imperfect shape includes as out-of-plane displacement v_0 as torsional imperfection φ_0, see Fig. 1.

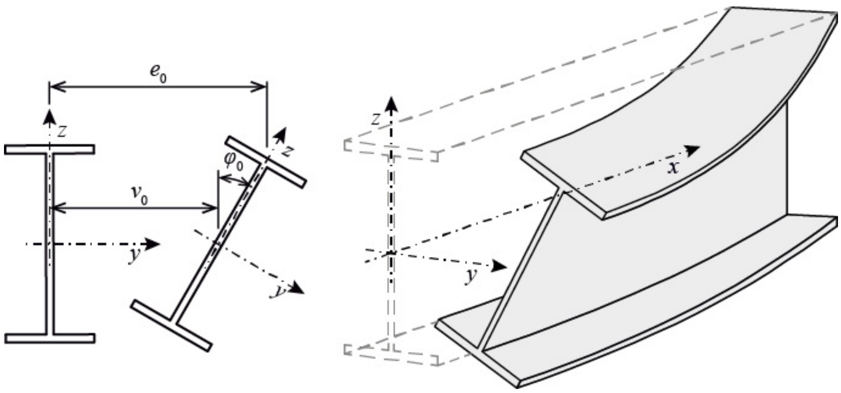

Fig. 1. initial out-of-straightness imperfection.

These imperfections are assumed to be affine to the deformed shape and to be shaped in sine wave form:

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

where a_{v0} and $a_{\varphi 0}$ are amplitudes given as

$$a_{v0} = \frac{e_0}{1 + \frac{h}{2}\frac{\pi^2 EI_z}{M_{cr}L^2}},\ a_{\varphi_0} = a_{v_0}\frac{\pi^2 EI_z}{M_{cr}L^2}, \tag{2}$$

where e_0 is the amplitude of deformation at mid-span, L is the span-length of the beam, h is the cross-section height, I_z is the second moment of area to the axis z, E is the Young's modulus of elasticity and M_{cr} is the elastic critical moment at lateral beam buckling, see e.g. [3].