

Using Chapter F of the *North American Specification for the Design of Cold-Formed Steel Structural Members*

Summary: The *North American Specification for the Design of Cold-Formed Steel Structural Members* is intended for use throughout the U.S., Canada and Mexico and was developed by the American Iron and Steel Institute, Canadian Standards Association, and CANACERO in Mexico. The *Specification* provides procedures for the design of load bearing cold-formed steel members in buildings and certain other applications.

INTRODUCTION

Cold-formed steel members and connections may be designed based on test data if the respective member or connection can not be designed using the equations contained in Chapters A through G of the *North American Specification for the Design of Cold-Formed Steel Structural Members*. Examples of applications that are designed based on test data are powder-driven pins, cold-formed steel rivets, and floor joists having edge-reinforced web holes.

When the design is to be based on test data it is imperative to properly define the appropriate factor of safety or resistance factor. *Specification* Chapter F Section F1 titled "Tests for Special Cases" provides guidance for determining the appropriate factor of safety or resistance factor.

The intent of this document is to demonstrate the application of the Section F1 provisions. Background information pertaining to Section F1 can be found in the *Commentary on the North American Specification for the Design of Cold-Formed Steel Structural Members* or W.W. Yu's *Cold-Formed Steel Design*.

Overview of Section F1

Section F1 does not stipulate the appropriate test protocol, but provides the required method to compute the resistance factor in Section F1.1 or the factor of safety in Section F1.2. **Appendix A presents the text of these Sections.**

Example Problem

Design strength equations for powder-driven pins used for steel-to-steel connections are not included in Chapter E, Connections and Joints, of the *North American Specification for the Design of Cold-Formed Steel*

Structural Members. Thus, Chapter F, Tests for Special Cases, can be utilized to establish the nominal strength, R_n , and the resistance factor, ϕ , and the factor of safety, Ω .

Chapter F provides the methodology for computing the resistance factor and the factor of safety. However, Chapter F does not stipulate the test protocol to be used. Guidance regarding an appropriate test protocol may be obtained from Part VI of the *AISI Manual Cold-Formed Steel Design*. Specifically, to assess the strength of a powder-driven pin, AISI TS-5-02 Test Methods for Mechanically Fastened Cold-Formed Steel Connections was used to develop data regarding the performance of pins in a single shear connection. The sheet-to-sheet test specimen as well as the test setup is defined by Section 7.2 of AISI TS-5-02.

As defined in Chapter F, the minimum number of tests that shall be conducted is three for the connection under study. There can be more than three tests if it is determined to be appropriate by either the researcher or the product manufacturer.

For this example it was decided that six tests were necessary. Using the guidelines from Section 7.2 of TS-5-02, the following test strength data was generated:

Test No.	Failure Load (lbs)
1	1385.5
2	1384.3
3	1436.6
4	1290.1
5	1365.0
6	1380.2

The nominal design strength, R_n , is defined as the average value of all of the above test data:

$$R_n = 1373 \text{ lbs.}$$

Chapter F requires that the deviation of any individual test result from the average shall not exceed $\pm 15\%$. If the 15% is exceeded, more tests shall be made until the deviation of any individual test result from the average value obtained from all tests does not exceed $\pm 15\%$, or until at least three additional have been made. For the above test data, the controlling data value is Test No. 4, i.e. $(1373-1290.1)/1373 = 0.06 < 0.15$ or 15%. Additional tests are not required. It is also important to note that test results cannot be eliminated unless a rationale for exclusion can be given.

All test specimens were cut from the same coil. Therefore, the uncoated sheet thickness and the material properties were determined from samples of the coil as per ASTM A370. When all of the test specimens are not fabricated from the same coil, the material properties must be determined for each coil. The material properties must be correlated to the respective test specimens.

The design tensile strength, F_u , for the connection material is 65 ksi. However, the measured tensile strength for the test specimens was 68 ksi. Chapter F stipulates that consideration must be given to any variation or difference that exists between the design tensile or yield strength and the measured tensile or yield strength of the test specimen, which ever is critical. In this example, the tensile strength of the connected sheets is the critical factor, therefore the R_n value must be adjusted by the ratio of the design tensile strength to the measured tensile strength, i.e. $65 \text{ ksi} / 68 \text{ ksi} = 0.96$. The measured tensile strength was determined in accordance with ASTM A370. Chapter F stipulates that R_n shall not be adjusted upward.

The design sheet thickness for the connections is 0.071 inches. However, the measured sheet thickness for the test specimens was 0.075 inches. Chapter F stipulates that consideration must be given to any variation or difference that exists between the design thickness and the thickness of the test specimen. Thus, the R_n value must be adjusted by the ratio of the design thickness to the measured thickness, i.e. $0.071" / 0.075" = 0.95$. Both the design thickness and the measured thickness are the base steel sheet thickness exclusive of coating. Chapter F stipulates the design thickness shall not be adjusted upward.

The adjusted nominal design strength = $1373 \text{ lbs} \times 0.96 \times 0.95 = 1252 \text{ lbs}$.

The coefficient of variation of the test data, V_p , is computed as the standard deviation divided by the mean of the test data. The standard deviation may be computed using the expressions given in any engineering statistics textbook or more easily determined by using the STDEV function in Excel. Using Excel, the standard deviation was computed as follows:

$$\text{STDEV} = 47.57$$

Correspondingly, the coefficient of variation, $V_p = 47.57 \text{ lbs} / 1373 \text{ lbs} = 0.0346$ or 3.4%. But, Chapter F requires that $V_p \geq 6.5\%$. Therefore, use $V_p = 0.065$.

Using Chapter F equation F1.1-2 the resistance factor is determined as follows:

$$\phi = C_\phi (M_m F_m P_m) e^{-\beta_0 \sqrt{V_M^2 + V_F^2 + C_p V_P^2 + V_Q^2}} \quad (\text{Eq. F1.1-2})$$

Where,

$C_\phi = 1.52$ for the United States and Mexico

For further information regarding the definition of the coefficients in Equation F1.1-2, refer to the *Specification*, Chapter F, Chapter F Table F1 and the *Commentary*.

The resistance factor is influenced by the number of tests performed for the connection under study. For example, in this test program six tests were performed for the single lap shear connection using sheets having 0.075 inch thickness. As the number of the same configuration tests are performed the resistance factor can be shown to increase. The adjustment factor, C_p , for the number of tests is determined by using Chapter F equation F1.1-3.

$$n = \text{number of tests} = 6 \\ m = n - 1 = 6 - 1 = 5$$

$$C_p = (1 + 1/n)m / (m - 2) \text{ for } n \geq 4 \\ = (1 + 1/6)(5) / (5 - 2) = 1.94 \quad (\text{Eq. F1.1-3})$$

$$\beta_0 = 3.5 \text{ for connections}$$

$$P_m = 1.0$$

The remaining parameters are listed in Table F1 and are a function of the type of component. For powder-driven pins the correct selection of type of component from Table F1 is "Connections Not Listed Above" and the parameters are:

$$M_m = 1.10 \\ V_m = 0.10 \\ F_m = 1.00 \\ V_F = 0.15 \\ V_Q = 0.21$$

Solving Eq. F1.1-2 yields $\phi = 0.603$.

The LRFD design strength, $\phi R_n = 0.60 \times 1252 \text{ lbs} = 751.2 \text{ lbs}$.

For Allowable Strength Design the factor of safety is determined by using Eq. F1.2-2 as follows:

$$\begin{aligned}\Omega &= 1.6/\phi && \text{(Eq. F1.2-2)} \\ &= 1.6/0.603 = 2.65\end{aligned}$$

The ASD allowable design strength = $R_n/\Omega = 1252/2.65 = 472.5$ lbs.

If a test setup includes multiple components of the product being tested, the standard deviation and the

coefficient of variation are to be based on the number of test setups that were tested. *Specification* Chapter F, however provides no guidance on how C_p should be calculated, given a test setup that includes multiple components many engineers reasonably choose to adjust the C_p value to reflect the number of components included in the entire test program.

Appendix A

The following excerpt of the Chapter F from the *North American Specification for the Design of Cold-Formed Steel Structural Members* is by permission of the American Iron and Steel Institute.

F. TESTS FOR SPECIAL CASES

- (a) Tests shall be made by an independent testing laboratory or by a testing laboratory of a manufacturer.
- (b) The provisions of Chapter F do not apply to cold-formed steel diaphragms. Refer to Section D5.

F1 Tests for Determining Structural Performance

F1.1 Load and Resistance Factor Design and Limit States Design

Any structural performance which is required to be established by tests shall be evaluated in accordance with the following performance procedure:

- (a) Evaluation of the test results shall be made on the basis of the average value of test data resulting from tests of not fewer than three identical specimens, provided the deviation of any individual test result from the average value obtained from all tests does not exceed ± 15 percent. If such deviation from the average value exceeds 15 percent, more tests of the same kind shall be made until the deviation of any individual test result from the average value obtained from all tests does not exceed ± 15 percent, or until at least three additional tests have been made. No test result shall be eliminated unless a rationale for its exclusion can be given. The average value of all tests made shall then be regarded as the nominal strength [resistance], R_n , for the series of the tests. R_n and the coefficient of variation V_P of the test results shall be determined by statistical analysis.
- (b) The strength of the tested elements, assemblies, connections, or members shall satisfy Eq. F1.1-1.

$$\Sigma \gamma_i Q_i \leq \phi R_n \tag{Eq. F1.1-1}$$

where

$\Sigma \gamma_i Q_i$ = Required strength [effect of factored loads] based on the most critical load combination determined in accordance with Section A5.1.2. γ_i and Q_i are load factors and load effects, respectively.

R_n = Average value of all test results

ϕ = Resistance factor

$$= C_\phi (M_m F_m P_m) e^{-\beta_o \sqrt{V_M^2 + V_F^2 + C_P V_P^2 + V_Q^2}} \tag{Eq. F1.1-2}$$

Appendix A (continued)

C_ϕ	= Calibration coefficient = 1.52 for United States and Mexico = 1.42 for Canada	
M_m	= Mean value of the material factor, M , listed in Table F1 for the type of component involved	
F_m	= Mean value of the fabrication factor, F , listed in Table F1 for the type of component involved	
P_m	= Mean value of the professional factor, P , for the tested component = 1.0	
β_o	= Target reliability index = 2.5 for structural members and 3.5 for connections for United States and Mexico = 3.0 for structural members and 4.0 for connections for Canada	
V_M	= Coefficient of variation of the material factor listed in Table F1 for the type of component involved	
V_F	= Coefficient of variation of the fabrication factor listed in Table F1 for the type of component involved	
C_P	= Correction factor = $(1+1/n)m/(m-2)$ for $n \geq 4$, and 5.7 for $n = 3$	(Eq. F1.1-3)
V_P	= Coefficient of variation of the test results, but not less than 6.5%	
m	= Degrees of freedom = $n-1$	
n	= Number of tests	
V_Q	= Coefficient of variation of the load effect = 0.21	
e	= Natural logarithmic base = 2.718...	

Note:

- * For beams having tension flange through-fastened to deck or sheathing and with compression flange laterally unbraced, ϕ shall be determined with a coefficient, C_ϕ , of 1.6 in lieu of 1.52 for the United States and Mexico, $\beta_o = 1.5$, and $V_Q = 0.43$.

The listing in Table F1 does not exclude the use of other documented statistical data if they are established from sufficient results on material properties and fabrication.

For steels not listed in Section A2.1, the values of M_m and V_M shall be determined by the statistical analysis for the materials used.

When distortions interfere with the proper functioning of the specimen in actual use, the load effects based on the critical load combination at the occurrence of the acceptable distortion shall also satisfy Eq. F1.1-1, except that the resistance factor ϕ is taken as unity and that the load factor for dead load is taken as 1.0.

- (c) If the yield point of the steel from which the tested sections are formed is larger than the specified value, the test results shall be adjusted down to the specified minimum yield point of the steel which the manufacturer intends to use. The test results shall not be adjusted upward if the yield point of the test specimen is less than the minimum specified yield point. Similar

Appendix A (continued)

adjustments shall be made on the basis of tensile strength instead of yield point where tensile strength is the critical factor.

Consideration must also be given to any variation or differences which may exist between the design thickness and the thickness of the specimens used in the tests.

TABLE F1
Statistical Data for the Determination of Resistance Factor

Type of Component	M_m	V_M	F_m	V_F
Transverse Stiffeners	1.10	0.10	1.00	0.05
Shear Stiffeners	1.00	0.06	1.00	0.05
Tension Members	1.10	0.10	1.00	0.05
Flexural Members				
Bending Strength	1.10	0.10	1.00	0.05
Lateral-Torsional Buckling Strength	1.00	0.06	1.00	0.05
One Flange Through-Fastened to Deck or Sheathing	1.10	0.10	1.00	0.05
Shear Strength	1.10	0.10	1.00	0.05
Combined Bending and Shear	1.10	0.10	1.00	0.05
Web Crippling Strength	1.10	0.10	1.00	0.05
Combined Bending and Web Crippling	1.10	0.10	1.00	0.05
Concentrically Loaded Compression Members	1.10	0.10	1.00	0.05
Combined Axial Load and Bending	1.05	0.10	1.00	0.05
Cylindrical Tubular Members				
Bending Strength	1.10	0.10	1.00	0.05
Axial Compression	1.10	0.10	1.00	0.05
Wall Studs and Wall Stud Assemblies				
Wall Studs in Compression	1.10	0.10	1.00	0.05
Wall Studs in Bending	1.10	0.10	1.00	0.05
Wall Studs with Combined Axial load and Bending	1.05	0.10	1.00	0.05
Structural Members Not Listed Above	1.00	0.10	1.00	0.05

Appendix A (continued)

TABLE F1 (Continued)
Statistical Data for the Determination of Resistance Factor

Type of Component	M_m	V_M	F_m	V_F
Welded Connections				
Arc Spot Welds				
Shear Strength of Welds	1.10	0.10	1.00	0.10
Plate Failure	1.10	0.08	1.00	0.15
Arc Seam Welds				
Shear Strength of Welds	1.10	0.10	1.00	0.10
Plate Tearing	1.10	0.10	1.00	0.10
Fillet Welds				
Shear Strength of Welds	1.10	0.10	1.00	0.10
Plate Failure	1.10	0.08	1.00	0.15
Flare Groove Welds				
Shear Strength of Welds	1.10	0.10	1.00	0.10
Plate Failure	1.10	0.10	1.00	0.10
Resistance Welds	1.10	0.10	1.00	0.10
Bolted Connections				
Minimum Spacing and Edge Distance	1.10	0.08	1.00	0.05
Tension Strength on Net Section	1.10	0.08	1.00	0.05
Bearing Strength	1.10	0.08	1.00	0.05
Screw Connections				
Minimum Spacing and Edge Distance	1.10	0.10	1.00	0.10
Tension Strength on Net Section	1.10	0.10	1.00	0.10
Bearing Strength	1.10	0.10	1.00	0.10
Connections Not Listed Above	1.10	0.10	1.00	0.15

Appendix A (continued)

F1.2 Allowable Strength Design

Where the composition or configuration of elements, assemblies, connections or details of cold-formed steel structural members are such that calculation of their strength cannot be made in accordance with the provisions of this *Specification*, their structural performance shall be established from tests and evaluated in accordance with Section F1.1, except as modified in this section for allowable strength design.

The allowable design strength shall be calculated as:

$$R = R_n / \Omega \quad (\text{Eq. F1.2-1})$$

where

R_n = Average value of all test results

Ω = Factor of safety to be computed as follows:

$$\Omega = \frac{1.6}{\phi} \quad (\text{Eq. F1.2-2})$$

in which ϕ is evaluated in accordance with Section F1.1.

The required allowable strength shall be determined from nominal loads and load combinations as described in A4.

References

North American Specification for the Design of Cold-Formed Steel Structural Members (2001), with 2004 Supplement, American Iron and Steel Institute, Washington, D.C.

Commentary on the North American Specification for the Design of Cold-Formed Steel Structural Members (2001), with 2004 Supplement, American Iron and Steel Institute, Washington, D.C.

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