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THE MISSING HOLISTIC APPROACH IN DESIGN APPLICATION OF EUROCODE 3

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Abstract

Steel Eurocodes have an important role in the correct and adequate design of steel structures. Most of the programs, which are used for the static analysis of these structures take into consideration the information offered by the Eurocodes, thus giving the opportunity to entrust them with the task of solving those problems which are not clear and easily understandable for the user. As will be proven in this article, Eurocode 3 in some cases does not offer proper, clear explanations regarding some decisions. The main criticism for the whole Eurocode package is that the user might not see clearly the connection between the scattered parts of the final solution.

Keywords: *Eurocode 3, steel structures, cold formed steel shapes, interpretation.*

1. Introduction

The structural design of buildings using manual calculus methods in the 21st century is considered an “old fashioned approach”, because deadlines push the designers, who are therefore forced to use a faster method, which means the use of static analysis programs. The question is: will an unexperienced recently graduated civil engineer be able to understand the results given by these programs? The process behind the scenes, running in that specific “black box”, the method used for analysis, and the decisions that the program is taking on our behalf, would mean hours of work using plain, manual calculus. What kind of obstacles do we encounter if we try to analyse a steel structure according to Eurocode 3? Authors search for answer to these questions using a 3D structural model represented in **Figure 1.**

2. Description of the structure

The transversal frames of the structure are made of thin – walled back-to-back C profiles. From a geometrical point of view the span of the structure is 12m, the distance between the frames is 4m and the eave height is 4m **[1]**.

The thin – walled, cold formed steel profiles (**Figure 2.**) were treated as class 4 sections, thus increasing the number of regulations, which have to be satisfied, since local buckling and distortion had to be taken into consideration. In this case it is necessary to use the first **[2]** and third part **[3]** of Eurocode 3.

The choice of the frame (**Figure 3.**) depends on its degree of utilization.

3. Resistance and stability checks according to Eurocode 3

The resistance check of the sections can be performed quite easily according to Eurocode 3, if the effective geometrical properties of the section are provided in special catalogues published by producers. Without effective cross section properties, the resistance checks also become more difficult.

Following the first part of Eurocode 3, which includes the procedure for stability resistance check of the structural bars (Figure 4), design engineers might expect an integrated image of the stability check process, however the broken mosaic pieces do not always match.

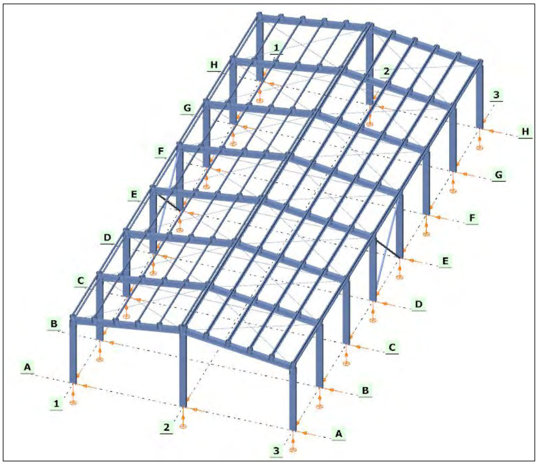


Figure 1. *3D structure*

Eurocode 3, during the process of global elastic analysis leads through a series of calculus, using the reduction factors that offer two approaches, which can be used: the method of equivalent structural element and the general method. For using the general case, the finite element method is recommended.

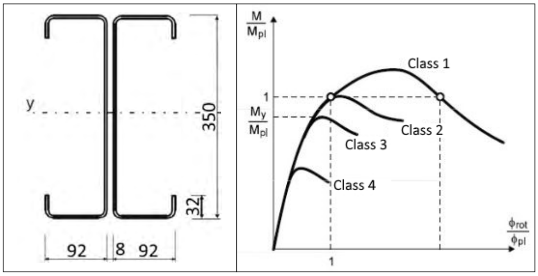
The equivalent structural element method assumes the extraction of the analysed individual element from the real structure with the boundary conditions coming from the 3D structure, which requires the equivalent structural element's buckling length that gives the real structure's stability check results. In other words, the accuracy of the approach lies in the correct evaluation of the buckling length. In Eurocode 3 there is no reference to the buckling lengths of bars or to any other Eurocodes, regarding this matter. This may lead to misunder-standings and confusion, therefore incorrect values might be used in further calculus by the design engineer.

4. Case study

In the analysis process the different buckling lengths chosen for the thin – walled column, which is presented in **Figure 3.** have a great influence on the degree of utilization of the structural element.

To represent the above mentioned situations, simple calculations were performed according to Eurocode 3. Let us consider that the column is subjected to NEd=500 kN pure compression.

The design buckling resistance of a compression member can be obtained according to clause 6.3.1 of EN 1993-1-1 [2] from the following equation:



a) b)

Figure 2. *a) 2C350/3 profile;*
b) Bending moment– rotation curve **[4]**

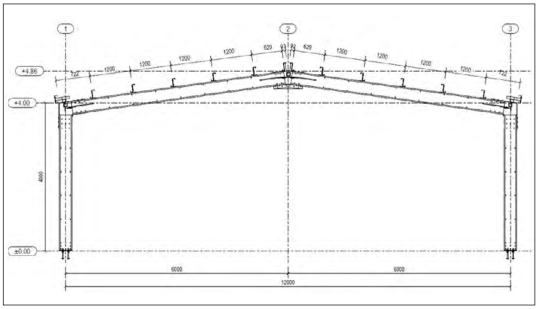


Figure 3. *Frame made of thin–walled, cold formed profiles*

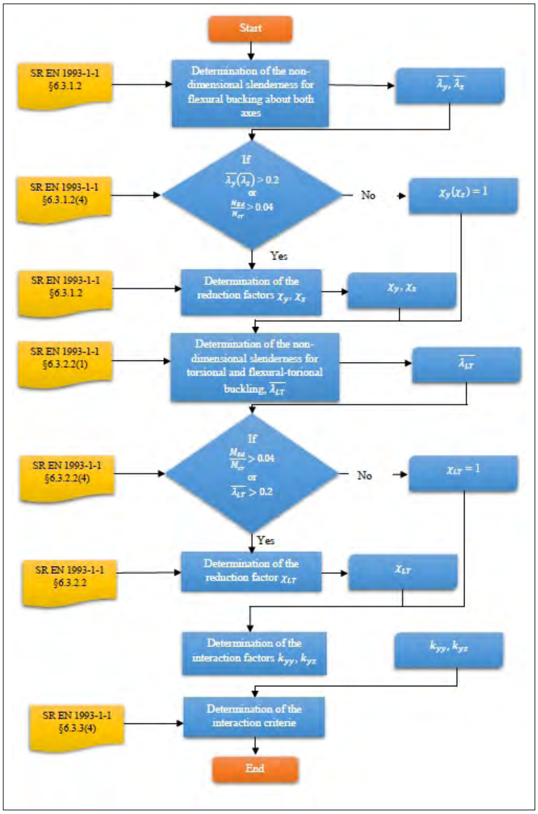


Figure 4. *The process of stability check*

$$N_{b,Rd} = \frac{\chi \cdot A_{eff} \cdot f_y}{\gamma_{M1}} \tag{1}$$

The buckling length is half the height of the column ($L_{eff} = L_o = 2000$ mm) in its plane and in the plane perpendicular to it:

$$L_{eff,y} = 0.5 \cdot L_o = 2000\ mm \tag{2}$$

$$L_{eff,z} = 0.5 \cdot L_o = 2000\ mm \tag{3}$$

$$N_{Ed}/N_{b,Rd,y} \cdot 100 = 77.51\% \tag{4}$$

$$N_{Ed}/N_{b,Rd,z} \cdot 100 = 87.99\% \tag{5}$$

The buckling length is 70% of the column's height ($L_{eff} = L_o = 2800$ mm) in the plane of the frame and in the perpendicular plane:

$$L_{eff,y} = 0.7 \cdot L_o = 2800\ mm \tag{6}$$

$$L_{eff,z} = 0.7 \cdot L_o = 2800\ mm \tag{7}$$

$$N_{Ed}/N_{b,Rd,y} \cdot 100 = 78.50\% \tag{8}$$

$$N_{Ed}/N_{b,Rd,z} \cdot 100 = 98.52\% \tag{9}$$

The buckling length is equal to the height of the column ($L_{eff} = L_o = 4000$ mm) in the plane of the frame and in the perpendicular plane:

$$L_{eff,y} = L_o = 4000\ mm \tag{10}$$

$$L_{eff,z} = L_o = 4000\ mm \tag{11}$$

$$N_{Ed}/N_{b,Rd,y} \cdot 100 = 80.08\% \tag{12}$$

$$N_{Ed}/N_{b,Rd,z} \cdot 100 = 127.11\% \tag{13}$$

The buckling length is doubled to the height of the column ($L_{eff} = L_o = 8000$ mm)) in the plane of the frame and in the perpendicular plane:

$$L_{eff,y} = L_o = 8000\ mm \tag{14}$$

$$L_{eff,z} = L_o = 80\ mm \tag{15}$$

$$N_{Ed}/N_{b,Rd,y} \cdot 100 = 87.60\% \tag{16}$$

$$N_{Ed}/N_{b,Rd,z} \cdot 100 = 353.95\% \tag{17}$$

When buckling occurs in the plane of the frame, a difference of 11-12% can be observed, while in the case of buckling along the plane perpendicular to the frame the difference in the results is 30-31%. This means that the incorrect choice of buckling length might result in values, which are acceptable according to the Eurocode, but in fact it exceeds the admissible limits.

5. Determination of interaction factors using two approaches

When performing the stability check taking into consideration the effects of the buckling and

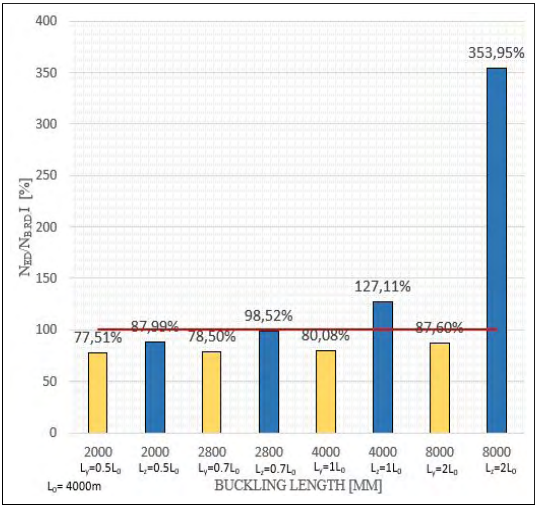


Figure 5. *The influence of different buckling lengths on the degree of utilization of the members*

torsion, it is necessary to determine the critical bending moment. As in case of buckling length, there is no formula provided in Eurocode 3 for the calculation of the critical moment. The determination of the critical bending moment, through formulas, can be done based on Annex I, included in Eurocode 9.

Besides the determination of the critical bending moment, another problem could be the identification of the interaction factors, by using two distinct methods, recommended by Eurocode 3, which at first might look similar. As mentioned in the handbook „Szerkezetépítés II." by Ferenc Papp, Ph.D [5]] the „Method 1", developed by a French-Belgian work team, provides a continuous transition from the cross – section resistance to the stability resistance. Meanwhile, the other procedure known as „Method 2", refined by a German–Austrian group, assures simple, easily understandable formulas, meanwhile the relationship between the resistances is not sophisticated.

The values of the interaction factors determined by using the two approaches, resulted in the following:

„Method 1" takes into consideration the critical forces in different buckling cases, on the contrary to „Method 2", produced the outcome of $k_{yy} = 0.95$.

Following the steps of „Method 2" the interaction factor results in $k_{yy} = 0.62$.

Comparing the approaces, the difference between the two results achieves 34 – 35%

6. Conclusions

The literature volume used for the deeper analysis of the structure's behaviour, with the exclusion of the Eurocodes, exceeds the number of twenty – thirty documents in different languages, having various lengths.

With the help of these publications it was possible to match the scattered mosaic pieces, enabling us to create an integrated image of how the process of manual verification of the structure works.

By following the process offered by Eurocode 3, one might encounter such problems that require decision making based on experience or engineering intuition. Having no experience, remains the intuition, which is similar to gambling based on good luck.

Because of these uncertainties, the results might be doubtful and at a certain point the practicing engineer might be led into a dead-end. The next generation of Eurocodes should concentrate on the holistic approach, offering a more stable support for practical engineers in design activity.

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