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Some Features of the European Norm for Cold-Formed Steel Design in comparison with the AISI Specification

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1 Introduction

In this paper a brief summary is given of the new European design standard for cold-formed steel members in comparison with the relevant North American (AISI) specification. The paper is prepared on the basis of a presentation by the authors, see Ádány and Schafer (2004). This summary does not aim, and it would not be possible in only a few pages, to provide a detailed and comprehensive overview on either the European or the North American specification. Instead, our goal is to highlight some of the basic features of the Eurocode, as well as to point out some key differences between the two specifications. To fulfill this goal, a short introduction to the Eurocodes is given, followed by a comparative table of selected regulations for the European and North American specifications. Finally, an illustrative numerical example is provided to show how different the actual member resistances can be when following the different code provisions.

2 The Eurocodes and NAS

"Eurocode" (EC) is a summarizing name of a series of structural engineering design standards. Among others, EC0 is for general provisions, EC1 for loads, EC2 for concrete structures, EC3 for steel structures, EC4 for composite structures, etc. Each EC has several sub-parts. In EC3, Part 1.1 is for general rules on steel structures, while, what is more important for now, Part 1.3 is for cold-formed steel design. It is important to emphasize that all the series of Eurocodes are not "ready," but instead are continuously developing and evolving documents, each part being in its own phase, some in a very preliminary phase, while others are closer to their final form. The comparison and the calculations presented here are based on a particular draft version, see EC3 (2002), since no final version is yet available.

The North American Specification (NAS) for cold-formed steel design, formerly the AISI Specification, is also constantly evolving. However, more formal versions are available with the most recently approved version being the 2001 version of the NAS. Based on building code adoption, at this time, the 1996 version of AISI is still probably the most commonly used. Comments regarding the NAS in the summary table that follow refer to the 2001 version of NAS, unless otherwise specifically stated.

3 Comparison at a glance

A brief comparison of the EC and NAS can be found in Table 1. All interpretations in the tables are those of the authors and do not represent official interpretations of the Eurocode or NAS committees.

Topic	EC3	NAS
Geographic target work	Multiple countries in Europe.	USA, Canada and Mexico
National specialties	Can be considered by the application of National Annexes.	Can be considered by the application of National Annexes.
Design Basis	Limit State Design (LSD)	Allowable Strength Design (ASD) and Load and Resistance Factor Design (LRFD) in USA, and Mexico; Limit State Design (LSD) in Canada
Plate Thickness	0.45 mm $\leq t_{cor} \leq$ 15 mm	$t_{cor} \leq$ 1 in. (25.4 mm)
Sections with longitudinal intermediate stiffeners	Intended to cover and mostly covered	Covered for intermediate stiffeners in flnges of members, but not webs
Standard materials	60+ standardized materials	ASTM materials
Yield strength	32 to 101 ksi	Maximum f_y = 80 ksi, but for special cases only
Non-standard materials	Allowed if certain requirements are satisfied. The requirements are given in the code in detail.	Limited provisions for “other steels”.
Effect of cold hardening	Can be taken into consideration, for fully effective sections (EC and NAS formulae are different).	Can be taken into consideration, for fully effective sections
Effect of rounded corners	Fictitious plane elements are introduced. Can be approximated by sharp corners if the inner radius is less than 5*t*.	Corner part (which is always fully effective) is treated separately from the flats.
Upper limit for corner radius	Exists: 0.04 $t\,E\,/\,f_y$.	None.
Geometrical limits	Width-to-thickness ratios of plates. Width-to-thickness rations of lips. Inclination of webs. Web height-to-thickness ratios.	Flat-width-to-thickness ratios of plates Web depth-to-thickness ratios. (the given limit values are similar to the correspondin EC limit values)
Handling local buckling	Effective width approach.	Effective width approach.
Effective width calculation	Winter formula (modified for outstand elements and elements with stress gradient).	Winter forumla (modifications may be adopted for unstiffened elements in a future NAS).
Distortional buckling	Must be considered, by thickness reduction of the effective part of stiffeners.	Not explicitly considered in NAS (2001). May be handled by Appendix 1 in a future NAS.
Hand-formulae for distortional buckling	Included for C/Z sections, but the proposed procedure is computationally demanding, including iterations.	Not included.
Rational analysis	Allowed in general, encouraged for sections other than C/Z, however, only very brief guidance is given for the numerical analysis.	New to NAS (2001) rational analysis is allowed and constant safely and resistance factors are provided.
Column buckling resistance	European multiple buckling curves (3 curves).	Single buckling curve.
Flexural, torsional, flexural-torsional buckling	All are included. Guidance for the effective length factors is given	Included, with little guidance on K.
Bending resistance of a cross-section.	Generally, it is calculated on the effective cross-section with the basic yield strength. If fully effective, cold hardening and/or partial plastic deformations are allowed. If not fully effective, plastic deformations are allowed in the tension side only.	Similar, except for cross-section subject to lateral-torsional buckling the effective section is calculated at the lateral-torsional buckling stress (instead of the yield stress).
Lateral-torsional buckling	Cross-sectional bending resistance is reduced. (similar but different buckling curve is used than for column buckling)	Single curve is used for predicting the lateral-torsional buckling strength of a fully effective section.
Local-global buckling interaction	The maximum stress for effective width calculation is assumed to be equal to the yield strength (with safety factor). The member resistance is calculated on the effective cross-section. The buckling length is reduced to consider local buckling	The effective section is calculated at the global buckling stress, not f_y. The member resistance is calculated on the effective cross-section. The buckling length is calculated directly from the critical stress.
Torsion	Von Mises stress must be calculated. (both St. Venant and warping stresses should be considered) For axial force and bending moments: effective section must be used, for torsion and shear: gross section is used. Considering cold hardenting effect and certain plastic deformations are allowed.	Currently no specific guidance.
Crippling	Empirical formulae. Sections with longitudinal web stiffeners are handled	Empirical formulae, updated extensively recently.

Table 1: Brief comparison of EC3 and NAS

Topic	EC3	NAS
Shear	Sections with longitudinal web stiffeners are handled.	Basic formulae only.
Serviceablilty Limit State	Guidance is given, actual limit values must be agreed with the client. In calculation of deflections a fictitious moment of inertia is proposed, interpolated from gross and effective inertia.	Method for defletion calculations is generally provided, no guidance given on limiting values or other serviceability issues.
.Design assisted by test	Allowed, detailed rules are given in general, and for specific purpose tests.	For strength determination, traditionally either design formula are used, or testing is used, without mixing.
Beams restrained by sheeting	Detailed calculation method is provided. Simplified method also exists	Design by test.

Table 1: Brief comparison of EC3 and NAS (continued)

4 Numerical example

To illustrate the differences between the EC3 and NAS, the bending moment resistance of a typical C-section is calculated according to both standards. The cross-section is selected in accordance with Schafer and Trestain (2002). The main dimensions are shown in Figure 1 (a). Figure 1 (b) and (c) demonstrate the main characteristics of the calculated effective sections. Note, Figure 1(c) corresponds to the method given for $h_0/b_0>4$ as the NAS has different methods for the web effective width for h_0/b_0 less than or greater than 4. As it can be seen, the effective sections of EC3 and NAS (method for $h_0/b_0>4$) are basically similar, although small differences exist as follows:

- Slightly different ineffective part both in the flange and in the web,
- Different handling of corners (in Eurocode: notional flat elements, in NAS: rounded corners plus the real flat parts),
- Reduced plate thickness for the edge stiffener (in Eurocode only).

It can easily be proved that the first two of the above-mentioned differences have only minor effect (within 1-2%), thus, the most important difference is the stiffener thickness which is reduced by the Eurocode to account for distortional buckling, This is the primary reason why the EC3 calculation results in a 6% smaller bending moment resistance in the example. Note too, that the difference between EC3 and NAS method for $h_0/b_0=4$ is even greater (17%).

As recent experimental research has shown, neither the EC3 nor the NAS results are particularly exact when failure is governed by distortional buckling, both specifications being slightly unsafe, see Ádány, Yu and Schafer (2004). Nevertheless, EC3 resistance prediction is generally closer to test results. Details of the calculation for Z and C sections according to EC3 are given in Ádány (2003).

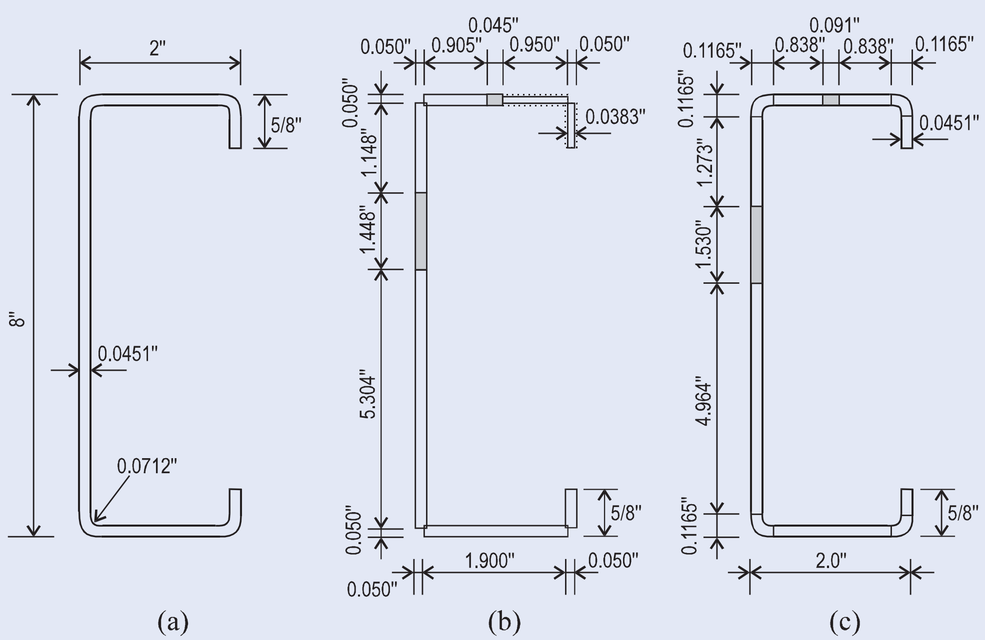

Figure 1: Gross and effective cross-sections

	EC3	NAS ($h_0/b_0 > 4$)	NAS ($h_0/b_0 \leq 4$)
Moment Resistance (kips-in)	35.60	38.30	42.66

Table 2: Calculated moment resistance

5 Conclusions

While the Eurocode and North American Specification share many basic similarities fundamental differences have emerged over time. Neither code is particularly easy to apply, but the Eurocode provisions even for standard C and Z sections are more onerous than the North American Specification. At the same time, Eurocode's treatment of a wider range of materials, explicit methods for distortional buckling, torsion, longitudinal web stiffeners, design augmented by testing, and other provisions provide a richer (and more complicated) array of potential solutions to the engineer. For those wishing to practice cold-formed steel design in Europe a steep learning curve awaits, but in some situations the ability to handle unique cross-sections and situations may make the extra work worthwhile.

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