= 0.425 for unstiffened compression elements
= 4.00 for stiffened compression elements
= 23.9 for stiffened elements subject to flexure

A.4 COMPRESSIVE STRENGTH

For sections where $\bar{\lambda}_p \leq 0.68$ and $\dfrac{KL}{r} \leq 0.63\sqrt{\dfrac{E}{F_y}}$ or $\dfrac{F_y}{F_e} \leq 0.04$, the design compressive strength, $\phi_c P_{n,csm}$, and the allowable compressive strength, $P_{n,csm}/\Omega_c$, should be determined as follows:

The nominal compressive strength at the limit state of yielding, $P_{n,csm}$, is given by:

$$P_{n,csm} = F_{csm} A_g \tag{A-5}$$

where

A_g = gross area of member, in.^{2} (mm^2)

F_{csm} = stress corresponding to ε_{csm}

$$= F_y + E_{sh}\,\varepsilon_y\left(\frac{\varepsilon_{csm}}{\varepsilon_y} - 1\right) \tag{A-6}$$

K, L and r are defined in Section 5.2, F_e is defined in Section 5.3, and ϕ_c and Ω_c are given in Section 5.1.

A.5 FLEXURAL STRENGTH

For sections where $\bar{\lambda}_p \leq 0.68$ and $L_b \leq 0.75L_p$, the design flexural strength, $\phi_b M_{n,csm}$, and the allowable flexural strength, $M_{n,csm}/\Omega_b$, should be determined as follows:

The nominal flexural strength at the limit state of yielding, $M_{n,csm}$, is given by:

(a) Major axis bending

$$M_{n,csm,x} = M_{p,x}\left(1 + \frac{E_{sh}}{E}\frac{S_x}{Z_x}\left(\frac{\varepsilon_{csm}}{\varepsilon_y} - 1\right) - \left(1 - \frac{S_x}{Z_x}\right)\Big/\left(\frac{\varepsilon_{csm}}{\varepsilon_y}\right)^2\right) \tag{A-7}$$

(b) Minor axis bending

$$M_{n,csm,y} = M_{p,y}\left(1 + \frac{E_{sh}}{E}\frac{S_y}{Z_y}\left(\frac{\varepsilon_{csm}}{\varepsilon_y} - 1\right) - \left(1 - \frac{S_y}{Z_y}\right)\Big/\left(\frac{\varepsilon_{csm}}{\varepsilon_y}\right)^{\alpha}\right) \tag{A-8}$$

where

M_p = plastic bending moment, kip-in. (N-mm)

Z = plastic section modulus about axis of bending, in.^{3} (mm^3)

S = elastic section modulus about axis of bending, in.^{3} (mm^3)

α = 2.0 for rectangular HSS or 1.2 for I-shaped sections

L_b and L_p are defined in Section 6.2 and ϕ_b and Ω_b are given in Section 6.1.

Appendix B
Commentary to the Design Provisions

B.1 INTRODUCTION

B.1.1 Purpose of the Commentary

This Appendix describes the work undertaken to derive the design provisions in this Design Guide. This Appendix will also facilitate the development of revisions to the design rules as, and when, new data become available.

B.1.2 How Does the Structural Performance of Stainless Steel Differ from Carbon Steel?

The structural performance of stainless steel differs from that of carbon steel because stainless steel has no definite yield point, shows an early departure from linear elastic behavior, and exhibits pronounced strain hardening. This impacts design rules in the following ways:

- The design strength is based on the 0.2% offset yield strength.
- There is a different buckling response for members subject to compression, unrestrained bending and shear buckling (also different levels of residual stresses for welded members).
- Greater deflections will occur in beams at high strains (the secant modulus is generally used for estimating these deflections).
- Different rules for the bearing strength of connections are necessary in order to limit deformation.

B.1.3 Design Specifications for Structural Stainless Steel

Specifications for the design of cold-formed structural stainless steel are available in the U.S. (ASCE, 2002), Australia/New Zealand (AS-NZS, 2001), South Africa (SABS, 1997), and Japan (SSBA, 2005). However, there are only European (CEN, 2006a) and Japanese (SSBA, 1995) specifications which cover the design of structural sections made from thicker walled material (welded, hot rolled, structural hollow sections). The Japanese specification is not available in English. A comparison of the various structural design standards for stainless steel is made in Baddoo (2003).

Eurocode 3: Design of Steel Structures, Supplementary Rules for Stainless Steels, Part 1-4 (EN 1993-1-4) (CEN, 2006a) gives rules which can be applied to welded, hot-rolled and cold-formed stainless steel members. It is a supplement rather than a standalone document, referring extensively to the following parts of Eurocode 3:

EN 1993-1-1	*Design of Steel Structures: General Rules and Rules for Buildings*
EN 1993-1-2	*Design of Steel Structures: Structural Fire Design*
EN 1993-1-3	*Design of Steel Structures: General Rules: Supplementary Rules for Cold-Formed Members and Sheeting*
EN 1993-1-5	*Design of Steel Structures: Plated Structural Elements*
EN 1993-1-8	*Design of Steel Structures: Design of Joints*
EN 1993-1-9	*Design of Steel Structures: Fatigue*
EN 1993-1-10	*Design of Steel Structures: Material Toughness and Through-Thickness Properties*

The design rules in the 1996 public draft of EN 1993-1-4 were initially based on the first edition of the European *Design Manual for Structural Stainless Steel* (Euro Inox and SCI, 1994), following a European joint industry project. The rules were derived on the basis of an extensive test program and took into account all known work carried out in Europe, U.S., South Africa and Australia. The *Design Manual* included a commentary which explains the basis of the development of the design rules and presents the results of the relevant test programs. Since 1994, the European *Design Manual* has been revised and extended two times, taking into account the results of further European research projects and new work from other parts of the world. EN 1993-1-4 (CEN, 2006a) aligns with the recommendations in the current third edition of the European *Design Manual* (Euro Inox and SCI, 2006a), except in the area of fire resistance where the rules in the *Design Manual* are less conservative.

B.1.4 Scope of the Design Guide

The intention at the start of writing this Design Guide was to modify the structural stainless steel rules in EN 1993-1-4 and present them in a format aligned with the AISC *Specification for Structural Steel Buildings*. However, due to the fundamental differences between the design rules in the AISC *Specification* and EN 1993-1-4, this approach was not possible and the following procedure was implemented:

1. Compare the rules for carbon steel and stainless steel in Eurocode 3.

2. Compare the rules for carbon steel in the AISC

Specification against all available stainless steel test data on members and connections.

3. Modify the AISC *Specification* carbon steel rules to suit the stainless steel data where necessary.

4. Calculate the stainless steel resistance factors to use with the recommended stainless steel design rules.

An Evolution Group has been established for each part of Eurocode 3 to oversee maintenance and future development activities and it is expected that revisions to all parts of Eurocode 3 will be issued in the future. The Evolution Group for EN 1993-1-4 is considering a number of developments to the standard, most of which will lead to less conservative design rules due to the far greater body of test data which is now available for structural stainless steel. These proposed developments have been taken into account during the preparation of this Design Guide.

The Design Guide gives guidance that a designer familiar with designing to the AISC *Specification* should be able to use easily. Where stainless steel behaves in a similar way to carbon steel, the Design Guide simply refers to the relevant section in the AISC *Specification*. Where the guidance in the AISC *Specification* would be unconservative or unduly conservative when applied to stainless steel, specific rules for stainless steel have been presented in a format as close as possible to the equivalent expressions in the AISC *Specification* for carbon steel.

The assumptions made and data used in order to calculate the resistance factors by means of a reliability analysis are described in Section B.2. Sections B.3 to B.11 deal with different aspects of structural design. In each section the design provisions in Eurocode 3 for both carbon steel and stainless steel are presented and compared to the provisions for carbon steel in the AISC *Specification*. Stainless steel data are then compared to the AISC provisions and new provisions for stainless steel presented where necessary. The results of the reliability analysis are then given.

It should be noted that the Design Guide is applicable to hot-rolled materials. Structural design of cold-formed stainless steels (including cold-worked austenitic stainless steels) are covered by ASCE/SEI 8-02, *Specification for the Design of Cold-Formed Stainless Steel Structural Members* (ASCE, 2002). See also Section B.1.3.

B.2 DETERMINATION OF STAINLESS STEEL RESISTANCE FACTORS

B.2.1 Probabilistic Basis and Reliability Index

Structural safety is a function of the resistance, R, of the structure as well as the load effects, Q. It is assumed that the resistance and the load effects are random variables because of the uncertainties associated with their inherent randomness. Based on the assumed probability distributions and first-order probabilistic theory, the reliability index, β, can be expressed as:

$$\beta = \frac{\ln\left(R_m/Q_m\right)}{\sqrt{V_R^2 + V_Q^2}} \qquad (Spec.\ \text{Eq. C-B3-2})$$

where

Q_m = mean value of the load effect
R_m = mean value of the resistance
V_Q = coefficient of variation of the load effect, Q (i.e., standard deviation divided by the mean)
V_R = coefficient of variation of the resistance, R (i.e., standard deviation divided by the mean)

In accordance with the assumptions made in the development of the LRFD approach for hot-rolled steel structures in the AISC *Specification*, a target reliability index has been set for members of $\beta = 2.6$ and for connections of $\beta = 4.0$ (Bartlett et al., 2003).

B.2.2 Load and Load Effects

A dead load factor of 1.2 and a live load factor of 1.6 for the basic combination of dead plus live load were assumed in the stainless steel reliability analysis. The analyses were carried out for a dead-to-live load ratio of 1:5 and 1:3. For all modes of loading, the load ratio 1:5 gave slightly more severe results, however, in accordance with the assumptions taken for the reliability analysis carried out for the AISC *Specification*, the values for a dead-to-live load ratio of 1:3 are considered more applicable for hot-rolled and welded structural sections (Bartlett et al., 2003) and were thus used to calculate the resistance factors.

Q_m and V_Q were calculated from the following equations given in Ellingwood et al. (1980). These expressions were also used by Lin et al. (1998):

$$Q_m = c(D_m + L_m) \qquad \text{(B-1)}$$

$$V_Q = \frac{\sqrt{\left(D_m V_D\right)^2 + \left(L_m V_L\right)^2}}{\left(D_m + L_m\right)} \qquad \text{(B-2)}$$

where

c = influence coefficient which transfers load intensities to load effects

The following values for the parameters were adopted: $D_m = 1.05D_n$, $V_D = 0.1$, $L_m/L = 1.0$, and $V_L = 0.25$.

The subscripts m, n, D and L refer to mean, nominal, dead and live respectively. Assuming a dead load-to-live load ratio of 1:3 gives $V_Q = 0.19$ and $Q_m = 1.33cL_m$.

B.2.3 Resistance

The randomness of the resistance, R, of a structural element is due to the variability inherent in the mechanical properties of the material, variations in dimensions, and the uncertainties in the design theory used to express the member strength. The mean resistance of a structural member, R_m, is defined as follows:

$$R_m = R_n(M_m)(F_m)(P_m) \tag{B-3}$$

where

R_n = nominal resistance of the structural elements

M_m, F_m, P_m = mean values of the random variables reflecting the uncertainties in material properties (i.e., F_y, F_u, etc.), the geometry of the cross section (i.e., A, t, L, etc.), and the design assumptions, respectively

M, known as the material factor, is taken as the ratio of the actual measured value of a mechanical property to the minimum specified value of that property given in the relevant ASTM specification. Similarly, *F*, known as the fabrication factor, is taken as the ratio of the actual measured value of that geometrical property to the nominal value of that property. *P*, known as the professional factor, is taken as the ratio of the measured failure load to the failure mode predicted from the design provision.

The coefficient of variation of the resistance, V_R, is calculated as the square-root-sum-of-squares of the material, fabrication and design model uncertainty coefficients of variation:

$$V_R = \sqrt{V_m^2 + V_f^2 + V_p^2} \tag{B-4}$$

B.2.3.1 Material Factor, M_m

Data on the statistical variation of material strengths were collected from literature (Groth and Johansson, 1990; Leffler, 1990; Outokumpu, 2006a; Outokumpu, 2006b; Outokumpu, 2008). Steel producers and manufacturers of stainless steel sections also supplied more recent data for this analysis. Much of their data was supplied on a confidential basis, so it is not possible to give a detailed breakdown of the material data herein.

The data analyzed demonstrated values of $M_m > 1.3$ for austenitic stainless steel and $M_m > 1.1$ for duplex stainless steel for the 0.2% offset yield overstrength ratio. Duplex stainless steels were introduced into standards in the 1970s and 1980s, so the minimum specified values are based on modern steelmaking technology and the gap between the actual and minimum specified values is less than that for austenitics. It is important to note that load-bearing duplex stainless steel represents only approximately 1 to 3% of the total tonnage of structural stainless steel, with austenitic stainless steels making up the balance. In order to best utilize the greater conservatism in the assessment of 0.2% offset yield strength for austenitic stainless steel, it was decided to analyze austenitic and duplex stainless steel as separate populations. For austenitic stainless steel, the material factor, M_m, is taken as 1.3, while for duplex stainless steel, M_m is taken as 1.1.

The choice of $M_m = 1.1$ for the 0.2% offset yield strength in the cold-formed stainless steel specification, ASCE/SEI 8-02, is perhaps surprisingly low. However, the analysis of material data carried out in order to select a value of M_m for this specification, showed that the cold-worked Types S30100 and S20100 (cold-worked tempers of ¼ hard and ½ hard) and Types S40900, S43000 and S43900 all demonstrated considerably lower values of M_m than hot-rolled Type S30400 stainless steel (Lin et al., 1998). As these types of stainless steel are not included in this Design Guide, there is no need to retain this value of $M_m = 1.1$.

Note that, nowadays, no significant difference is expected between the strengths of standard (e.g., S30400) and low carbon (e.g., S30403) types. Steelmakers generally produce material that fulfills both standard and L specifications, as only the maximum carbon content is specified. The low specified minimum yield stress values in ASTM A240 for Type S30403/S31603 (170 MPa compared to 205 MPa for standard types) are historical and are not representative of today's practice. As the smaller specified minimum yield stress will lead to artificially high M_m values, it was decided not to include the data for the L types in this assessment.

The coefficient of variation, V_m, was also calculated from the body of material data collected for this project and a value of 0.105 was taken as representative for both austenitic and duplex stainless steel populations. Parametric studies showed that the value of the resistance factor, ϕ, strongly correlates with the overstrength ratio, M_m, whereas variations in V_m only lead to small changes in ϕ. The choice of coefficient of variation is therefore less significant than the choice of a conservative M_m factor. The material data indicated a value of $M_m = 1.1$ and $V_m = 0.05$ was applicable to the ultimate tensile strength.

Table B-1 shows the values for M_m that have been assumed in AISC and ASCE specifications for hot-rolled and cold-formed carbon steel and stainless steel. The values for the coefficient of variation are given in brackets (V_m). The values assumed for this Design Guide are also given for comparison.

B.2.3.2 Fabrication Factor, F_m

This factor takes into account uncertainties caused by initial imperfections, tolerances and variations in geometric properties. It also reflects the differences between the designed and manufactured cross-sectional dimensions. No data was collected in this study. It was assumed that the values used in the cold-formed stainless steel specification, ASCE/SEI 8-02,

Table B-1. Reliability and Random Variable Factors for U.S. Steel Design Standards and Eurocode 3 (EN 1993-1-1 and -4)

		AISC 360-10 (AISC, 2010c)	AISI *Cold-Formed Specification* (AISI, 2007)	ASCE/SEI 8-02 (ASCE, 2002)	AISC Design Guide on Stainless Steel	EN 1993-1-1 (CEN, 2005a)	EN 1993-1-4 (CEN, 2006a)
		Carbon Steel	Carbon Steel	Stainless Steel	Stainless Steel	Carbon Steel	Stainless Steel
		Hot-Rolled/ Welded	Cold-Formed	Cold-Formed	Hot-Rolled/ Welded	Hot-Rolled/ Welded	Hot-Rolled/ Welded and Cold-Formed
β Reliability index	Members	2.60	2.50	3.00	2.60	3.80	3.80
	Connections	4.00	3.50	4.00	4.00	3.80	3.80
Material random variable	$M_m(V_m)$	1.028 (0.058)	1.10 (0.10)	F_y : 1.10 (0.10) F_u : 1.10 (0.05)	Austenitic: F_y : 1.3 (0.105) F_u : 1.1 (0.105) Duplex: F_y : 1.1 (0.105) F_u : 1.1 (0.105)	N/A	N/A
Geometry random variable	$F_m(V_f)$	Members: 1.00 (0.05) Bolted conns: 1.00 (0.05) Welded conns: 1.00 (0.15)	1.00 (0.05)	Members: 1.00 (0.05) Bolted conns: 1.00 (0.05) Welded conns: 1.00 (0.15)	Members: 1.00 (0.05) Bolted conns: 1.00 (0.05) Welded conns: 1.00 (0.15)	N/A	N/A

The shading indicates carbon steel factors; no shading indicates stainless steel factors.

which were the same as those used in the development of the AISC LRFD criteria for hot-rolled structural steel members, apply. The following values are assumed:

For stainless steel members and bolted connections, $F_m = 1.00$ and $V_f = 0.05$

For welded connections, $F_m = 1.00$ and $V_f = 0.15$

These values are also shown in Table B-1.

B.2.3.3 Professional Factor, P_m

The professional factor depends on the failure mode in question, and is defined for each specific case in Sections B.3 to B.11. Note that there are no test data for hot-rolled austenitic stainless steel structural sections (a few tests have been carried out on hot-rolled ferritic stainless steel sections). The test data used to assess the professional factor were data on hollow structural sections (HSS) (austenitic and duplex) and welded I-shaped members. As a general rule, it is expected that hot-rolled sections will perform better than welded sections because of the absence of residual stresses developed during welding. In some cases, data on cold-formed stainless steel sections were also considered.

Table B-2 and Table B-3 show the values for random variables, P_m and V_p, for austenitic and duplex stainless steels, respectively, which were calculated in this reliability analysis from an assessment of the stainless steel data against the recommended design models.

B.2.4 Determination of Resistance Factor

Following the assumptions and procedures described in Lin et al. (1992) and Bartlett et al. (2003), the resistance factor was calculated from:

$$\phi = \frac{1.481 M_m F_m P_m}{\exp\left(\beta\sqrt{V_R^2 + V_Q^2}\right)} \tag{B-5}$$

Using all of the assumptions discussed in the previous section, values of the resistance factor, ϕ, were derived for each expression in this Design Guide and these are presented in Table B-2 and Table B-3.

In general, the reliability analysis shows that the carbon steel resistance factors can be safely used with the AISC stainless steel design curves with the following two exceptions:

- Round HSS in compression ($\phi_{stainless\ steel} = 0.85$, $\phi_{carbon\ steel} = 0.90$)

- Fillet welds ($\phi_{aust\ stainless\ steel} = 0.55$, $\phi_{duplex\ stainless\ steel} = 0.60$, $\phi_{carbon\ steel} = 0.75$)

The safety factor, Ω, for use in allowable strength designs, was calculated in accordance with Duncan et al. (2006).

Note that Eurocode 3 defines only three partial safety factors for resistance:

- Resistance of cross sections to excessive yielding, including local buckling, γ_{M0}
- Resistance of members to instability assessed by member checks, γ_{M1}
- Resistance of cross sections in tension to fracture, γ_{M2}
- Resistance of bolts, rivets, welds, pins and plates in bearing, γ_{M2}

The recommended values of these factors for stainless steel are $\gamma_{M0} = \gamma_{M1} = 1.1$ and $\gamma_{M2} = 1.25$. For carbon steel, the values are $\gamma_{M0} = \gamma_{M1} = 1.0$ and $\gamma_{M2} = 1.25$. Re-evaluation of these factors is now underway in Europe.

B.2.5 Precipitation Hardening Stainless Steels

Design provisions relating to precipitation hardening stainless steel Type S17400 in this Design Guide are limited to:

- Strength of unthreaded tension rods failing by yielding
- Tension and shear strength of bolts and threaded parts

Insufficient data were available to enable a reliability analysis to be carried out for tension rods and bolts in the same way as for austenitic and duplex stainless steels. Therefore the appropriate resistance factors for austenitic and duplex stainless steel were reduced by 10% for precipitation hardening Type S17400 stainless steel to give an extra margin of safety.

B.3 SECTION CLASSIFICATION

B.3.1 Eurocode 3 Methodology for Carbon Steel and Stainless Steel

Compression elements of cross sections are classified as Class 1, 2 or 3 in Eurocode 3 depending upon their width-to-thickness ratios. Those compression elements that do not meet the criteria for Class 3 are then classified as Class 4 elements. The limiting ratios for stainless steel in EN 1993-1-4 are more conservative than those for carbon steel in EN 1993-1-1. The limiting ratios for Class 3 elements were derived from experimental stainless steel data whereas the limiting ratios for Classes 1 and 2 were derived during the preparation of the first edition of the European *Design Manual for Structural Stainless Steel* in the late 1980s by making reference to other data and applying engineering argument. The process of deriving these ratios is described in the Commentary to the European *Design Manual* (Euro Inox and SCI, 2006b).

B.3.2 The AISC *Specification* Methodology for Carbon Steel

The AISC *Specification* similarly adopts the concept of section classification. For compression elements used in members subject to flexure the terms are compact, noncompact and slender, while for compression elements used in members subject to compression, the terms are nonslender and slender. The class "compact" effectively covers Class 1 and Class 2 in the Eurocodes. [Note that the AISC *Seismic Provisions for Structural Steel Buildings* (AISC, 2010b) uses the terms highly and moderately ductile, where the former corresponds to Class 1 in the Eurocode.]

B.3.3 Recommendations for the AISC Design Guide

Over the last twenty years, considerable further research has been conducted on structural stainless steel. Many additional experimental results on cross-section resistance now exist, including both stub column and bending tests. Analysis of the test data by Gardner and Theofanous (2008) reveals that the current slenderness limits in EN 1993-1-4 for stainless steels are overly conservative and that in many cases harmonization with the equivalent carbon steel limits in EN 1993-1-1 are justified. As it is expected that these new limits proposed in this paper will be adopted in the next revision of EN 1993-1-4, it has been decided to adopt these less onerous limits in this Design Guide.

The section classification limits for carbon steel in the AISC *Specification* are given in Table B-4a and Table B-4b. The limits adopted in this Design Guide (Section 3.3.1) are also shown in this table. In general, these are the limits recommended in Gardner and Theofanous (2008); however, in the cases where the stainless limits were higher than the AISC carbon steel limits (web and flange of HSS in bending, and round HSS in bending), the limits were reduced to match the AISC carbon steel limits.

Note that there are minor differences in the width-to-thickness definitions, e.g., in the AISC *Specification*, half the flange width is used to calculate the flange slenderness whereas in Eurocode 3 only the outstanding portion of the flange, measured from the toe of the fillet, is used.

B.3.4 Determination of Resistance Factors

Gardner and Theofanous (2008) report that a statistical analysis in accordance with EN 1990 Annex D (CEN, 2002) was

Table B-2. Summary of Results for Derivation of ϕ Factors for AISC Design Guide Expressions—Austenitic Stainless Steel											
Limit State	**No. Results**	M_m[a]	F_m	P_m	R_m/R_n	V_m	V_f	V_p	V_R	**ϕ (Calculated)**[b]	**ϕ (Recommended)**
Round HSS in compression, nonslender	25	1.3	1	1.043	1.356	0.105	0.05	0.154	0.193	0.998	0.85[c]
Rect. HSS in compression, nonslender	33	1.3	1	1.388	1.805	0.105	0.05	0.210	0.240	1.211	0.90
Welded I-shaped members in compression, nonslender	12	1.3	1	1.116	1.451	0.105	0.05	0.238	0.265	0.925	0.90
Rect. HSS and welded I-shaped members in compression, nonslender	45	1.3	1	1.316	1.711	0.105	0.05	0.234	0.261	1.100	0.90
Rect. HSS in compression, slender	23	1.3	1	1.521	1.978	0.105	0.05	0.340	0.360	1.021	0.90
I-shaped members in compression, slender	9	1.3	1	1.136	1.594	0.105	0.05	0.164	0.201	1.071	0.90
Flexural-torsional buckling	15	1.3	1	1.261	1.639	0.105	0.05	0.268	0.292	0.985	0.90
Round HSS in flexure, yielding	8	1.3	1	1.399	1.818	0.105	0.05	0.281	0.304	1.064	0.90
Rect. HSS in flexure, yielding	37	1.3	1	1.413	1.837	0.105	0.05	0.122	0.169	1.414	0.90
I-Shaped members in flexure, yielding	5	1.3	1	1.137	1.478	0.105	0.05	0.033	0.121	1.227	0.90
All members in flexure, yielding	50	1.3	1	1.383	1.807	0.105	0.05	0.163	0.201	1.306	0.90
Lateral-torsional buckling	14	1.3	1	1.261	1.640	0.105	0.05	0.191	0.224	1.139	0.90
Shear buckling	15	1.3	1	1.116	1.451	0.105	0.05	0.108	0.159	1.137	0.90

Table B-2 (continued). Summary of Results for Derivation of ϕ Factors for AISC Design Guide Expressions—Austenitic Stainless Steel											
Limit State	**No. Results**	M_m[a]	F_m	P_m	R_m/R_n	V_m	V_f	V_p	V_R	ϕ (Calcu-lated)[b]	ϕ (Recom-mended)
Combined flexure & compression	26	1.3	1	1.570	2.041	0.105	0.05	0.341	0.360	1.052	0.90
Fillet weld (long.)	11	1.1	1	0.941	1.035	0.050	0.15	0.033	0.162	0.571	0.55
Fillet weld (transverse)	12	1.1	1	1.141	1.255	0.050	0.15	0.048	0.165	0.685	0.60
Groove welds	No Data	—	—	—	—	—	—	—	—	—	0.60
Tension rupture	8	1.1	1	1.193	1.312	0.050	0.05	0.200	0.073	0.870	0.75
Shear bolts	11	1.1	1	1.076	1.184	0.050	0.05	0.050	0.086	0.769	0.75
Bearing bolts	4	1.1	1	1.451	1.596	0.050	0.05	0.072	0.101	1.076	0.75
Tension bolts	12	1.1	1	1.091	1.200	0.050	0.05	0.015	0.072	0.797	0.75

[a] M_m = 1.3 for 0.2% offset yield strength and = 1.1 for ultimate tensile strength.
[b] If M_m was assumed to be 1.2 instead of 1.3, the calculated values of ϕ would still lie above the recommended values of ϕ in all cases except for welded I-shape compressive buckling (0.854).
[c] Assumed resistance factor was affected by the presence of outlying test points (see Section B.5.1).

carried out to verify that a partial safety factor, γ_{M0}, of 1.1 could be used in conjunction with the section classification limits. The reliability analysis carried out for this Design Guide is reported in Section B.5 for members in compression and Section B.6 for members in flexure.

B.4 DESIGN OF MEMBERS FOR TENSION

The design of tension members in Eurocode 3 (carbon steel and stainless steel) involves comparing the plastic resistance of the gross section, $N_{pl,Rd}$, (with appropriate resistance factors) to the design ultimate resistance of the net section at holes for fasteners, $N_{u,Rd}$, (again, with appropriate resistance factors) and taking the smaller value, where

$$N_{pl,Rd} = \frac{A f_y}{\gamma_{M0}} \text{ and } N_{u,Rd} = \frac{0.9 A_{net} f_u}{\gamma_{M2}}$$

(6.6 and 6.7 of EN 1993-1-1)

The approach in the AISC *Specification* for carbon steel is similar to that given in Eurocode 3 except a shear lag factor, U, is introduced into the expression for the ultimate resistance in place of the factor 0.9 in the Eurocode.

The design guidance presented in the AISC *Specification* for carbon steel is adopted unaltered in this Design Guide (Chapter 4).

B.4.1 Determination of Resistance Factor

For tensile yielding in the gross section, P_m is 1.0 and V_p is 0, as the theory can be assumed to be exactly correct, and it is the fabrication and material variability that cause fluctuations in the result. This gives a resistance factor of 0.98, which justifies the use of the AISC *Specification* carbon steel factor, $\phi_t = 0.90$.

For a discussion of tension rupture failure at the net section, see Section B.9.2.

B.5 DESIGN OF MEMBERS FOR COMPRESSION

B.5.1 Flexural Buckling of Members Without Slender Elements

B.5.1.1 Eurocode 3 Methodology for Carbon Steel and Stainless Steel

For design of columns to Eurocode 3, the flexural buckling resistance of compression members, $N_{b,Rd}$, is calculated from:

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}} \quad \text{(6.47 of EN 1993-1-1)}$$

Where the flexural buckling reduction factor, χ, is given by:

Table B-3. Summary of Results for Derivation of ϕ Factors for AISC Design Guide Expressions—Duplex Stainless Steel											
Limit State	**No. Results**	M_m	F_m	P_m	R_m/R_n	V_m	V_f	V_p	V_R	**ϕ (Calcu-lated)**	**ϕ (Recom-mended)**
Round HSS in compression, nonslender	No Data	—	—	—	—	—	—	—	—	—	0.85
Rect. HSS in compression, nonslender	No Data	—	—	—	—	—	—	—	—	—	0.90
Welded I-shaped members in compression, nonslender	3	1.1	1	1.093	1.202	0.105	0.05	0.083	0.143	0.965	0.90
Rect. HSS in compression, slender	No Data	—	—	—	—	—	—	—	—	—	0.90
I-shaped members in compression, slender	6	1.1	1	1.221	1.343	0.105	0.05	0.102	1.343	1.058	0.90
Flexural-torsional buckling	No Data	—	—	—	—	—	—	—	—	—	0.90
Round HSS in flexure, yielding	3	1.1	1	1.314	1.445	0.105	0.05	0.011	0.117	1.207	0.90
Rect. HSS in flexure, yielding	15	1.1	1	1.253	1.378	0.105	0.05	0.069	0.135	1.121	0.90
I-shaped members in flexure, yielding	1	1.1	1	1.262	1.389	0.105	0.05	0.000	0.116	1.160	0.90
All members in flexure, yielding	19	1.1	1	1.263	1.389	0.105	0.05	0.063	0.132	1.135	0.90
Lateral-torsional buckling	2	1.1	1	1.503	1.654	0.105	0.05	0.267	0.291	0.997	0.90
Shear buckling	4	1.1	1	1.169	1.286	0.105	0.05	0.092	0.149	1.024	0.90
Combined flexure & compression	No Data	—	—	—	—	—	—	—	—	—	0.90

Table B-3 (continued). Summary of Results for Derivation of ϕ Factors for AISC Design Guide Expressions—Duplex Stainless Steel											
Limit State	**No. Results**	M_m	F_m	P_m	R_m/R_n	V_m	V_f	V_p	V_R	**ϕ (Calcu-lated)**	**ϕ (Recom-mended)**
Fillet weld (long.)	11	1.1	1	1.017	1.118	0.050	0.15	0.025	0.160	0.619	0.60
Fillet weld (transverse)	12	1.1	1	1.268	1.395	0.050	0.15	0.022	0.160	0.773	0.60
Groove welds	No Data	—	—	—	—	—	—	—	—	—	0.60
Tension rupture	2	1.1	1	1.181	1.299	0.050	0.05	0.083	0.050	0.810	0.75
Shear in bolts	7	1.1	1	1.046	1.151	0.050	0.05	0.042	0.050	0.753	0.75
Bearing in bolts	No Data	—	—	—	—	—	—	—	—	—	0.75
Tension in bolts	No Data	—	—	—	—	—	—	—	—	—	0.75

Table B-4a. Section Classification Limits in AISC *Specification* and AISC Design Guide, *Structural Stainless Steel*					
Members Subject to Axial Compression					
	Case	**Description of Element**	**Width-to-Thickness Ratio**	**Limiting Width-to-Thickness Ratio λ_r (nonslender/slender): Carbon Steel**	**Stainless Steel**
Unstiffened Elements	1	Flanges of rolled I-shaped sections, plates projecting from rolled I-shaped sections; outstanding legs of pairs of angles connected with continuous contact, flanges of channels, and flanges of tees	b/t	$0.56\sqrt{\frac{E}{F_y}}$	$0.47\sqrt{\frac{E}{F_y}}$
Unstiffened Elements	2	Flanges of built-up I-shaped sections and plates or angle legs projecting from built-up I-shaped sections	b/t	$0.64\sqrt{\frac{k_c E}{F_y}}$ where $k_c = \frac{4}{h/t_w}$	$0.47\sqrt{\frac{E}{F_y}}$
Unstiffened Elements	3	Legs of single angles, legs of double angles with separators, and all other unstiffened elements	b/t	$0.45\sqrt{\frac{E}{F_y}}$	$0.38\sqrt{\frac{E}{F_y}}$
Stiffened Elements	4	Webs of doubly symmetric I-shaped sections and channels	h/t_w	$1.49\sqrt{\frac{E}{F_y}}$	$1.24\sqrt{\frac{E}{F_y}}$
Stiffened Elements	5	Walls of rectangular HSS and boxes of uniform thickness	b/t	$1.40\sqrt{\frac{E}{F_y}}$	$1.24\sqrt{\frac{E}{F_y}}$
Stiffened Elements	6	All other stiffened elements	b/t	$1.49\sqrt{\frac{E}{F_y}}$	$1.24\sqrt{\frac{E}{F_y}}$
Stiffened Elements	7	Round HSS	D/t	$0.11\frac{E}{F_y}$	$0.10\frac{E}{F_y}$