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STRUCTURES WITH UGLI IMPERFECTIONS

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Abstract: *Derivation of the basic formulae for determination of the flexural buckling resistance of frames with members with non-uniform cross-sections and/or non-uniform axial compression forces. Similar formulae given in EN 1993-1-1 (2005) are limited to frames with uniform cross-sections and compression forces. Detailed description of the procedure of iterative calculation (Baláž, I., 2008). Graphical interpretation of the method proposed by the authors and numerical examples for members with uniform cross-sections and uniform axial compression forces.*

Keywords: ***stability, metal structures, flexural buckling resistance, imperfections in the form of first buckling mode.***

1. Introduction

The proposed procedure was the first time published in Baláž (2008) and was verified by calculating of several numerical examples. The procedure is based on Chladný`s method. Derivation of the basic formulae used in this paper differ from the ones published by Chladný in publication Baláž et al. (2007, 2010). The way of calculation proposed by Baláž (2008) was used also in PhD thesis written by Kováč (2010).

Prof. Chladný proposed his method the first time in 2000, and it was the first time accepted in draft prEN 1993-1-1 (5 June 2002). His contribution is acknowledged in publication (Sedlacek et al., 2004). See there item [52]. Chladný derived the formula for $e_{0,\mathrm{d}}$ and is the author of the method given in EN 1993-1-1 (2005), 5.3.2(11). He later generalized it also for non-uniform cross-sections and non-uniform compression forces. This generalization is used in STN EN 1993-1-1/NA (2007) and in EN 1999-1-1 (2007), 5.3.2(11). Chladný applied his method in design of bridges in practice, e.g. in design of basket handle arch type Apollo bridge in Bratislava, Pentele bridge in Dunaújváros and in investigations of continuous truss bridges. He further modified his method to be convenient for basket handle arch type bridges in the National Annex STN EN 1993-2/NA (2009). Chladný described details of his method and published numerical examples in Baláž et al. (2007, 2010).

2. Flexural buckling resistance of frames with non-uniform members and non-uniform compression normal forces

Flexural buckling resistance of the frame, which consists of members with variable cross-sections, with any boundary conditions, supports and/or variable foundation and under variable axial forces may be verified by the following condition

$$\left|\frac{N_{\mathrm{Ed}}(x)}{N_{\mathrm{Rd}}(x)}+\frac{M_{\mathrm{Ed,ugli}}^{\mathrm{II}}(x)}{M_{\mathrm{Rd}}(x)}\right|_{\max}\leq 1 \qquad (1)$$

where

$N_{\mathrm{Ed}}(x)$ is the axial force distribution, positive if compression, which is effect of the actions. The design values of the axial forces may be calculated by the 1st order theory,

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$M^{\mathrm{II}}_{\mathrm{Ed,ugli}}(x)$ is the bending moment distribution, which is the result of axial forces acting in members of frame having "unique global and local initial imperfection" („ugli" imperfection). The design values of this bending moment shall be calculated by the 2nd order theory. The „ugli" imperfection is an equivalent geometrical imperfection, which purpose is to cover in numerical model all imperfections (geometrical and structural) of real structure.

$N_{\mathrm{Rd}}(x)$ is the distribution of the axial force resistance depending on the cross-section class,

$M_{\mathrm{Rd}}(x)$ is the distribution of the bending moment resistance depending on the cross-section class.

The characteristics relating to critical cross-section, which is the cross-section relevant for assessment of flexural buckling resistance of the frame, are below denoted by index „ m ". The most onerous condition (1) occurring in critical cross-section „ m ", may be then rewritten in the form

$$\frac{N_{\mathrm{Ed,m}}}{N_{\mathrm{Rd,m}}}+\frac{M^{\mathrm{II}}_{\mathrm{Ed,ugli,m}}}{M_{\mathrm{Rd,m}}}\le 1 \tag{2}$$

The "ugli" imperfection is defined as follows

$$\eta_{\mathrm{ugli}}(x)=\eta_{0,\mathrm{ugli,m}}\eta_{\mathrm{cr}}(x) \tag{3}$$

where

$\eta_{\mathrm{cr}}(x)$ is the first elastic critical buckling mode, with the amplitude $|\eta_{\mathrm{cr}}(x)|_{\max}=1$.

$\eta_{0,\mathrm{ugli,m}}$ is the amplitude of „ugli" imperfection depending on characteristics of critical cross-section „ m ". Index „ 0 " will in this paper indicate that a value is amplitude of a deflection..

3. Conclusions

New very promising and useful method for design and verification of stability and flexural buckling resistance of metal members and frames with equivalent uniform global and local initial imperfections is presented. The original method was developed by Chladný and today is used in Eurocodes EN 1993-1-1 (2005) and EN 1999-1-1 (2007). It may be used also for frames with non-uniform cross-sections and/or non-uniform axial force distribution. In the paper new way of derivation of basic formulae of the method and clear step by step description of its application based on this derivation are presented. The original graphical interpretation of the method developed by authors is valid for frames with uniform cross-sections under uniform axial compression forces and enables to obtain very easy the maximum value of bending moment due to equivalent "ugli" imperfection. Several numerical examples show in details application of this method, which may be further developed and used also for lateral torsional buckling of beams.

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