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DEVELOPMENTS IN CZECHOSLOVAK SPECIFICATIONS FOR STEEL COLUMN DESIGN

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ABSTRACT

The current Czechoslovak design rules are based on Limit States Design philosophy. An "actual" column is considered, all initial imperfections being expressed by an equivalent initial curvature. The limiting state is given by that load which brings about an onset of yielding in the column. The revision of the Czechoslovak Specifications, which is under preparation, is likely to perform the first step from the deterministic concept to the probabilistic one. Two column curves, corresponding to two groups of steel profiles, are proposed.

1. INTRODUCTION

The current specifications for structural steel design in Czechoslovakia are based on Limit States Design philosophy, which was introduced in the entire area of civil engineering. The basis of the design concept is formulated in the document ČSN 73 0031 /1/, being common for all structural mateirals. According to it, the designer must consider two limit states :

(i) Limit State of Strength

This requires that the "maximum" loading effect shall be less or (at least) equal to the defined "minimum" strength of the structural element under consideration.

(ii) Limit State of Deformation

Requiring that the deformations, vibrations etc., corresponding to normal service conditions, shall be within permissible limits of serviceability. The objective of this contribution is to comment on the development of the criteria for the design of steel columns, related to the revision of the document ČSN 73 1401 "Structural Steel Design", which is under preparation.

2. COLUMN STRENGTH IN THE CURRENT CZECHOSLOVAK SPECIFICATIONS ČSN 73 1401

The ČSN specifications regard loading and resistance functions as independant variables, and define the "maximum" load effect and the "minimum" strength of the structural element under consideration /3/. The design procedure for steel columns is schematically demonstrated in Fig. 1.

For a particular slenderness ratio λ_1, the axial stress δ_V corresponding to the defined "maximum" axial force N_v (effect of factored loads, considering the simultaneous effect of several live loads) must be less or at least equal to the defined "minimum" load-carrying capacity of the column under consideration (curve y in Fig. 1).

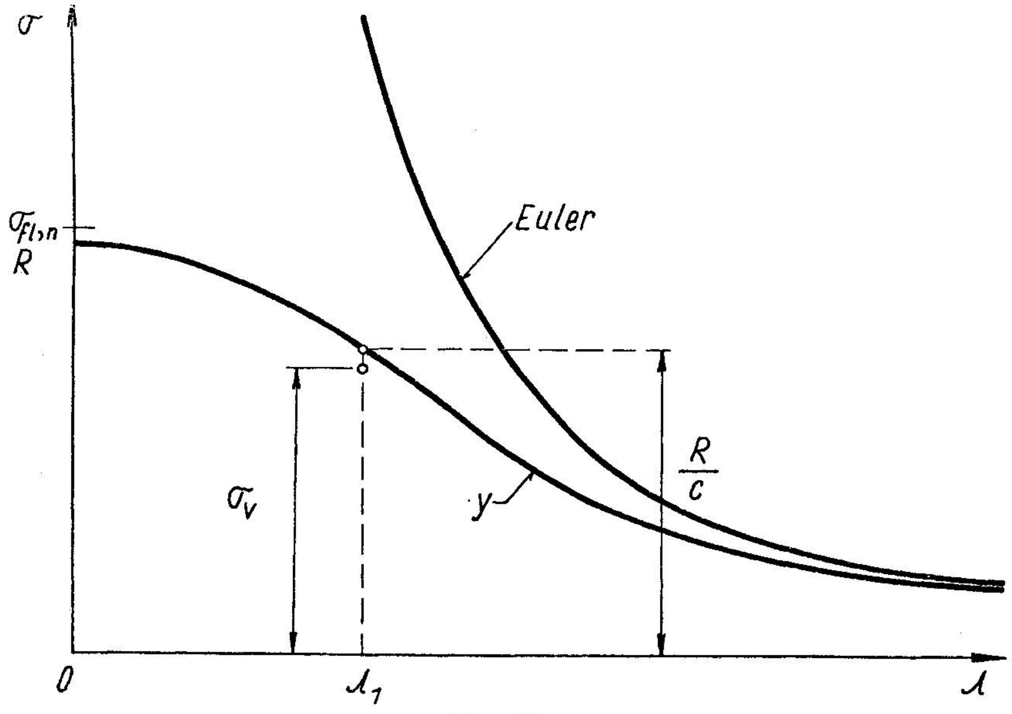

Fig. 1

The latter is related (i) to the s.c. "design stress" $R < \sigma_{fl,n}$ (where $\sigma_{fl,n}$ denotes the normative yield point stress, obtained from a statistical analysis of a population of experimental data with due regard to the selected probability, and considering the chance of underrolling of the column section), and (ii) to a "buckling coefficient" c. This can be written as follows :

$$\frac{N_V}{F} = \sigma_V \leq \frac{R}{c} = \frac{k\,\sigma_{fl,n}}{c}\,, \tag{1a}$$

or

$$c\,\frac{N}{F} = c\,\sigma_V \leq R = k\,\sigma_{fl,n}\,. \tag{1b}$$

F designates the area of the column cross section ; k is a non-homogeneity factor, relating R to the specified yield stress $\sigma_{fl,n}$.

3. BUCKLING COEFFICIENT c

The derivation of the "buckling coefficient" c is based (following Dutheil's concept) on the assumption of an "actual column", all initial imperfections being expressed by means of an equivalent initial curvature. The limiting state of the column is then given by that axial force which brings about the onset of yielding in the most loaded fibres of the column :

$$\bar{\sigma}_0\left(1+\frac{m_0}{1-\frac{\bar{\sigma}_0}{\sigma_{cr}}}\right) = \sigma_{fl}\,, \tag{2}$$

$\bar{\sigma}_0 = N_0/F$, $\sigma_{cr} = \pi^2 E/\lambda^2$, σ_{fl} denotes the yield stress and $m_o = e_o/j$; e_o designating the amplitude of the initial curvature and j the core radius of the cross section.

In the currently held edition of ČSN, the non-dimensional magnitude of m_o has been selected as a function of the second power of the slenderness ratio λ :

$$m_0 = 0.3\left(\frac{\lambda}{100}\right)^2 = \frac{622}{\sigma_{cr}}\,, \tag{3}$$

the aim being to allow for the fact that the load-carrying capacity of slender columns is more affected by initial imperfections than that of bulky ones /4/.

Then, by definition, the buckling coefficient

$$c = \frac{\sigma_{fl}}{\bar{\sigma}_0}\,; \tag{4}$$

$\bar{\sigma}_0$ follows from Eg. (2) :

$$\bar{\sigma}_0 = \frac{1}{2}\left[\sigma_{fl} + (1+m_0)\sigma_{cr}\right] - \sqrt{\frac{1}{4}\left[\sigma_{fl}(1+m_0)\sigma_{cr}\right]^2 - \sigma_{fl}\,\sigma_{cr}}\,. \tag{5}$$

4. TREND OF THE REVISION OF THE CZECHOSLOVAK DESIGN CONCEPT

The strength of a steel column depends on several random variables ; such as mechanical properties of the column material, residual stresses, crookedness, rate of loading etc. While the deterministic concepts (one of which forms the basis of the currently held Czechoslovak design rules) express the effect of all variables by just one or two factors, the probabilistic approach, applied recently by ECSSA, results from a large-scale experimental program and statistical evaluation of obtained data. The column curve (or curves) in the latter case is only a mathematical description of the "boundary" line defining the "minimum" strength.

It is the authors' opinion that more attention ought to be paid to the probabilistic concept in the design of steel columns in Czechoslovakia in the near future /6, 7/. Nevertheless, it is likely that the revision of ČSN 73 1401 under preparation will perform only a first step in this direction /8, 9/ ; this being due to the lack of experimental data relating to Czechoslovak steel profiles.

The main features of the aforesaid revision, proposed by Chalupa /9/ and the Czechoslovak Permanent Committee "Steel Structure Specifications", are as follows :

(i) The revised column curves will again be based on Dutheil's concept, a second-power relationship for m_o being introduced (*). Instead of (3), however, the formula

$$m_0 = 0.26\,\frac{\sigma_{fl}}{\sigma_{cr}} = 0.26\left(\frac{\lambda}{\lambda_{fl}}\right)^2 \qquad (6)$$

is going to be proposed. The introduction of $\lambda_{fl} = \pi\sqrt{E/\sigma_{fl}}$ enables the designer to use the formula for different steel grades.

(ii) Eq. (2) can be rewritten in the following way :

$$\left(\frac{\sigma_{cr}}{\bar{\sigma}_0} - 1\right)\left(1 - \frac{\bar{\sigma}_0}{\sigma_{fl}}\right) = \bar{a}. \qquad (7)$$

$\bar{a}$ denotes a "buckling characteristic", reflecting the interaction of σ_{cr} with σ_{fl}, which makes it possible to introduce more than one column curve.

Two column curves are proposed in the draft of the new ČSN ; they relate to

$\bar{a} = 0.17$ (tubes, etc.)

and

$\bar{a} = 0{,}26$ (other sections).

The reader will note that the aforementioned proposal is very similar to the first and second curves of ECSSA /10/, which correspond to $\bar{a} = 0.16$ and $\bar{a} = 0.27$.

(iii) The buckling coefficient c is likely to be presented merely for the most common steel grade 37 (see Table 1), whose yield stress $\sigma_{fl} = 2400$ kp/cm^2.

(*) Further consideration to this point will, however, be given. The writers also hope that this question will be discussed at the Paris Colloquium.

For other steels, it can be obtained in the same table, using, however, a reduced slenderness ratio

$$\lambda' = \lambda \sqrt{\frac{\sigma_{fl}}{2400}}$$

So, for example, for steel grade 52 (σ_{fl} = 3600 kp/cm^2 and λ = 100, the value of c is to be found for $\lambda = 100 \sqrt{3600/2400} = 122$.

5. SUMMARY

The currently held Czechoslovak Specifications ČSN - Section "Column Strength" is based on Dutheil's concept, a second-power relationship for an equivalent initial curvature being used.

In the preliminary draft of the Revised Edition of ČSN, two column curves, corresponding to two groups of sections ($\bar{a}$ = 0.17 and $\bar{a}$ 0.26) are proposed. This represents the first step from the "deterministic" concept to the "statistical" approach.

Table 1

λ	Steel grade 37	
	$\bar{a}$ = 0.17	$\bar{a}$ = 0.26
20	1.01	1.01
40	1.04	1.06
60	1.12	1.17
80	1.30	1.41
100	1.66	1.82
120	2.20	2.41
140	2.86	3.13
160	3.66	3.99
180	4.58	4.97
200	5.59	6.07

In the authors' opinion, in a near future, our design rules ought to be related closer to the results of experimental and probabilistic investigations ; more attention being paid to individual variables, particularly to the effect of residual stresses.

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