
Théodore Gautier L. J. Bikoko 1, Jean Claude Tchamba 2

1 School of Civil and Environmental Engineering, University of The Witwatersrand, Johannesburg, South Africa
2 Civil Engineering Laboratory, ENSET, University of Douala, P.O. Box: 1872, Douala, Cameroon

Abstract: Nowadays; design, fabrication and erection of steel structures can be taken place at different locations as a result of rapid globalization; owners may require the use of widely accepted steel design codes. Therefore, engineers are faced with the challenge of being competent with several design specifications for a particular material type. The South African/Canadian Standard (SANS 10162-1:2005/CAN/CSA-S16-01:2005), European code(Eurocode 3) and Australian/New Zealand (AS4100:1998/NZS3404:1997) standard are accepted steel structure design specifications that utilize limit state principles with some similarities and differences in application. Hereby a study has been undertaken to identify the similarities and the differences presented in these standards/codes through steel column design buckling resistance. Classification of cross-sections, effective lengths, column buckling curves and a worked example are considered in this paper. The results show that the differences in capacity between codes vary with the slenderness ratio of the column.


I. Introduction

During last two decades many changes had occurred in the science of Structural Engineering. Knowledge of structural theory had expanded and the use of computer aided design has encouraged greater sophistication in the analysis of steel structure in the elastic and inelastic range. Also steel quality and constructional methods are continually being improved and these factors help in development of “rational design technique”. Design in steel used to be regarded as a “black art” where one only reached a level of competence after 20 years of hard work experience. Whilst, of course, experience is still very important, the designer is now much better supported and is able to be more accurate. Computers have made routine, levels of analysis that would otherwise have taken much manual calculation much easier. Codes of practice have become more comprehensive.

In Europe, “Design of Steel Structures, EN 1993(2003)” was developed by the European Committee for Standardization. This specification, hereafter referred to as EC3, is based on limit state principles using partial safety factor ($\gamma_M$). In general, the characteristic strength is divided by a partial safety factor and then compared with the factored loads.

The Canadian Standard on limit states design of steel structures was developed in collaboration with the South African SANS 10162-1, as a result of an initiative by and cooperation between the Canadian Institute of Steel Construction and the Southern African Institute of Steel Construction. The outcome is an identical standard being applied in both countries. The Canadian standard was reaffirmed in 2007, with some changes. None of these changes affect the clauses under consideration.

The New Zealand standard on steel structures, NZS 3404:1997 was published jointly with the Australian standard on steel structures, AS 4100:1998.


The cross-sections classification is compared. The effective lengths and the buckling curves are also compared. In order to illustrate what has been said below a worked example is proposed. Results and discussion are presented. Finally, conclusions for this research are given.
II. Classification of Cross Sections

The definitions of cross-sections in SANS 10162: 1-2005/ CAN/CSA-S16-01:2005, Eurocode 3 and AS 4100:1998/NZS 3404:1997 codes have similarities. The classification of a specific cross-section in SANS 10162: 1-2005/ CAN/CSA-S16-01:2005, Eurocode 3 and AS 4100:1998/NZS 3404:1997 codes depends on the width-to-thickness ratio and the material yield strength, $f_y$, of each of its compression members. SANS 10162: 1-2005/ CAN/CSA-S16-01:2005, Eurocode 3 and AS 4100:1998/NZS 3404:1997 gives the formulation to calculate the effective dimensions of class 4 (slender) section and subsequently specify the corresponding design strength formulae for class 4 (slender) sections. Eurocode 3 specifies the limiting width-to-thickness ratios for class 1, class 2, class 3 and class 4 cross sections whereas in SANS 10162: 1-2005/ CAN/CSA-S16-01:2005 we have to just check that the section doesn’t fall in slender class (class 4) so that whole cross sectional area is effective in compression (see in Table 1 and Table 2 the limiting values to Eurocode 3 for each class and SANS 10162: 1-2005/ CAN/CSA-S16-01:2005 for sections other than class 4 respectively).

Table 1. (a)(Sheet 1 of 2): Maximum width-to-thickness ratios for compression parts (Eurocode 3),
(b) (Sheet 2 of 2): Maximum width-to-thickness ratios for compression parts (Eurocode 3).


<table>
<thead>
<tr>
<th>Description of element</th>
<th>Maximum width-to-thickness ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flange of I-sections, T-sections, and channels</td>
<td>$\frac{b}{t} \leq \frac{200}{\sqrt{f_y}}$</td>
</tr>
<tr>
<td>Webs supported on both edges</td>
<td>$\frac{b}{t} \leq \frac{670}{\sqrt{f_y}}$</td>
</tr>
</tbody>
</table>

It should also be emphasized that minor differences in the width-thickness ratio definitions are also present. For example, in SANS 10162: 1-2005/ CAN/CSA-S16-01:2005 and AS 4100:1998/NZS 3404:1997 half the flange width is used in determining the flange slenderness. In Eurocode 3, however, only the outstanding portion of the flange that is measured from the toe of the fillet is used in calculations.

III. Effective Lengths (Buckling Lengths) and The Column Buckling Curves

Eurocode 3 gives no direct guidance on calculating the buckling length. In SANS 10162: 1-2005/CAN/CSA-S16-01:2005 in variation between 0.65 and 2.0 would apply to the majority of cases likely to be encountered in actual structures whereas in AS 4100:1998/NZS 3404:1997 in variation between 0.7 and 2.2 would apply as well. Figure 1(a) and Figure 1(b) illustrates six idealized cases to SANS 10162: 1-2005/CAN/CSA-S16-01:2005 and AS 4100:1998/NZS3404:1997 respectively.

![Figure 1](image1.png)


To take into account the various imperfections (lack of verticality, lack of straightness, lack of flatness, lack of fit, eccentricity of loading, residual stresses etc.) which the Euler formula does not allow for, SANS 10162: 1-2005/CAN/CSA-S16-01:2005, Eurocode 3 and AS 4100:1998/NZS 3404:1997 uses the Perry-Robertson approach (Ayrton and Perry 1886; Robertson 1925).

Figure 3 shows the column buckling curves; it presents the strength reduction factor, $\chi$ as a function of the non-dimensional slenderness, $\lambda$ to Eurocode 3. The figure 3 indicates that increasing the non-dimensional slenderness reduces the strength reduction factor of the columns. Figure 4 shows the buckling curves and defines the parameter $(n)$ used to take into account the column imperfections to SANS 10162: 1-2005/CAN/CSA-S16-01:2005. Figure 5 shows the buckling curves and the variation of slenderness reduction factor, $\alpha_c$ with modified slenderness ratio, $\lambda_m$ as given in the Australian/New Zealand standard. It indicates that increasing the modified slenderness ratio reduces the slenderness reduction factor of the columns.

Two column strength curves are given in SANS 10162: 1-2005/CAN/CSA-S16-01:2005 whereas five separate curves are presented in Eurocode 3 and in AS 4100:1998/NZS 3404:1997 (see in Fig. 3, Fig. 4 and Fig. 5 column buckling curves to Eurocode 3, SANS 10162: 1-2005/ CAN/CSA-S16-01:2005 and AS 4100:1998/NZS3404:1997 respectively).

Eurocode 3 utilizes an imperfection coefficient $(\alpha)$ to distinguish between different column strength curves. For flexural buckling, five cases termed as $\alpha_a, \alpha_b, \alpha_c, \alpha_d$ (see Fig. 3) are given for which the $\alpha$ values are 0.13, 0.21, 0.34, 0.49, and 0.76, respectively. The choice as to which buckling curve to adopt is dependent upon the geometry and material properties of the cross section and upon the axis of buckling. The rules for selecting the appropriate column strength curve are tabulated in Table 6.2 of Eurocode 3. Hereby the appropriate column strength curve is presented in Table 3 of this paper.
Figure 3: Eurocode 3 Part 1.1 buckling curves -Structural Steel Design: Eurocodes and Deformation Based Approach (CSM). Presentation at School of Civil and Environmental Engineering, University of The Witwatersrand (Gardner, 2011).

Table 3. Selection of buckling curve for a cross-section (Extract from Table 6.2 of EN 1993-1-1).

SANS 10162: 1-2005/ CAN/CSA-S16-01:2005 utilizes a parameter \( n \) (see Fig. 4) to take into account the column imperfections. For flexural buckling, \( n = 1.34 \) (for hot-rolled, fabricated structural sections, and hollow structural sections manufactured according to SANS 657-1/CSA Standard G40.20, class C); or 2.24 (for doubly symmetric welded three-plate members with flange edges oxy-flame-cut and hollow structural sections manufactured according to ISO 657-14/CSA Standard G40.20, class H).

Figure 4: SANS 10162-1:2005/CAN/CSA-S16-01:2005 buckling curves (CSA, 2005).
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AS 4100:1998/NZS 3404:1997 uses a member section type constant ($\alpha_b$) (see Fig. 5) ($\alpha_b = -1, -0.5, 0, 0.5, 1$) to allow for imperfections. The value of this constant varies according to the member type (hot-rolled, cold-formed, welded, etc).


IV. Worked Example

4.1. General

To compare the design buckling resistance between codes it is best to consider same section with same properties; same steel grades; same effective lengths; same modulus of elasticities and same shear modulus.

4.2. Example

Determine the design buckling resistance of a PFC 180x70 SA parallel flange channel section, Grade 300W steel. Assume the effective length is 2000mm. Take modulus of Elasticity $E= 200 \times 10^3$ N/mm$^2$ and shear modulus $G= 77 \ 000$ N/mm$^2$.


Section properties of PFC 180x70 SA Parallel Flange Channel:

- $A = 2.68 \times 10^3$ mm$^2$
- $h_w = 136$ mm
- $h = 180$ mm
- $b = 70$ mm
- $t_w = 7.0$ mm
- $a = 43.5$ mm
- $a_1 = 21.5$ mm
- $r_x = 71.0$ mm
- $r_y = 21.8$ mm
- $I_x = 13.5 \times 10^6$ mm$^4$
- $I_y = 1.27 \times 10^4$ mm$^4$
- $C_w = 6.52 \times 10^9$ mm$^6$
- $J = 82.3 \times 10^3$ mm$^4$

Calculation of the elastic critical buckling stress in axial compression ($f_{ex}$):

The elastic critical buckling stress in axial compression for $x$-x and $y$-y axis flexural buckling are determined, by the following expressions:

- $f_{ex} = \frac{\pi^2 E}{(\frac{r}{L})^2} = 2482$ Mpa
- $f_{ey} = \frac{\pi^2 E}{(\frac{r}{L})^2} = 235$ Mpa respectively.

where $E$ is the Young’s modulus, $K$ the effective length factor, $L$ the actual length of the column and $r$ the radius of gyration about $x$-x or $y$-y axis.

- $f_{ex} = \frac{\pi^2 E C_w}{(K L^2) b} + \frac{G J}{1 - \frac{K L^2}{A t_w}} = 481$ Mpa

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is the elastic critical buckling stress in axial compression for torsional buckling in which $E$ is the Young’s modulus, $C_w$, the warping torsional constant, $KL$ the effective length, $G$ the shear modulus, $I$ St. Venant torsional constant, $A$ the area of cross-section and $r_o^2$ the polar radius of gyration.

$$\Omega = 1 - \left[ \frac{x_0^2 + x_1^2}{r_o^2} \right] = 1 - \frac{x_0^2}{r_o^2} = 0.745$$  \hspace{1cm} (4)

is the factor which takes into account the position of the shear centre relative to the centroid of the cross-section as well as the radius of gyration.

$$f_{exc} = \frac{f_{exy} + f_{ez}}{2\Omega} \left[ 1 - \sqrt{1 - \frac{4f_{exy} f_{ez}}{(f_{exy} - f_{ez})^2}} \right] = 455 \text{ Mpa}$$  \hspace{1cm} (5)

is the flexural-torsional buckling stress.

$f_e = \min(f_{ex}, f_{ez}) = 235 \text{ Mpa}$  \hspace{1cm} (6)

is the elastic critical buckling stress in axial compression.

Therefore the factored compressive resistance of member ($C_r$) is:

$$C_r = \Phi A f_y (1 + \lambda^2 n^{-1/n})$$  \hspace{1cm} (7)

where $\lambda = \frac{x_0}{r_o} = 1.130; \Phi = 0.9; A = 2.68 \times 10^3 \text{ mm}^2; f_y = 300 \text{ Mpa} \text{ and } n = 1.34.$

$C_r = 0.9 \times 2.68 \times 10^3 \times 300 \times 10^{-3} \times (1 + 1.130^2 \times 300^{-1/1.34})$

$\therefore C_r = 378 \text{ kN}$

4.4. Solution by Eurocode 3 Method

Section properties of PFC 180x70 SA Parallel Flange Channel:

$A = 2.68 \times 10^3 \text{ mm}^2 \hspace{0.5cm} d = 136 \text{ mm} \hspace{0.5cm} h = 180 \text{ mm}$

$b = 70 \text{ mm} \hspace{0.5cm} t_f = 10.9 \text{ mm} \hspace{0.5cm} t_w = 7.0 \text{ mm}$

$r = 12 \text{ mm} \hspace{0.5cm} I_y = 13.5 \times 10^6 \text{ mm}^4 \hspace{0.5cm} I_z = 1.27 \times 10^6 \text{ mm}^4$

Calculation of reduction factor ($\Phi$):

The elastic critical buckling loads for $y$-y and $z$-z axis are given by:

$$N_{cr,y} = \frac{\pi^2 E I_y}{2 k_{cr}} = 6667347 \text{ N}$$  \hspace{1cm} (8)

and

$$N_{cr,z} = \frac{\pi^2 E I_z}{k_{cr}} = 627224.5 \text{ N}$$  \hspace{1cm} (9)

respectively.

$$\lambda_y = \sqrt{\frac{A f_y}{N_{cr,y}}} = 0.347$$  \hspace{1cm} (10)

and

$$\lambda_z = \sqrt{\frac{A f_z}{N_{cr,z}}} = 1.132$$  \hspace{1cm} (11)

are the non-dimensional slenderness for major and minor axis respectively.

$$\Phi_y = 0.5 / \lambda_y + a_y (\lambda_y - 0.2) + \lambda_y^2 = 0.596$$  \hspace{1cm} (12)

and

$$\Phi_z = 0.5 / \lambda_z + a_z (\lambda_z - 0.2) + \lambda_z^2 = 1.369$$  \hspace{1cm} (13)

are values to determine the reduction factor for major and minor axis respectively, where $a_y = 0.49$ and $a_z = 0.49$ are the imperfection factors for major and minor axis respectively.

$$\chi_y = \frac{1}{\sqrt{\Phi_y + \Phi_z - \lambda_y^2}} = 0.924$$  \hspace{1cm} (14)
\[ \chi = \min(\chi_x, \chi_y) = 0.467 \]  
(15)

are the reduction factors for major and minor axis respectively.

\[ \chi = \min(\chi_x, \chi_y) = 0.467 \]  
(16)

is the reduction factor.

Therefore the design buckling resistance \( (N_{b,Rd}) \) is:

\[ N_{b,Rd} = \chi A f / \gamma M1 \]  
(17)

for class 1, 2 or 3 cross-sections.

\[ N_{b,rd} = 0.468 \times 2.68 \times 10^3 \times 300 / 1.00 = 373943.3 \text{ N} \]

\[ \therefore N_{b,Rd} = 374 \text{ kN} \]


Section properties of PFC 180x70 SA Parallel Flange Channel:

\[ A = 2.68 \times 10^3 \text{ mm}^2 \]
\[ h_w = 136 \text{ mm} \]
\[ d = 180 \text{ mm} \]
\[ b_f = 70 \text{ mm} \]
\[ t_f = 10.9 \text{ mm} \]
\[ t_w = 7.0 \text{ mm} \]
\[ r_x = 71.0 \text{ mm} \]
\[ r_y = 21.8 \text{ mm} \]
\[ I_x = 13.5 \times 10^6 \text{ mm}^4 \]
\[ I_y = 1.27 \times 10^6 \text{ mm}^4 \]
\[ J = 82.3 \times 10^3 \text{ mm}^4 \]

Column section is a hot-rolled PFC (flange thickness of 10.9 mm) with form factor \( k_f = 1 \) so from Table of AS 4100:1998/NZS3404:1997, \( \alpha_c = 0.5 \).

From Table of AS 4100:1998/NZS3404:1997, \( \alpha_{cx} = 0.912 \) (Interpolating between values of \( \lambda_{nx} = 30 \) and 35), and \( \alpha_{cy} = 0.482 \) (interpolating between values of \( \lambda_{ny} = 100 \) and 105).

\[ \alpha_c = \min(\alpha_{cx}, \alpha_{cy}) = \min(0.912; 0.482) \]

\[ \therefore \alpha_c = 0.482 \] where \( \alpha_c \) is the member slenderness reduction factor.

Therefore the member capacity (\( \Phi N_c \)) is:

\[ \Phi N_c = \Phi k_f A_n f_y \alpha_c = 0.9 \times 1 \times 2.68 \times 10^3 \times 300 \times 0.482 = 351 \text{ kN} \]

\[ \therefore \Phi N_c = 351 \text{ kN} \]

V. Results And Discussion

The section slenderness, slenderness limits and section classification for a PFC SA of each standard/code are listed in Table 4. It indicates that the flange slenderness of the sections in the three standards are very similar. The AS 4100:1998/NZS3404:1997 web slenderness of the sections, flange and web slenderness limits are higher than Eurocode 3 and SANS 10162: 1-2005/ CAN/CSA-S16-01:2005. The web slenderness of Eurocode 3 and SANS 10162: 1-2005/ CAN/CSA-S16-01:2005 are the same.

Table 4: Summary of a PFC SA section slenderness, slenderness limits and section classification.

<table>
<thead>
<tr>
<th>Standard/Code</th>
<th>Flange Slenderness</th>
<th>Web Slenderness</th>
<th>Flange Slenderness Limit</th>
<th>Web Slenderness Limit</th>
<th>Section Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS 4100:1998/NZS3404:1997</td>
<td>6.33</td>
<td>24.75</td>
<td>16</td>
<td>45</td>
<td>N/A*</td>
</tr>
<tr>
<td>Eurocode 3</td>
<td>4.67</td>
<td>19.42</td>
<td>7.92</td>
<td>29.04</td>
<td>Class 1</td>
</tr>
<tr>
<td>SANS 10162: 1-2005/ CAN/CSA-S16-01:2005</td>
<td>6.4</td>
<td>19.4</td>
<td>11.5</td>
<td>38.7</td>
<td>Not Class 4</td>
</tr>
</tbody>
</table>

* Not Applicable

Table 5 shows the comparison results between codes for a PFC 180x70 SA for slenderness ratio ranging from 45.87 to 504.58. The positive and negative percentage difference shown in table indicate that applicable standards/code overestimate and underestimate capacity respectively.
Table 5: Summary of differences in capacity between codes for varying slenderness ratios for a PFC SA section. Positive values indicate that applicable standards overestimate member capacity (un-conservative).

<table>
<thead>
<tr>
<th>Slenderness ratio</th>
<th>( \Phi_0 ) (N)</th>
<th>% Diff. With EC3</th>
<th>( N_{b,Rd} ) (N)</th>
<th>% Diff. With SANS/CAN*</th>
<th>( C_r ) (N)</th>
<th>% Diff. With AS 4100:1998/NZS 3404:1997</th>
</tr>
</thead>
<tbody>
<tr>
<td>45.87</td>
<td>723600</td>
<td>10.66</td>
<td>646408.9</td>
<td>3.30</td>
<td>625030</td>
<td>-13.62</td>
</tr>
<tr>
<td>91.74</td>
<td>350946</td>
<td>-6.15</td>
<td>373943.3</td>
<td>-1</td>
<td>377739.7</td>
<td>7.09</td>
</tr>
<tr>
<td>137.61</td>
<td>195372</td>
<td>-5.25</td>
<td>206213.7</td>
<td>-3.60</td>
<td>213933.5</td>
<td>8.67</td>
</tr>
<tr>
<td>183.48</td>
<td>120117.6</td>
<td>-4.78</td>
<td>126156.1</td>
<td>-3.50</td>
<td>130723.4</td>
<td>8.11</td>
</tr>
<tr>
<td>229.35</td>
<td>78872.4</td>
<td>-6.60</td>
<td>84441.47</td>
<td>-2.51</td>
<td>86617.89</td>
<td>8.94</td>
</tr>
<tr>
<td>275.22</td>
<td>57888</td>
<td>-4.03</td>
<td>60321.5</td>
<td>-1.40</td>
<td>6180.76</td>
<td>5.38</td>
</tr>
<tr>
<td>321.1</td>
<td>43416</td>
<td>-3.94</td>
<td>45197</td>
<td>-0.37</td>
<td>45368.04</td>
<td>4.30</td>
</tr>
<tr>
<td>366.97</td>
<td>33285.6</td>
<td>-5.19</td>
<td>35110.24</td>
<td>0.52</td>
<td>34926.82</td>
<td>4.70</td>
</tr>
<tr>
<td>412.84</td>
<td>26049.6</td>
<td>-7.14</td>
<td>28054.36</td>
<td>1.28</td>
<td>27692.9</td>
<td>5.93</td>
</tr>
<tr>
<td>458.71</td>
<td>21708</td>
<td>-5.32</td>
<td>22928.21</td>
<td>1.94</td>
<td>22483.36</td>
<td>3.44</td>
</tr>
<tr>
<td>504.58</td>
<td>17366.4</td>
<td>-9.01</td>
<td>19087.97</td>
<td>2.50</td>
<td>18611.18</td>
<td>6.68</td>
</tr>
</tbody>
</table>


It shows that the differences in capacity between codes vary with the slenderness ratio of the column.

For a PFC SA parallel flange channel section, Eurocode 3 gives higher capacity about a range of 3% - 10% than AS 4100:1998/NZS3404:1997 (see Table 5) between the slenderness ratio values of 91.74 - 504.58. And at slenderness ratio value of 45.87, AS 4100:1998/NZS3404:1997 gives 10.66% (see Table 5) higher capacity compared to Eurocode 3. The difference between Eurocode 3 and SANS 10162-1:2005/CAN/CSA-S16-01:2005 is minimal and in the range of 0% - 4% (see Table 5). From slenderness ratio value of 91.74 - 504.58, SANS 10162-1:2005/CAN/CSA-S16-01:2005 gives higher capacity compared to AS 4100:1998/NZS3404:1997 about a range of 4% - 9% (see Table 5). And at slenderness ratio value of 45.87, AS 4100:1998/NZS3404:1997 gives 13.62% (see Table 5) higher capacity compared to SANS 10162-1:2005/CAN/CSA-S16-01:2005.

The curves of Figure 6 illustrate the comparison of the column design buckling resistance for varying slenderness ratio of the PFC SA column section. We observe that the design buckling resistance of the column of each standard/code decreases when its slenderness ratio increases also the differences in capacity between codes vary with the slenderness ratio of the column.

Figure 6: Comparison of a steel column design buckling resistance for varying slenderness ratios.

VI. Conclusions

The following conclusions were obtained based on the conducted studies in this paper:


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Notations

$A$ Area of cross-section

$A_e$ Effective area of cross-section

$A_s$ Gross section area

$A_n$ Net area of cross-section

$b$ Width of a cross-section

$\beta_f$ Width of a cross-section

$C_r$ Factored compressive resistance of member
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\( C_{\text{WT}} \) \quad Warping torsional constant
\( d \) \quad Depth of straight portion of a web
\( E \) \quad Elastic modulus of steel
\( f_c \) \quad Elastic critical buckling stress in axial compression
\( f_{c,x} \) \quad Elastic critical buckling stress in axial compression for x-x axis flexural buckling
\( f_{c,t} \) \quad Flexural-torsional buckling stress
\( f_{c,y} \) \quad Elastic critical buckling stress in axial compression for y-y axis flexural buckling
\( f_{c,z} \) \quad Elastic critical buckling stress in axial compression for torsional buckling
\( f_y \) \quad Yield stress
\( G \) \quad Shear modulus of steel
\( h \) \quad Depth of a cross-section
\( h_w \) \quad Depth of straight portion of a web
\( I_x \) \quad Moment of inertia about x-x axis
\( I_y \) \quad Moment of inertia about y-y axis
\( I_z \) \quad Moment of inertia about z-z axis
\( \bar{J} \) \quad St Venant torsional constant of a cross-section
\( k_f \) \quad Form factor
\( K_L \) \quad Effective length
\( K_L \) \quad Effective slenderness ratio
\( L \) \quad Buckling length
\( n \) \quad Parameter
\( N_{b,rd} \) \quad Design buckling resistance
\( N_c \) \quad Nominal compressive capacity of member
\( N_{c,y} \) \quad Elastic critical buckling force for y-y axis
\( N_{c,z} \) \quad Elastic critical buckling force for z-z axis
\( r_g \) \quad Polar radius of gyration
\( r_x \) \quad Radius of gyration about x
\( r_y \) \quad Radius of gyration about y
\( t_f \) \quad Flange thickness
\( t_w \) \quad Web thickness
\( x_0 \) \quad Principal x-coordinate of shear centre with respect to centroid of cross-section
\( y_0 \) \quad Principal y-coordinate of shear centre with respect to centroid of cross-section
\( \bar{\lambda}_x \) \quad Non-dimensional slenderness for major axis
\( \bar{\lambda}_z \) \quad Non-dimensional slenderness for minor axis
\( \alpha_b \) \quad Member section constant
\( \alpha_c \) \quad Member slenderness reduction factor
\( \alpha_{c,x} \) \quad Member slenderness reduction factor for x-axis
\( \alpha_{c,y} \) \quad Member slenderness reduction factor for y-axis
\( \alpha_f \) \quad EC3 imperfection factor for major axis
\( \alpha_e \) \quad EC3 imperfection factor for minor axis
\( \Phi_y \) \quad Value to determine the reduction for major axis
\( \Phi_x \) \quad Value to determine the reduction for minor axis
\( \chi_y \) \quad Reduction factor for major axis
\( \chi_z \) \quad Reduction factor for minor axis
\( \chi \) \quad Reduction factor
\( \Phi \) \quad Capacity reduction factor
\( \gamma_{MI} \) \quad Partial factor for member instability
\( \lambda_{x2} \) \quad Modified slenderness ratio for x-axis
\( \lambda_{ny} \) \quad Modified slenderness ratio for y-axis
\( \Omega \) \quad A factor which takes into account the position of the shear centre relative to the centroid of the cross-section as well as the radius of gyration

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