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Load and resistance factor design of cold-formed steel: Calibration of the AISI design provisions

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Ninth Progress Report

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Department of Civil Engineering
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ROLLA, MISSOURI

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I. INTRODUCTION

In the design of steel buildings, the "Allowable Stress Criteria" have long been used for the design of cold-formed steel structural members in the United States and other countries.[1] In view of the fact that the mathematical theory of probability, which has been so successfully applied in other fields of engineering, would seem to be equally applicable to cold-formed steel design by providing a more uniform degree of structural safety, the "Limit State Design" method based on the probabilistic concept has been used in Canada and Europe for the design of cold-formed steel structural members.[2]

In the United States, a research project on "Load and Resistance Factor Design of Cold-Formed Steel Members" was condudted by Rang, Supornsilaphachai, Snyder, Pan, Galambos, and Yu during the period from 1979 through 1985.[3-11] The tentative load and resistance factor design (LRFD) criteria for cold-formed structural members were proposed in the Seventh Progress Report[9] on the basis of the 1980 Edition of the AISI allowable stress design specification.[12]

In 1986, a major revision was made in the AISI Specification to reflect the results of recent research projects and improvements in design techniques.[13] Consequently, the tentative LRFD criteria proposed in the Seventh Progress Report were revised in 1987.

This progress report contains the calibrations of the AISI design provisions included in the 1986 Specification. The procedures used for calibration are summarized in Article II. Articles III through XI deal with (a) bending strength, (b) web crippling of beams, (c) combined bending and web crippling, (d) concentrically loaded compression members, (e) combined axial load and bending, (f) welded connections, (g) bolted connections, (h) stiffeners, and (i) wall studs and wall stud assemblies. The results of these calibrations will be used in the revision of the proposed LRFD Specification for cold-formed steel structural members.

II. PROCEDURES FOR CALIBRATION OF DESIGN PROVISIONS

For the purpose of facilitating the steps used in the calibration of various provisions of the AISI Specification, the following procedures have been formulated, and all the calibrations in this report are based on the formulas derived herein.

The load and resistance factor design criteria for the combination of dead and live loads can be expressed in the following equation:

$$\phi R_n \geq \gamma_D C_D D_C + \gamma_L C_L L_C \qquad \text{(II.1)}$$

The right side of the equation represents the effects of a combination of dead load, D_C, and live load, L_C, whereas, the left side relates to the nominal resistance, R_n, of a structural member; γ_D and γ_L are load factors associated with the dead load and live load, respectively; ϕ is the resistance factor, and C_D and C_L are deterministic influence coefficients, which transform the load intensities to load effects.

The resistance of a structural member is assumed to be of the following form:

$$R = R_n MFP \qquad \text{(II.2)}$$

in which M, F, and P are dimensionless random variables reflecting the uncertainties in the material properties (i.e., F_y, F_u, etc.), the geometry of the cross-section (i.e., S_x, A, etc.), and the design assumptions.

The mean resistance, R_m, is

$$R_m = R_n M_m F_m P_m \tag{II.3}$$

In the above equation, M_m, F_m, and P_m are the mean values of M, F, and P, respectively.

By using the first order probabilistic theory and assuming that there is no correlation between M, F, and P, one finds that the coefficient of variation of the resistance is

$$V_R = \sqrt{V_M{}^2+V_F{}^2+V_P{}^2} \tag{II.4}$$

in which V_M, V_F, and V_P are coefficients of variation of the random variables M, F, and P, respectively.

The mean load effect, Q_m, for a combination of dead and live loads is assumed to be of the form

$$Q_m = C_D C_m D_m + C_L B_m L_m \tag{II.5}$$

in which, B_m and C_m are mean values of random variables reflecting the uncertainties in the transformation of load intensities into load effects.

By assuming C_m=B_m=1.0 and C_D=C_L, the coefficient of variation of load effects, V_Q, is

$$V_Q = \frac{\sqrt{(D_m V_D)^2+(L_m V_L)^2}}{D_m+L_m} \qquad (II.6)$$

where D_m and L_m are the mean dead and live load intensities, respectively, and V_D and V_L are the corresponding coefficients of variation.

Load statistics have been analyzed in Ref. 14, where it was shown that D_m=1.05D_n, V_D=0.1, L_m=L_n, V_L=0.25. The mean live load intensity equals to the code live load intensity if the tributary area is small enough so that no live load reduction is required. Substitution of the load statistics into Eq. (II.6) gives

$$V_Q = \frac{\sqrt{(1.05D_n/L_n)^2 V_D{}^2+V_L{}^2}}{(1.05D_n/L_n+1)} \qquad (II.7)$$

Thus, V_Q depends on the dead-to-live load ratio. Cold-formed members typically have relatively small D_n/L_n ratios. For the purposes of checking the reliability of the LRFD criteria, it will be assumed that D_n/L_n = 1/5, and so V_Q = 0.21.

In this approach, the structural safety, which is represented by a safety index, β, measures the reliability of the member. This safety index can be determined on the basis of statistics of resistances and load effects as follows:

$$\beta = \frac{\ln(R_m/Q_m)}{\sqrt{V_R{}^2+V_Q{}^2}} \qquad (II.8)$$

Once the safety index is selected, the resistance factor can be determined.

The values of the reliability index β vary considerably for the different kinds of loading, the different types of construction, and the different types of members within a given material design specification. In order to achieve more consistent reliability, it was suggested in Ref. 15 that the following values of β would provide this improved consistency while at the same time give, on the average, essentially the design by the new LRFD method as is obtained by current design for all materials of construction. These target reliabilities β_o for use in LRFD are:

For basic case: Gravity loading, $\beta_o = 3.0$

For connections: $\beta_o = 4.5$

For wind loading: $\beta_o = 2.5$

For cold-formed simply supported braced steel beams with stiffened flanges, which were designed according to the 1986 AISI allowable stress design specification or to any previous version of this specification, it is shown in the commentary of the Tenth Progress Report that for the representative dead-to-live load ratio of 1/5 the reliability index $\beta = 2.8$. Considering the fact that for other such load ratios, or for other types of members, the reliability index inherent in current cold-formed steel construction could be more or less than this value of 2.8, a somewhat lower target reliability index of $\beta_o = 2.5$ is recommended as a lower limit for the new LRFD Specification.

The resistance factors ϕ will be selected such that $\beta_o = 2.5$ is essentially the lower bound of the actual β-values for members. In order to assure that failure of a structure is not initiated in the connections, a higher target reliability of $\beta_o = 3.5$ is recommended for joints and fasteners. These two targets of 2.5 and 3.5 for members and connections, respectively, are somewhat lower than those recommended by ANSI A58.1-82 (i.e., 3.0 and 4.5, respectively), but they are essentially the same targets as are the basis for the 1986 AISC LRFD Specification.

In this report, the ϕ factors are determined for the load combination of $1.2D_n+1.6L_n$ to approximately provide a target β_o of 2.5 for members and 3.5 for connections, respectively. For practical reasons, it is desirable to have relatively few different resistance factors, and therefore the actual values of β will differ from the derived targets. This means that

$$\phi R_n = C(1.2D_n+1.6L_n) = (1.2D_n/L_n+1.6)CL_n \qquad \text{(II.9)}$$

where C is the deterministic influence coefficient translating load intensities to load effects.

By assuming $D_n/L_n = 1/5$, Eqs. (II.9) and (II.5) can be rewritten as follows:

$$R_n = 1.84(CL_n/\phi) \qquad \text{(II.10)}$$

or $CL_n = \phi R_n/1.84$

$$Q_m = (1.05D_n/L_n+1)CL_n = 1.21CL_n = \phi R_n/1.521 \qquad \text{(II.11)}$$

Therefore,

$$\frac{R_m}{Q_m} = \frac{1.521}{\phi} \frac{R_m}{R_n} \tag{II.12}$$

Because the target β_o can be determined from the following equation by using $V_Q = 0.21$,

$$\text{Target } \beta_o = \frac{\ln(R_m/Q_m)}{\sqrt{V_R^2+V_Q^2}}$$

the R_m/Q_m ratio can also be obtained from Eq. (II.13)

$$R_m/Q_m = \exp(\beta_o\sqrt{V_R^2+V_Q^2}) \tag{II.13}$$

Thus, the ϕ factors can be computed from Eqs. (II.12) and (II.13) as follows:

$$\phi = \frac{1.521}{\exp(\beta_o\sqrt{V_R^2+V_Q^2})}\left(\frac{R_m}{R_n}\right) \tag{II.14}$$

III. CALIBRATION OF THE AISI DESIGN PROVISIONS ON BENDING STRENGTH

III.1 General Remarks

The objective of this article is to determine the safety index for bending strength of flexural members by calibrating the AISI design formulas. In this process, the mean values and coefficients of variation were obtained from the statistical analyses of the test data on mechanical properties and ultimate moments of beams.

III.2 Calibration of the Nominal Section Strength for Bending

According to Section C3.1.1 of the 1986 AISI Specification, section strength shall be calculated either on the basis of initiation of yielding using effective section (Procedure I) or on the basis of the inelastic reserve capacity (Procedure II) as applicable. This calibration deals only with Procedure I which states that the effective yield moment based on section strength, M_n, shall be determined as follows:

$$M_n = S_e F_y \tag{III.2.1}$$

where

F_y = Design yield stress

S_e = Elastic section modulus of the effective section calculated with the extreme compression or tension fiber at F_y

The effective widths, b, of compression elements are determined in accordance with Sections B2 , B3, B4 and B5 of the 1986 AISI Specification as follows:

The following notation is used in Cases (6) and (7) of this section.

S = $1.28\sqrt{E/f}$

k = Buckling coefficient

b_0 = Dimension defined in Figure 5.

d, w, D = Dimensions defined in Figure 4.

d_s = Reduced effective width of the stiffener (see Figure 4.)

d'_s = Effective width of the stiffener (see Figure 4)

C_1, C_2 = Coefficients defined in Figures 4 and 5

A_s = Reduced area of the stiffener as specified in this section. A_s is to be used in computing the overall effective section properties. The centroid of the stiffener is to be considered located at the centroid of the full area of the stiffener, and the moment of inertia of the stiffener about its own centroidal axis shall be that of the full section of the stiffener.

I_a = Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element.

I_s, A'_s = Moment of inertia of the full stiffener about its own centroidal axis parallel to the element to be stiffened and the effective area of the stiffener, respectively. For edge stiffeners the round corner between the stiffener and the element to be stiffened shall not be considered as a part of the stiffener.

For the stiffener shown in Figure 4,

$I_s = (d^3 t \sin^2\theta)/12$

$A'_s = d'_s t$

(1) For uniformly compressed stiffened elements, the effective widths, b, shall be determined from the following formulas:

$$b = w \quad \text{when } \lambda \leq 0.673 \qquad \text{(III.2.2)}$$

$$b = \rho w \quad \text{when } \lambda > 0.673 \qquad \text{(III.2.3)}$$

where

w = Flat width as shown in Figure 1

$$\rho = (1-0.22/\lambda)/\lambda \qquad \text{(III.2.4)}$$

$$\lambda = (1.052/\sqrt{k})(w/t)(\sqrt{f/E}) \qquad \text{(III.2.5)}$$

k = 4.0 for stiffened elements supported by a web on each longitudinal edge

(2) For uniformly compressed stiffened elements with circular holes, the effective widths, b, shall be determined as follows:

For $0.50 \geq d_h/w \geq 0$, and $w/t \leq 70$

center-to-center spacing of holes > 0.50w and $3d_h$,

$$b = w - d_h \quad \text{when } \lambda \leq 0.673 \qquad \text{(III.2.6)}$$

$$b = w[1-0.22/\lambda-(0.8d_h)/w]/\lambda \text{ when } \lambda > 0.673 \qquad \text{(III.2.7)}$$

where

d_h = Diameter of holes

(3) For webs and stiffened elements with stress gradient, the effective widths, b_1 and b_2, shall be determined from the following formulas:

$$b_1 = b_e/(3-\Psi) \qquad \text{(III.2.8)}$$

For $\Psi \leq -0.236$

$$b_2 = b_e/2 \qquad \text{(III.2.9)}$$

b_1+b_2 shall not exceed the compression portion of the web calculated on the basis of effective section

For $\Psi > -0.236$

$$b_2 = b_e - b_1 \qquad \text{(III.2.10)}$$

where

b_e = Effective width b determined in accordance with Case (1) with f_1 substituted for f and with k determined as follows:

$$k = 4+2(1-\Psi)^3+2(1-\Psi) \qquad \text{(III.2.11)}$$

$\Psi = f_2/f_1$

f_1, f_2 = Stress shown in Figure 2 calculated on the basis of effective section. f_1 is compression (+) and f_2 can be either tension (-) or compression. In case f_1 and f_2 are both compression, $f_1 \geq f_2$

(4) For uniformly compressed unstiffened elements, the effective widths, b, shall be determined in accordance with Case (1) with the exception that k shall be taken as 0.43 (see Figure 3).

(5) For unstiffened elements and edge stiffeners with stress gradient, the effective widths, b, shall be determined in accordance with Case (1) with $f=f_3$ as in Figure 4 in the element and $k=0.43$.

(6) For uniformly compressed elements with an intermediate stiffener (see Figure 5):

Case I: $b_0/t \leq S$ (III.2.12)

$I_a = 0$ (no intermediate stiffener needed) (III.2.13)

$b = w$ (III.2.14)

$A_s = A_s'$ (III.2.15)

Case II: $S<b_0/t<3S$ (III.2.16)

$I_a/t^4 = [50(b_0/t)/S]-50$ (III.2.17)

b and A_s shall be calculated according to Case (1) where

$k = 3(I_s/I_a)^{1/2}+1 \leq 4$ (III.2.18)

$A_s = A_s'(I_s/I_a) \leq A_s'$ (III.2.19)

Case III. $b_0/t \geq 3S$

$I_a/t^4 = [128(b_0/t)/S]-285$ (III.2.20)

b and A_s are calculated according to Case (1) where

$k = 3(I_s/I_a)^{1/3}+1 \leq 4$ (III.2.21)

$A_s = A_s'(I_s/I_a) \leq A_s'$ (III.2.22)

(7) For uniformly compressed elements with an edge stiffener (see Figure 4):

Case I: $w/t \leq S/3$ (III.2.23)

$I_a = 0$ (no edge stiffener needed) (III.2.24)

$b = w$ (III.2.25)

$d_s = d_s'$ for simple lip stiffener (III.2.26)

$A_s = A_s'$ for other stiffener shapes (III.2.27)

Case II: $S/3<w/t<S$

$I_a/t^4 = 399\{[(w/t)/S]-0.33\}^3$ (III.2.28)

$n = 1/2$

$C_2 = I_s/I_a \leq 1$ (III.2.29)

$C_1 = 2-C_2$ (III.2.30)

b shall be calculated according to Case (1) where

$k = [4.82-5(D/w)](I_s/I_a)^n+0.43 \leq 5.25-5(D/w)$ (III.2.31)

for $0.8 \geq D/w > 0.25$

$k = 3.57(I_s/I_a)^n+0.43 \leq 4.0$ (III.2.32)

for $(D/w) \leq 0.25$

$d_s = d_s'(I_s/I_a) \leq d_s'$ (III.2.33)

for simple lip stiffener

$A_s = A_s'(I_s/I_a) \leq A_s'$ (III.2.34)

for other stiffener shapes

Case III: $w/t \geq S$

$I_a/t^4 = [115(w/t)/S]+5$ (III.2.35)

C_1, C_2, b, k, d_s, A_s are calculated per Case II with n=1/3.

(8) For the determination of the effective width, the intermediate stiffener of an edge stiffened element or the stiffeners of a stiffened element with more than one stiffener shall be disregarded unless each intermediate stiffener has the minimum I_s as follows:

$I_{min} = \left[3.66\sqrt{(w/t)^2-(0.136E)/F_y}\right]t^4$ (III.2.36)

but not less than $18.4t^4$

where

w/t = Width-thickness ratio of the larger stiffened sub-element

I_s = Moment of inertia of the full stiffener about its own centroid axis parallel to the element to be stiffened

In the calibration, the tested ultimate moments for beams, $(M_u)_{test}$, were obtained from Refs. 16 through 22; the predicted values of $(M_u)_{pred}$ were computed according to the 1986 AISI design formulas mentioned above. The tested and predicted ultimate moments are listed in Tables 1 through 6. On the basis of the statistical analysis of material properties reported in Ref. 3 and the study of dimensional properties given in Ref. 23 , it was decided that the following values be used in this study: $M_m = 1.10$, $V_M = 0.10$, $F_m = 1.0$ and $V_F = 0.05$. Based on these values, the safety indexes were computed and summarized in Table 74. It can be seen that six different cases have been studied according to the types of the compression flanges. The results indicate that by using $\phi = 0.95$ for stiffened compression flanges and $\phi = 0.9$ for unstiffened compression flanges, the values of β vary from 2.53 to 4.08 which are satisfactory to target β of 2.5.

III.3 Calibration of the Lateral Buckling Strength for Bending

Cold-formed steel flexural members, when loaded in the plane of the web, may twist and deflect laterally as well as vertically if adequate braces are not provided. To prevent lateral buckling, the moment shall not exceed the allowable moment as specified in Section C3.1.1 nor the following allowable moment specified in Section C3.1.2 of the 1986 AISI Specification.

For the laterally unbraced segments of doubly- or singly-symmetric sections subject to lateral buckling, M_n shall be determined as follows:

$$M_n = S_c(M_c/S_f) \tag{III.3.1}$$

where

S_f = Elastic section modulus of the full unreduced section for the extreme compression fiber

S_c = Elastic section modulus of the effective section calculated at a stress M_c/S_f in the extreme compression fiber

M_c = Critical moment calculated according to (a) or (b) below:

(a) For I- or Z-section bent about the centroidal axis (x-axis) perpendicular to the web:

For $M_e \geq 2.78M_y$

$$M_c = M_y \tag{III.3.2}$$

For $2.78M_y > M_e > 0.56M_y$

$$M_c = (10/9)M_y(1-10M_y/36M_e) \tag{III.3.3}$$

For $M_e \leq 0.56M_y$

$$M_c = M_e \tag{III.3.4}$$

where

M_y = Moment causing initial yield at the extreme compression fiber of the full section

$$= S_fF_y \tag{III.3.5}$$

M_e = Elastic critical moment determined either as defined in (b) below or as follows:

$= \pi^2 EC_b(dI_{yc}/L^2)$ for doubly-symmetric I-sections

(III.3.6)

$= \pi^2 EC_b(dI_{yc}/2L^2)$ for point-symmetric Z-sections

(III.3.7)

L = Unbraced length of the member

I_{yc} = Moment of inertia of the compression portion of a section about the gravity axis of the entire section parallel to the web, using the full unreduced section

Other terms are defined in (b) below.

(b) For singly-symmetric sections (x-axis is assumed to be the axis of symmetry):

For $M_e > 0.5M_y$

$$M_c = M_y(1-M_y/4M_e) \quad \text{(III.3.8)}$$

For $M_e \leq 0.5M_y$

$$M_c = M_e \quad \text{(III.3.9)}$$

where

M_y is as defined in (a) above

M_e = Elastic critical moment

M_e = $C_b r_0 A\sqrt{\sigma_{ey}\sigma_t}$ for bending about the symmetry axis (x-axis is the axis of symmetry oriented such that the shear center has a negative x-coordinate.) Alternatively, M_e can be calculated using the formula for doubly-symmetric I-sections given in (a) above (III.3.10)

M_e = $C_s A\sigma_{ex}\left[j+C_s\sqrt{j^2+r_0^{\,2}(\sigma_t/\sigma_{ex})}\right]/C_{TF}$ for bending centroidal axis perpendicular to the symmetry axis

(III.3.11)

C_s = +1 for moment causing compression on the shear center side of the centroid

C_s = -1 for moment causing tension on the shear center side of the centroid

$$\sigma_{ex} = \pi^2 E/(K_x L_x/r_x)^2 \qquad \text{(III.3.12)}$$

$$\sigma_{ey} = \pi^2 E/(K_y L_y/r_y)^2 \qquad \text{(III.3.13)}$$

$$\sigma_t = 1/(Ar_0^2)\left[GJ+\pi^2 EC_w/(K_t L_t)^2\right] \qquad \text{(III.3.14)}$$

A = Full cross-sectional area

C_b = Bending coefficient which can conservatively be taken as unity, or calculated from

$$C_b = 1.75+1.05(M_1/M_2)+0.3(M_1/M_2)^2 \leq 2.3$$

where

M_1 is the smaller and M_2 the larger bending moment at the ends of the unbraced length, taken about the strong axis of the member, and where M_1/M_2, the ratio of end moments, is positive when M_1 and M_2 have the same sign (reverse curvature bending) and negative when they are of opposite sign (single curvature bending). When the bending moment at any point within an unbraced length is larger than that at both ends of this length, and for members subject to combined axial load and bending moment, C_b shall be taken as unity.

E = Modulus of elasticity

d = Depth of section

$C_{TF} = 0.6-0.4(M_1/M_2)$

where

M_1 is the smaller and M_2 the larger bending moment at the ends of the unbraced length, and where M_1/M_2, the ratio of end moments, is positive when M_1 and M_2 have the same sign (reverse curvature bending) and negative when they are of opposite sign (single curvature bending). When the bending moment at any point within an unbraced length is larger than that at both ends of this length, and for members subject to combined axial load and bending moment, C_b shall be taken as unity.

r_0 = Polar radius of gyration of the cross section about the shear center

$$= \sqrt{r_x^2+r_y^2+x_0^2} \qquad (III.3.15)$$

r_x, r_y = Radii of gyration of the cross section about the centroidal principal axes

G = Shear modulus

K_x, K_y, K_t = Effective length factors for bending about the x- and y-axes, and for twisting

L_x, L_y, L_t = Unbraced length of compression member for bending about the x- and y-axes, and for twisting

x_0 = Distance from the shear center to the centroid along the principal x-axis, taken as negative

J = St. Venant torsion constant of the cross section

C_w = Torsional warping constant of the cross section

$$j = 1/(2I_y)(\int_A x^3 dA+\int_A xy^2 dA)-x_0 \qquad \text{(III.3.16)}$$

A total of 74 tests on lateral buckling of cold-formed steel beams were reported in Ref. 24. Among these tests, the dimensions and cross-sectional properties of the 47 relatively long I-beams which failed in elastic buckling are as follows:

Thickness (t): 0.0598 in.

Depth (d): 4 in.

Width (2B): 2 in.

Area: 0.705 $in.^2$

Moment of inertia about x-axis (I_x): 1.515 $in.^4$

Moment of inertia about y-axis (I_y): 0.0806 $in.^4$

Torsional constant (J): 0.00260 $in.^4$

Radius of gyration about y-axis (r_y): 0.338 in.

It shall be noted that the torsional constant provided in Ref. 24 was based on a web considered to be a one piece element instead of two pieces. The latter is used for the AISI approach (J=0.00082 $in.^4$). Since the connection for the web was not clearly shown in Ref. 24, both values were used in this calibration.

In addition to the AISI design formula, the theoretical approach and the Structural Stability Research Council (SSRC) approach[25] are used in this calibration.

The theoretical critical moment, M_{cr}, can be determined by the following formula:

$$M_{cr} = \frac{\pi^2 E}{L^2}\sqrt{I_y C_w}\sqrt{1+\frac{GJL^2}{\pi^2 EC_w}} \qquad \text{(III.3.17)}$$

For the SSRC approach, the buckling load, $(P_u)_p$, for a beam subjected to a concentrated load at the mid-span can be predicted by using the following equation:

$$(P_u)_p = \frac{1}{L^3}\left[2\pi^2 EC_b I_y d\right]\left[\sqrt{1+C_2{}^2+\frac{4GJL^2}{\pi^2 EI_y d^2}}-C_2\right] \qquad \text{(III.3.18)}$$

in which the values of C_b and C_2 are taken as 1.35 and 0.55, respectively.

The tested failure loads, $(P_u)_t$, and the predicted loads, $(P_u)_p$, are listed in Table 7. The mean values and the coefficients of variation for the tested-to-predicted load ratios, $(P_u)_t/(P_u)_p$, for five different cases are listed in Table 8.

Since all test specimens used in this calibration failed in the elastic range, only the modulus of elasticity was considered in the uncertainties of material properties. Therefore, $M_m = 1.00$ and $V_M = 0.06$.[23] The mean value of the fabrication factor F_m was assumed to be unity with a coefficient of variation $V_F = 0.05$. Based on these values, the safety indexes were computed and summarized in Table 75. Five different cases have been studied with $\phi = 0.90$, and the values of β

vary from 2.35 to 3.80. It can be seen that the β values obtained by using $J = 0.00082$ in.^{4} (AISI consideration) for all three approachs are satisfactory to the target β of 2.5.

IV. CALIBRATION OF THE AISI DESIGN PROVISIONS ON WEB CRIPPLING OF BEAMS

IV.1 AISI Design Provisions on Web Crippling Strength of Beams

To avoid crippling of unreinforced flat webs of flexural members having a flat width ratio, h/t, equal to or less than 200, concentrated loads and reactions shall not exceed the value of P_a given in Table IV.1 according to Section C3.4 of the AISI Specification. Webs of flexural members for which h/t is greater than 200 shall be provided with adequate means of transmitting concentrated loads and/or reactions directly into the webs.

Table IV.1

P_a

		Shapes Having Single Webs		I-beams or Similar Sections$_{(1)}$
		Stiffened Flanges	Unstiffened Flanges	Stiffened and Unstiffened Flanges
Opposing Loads Spaced >1.5h$_{(2)}$	End Reaction$_{(3)}$	Eq. IV.1.1	Eq. IV.1.2	Eq. IV.1.3
	Interior Reaction$_{(4)}$	Eq. IV.1.4	Eq. IV.1.4	Eq. IV.1.5
Opposing Loads Spaced $\leq$1.5h$_{(5)}$	End Reaction$_{(3)}$	Eq. IV.1.6	Eq. IV.1.6	Eq. IV.1.7
	Interior Reaction$_{(4)}$	Eq. IV.1.8	Eq. IV.1.8	Eq. IV.1.9

The formulas in Table IV.1 apply to beams when $R/t \leq 6$ and to deck when $R/t \leq 7$, $N/t \leq 210$ and $N/h \leq 3.5$.

Footnotes and Equation References to Table IV.1:

(1) I-sections made of two channels connected back to back or similar sections which provide a high degree of restraint against rotation of the web (such as I-sections made by welding two angles to a channel).

(2) At locations of one concentrated load or reaction acting either on the top or bottom flange, when the clear distance between the bearing edges of this and adjacent opposite concentrated loads or reactions is greater than 1.5h.

(3) For end reactions of beams or concentrated loads on the end of cantilevers when the distance from the edge of the bearing to the end of the beam is less than 1.5h.

(4) For reactions and concentrated loads when the distance from the edge of bearing to the end of the beam is equal to or greater than 1.5h.

(5) At locations of two opposite concentrated loads or of a concentrated load and an opposite reaction acting simultaneously on the top and bottom flanges, when the clear distance between their adjacent bearing edges is equal to or less than 1.5h.

Equations for Table IV.1:

$$t^2kC_3C_4C_\theta[179-0.33(h/t)][1+0.01(N/t)] \quad \text{(IV.1.1)}$$

$$t^2kC_3C_4C_\theta[117-0.15(h/t)][1+0.01(N/t)] \quad \text{(IV.1.2)}$$

When $N/t>60$, the factor $[1+0.01(N/t)]$ may be increased to $[0.71+0.015(N/t)]$

$$t^2F_yC_6(5.0+0.63\sqrt{N/t}) \quad \text{(IV.1.3)}$$

$$t^2kC_1C_2C_\theta[291-0.40(h/t)][1+0.007(N/t)] \quad \text{(IV.1.4)}$$

When $N/t>60$, the factor $[1+0.007(N/t)]$ may be increased to $[0.75+0.011(N/t)]$

$$t^2F_yC_5(0.88+0.12m)(7.50+1.63\sqrt{N/t}) \quad \text{(IV.1.5)}$$

$$t^2kC_3C_4C_\theta[132-0.31(h/t)][1+0.01(N/t)] \quad \text{(IV.1.6)}$$

$$t^2F_yC_8(0.64+0.31m)(5.0+0.63\sqrt{N/t}) \quad \text{(IV.1.7)}$$

$$t^2kC_1C_2C_\theta[417-1.22(h/t)][1+0.0013(N/t)] \quad \text{(IV.1.8)}$$

$$t^2F_yC_7(0.82+0.15m)(7.50+1.63\sqrt{N/t}) \quad \text{(IV.1.9)}$$

In the above referenced formulas,

P_a = Allowable concentrated load or reaction per web

$$C_1 = (1.22-0.22k) \quad \text{(IV.1.10)}$$

$$C_2 = (1.06-0.06R/t) \le 1.0 \quad \text{(IV.1.11)}$$

$$C_3 = (1.33-0.33k) \quad \text{(IV.1.12)}$$

$$C_4 = (1.15-0.15R/t) \le 1.0 \text{ but not less than } 0.50 \quad \text{(IV.1.13)}$$

$$C_5 = (1.49-0.53k) \ge 0.6 \quad \text{(IV.1.14)}$$

$$C_6 = 1+(h/t)/750, \quad \text{when } h/t \le 150 \quad \text{(IV.1.15)}$$

$$= 1.20, \quad \text{when } h/t>150 \quad \text{(IV.1.16)}$$

$$C_7 = 1/k, \quad \text{when } h/t \le 66.5 \quad \text{(IV.1.17)}$$

$$= [1.10-(h/t)/665]/k, \quad \text{when } h/t>66.5 \quad \text{(IV.1.18)}$$

$$C_8 = [0.98-(h/t)/865]/k \quad \text{(IV.1.19)}$$

$$C_\theta = 0.7+0.3(\theta/90)^2 \quad \text{(IV.1.20)}$$

F_y = Design yield stress of the web, ksi

h = Depth of the flat portion of the web measured along the plane of the web

$$k = F_y/33 \quad \text{(IV.1.21)}$$

$m = t/0.075$ (IV.1.22)

t = Web thickness, inches

N = Actual length of bearing, inches. For the case of two equal and opposite concentrated loads distributed over unequal bearing lengths, the smaller value of N shall be taken

R = Inside bend radius

θ = Angle between the plane of the web and the plane of the bearing surface $\geq 45^{o}$, but not more than 90^{o}

The above listed equations were derived on the basis of the ultimate web crippling loads and a factor of safety of 1.85 for single unreinforced webs and 2.0 for I-beams or similar sections.

IV.2 Calibration of the AISI Design Provisions on Web Crippling Strength of Beams

In this investigation, the AISI design formulas were calibrated by using the results of 589 tests, which included 375 tests for beams having single unreinforced webs and 214 tests for I-beam sections.

Based on the test data obtained from Refs. 26 through 28 and the predicted web crippling loads, $(P_u)_{pred}$, computed from the equations listed above, the professional factors were determined by using the ratios of $(P_u)_{test}/(P_u)_{pred}$ as given in Tables 9 through 20. The meam values and coefficients of variation of the professional factors (P_m and V_P) are also included in the tables mentioned above.

By using the above mentioned values and the values of M_m, V_M, F_m, and V_F listed in Table 76, the values of the safety index for 15 different cases were determined by using ϕ = 0.75 and 0.80 for single unreinforced webs and I-sections, respectively. All the computed values of the safety index are listed in Table 76. From this Table, it can be seen that the safety indexes β vary from 2.36 to 3.80. The low β values are based on the calibration of Canadian tests.

V. CALIBRATION OF THE AISI DESIGN PROVISIONS ON COMBINED BENDING AND WEB CRIPPLING

V.1 AISI Design Provisions on Combined Bending and Web Crippling

In the 1986 edition of AISI Specification, the design criteria are stated in Section C3.5 as follows:

Unreinforced flat webs of shapes subjected to a combination of bending and concentrated load or reaction shall be designed to meet the following requirements:

(a) For shapes having single unreinforced webs:

$$1.2(P/P_a)+(M/M_a) \leq 1.5 \qquad \text{(V.1.1)}$$

Exception: At the interior supports of continuous spans, the above formula is not applicable to deck or beams with two or more single webs, provided the compression edges of adjacent webs are laterally supported in the negative moment region by continuous or intermittently connected flange elements, rigid cladding, or lateral bracing, and the spacing between adjacent webs does not exceed 10 inches.

(b) For shapes having multiple unreinforced webs such as I-sections made of two channels connected back-to-back, or similar sections which provide a high degree of restraint against rotation of the web (such as I-sections made by welding two angles to a channel);

$$1.1(P/P_a)+(M/M_a) \le 1.5 \qquad (V.1.2)$$

Exception: When $h/t \le 2.33/\sqrt{(F_y/E)}$ and $\lambda \le 0.673$, the allowable concentrated load or reaction may be determined by Section C3.4.

In the above formulas,

P = Concentrated load or reaction in the presence of bending moment

P_a = Allowable concentrated load or reaction in the absence of bending moment determined in accordance with Section C3.4

M = Applied bending moment at, or immediately adjacent to, the point of application of the concentrated load or reaction

M_a = Allowable bending moment if bending alone exists

w = Flat width of the beam flange which contacts the bearing plate

t = Thickness of the web or flange

λ = Slenderness factor given by Section B2.1

V.2 Calibration of the AISI Design Provisions on Combined Bending and Web Crippling

The interaction formulas listed above are based on the allowable loads and moments. In order to predict the ultimate failure load for combined bending and web crippling, the interaction formulas have been rewritten as follows:

$$1.07(P_u/P_n)+(M_u/M_n) \le 1.42 \qquad (V.2.1)$$

$$0.82(P_u/P_n)+(M_u/M_n) \le 1.32 \qquad (V.2.2)$$

where

P_u = Ultimate concentrated load or reaction in the presence of bending moment

P_n = Nominal concentrated load or reaction in the absence of bending moment

M_u = Ultimate bending moment at, or immediately adjacent to, the point of application of the concentrated load or reaction

M_n = Nominal bending moment if bending alone exists

Equation (V.2.1) is derived from equation (V.1.1) by using a safety factor of 1.85 for web crippling load and a safety factor of 1.67 for bending moment ; equation (V.2.2) is derived from equation (V.1.2) by using a safety factor of 2.0 for web crippling and a safety factor of 1.67 for bending moment.

A total of 551 tests were used in this calibration, which included 445 tests for beams having single unreinforced webs and 106 tests for I-beam sections. The tested failure loads, $(P_u)_{test}$, were obtained from Refs. 26 through 30. The predicted values of $(P_u)_{pred}$ were computed according to the interaction formulas derived above. The tested and predicted failure loads and their ratios, $(P_u)_{test}/(P_u)_{pred}$, are listed in Tables 21 through 25. The mean values and coefficients of variation of the professional factors (P_m and V_P) are also included in the tables mentioned above.

By using the above mentioned values and the values of M_m, V_M, F_m, and V_F listed in Table 77, the values of the safety index for six different cases were determined on the basis of $\phi_w = 0.75$ and 0.80 for single unreinforced webs and I-sections, respectively. All the computed values of the safety index are listed in Table 77. From this Table, it can be seen that the safety indexes β vary from 2.45 to 3.27 which are satisfactory to the target β of 2.5.

VI. CALIBRATION OF THE AISI DESIGN PROVISIONS ON CONCENTRICALLY LOADED COMPRESSION MEMBERS

VI.1 AISI Design Provisions on Concentrically Loaded Compression Members

Section C4 of the 1986 AISI Specification contains the following requirements for compression members in which the resultant of all loads acting on the member is an axial load passing through the centroid of the effective section at the stress, F_n, defined in that section.

(a) The axial load shall not exceed P_a calculated as follows:

$$P_a = P_n/\Omega_c \tag{VI.1.1}$$

where

$$P_n = A_e F_n \tag{VI.1.2}$$

A_e = Effective area at the stress F_n.

F_n is determined as follows:

For $F_e > F_y/2$ $\quad F_n = F_y(1-F_y/4F_e)$ (VI.1.3)

For $F_e \leq F_y/2$ $\quad F_n = F_e$ (VI.1.4)

F_e is the least of the elastic flexural, torsional and torsional-flexural buckling stress.

Ω_c = Factor of safety for axial compression

(b) For C and Z-shapes, and single-angle sections with unstiffened flanges, P_n shall be taken as the smaller of P_n calculated above and P_n calculated as follows:

$$P_n = A\pi^2E/[25.7(w/t)^2] \tag{VI.1.5}$$

where

A = Area of the full, unreduced cross section

w = Flat width of the unstiffened element

t = Thickness of the unstiffened element

(c) Angle sections shall be designed for the applied axial load, P, acting simultaneously with a moment equal to PL/1000 applied about the minor principal axis causing compression in the tips of the angle legs.

(d) The slenderness ratio, KL/r, of all compression members preferably should not exceed 200, except that during construction only, KL/r preferably should not exceed 300.

For doubly-symmetric sections, closed cross sections and any other sections which can be shown not to be subject to torsional or torsional-flexural buckling, the elastic flexural buckling stress, F_e, shall be determined as follows:

$$F_e = \pi^2 E/(KL/r)^2 \qquad \text{(VI.1.6)}$$

E = Modulus of elasticity

K = Effective length factor

L = Unbraced length of member

r = Radius of gyration of the full, unreduced section

For sections subject to torsional or torsional-flexural buckling, F_e shall be taken as the smaller of F_e calculated above and F_e calculated as follows:

$$F_e = \left[(\sigma_{ex}+\sigma_t) - \sqrt{(\sigma_{ex}+\sigma_t)^2 - 4\beta\sigma_{ex}\sigma_t}\right]/(2\beta) \qquad \text{(VI.1.7)}$$

where

σ_t and σ_{ex} are as defined in Article III.3 of this report

$$\beta = 1-(x_0/r_0)^2 \tag{VI.1.8}$$

Alternatively, a conservative estimate of F_e can be obtained using the following equation:

$$F_e = \sigma_t\sigma_{ex}/(\sigma_t+\sigma_{ex}) \tag{VI.1.9}$$

For singly-symmetric sections, the x-axis is assumed to be the axis of symmetry.

For shapes whose cross sections do not have any symmetry, either about an axis or about a point, F_e shall be determined by rational analysis.

VI.2 Calibration of the AISI Design Provisions on Concentrically Loaded Compression Members

A total of 264 tests were used in this calibration. The tested failure loads, $(P_u)_{test}$, were obtained from Refs. 21 and 31 through 39. The predicted values of $(P_u)_{pred}$ were computed according to the 1986 AISI design formulas mentioned above. The tested and predicted failure loads are listed in Tables 26 through 39. The mean values and the coefficients of variation of the tested-to-predicted load ratios, $(P_u)_{test}/(P_u)_{pred}$, are also included in these tables.

On the basis of the studies of dimensional and material properties summarized in the First and Second Progress Reports[3,4], the values of M_m, V_M, F_m and V_F are listed in Table 78. Based on all these values, the safety indexes were computed and presented in the same table. This calibration included 14 different cases according to the types of columns, the types of compression flanges (stiffened or unstiffened), and the types of failure modes (flexural, torsional or torsional-flexural buckling). From these results, it can be seen that the use of $\phi = 0.85$ will provide the values of β ranging from 2.39 to 3.34 which are satisfactory to the target β of 2.5.

VII. CALIBRATION OF THE AISI DESIGN PROVISIONS ON COMBINED AXIAL LOAD AND BENDING

VII.1 AISI Design Provisions on Combined Axial Load and Bending

In the 1986 edition of AISI Specification, the design criteria are stated in Section C5 as follows:

The axial force and bending moments shall satisfy the following interaction equations:

$$P/P_a+C_{mx}M_x/(M_{ax}\alpha_x)+C_{my}M_y/(M_{ay}\alpha_y) \leq 1.0 \qquad \text{(VII.1.1)}$$

$$P/P_{ao}+M_x/M_{axo}+M_y/M_{ayo} \leq 1.0 \qquad \text{(VII.1.2)}$$

When $P/P_a \leq 0.15$, the following formula may be used in lieu of the above two formulas:

$$P/P_a+M_x/M_{ax}+M_y/M_{ay} \leq 1.0 \qquad \text{(VII.1.3)}$$

where

P = Applied axial load

M_x and M_y = Applied moments with respect to the centroidal axes of the effective section determined for the axial load alone. For angle sections, M_y shall be taken either as the applied moment or the applied moment plus PL/1000, whichever results in a lower value of P_a

P_a = Allowable axial load

P_{ao} = Allowable axial load determined with $F_n = F_y$

M_{ax} and M_{ay} = Allowable moments about the centroidal axes

M_{axo} and M_{ayo} = Allowable moments about the centroidal axes excluding lateral buckling

$1/\alpha_x$, $1/\alpha_y$ = Magnification factors

$$= 1/[1-(\Omega_c P/P_{cr})] \qquad \text{(VII.1.4)}$$

Ω_c = Factor of safety used in determining P_a

$$P_{cr} = \pi^2 EI_b/(K_b L_b)^2 \qquad \text{(VII.1.5)}$$

I_b = Moment of inertia of the full, unreduced cross section about the axis of bending

L_b = Actual unbraced length in the plane of bending

K_b = Effective length factor in the plane of bending

C_{mx}, C_{my} = Coefficients whose value shall be taken as follows:

1. For compression members in frames subject to joint translation(sidesway) $C_m = 0.85$

2. For restrained compression members in frames braced against joint translation and not subject to transverse loading between their supports in the plane of bending

$$C_m = 0.6 - 0.4(M_1/M_2) \qquad \text{(VII.1.6)}$$

where

M_1/M_2 is the ratio of the smaller to the larger moment at the ends of that portion of the member under consideration which is unbraced in the plane of bending. M_1/M_2 is positive when the member is bent in reverse curvature and negative when it is bent in single curvature.

3. For compression members in frames braced against joint translation in the plane of loading and subject to transverse loading between their supports, the value of C_m may be determined by rational analysis. However, in lieu of such analysis, the following values may be used:

   (a) for members whose ends are restrained, $C_m = 0.85$,

   (b) for members whose ends are unrestrained, $C_m = 1.0$

VII.2 Calibration of the AISI Design Provisions on Combined Axial Load and Bending

The interaction formulas listed above are based on the allowable loads and moments. In order to predict the ultimate failure load for combined axial load and bending, the interaction formulas have been rewritten as follows:

$$P_u/P_n+C_{mx}M_{ux}/(M_{nx}\alpha_x)+C_{my}M_{uy}/(M_{ny}\alpha_y) \le 1.0 \qquad \text{(VII.2.1)}$$

$$P_u/P_y+M_{ux}/M_{nxo}+M_{uy}/M_{nyo} \le 1.0 \qquad \text{(VII.2.2)}$$

When $P_u/P_n \le 0.15$, the following formula may be used in lieu of the above two formulas:

$$P_u/P_n+M_{ux}/M_{nx}+M_{uy}/M_{ny} \le 1.0 \qquad \text{(VII.2.3)}$$

where

P_u = Ultimate failure load

M_{ux} and M_{uy} = Ultimate moments with respect to the centroidal axes of the effective section determined for the axial load alone

P_n = Nominal failure load

P_y = Nominal failure load determined with

$$F_n = F_y$$

M_{nx} and M_{ny} = Nominal ultimate moments

M_{nxo} and M_{nyo} = Nominal ultimate moments excluding lateral buckling

A total of 144 tests were used in this calibration. The tested failure loads, $(P_u)_{test}$, were obtained from Refs. 40 through 44. The predicted values of $(P_u)_{pred}$ were computed according to the interaction formulas derived above. The tested and predicted failure loads and their ratios, $(P_u)_{test}/(P_u)_{pred}$, are listed in Tables 40 through 48.

In view of the fact that the modulus of elasticity is the dominant material parameter for elastic buckling and the yield point of steel is a dominant material parameter for inelastic buckling, it is assumed that M_m = 1.05 and V_M = 0.10. These values are based on E_m = E, V_E = 0.06, $(\sigma_y)_m = 1.10\ F_y$ and $V_{\sigma_y/F_y} = 0.10$, where σ_y and F_y are the actual and specified yield points, respectively.

Based on all these values, the safety indexes were computed and summarized in Table 79. Nine different cases have been studied according to the types of sections (hat sections and lipped channel sections), the stability conditions (locally stable and locally unstable), and the loading conditions. From these results, it can be seen that based on $\phi_c = 0.85$, the values of safety index vary from 2.7 to 3.34 which are satisfactory to the target β of 2.5.

VIII. CALIBRATION OF THE AISI DESIGN PROVISIONS ON WELDED CONNECTIONS

VIII.1 AISI Design Provisions on Welded Connections

Welded connections shall be designed to transmit the maximum load in the connected member. Proper regard shall be given to eccentricity. The load on each weld shall not exceed P_a, calculated as follows:

$$P_a = P_n/\Omega_w \qquad \text{(VIII.1.1)}$$

where

Ω_w = Factor of safety for arc welded connections
= 2.50

P_n = Nominal strength of welds determined according to the following formulas.

(1) The maximum load for a groove weld in a butt joint, welded from one or both sides, shall be determined on the basis of the lower strength base steel in the connection, provided that an effective throat equal to or greater than the thickness of the material is consistently obtained.

(2) The nominal shear load, P_n, on each arc spot weld between sheet or sheets and supporting member shall not exceed the smaller of either

$$P_n = 0.625 d_e^2 F_{xx}; \text{ or} \qquad \text{(VIII.1.2)}$$

For $(d_a/t) \leq 0.815\sqrt{(E/F_u)}$:

$$P_n = 2.20 t d_a F_u; \qquad \text{(VIII.1.3)}$$

For $0.815\sqrt{(E/F_u)} < (d_a/t) < 1.397\sqrt{(E/F_u)}$:

$$P_n = 0.280\left[1+5.59t\sqrt{E}/(d_a\sqrt{F_u})\right] t d_a F_u; \quad \text{(VIII.1.4)}$$

For $(d_a/t) \geq 1.397\sqrt{(E/F_u)}$:

$$P_n = 1.40 t d_a F_u \quad \text{(VIII.1.5)}$$

where

d = Visible diameter of outer surface of arc spot weld

d_a = Average diameter of the arc spot weld at mid-thickness of t [where d_a = (d-t) for a single sheet, and (d-2t) for multiple sheets (not more than four lapped sheets over a supporting member)]

d_e = Effective diameter of fused area

$$d_e = 0.7d-1.5t \text{ but } \leq 0.55d \quad \text{(VIII.1.6)}$$

t = Total combined base steel thickness (exclusive of coatings) of sheets involved in shear transfer

F_{xx} = Stress level designation in AWS electrode classification

F_u = Tensile strength

The distance measured in the line of force from the centerline of a weld to the nearest edge of an adjacent weld or to the end of the connected part toward which the force is directed shall not be less than the value of e_{min} as given below:

$$e_{min} = e\Omega_e \quad \text{(VIII.1.7)}$$

where

$$e = P/F_u t \quad \text{(VIII.1.8)}$$

Ω_e = Factor of safety for sheet tearing

= 2.0 when $F_u/F_{sy} \geq 1.15$

= 2.22 when $F_u/F_{sy} < 1.15$

P = Force transmitted by weld

F_{sy} = Specified yield point

t = Thickness of thinnest connected sheet

(3) The shear load, P_n, on each arc seam weld shall not exceed either

$$P_n = \left[d_e^2/4+Ld_e/3\right]2.5F_{xx}; \text{ or} \quad \text{(VIII.1.9)}$$

$$P_n = 2.5tF_u(0.25L+0.96d_a) \quad \text{(VIII.1.10)}$$

where

d = width of arc seam weld

L = Length of seam weld not including the circular ends

(For computation purposes, L shall not exceed 3d)

d_a = Average width of seam weld

where

$$d_a = (d-t) \text{ for a single sheet, and} \quad \text{(VIII.1.11)}$$

$$(d-2t) \text{ for a double sheet} \quad \text{(VIII.1.12)}$$

d_e = Effective width of arc seam weld at fused surfaces

$$d_e = 0.7d-1.5t \quad \text{(VIII.1.13)}$$

(4) The shear load, P_n, on a fillet weld in lap and T-joints shall not exceed the following:

For longitudinal loading:

For $L/t < 25$:

$$P_n = (1-0.01L/t)tLF_u \quad \text{(VIII.1.14)}$$

For $L/t \geq 25$:

$$P_n = 0.75tLF_u \qquad \text{(VIII.1.15)}$$

For transverse loading:

$$P_n = tLF_u \qquad \text{(VIII.1.16)}$$

where

t = Least value of the thickness of two plates

In addition, for $t > 0.150$ inch the allowable load for a fillet weld in lap and T-joints shall not exceed:

$$P_n = 0.75t_wLF_{xx} \qquad \text{(VIII.1.17)}$$

where

L = Length of fillet weld

t_w = Effective throat = $0.707w_1$ or $0.707w_2$, whichever is smaller

(5) For flare groove welds, the shear load, P_n, on a weld shall be governed by the thickness, t, of the sheet steel adjacent to the weld. The load shall not exceed:

For flare-bevel groove welds, transverse loading:

$$P_n = 0.833tLF_u \qquad \text{(VIII.1.18)}$$

For flare groove welds, longitudinal loading:

If the effective throat, t_w, is equal to or greater than t but less than 2t or if the lip height is less than weld length, L, then:

$$P_n = 0.75tLF_u \qquad \text{(VIII.1.19)}$$

If t_w is equal to or greater than 2t and the lip height is equal to or greater than L, then:

$$P_n = 1.50tLF_u \qquad \text{(VIII.1.20)}$$

In addition, if $t > 0.15$ inch, then:

$$P_n = 0.75t_wLF_{xx} \qquad \text{(VIII.1.21)}$$

(6) In sheets joined by spot welding the allowable shear per spot, P_a, shall be as follows:

Table VIII.1

Thickness of Thinnest Outside Sheet, in.	Allowable Shear Strength per Spot, kips	Thickness of Thinnest Outside Sheet, in.	Allowable Shear Strength per Spot, kips
0.010	0.050	0.080	1.330
0.020	0.175	0.094	1.725
0.030	0.400	0.109	2.395
0.040	0.570	0.125	2.880
0.050	0.660	0.188	4.000
0.060	0.910	0.250	6.000

VIII.2 Calibration of the AISI Design Provisions on Welded Connections

(1) For shear strength of arc spot welds, 32 tests were used in the calibration. The tested loads, $(P_u)_{test}$, were obtained from Ref. 45 and the predicted values, $(P_u)_{pred}$, were computed from the AISI design formulas. The tested and predicted loads with the mean value and coefficient of variation of their ratios, $(P_u)_{test}/(P_u)_{pred}$, are listed in Table 49. The mean value of the material factors, M_m, was taken as

1.10. The mean value of the fabrication factors, F_m, was assumed to be equal to unity. The coefficient of variation of the material properties, V_M, was taken as 0.10 and the coefficient of variation of the fabrication factors, V_F, was assumed to be 0.10. By using these values and $\phi = 0.60$, the value of β was found to be 3.55 which is larger than the target β of 3.5.

(2) With regard to the type of plate failure considered in the design criteria, the ϕ factors used and the safety indexes computed are listed in Table 80. All the statistical data presented in Table 80 were obtained from Ref. 11. It can be seen that for all cases the β values are larger than the target β of 3.5.

(3) For plate tearing of arc seam welds, 23 tests were used in the calibration. The tested loads, $(P_u)_{test}$, were obtained from Ref. 45 and the predicted values, $(P_u)_{pred}$, were computed from the AISI design formulas. The tested and predicted loads with the mean value and coefficient of variation of their ratios are listed in Table 50. Based on $M_m = 1.10$, $V_M = 0.10$, $F_m = 1.0$, $V_F = 0.10$, and $\phi = 0.60$, the value of β was found to be 3.81 which is larger than the target β of 3.5.

(4) For fillet welds, the ϕ factors used in the calibration and the safety indexes computed for longitudinal and transverse loading are listed in Table 80. All the statistical data presented in this table were obtained from Ref. 11. It can be seen that for all cases the β values are larger than the target β of 3.5.

(5) For plate tearing failure of transverse flare bevel welds, 42 tests were reported in Ref. 45. They were used in the calibration. The tested and predicted loads with the mean value and coefficient of variation of their ratios are listed in Table 51. Based on $M_m = 1.10$, $V_M = 0.10$, $F_m = 1.0$, $V_F = 0.10$, and $\phi = 0.55$, the value of β was found to be 3.81 which is larger than the target β of 3.5.

(6) For plate tearing failure of longitudinal flare bevel welds, 10 tests were reported in Ref. 45. They were used in the calibration. The tested and predicted loads with the mean value and coefficient of variation of their ratios are listed in Table 52. Based on $F_m = 1.10$, $V_M = 0.10$, $F_m = 1.0$, $V_F = 0.10$, and $\phi = 0.55$, the value of β was found to be 3.56 which is larger than the target β of 3.5.

(7) For resistance welds, 13 tests were used in the calibration. The test loads were obtained from Refs. 46 and 47. The predicted loads were based on a safety factor of 2.5. The tested and predicted loads with the mean value and coefficient of variation of their ratios are listed in Table 53. Based on $M_m = 1.10$, $V_M = 0.10$, $F_m = 1.00$, $V_F = 0.10$, and $\phi = 0.65$, the value of β was found to be 3.71 which is larger than the target β of 3.5.

IX. CALIBRATION OF THE AISI DESIGN PROVISIONS ON BOLTED CONNECTIONS

IX.1 AISI Design Provisions on Bolted Connections

Bolted connections shall be designed to transmit the maximum load in the connected member. Proper regard shall be given to eccentricity. The distance, e, measured in the line of force from the center of a standard hole to the nearest edge of an adjacent hole or to the end of the connected part toward which the force is directed shall not be less than the value of e_{min} determined as follows:

$$e_{min} = e\Omega_e \tag{IX.1.1}$$

where

$$e = P/F_u t \tag{IX.1.2}$$

(a) When $F_u/F_{sy} \geq 1.15$:

Ω_e = Factor of safety for sheet tearing

= 2.0

(b) When $F_u/F_{sy} < 1.15$:

Ω_e = Factor of safety for sheet tearing

= 2.22

where

P = Force transmitted by bolt

t = Thickness of thinnest connected part

F_u = Tensile strength of the connected part

F_{sy} = Specified yield point of the connected part

(1) The tension force on the net section of a bolted connection shall not exceed T_a from Section C2 of the AISI Specification or P_a calculated as follows:

$$P_a = P_n/\Omega_t \qquad \text{(IX.1.3)}$$

where

$P_n = A_n F_t$

A_n = Net section area

F_t and Ω_t are determined as follows:

(a) When $t \geq 3/16$ in.:

Use AISC Specification[48]

(b) When $t < 3/16$ inch and washers are provided under both the bolt head and nut

$$F_t = (1.0-0.9r+3rd/s)F_u \leq F_u \qquad \text{(IX.1.4)}$$

Ω_t = Factor of safety for tension on the net section

= 2.0 for double shear

= 2.22 for single shear

(c) When $t < 3/16$ inch and either washers are not provided under the bolt head and nut, or only one washer is provided under either the bolt head or nut

$$F_t = (1.0-r+2.5rd/s)F_u \leq F_u \qquad \text{(IX.1.5)}$$

Ω_t = Factor of safety for tension on the net section

= 2.22

where

r = Force transmitted by the bolt or bolts at the section considered, divided by the tension force in the member at that section. If r is less than 0.2, it may be taken equal to zero

s = Spacing of bolts perpendicular to line of stress. In the case of a single bolt, s = width of sheet

F_t = Nominal tension stress limit on net section

(2) The bearing force shall not exceed P_a calculated as follows:

$$P_a = P_n/\Omega_b \qquad \text{(IX.1.6)}$$

where

$$P_n = F_p dt \qquad \text{(IX.1.7)}$$

Ω_b = Safety factor for bearing

= 2.22

F_p = Nominal bearing stress as given in Tables IX.1-1 and IX.1-2

Table IX.1-1
Nominal Bearing Stress for Bolted Connections
with Washers under Both Bolt Head and Nut

Thickness of connected part in.	Type of joint	F_u/F_{sy} ratio of connected part	Nominal bearing stress, F_p
≥ 0.024 but < 3/16	Inside sheet of double shear connection	≥ 1.15	$3.33F_u$
		< 1.15	$3.00F_u$
	Single shear and outside sheets of double shear connection	No limit	$3.00F_u$
≥ 3/16	See AISC Specification		

Table IX.1-2
Nominal Bearing Stress for Bolted Connections
Without Washers Under Both Bolt Head and Nut,
or With Only One Washer

Thickness of connected part in.	Type of joint	F_u/F_{sy} ratio of connected part	Nominal bearing stress, F_p
$\geq$ 0.036 but < 3/16	Inside sheet of double shear connection	$\geq$ 1.15	$3.00F_u$
	Single shear and outside sheets of double shear connection	$\geq$ 1.15	$2.22F_u$
$\geq$ 3/16	See AISC Specification		

(3) The bolt force resulting from shear, tension or combination of shear and tension shall not exceed allowable bolt force, P_a, calculated as follows:

$$P_a = A_b F \qquad \text{(IX.1.8)}$$

where

A_b = Gross cross-sectional area of bolt

F is given by F_v, F_t or F_t' in Tables IX.1-3 and IX.1-4

Table IX.1-3

Description of Bolts	Allowable shear Stress, F_v, ksi		Allowable Tension Stress, F_t, ksi
	Threads not Excluded from Shear Plane	Threads Excluded from Shear Plane	
A325 Bolts	21	30	44
A354 Grade B Bolts (1/4 in. ≤ d < 1/2 in.)	24	40	49
A449 Bolts (1/4 in. ≤ d < 1/2 in.)	18	30	40
A490 Bolts	28	40	54
A307 Bolts, Grade A (1/4 in. ≤ d < 1/2 in.)	9		18
A307 Bolts, Grade A (d ≥ 1/2 in.)	10		20

When bolts are subject to a combination of shear and tension, the tension force shall not exceed to a combination of shear and tension, the tension force shall not exceed the allowable force, P_a, based on F_t', given in Table IX.1-4, where f_v the shear stress produced by the same forces, shall not exceed the allowable value F_v given in Table IX.1-3.

Table IX.1-4
Allowable Tension Stress, F_t' for Bolts
Subject to the Combination of Shear and Tension

Description of Bolts	Threads Not Excluded from Shear Planes	Threads Excluded from Shear Planes
A325 Bolts	$55 - 1.8f_v \leq 44$	$55 - 1.4f_v \leq 44$
A354 Grade BD Bolts	$61 - 1.8f_v \leq 49$	$61 - 1.4f_v \leq 49$
A449 Bolts	$50 - 1.8f_v \leq 40$	$50 - 1.4f_v \leq 40$
A490 Bolts	$68 - 1.8f_v \leq 54$	$68 - 1.4f_v \leq 54$
A307 Bolts, Grade A When $1/4\text{in.} \leq d < 1/2$ in.	$23 - 1.8f_v \leq 18$	
When $d \geq 1/2\text{in.}$	$26 - 1.8f_v \leq 20$	

IX.2 Calibration of the AISI Design Provisions on Bolted Connections

(1) Minimum Spacing and Edge Distance in Line of Stress

In this calibration, the mean value M_m computed by $(F_u)_{test}/(F_u)_{specified}$, was found to be 1.10[4]. F_m was assumed to be 1.00 and P_m was determined according to $(P_u)_t/(P_u)_p$, in which $(P_u)_t$ is the tested failure load and $(P_u)_p$ is the predicted failure load. The tested values were obtained from Refs. 49 through 55. The tested and predicted failure loads are listed in Tables 54 through 59 for six different cases. The mean values and coefficients of variation of professional factors, P, are summarized as follows:

Case 1. Single shear, with washers, $F_u/F_y \geq 1.15$ (49 tests)

$P_m = 1.13$, $V_p = 0.12$ (see Table 54)

Case 2. Double shear, with washers, $F_u/F_y \geq 1.15$ (39 tests)

$P_m = 1.18$, $V_p = 0.14$ (see Table 55)

Case 3. Single shear, with washers, $F_u/F_y < 1.15$ (7 tests)

$P_m = 0.84$, $V_p = 0.05$ (see Table 56)

Case 4. Double shear, with washers, $F_u/F_y < 1.15$ (10 tests)

$P_m = 0.94$, $V_p = 0.09$ (see Table 57)

Case 5. Single shear, without washers, $F_u/F_y \geq 1.15$ (8 tests)

$P_m = 1.06$, $V_p = 0.11$ (see Table 58)

Case 6. Single shear, without washers, $F_u/F_y < 1.15$ (8 tests)

$P_m = 1.14$, $V_p = 0.19$ (see Table 59)

Based on all these values, the safety indexes were computed and summarized in Table 81. By using different ϕ factors for different cases, the values of β vary from 3.61 to 3.90 which are larger than the target β of 3.5.

(2) Tension Stress on Net Section

In this calibration, $M_m = 1.10$ and $F_m = 1.00$. The mean value P_m was determined from the ratios of $(\sigma_{net})_t/(\sigma_{net})_p$, in which $(\sigma_{net})_t$ is the tested value and $(\sigma_{net})_p$ is the predicted value. The tested values were obtained from the experimental data given in Refs. 49, 50 and 54. The tested and predicted values are listed in Tables 60 and 61. The following is a summary of P_m and V_p for three different cases:

Case 7. $t < 3/16$ in., double shear, with washers (51 tests)

$P_m = 1.14$, $V_P = 0.20$ (see Table 60)

Case 8. $t < 3/16$ in., single shear, with washers (58 tests)

$P_m = 0.95$, $V_P = 0.21$ (see Table 61)

Case 9. $t < 3/16$ in., single shear, without washers (37 test data presented in Fig. 10 of Ref. 55)

$P_m = 1.04$, $V_P = 0.14$

Based on all these values, the safety indexes were computed and summarized in Table 81. By using different ϕ factors for different cases, the values of β vary from 3.41 to 3.63, which are satisfactory to the target β of 3.5.

(3) Bearing Stress in Bolted Connections

In this calibration, $M_m = 1.10$ and $F_m = 1.00$. The mean value P_m was determined from the ratios of $(P_u)_t/(P_u)_p$, in which $(P_u)_t$ is the tested failure load and $(P_u)_p$ is the predicted failure load. The tested values were obtained from Refs. 49 through 55. The tested and predicted failure loads are listed in Tables 62 through 67 for six different cases. The mean values and coefficients of variation of professional factor, P, are summarized as follows:

Case 10. $0.024 \le t < 3/16$ in., double shear, with washers,

$F_u/F_y \ge 1.15$ (18 tests)

$P_m = 1.08$, $V_P = 0.23$ (see Table 62)

Case 11. $0.024 \le t < 3/16$ in., double shear, with washers,

$F_u/F_y < 1.15$ (5 tests)

$P_m = 0.97$, $V_p = 0.07$ (see Table 63)

Case 12. $0.024 \le t < 3/16$ in., single shear, with washers,

$F_u/F_y \ge 1.15$ (24 tests)

$P_m = 1.02$, $V_p = 0.20$ (see Table 64)

Case 13. $0.024 \le t < 3/16$ in., single shear, with washers,

$F_u/F_y < 1.15$ (16 tests)

$P_m = 1.05$, $V_p = 0.13$ (see Table 65)

Case 14. $0.036 \le t < 3/16$ in., single shear, without washers,

$F_u/F_y \ge 1.15$ (13 tests)

$P_m = 1.01$, $V_p = 0.04$ (see Table 66)

Case 15. $0.036 \le t < 3/16$ in., double shear, without washers,

$F_u/F_y \ge 1.15$ (8 tests)

$P_m = 0.93$, $V_p = 0.05$ (see Table 67)

Based on all these values, the safety indexes were computed and summarized in Table 81. By using different ϕ factors for different cases, the values of β vary from 3.43 to 4.06, which are satisfactory to the target β of 3.5.

(4) Shear Stress on A307 Bolts

The mean shear resistance of a bolt can be written in the following form[4]:

$$R_m = (\tau_f/\sigma_f)_m(\sigma_f/F_u)_m(A_{SA}F_u) \qquad \text{(IX.2.1)}$$

in which τ_f is the actual ultimate shear stress, σ_f the actual ultimate tensile stress and F_u the nominal ultimate tensile stress of the bolt material. The term A_{SA} represents the stress area equal to the shank area if the shear plane passes through the shank, and it is the root area if the shear plane passes through the threads.

The coefficient of variation of the resistance, V_R, contains three parameters, V_M, V_F and V_P as shown below:

$$V_R = \sqrt{V_M^2+V_F^2+V_P^2} \tag{IX.2.2}$$

In view of the fact that a combination of the coefficient of variation of the bolt material properties, V_M, and the design assumptions, V_P, can be considered to be

$$\sqrt{V_M^2+V_P^2} = \sqrt{V^2_{\tau_f/\sigma_f}+V^2_{\sigma_f/F_u}} \tag{IX.2.3}$$

the value of V_R can be computed as follows:

$$V_R = \sqrt{V^2_{\tau_f/\sigma_f}+V^2_{\sigma_f/F_u}+0.05^2} \tag{IX.2.4}$$

In the above equation, the value of V_F is assumed to be 0.05 to reflect the tolerance of the cross-sectional area of the bolt.

The following statistical data were computed on the basis of the test data provided in Refs. 49, 50, 56 and 57 for bolted connection tests.

Case 16. Double shear, with washers, 3/8 in. diameter (11 tests)

$(\tau_f/\sigma_f)_m = 0.68,\ V = 0.11$

$(\sigma_f/F_u)_m = 1.28,\ V = 0.08$

Case 17. Double shear, with washers, 3/4 in. diameter (8 tests)

$(\tau_f/\sigma_f)_m = 0.60,\ V = 0.10$

$(\sigma_f/F_u)_m = 1.13,\ V = 0.08$

Case 18. Single shear, with washers, 3/8 in. diameter (19 tests)

$(\tau_f/\sigma_f)_m = 0.75,\ V = 0.10$

$(\sigma_f/F_u)_m = 1.28,\ V = 0.08$

Case 19. Single shear, with washers, 1/2 in. diameter (11 tests)

$(\tau_f/\sigma_f)_m = 0.63,\ V = 0.06$

$(\sigma_f/F_u)_m = 1.36,\ V = 0.08$

Case 20. Single shear, with washers, 3/4 in. diameter (14 tests)

$(\tau_f/\sigma_f)_m = 0.76,\ V = 0.06$

$(\sigma_f/F_u)_m = 1.13,\ V = 0.08$

Based on all these values, the safety indexes were computed and summarized in Table 81. By using $\phi = 0.65$ for different cases, the values of β vary from 3.85 to 5.23 which are larger than the target β of 3.5.

X. CALIBRATION OF THE AISI DESIGN PROVISIONS ON STIFFENERS

X.1 AISI Design Provisions on Transverse Stiffeners

According to Section B6.1 of the 1986 AISI Specification, transverse stiffeners attached to beam webs at points of concentrated loads or reactions, shall be designed as compression members. Concentrated loads or reactions shall be applied directly into the stiffeners, or each stiffener shall be fitted accurately to the flat portion of the flange to provide direct load bearing into the end of the stiffener. Means for shear transfer between the stiffener and the web shall be provided according to Chapter E of the AISI Specification. The concentrated loads or reactions shall not exceed the smaller of the allowable loads, P_a, given by (a) and (b) as follows:

(a) $P_a = P_n/\Omega_{st}$ (X.1.1)

where

$P_n = F_{wy}A_c$ (X.1.2)

$\Omega_{st} = 2.00$

$A_c = 18t^2+A_s$, for transverse stiffeners at interior support and under concentrated load (X.1.3)

$A_c = 10t^2+A_s$, for transverse stiffeners at end support (X.1.4)

F_{wy} = Lower value of beam web, F_y or stiffener section, F_{ys}

(b) $P_a = P_n/\Omega_c$ (X.1.5)

where

P_n = Nominal axial load evaluated according to Section C4(a) of the AISI Specification with A_e replaced by A_b

Ω_c = Factor of safety for axial compression evaluated according to Section C4(a) of the AISI Specification

A_b = b_1t+A_s, for transverse stiffeners at interior support and under concentrated load (X.1.6)

A_b = b_2t+A_s, for transverse stiffeners at end support (X.1.7)

A_s = Cross sectional area of transverse stiffeners

b_1 = $25t[0.0024(L_{st}/t)+0.72] \leq 25t$ (X.1.8)

b_2 = $12t[0.0044(L_{st}/t)+0.83] \leq 12t$ (X.1.9)

L_{st} = Length of transverse stiffener

t = Base thickness of beam web

The w/t_s ratio for the stiffened and unstiffened elements of cold-formed steel transverse stiffeners shall not exceed $1.28\sqrt{(E/F_{ys})}$ and $0.37\sqrt{(E/F_{ys})}$ respectively, where F_{ys} is the yield stress, F_y, and t_s the thickness of the stiffener steel.

X.2 Calibration of the AISI Design Provisions on Transverse Stiffeners

A total of 61 tests were used in this calibration. The tested failure loads, $(P_u)_{test}$, were obtained from Ref. 59. The predicted values of $(P_u)_{pred}$ were computed according to the AISI design formulas mentioned above. The tested and predicted failure loads are listed in Tables 68 and 69. The mean values and the coefficients of variation of the tested-to-predicted load ratios, $(P_u)_{test}/(P_u)_{pred}$, are also included in these tables.

On the basis of the studies of dimensional and material properties summarized in the First and Second Progress Reports, the values of M_m, V_M, F_m and V_F are listed in Table 82. Based on all these values, the safety indexes were computed and presented in the same table. This calibration included 3 different cases : (1) transverse stiffeners at interior support and under concentrated load, (2) transverse stiffeners at end support and (3) sum of cases 1 and 2. From these results, it can be seen that the use of $\phi = 0.85$ will provide the values of β ranging from 3.32 to 3.41 which exceed considerably the target β of 2.5.

X.3 AISI Design Provisions on Shear Stiffeners

According to Section B6.2 of the 1986 AISI Specification, where shear stiffeners are required, the spacing shall be such that the web shear force shall not exceed the allowable shear force, V_a, permitted by Section C3.2 of the AISI Specification, and the ratio a/h shall not exceed $[260/(h/t)]^2$ nor 3.0.

The actual moment of inertia, I_s, of a pair of attached shear stiffeners, or of a single shear stiffener, with reference to an axis in the plane of the web, shall have a minimum value of

$$I_{smin} = 5ht^3[h/a-0.7(a/h)] \geq (h/50)^4 \qquad (X.3.1)$$

The gross area of shear stiffeners shall be not less than

$$A_{st} = [(1-C_v)/2]\left\{a/h-(a/h)^2/[(a/h)+\sqrt{1+(a/h)^2}]\right\}YDht \qquad (X.3.2)$$

where

$$C_v = 45{,}000k_v/[F_y(h/t)^2] \text{ when } C_v \le 0.8 \quad (X.3.3)$$

$$C_v = [190/(h/t)](\sqrt{k_v/F_y}) \text{ when } C_v > 0.8 \quad (X.3.4)$$

$$k_v = 4.00 + 5.34/(a/h)^2 \text{ when } a/h \le 1.0 \quad (X.3.5)$$

$$k_v = 5.34 + 4.00/(a/h)^2 \text{ when } a/h > 1.0 \quad (X.3.6)$$

a = Distance between transverse stiffeners

Y = Yield point of web steel/Yield point of stiffener steel

D = 1.0 for stiffeners furnished in pairs

D = 1.8 for single-angle stiffeners

D = 2.4 for single-plate stiffeners

X.4 Calibration of the AISI Design Provisions on Shear Stiffeners

A total of 32 tests were used in the calibration of shear strength of beams with shear stiffeners. The tested failure shear forces, $(V_u)_{test}$, were obtained from Ref. 59. The predicted values of $(V_u)_{pred}$ were computed according to the design formulas listed in Section C3.2 of the AISI Specification. The tested and predicted failure shear forces are listed in Table 70. It should be noted that because of large amount of postbuckling strength develpoed in some tests, only 22 tests were used in the statistic analysis. The mean value and the coefficient of variation of the tested-to-predicted load ratios, $(V_u)_{test}/(V_u)_{pred}$, are also included in this table.

On the basis of the studies of dimensional and material properties summarized in the First and Second Progress Reports, the values of M_m, V_M, F_m and V_F were taken as 1.00, 0.06, 1.00 and 0.05 , respectively, Based on all these values and $\phi = 0.90$, the safety index was found to be 4.10 which exceed considerably the target β of 2.5.

XI. CALIBRATION OF THE AISI DESIGN PROVISIONS ON WALL STUDS AND WALL STUD ASSEMBLIES

XI.1 AISI Design Provisions on Wall Studs in Compression

According to Section D4.1 of the 1986 AISI Specification, for studs having identical sheathing attached to both flanges, and neglecting any rotational restraint provided by the sheathing, the applied axial load, P, shall not exceed P_a calculated as follows:

$$P_a = A_e F_n / \Omega_c \qquad \text{(XI.1.1)}$$

where

A_e = Effective area determined at F_n

Ω_c = Factor of safety for axial compression

F_n = The lowest value determined by the following three conditions:

(a) To prevent column buckling between fasteners in the plane of the wall, F_n shall be calculated according to Section C4 of the AISI Specification with KL equal to two times the distance between fasteners.

(b) To prevent flexural and/or torsional overall column buckling, F_n shall be calculated in accordance with Section C4 of the AISI Specification with F_e taken as the smaller of the two σ_{CR} values specified for the following section types, where σ_{CR} is the theoretical elastic buckling stress under concentric loading.

(1) Singly-symmetric channels and C-Sections

$$\sigma_{CR} = \sigma_{ey} + \overline{Q}_a \qquad \text{(XI.1.2)}$$

$$\sigma_{CR} = 1/(2\beta)\left[(\sigma_{ex}+\sigma_{tQ})-\sqrt{(\sigma_{ex}+\sigma_{tQ})^2-(4\beta\sigma_{ex}\sigma_{tQ})}\right] \tag{XI.1.3}$$

(2) Z-Sections

$$\sigma_{CR} = \sigma_t+\bar{Q}_t \tag{XI.1.4}$$

$$\sigma_{CR} = 1/2\left\{(\sigma_{ex}+\sigma_{ey}+\bar{Q}_a)-\left[(\sigma_{ex}+\sigma_{ey}+\bar{Q}_a)^2-4(\sigma_{ex}\sigma_{ey}+\sigma_{ex}\bar{Q}_a-\sigma_{exy}{}^2)\right]^{1/2}\right\} \tag{XI.1.5}$$

(3) I-Sections (doubly-symmetric)

$$\sigma_{CR} = \sigma_{ey}+\bar{Q}_a \tag{XI.1.6}$$

$$\sigma_{CR} = \sigma_{ex} \tag{XI.1.7}$$

In the above formulas

$$\sigma_{ex} = \pi^2E/(K_xL_x/r_x)^2 \tag{XI.1.8}$$

$$\sigma_{exy} = (\pi^2EI_{xy})/(AL^2) \tag{XI.1.9}$$

$$\sigma_{ey} = \pi^2E/(K_yL_y/r_y)^2 \tag{XI.1.10}$$

$$\sigma_t = 1/(Ar_o{}^2)\left[GJ+\pi^2EC_w/(K_tL_t)^2\right] \tag{XI.1.11}$$

$$\sigma_{tQ} = \sigma_t+\bar{Q}_t \tag{XI.1.12}$$

$\bar{Q}$ = $\bar{q}B$ = Design shear rigidity for sheathing on both sides of the wall assembly (XI.1.13)

$\bar{q}$ = Design shear rigidity for sheathing per inch of stud spacing (see Table XI.1)

B = Stud spacing

$$\bar{Q}_a = \bar{Q}/A \tag{XI.1.14}$$

A = Area of full unreduced cross section

L = Length of stud

$$\bar{Q}_t = (\bar{Q}d^2)/(4Ar_0{}^2) \tag{XI.1.15}$$

d = Depth of section

I_{xy} = Product of inertia

(c) To prevent shear failure of the sheathing, a value of F_n shall be used in the following equations so that the shear strain of the sheathing, γ, does not exceed the permissible shear strain, $\bar{\gamma}$. The shear strain, γ, shall be determined as follows:

$$\gamma = (\pi/L)[C_1+(E_1 d/2)] \qquad \text{(XI.1.16)}$$

where

C_1 and E_1 are the absolute values of C_1 and E_1 specified below for each section type:

(1) Singly-Symmetric Channels

$$C_1 = (F_n C_o)/(\sigma_{ey}-F_n+\bar{Q}_a) \qquad \text{(XI.1.17)}$$

$$E_1 = \frac{F_n[(\sigma_{ex}-F_n)(r_o^2 E_o-x_o D_o)-F_n x_o(D_o-x_o E_o)]}{(\sigma_{ex}-F_n)r_o^2(\sigma_{tQ}-F_n)-(F_n x_o)^2} \qquad \text{(XI.1.18)}$$

(2) Z-Sections

$$C_1 = \frac{F_n[C_o(\sigma_{ex}-F_n)-D_o\sigma_{exy}]}{(\sigma_{ey}-F_n+\bar{Q}_a)(\sigma_{ex}-F_n)-\sigma_{exy}^2} \qquad \text{(XI.1.19)}$$

$$E_1 = (F_n E_o)/(\sigma_{tQ}-F_n) \qquad \text{(XI.1.20)}$$

(3) I-Sections

$$C_1 = (F_n C_o)/(\sigma_{ey}-F_n+\bar{Q}_a) \qquad \text{(XI.1.21)}$$

$$E_1 = 0$$

where

x_o = distance from shear center to centroid along principal x-axis, in. (absolute value)

C_o, E_o, and D_o are initial column imperfections which shall be assumed to be at least

C_o = L/350 in a direction parallel to the wall (XI.1.22)

D_o = L/700 in a direction perpendicular to the wall (XI.1.23)

E_o = L/(dx10,000), rad., a measure of the initial twist of the stud from the initial, ideal, unbuckled shape. (XI.1.24)

If $F_n > 0.5F_y$, then in the definitions for σ_{ey}, σ_{ex}, σ_{exy} and σ_{tQ}, the parameters E and G shall be replaced by E' and G', respectively, as defined below

$$E' = 4EF_n(F_y-F_n)/F_y^2 \tag{XI.1.25}$$

$$G' = G(E'/E) \tag{XI.1.26}$$

Sheathing parameters $\bar{q}_o$ and $\bar{\gamma}$ may be determined from representative full-scale tests, conducted and evaluated as described by published documented methods, or from the small-scale-test values given in Table XI.1

TABLE XI.1
Sheathing Parameters(1)

Sheathing(2)	$\bar{q}_o$(3) k/in.	$\bar{\gamma}$ in./in.
3/8 to 5/8 in. thick gypsum	2.0	0.008
Lignocellulosic board	1.0	0.009
Fiberboard (regular or impregnated)	0.6	0.007
Fiberboard (heavy impregnated)	1.2	0.010

(1) The values given are subject to the following limitations:

All values are for sheathing on both sides of the wall assembly.

All fasteners are No. 6, type S-12, self-drilling drywall screws with pan or bugle head, or equivalent, at 6-to 12-inch spacing.

(2) All sheathing is 1/2-inch thick except as noted.

(3) $\bar{q} = \bar{q}_o(2-s/12)$ (XI.1.27)

where s = fastener spacing, in.

For other types of sheathing, $\bar{q}_o$ and $\bar{\gamma}$ may be determined conservatively from representative small-specimen tests as described by published documented methods.

XI.2 Calibration of the AISI Design Provisions on Wall Studs in Compression

Due to the lack of test data on wall studs, only 7 tests were used in the calibration. The tested failure loads, $(P_u)_{test}$, were obtained from Ref. 60. The predicted values of $(P_u)_{pred}$ were computed according to the 1986 AISI design formulas mentioned above. The tested and predicted failure loads are listed in Table 71. The mean value and the coefficient of variation of the tested-to-predicted load ratios, $(P_u)_{test}/(P_u)_{pred}$, are also included in this table. Based on $M_m = 1.10$, $V_M = 0.10$, $F_m = 1.0$, $V_F = 0.05$, and $\phi = 0.85$, the value of β was found to be 3.14 which is larger than the the target β of 2.5.

XI.3 AISI Design Provisions on Wall Studs in Bending

According to Section D4.2 of the 1986 AISI Specification, for studs having identical sheathing attached to both flanges, and neglecting any rotational restraint provided by the sheathing, the allowable moments are M_{axo} and M_{ayo}, where

M_{axo} and M_{ayo} = Allowable moments about the centroidal axes determined in accordance with Section C3.1 of the AISI Specification, excluding the provisions of

Section C3.1.2 (lateral buckling)

XI.4 Calibration of the AISI Design Provisions on Wall Studs in Bending

The test data on wall studs in bending are very limited. Only two tests with stiffened compression flanges were used in the calibration. The tested ultimate moments, $(M_u)_{test}$, were obtained from Ref. 61. The predicted values of $(M_u)_{pred}$ were computed according to the 1986 AISI design formulas mentioned above. The tested and predicted ultimate moments are listed in Table 72. The mean value and the coefficient of variation of the tested-to-predicted moment ratios, $(M_u)_{test}/(M_u)_{pred}$, are also included in this table. Based on $M_m = 1.10$, $V_M = 0.10$, $F_m = 1.0$, $V_F = 0.05$, and $\phi = 0.95$, the value of β was found to be 3.37 which is larger than the the target β of 2.5.

XI.5 AISI Design Provisions on Wall Studs with Combined Axial Load and Bending

According to Section D4.3 of the 1986 AISI Specification, the axial load and bending moments shall satisfy the interaction equations of Section C5 of the AISI Specification with the following redefined terms:

P_a = Allowable axial load determined according to Section D4.1 of the AISI Specification

M_{ax} and M_{ay} in Equations C5-1 and C5-3 shall be replaced by allowable moments, M_{axo} and M_{ayo}, respectively.

XI.6 Calibration of the AISI Design Provisions on Wall Studs with Combined Axial Load and Bending

Only 10 tests of wall studs with stiffened compression flanges were used in the calibration. The tested failure loads, $(P_u)_{test}$, were obtained from Ref. 61. The predicted values of $(P_u)_{pred}$ were computed according to the 1986 AISI design formulas mentioned above. The tested and predicted failure loads are listed in Table 73. The mean value and the coefficient of variation of the tested-to-predicted load ratios, $(P_u)_{test}/(P_u)_{pred}$, are also included in this table. Based on $M_m = 1.05$, $V_M = 0.10$, $F_m = 1.0$, $V_F = 0.05$, and $\phi_c = 0.85$, the value of β was found to be 2.94 which is larger than the the target β of 2.5.

XII. SUMMARY AND FUTURE STUDY

During the period of January 1987 through February 1988, the following design provisions included in the 1986 edition of the AISI allowable stress design specification were calibrated:

(1) Bending Strength

(2) Web Crippling of Beams

(3) Combined Bending and Web Crippling

(4) Concentrically Loaded Compression Members

(5) Combined Axial Load and Bending

(6) Welded Connections

(7) Bolted Connections

(8) Stiffeners

(9) Wall Studs and Wall Stud Assemblies

The research findings are presented in this report.

In addition to the calibration of the AISI design provisions, a revised draft of the Load and Resistance Factor Design Specification for Cold-Formed Steel Structural Members was prepared. This specification is presented in the Tenth Progress Report.[58] On the basis of the first order probabilistic theory, the values of safety index for different cases have been determined for a D_c/L_c ratio of 1/5 by using the available test data and various resistance factors, ϕ, proposed in the revised draft of the LRFD Specification.

Future studies concerning the development of the LRFD criteria will include the following tasks:

(1) Calibration of the AISI allowable stress design criteria by using additional test data.

(2) Refinement of the proposed LRFD Specification.

(3) Completion of the commentary on LRFD criteria.

(4) Preparation of design examples and design aids for the use of LRFD design criteria.

XIII. ACKNOWLEDGMENTS

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Table 1

Comparison of Tested and Predicted Ultimate Moments of Cold-Formed Steel Beams

Having Stiffened Compression Flanges

(Fully Effective Flanges and Webs)

Specimen	w/t	Fy (ksi)	(Mu)pred (in.-kips)	(Mu)test (in.-kips)	(Mu)test / (Mu)pred	Cross Section	Reference
4-2.5-10/1	13.4	35.7	112.510	120.20	1.0683	Fig. 6	16
6-3-9/1	15.8	33.1	225.856	254.70	1.1277	Fig. 6	16
8-3-9/1	16.0	33.1	333.151	375.00	1.1256	Fig. 6	16
4-2.5-12/1	17.7	35.1	91.710	108.20	1.1798	Fig. 6	16
8-3-12/1	22.0	36.2	279.755	291.70	1.0427	Fig. 6	16
6-3-12/1	22.4	35.1	183.264	199.00	1.0859	Fig. 6	16
8-4-9/1	22.5	33.1	389.433	440.00	1.1298	Fig. 6	16
4-2-16/1	27.6	30.2	39.776	43.10	1.0836	Fig. 6	16

Number of specimens	N = 8
Mean	Pm = 1.10543
Coefficient of variation	Vp = 0.03928

Table 2

Comparison of Tested and Predicted Ultimate Moments of Cold-Formed Steel Beams

Having Stiffened Compression Flanges

(Partially Effective Flanges and Fully Effective Webs)

Specimen	w/t	Fy (ksi)	(Mu)pred (in.-kips)	(Mu)test (in.-kips)	(Mu)test / (Mu)pred	Cross Section	Reference
8-4-12/1	30.5	36.2	306.633	325.00	1.0599	Fig. 6	16
B1	35.2	35.8	197.144	268.20	1.3600	Fig. 7	17
4-2.5-16/1	37.1	30.2	48.941	49.20	1.0053	Fig. 6	16
8-3-15/1	41.6	37.9	165.735	153.00	0.9232	Fig. 6	16
6-3-16/1	43.6	30.3	90.425	92.60	1.0241	Fig. 6	16
A2	48.8	35.8	218.057	266.40	1.2217	Fig. 7	17
F-3	51.2	38.0	2.772	3.47	1.2518	Fig. 8	18
8-4-15/1	55.5	37.9	183.841	193.20	1.0509	Fig. 6	16
AS304F-2	71.5	38.0	3.330	3.56	1.0687	Fig. 8	19
F-2	84.7	38.0	3.360	3.51	1.0444	Fig. 8	18
16ga#3n	85.4	31.0	21.719	28.20	1.2984	Fig. 9	20
16ga#1n	93.4	27.5	17.859	19.60	1.0975	Fig. 9	20
AS304F-3	103.0	38.0	3.612	3.84	1.0631	Fig. 8	19
18ga#3n	105.1	37.4	18.732	20.20	1.0784	Fig. 9	20

Table 2 (Continued)

Specimen	w/t	Fy (ksi)	(Mu)pred (in.-kips)	(Mu)test (in.-kips)	(Mu)test / (Mu)pred	Cross Section	Reference
F-6a	123.0	38.0	3.376	3.91	1.1582	Fig. 8	18
20ga#2n	141.6	30.15	10.167	12.00	1.1803	Fig. 9	20
AS304F-4	150.2	30.8	3.748	4.18	1.1153	Fig. 8	19
22ga#Xn	150.8	25.85	8.286	8.90	1.0741	Fig. 9	20
F-8a	153.3	38.0	3.519	4.01	1.1395	Fig. 8	18
F-7	154.4	38.0	3.415	3.94	1.1537	Fig. 8	18
16ga#9w	161.5	56.85	38.502	42.50	1.1038	Fig. 9	20
22ga#3n	167.8	24.7	6.690	7.30	1.0912	Fig. 9	20
16ga#6w	169.3	47.2	31.212	37.40	1.1983	Fig. 9	20
22ga#1n	170.1	25.75	6.707	8.30	1.1375	Fig. 9	20
18ga#7w	213.6	36.05	17.745	17.90	1.0087	Fig. 9	20
18ga#6w	219.4	24.4	12.794	14.00	1.0943	Fig. 9	20
20ga#7w	279.6	30.65	10.348	10.50	1.0147	Fig. 9	20
20ga#8w	298.9	25.1	8.053	10.00	1.2418	Fig. 9	20
22ga#2w	334.2	28.0	7.366	7.50	1.0182	Fig. 9	20
22ga#3w	338.9	27.65	7.287	7.60	1.0430	Fig. 9	20

Table 2 (Continued)

Number of specimens	$N = 30$
Mean	$Pm = 1.114$
Coefficient of variation	$Vp = 0.08889$

Table 3

Comparison of Tested and Predicted Ultimate Moments of Cold-Formed Steel Beams

Having Stiffened Compression Flanges

(Partially Effective Flanges and Partially Effective Webs)

Specimen	w/t	Fy (ksi)	(Mu)pred (in.-kips)	(Mu)test (in.-kips)	(Mu)test / (Mu)pred	Cross Section	Reference
E1	32.2	37.9	133.634	144.00	1.0776	Fig. 7	17
D1	48.3	37.9	153.667	153.00	0.9957	Fig. 7	17
G1	49.1	32.2	81.765	97.40	1.1912	Fig. 7	17
C1	76.5	37.9	181.350	176.40	0.9727	Fig. 7	17
F1	82.7	30.7	77.325	90.54	1.1709	Fig. 7	17

Number of specimens	N = 5
Mean	Pm = 1.08162
Coefficient of variation	Vp = 0.09157

Table 4

Comparison of Tested and Predicted Ultimate Moments of Cold-Formed Steel Beams

Having Unstiffened Compression Flanges

(Fully Effective Flanges and Fully Effective Webs)

Specimen	w/t	Fy (ksi)	(Mu)pred (in.-kips)	(Mu)test (in.-kips)	(Mu)test / (Mu)pred	Cross Section	Reference
B-11	7.7	50.2	17.301	24.90	1.4392	Fig. 10	21
B-18	7.9	33.8	15.748	23.50	1.4923	Fig. 10	21
B-17	10.3	33.8	18.197	24.90	1.3684	Fig. 10	21

Number of specimens	N = 3
Mean	Pm = 1.4333
Coefficient of variation	Vp = 0.04337

Table 5

Comparison of Tested and Predicted Ultimate Moments of Cold-Formed Steel Beams

Having Unstiffened Compression Flanges

(Partially Effective Flanges and Fully Effective Webs)

Specimen	w/t	Fy (ksi)	(Mu)pred (in.-kips)	(Mu)test (in.-kips)	(Mu)test / (Mu)pred	Cross Section	Reference
B-10	10.52	50.20	20.261	25.70	1.2684	Fig. 10	21
B-16	12.74	33.80	21.059	25.80	1.2251	Fig. 10	21
B-9	13.26	50.20	21.261	27.00	1.2699	Fig. 10	21
B-15	14.07	10.89	29.579	34.40	1.1630	Fig. 10	21
16-1-1	16.21	36.80	24.256	30.80	1.2698	Fig. 11	22
16-1-3	16.32	36.80	24.750	30.50	1.2323	Fig. 11	22
16-1-2	16.40	36.80	24.583	30.60	1.2448	Fig. 11	22
B-14	16.65	35.90	31.966	34.70	1.0855	Fig. 10	21
B-8	16.82	50.20	21.365	26.40	1.2357	Fig. 10	21
18-1-3	19.07	34.90	66.655	64.80	0.9722	Fig. 11	22
14-1.5-3	19.24	37.30	108.571	94.30	0.8674	Fig. 11	22
14-1.5-1	19.32	37.30	109.315	104.40	0.9550	Fig. 11	22
B-7	19.44	51.30	22.593	25.80	1.1419	Fig. 10	21
B-13	19.50	35.90	42.821	51.20	1.1957	Fig. 10	21

Table 5 (Continued)

Specimen	w/t	Fy (ksi)	(Mu)pred (in.-kips)	(Mu)test (in.-kips)	(Mu)test / (Mu)pred	Cross Section	Reference
18-1-1	20.20	34.90	65.733	64.80	0.9858	Fig. 11	22
18-1-2	20.29	34.90	64.534	59.90	0.9282	Fig. 11	22
16-1.25-3	20.35	32.60	67.832	74.30	1.0954	Fig. 11	22
16-1.25-2	20.58	32.60	71.039	67.00	0.9431	Fig. 11	22
16-1.25-1	20.82	32.60	70.171	67.50	0.9619	Fig. 11	22
B-12	21.24	35.90	43.016	50.60	1.1763	Fig. 10	21
B-6	23.71	51.30	41.740	52.40	1.2554	Fig. 10	21
16-1.5-1	23.96	38.70	30.704	29.00	0.9445	Fig. 11	22
16-1.5-3	24.00	38.70	31.000	30.20	0.9742	Fig. 11	22
16-1.5-2	24.51	38.70	30.452	35.80	1.1756	Fig. 11	22
UP-9	25.97	42.00	32.824	36.90	1.1242	Fig. 10	21
12-3-3	27.97	29.20	154.670	196.20	1.2685	Fig. 11	22
16-1.75-1	28.73	32.60	76.850	70.00	0.9109	Fig. 11	22
16-1.75-3	29.07	32.60	77.001	75.60	0.9818	Fig. 11	22
B-5	29.78	51.30	42.567	52.30	1.2287	Fig. 10	21
14-2.5-1	30.06	37.30	117.858	121.80	1.0334	Fig. 11	22
14-2.5-3	30.29	37.30	117.130	118.50	1.0120	Fig. 11	22
UP-10	32.09	36.00	13.729	14.30	1.0416	Fig. 10	21

Table 5 (Continued)

Specimen	w/t	Fy (ksi)	(Mu)pred (in.-kips)	(Mu)test (in.-kips)	(Mu)test / (Mu)pred	Cross Section	Reference
B-4	36.87	51.00	42.181	54.30	1.2873	Fig. 10	21
UP-11	38.05	36.00	13.953	15.50	1.1109	Fig. 10	21
14-3.25-1	41.01	28.20	108.978	118.40	1.0865	Fig. 11	22
14-3.25-3	42.77	28.20	104.926	160.00	1.5249	Fig. 11	22
14-3.25-2	43.36	28.20	102.743	158.00	1.5378	Fig. 11	22
B-3	44.47	53.80	68.170	81.20	1.1911	Fig. 10	21
12-5-2	46.73	29.20	170.036	187.20	1.1009	Fig. 11	22
12-5-1	47.24	29.20	166.732	157.70	0.9458	Fig. 11	22

Number of specimens	N = 40
Mean	Pm = 1.12384
Coefficient of variation	Vp = 0.13923

Table 6

Comparison of Tested and Predicted Ultimate Moments of Cold-Formed Steel Beams

Having Unstiffened Compression Flanges

(Partially Effective Flanges and Partially Effective Webs)

Specimen	w/t	Fy (ksi)	(Mu)pred (in.-kips)	(Mu)test (in.-kips)	(Mu)test / (Mu)pred	Cross Section	Reference
16-1.75-2	28.86	32.60	75.396	69.80	0.9258	Fig. 11	22
18-1.5-2	29.45	34.90	65.682	69.80	1.0627	Fig. 11	22
18-1.5-3	29.89	34.90	61.854	60.10	0.9716	Fig. 11	22
18-1.5-1	30.14	34.90	65.947	66.40	1.0069	Fig. 11	22
16-2.5-3	44.67	35.10	81.459	89.50	1.0987	Fig. 11	22
16-2.5-2	45.09	35.10	81.667	80.30	0.9833	Fig. 11	22
16-2.5-1	47.01	35.10	74.916	80.30	1.0720	Fig. 11	22
16-3-1	52.08	32.60	78.748	85.80	1.0896	Fig. 11	22
16-3-2	52.69	32.60	77.137	80.30	1.0410	Fig. 11	22
16-3-3	52.96	32.60	76.270	81.20	1.0646	Fig. 11	22

Number of specimens	N = 10
Mean	Pm = 1.03162
Coefficient of variation	Vp = 0.05538

Table 7

Predicted Failure Loads of Cold-Formed Steel I-Beams

Subjected to Elastic Lateral Buckling

Specimen	L (in.)	Fy (ksi)	Pu1 (lbs)	Pu2 (lbs)	Pu3 (lbs)	Pu4 (lbs)	Pu5 (lbs)	Pt (lbs)	Cross Section	Reference
S-1/1	90	42.7	257.5	475.6	491.0	333.5	313.0	520.0	Fig. 12	24
S-1/2	90	42.7	257.5	475.6	491.0	333.5	313.0	720.0	Fig. 12	24
S-2/1	90	42.7	257.5	475.6	491.0	333.5	313.0	710.0	Fig. 12	24
S-3/1	90	42.7	257.5	475.6	491.0	333.5	313.0	500.0	Fig. 12	24
S-3/2	90	42.7	257.5	475.6	491.0	333.5	313.0	580.0	Fig. 12	24
S-4/1	90	42.7	257.5	475.6	491.0	333.5	313.0	710.0	Fig. 12	24
T-1/1	138	42.7	71.4	186.8	207.0	118.6	119.0	200.0	Fig. 12	24
T-1/2	138	42.7	71.4	186.8	207.0	118.6	119.0	210.0	Fig. 12	24
T-1/3	138	42.7	71.4	186.8	207.0	118.6	119.0	260.0	Fig. 12	24
T-1/4	138	42.7	71.4	186.8	207.0	118.6	119.0	200.0	Fig. 12	24
T-2/1	138	42.7	71.4	186.8	207.0	118.6	119.0	220.0	Fig. 12	24
T-2/2	138	42.7	71.4	186.8	207.0	118.6	119.0	270.0	Fig. 12	24
T-2/3	138	42.7	71.4	186.8	207.0	118.6	119.0	280.0	Fig. 12	24
T-2/4	138	42.7	71.4	186.8	207.0	118.6	119.0	340.0	Fig. 12	24

Table 7 (Continued)

Specimen	L (in.)	Fy (ksi)	Pu1 (lbs)	Pu2 (lbs)	Pu3 (lbs)	Pu4 (lbs)	Pu5 (lbs)	Pt (lbs)	Cross Section	Reference
T-3/1	138	42.7	71.4	186.8	207.0	118.6	119.0	230.0	Fig. 12	24
T-3/2	138	42.7	71.4	186.8	207.0	118.6	119.0	220.0	Fig. 12	24
T-3/3	138	42.7	71.4	186.8	207.0	118.6	119.0	260.0	Fig. 12	24
U-1/1	117	42.7	117.2	266.2	288.0	175.0	171.0	270.0	Fig. 12	24
U-1/2	117	42.7	117.2	266.2	288.0	175.0	171.0	330.0	Fig. 12	24
U-1/3	117	42.7	117.2	266.2	288.0	175.0	171.0	360.0	Fig. 12	24
U-1/4	117	42.7	117.2	266.2	288.0	175.0	171.0	260.0	Fig. 12	24
U-1/5	117	42.7	117.2	266.2	288.0	175.0	171.0	260.0	Fig. 12	24
U-1/6	117	42.7	117.2	266.2	288.0	175.0	171.0	440.0	Fig. 12	24
U-1/7	117	42.7	117.2	266.2	288.0	175.0	171.0	390.0	Fig. 12	24
U-2/1	117	42.7	117.2	266.2	288.0	175.0	171.0	280.0	Fig. 12	24
U-2/2	117	42.7	117.2	266.2	288.0	175.0	171.0	330.0	Fig. 12	24
U-2/3	117	42.7	117.2	266.2	288.0	175.0	171.0	260.0	Fig. 12	24
U-2/4	117	42.7	117.2	266.2	288.0	175.0	171.0	270.0	Fig. 12	24
V-1/1	85.5	42.7	300.3	534.2	547.0	379.8	354.0	620.0	Fig. 12	24
V-1/2	85.5	42.7	300.3	534.2	547.0	379.8	354.0	930.0	Fig. 12	24
V-1/3	85.5	42.7	300.3	534.2	547.0	379.8	354.0	680.0	Fig. 12	24
V-1/4	85.5	42.7	300.3	534.2	547.0	379.8	354.0	750.0	Fig. 12	24

Table 7 (Continued)

Specimen	L (in.)	Fy (ksi)	Pu1 (lbs)	Pu2 (lbs)	Pu3 (lbs)	Pu4 (lbs)	Pu5 (lbs)	Pt (lbs)	Cross Section	Reference
V-2/1	85.5	42.7	300.3	534.2	547.0	379.8	354.0	670.0	Fig. 12	24
V-2/2	85.5	42.7	300.3	534.2	547.0	379.8	354.0	550.0	Fig. 12	24
V-2/3	85.5	42.7	300.3	534.2	547.0	379.8	354.0	850.0	Fig. 12	24
W-1/1	70.75	42.7	530.0	828.4	820.0	620.7	566.0	730.0	Fig. 12	24
W-1/2	70.75	42.7	530.0	828.4	820.0	620.7	566.0	1150.0	Fig. 12	24
W-1/3	70.75	42.7	530.0	828.4	820.0	620.7	566.0	1280.0	Fig. 12	24
W-1/4	70.75	42.7	530.0	828.4	820.0	620.7	566.0	840.0	Fig. 12	24
W-1/5	70.75	42.7	530.0	828.4	820.0	620.7	566.0	1070.0	Fig. 12	24
W-1/6	70.75	42.7	530.0	828.4	820.0	620.7	566.0	860.0	Fig. 12	24
X-1/1	61.5	42.7	804.8	1142.6	1121.0	902.3	811.0	950.0	Fig. 12	24
X-1/2	61.5	42.7	804.8	1142.6	1121.0	902.3	811.0	1070.0	Fig. 12	24
X-2/1	61.5	42.7	804.8	1142.6	1121.0	902.3	811.0	1150.0	Fig. 12	24
X-3/1	61.5	42.7	804.8	1142.6	1121.0	902.3	811.0	1650.0	Fig. 12	24
X-3/2	61.5	42.7	804.8	1142.6	1121.0	902.3	811.0	1070.0	Fig. 12	24
X-3/3	61.5	42.7	804.8	1142.6	1121.0	902.3	811.0	1250.0	Fig. 12	24

Table 7 (Continued)

Pu1 = Ultimate load determined by the AISI Specification.

Pu2 = Ultimate load determined by theoretical formula considering web as a single element (J = 0.0026).

Pu3 = Ultimate load determined by SSRC formula considering web as a single element (J = 0.0026).

Pu4 = Ultimate load determined by theoretical formula considering web as two elements (J = 0.00082).

Pu5 = Ultimate load determined by SSRC formula considering web as two elements (J = 0.00082).

Pt = Tested failure load.

Table 8
Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel I-Beams Subjected to Elastic Lateral Buckling

Specimen	$\frac{Pt}{Pu1}$	$\frac{Pt}{Pu2}$	$\frac{Pt}{Pu3}$	$\frac{Pt}{Pu4}$	$\frac{Pt}{Pu5}$
S-1/1	2.0196	1.0934	1.06	1.5594	1.6613
S-1/2	2.7963	1.5139	1.47	2.1592	2.3003
S-2/1	2.7575	1.4929	1.45	2.1292	2.2684
S-3/1	1.9418	1.0513	1.02	1.4995	1.5974
S-3/2	2.2526	1.2196	1.18	1.7394	1.8530
S-4/1	2.7575	1.4929	1.50	2.1292	2.2684
T-1/1	2.8002	1.0709	0.97	1.6858	1.6807
T-1/2	2.9402	1.1245	1.01	1.7701	1.7647
T-1/3	3.6403	1.3922	1.26	2.1915	2.1849
T-1/4	2.8002	1.0709	0.97	1.6858	1.6807
T-2/1	2.0802	1.1780	1.06	1.8543	1.8087
T-2/2	3.7803	1.4458	1.30	2.2758	2.2689
T-2/3	3.9203	1.4993	1.35	2.3601	2.3529
T-2/4	4.7604	1.8206	1.64	2.8658	2.8571
T-3/1	3.2203	1.2316	1.11	1.9386	1.9328
T-3/2	3.0802	1.1780	1.06	1.8543	1.8487
T-3/3	3.6403	1.3922	1.26	2.1915	2.1849
U-1/1	2.3038	1.0141	0.94	1.5428	1.5789
U-1/2	2.8158	1.2395	1.15	1.8857	1.9298
U-1/3	3.0718	1.3521	1.25	2.0571	2.1053
U-1/4	2.2185	0.9765	0.90	1.4857	1.5205
U-1/5	2.2185	0.9765	0.90	1.4857	1.5205
U-1/6	3.7544	1.6526	1.53	2.5142	2.5731
U-1/7	3.3278	1.4648	1.35	2.2285	2.2807
U-2/1	2.3891	1.0517	0.97	1.6000	1.6374
U-2/2	2.8158	1.2395	1.15	1.8857	1.9298
U-2/3	2.2185	0.9765	0.90	1.4857	1.5205
U-2/4	2.3038	1.0141	0.94	1.5428	1.5789
V-1/1	2.0645	1.1606	1.13	1.6326	1.7514
V-1/2	3.0967	1.7408	1.70	2.4489	2.6271
V-1/3	2.2643	1.2729	1.24	1.7906	1.9209
V-1/4	2.4974	1.4039	1.37	1.9749	2.1186
V-2/1	2.2310	1.2542	1.23	1.7643	1.8927
V-2/2	1.8314	1.0295	1.01	1.4483	1.5537
V-2/3	2.8304	1.5911	1.55	2.2382	2.4011
W-1/1	1.3773	0.8812	0.89	1.1762	1.2898
W-1/2	2.1097	1.3882	1.40	1.8529	2.0318

Table 8 (Continued)

Specimen	$\frac{Pt}{Pu1}$	$\frac{Pt}{Pu2}$	$\frac{Pt}{Pu3}$	$\frac{Pt}{Pu4}$	$\frac{Pt}{Pu5}$
W-1/3	2.4150	1.5451	1.56	2.0623	2.2615
W-1/4	1.5848	1.0140	1.02	1.3534	1.4841
W-1/5	2.0188	1.2916	1.31	1.7240	1.8905
W-1/6	1.6226	1.0381	1.05	1.3856	1.5194
X-1/1	1.1804	0.8314	0.85	1.0529	1.1714
X-1/2	1.3295	0.9365	0.95	1.1858	1.3194
X-2/1	1.4289	1.0065	1.03	1.2745	1.4180
X-3/1	2.0501	1.4441	1.47	1.8286	2.0345
X-3/2	1.3295	0.9365	0.95	1.1858	1.3194
X-3/3	1.5531	1.0940	1.12	1.3853	1.5413
Number of specimens N = 47					
Mean Pm =	2.5213	1.2359	1.18	1.7951	1.8782
C.V. Vp =	0.30955	0.19494	0.19	0.21994	0.20534

Table 9

Comparison of Tested and Predicted Web Crippling Loads for Beams Having Stiffened Flanges

Single Unreinforced Webs, End One-Flange Loading

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
SU-1-EOF-1	0.0475	21.05	208.06	2.632	43.82	0.503	0.575	1.142
SU-1-EOF-2	0.0480	20.83	205.52	2.604	43.82	0.520	0.505	0.972
SU-1-EOF-5	0.0490	61.22	201.22	2.551	43.82	0.742	0.650	0.876
SU-1-EOF-6	0.0500	60.00	197.28	2.812	43.82	0.736	0.620	0.842
SU-4-EOF-1	0.0500	20.00	96.52	1.740	47.12	0.894	0.898	1.004
SU-4-EOF-2	0.0500	20.00	96.62	1.562	47.12	0.921	0.905	0.983
SU-4-EOF-3	0.0496	40.32	97.22	1.732	47.12	1.031	1.038	1.007
SU-4-EOF-4	0.0495	40.40	97.90	1.770	47.12	1.020	1.000	0.981
SU-4-EOF-5	0.0500	60.00	96.78	1.692	47.12	1.206	1.125	0.933
SU-4-EOF-6	0.0490	61.22	99.08	1.753	47.12	1.150	1.105	0.961
SU-5-EOF-1	0.0500	20.00	121.76	1.876	47.12	0.825	0.880	1.067
SU-5-EOF-2	0.0511	19.57	118.49	1.757	47.12	0.883	0.838	0.949
SU-5-EOF-3	0.0510	39.22	119.69	1.839	47.12	1.009	0.990	0.981
SU-5-EOF-4	0.0505	39.60	120.85	2.012	47.12	0.960	0.970	1.010

Table 9 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
SU-5-EOF-5	0.0506	59.29	120.34	1.854	47.12	1.134	1.006	0.887
SU-5-EOF-6	0.0501	59.88	121.54	1.872	47.12	1.109	1.068	0.963
SU-6'-EOF-1	0.0498	20.08	146.29	1.725	47.12	0.792	0.888	1.121
SU-6'-EOF-2	0.0495	20.20	147.33	1.895	47.12	0.759	0.875	1.153
SU-6'-EOF-3	0.0493	40.57	147.85	1.742	47.12	0.905	0.903	0.998
SU-6'-EOF-4	0.0490	40.82	148.90	1.994	47.12	0.855	0.935	1.094
SU-6'-EOF-5	0.0500	60.00	145.88	1.876	47.12	1.042	1.045	1.003
SU-6'-EOF-6	0.0500	60.00	146.02	1.876	47.12	1.042	1.119	1.074
M-SU-4-EOF-1	0.0500	20.00	96.00	1.796	47.12	0.887	0.875	0.987
M-SU-4-EOF-2	0.0507	19.72	95.44	1.850	47.12	0.902	0.873	0.968
M-SU-4-EOF-5	0.0500	60.00	95.90	1.718	47.12	1.203	1.483	1.233
M-SU-4-EOF-6	0.0500	60.00	96.38	1.876	47.12	1.170	1.406	1.202
M-SU-6'-EOF-1	0.0501	19.96	145.13	1.872	47.12	0.783	0.850	1.085
M-SU-6'-EOF-2	0.0505	19.80	144.06	1.857	47.12	0.799	0.869	1.088
M-SU-6'-EOF-5	0.0500	60.00	145.30	1.876	47.12	1.044	1.175	1.126
M-SU-6'-EOF-6	0.0510	58.82	142.71	1.839	47.12	1.092	1.180	1.081

Table 9 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
50	0.0611	24.55	47.10	1.000	33.60	1.428	1.443	1.011
51	0.0616	40.58	46.70	1.000	33.00	1.623	1.790	1.103
53	0.0598	25.08	48.16	3.000	32.60	0.940	0.863	0.918
54	0.0601	41.60	47.92	3.000	29.10	0.996	1.113	1.118
55	0.0663	11.31	43.24	1.000	54.20	1.933	1.795	0.929
56	0.0655	22.90	43.80	1.000	53.70	2.078	2.073	0.998
57	0.0633	39.49	45.39	1.000	54.50	2.210	2.498	1.130
58	0.0647	11.59	44.37	3.000	52.40	1.274	0.955	0.749
59	0.0643	23.33	44.65	3.000	55.40	1.418	1.670	1.178
60	0.0635	39.37	45.24	3.000	55.20	1.562	2.100	1.345
61	0.0608	12.34	96.68	1.000	32.80	1.129	0.880	0.779
62	0.0595	25.21	98.84	1.000	30.50	1.143	1.005	0.879
63	0.0599	41.74	98.16	1.000	38.70	1.536	1.188	0.773
64	0.0601	12.48	97.82	3.000	33.90	0.788	0.575	0.729
65	0.0604	24.83	97.33	3.000	32.40	0.860	0.920	1.070
66	0.0601	41.60	97.84	3.000	31.30	0.944	0.975	1.033

Table 9 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	$\frac{(Pu)test}{(Pu)pred}$
67	0.0672	11.16	87.29	1.000	54.50	1.813	1.605	0.885
68	0.0668	22.46	87.81	1.000	52.50	1.951	1.750	0.897
69	0.0664	37.65	88.36	1.000	52.60	2.169	1.963	0.905
70	0.0670	11.19	87.55	3.000	53.80	1.256	1.200	0.955
71	0.0685	21.90	85.59	3.000	52.50	1.436	1.675	1.166
72	0.0689	36.28	85.08	3.000	53.60	1.640	1.970	1.201
18-F2	0.0445	56.18	166.54	1.933	32.80	0.615	0.550	0.895
18-F3	0.0445	56.18	166.54	1.933	32.80	0.615	0.580	0.944
18-C1	0.0445	56.18	65.42	1.933	32.80	0.777	0.765	0.984
18-C4	0.0445	56.18	65.42	1.933	32.80	0.777	0.725	0.933
18-H5	0.0445	56.18	166.54	1.933	32.80	0.615	0.610	0.992
18-H5	0.0445	56.18	166.54	1.933	32.80	0.615	0.650	1.058
18-G1	0.0445	56.18	65.42	1.933	32.80	0.777	0.710	0.914
18-G3	0.0445	56.18	65.42	1.933	32.80	0.777	0.695	0.894
16-E1	0.0636	39.31	116.02	1.352	27.00	1.214	1.220	1.005
16-E4	0.0636	39.31	116.02	1.352	27.00	1.214	1.230	1.013

Table 9 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
16-B2	0.0636	39.31	45.17	1.352	27.00	1.412	1.550	1.097
16-B4	0.0636	39.31	45.17	1.352	27.00	1.412	1.530	1.083
14-D4	0.0724	34.53	101.59	1.188	37.75	2.022	1.700	0.841
14-D6	0.0724	34.53	101.59	1.188	37.75	2.022	1.695	0.838
14-A1	0.0724	34.53	39.43	1.188	37.75	2.303	2.110	0.916
14-A6	0.0724	34.53	39.43	1.188	37.75	2.303	2.260	0.981

Number of specimens	N = 68
Mean	Pm = 0.999
Coefficient of variation	Vp = 0.119

* All test specimems were obtained from reference 26.

Table 10

Comparison of Tested and Predicted Web Crippling Loads for Beams Having Unstiffened Flanges

Single Unreinforced Webs, End One-Flange Loading

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
U-SU-17-EOF-1	0.0490	20.41	99.22	0.959	36.26	0.580	0.628	1.083
U-SU-17-EOF-2	0.0490	20.41	98.14	0.959	36.26	0.581	0.598	1.030
U-SU-17-EOF-5	0.0490	61.22	97.82	0.959	36.26	0.776	0.898	1.157
U-SU-17-EOF-6	0.0485	61.86	99.44	0.969	36.26	0.761	0.835	1.097
U-SU-18-EOF-1	0.0485	20.62	195.01	0.969	36.26	0.488	0.472	0.967
U-SU-18-EOF-2	0.0490	20.41	194.65	0.959	36.26	0.497	0.428	0.860
U-SU-18-EOF-5	0.0500	60.00	190.62	0.940	36.26	0.692	0.568	0.821
U-SU-18-EOF-6	0.0490	61.22	194.57	0.959	36.26	0.665	0.545	0.820
73	0.0602	12.46	147.51	1.000	31.90	0.698	0.700	1.003
74	0.0604	24.83	147.00	1.000	31.70	0.776	0.790	1.018
75	0.0597	41.88	148.76	1.000	31.00	0.846	0.855	1.011
76	0.0600	12.50	148.00	3.000	34.50	0.511	0.410	0.802
77	0.0598	25.08	148.49	3.000	32.00	0.536	0.450	0.840
78	0.0599	41.74	148.25	3.000	30.00	0.582	0.525	0.902

Table 10 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
79	0.0645	11.63	137.53	1.000	51.40	1.051	1.015	0.966
80	0.0638	23.51	139.06	1.000	54.00	1.153	0.913	0.792
81	0.0636	39.31	139.51	1.000	51.60	1.270	1.073	0.845
82	0.0638	11.76	139.06	3.000	54.70	0.734	0.748	1.019
83	0.0641	23.40	138.41	3.000	54.70	0.818	0.808	0.988
84	0.0634	39.43	139.95	3.000	54.80	0.902	0.918	1.018
85	0.0611	12.27	194.44	1.000	31.80	0.662	0.755	1.140
86	0.0609	24.63	195.07	1.000	32.20	0.735	0.625	0.850
88	0.0600	12.50	198.00	3.000	31.40	0.441	0.418	0.947
89	0.0599	25.04	198.33	3.000	31.10	0.485	0.750	1.547
91	0.0691	10.85	171.64	1.000	56.10	1.166	1.170	1.004
92	0.0689	21.77	172.13	1.000	54.90	1.263	1.228	0.972
93	0.0681	36.71	174.16	1.000	53.90	1.372	1.285	0.937
94	0.0668	11.23	177.69	3.000	54.00	0.749	1.015	1.355
95	0.0658	22.80	180.40	3.000	53.40	0.795	0.973	1.224
96	0.0666	37.54	178.23	3.000	53.80	0.917	0.950	1.036

Table 10 (Continued)

Number of specimens	$N = 30$
Mean	$P_m = 1.002$
Coefficient of variation	$V_p = 0.163$

* All test specimens were obtained from reference 26.

Table 11

Comparison of Tested and Predicted Loads for Web Crippling

Single Unreinforced Webs, Interior One-Flange Loading

(UMR and Cornell Tests)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
SU-1-IOF-1	0.0480	20.83	204.77	2.770	43.82	1.122	1.260	1.123
SU-1-IOF-2	0.0475	21.05	208.59	2.630	43.82	1.102	1.175	1.066
SU-1-IOF-5	0.0485	61.86	203.20	2.580	43.82	1.453	1.450	0.998
SU-1-IOF-6	0.0480	62.50	205.19	2.600	43.82	1.420	1.385	0.975
SU-5-IOF-1	0.0495	20.20	123.11	1.900	47.12	1.528	1.403	0.918
SU-5-IOF-2	0.0502	19.92	121.05	1.870	47.12	1.577	1.480	0.938
SU-5-IOF-3	0.0500	40.00	121.90	1.950	47.12	1.753	1.750	0.998
SU-5-IOF-4	0.0505	39.60	120.38	1.860	47.12	1.791	1.830	1.022
SU-5-IOF-5	0.0504	59.52	120.74	1.780	47.12	1.986	2.080	1.047
SU-5-IOF-6	0.0503	59.64	121.10	1.870	47.12	1.968	1.835	0.932
SU-6'-IOF-1	0.0500	20.00	145.42	1.880	47.12	1.502	1.480	0.985
SU-6'-IOF-2	0.0500	20.00	146.20	1.720	47.12	1.515	1.580	1.043
SU-6'-IOF-3	0.0495	40.40	147.09	1.810	47.12	1.657	1.890	1.141
SU-6'-IOF-4	0.0497	40.24	147.68	1.890	47.12	1.659	1.815	1.094

Table 11 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
SU-6'-10F-5	0.0492	60.98	148.33	1.910	47.12	1.805	2.085	1.155
SU-6'-10F-6	0.0503	59.64	144.96	1.790	47.12	1.901	1.890	0.994
M-SU-6'-10F-1	0.0502	19.92	145.37	1.870	47.12	1.514	1.650	1.089
M-SU-6'-10F-2	0.0500	20.00	145.80	1.880	47.12	1.501	1.643	1.094
M-SU-6'-10F-5	0.0505	59.41	144.28	1.860	47.12	1.906	2.045	1.072
M-SU-6'-10F-6	0.0498	60.24	145.87	1.880	47.12	1.853	2.140	1.154
U-SU-17-10F-5	0.0490	61.22	98.16	0.959	36.26	1.716	1.500	0.874
U-SU-17-10F-6	0.0490	61.22	98.02	0.958	36.26	1.717	1.525	0.890
U-SU-18-10F-5	0.0490	61.22	192.71	0.959	36.26	1.458	1.690	1.159
U-SU-18-10F-6	0.0490	61.22	194.12	0.959	36.26	1.454	1.465	1.007
13	0.0605	12.40	97.17	1.000	34.00	1.891	2.030	1.074
14	0.0597	25.13	98.50	1.000	36.90	2.114	1.880	0.889
16	0.0597	12.56	98.50	3.000	37.00	1.726	1.720	0.997
17	0.0604	24.83	97.34	3.000	32.60	1.732	1.980	1.143
18	0.0605	41.32	97.17	3.000	32.70	1.913	1.910	0.998
19	0.0646	11.61	90.88	1.000	54.00	2.979	3.500	1.175

Table 11 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	$\frac{(Pu)test}{(Pu)pred}$
20	0.0654	22.94	89.74	1.000	53.60	3.267	3.390	1.038
22	0.0646	11.61	90.88	3.000	54.00	2.622	3.110	1.186
23	0.0649	23.11	90.45	3.000	53.00	2.813	3.140	1.116
24	0.0659	37.94	89.05	3.000	53.20	3.171	3.350	1.056
25	0.0601	12.48	147.75	1.000	37.70	1.856	1.550	0.835
26	0.0595	25.21	149.26	1.000	35.80	1.887	1.538	0.815
28	0.0601	12.48	147.75	3.000	41.70	1.756	1.300	0.740
29	0.0595	25.21	149.26	3.000	33.00	1.559	1.410	0.904
30	0.0587	42.59	151.31	3.000	32.30	1.640	1.525	0.930
31	0.0650	11.54	136.46	1.000	54.50	2.812	2.400	0.853
34	0.0637	11.77	139.29	3.000	54.70	2.374	2.400	1.011
35	0.0640	23.44	138.63	3.000	54.20	2.565	2.363	0.921
36	0.0633	39.49	140.18	3.000	54.10	2.739	2.413	0.881
37	0.0603	12.44	197.01	1.000	32.10	1.510	1.450	0.960
38	0.0616	24.35	192.81	1.000	33.20	1.755	1.550	0.883
39	0.0612	40.85	197.08	1.000	38.20	2.110	1.700	0.810

Table 11 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
40	0.0592	12.67	200.70	3.000	30.90	1.236	1.375	1.112
41	0.0607	24.71	195.69	3.000	32.50	1.469	1.400	0.953
42	0.0609	41.05	195.04	3.000	32.30	1.617	1.450	0.900
43	0.0664	11.30	178.72	1.000	53.80	2.699	2.390	0.886
44	0.0664	22.59	178.72	1.000	54.20	2.907	2.300	0.800
46	0.0660	11.36	179.82	3.000	55.80	2.392	2.250	0.941
47	0.0669	22.42	177.37	3.000	54.10	2.598	2.526	0.972
48	0.0661	37.82	179.54	3.000	53.40	2.739	2.576	0.940

Number of specimens	N = 54
Mean	Pm = 0.991
Coefficient of variation	Vp = 0.109

* All test specimens were obtained from reference 26.

Table 12

Comparison of Tested and Predicted Loads for Web Crippling

Single Unreinforced Webs, Interior One-Flange Loading

(Canadian Tests)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
5W-IOF	0.0380	26.30	98.85	2.470	39.80	0.829	0.607	0.732
6W-IOF	0.0240	41.70	157.75	3.920	38.50	0.289	0.282	0.976
7W-IOF	0.0600	16.70	127.78	1.570	33.50	1.730	1.550	0.896
14W-IOF	0.0380	26.30	100.37	2.470	39.80	0.731	0.563	0.770
15W-IOF	0.0240	41.70	161.14	3.920	38.50	0.254	0.207	0.992
16W-IOF	0.0600	16.70	129.87	1.570	33.50	1.526	1.437	0.942
23W-IOF	0.0390	25.60	100.14	2.410	39.80	0.694	0.475	0.684
24W-IOF	0.0250	40.00	158.09	3.760	38.50	0.251	0.219	0.873
25W-IOF	0.0610	16.40	128.55	1.540	33.50	1.429	1.200	0.840
26W-IOF	0.0400	25.00	197.07	2.350	39.80	0.622	0.450	0.724
34W-IOF	0.0240	41.70	156.77	3.920	38.50	0.291	0.313	1.076
35W-IOF	0.0240	83.30	155.93	3.920	38.50	0.376	0.388	1.032
36W-IOF	0.0240	125.00	155.93	3.920	38.50	0.480	0.450	0.938
51W-IOF	0.0360	27.80	110.33	2.610	39.80	0.648	0.534	0.824

Table 12 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
52W-IOF	0.0240	41.70	167.81	3.920	38.50	0.251	0.259	1.032
54W-IOF	0.0360	27.80	138.97	2.610	39.80	0.555	0.422	0.760
55W-IOF	0.0380	26.30	131.17	2.470	39.80	0.628	0.438	0.698
56W-IOF	0.0360	27.80	139.80	2.610	39.80	0.555	0.425	0.766
57W-IOF	0.0600	16.70	62.04	1.570	33.50	1.933	1.463	0.757
60W-IOF	0.0450	22.20	82.72	2.090	36.70	1.131	0.988	0.874
61W-IOF	0.0450	44.40	82.72	2.090	36.70	1.283	1.185	0.924
62W-IOF	0.0450	66.70	83.16	2.090	36.70	1.451	1.288	0.888
69W-IOF	0.0380	78.90	99.01	2.470	39.80	1.140	0.950	0.833
89W-IOF	0.0240	41.70	170.31	3.920	38.50	0.250	0.250	1.000
91W-IOF	0.0380	26.30	108.49	2.470	39.80	0.725	0.575	0.793
103W-IOF	0.0380	26.30	135.38	2.470	39.80	0.623	0.525	0.843
124W-IOF	0.0240	208.30	158.43	3.920	38.50	0.683	0.400	0.586
125W-IOF	0.0240	166.70	158.02	3.920	38.50	0.581	0.400	0.688
128W-IOF	0.0240	166.70	156.77	3.920	38.50	0.582	0.420	0.722
134W-IOF	0.0380	105.30	99.54	2.470	39.80	1.343	1.111	0.827

Table 12 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
135W-IOF	0.0380	131.60	100.06	2.470	39.80	1.546	1.219	0.789
136W-IOF	0.0380	26.30	99.54	2.470	39.80	0.834	0.745	0.893
137W-IOF	0.0380	52.60	99.01	2.470	39.80	0.964	0.880	0.913
139W-IOF	0.0240	41.70	156.77	3.920	38.50	0.291	0.235	0.808
33WR-IOF	0.0334	59.90	113.76	5.630	41.20	0.534	0.505	0.946
42WR-IOF	0.0395	50.60	95.30	6.330	43.40	0.725	0.721	0.995
69WR-IOF	0.0395	50.60	120.51	6.330	43.40	0.625	0.691	1.106
81WR-IOF	0.0606	33.00	79.72	6.190	43.80	1.456	1.485	1.020

Number of specimens	N = 38
Mean	Pm = 0.8618
Coefficient of variation	Vp = 0.1425

* All test specimens were obtained from references 27 and 28.

Table 13

Comparison of Tested and Predicted Loads for Web Crippling

Single Unreinforced Webs, End Two-Flange Loading

(UMR Tests)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
SU-1-ETF-1	0.0460	21.74	213.59	2.717	43.82	0.278	0.320	1.153
SU-1-ETF-2	0.0470	21.28	209.45	2.660	43.82	0.298	0.310	1.042
SU-1-ETF-5	0.0475	63.16	207.31	2.632	43.82	0.414	0.380	0.917
SU-1-ETF-6	0.0480	62.50	205.27	2.604	43.82	0.428	0.355	0.830
SU-4-ETF-1	0.0500	20.00	97.28	1.876	47.12	0.603	0.685	1.136
SU-4-ETF-2	0.0515	19.42	93.92	1.971	47.12	0.633	0.668	1.056
SU-4-ETF-3	0.0510	39.22	95.08	1.839	47.12	0.737	0.745	1.011
SU-4-ETF-4	0.0510	39.22	94.61	1.839	47.12	0.738	0.750	1.017
SU-4-ETF-5	0.0500	60.00	96.82	1.876	47.12	0.804	0.765	0.952
SU-4-ETF-6	0.0500	60.00	96.70	1.876	47.12	0.804	0.775	0.964
SU-5-ETF-1	0.0505	19.80	120.08	1.778	47.12	0.582	0.600	1.031
SU-5-ETF-2	0.0508	19.69	119.98	1.768	47.12	0.589	0.615	1.044
SU-5-ETF-3	0.0507	39.45	120.37	1.850	47.12	0.673	0.615	0.914
SU-5-ETF-4	0.0501	39.92	121.48	2.028	47.12	0.637	0.625	0.982
SU-5-ETF-5	0.0509	58.94	119.33	1.843	47.12	0.776	0.685	0.883

Table 13 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
SU-5-ETF-6	0.0503	59.64	120.99	1.865	47.12	0.754	0.675	0.895
SU-6'-ETF-1	0.0490	20.41	148.55	1.914	47.12	0.488	0.585	1.198
SU-6'-ETF-2	0.0500	20.00	145.44	1.876	47.12	0.516	0.545	1.057
SU-6'-ETF-3	0.0491	40.73	148.31	1.990	47.12	0.565	0.608	1.076
SU-6'-ETF-4	0.0496	40.32	146.77	1.891	47.12	0.588	0.595	1.011
SU-6'-ETF-5	0.0495	60.61	147.68	1.895	47.12	0.667	0.665	0.996
SU-6'-ETF-6	0.0500	60.00	145.74	1.876	47.12	0.685	0.660	0.963
U-SU-17-ETF-5	0.0485	61.86	100.04	0.969	36.26	0.756	0.780	1.032
U-SU-17-ETF-6	0.0490	61.22	98.61	0.959	36.26	0.772	0.755	0.978
U-SU-19-ETF-5	0.0490	61.22	194.80	0.959	36.26	0.547	0.455	0.832
U-SU-19-ETF-6	0.0490	61.22	194.47	0.959	36.26	0.548	0.470	0.858

Number of specimens	N = 26
Mean	Pm = 0.993
Coefficient of variation	Vp = 0.093

* All test specimens were obtained from reference 26.

Table 14

Comparison of Tested and Predicted Loads for Web Crippling

Single Unreinforced Webs, End Two-Flange Loading

(Canadian Tests)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
5W-ETF	0.0600	16.70	127.78	1.570	33.50	0.660	0.958	1.452
8W-ETF	0.0600	16.70	30.34	1.570	33.50	0.776	1.025	1.321
9W-ETF	0.0380	26.30	47.17	2.470	39.80	0.305	0.420	1.377
10W-ETF	0.0240	41.70	76.97	3.920	38.50	0.089	0.180	2.023
11W-ETF	0.0600	16.70	63.01	1.570	33.50	0.712	1.038	1.458
12W-ETF	0.0380	26.30	100.37	2.470	39.80	0.263	0.358	1.361
13W-ETF	0.0240	41.70	161.14	3.920	38.50	0.068	0.124	1.824
14W-ETF	0.0600	16.70	129.87	1.570	33.50	0.580	0.885	1.526
17W-ETF	0.0600	16.70	31.51	1.570	33.50	0.697	1.090	1.564
18W-ETF	0.0380	26.30	49.02	2.470	39.80	0.275	0.351	1.276
19W-ETF	0.0240	41.70	80.05	3.920	38.50	0.079	0.195	2.468
20W-ETF	0.0600	16.70	65.55	1.570	33.50	0.636	0.863	1.357
21W-ETF	0.0390	25.60	100.14	2.410	39.80	0.251	0.278	1.108
22W-ETF	0.0250	40.00	156.09	3.760	38.50	0.070	0.090	1.286

Table 14 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
23W-ETF	0.0610	16.40	128.55	1.540	33.50	0.546	0.431	0.789
24W-ETF	0.0400	25.00	197.07	2.350	39.80	0.188	0.201	1.069
26W-ETF	0.0240	41.70	155.93	3.920	38.50	0.078	0.163	2.090
27W-ETF	0.0240	41.70	155.93	3.920	38.50	0.078	0.150	1.923
28W-ETF	0.0240	41.70	81.35	3.920	38.50	0.100	0.195	1.950
29W-ETF	0.0380	26.30	99.54	2.470	39.80	0.299	0.402	1.345
30W-ETF	0.0240	41.70	157.18	3.920	38.50	0.078	0.146	1.872
31W-ETF	0.0600	16.70	63.04	1.570	33.50	0.807	1.010	1.252
32W-ETF	0.0600	16.70	28.54	1.570	33.50	0.884	1.160	1.312
33W-ETF	0.0380	26.30	46.12	2.470	39.80	0.348	0.350	1.006
34W-ETF	0.0240	41.70	155.93	3.920	38.50	0.078	0.125	1.603
35W-ETF	0.0380	26.30	97.96	2.470	39.80	0.301	0.332	1.103
36W-ETF	0.0600	16.70	62.04	1.570	33.50	0.810	1.110	1.370
2WR-ETF	0.0395	50.60	72.53	4.760	43.40	0.281	0.548	1.950
3WR-ETF	0.0606	33.00	47.23	3.610	43.80	0.764	1.246	1.631
4WR-ETF	0.0606	33.00	46.22	3.860	43.80	0.719	1.246	1.733

Table 14 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
6WR-ETF	0.0606	33.00	43.09	5.920	43.80	0.634	1.122	1.770
7WR-ETF	0.0606	33.00	61.23	4.130	43.80	0.565	1.067	1.889
11WR-ETF	0.0395	50.60	120.51	6.330	43.40	0.192	0.340	1.771
12WR-ETF	0.0606	33.00	80.68	5.170	43.80	0.454	0.923	2.033
14WR-ETF	0.0606	33.00	79.72	6.190	43.80	0.456	0.948	2.079
1E-ETF	0.0620	32.30	42.09	2.520	42.50	0.974	2.005	2.059
2E-ETF	0.0620	48.40	42.09	2.520	42.50	1.093	1.831	1.675
1C-ETF	0.0360	41.70	77.50	3.470	41.50	0.252	0.478	1.897
2C-ETF	0.0360	55.60	77.50	3.470	41.50	0.276	0.493	1.786
3C-ETF	0.0360	83.30	77.50	3.470	41.50	0.326	0.623	1.911
4C-ETF	0.0360	111.10	77.50	3.470	41.50	0.375	0.747	1.992
5C-ETF	0.0320	46.90	87.17	3.910	40.90	0.178	0.295	1.657
6C-ETF	0.0320	62.50	87.17	3.910	40.90	0.197	0.362	1.838
7C-ETF	0.0320	93.70	87.17	3.910	40.90	0.235	0.455	1.936
8C-ETF	0.0320	125.00	87.17	3.910	40.90	0.272	0.447	1.643
1R-ETF	0.0490	30.60	25.50	5.100	48.40	0.412	1.121	2.721

Table 14 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
2R-ETF	0.0490	40.80	25.50	5.100	48.40	0.444	1.122	2.527
3R-ETF	0.0490	61.20	25.50	5.100	48.40	0.508	1.301	2.561
7R-ETF	0.0490	30.60	24.56	5.100	49.00	0.388	1.104	2.845
8R-ETF	0.0490	40.80	24.56	5.100	49.00	0.419	1.158	2.764
9R-ETF	0.0490	61.20	24.56	5.100	49.00	0.480	1.256	2.617
13R-ETF	0.0470	31.90	49.69	1.340	41.30	0.530	0.670	1.264
14R-ETF	0.0470	42.60	49.69	1.340	41.30	0.573	0.796	1.389
15R-ETF	0.0470	63.80	49.69	1.340	41.30	0.659	0.930	1.411
16R-ETF	0.0250	60.00	94.93	2.520	48.80	0.141	0.187	1.326
17R-ETF	0.0250	80.00	94.93	2.520	48.80	0.160	0.233	1.456
18R-ETF	0.0250	120.00	94.93	2.520	48.80	0.195	0.280	1.436
25R-ETF	0.0500	30.00	52.06	3.120	42.30	0.544	0.801	1.472
26R-ETF	0.0500	40.00	52.06	3.120	42.30	0.585	0.914	1.562
27R-ETF	0.0500	60.00	52.06	3.120	42.30	0.669	1.085	1.622
28R-ETF	0.0320	46.90	82.57	4.880	44.50	0.174	0.370	2.126
29R-ETF	0.0320	62.50	82.57	4.880	44.50	0.192	0.392	2.042

Table 14 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
30R-ETF	0.0320	93.70	82.57	4.880	44.50	0.229	0.479	2.092

Number of specimens	N = 63
Mean	Pm = 1.7233
Coefficient of variation	Vp = 0.2622

* All test specimens were obtained from references 27 and 28.

Table 15

Comparison of Tested and Predicted Loads for Web Crippling

Single Unreinforced Webs, Interior Two-Flange Loading

(UMR Tests)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
SU-1-ITF-1	0.0480	20.83	205.35	2.600	43.82	0.805	0.770	0.956
SU-1-ITF-2	0.0475	21.05	207.33	2.630	43.82	0.776	0.785	1.012
SU-1-ITF-5	0.0480	62.50	205.39	2.600	43.82	0.847	0.795	0.938
SU-1-ITF-6	0.0470	63.83	209.89	2.660	43.82	0.784	0.820	1.046
SU-4-ITF-1	0.0517	19.36	93.69	1.820	47.12	1.883	1.715	0.911
SU-4-ITF-2	0.0519	19.28	93.62	1.810	47.12	1.899	1.725	0.908
SU-4-ITF-3	0.0500	40.00	96.80	1.880	47.12	1.777	1.915	1.078
SU-4-ITF-4	0.0506	39.41	95.67	1.850	47.12	1.828	1.980	1.083
SU-4-ITF-5	0.0522	57.52	92.83	2.020	47.12	1.994	2.210	1.108
SU-4-ITF-6	0.0510	58.82	94.64	1.990	47.12	1.895	2.310	1.218
SU-5-ITF-1	0.0500	20.00	121.58	1.880	47.12	1.557	1.508	0.969
SU-5-ITF-2	0.0503	19.88	120.68	1.870	47.12	1.583	1.530	0.967
SU-5-ITF-3	0.0505	39.60	120.61	1.860	47.12	1.637	1.550	0.947
SU-5-ITF-4	0.0501	39.92	121.23	1.870	47.12	1.606	1.710	1.064
SU-5-ITF-5	0.0500	59.64	120.45	1.790	47.12	1.647	1.620	0.984

Table 15 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
SU-5-ITF-6	0.0503	60.00	121.50	1.800	47.12	1.670	1.610	0.964
SU-6'-ITF-1	0.0495	20.20	146.57	1.900	47.12	1.350	1.465	1.085
SU-6'-ITF-2	0.0496	20.16	146.69	1.730	47.12	1.369	1.233	0.901
SU-6'-ITF-3	0.0500	40.00	145.20	1.720	47.12	1.438	1.225	0.852
SU-6'-ITF-4	0.0495	40.40	147.09	1.900	47.12	1.381	1.280	0.927
SU-6'-ITF-5	0.0504	59.52	144.39	1.860	47.12	1.490	1.330	0.893
SU-6'-ITF-6	0.0490	61.22	148.57	1.910	47.12	1.376	1.250	0.908
U-SU-17-ITF-5	0.0495	60.61	96.14	0.949	36.26	1.576	1.605	1.018
U-SU-17-ITF-6	0.0490	61.22	96.18	0.959	36.26	1.544	1.605	1.040
U-SU-19-ITF-5	0.0490	61.22	194.49	0.959	36.26	0.922	0.750	0.813
U-SU-19-ITF-6	0.0490	61.22	195.78	0.959	36.26	0.914	0.745	0.815

Number of specimens	N = 26
Mean	Pm = 0.977
Coefficient of variation	Vp = 0.096

* All test specimens were obtained from reference 26.

Table 16

Comparison of Tested and Predicted Loads for Web Crippling

Single Unreinforced Webs, Interior Two-Flange Loading

(Canadian Tests)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
1W-ITF	0.0600	16.70	28.28	1.570	33.50	2.524	1.500	0.594
2W-ITF	0.0380	26.30	46.17	2.470	39.80	1.042	0.675	0.648
3W-ITF	0.0240	41.70	73.77	3.920	38.50	0.341	0.332	0.974
4W-ITF	0.0240	41.70	156.77	3.920	38.50	0.235	0.375	1.596
5W-ITF	0.0240	41.70	158.22	3.920	38.50	0.205	0.338	1.649
6W-ITF	0.0600	16.70	61.54	1.570	33.50	2.271	1.688	0.743
7W-ITF	0.0380	26.30	98.22	2.470	39.80	0.861	0.719	0.835
8W-ITF	0.0600	16.70	61.87	1.570	33.50	2.269	1.613	0.711
9W-ITF	0.0600	16.70	61.87	1.570	33.50	2.269	1.625	0.716
10W-ITF	0.0240	41.70	82.81	3.920	38.50	0.289	0.350	1.211
11W-ITF	0.0380	26.30	51.91	2.470	39.80	0.903	0.688	0.762
12W-ITF	0.0600	16.70	33.84	1.570	33.50	2.201	1.375	0.625
13W-ITF	0.0240	41.70	170.31	3.920	38.50	0.191	0.263	1.377
14W-ITF	0.0380	26.30	108.49	2.470	39.80	0.727	0.700	0.963

Table 16 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
15W-ITF	0.0600	16.70	68.51	1.570	33.50	1.952	1.525	0.781
16W-ITF	0.0240	41.70	103.44	3.920	38.50	0.240	0.313	1.304
17W-ITF	0.0380	26.30	67.75	2.470	39.80	0.768	0.713	0.928
18W-ITF	0.0600	16.70	43.05	1.570	33.50	1.919	1.363	0.710
20W-ITF	0.0380	26.30	135.38	2.470	39.80	0.578	0.550	0.952
21W-ITF	0.0600	16.70	87.88	1.570	33.50	1.630	1.288	0.790
22W-ITF	0.0600	16.70	30.37	1.570	33.50	2.524	1.900	0.753
23W-ITF	0.0380	26.30	47.43	2.470	39.80	1.054	0.750	0.712
24W-ITF	0.0240	41.70	74.68	3.920	38.50	0.339	0.350	1.032
25W-ITF	0.0240	83.30	159.18	3.920	38.50	0.246	0.425	1.728
26W-ITF	0.0240	125.00	156.35	3.920	38.50	0.259	0.485	1.873
27W-ITF	0.0380	52.60	98.75	2.470	39.80	0.887	0.738	0.832
28W-ITF	0.0380	78.90	99.01	2.470	39.80	0.915	0.829	0.906
29W-ITF	0.0600	33.30	63.04	1.570	33.50	2.307	2.094	0.908
30W-ITF	0.0600	50.00	62.71	1.570	33.50	2.358	2.430	1.031
31W-ITF	0.0240	41.70	155.93	3.920	38.50	0.236	0.277	1.174

Table 16 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
32W-ITF	0.0380	26.30	97.96	2.470	39.80	0.862	0.623	0.723
33W-ITF	0.0600	16.70	62.04	1.570	33.50	2.267	2.025	0.893
2WR-ITF	0.0395	50.60	72.53	4.760	43.40	0.957	0.908	0.949
3WR-ITF	0.0606	33.00	47.23	3.610	43.80	2.643	2.070	0.783
6WR-ITF	0.0606	33.00	46.22	3.860	43.80	2.605	2.095	0.804
9WR-ITF	0.0606	33.00	43.09	5.920	43.80	2.240	1.871	0.835
14WR-ITF	0.0395	50.60	95.30	6.330	43.40	0.677	0.911	1.346
15WR-ITF	0.0606	33.00	63.07	4.130	43.80	2.123	2.015	0.949
3U-ITF	0.0320	46.90	42.29	4.880	42.30	0.597	0.628	1.052
4U-ITF	0.0320	62.50	42.29	4.880	42.30	0.607	0.762	1.255
5U-ITF	0.0320	46.90	42.29	4.880	42.30	0.597	0.690	1.156
6U-ITF	0.0320	62.50	42.29	4.880	42.30	0.607	0.830	1.367
9U-ITF	0.0320	46.90	42.29	4.880	42.30	0.597	0.695	1.164
10U-ITF	0.0320	62.50	42.29	4.880	42.30	0.607	0.760	1.252
1C-ITF	0.0360	41.70	77.50	3.470	41.50	0.778	0.888	1.141
2C-ITF	0.0360	55.60	77.50	3.470	41.50	0.791	0.945	1.195

Table 16 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
3C-ITF	0.0360	83.30	77.50	3.470	41.50	0.817	1.050	1.285
4C-ITF	0.0360	111.10	77.50	3.470	41.50	0.845	1.247	1.476
5C-ITF	0.0320	46.90	87.17	3.910	40.90	0.571	0.657	1.151
6C-ITF	0.0320	62.50	87.17	3.910	40.90	0.582	0.655	1.125
7C-ITF	0.0320	93.70	87.17	3.910	40.90	0.604	0.795	1.316
8C-ITF	0.0320	125.00	87.17	3.910	40.90	0.626	0.850	1.358
1R-ITF	0.0490	30.60	25.50	5.100	48.40	1.630	1.705	1.046
2R-ITF	0.0490	40.80	25.50	5.100	48.40	1.651	1.844	1.117
3R-ITF	0.0490	61.20	25.50	5.100	48.40	1.692	1.995	1.179
7R-ITF	0.0490	30.60	24.56	5.100	49.00	1.542	1.424	0.924
8R-ITF	0.0490	40.80	24.56	5.100	49.00	1.562	1.745	1.117
9R-ITF	0.0490	61.20	24.56	5.100	49.00	1.601	1.966	1.228
13R-ITF	0.0470	31.90	49.69	1.340	41.30	1.360	1.053	0.774
14R-ITF	0.0470	42.60	49.69	1.340	41.30	1.379	1.171	0.849
15R-ITF	0.0470	63.80	49.69	1.340	41.30	1.414	1.347	0.953
16R-ITF	0.0250	60.00	94.93	2.520	48.80	0.349	0.347	0.994

Table 16 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
17R-ITF	0.0250	80.00	94.93	2.520	48.80	0.358	0.375	1.048
18R-ITF	0.0250	120.00	94.93	2.520	48.80	0.375	0.419	1.117
25R-ITF	0.0500	30.00	52.06	3.120	42.30	1.751	1.407	0.804
26R-ITF	0.0500	40.00	52.06	3.120	42.30	1.773	1.492	0.842
27R-ITF	0.0500	60.00	52.06	3.120	42.30	1.818	1.644	0.904
28R-ITF	0.0320	46.90	82.57	4.880	44.50	0.596	0.666	1.117
29R-ITF	0.0320	62.50	82.57	4.880	44.50	0.607	0.700	1.153
30R-ITF	0.0320	93.70	82.57	4.880	44.50	0.630	0.744	1.181

Number of specimens	N = 70
Mean	Pm = 1.0391
Coefficient of variation	Vp = 0.2595

* All test specimens were obtained from references 27 and 28.

Table 17

Comparison of Tested and Predicted Loads for Web Crippling

I-Sections, End One-Flange Loading

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
I-1-EOF-1	0.0475	21.05	207.09	2.630	43.82	1.867	1.840	0.986
I-1-EOF-2	0.0470	21.28	208.45	2.660	43.82	1.831	1.770	0.967
I-1-EOF-5	0.0470	63.83	209.53	2.660	43.82	2.322	2.175	0.937
I-1-EOF-6	0.0460	65.22	213.87	2.720	43.82	2.236	2.210	0.988
I-3-EOF-1	0.0490	20.41	148.22	1.910	47.12	2.120	2.355	1.111
I-3-EOF-2	0.0500	20.00	144.74	1.800	47.12	2.191	2.470	1.127
I-3-EOF-5	0.0495	60.61	146.73	1.900	47.12	2.725	2.990	1.097
I-3-EOF-6	0.0490	61.22	148.35	1.910	47.12	2.681	2.750	1.026
I-3'-EOF-1	0.0460	21.74	150.48	2.040	33.46	1.345	1.890	1.405
I-3'-EOF-2	0.0460	21.74	150.54	2.040	33.46	1.345	1.690	1.257
I-3'-EOF-5	0.0460	65.22	152.22	2.040	33.46	1.707	2.390	1.400
I-3'-EOF-6	0.0460	65.22	150.85	2.040	33.46	1.707	2.440	1.429
I-5'-EOF-5	0.0600	50.00	119.67	1.560	47.13	3.706	4.120	1.112
I-5'-EOF-6	0.0600	50.00	119.62	1.560	47.13	3.706	4.470	1.206

Table 17 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
I-6-EOF-1	0.0750	13.32	96.62	1.250	42.86	3.964	5.200	1.312
I-6-EOF-2	0.0752	13.30	96.36	1.250	42.86	3.982	5.385	1.352
I-6-EOF-5	0.0750	39.95	96.68	1.250	42.86	4.874	5.630	1.155
I-6-EOF-6	0.0752	39.89	96.22	1.250	42.86	4.894	5.315	1.086
I-6-EOF-7	0.0775	38.71	92.49	1.250	42.86	5.141	5.635	1.096
I-6-EOF-8	0.0760	39.47	95.08	1.250	42.86	4.980	6.750	1.355
I-6"-EOF-1	0.0470	21.28	149.51	2.000	33.46	1.398	1.780	1.274
I-6"-EOF-2	0.0460	21.74	148.52	2.040	33.46	1.343	1.920	1.430
I-6"-EOF-5	0.0460	65.22	149.63	2.040	33.46	1.707	2.540	1.488
I-6"-EOF-6	0.0460	65.22	152.46	2.040	33.46	1.707	2.350	1.377
I-9-EOF-1	0.0460	21.74	148.30	2.040	33.46	1.342	2.075	1.546
I-9-EOF-2	0.0460	21.74	149.98	2.040	33.46	1.345	1.825	1.357
I-9-EOF-5	0.0460	65.22	150.22	2.040	33.46	1.707	2.510	1.470
I-9-EOF-6	0.0460	65.22	148.78	2.040	33.46	1.705	2.565	1.504
I-12-EOF-1	0.0510	19.61	143.98	1.840	53.79	2.591	2.470	0.953
I-12-EOF-2	0.0503	19.80	145.43	1.860	53.79	2.532	2.505	0.989

Table 17 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
I-12-EOF-5	0.0510	58.82	143.78	1.840	53.79	3.266	2.960	0.906
I-12-EOF-6	0.0510	58.82	143.28	1.840	53.79	3.264	2.830	0.867
I-12'-EOF-5	0.1080	27.78	48.95	1.010	45.68	9.415	10.250	1.089
I-12'-EOF-6	0.1075	27.91	49.42	1.020	45.68	9.342	11.580	1.240
I-16-EOF-1	0.0530	18.87	73.08	1.770	53.79	2.599	2.560	1.001
I-16-EOF-2	0.0505	19.80	77.09	1.860	53.79	2.354	3.575	1.519
I-16-EOF-5	0.0510	58.82	76.41	1.840	53.79	3.019	3.050	1.010
I-16-EOF-6	0.0510	58.82	77.20	1.840	53.79	3.022	3.150	1.042
I-U-17-EOF-5	0.0490	61.22	99.02	0.959	36.26	1.950	2.555	1.311
I-U-17-EOF-6	0.0490	61.22	97.61	0.959	36.26	1.946	2.230	1.146
I-U-18-EOF-5	0.0485	61.86	196.78	0.969	36.26	2.030	2.040	1.005
I-U-18-EOF-6	0.0490	61.22	194.76	0.959	36.26	2.067	2.285	1.106
2a-2-EOF	0.0603	16.58	64.00	---	30.20	1.799	1.770	0.984
2a-3-EOF	0.0603	41.46	64.00	---	30.20	2.151	1.900	0.883
2b-3-EOF	0.0603	16.58	64.00	---	30.20	1.799	1.950	1.084
2b-4-EOF	0.0603	24.88	64.00	---	30.20	1.935	2.100	1.085

Table 17 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
4a-3-EOF	0.0609	16.420	98.16	---	30.20	1.908	1.870	0.980
4b-2-EOF	0.0609	24.630	98.16	---	30.20	2.052	2.250	1.096
6a-3-EOF	0.0647	15.460	121.34	---	37.30	2.706	1.850	0.684
6b-2-EOF	0.0647	23.180	121.34	---	37.30	2.906	2.180	0.750
6b-3-EOF	0.0647	38.640	121.34	---	37.30	3.224	2.390	0.741
9b-2-EOF	0.1070	7.477	34.82	---	35.10	5.643	5.700	1.010
10a-3-EOF	0.1082	9.240	52.72	---	35.10	6.069	6.170	1.017
10b-2-EOF	0.1082	13.860	52.72	---	35.10	6.445	7.350	1.140
10b-3-EOF	0.1082	27.730	52.72	---	35.10	7.293	8.500	1.166
11-3-EOF	0.1092	9.160	70.71	---	36.20	6.511	5.600	0.860
12-2-EOF	0.1109	13.530	69.68	---	36.20	7.103	6.620	0.932
12-3-EOF	0.1109	22.540	69.68	---	36.20	7.754	6.000	0.774
13a-2-EOF	0.1342	7.452	27.51	---	35.70	8.940	7.940	0.888
13b-2-EOF	0.1342	11.180	27.51	---	35.70	9.451	8.370	0.886
14a-3-EOF	0.1478	6.766	38.19	---	33.10	10.070	9.350	0.929
14b-2-EOF	0.1478	10.150	38.19	---	33.10	10.626	10.720	1.009

Table 17 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
14b-3-EOF	0.1478	16.910	38.19	---	33.10	11.506	12.600	1.095
15a-3-EOF	0.1473	6.790	52.10	---	33.10	10.182	9.400	0.923
15b-2-EOF	0.1473	10.180	52.10	---	33.10	10.745	11.450	1.066
15b-3-EOF	0.1473	16.970	52.10	---	33.10	11.636	12.100	1.040
16e-1-EOF	0.0460	21.740	172.35	---	32.20	1.294	1.113	0.860
16f-1-EOF	0.0460	54.350	172.35	---	32.20	1.571	1.275	0.812
17e-1-EOF	0.0755	13.240	103.70	---	35.80	3.617	3.600	0.995
17f-1-EOF	0.0755	33.110	103.70	---	35.80	3.994	4.075	1.020
18b-1-EOF	0.1230	8.130	63.85	---	37.60	8.373	7.125	0.851
18b-2-EOF	0.1230	20.330	63.85	---	37.60	9.652	10.330	1.070

Number of specimens	N = 72
Mean	Pm = 1.096
Coefficient of variation	Vp = 0.188

* All test specimens were obtained from reference 26.

Table 18

Comparison of Tested and Predicted Loads for Web Crippling

I-Sections, Interior One-Flange Loading

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
I-1-IOF-1	0.0480	20.83	205.92	2.600	43.82	2.2659	2.385	1.0526
I-1-IOF-2	0.0480	20.83	207.31	2.600	43.82	2.2659	2.490	1.0989
I-1-IOF-5	0.0485	61.86	203.69	2.580	43.82	3.1477	2.910	0.9245
I-1-IOF-6	0.0480	62.50	205.35	2.600	43.82	3.0906	2.850	0.9221
I-3-IOF-1	0.0490	20.41	148.61	1.910	47.12	2.3598	2.505	1.0615
I-3-IOF-2	0.0500	20.00	145.78	1.880	47.12	2.4490	2.450	1.0004
I-6"-IOF-1	0.0470	21.28	148.89	2.000	33.46	2.0171	1.800	0.8924
I-6"-IOF-2	0.0460	21.74	149.09	2.040	33.46	1.9394	1.805	0.9307
I-9-IOF-1	0.0465	21.51	148.30	2.020	33.46	1.9780	1.680	0.8493
I-9-IOF-2	0.0460	21.74	150.28	2.040	33.46	1.9394	1.540	0.7941
I-9-IOF-5	0.0460	65.22	149.48	2.040	33.46	2.6528	1.975	0.7445
I-9-IOF-6	0.0455	65.93	150.75	2.060	33.46	2.6023	1.885	0.7244
I-12-IOF-1	0.0505	19.80	145.19	1.860	53.79	2.4312	2.645	1.0879
I-12-IOF-2	0.0515	19.42	142.64	1.820	53.79	2.5206	2.660	1.0553

Table 18 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
1-12-10F-5	0.0505	59.41	145.88	1.860	53.79	3.3049	3.365	1.0182
1-U-18-10F-5	0.0490	61.22	195.04	0.959	36.26	3.0619	2.730	0.8916
1-U-18-10F-6	0.0490	61.22	194.65	0.959	36.26	3.0619	2.565	0.8377
1a-1-10F	0.0460	27.17	170.17	---	32.20	2.0190	1.825	0.9039
4a-1-10F	0.0609	16.42	98.16	---	30.20	3.0993	3.750	1.2099
4a-2-10F	0.0609	24.63	98.16	---	30.20	3.4250	3.850	1.1241
6a-1-10F	0.0647	15.46	121.34	---	37.30	3.8004	4.000	1.0525
6a-2-10F	0.0647	23.18	121.34	---	37.30	4.1933	4.400	1.0493
6b-1-10F	0.0647	38.64	121.34	---	37.30	4.8164	4.300	0.8928
11-1-10F	0.1092	9.16	70.71	---	36.20	10.2738	11.000	1.0707
11-2-10F	0.1092	13.74	70.71	---	36.20	11.1881	12.400	1.1083
18c-1-10F	0.1230	8.13	63.85	---	37.60	13.1716	10.500	0.7972
18c-2-10F	0.1230	20.33	63.85	---	37.60	16.0947	12.900	0.8015

Table 18 (Continued)

Number of specimens	N = 27
Mean	Pm = 0.959
Coefficient of variation	Vp = 0.133

* All test specimens were obtained from reference 26.

Table 19

Comparison of Tested and Predicted Loads for Web Crippling

I-Sections, End Two-Flange Loading

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
I-1-ETF-1	0.0480	20.83	205.04	2.604	43.82	0.744	0.705	0.948
I-1-ETF-2	0.0490	20.41	201.45	2.551	43.82	0.780	0.690	0.884
I-1-ETF-5	0.0490	61.22	200.31	2.551	43.82	0.988	0.890	0.901
I-1-ETF-6	0.0490	61.22	201.41	2.551	43.82	0.987	0.935	0.948
I-3-ETF-1	0.0500	20.00	145.12	1.876	47.12	0.884	0.805	0.910
I-3-ETF-2	0.0495	20.20	146.53	1.895	47.12	0.865	0.850	0.983
I-3-ETF-5	0.0500	60.00	145.52	1.876	47.12	1.116	1.120	1.004
I-3-ETF-6	0.0490	61.22	148.53	1.914	47.12	1.067	1.035	0.970
I-3-ETF-1*	0.0500	20.00	145.18	1.876	47.12	0.884	0.820	0.927
I-3-ETF-2*	0.0500	20.00	145.40	1.876	47.12	0.884	0.810	0.916
I-3-ETF-5*	0.0490	61.22	148.49	1.914	47.12	1.067	1.005	0.942
I-3-ETF-6*	0.0500	60.00	145.32	1.876	47.12	1.116	0.960	0.860
I-5'-ETF-5	0.0600	50.00	119.62	1.563	47.13	1.673	1.470	0.879
I-5'-ETF-6	0.0600	50.00	119.95	1.823	47.13	1.672	1.405	0.840

Table 19 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
I-6-ETF-1	0.0751	13.32	96.07	1.249	42.86	2.238	2.035	0.909
I-6-ETF-2	0.0750	13.33	96.73	1.251	42.86	2.230	2.105	0.944
I-6-ETF-5	0.0752	39.89	95.94	1.247	42.86	2.760	2.935	1.064
I-6-ETF-6	0.0752	39.89	96.36	1.247	42.86	2.758	3.060	1.109
I-6-ETF-7	0.0750	40.00	96.53	1.251	42.86	2.742	2.690	0.981
I-6-ETF-8	0.0760	39.47	95.24	1.234	42.86	2.825	2.400	0.850
I-6"-ETF-1	0.0470	21.28	147.30	1.996	33.46	0.776	0.885	1.140
I-6"-ETF-2	0.0460	21.74	151.59	2.039	33.46	0.738	0.845	1.144
I-6"-ETF-5	0.0460	65.22	152.59	2.039	33.46	0.936	1.065	1.138
I-6"-ETF-6	0.0460	65.22	152.26	2.039	33.46	0.936	1.095	1.169
I-12'-ETF-5	0.1080	27.78	49.01	1.013	45.68	6.405	4.650	0.726
I-12'-ETF-6	0.1080	27.78	49.02	1.013	45.68	6.405	5.245	0.819
2b-6-ETF	0.0603	24.88	64.00	---	30.20	1.569	1.870	1.192
3-4-ETF	0.0599	41.74	64.27	---	30.20	1.720	1.800	1.046
4a-6-ETF	0.0609	16.42	98.16	---	30.20	1.425	1.600	1.123
4a-7-ETF	0.0609	24.63	98.16	---	30.20	1.532	1.700	1.109

Table 19 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
4b-4-ETF	0.0609	41.05	98.16	---	30.20	1.703	1.900	1.116
6a-5-ETF	0.0647	15.46	121.34	---	37.30	1.570	1.850	1.178
6a-6-ETF	0.0647	23.18	121.34	---	37.30	1.686	1.920	1.139
6b-5-ETF	0.0647	38.64	121.34	---	37.30	1.870	2.250	1.203
9a-3-ETF	0.1070	9.35	34.82	---	35.10	5.311	5.100	0.960
9b-5-ETF	0.1070	9.35	34.82	---	35.10	5.311	5.350	1.007
9b-6-ETF	0.1070	14.02	34.82	---	35.10	5.641	5.950	1.055
9b-7-ETF	0.1070	23.36	34.82	---	35.10	6.164	6.850	1.111
10a-6-ETF	0.1082	9.24	52.72	---	35.10	5.327	5.900	1.107
10a-7-ETF	0.1082	13.86	52.72	---	35.10	5.657	5.950	1.052
10b-5-ETF	0.1082	23.11	52.72	---	35.10	6.180	7.750	1.254
13a-5-ETF	0.1342	7.45	27.51	---	35.70	9.030	6.750	0.748
13a-6-ETF	0.1342	11.18	27.51	---	35.70	9.546	8.500	0.890
13b-4-ETF	0.1342	18.63	27.51	---	35.70	10.365	12.800	1.235
14a-6-ETF	0.1478	6.77	38.25	---	33.10	11.182	8.900	0.796
14a-7-ETF	0.1478	10.15	38.25	---	33.10	11.799	11.150	0.945

Table 19 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
14b-5-ETF	0.1478	16.91	38.25	---	33.10	12.777	12.300	0.963
16d-3-ETF	0.0460	21.74	172.35	---	32.20	0.716	0.880	1.228
16d-4-ETF	0.0460	54.35	172.35	---	32.20	0.870	0.920	1.058
17d-3-ETF	0.0755	13.25	103.70	---	35.80	2.241	2.450	1.093
17d-4-ETF	0.0755	33.11	103.70	---	35.80	2.648	3.060	1.155
18a-3-ETF.	0.1230	8.13	63.85	---	37.60	7.047	6.800	0.965
16a-4-ETF	0.1230	20.33	63.85	---	37.60	8.123	7.500	0.923

Number of specimens	N = 53
Mean	Pm = 1.010
Coefficient of variation	Vp = 0.129

* All test specimens were obtained from reference 26.

Table 20

Comparison of Tested and Predicted Loads for Web Crippling

I-Sections, Interior Two-Flange Loading

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
I-1-ITF-1	0.0465	21.51	211.89	2.688	43.82	1.531	1.625	1.062
I-1-ITF-2	0.0480	20.83	206.06	2.604	43.82	1.642	1.665	1.014
I-1-ITF-5	0.0460	65.22	214.13	2.717	43.82	2.044	1.875	0.918
I-1-ITF-6	0.0470	63.83	209.47	2.660	43.82	2.143	1.920	0.896
I-3-ITF-1	0.0500	20.00	145.68	1.796	47.12	1.975	1.915	0.970
I-3-ITF-2	0.0500	20.00	145.68	1.876	47.12	1.975	2.080	1.053
I-3-ITF-5	0.0500	60.00	145.48	1.796	47.12	2.687	2.375	0.884
I-3-ITF-6	0.0490	61.22	148.63	1.914	47.12	2.578	2.205	0.855
I-3-ITF-1*	0.0490	20.41	148.47	1.914	47.12	1.893	2.090	1.104
I-3-ITF-2*	0.0500	20.00	145.84	1.876	47.12	1.974	2.170	1.099
I-3-ITF-5*	0.0495	60.61	147.23	1.895	47.12	2.631	2.205	0.838
I-3-ITF-6*	0.0490	61.22	148.76	1.914	47.12	2.577	2.335	0.906
I-5'-ITF-5	0.0610	49.18	117.82	1.538	47.13	4.034	3.775	0.936
I-5'-ITF-6	0.0615	48.78	116.93	1.779	47.13	4.101	4.270	1.041

Table 20 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
I-6-ITF-1	0.0750	13.33	96.73	1.251	42.86	4.618	4.480	0.970
I-6-ITF-2	0.0751	13.32	96.60	1.249	42.86	4.631	4.570	0.987
I-6-ITF-5	0.0751	39.95	96.01	1.249	42.86	6.133	4.975	0.811
I-6-ITF-6	0.0750	40.00	96.12	1.251	42.86	6.117	5.300	0.866
I-6-ITF-7	0.0760	39.47	95.25	1.234	42.86	6.278	5.956	0.949
I-6-ITF-8	0.0760	39.47	95.55	1.234	42.86	6.275	6.195	0.987
I-6"-ITF-1	0.0460	21.74	152.09	2.039	33.46	1.673	2.138	1.278
I-6"-ITF-2	0.0465	21.51	150.24	2.017	33.46	1.712	1.958	1.143
I-6"-ITF-5	0.0460	65.22	152.17	2.039	33.46	2.288	2.380	1.040
I-6"-ITF-6	0.0460	65.22	152.20	2.039	33.46	2.288	2.390	1.044
I-12'-ITF-5	0.1080	27.78	49.07	1.013	45.68	12.812	10.370	0.809
I-12'-ITF-6	0.1080	27.78	48.93	1.013	45.68	12.812	11.390	0.889
2a-4-ITF	0.0603	16.58	64.00	---	30.20	3.187	3.570	1.120
2b-5-ITF	0.0603	24.88	64.00	---	30.20	3.522	3.920	1.113
3-3-ITF	0.0599	41.74	64.27	---	30.20	4.006	4.850	1.211
4a-4-ITF	0.0609	16.42	98.16	---	30.20	3.092	3.500	1.132

Table 20 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
4a-5-ITF	0.0609	24.63	98.16	---	30.20	3.417	3.800	1.112
4b-3-ITF	0.0609	41.05	98.16	---	30.20	3.933	4.750	1.208
6a-4-ITF	0.0647	23.18	121.34	---	37.30	3.688	3.640	0.987
6b-4-ITF	0.0647	38.64	121.34	---	37.30	4.236	4.250	1.003
9a-1-ITF	0.1070	9.35	34.82	---	35.10	9.741	10.600	1.088
9a-2-ITF	0.1070	14.02	34.82	---	35.10	10.614	12.900	1.215
9b-3-ITF	0.1070	9.35	34.82	---	35.10	9.741	9.800	1.006
9b-4-ITF	0.1070	14.02	34.82	---	35.10	10.614	10.850	1.022
9b-5-ITF	0.1070	23.36	34.82	---	35.10	11.997	12.900	1.075
10a-4-ITF	0.1082	9.24	52.72	---	35.10	9.962	10.350	1.039
10a-5-ITF	0.1082	13.86	52.72	---	35.10	10.851	11.550	1.064
10b-4-ITF	0.1082	23.11	52.72	---	35.10	12.261	12.550	1.024
11-4-ITF	0.1092	9.16	70.71	---	36.20	10.084	11.600	1.150
11-5-ITF	0.1092	13.74	70.71	---	36.20	10.981	11.100	1.011
12-4-ITF	0.1109	22.54	69.68	---	36.20	12.805	12.800	1.000
12-5-ITF	0.1109	27.05	69.68	---	36.20	13.425	14.400	1.073

Table 20 (Continued)

Specimen	t (in.)	N/t	h/t	R/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
13a-3-ITF	0.1342	7.45	27.51	---	35.70	15.442	15.750	1.020
13a-4-ITF	0.1342	11.18	27.51	---	35.70	16.731	17.350	1.037
13b-3-ITF	0.1342	18.63	27.51	---	35.70	18.777	18.050	0.961
14a-4-ITF	0.1478	6.77	38.25	---	33.10	18.862	16.650	0.883
14a-5-ITF	0.1478	10.15	38.25	---	33.10	20.390	20.300	0.996
14b-4-ITF	0.1478	16.91	38.25	---	33.10	22.813	21.950	0.962
15a-4-ITF	0.1473	6.79	52.10	---	33.10	18.729	17.950	0.958
15a-5-ITF	0.1473	10.18	52.10	---	33.10	20.248	19.750	0.975
15a-6-ITF	0.1473	16.97	52.10	---	33.10	22.656	23.900	1.055
15b-4-ITF	0.1473	20.37	52.10	---	33.10	23.676	20.100	0.849
16d-1-ITF	0.0460	21.74	172.35	---	32.20	1.615	1.600	0.991
16d-2-ITF	0.0460	54.35	172.35	---	32.20	2.086	1.960	0.940
17d-1-ITF	0.0755	13.25	103.70	---	35.80	4.626	6.260	1.353
17d-2-ITF	0.0755	33.11	103.70	---	35.80	5.811	6.750	1.162
18a-1-ITF	0.1230	8.13	63.85	---	37.60	12.915	12.900	0.999
18a-2-ITF	0.1230	20.33	63.85	---	37.60	15.781	14.600	0.925

Table 20 (Continued)

Number of specimens	N = 62
Mean	Pm = 1.017
Coefficient of variation	Vp = 0.109

* All test specimens were obtained from reference 26.

Table 21
Comparison of Tested and Predicted Loads
for Combined Bending and Web Crippling
Single Unreinforced Webs, Interior One-Flange Loading
UMR and Cornell Tests

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	$\frac{(Pu)test}{(Pu)pred}$
SU-BC-1-1	46.0	3.00	1.175	1.140	0.9702
SU-BC-1-2	46.0	3.00	1.162	1.180	1.0155
SU-BC-1-3	80.0	3.00	0.888	0.860	0.9685
SU-BC-1-4	80.0	3.00	0.900	0.890	0.9889
SU-BC-1-5	144.0	3.00	0.625	0.610	0.9760
SU-BC-1-6	144.0	3.00	0.606	0.530	0.8746
SU-BC-3-1	72.0	3.00	1.400	1.200	0.8751
SU-BC-3-2	72.0	3.00	1.400	1.335	0.9536
SU-BC-3-3	100.0	3.00	1.262	1.105	0.8756
SU-BC-3-4	100.0	3.00	1.262	1.170	0.9271
SU-BC-3-5	134.0	3.00	1.075	0.925	0.8605
SU-BC-3-6	134.0	3.00	1.113	1.020	0.9164
SU-BC-15-1	52.0	3.00	2.000	2.090	1.0450
SU-BC-15-2	52.0	3.00	2.100	2.075	0.9881
SU-BC-15-3	92.0	3.00	1.675	1.840	1.0985
SU-BC-15-4	92.0	3.00	1.625	1.800	1.1077
SU-BC-15-5	144.0	3.00	1.337	1.500	1.1219
SU-BC-15-6	144.0	3.00	1.387	1.500	1.0815
SU-4-IOF-1	30.0	1.00	1.612	1.526	0.9467
SU-4-IOF-2	30.0	1.00	1.585	1.525	0.9621
SU-4-IOF-3	30.0	2.00	1.825	1.770	0.9699
SU-4-IOF-4	30.0	2.00	1.825	1.775	0.9726
SU-4-IOF-5	30.0	3.00	2.025	2.085	1.0296
SU-4-IOF-6	30.0	3.00	2.025	1.985	0.9802
M-SU-4-IOF-1	30.0	1.00	1.626	1.605	0.9871
M-SU-4-IOF-2	30.0	1.00	1.657	1.630	0.9861
M-SU-4-IOF-5	30.0	3.00	2.075	2.200	1.0602
M-SU-4-IOF-6	30.0	3.00	2.025	2.075	1.0247
SU-BC-6-1	58.0	3.00	0.763	0.880	1.1533
SU-BC-6-2	58.0	3.00	0.769	0.840	1.0923

Table 21 (Continued)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
SU-BC-6-3	86.0	3.00	0.575	0.565	0.9826
SU-BC-6-4	86.0	3.00	0.550	0.650	1.1818
SU-BC-16-1	72.0	3.00	1.337	1.440	1.0770
SU-BC-16-2	72.0	3.00	1.300	1.350	1.0385
SU-BC-16-3	112.0	3.00	0.988	1.005	1.0172
SU-BC-13-4	112.0	3.00	1.013	1.105	1.0908
SU-BC-7-1	84.0	3.00	0.900	1.000	1.1111
SU-BC-7-2	84.0	3.00	0.875	0.940	1.0743
SU-BC-7-3	116.0	3.00	0.719	0.700	0.9736
SU-BC-7-4	116.0	3.00	0.725	0.755	1.0414
SU-BC-8-1	94.0	3.00	1.400	1.535	1.0964
SU-BC-8-2	94.0	3.00	1.412	1.470	1.0411
SU-BC-8-3	126.0	3.00	1.200	1.310	1.0917
SU-BC-8-4	126.0	3.00	1.200	1.300	1.0833
SU-BC-8'-1	78.0	3.00	2.100	2.205	1.0500
SU-BC-8'-2	78.0	3.00	2.100	2.365	1.1262
SU-BC-8'-3	144.0	3.00	1.600	1.590	0.9938
SU-BC-8'-4	144.0	3.00	1.625	1.700	1.0462
CJ-18	116.0	3.50	1.212	1.160	0.9571
CJ-19	78.0	3.50	1.458	1.380	0.9465
CJ-21	102.0	3.50	1.814	1.960	1.0805
CJ-22	50.8	3.50	2.466	2.620	1.0624
CJ-23	25.8	3.50	2.991	2.940	0.9829
CJ-24	77.2	3.50	2.741	2.880	1.0507
CJ-25	51.8	3.50	3.294	3.280	0.9957
CJ-26	29.0	3.50	4.031	3.820	0.9477
1	12.0	0.75	2.083	1.930	0.9265
2	12.0	1.50	2.302	2.260	0.9818
3	12.0	2.50	2.334	2.620	1.1225
4	12.0	0.75	1.832	1.665	0.9088
5	12.0	1.50	1.897	1.865	0.9831
6	12.0	2.50	2.105	2.020	0.9596
7	12.0	0.75	3.189	2.850	0.8937
8	12.0	1.50	3.450	3.340	0.9681
9	12.0	2.50	3.750	4.100	1.0933

Table 21 (Continued)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
10	12.0	0.75	2.803	2.790	0.9954
11	12.0	1.50	3.000	3.100	1.0333
12	12.0	2.50	3.270	3.540	1.0826
15	24.0	2.50	2.100	2.210	1.0524
21	24.0	2.50	3.511	3.750	1.0681
27	36.0	2.50	1.912	1.775	0.9283
32	36.0	1.50	2.943	2.663	0.9049
33	36.0	2.50	3.223	2.875	0.8920
45	48.0	2.50	3.373	3.065	0.9087

Number of specimens	N = 74
Mean	Pm = 1.0086
Coefficient of Variation	Vp = 0.0744

* All test specimens were obtained from references 26 and 29.

Table 22
Comparison of Tested and Predicted Loads
for Combined Bending and Web Crippling
Single Unreinforced Webs, Interior One-Flange Loading
Canadian Tests (Brake-Formed Sections)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
1W-CBC	18.0	1.00	1.237	0.995	0.8044
2W-CBC	18.3	1.00	0.631	0.475	0.7528
3W-CBC	18.4	1.00	0.266	0.207	0.7782
4W-CBC	18.4	1.00	1.750	1.344	0.7680
10W-CBC	20.0	1.00	1.000	0.950	0.9500
11W-CBC	20.0	1.00	0.506	0.457	0.9032
12W-CBC	20.0	1.00	0.216	0.194	0.8981
13W-CBC	20.0	1.00	1.400	1.338	0.9557
19W-CBC	20.0	1.00	0.888	0.813	0.9155
20W-CBC	20.0	1.00	0.450	0.400	0.8889
21W-CBC	20.0	1.00	0.194	0.175	0.9021
22W-CBC	20.0	1.00	1.300	1.100	0.8462
28W-CBC	30.5	1.00	0.300	0.238	0.7933
29W-CBC	30.5	3.00	0.419	0.294	0.7017
30W-CBC	30.8	2.00	0.325	0.288	0.8862
31W-CBC	37.0	2.00	0.306	0.275	0.8987
32W-CBC	37.0	1.00	0.281	0.225	0.8007
33W-CBC	37.0	3.00	0.356	0.338	0.9494
37W-CBC	37.0	1.00	0.231	0.188	0.8139
38W-CBC	37.0	2.00	0.275	0.238	0.8655
39W-CBC	37.0	3.00	0.325	0.288	0.8862
40W-CBC	20.0	1.00	0.513	0.388	0.7563
41W-CBC	20.0	1.00	0.241	0.225	0.9336
42W-CBC	20.0	1.00	1.025	1.163	1.1346
43W-CBC	20.0	1.00	1.050	1.150	1.0952
44W-CBC	20.0	1.00	0.525	0.363	0.6914
45W-CBC	20.0	1.00	0.525	0.388	0.7390
46W-CBC	20.0	1.00	0.519	0.375	0.7225
47W-CBC	20.0	1.00	0.300	0.320	1.0667
48W-CBC	20.0	2.00	0.363	0.430	1.1846

Table 22 (Continued)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
49W-CBC	20.0	3.00	0.444	0.463	1.0428
50W-CBC	20.0	1.00	1.425	1.534	1.0765
53W-CBC	20.0	1.00	1.412	1.409	0.9979
58W-CBC	12.5	2.00	2.136	1.863	0.8722
59W-CBC	12.5	3.00	2.338	2.050	0.8768
63W-CBC	30.5	1.00	1.450	1.113	0.7676
64W-CBC	30.5	1.00	0.713	0.532	0.7461
65W-CBC	36.5	1.00	1.325	1.050	0.7925
66W-CBC	36.5	1.00	0.669	0.488	0.7294
67W-CBC	66.5	1.00	0.938	0.700	0.7463
68W-CBC	66.3	1.00	0.400	0.325	0.8125
71W-CBC	39.7	1.00	0.155	0.125	0.8065
72W-CBC	39.7	1.00	0.347	0.325	0.9366
73W-CBC	39.4	1.00	0.669	0.638	0.9537
74W-CBC	39.5	1.00	0.525	0.500	0.9524
75W-CBC	39.5	1.00	1.063	1.013	0.9530
76W-CBC	39.0	1.00	0.181	0.138	0.7624
77W-CBC	38.9	1.00	0.369	0.338	0.9160
78W-CBC	39.3	1.00	0.713	0.688	0.9663
80W-CBC	38.5	1.00	0.600	0.488	0.8133
81W-CBC	38.4	1.00	1.125	1.075	0.9556
82W-CBC	69.0	1.00	0.106	0.100	0.9434
83W-CBC	20.0	1.00	0.222	0.238	1.0721
84W-CBC	69.0	1.00	0.231	0.213	0.9221
85W-CBC	20.0	1.00	0.525	0.463	0.8819
86W-CBC	69.0	1.00	0.444	0.425	0.9572
87W-CBC	20.3	1.00	1.063	0.988	0.9294
88W-CBC	69.0	1.00	0.184	0.150	0.8152
90W-CBC	69.0	1.00	0.394	0.375	0.9518
92W-CBC	69.0	1.00	0.756	0.750	0.9921
93W-CBC	21.0	1.00	1.425	1.250	0.8772
94W-CBC	69.0	1.00	0.130	0.100	0.7692
95W-CBC	20.5	1.00	0.231	0.213	0.9221
96W-CBC	68.5	1.00	0.256	0.225	0.8789
97W-CBC	20.5	1.00	0.525	0.475	0.9048

Table 22 (Continued)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
98W-CBC	68.0	1.00	0.475	0.463	0.9747
99W-CBC	20.5	1.00	1.050	0.950	0.9048
102W-CBC	69.0	1.00	0.488	0.350	0.7172
104W-CBC	67.5	1.00	0.850	0.800	0.9412
105W-CBC	21.0	1.00	1.400	1.250	0.8929
106W-CBC	69.2	1.00	0.198	0.175	0.8838
107W-CBC	22.3	1.00	0.290	0.300	1.0345
108W-CBC	22.3	2.00	0.363	0.350	0.9642
109W-CBC	68.3	1.00	0.513	0.450	0.8772
110W-CBC	22.0	1.00	1.162	1.000	0.8606
111W-CBC	22.5	2.00	1.225	1.100	0.8980
115W-CBC	68.0	1.00	0.134	0.100	0.7463
118W-CBC	40.3	1.00	0.775	0.675	0.8710
119W-CBC	39.8	1.00	0.406	0.300	0.7389
120W-CBC	39.5	1.00	0.181	0.150	0.8287
121W-CBC	21.0	2.00	0.581	0.400	0.6885
122W-CBC	22.3	4.00	2.100	2.200	1.0476
123W-CBC	22.0	5.00	2.325	2.500	1.0753
126W-CBC	19.5	4.00	0.488	0.400	0.8197
127W-CBC	19.5	5.00	0.563	0.450	0.7993
130W-CBC	12.5	4.00	2.565	2.165	0.8441
131W-CBC	12.5	5.00	2.883	2.670	0.9261
132W-CBC	20.0	4.00	0.488	0.466	0.9549
133W-CBC	20.0	5.00	0.556	0.459	0.8255
138W-CBC	21.0	2.00	0.563	0.506	0.8988
141W-CBC	20.5	1.00	1.700	1.628	0.9576
142W-CBC	30.5	1.00	0.272	0.206	0.7574
143W-CBC	30.5	1.00	0.512	0.453	0.8848
144W-CBC	30.5	1.00	1.437	1.283	0.8928
145W-CBC	92.0	3.00	0.216	0.157	0.7269
146W-CBC	92.0	3.00	0.213	0.154	0.7230
147W-CBC	92.0	3.00	0.219	0.156	0.7123
148W-CBC	92.0	5.00	0.241	0.174	0.7220
149W-CBC	92.0	5.00	0.231	0.170	0.7359
151W-CBC	92.0	3.00	0.170	0.127	0.7471

Table 22 (Continued)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
152W-CBC	92.0	3.00	0.169	0.130	0.7692
153W-CBC	92.0	2.00	0.156	0.112	0.7179
154W-CBC	92.0	2.00	0.156	0.110	0.7051
155W-CBC	92.0	4.00	0.178	0.131	0.7360
156W-CBC	92.0	4.00	0.168	0.121	0.7202
157W-CBC	40.0	2.00	0.306	0.252	0.8235
158W-CBC	40.0	2.00	0.303	0.241	0.7954
159W-CBC	40.0	3.00	0.350	0.298	0.8514
160W-CBC	40.0	3.00	0.350	0.297	0.8486
161W-CBC	40.0	4.00	0.406	0.351	0.8645
162W-CBC	40.0	4.00	0.394	0.313	0.7944
163W-CBC	40.0	4.00	0.400	0.308	0.7700
164W-CBC	40.0	5.00	0.438	0.344	0.7854
167W-CBC	40.0	2.00	0.269	0.227	0.8439
168W-CBC	40.0	2.00	0.269	0.227	0.8439
169W-CBC	40.0	3.00	0.303	0.249	0.8218
170W-CBC	40.0	3.00	0.303	0.239	0.7888
171W-CBC	40.0	4.00	0.331	0.270	0.8157
172W-CBC	40.0	4.00	0.331	0.253	0.7644
173W-CBC	40.0	4.00	0.331	0.268	0.8097
174W-CBC	28.0	2.00	0.319	0.269	0.8433
175W-CBC	28.0	2.00	0.319	0.262	0.8213
176W-CBC	28.0	3.00	0.369	0.254	0.6883
177W-CBC	28.0	3.00	0.369	0.270	0.7317
178W-CBC	28.0	4.00	0.413	0.346	0.8378
179W-CBC	16.0	2.00	0.388	0.308	0.7938
180W-CBC	16.0	2.00	0.394	0.320	0.8122
181W-CBC	16.0	3.00	0.475	0.400	0.8421
182W-CBC	16.0	3.00	0.475	0.358	0.7537
183W-CBC	16.0	3.00	0.475	0.377	0.7937
184W-CBC	18.0	3.00	0.544	0.395	0.7261
185W-CBC	18.0	3.00	0.900	0.745	0.8278
186W-CBC	18.0	3.00	0.538	0.410	0.7621
187W-CBC	18.0	3.00	0.913	0.749	0.8204
189W-CBC	23.0	6.00	1.100	0.930	0.8455

Table 22 (Continued)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
191W-CBC	23.0	6.00	1.113	0.930	0.8356
192W-CBC	23.0	6.00	1.125	0.890	0.7911
193W-CBC	23.0	6.00	1.125	0.840	0.7467
195W-CBC	23.0	6.00	1.425	1.100	0.7719
197W-CBC	23.0	6.00	1.425	1.175	0.8246
198W-CBC	17.0	3.00	0.600	0.455	0.7583
199W-CBC	17.0	3.00	1.225	1.000	0.8163
200W-CBC	18.0	3.00	0.588	0.450	0.7653
201W-CBC	18.0	3.00	1.187	0.950	0.8003
4WR-CBC	116.0	2.00	0.341	0.256	0.7507
5WR-CBC	52.0	2.00	0.581	0.442	0.7608
6WR-CBC	20.0	2.00	0.900	0.699	0.7767
7WR-CBC	116.0	2.00	0.681	0.516	0.7577
8WR-CBC	52.0	2.00	1.212	0.925	0.7632
9WR-CBC	20.0	2.00	2.000	1.549	0.7745
16WR-CBC	116.0	2.00	0.675	0.538	0.7970
17WR-CBC	52.0	2.00	1.200	0.952	0.7933
18WR-CBC	20.0	2.00	1.975	1.518	0.7686
25WR-CBC	116.0	2.00	0.663	0.489	0.7376
26WR-CBC	52.0	2.00	1.150	0.864	0.7513
27WR-CBC	20.0	2.00	1.800	1.372	0.7622
31WR-CBC	116.0	2.00	0.281	0.225	0.8007
32WR-CBC	52.0	2.00	0.425	0.367	0.8635
34WR-CBC	116.0	2.00	0.644	0.663	1.0295
35WR-CBC	52.0	2.00	1.125	1.185	1.0533
36WR-CBC	20.0	2.00	1.825	1.650	0.9041
40WR-CBC	116.0	2.00	0.322	0.297	0.9224
41WR-CBC	52.0	2.00	0.513	0.506	0.9864
43WR-CBC	116.0	2.00	0.669	0.644	0.9626
44WR-CBC	52.0	2.00	1.150	1.101	0.9574
45WR-CBC	20.0	2.00	1.800	1.672	0.9289
61WR-CBC	116.0	2.00	0.694	0.687	0.9899
62WR-CBC	52.0	2.00	1.125	1.235	1.0978
63WR-CBC	20.0	2.00	1.625	1.515	0.9323
67WR-CBC	116.0	2.00	0.400	0.303	0.7575

Table 22 (Continued)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
68WR-CBC	52.0	2.00	0.563	0.523	0.9290
70WR-CBC	116.0	2.00	0.725	0.666	0.9186
71WR-CBC	52.0	2.00	1.150	1.189	1.0339
72WR-CBC	20.0	2.00	1.625	1.616	0.9945
79WR-CBC	116.0	2.00	0.713	0.666	0.9341
80WR-CBC	52.0	2.00	1.100	1.093	0.9936
82WR-CBC	116.0	4.00	0.331	0.285	0.8610
83WR-CBC	52.0	6.00	0.663	0.645	0.9729
88WR-CBC	116.0	4.00	0.688	0.745	1.0828
89WR-CBC	52.0	6.00	1.375	1.542	1.1215
99WR-CBC	52.0	6.00	1.475	1.675	1.1356
100WR-CBC	116.0	4.00	0.788	0.823	1.0444
102WR-CBC	52.0	4.00	0.675	0.537	0.7956
103WR-CBC	52.0	4.00	1.337	1.152	0.8616
106WR-CBC	52.0	4.00	1.325	1.190	0.8981
109WR-CBC	52.0	4.00	1.275	1.070	0.8392
111WR-CBC	52.0	4.00	0.538	0.482	0.8959
112WR-CBC	52.0	4.00	1.250	1.222	0.9776
114WR-CBC	52.0	4.00	0.613	0.623	1.0163
115WR-CBC	52.0	4.00	1.275	1.333	1.0455
121WR-CBC	52.0	4.00	1.250	1.403	1.1224
123WR-CBC	52.0	4.00	0.706	0.622	0.8810
124WR-CBC	52.0	4.00	1.300	1.422	1.0938
127WR-CBC	52.0	4.00	1.237	1.448	1.1706
129WR-CBC	20.0	4.00	1.150	0.875	0.7609
130WR-CBC	20.0	4.00	2.350	1.875	0.7979
133WR-CBC	20.0	4.00	2.300	1.925	0.8370
136WR-CBC	20.0	4.00	2.109	1.675	0.7976
138WR-CBC	20.0	4.00	0.794	0.675	0.8501
139WR-CBC	20.0	4.00	2.125	2.175	1.0235
141WR-CBC	20.0	4.00	0.963	1.000	1.0384
142WR-CBC	20.0	4.00	2.100	2.225	1.0595

Number of specimens	N = 202
Mean	Pm = 0.8684
Coefficient of Variation	Vp = 0.1285

* All test specimens were obtained from references 27 and 28.

Table 23
Comparison of Tested and Predicted Loads
for Combined Bending and Web Crippling
Single Unreinforced Webs, Interior One-Flange Loading
Canadian Tests (Roll-Formed Sections)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
1E-CBC	52.0	2.00	0.900	0.893	0.9922
2E-CBC	115.0	2.00	0.475	0.455	0.9579
3E-CBC	52.5	3.00	0.925	0.956	1.0335
4E-CBC	52.0	4.00	0.975	1.070	1.0974
5E-CBC	21.3	2.00	1.613	1.493	0.9256
6E-CBC	20.5	3.00	1.775	1.744	0.9825
7E-CBC	20.3	4.00	1.925	1.908	0.9912
1C-CBC	137.5	2.00	0.192	0.175	0.9115
2C-CBC	136.0	3.00	0.200	0.180	0.9000
3C-CBC	136.3	4.00	0.206	0.191	0.9272
4C-CBC	140.0	1.50	0.185	0.158	0.8541
5C-CBC	140.0	1.50	0.138	0.136	0.9855
6C-CBC	140.0	2.00	0.140	0.128	0.9143
7C-CBC	140.0	3.00	0.146	0.144	0.9863
8C-CBC	140.0	4.00	0.152	0.141	0.9276
9C-CBC	63.0	1.50	0.342	0.306	0.8947
10C-CBC	63.5	2.00	0.350	0.323	0.9229
11C-CBC	63.5	3.00	0.375	0.343	0.9147
12C-CBC	63.5	4.00	0.396	0.375	0.9470
13C-CBC	64.5	1.50	0.242	0.228	0.9421
14C-CBC	62.5	2.00	0.258	0.250	0.9670
15C-CBC	62.5	3.00	0.279	0.265	0.9498
16C-CBC	62.5	4.00	0.300	0.294	0.9800
17C-CBC	25.5	1.50	0.575	0.568	0.9878
18C-CBC	25.0	2.00	0.608	0.603	0.9918
19C-CBC	25.5	3.00	0.683	0.695	1.0176
20C-CBC	25.0	4.00	0.767	0.780	1.0169
21C-CBC	25.0	1.50	0.408	0.420	1.0294
22C-CBC	25.0	2.00	0.433	0.460	1.0624
23C-CBC	25.5	3.00	0.496	0.545	1.0988

Table 23 (Continued)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
24C-CBC	25.5	4.00	0.558	0.598	1.0717
1U-CBC	65.0	2.00	0.140	0.107	0.7643
2U-CBC	67.0	1.50	0.133	0.116	0.8722
3U-CBC	64.5	2.00	0.142	0.122	0.8592
4U-CBC	65.0	1.50	0.138	0.114	0.8261
5U-CBC	27.5	2.00	0.271	0.212	0.7823
6U-CBC	30.0	1.50	0.246	0.212	0.8618
7U-CBC	29.0	2.00	0.262	0.244	0.9313
8U-CBC	30.5	1.50	0.242	0.220	0.9091
9U-CBC	64.5	2.00	0.123	0.117	0.9512
10U-CBC	65.5	1.50	0.120	0.131	1.0917
11U-CBC	65.0	2.00	0.123	0.112	0.9106
12U-CBC	65.0	1.50	0.120	0.131	1.0917
13U-CBC	64.0	2.00	0.138	0.123	0.8913
14U-CBC	64.5	1.50	0.134	0.118	0.8806
15U-CBC	64.0	2.00	0.138	0.127	0.9203
16U-CBC	64.5	1.50	0.134	0.110	0.8209
17U-CBC	15.0	2.00	0.369	0.420	1.1382
18U-CBC	15.5	1.50	0.338	0.382	1.1302
19U-CBC	16.0	2.00	0.353	0.404	1.1445
20U-CBC	15.5	1.50	0.338	0.416	1.2308
21U-CBC	18.5	2.00	0.344	0.339	0.9855
22U-CBC	14.5	1.50	0.375	0.373	0.9947
23U-CBC	17.0	2.00	0.363	0.319	0.8788
24U-CBC	15.0	1.50	0.369	0.356	0.9648
25U-CBC	27.0	3.00	0.304	0.269	0.8849
26U-CBC	28.5	3.00	0.292	0.268	0.9178
5R-CBC	64.0	1.50	0.400	0.338	0.8450
6R-CBC	64.0	2.00	0.406	0.352	0.8670
7R-CBC	64.0	3.00	0.419	0.376	0.8974
8R-CBC	26.0	1.50	0.762	0.784	1.0289
9R-CBC	26.0	2.00	0.787	0.786	0.9987
10R-CBC	26.0	3.00	0.837	0.830	0.9916
11R-CBC	26.0	2.00	0.787	0.783	0.9949
12R-CBC	26.0	2.00	0.787	0.777	0.9873

Table 23 (Continued)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
13R-CBC	26.0	2.00	0.787	0.771	0.9797
29R-CBC	64.0	1.50	0.345	0.268	0.7768
30R-CBC	64.0	2.00	0.355	0.271	0.7634
31R-CBC	64.0	3.00	0.365	0.278	0.7616
32R-CBC	26.0	1.50	0.680	0.610	0.8971
33R-CBC	26.0	2.00	0.700	0.650	0.9286
34R-CBC	26.0	3.00	0.750	0.677	0.9027
48R-CBC	64.0	2.00	0.350	0.258	0.7371
55R-CBC	64.0	1.50	0.221	0.235	1.0633
56R-CBC	64.0	2.00	0.225	0.241	1.0711
57R-CBC	64.0	3.00	0.231	0.247	1.0693
58R-CBC	26.0	1.50	0.467	0.522	1.1178
59R-CBC	26.0	2.00	0.483	0.556	1.1511
60R-CBC	26.0	3.00	0.512	0.600	1.1719
64R-CBC	64.0	1.50	0.125	0.103	0.8240
65R-CBC	64.0	2.00	0.131	0.111	0.8473
66R-CBC	64.0	3.00	0.138	0.112	0.8116
67R-CBC	26.0	1.50	0.235	0.193	0.8213
68R-CBC	26.0	2.00	0.252	0.218	0.8651
69R-CBC	26.0	3.00	0.283	0.247	0.8728
90R-CBC	140.0	1.50	0.325	0.299	0.9200
91R-CBC	140.0	2.00	0.329	0.290	0.8815
92R-CBC	140.0	3.00	0.338	0.309	0.9142
93R-CBC	64.0	1.50	0.608	0.562	0.9243
94R-CBC	64.0	2.00	0.617	0.597	0.9676
95R-CBC	64.0	3.00	0.650	0.649	0.9985
96R-CBC	26.0	1.50	1.067	0.954	0.8941
97R-CBC	26.0	2.00	1.100	1.009	0.9173
98R-CBC	26.0	3.00	1.183	1.144	0.9670
99R-CBC	140.0	1.50	0.167	0.148	0.8862
100R-CBC	140.0	2.00	0.169	0.160	0.9467
101R-CBC	140.0	3.00	0.177	0.164	0.9266
102R-CBC	64.0	1.50	0.296	0.295	0.9966
103R-CBC	64.0	2.00	0.304	0.315	1.0362
104R-CBC	64.0	3.00	0.333	0.330	0.9910

Table 23 (Continued)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
105R-CBC	26.0	1.50	0.483	0.451	0.9337
106R-CBC	26.0	2.00	0.508	0.502	0.9882
107R-CBC	26.0	3.00	0.583	0.586	1.0051

Number of specimens	N = 103
Mean	Pm = 0.9510
Coefficient of Variation	Vp = 0.1015

* All test specimens were obtained from reference 26.

Table 24
Comparison of Tested and Predicted Loads
for Combined Bending and Web Crippling
Single Unreinforced Webs, Interior One-Flange Loading
Hoglund's Tests

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
301	49.6	0.20	0.384	0.514	1.3385
302	32.8	0.20	0.425	0.503	1.1835
303	101.3	0.20	0.241	0.281	1.1660
304	101.8	0.20	0.234	0.266	1.1368
305	57.6	0.20	0.469	0.596	1.2708
306	57.4	0.20	0.475	0.642	1.3516
307	57.4	0.20	0.669	0.959	1.4335
308	57.5	0.20	0.675	0.924	1.3689
309	117.5	0.20	0.319	0.382	1.1975
310	117.7	0.20	0.319	0.368	1.1536
311	117.6	0.20	0.431	0.569	1.3202
312	117.4	0.20	0.494	0.642	1.2996
5023	239.1	3.90	0.052	0.038	0.7308
5024	241.1	3.90	0.051	0.037	0.7255
5025	241.2	3.90	0.070	0.057	0.8143
5026	232.5	3.90	0.070	0.055	0.7857
5027	236.1	3.90	0.088	0.079	0.8977
5028	235.8	3.90	0.083	0.076	0.9157
5029	236.4	3.90	0.051	0.042	0.8235
5030	234.9	3.90	0.047	0.042	0.8936
5031	238.2	3.90	0.066	0.062	0.9394
5032	239.6	3.90	0.067	0.058	0.8657
5033	236.7	3.90	0.081	0.079	0.9753
5034	234.8	3.90	0.083	0.084	1.0120
5038	61.7	2.40	0.156	0.158	1.0128
5039	61.5	2.40	0.161	0.168	1.0435
5040	45.2	2.40	0.200	0.210	1.0500
5041	45.4	2.40	0.203	0.208	1.0246
5042	50.0	2.40	0.241	0.241	1.0000
5043	49.7	2.40	0.225	0.263	1.1689

Table 24 (Continued)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
5044	35.2	2.40	0.306	0.344	1.1242
5045	35.2	2.40	0.300	0.327	1.0900
5046	36.5	3.90	0.322	0.366	1.1366
5047	57.1	2.40	0.275	0.332	1.2073
5048	57.0	2.40	0.272	0.321	1.1801
5049	40.2	2.40	0.363	0.466	1.2837
5050	40.2	2.40	0.363	0.490	1.3499
5051	40.9	3.90	0.406	0.465	1.1453
5066	407.3	3.90	0.054	0.039	0.7222
5067	416.7	3.90	0.052	0.041	0.7885
5068	416.7	3.90	0.054	0.041	0.7593
5069	362.5	3.90	0.077	0.064	0.8312
5070	367.4	3.90	0.078	0.068	0.8718
5071	358.6	3.90	0.114	0.112	0.9825
5072	358.1	3.90	0.120	0.116	0.9667
5076	281.3	3.90	0.070	0.057	0.8143
5077	277.0	3.90	0.080	0.061	0.7625
5078	359.8	3.90	0.075	0.073	0.9733
5079	361.2	3.90	0.077	0.073	0.9481
5080	361.8	3.90	0.116	0.115	0.9914
5081	356.8	3.90	0.122	0.116	0.9508
5085	69.2	3.90	0.238	0.245	1.0294
5086	69.2	3.90	0.238	0.235	0.9874
5087	50.2	3.90	0.313	0.321	1.0256
5088	45.3	3.90	0.331	0.330	0.9970
5089	74.7	2.40	0.281	0.321	1.1423
5090	74.8	2.40	0.281	0.321	1.1423
5091	79.5	2.40	0.431	0.490	1.1369
5092	79.5	2.40	0.431	0.518	1.2019
5093	56.2	2.40	0.538	0.601	1.1171
5094	56.0	2.40	0.538	0.602	1.1190
5095	56.2	3.90	0.606	0.658	1.0858
5109	322.9	2.40	0.127	0.083	0.6535
5110	317.6	2.40	0.114	0.083	0.7281
5111	491.3	2.40	0.100	0.097	0.9700

Table 24 (Continued)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
5112	493.0	2.40	0.100	0.098	0.9800

Number of specimens	N = 66
Mean	Pm = 1.0318
Coefficient of Variation	Vp = 0.1801

* All test specimens were obtained from reference 30.

Table 25
Comparison of Tested and Predicted Loads
for Combined Bending and Web Crippling
I-Sections, Interior One-Flange Loading
UMR Tests

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
I-BC-6-1	26.0	3.00	1.753	1.890	1.0782
I-BC-6-2	26.0	3.00	1.727	1.870	1.0828
I-BC-6-3	34.0	3.00	1.342	1.405	1.0469
I-BC-6-4	34.0	3.00	1.359	1.425	1.0486
I-BC-6-5	48.0	3.00	1.022	1.015	0.9932
I-BC-6-6	48.0	3.00	0.994	1.035	1.0412
I-BC-8-1	28.0	3.00	5.306	6.755	1.2731
I-BC-8-2	28.0	3.00	5.300	6.525	1.2311
I-BC-8-3	42.0	3.00	3.994	5.005	1.2531
I-BC-8-4	42.0	3.00	3.869	4.750	1.2277
I-BC-8-5	82.0	3.00	2.269	2.545	1.1216
I-BC-8-6	82.0	3.00	2.281	2.585	1.1333
I-BC-10-1	32.0	3.00	10.050	11.500	1.1443
I-BC-10-2	32.0	3.00	10.000	12.070	1.2070
I-BC-10-3	50.0	3.00	7.200	9.645	1.3396
I-BC-10-4	50.0	3.00	7.288	8.645	1.1862
I-BC-10-5	94.0	3.00	4.406	5.065	1.1496
I-BC-10-6	94.0	3.00	4.375	4.895	1.1189
3-1-IOF	10.0	3.00	4.038	4.850	1.2011
3-2-IOF	10.0	2.50	3.825	4.800	1.2549
9B-1-IOF	10.0	0.80	9.346	10.300	1.1021
10A-1-IOF	16.0	1.00	9.973	9.600	0.9626
10A-2-IOF	16.0	1.50	10.864	12.000	1.1046
10B-1-IOF	16.0	3.00	12.873	15.200	1.1808
13A-1-IOF	16.0	1.00	11.750	15.300	1.3021
13B-1-IOF	16.0	1.50	12.700	15.100	1.1890
14A-1-IOF	16.0	1.00	17.600	16.500	0.9375
14A-2-IOF	16.0	1.50	19.000	18.150	0.9553
14B-1-IOF	16.0	2.50	21.725	22.150	1.0196
15A-1-IOF	16.0	1.00	18.022	17.350	0.9627

Table 25 (Continued)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
15A-2-IOF	16.0	1.50	19.483	20.250	1.0394
15B-1-IOF	16.0	2.50	21.801	21.150	0.9701
I-BC-4-1	35.0	3.00	2.009	2.025	1.0080
I-BC-4-2	35.0	3.00	2.047	1.940	0.9477
I-BC-4-3	60.0	3.00	1.450	1.530	1.0552
I-BC-4-4	60.0	3.00	1.414	1.445	1.0219
I-BC-4-5	118.0	3.00	0.794	0.830	1.0453
I-BC-4-6	118.0	3.00	0.802	0.875	1.0910
I-BC-5-1	40.0	3.00	3.124	2.590	0.8291
I-BC-5-2	40.0	3.00	3.069	2.515	0.8195
I-BC-5-3	72.0	3.00	2.622	2.505	0.9554
I-BC-5-4	72.0	3.00	2.612	2.470	0.9456
I-BC-5-5	130.0	3.00	1.784	1.785	1.0006
I-BC-5-6	130.0	3.00	1.794	1.640	0.9142
I-BC-9-1	52.0	3.00	5.688	5.810	1.0214
I-BC-9-2	52.0	3.00	5.663	5.785	1.0215
I-BC-9-3	92.0	3.00	3.944	4.040	1.0130
I-BC-9-4	92.0	3.00	3.950	4.200	1.0633
I-BC-9-5	144.0	3.00	2.766	2.675	0.9671
I-BC-9-6	144.0	3.00	2.775	2.490	0.8973
I-BC-9'-1	38.0	3.00	3.359	3.315	0.9869
I-BC-9'-2	38.0	3.00	3.450	2.955	0.8565
I-BC-9'-3	68.0	3.00	2.491	2.590	1.0397
I-BC-9'-4	68.0	3.00	2.562	2.695	1.0519
I-BC-9'-5	144.0	3.00	1.505	1.630	1.0831
I-BC-9'-6	144.0	3.00	1.544	1.600	1.0363
I-BC-13-1	60.0	3.00	12.850	13.870	1.0794
I-BC-13-2	60.0	3.00	12.450	13.010	1.0450
I-BC-13-3	80.0	3.00	10.725	12.390	1.1552
I-BC-13-4	80.0	3.00	10.925	11.620	1.0636
I-BC-13-5	108.0	3.00	9.325	10.490	1.1249
I-BC-13-6	108.0	3.00	9.050	10.500	1.1602
I-3-IOF-5	34.0	3.00	3.214	3.025	0.9412
I-3-IOF-6	34.0	3.00	3.214	3.005	0.9350
I-3'-IOF-1	32.0	1.00	1.939	1.810	0.9335

Table 25 (Continued)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
I-3'-IOF-2	32.0	1.00	1.939	1.850	0.9541
I-3'-IOF-5	32.0	3.00	2.653	2.100	0.7916
I-3'-IOF-6	32.0	3.00	2.653	2.315	0.8726
I-5'-IOF-5	34.0	3.00	4.611	4.155	0.9011
I-5'-IOF-6	34.0	3.00	4.473	4.000	0.8943
I-6-IOF-1	34.0	1.00	4.975	5.535	1.1126
I-6-IOF-2	34.0	1.00	4.975	5.400	1.0854
I-6-IOF-5	34.0	3.00	6.263	6.000	0.9580
I-6-IOF-6	34.0	3.00	6.225	6.485	1.0418
I-6-IOF-7	34.0	3.00	6.300	7.000	1.1111
I-6-IOF-8	34.0	3.00	6.225	6.975	1.1205
I-6"-IOF-5	32.0	3.00	2.653	2.155	0.8123
I-6"-IOF-6	32.0	3.00	2.653	2.315	0.8726
I-12-IOF-6	34.0	3.00	3.363	3.370	1.0021
I-12'-IOF-5	28.0	3.00	12.550	12.070	0.9618
I-12'-IOF-6	28.0	3.00	12.288	12.750	1.0376
I-16-IOF-1	24.0	1.00	2.431	2.730	1.1230
I-16-IOF-2	24.0	1.00	2.431	2.838	1.1674
I-16-IOF-5	24.0	3.00	3.200	3.530	1.1031
I-16-IOF-6	24.0	3.00	3.306	3.900	1.1797
I-U-17-IOF-5	26.0	3.00	3.020	2.565	0.8493
I-U-17-IOF-6	26.0	3.00	3.000	2.500	0.8333
1B-1-IOF	36.0	2.50	2.431	2.325	0.9564
1C-1-IOF	36.0	3.50	2.591	2.600	1.0035
2A-1-IOF	24.0	1.00	2.587	2.700	1.0437
2B-1-IOF	10.0	1.00	3.042	3.250	1.0684
2B-2-IOF	10.0	1.50	3.362	3.900	1.1600
4B-1-IOF	16.0	3.00	4.160	4.350	1.0457
5A-1-IOF	16.0	1.25	3.676	3.725	1.0133
5B-1-IOF	16.0	2.50	4.428	4.100	0.9259
5C-1-IOF	16.0	3.50	4.899	4.650	0.9492
7A-1-IOF	36.0	1.25	5.235	5.700	1.0888
7B-1-IOF	36.0	3.50	6.556	7.800	1.1897
8-1-IOF	36.0	2.50	6.297	6.750	1.0719
12-1-IOF	16.0	2.50	13.020	15.700	1.2058

Table 25 (Continued)

Specimen	L (in.)	N (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred
16A-1-IOF	33.0	1.50	2.121	2.245	1.0585
16B-1-IOF	33.0	2.50	2.353	2.800	1.1900
16C-1-IOF	33.0	3.50	2.541	3.250	1.2790
17A-1-IOF	36.0	1.25	4.800	5.830	1.2146
17B-1-IOF	36.0	2.50	5.381	7.630	1.4180
17C-1-IOF	36.0	3.50	5.738	7.240	1.2618

Number of specimens	N = 106
Mean	Pm = 1.0556
Coefficient of Variation	Vp = 0.1174

* All test specimens were obtained from referenec 26.

Table 26

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Stub Columns with Fully Effective Widths

Specimen	w/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
RA1	20.90	38.28	1030.300	1216.00	1.1802	Fig. 13	31
WA1	21.00	35.21	947.912	1259.00	1.3282	Fig. 13	31
WB1	30.90	31.09	759.759	863.40	1.1364	Fig. 13	31
RB1	31.40	32.34	790.218	846.90	1.0717	Fig. 13	31
16A	32.50	39.01	1920.836	1974.70	1.0140	Fig. 13	31

Number of specimens	N = 5
Mean	Pm = 1.1461
Coefficient of variation	Vp = 0.10452

Table 27

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Stub Columns with Partially Effective Widths

Specimen	w/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
RC1	40.10	33.22	759.153	812.60	1.0704	Fig. 13	31
WC1	40.20	33.98	771.569	796.10	1.0318	Fig. 13	31
17A	39.60	44.50	1601.524	1554.60	1.0281	Fig. 13	31
1A	44.60	45.00	1682.595	1661.30	0.9873	Fig. 13	31
4B	44.90	44.90	1626.656	1637.20	1.0065	Fig. 13	31
WT1	48.00	42.40	1665.667	1653.70	0.9928	Fig. 13	31
RT1	48.00	44.40	1716.956	1989.10	1.1585	Fig. 13	31
WD1	49.10	31.00	545.961	584.40	1.0704	Fig. 13	31
RD1	50.00	29.70	530.213	633.90	1.1956	Fig. 13	31
SD11	57.30	41.90	31.122	33.90	1.0893	Fig. 14	32
5A	59.00	39.40	919.755	875.20	0.9516	Fig. 13	31
RE1	59.40	36.30	407.062	472.90	1.1617	Fig. 13	31
WE1	59.70	32.40	379.037	386.80	1.0205	Fig. 13	31
2A	60.50	39.80	948.947	838.10	0.8832	Fig. 13	31

Table 27 (Continued)

Specimen	w/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
WG1	64.00	41.30	341.036	325.60	0.9547	Fig. 13	31
RG1	65.00	53.50	399.178	380.90	0.9542	Fig. 13	31
WF3	80.20	47.50	283.391	275.60	0.9725	Fig. 13	31
RF3	80.40	54.80	307.710	318.50	1.0351	Fig. 13	31
WF4	81.10	47.60	283.735	289.00	1.0186	Fig. 13	31
3A	82.10	30.50	390.270	442.70	1.1343	Fig. 13	31
SD21	83.20	41.90	31.915	34.00	1.0653	Fig. 14	32
6A	85.20	33.70	406.429	418.90	1.0307	Fig. 13	31
SD31	117.70	41.90	32.424	36.40	1.1226	Fig. 14	32
SD41	152.20	41.90	32.723	35.90	1.0971	Fig. 14	32

Number of specimens	N = 24
Mean	Pm = 1.05053
Coefficient of variation	Vp = 0.07971

Table 28

Comparison of Tested and Predicted Failure Loads of Steel Stiffened Thin Plates in Compression with Partially Effective Widths

Specimen	w/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
AS	43.60	40.70	96.096	96.20	1.0011	Plate	33
ACW	43.80	29.61	77.287	84.00	1.0869	Plate	33
ASW	43.80	29.61	78.559	85.80	1.0922	Plate	33
AC	44.00	40.70	96.410	100.40	1.0414	Plate	33
BS	53.00	40.70	102.214	116.20	1.1368	Plate	33
BSW	53.80	28.40	81.326	77.70	0.9554	Plate	33
BC	53.90	40.70	102.686	110.40	1.0751	Plate	33
CCW	63.30	28.60	85.847	89.70	1.0449	Plate	33
CSW	63.30	28.60	85.847	81.80	0.9529	Plate	33
CC	66.50	40.70	107.947	130.30	1.2071	Plate	33
CS	66.70	40.70	65.000	67.40	1.0369	Plate	33
DS	80.30	40.70	111.800	120.10	1.0742	Plate	33
DCW	80.50	33.00	98.922	101.80	1.0291	Plate	33
DC	80.60	40.70	111.869	130.80	1.1692	Plate	33

Table 28 (Continued)

Specimen	w/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
DSW	81.30	33.00	99.104	91.70	0.9253	Plate	33

Number of specimens	N = 15
Mean	Pm = 1.05523
Coefficient of variation	Vp = 0.07488

Table 29

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Stub Columns

Having Unstiffened Compression Flanges

(Fully Effective Flanges and Webs)

Specimen	w/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	$\frac{(Pu)test}{(Pu)pred}$	Cross Section	Reference
12-1-1	6.48	35.40	25.027	29.70	1.1867	Fig. 12	34
12-1-2	6.48	35.40	25.027	27.80	1.1108	Fig. 12	34
12-1-3	6.48	35.40	25.027	25.50	1.0189	Fig. 12	34

Number of specimens	N = 3
Mean	Pm = 1.1055
Coefficient of variation	Vp = 0.07601

Table 30

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Stub Columns

Having Unstiffened Compression Flanges

(Partially Effective Flanges and Fully Effective Webs)

Specimen	w/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
12-2-1	15.80	35.40	36.833	40.50	1.0996	Fig. 12	34
12-2-2	15.80	35.40	36.833	43.00	1.1674	Fig. 12	34
12-2-3	15.80	35.40	36.833	39.60	1.0751	Fig. 12	34
16-1.25-1	16.37	34.50	17.686	16.70	0.9442	Fig. 12	34
16-1.25-2	16.37	34.50	17.686	15.90	0.8990	Fig. 12	34
16-1.25-3	16.37	34.50	17.686	15.30	0.8651	Fig. 12	34
14-1.5-1	16.78	49.40	30.388	32.70	1.0761	Fig. 12	34
14-1.5-2	16.78	49.40	30.388	31.00	1.0201	Fig. 12	34
14-1.5-3	16.78	49.40	30.388	30.00	0.9872	Fig. 12	34
18-1-1	18.83	34.00	10.827	11.00	1.0160	Fig. 12	34
18-1-3	18.83	34.00	10.827	10.40	0.9606	Fig. 12	34
16-1.75-1	24.53	34.50	18.077	17.00	0.9404	Fig. 12	34
16-1.75-2	24.53	34.50	18.077	18.60	1.0289	Fig. 12	34
16-1.75-3	24.53	34.50	18.077	15.00	0.8298	Fig. 12	34

Table 30 (Continued)

Specimen	w/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
12-3-1	25.02	43.94	54.831	60.00	1.0943	Fig. 12	34
12-3-2	25.02	43.94	54.831	62.40	1.1380	Fig. 12	34
12-3-3	25.02	43.94	54.831	69.60	1.2694	Fig. 12	34
14-2.25-1	26.66	20.09	30.461	30.70	1.0078	Fig. 12	34
14-2.25-2	26.66	20.09	30.461	32.20	1.0571	Fig. 12	34
14-2.25-3	26.66	20.09	30.461	29.40	0.9652	Fig. 12	34
18-1.5-1	29.98	34.00	11.155	11.00	0.9861	Fig. 12	34
18-1.5-2	29.98	34.00	11.155	11.05	0.9906	Fig. 12	34
18-1.5-3	29.98	34.00	11.155	11.20	1.0040	Fig. 12	34
12-5-1	43.67	35.40	56.504	73.00	1.2919	Fig. 12	34
12-5-2	43.67	35.40	56.504	71.10	1.2583	Fig. 12	34
12-5-3	43.67	35.40	56.504	67.20	1.1893	Fig. 12	34
18-2.5-1	51.44	34.00	11.395	12.75	1.1189	Fig. 12	34
18-2.5-2	51.44	34.00	11.395	11.95	1.0487	Fig. 12	34

Table 30 (Continued)

Number of specimens	$N = 28$
Mean	$Pm = 1.0475$
Coefficient of variation	$Vp = 0.11072$

Table 31

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Stub Columns

Having Unstiffened Compression Flanges

(Partially Effective Flanges and Partially Effective Webs)

Specimen	w/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
UD-11	16.24	41.90	18.772	24.65	1.3131	Fig. 12	32
UD-21	20.55	41.90	19.221	25.85	1.3449	Fig. 12	32
20-1-1	24.14	34.00	7.339	6.43	0.8761	Fig. 12	34
20-1-2	24.14	34.00	7.339	6.43	0.8761	Fig. 12	34
20-1-3	24.14	34.00	7.339	6.23	0.8489	Fig. 12	34
UD-31	24.86	41.90	19.531	27.05	1.3850	Fig. 12	32
UD-41	29.17	41.90	19.745	27.44	1.3897	Fig. 12	32
SC-V1	29.74	33.18	12.365	15.11	1.2220	Fig. 10	21
SC-V2	29.76	31.05	11.909	14.30	1.2008	Fig. 10	21
SC-IV2	34.98	30.50	11.559	13.99	1.2103	Fig. 10	21
SC-IV1	35.25	31.29	11.862	14.31	1.2064	Fig. 10	21
14-3.25-1	40.37	49.40	39.690	43.00	1.0834	Fig. 12	34
14-3.25-2	40.37	49.40	39.690	44.00	1.1086	Fig. 12	34
14-3.25-3	40.37	49.40	39.690	42.00	1.0582	Fig. 12	34

Table 31 (Continued)

Specimen	w/t	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
SC-1111	42.93	31.29	12.499	19.79	1.5833	Fig. 10	21
SC-1112	42.95	31.11	12.458	17.44	1.4000	Fig. 10	21
16-3-1	43.29	34.50	24.080	25.00	1.0382	Fig. 12	34
16-3-2	43.29	34.50	24.080	25.00	1.0382	Fig. 12	34
16-3-3	43.29	34.50	24.080	24.00	0.9967	Fig. 12	34
20-1.75-1	44.11	34.00	7.602	7.130	0.9378	Fig. 12	34
20-1.75-2	44.11	34.00	7.602	6.84	0.8998	Fig. 12	34
SC-112	50.08	30.26	12.581	20.18	1.6040	Fig. 10	21
SC-111	51.52	25.68	10.913	17.15	1.5715	Fig. 10	21
SC-11	57.63	31.59	13.021	22.20	1.7049	Fig. 10	21
SC-12	57.71	30.73	12.767	21.70	1.6997	Fig. 10	21

Table 31 (Continued)

Number of specimens	$N = 25$
Mean	$Pm = 1.22391$
Coefficient of variation	$Vp = 0.21814$

Table 32

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Columns Having Unstiffened Compression Flanges Subjected to Elastic Flexural Buckling

Specimen	KL/r	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
4A16P1	151.0	34.3	8.807	8.400	0.9538	Fig. 12	35
4A16P2	151.0	34.3	8.807	9.000	1.0219	Fig. 12	35
4A16P3	151.0	34.3	8.807	8.550	1.0162	Fig. 12	35
6A16P1	222.0	34.3	4.148	3.970	0.9571	Fig. 12	35
6A16P2	222.0	34.3	4.148	4.190	1.0101	Fig. 12	35
6A16P3	222.0	34.3	4.148	3.910	0.9426	Fig. 12	35
8A16P1	294.0	34.3	2.381	2.220	0.9324	Fig. 12	35
8A16P2	294.0	34.3	2.381	2.220	0.9324	Fig. 12	35
8A16P3	294.0	34.3	2.381	2.150	0.9030	Fig. 12	35

Number of specimens	N = 9
Mean	Pm = 0.9633
Coefficient of variation	Vp = 0.04424

Table 33

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Columns Having Unstiffened Compression Flanges Subjected to Inelastic Flexural Buckling

Specimen	KL/r	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
HRSK10-C1	36.0	47.8	26.246	27.55	1.0497	Fig. 15	36
HRSK10-C2	48.0	47.8	25.099	26.68	1.0630	Fig. 15	36
HRSK10-C3	56.0	47.8	24.152	26.39	1.0927	Fig. 15	36
HRSK10-C4	65.0	47.8	22.913	25.23	1.1011	Fig. 15	36
HRSK10-C5	65.0	47.8	22.913	24.65	1.0759	Fig. 15	36
HRSK10-C6	90.0	47.8	18.505	22.91	1.2380	Fig. 15	36
HRSK9-J1	40.0	50.0	32.689	33.35	1.0202	Fig. 15	36
HRSK9-J2	60.0	50.0	29.675	31.94	1.0763	Fig. 15	36
HRSK9-J3	80.0	50.0	25.465	29.13	1.1443	Fig. 15	36
HRSK9-J4	95.0	50.0	21.500	24.57	1.1428	Fig. 15	36
U-11	12.9	41.9	18.772	24.69	1.3153	Fig. 12	32
U-12	55.7	41.9	17.431	21.36	1.2254	Fig. 12	32
U-13	89.1	41.9	15.041	20.40	1.3563	Fig. 12	32
U-14	116.6	41.9	11.854	12.17	1.0267	Fig. 12	32

Table 33 (Continued)

Specimen	KL/r	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
U-21	12.0	41.9	19.221	26.11	1.3584	Fig. 12	32
U-22	12.0	41.9	19.221	25.36	1.3194	Fig. 12	32
U-23	53.0	41.9	18.060	24.00	1.3289	Fig. 12	32
U-24	85.6	41.9	15.795	20.39	1.2909	Fig. 12	32
U-25	108.0	41.9	13.440	14.98	1.1146	Fig. 12	32
U-31	9.5	41.9	19.531	26.91	1.3778	Fig. 12	32
U-32	42.2	41.9	18.768	23.52	1.2532	Fig. 12	32
U-33	77.9	41.9	16.719	22.70	1.3577	Fig. 12	32
U-34	95.5	41.9	15.140	17.94	1.1849	Fig. 12	32
U-41	7.9	41.9	19.745	27.44	1.3897	Fig. 12	32
U-42	44.1	41.9	18.894	23.38	1.2374	Fig. 12	32
U-43	92.4	41.9	15.652	20.06	1.2816	Fig. 12	32
LC-11	49.5	31.6	12.507	14.95	1.1953	Fig. 12	21
LC-12	72.1	31.6	12.046	14.06	1.1672	Fig. 12	21
LC-13	95.8	30.7	10.818	11.00	1.0168	Fig. 12	21
LC-111	52.7	30.3	12.226	16.16	1.3218	Fig. 12	21

Table 33 (Continued)

Specimen	KL/r	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
LC-II2	83.1	30.3	11.153	13.16	1.1800	Fig. 12	21
LC-II3	113.1	25.7	9.384	9.95	1.0603	Fig. 12	21
LC-III1	58.1	31.3	12.279	16.50	1.3438	Fig. 12	21
LC-III2	98.5	31.1	10.410	11.66	1.1201	Fig. 12	21
LC-III3	138.3	25.7	8.066	8.82	1.0935	Fig. 12	21
LC-IV1	68.7	31.1	10.559	12.19	1.1545	Fig. 12	21
LC-IV2	97.4	30.5	9.776	11.30	1.1559	Fig. 12	21
LC-IV3	125.0	31.3	8.661	8.96	1.0345	Fig. 12	21
LC-V1	73.5	33.2	11.263	14.61	1.2972	Fig. 12	21
LC-V2	91.7	30.6	10.231	12.64	1.2355	Fig. 12	21
LC-V3	122.4	30.6	8.638	10.75	1.2445	Fig. 12	21

Number of specimens N = 41

Mean Pm = 1.1962

Coefficient of variation Vp = 0.09608

Table 34

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Columns

Having Stiffened Compression Flanges Subjected to Inelastic Flexural Buckling

Specimen	KL/r	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
S-11	8.5	41.9	31.122	34.83	1.1191	Fig. 12	32
S-12	39.0	41.9	29.718	32.16	1.0822	Fig. 12	32
S-13	69.1	41.9	26.525	29.76	1.1220	Fig. 12	32
S-14	114.1	41.9	18.102	17.97	0.9927	Fig. 12	32
S-21	11.7	41.9	31.915	34.92	1.0942	Fig. 12	32
S-22	66.0	41.9	27.795	28.02	1.0081	Fig. 12	32
S-23	102.0	41.9	21.693	21.42	0.9874	Fig. 12	32
S-24	123.5	41.9	16.688	17.72	1.0618	Fig. 12	32
S-31	7.0	41.9	32.424	36.92	1.1387	Fig. 12	32
S-32	29.0	41.9	31.790	35.03	1.1019	Fig. 12	32
S-33	109.8	41.9	20.528	19.53	0.9514	Fig. 12	32
S-34	109.8	41.9	20.528	19.03	0.9270	Fig. 12	32
S-35	109.8	41.9	20.528	18.14	0.8837	Fig. 12	32
S-41	13.8	41.9	32.723	36.65	1.1200	Fig. 12	32

Table 34 (Continued)

Specimen	KL/r	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
S-42	42.6	41.9	31.147	33.67	1.0810	Fig. 12	32
S-43	65.5	41.9	28.719	29.20	1.0167	Fig. 12	32
S-44	116.0	41.9	19.352	17.58	0.9084	Fig. 12	32
S-45	138.2	41.9	14.716	13.71	0.9316	Fig. 12	32

Number of specimens	N = 18
Mean	Pm = 1.029
Coefficient of variation	Vp = 0.08131

Table 35

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Columns

Subjected to Inelastic Flexural Buckling (Including the Cold Work)

Specimen	KL/r	Fya (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
UC-11	40.3	43.6	16.380	16.51	1.0079	Fig. 16	37
UC-12	61.2	43.6	15.217	13.89	0.9182	Fig. 16	37
UC-13	82.4	43.6	13.490	13.03	0.9659	Fig. 16	37
UC-21	39.2	43.6	16.425	16.60	1.0107	Fig. 16	37
UC-22	60.5	43.6	15.265	13.75	0.9008	Fig. 16	37
UC-23	81.4	43.6	13.584	13.09	0.9636	Fig. 16	37
SC-11	31.2	41.4	29.340	33.39	1.1380	Fig. 16	37
SC-12	59.8	41.4	27.013	31.67	1.1724	Fig. 16	37
SC-13	82.2	41.4	24.106	29.41	1.2200	Fig. 16	37
SC-21	38.2	42.1	45.073	48.10	1.0672	Fig. 16	37
SC-22	59.6	42.1	42.132	48.62	1.1540	Fig. 16	37
SC-23	82.9	42.1	37.356	45.88	1.2282	Fig. 16	37

Table 35 (Continued)

Number of specimens	$N = 12$
Mean	$P_m = 1.0618$
Coefficient of variation	$V_p = 0.11062$

Table 36

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Columns

Subjected to Elastic Torsional-Flexural Buckling

Specimen	KL/r	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	$\frac{(Pu)test}{(Pu)pred}$	Cross Section	Reference
A-E1	21.8	44.7	3.306	4.34	1.3128	Fig. 17	38
A-E2	21.8	44.7	3.306	4.34	1.3128	Fig. 17	38
LA-E1	47.6	47.0	4.406	4.56	1.0350	Fig. 17	38
LA-E2	47.6	47.0	4.406	4.54	1.0304	Fig. 17	38
CH-E1	62.6	45.2	3.033	3.51	1.1573	Fig. 17	38
CH-E2	62.6	45.2	3.033	3.77	1.2430	Fig. 17	38
H-E1	51.3	46.9	4.968	5.26	1.0588	Fig. 17	38
H-E2	51.3	46.9	4.968	5.33	1.0729	Fig. 17	38

Number of specimens	N = 8
Mean	Pm = 1.1529
Coefficient of variation	Vp = 0.10544

Table 37

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Columns

Subjected to Inelastic Torsional-Flexural Buckling

Specimen	L (in.)	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
A-11	56.0	44.7	17.018	18.96	1.1140	Fig. 17	38
A-12	40.0	44.7	17.011	17.93	1.0540	Fig. 17	38
A-13	55.0	41.4	16.367	20.20	1.2342	Fig. 17	38
A-14	55.0	41.4	16.320	20.56	1.2598	Fig. 17	38
A-15	30.0	41.4	15.970	21.77	1.3632	Fig. 17	38
A-16	40.0	30.0	7.492	6.54	0.8800	Fig. 17	38
LA-11	60.0	47.0	22.900	24.23	1.0581	Fig. 17	38
LA-12	40.0	45.6	25.667	29.62	1.1540	Fig. 17	38
LA-13	50.0	47.0	14.321	19.99	1.3959	Fig. 17	38
LA-14	65.0	45.6	24.082	25.85	1.0734	Fig. 17	38
LA-15	59.0	31.7	11.843	13.31	1.1239	Fig. 17	38
LA-16	50.0	31.7	14.111	12.84	0.9100	Fig. 17	38
LA-17	50.0	32.2	9.866	9.85	0.9984	Fig. 17	38
LA-18	50.0	34.2	11.826	12.16	1.0282	Fig. 17	38

Table 37 (Continued)

Specimen	L (in.)	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
LA-19	50.0	32.2	10.639	10.93	1.0274	Fig. 17	38
CH-11	55.0	45.2	17.465	25.63	1.4675	Fig. 17	38
CH-12	34.0	31.0	12.610	13.39	1.0619	Fig. 17	38
CH-13	40.0	31.0	12.063	12.66	1.0495	Fig. 17	38
CH-14	60.0	31.0	9.308	11.32	1.2162	Fig. 17	38
CH-15	60.0	30.4	16.124	15.33	0.9508	Fig. 17	38
CH-16	55.0	30.4	12.866	15.14	1.1767	Fig. 17	38
CH-17	50.0	31.0	11.039	12.44	1.1269	Fig. 17	38
CH-18	55.0	30.4	12.937	14.67	1.1340	Fig. 17	38
CH-19	45.0	31.0	9.113	10.20	1.1193	Fig. 17	38
H-11	45.0	46.9	42.586	40.16	0.9807	Fig. 17	38
H-12	50.0	46.9	46.105	46.51	1.0324	Fig. 17	38
H-13	60.0	46.9	39.902	33.22	0.8586	Fig. 17	38
H-14	50.0	36.5	19.199	15.54	0.8094	Fig. 17	38
H-15	50.0	36.5	15.936	12.62	0.7919	Fig. 17	38
H-16	60.0	30.7	20.080	18.43	0.9389	Fig. 17	38

Table 37 (Continued)

Number of specimens	$N = 30$
Mean	$P_m = 1.0796$
Coefficient of variation	$V_p = 0.15061$

Table 38
Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Stub Columns with Circular Perforations

Specimen	d (in.)	Fy (ksi)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
1	0.00	48.50	15.10	1.019	Fig. 18	39
2	0.00	47.10	14.80	1.024	Fig. 18	39
3	0.50	49.60	14.50	1.006	Fig. 18	39
4	0.75	47.10	14.15	1.054	Fig. 18	39
5	1.04	49.60	14.05	1.028	Fig. 18	39
6	1.25	51.55	13.80	0.996	Fig. 18	39
7	1.50	48.50	12.65	0.992	Fig. 18	39
8	1.75	51.55	13.60	1.035	Fig. 18	39
9	0.50	49.60	15.50	1.075	Fig. 18	39
10	1.04	48.50	14.68	1.097	Fig. 18	39
11	1.50	48.50	14.50	1.137	Fig. 18	39
12	0.00	47.00	27.90	1.274	Fig. 18	39
13	1.04	47.60	24.60	1.159	Fig. 18	39
14	1.50	47.60	24.00	1.214	Fig. 18	39

Number of Specimens	N = 14
Mean	Pm = 1.0793
Coefficient of Variation	Vp = 0.08042

Table 39
Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Long Columns with Circular Perforations

Specimen	d (in.)	L (in.)	Fy (ksi)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
L1	0.50	63.00	51.60	10.05	1.275	Fig. 18	39
L2	0.50	63.00	45.70	8.50	1.091	Fig. 18	39
L3	1.00	27.00	42.90	11.35	1.038	Fig. 18	39
L4	0.00	27.00	44.90	12.40	0.986	Fig. 18	39
L5	1.00	27.00	42.90	11.55	1.056	Fig. 18	39
L6	1.00	63.00	46.10	8.50	1.160	Fig. 18	39
L7	1.50	63.00	45.50	8.45	1.237	Fig. 18	39
L8	1.00	63.00	41.90	7.05	0.984	Fig. 18	39
L9	1.00	39.00	43.80	9.40	0.922	Fig. 18	39
L10	1.50	38.90	42.30	10.10	1.077	Fig. 18	39
L11	0.00	39.00	43.80	8.65	0.763	Fig. 18	39
L12	0.00	27.00	41.90	11.90	1.000	Fig. 18	39
L13	0.00	63.00	42.90	8.00	0.980	Fig. 18	39
L14	0.50	39.10	42.90	9.60	0.906	Fig. 18	39
L15	0.00	45.00	48.30	22.40	1.155	Fig. 18	39
L16	1.00	51.00	48.10	17.20	1.138	Fig. 18	39
L17	1.50	51.10	48.10	15.00	1.089	Fig. 18	39
L18	1.00	45.00	47.60	18.20	1.105	Fig. 18	39
L19	1.50	27.00	51.50	21.20	1.095	Fig. 18	39
L20	1.00	45.00	47.60	19.00	1.154	Fig. 18	39
L21	1.00	45.00	44.50	15.85	1.005	Fig. 18	39
L22	1.50	45.00	46.70	20.00	1.342	Fig. 18	39
L23	1.50	45.00	46.70	15.85	1.064	Fig. 18	39
L24	1.00	45.00	44.50	16.20	1.027	Fig. 18	39
L25	0.00	62.50	48.30	13.44	0.961	Fig. 18	39
L26	1.00	45.00	45.80	19.10	1.189	Fig. 18	39
L27	1.00	27.00	48.30	21.90	1.103	Fig. 18	39
L28	1.00	27.00	42.30	22.40	1.261	Fig. 18	39
L29	0.00	27.00	42.30	22.00	1.066	Fig. 18	39
L30	0.00	27.00	42.30	22.40	1.085	Fig. 18	39
L31	1.00	45.00	46.70	18.10	1.112	Fig. 18	39
L32	1.00	63.00	47.90	13.30	1.150	Fig. 18	39

Number of specimens	N = 32
Mean	Pm = 1.0805
Coefficient of Variation	Vp = 0.10772

Table 40

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Beam-Columns

Hat Sections Studied by Pekoz and Winter (1967)

Specimen	L (in.)	Fy (ksi)	Ex (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
H2-1-1	52.5	45.5	0.098	3.960	3.990	1.0076	Fig. 19	40
H2-1-2	52.5	45.5	0.900	2.040	2.210	1.0833	Fig. 19	40
H2-1-3	52.5	45.5	1.400	1.620	1.565	0.9660	Fig. 19	40
H2-2-1	52.5	45.5	0.000	3.625	3.730	1.0290	Fig. 19	40
H2-2-2	52.5	45.5	1.330	1.770	1.830	1.0339	Fig. 19	40
H2-2-3	52.5	45.5	1.860	1.360	1.285	0.9449	Fig. 19	40
H2-3-1	52.5	45.5	0.000	3.180	3.220	1.0126	Fig. 19	40
H2-3-2	52.5	45.5	0.760	1.680	1.780	1.0595	Fig. 19	40
H2-3-3	52.5	45.5	1.260	1.250	1.280	1.0240	Fig. 19	40
H3-1-1	52.5	48.2	0.000	3.510	3.995	1.1414	Fig. 19	40
H3-1-2	52.5	48.2	0.946	1.800	1.805	1.0028	Fig. 19	40
H3-1-3	52.5	48.2	1.446	1.470	1.545	1.0510	Fig. 19	40
H3-2-1	52.5	48.2	0.000	2.580	3.060	1.1860	Fig. 19	40
H3-2-2	52.5	48.2	1.017	1.560	1.520	0.9744	Fig. 19	40

Table 40 (Continued)

Specimen	L (in.)	Fy (ksi)	Ex (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
H3-2-3	52.5	48.2	1.517	1.320	1.270	0.9620	Fig. 19	40
H3-3-1	52.5	48.2	0.000	2.438	2.840	1.1651	Fig. 19	40
H3-3-2	52.5	48.2	0.759	1.440	1.465	1.0174	Fig. 19	40
H3-3-3	52.5	48.2	1.273	1.140	1.140	1.0000	Fig. 19	40

Number of specimens	N = 18
Mean	Pm = 1.0367
Coefficient of variation	Vp = 0.06619

Note: Ex = Eccentricity in the x-direction.

Table 41

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Beam-Columns

Lipped Channel Sections Studied by Thomasson (1978)

Specimen	L (in.)	Fy (ksi)	Ex (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
A71	105.9	56.71	0.0	3.72	3.60	0.9700	Fig. 20	41
A74	105.9	57.29	0.0	3.78	3.64	0.9700	Fig. 20	41
A75	105.9	57.72	0.0	3.72	3.48	0.9400	Fig. 20	41
A76	105.9	41.77	0.0	3.30	3.26	0.9879	Fig. 20	41
A101	105.9	67.30	0.0	7.92	8.30	1.0480	Fig. 20	41
A102	105.9	66.72	0.0	7.92	7.87	0.9937	Fig. 20	41
A103	105.9	66.72	0.0	7.80	8.34	1.0692	Fig. 20	41
A104	105.9	68.89	0.0	8.28	7.76	0.9372	Fig. 20	41
A151	105.9	55.40	0.0	14.88	17.20	1.1559	Fig. 20	41
A152	105.9	54.97	0.0	14.40	15.70	1.0903	Fig. 20	41
A153	105.9	57.29	0.0	13.68	16.00	1.1696	Fig. 20	41
A154	105.9	57.00	0.0	14.40	16.40	1.1389	Fig. 20	41
A156	105.9	55.26	0.0	13.92	15.50	1.1135	Fig. 20	41

Table 41 (Continued)

Number of specimens	N = 13
Mean	Pm = 1.0509
Coefficient of variation	Vp = 0.07792

Note: Ex = Eccentricity in the x-direction

Table 42

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Beam-Columns

Lipped Channel Sections Studied by Loughlan (1979)

Specimen	L (in.)	Fy (ksi)	Ex (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
L1	72.0	35.1	-0.292	3.18	3.12	0.9811	Fig. 20	42
L2	48.0	35.1	-0.294	3.36	3.60	1.0714	Fig. 20	42
L3	72.0	35.1	-0.402	3.60	3.52	0.9778	Fig. 20	42
L4	60.0	35.1	-0.404	3.96	3.78	0.9545	Fig. 20	42
L5	48.0	35.1	-0.407	3.84	4.10	1.0677	Fig. 20	42
L6	72.0	35.1	-0.066	3.60	3.80	1.0556	Fig. 20	42
L7	60.0	35.1	-0.066	3.84	3.97	1.0339	Fig. 20	42
L8	48.0	35.1	-0.066	4.02	4.31	1.0721	Fig. 20	42
L9	72.0	35.1	-0.184	4.08	4.34	1.0637	Fig. 20	42
L10	60.0	35.1	-0.186	4.20	4.57	1.0881	Fig. 20	42
L11	48.0	35.1	-0.186	4.56	4.65	1.0197	Fig. 20	42
L12	72.0	35.1	-0.182	3.30	3.35	1.0152	Fig. 20	42
L13	60.0	35.1	-0.183	3.48	3.53	1.0144	Fig. 20	42
L14	48.0	35.1	-0.181	3.60	3.85	1.0694	Fig. 20	42

Table 42 (Continued)

Specimen	L (in.)	Fy (ksi)	Ex (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
L15	72.0	35.1	0.000	4.56	4.90	1.0746	Fig. 20	42
L16	60.0	35.1	0.000	5.04	5.18	1.0278	Fig. 20	42
L17	48.0	35.1	0.000	4.86	5.31	1.0926	Fig. 20	42
L18	72.0	35.1	-0.220	2.94	3.13	1.0646	Fig. 20	42
L19	60.0	35.1	-0.222	3.06	3.39	1.1078	Fig. 20	42
L20	48.0	35.1	-0.224	3.42	3.67	1.0731	Fig. 20	42
L21	72.0	35.1	-0.159	3.90	3.86	0.9897	Fig. 20	42
L22	60.0	35.1	-0.159	3.96	4.42	1.1162	Fig. 20	42
L23	48.0	35.1	-0.161	4.08	4.14	1.0147	Fig. 20	42
L24	72.0	33.8	0.000	10.80	14.80	1.3704	Fig. 20	42
L25	72.0	33.8	-0.083	13.20	16.00	1.2121	Fig. 20	42
L26	60.0	33.8	-0.083	14.16	16.40	1.1582	Fig. 20	42
L27	48.0	33.8	-0.083	14.40	16.60	1.1528	Fig. 20	42
L28	72.0	33.8	-0.106	9.12	11.50	1.2610	Fig. 20	42
L29	60.0	33.8	-0.106	10.08	12.60	1.2500	Fig. 20	42
L30	48.0	33.8	-0.106	10.56	13.60	1.2879	Fig. 20	42

Table 42 (Continued)

Specimen	L (in.)	Fy (ksi)	Ex (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
L31	72.0	33.8	0.000	13.68	17.00	1.2427	Fig. 20	42
L32	60.0	33.8	0.000	14.16	17.00	1.2006	Fig. 20	42
L33	48.0	33.8	0.000	14.88	18.00	1.2097	Fig. 20	42

Number of specimens	N = 33
Mean	Pm = 1.1028
Coefficient of variation	Vp = 0.09182

Note: Ex = Eccentricity in the x-direction

Table 43

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Beam-Columns

Lipped Channel Sections Studied by Mulligan and Pekoz (1983)

Specimen	L (in.)	Fy (ksi)	Ex (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
CLC/1	60.00	32.41	0.000	8.40	9.80	1.1667	Fig. 20	43
CLC/2	72.02	31.95	0.000	8.40	10.40	1.2381	Fig. 20	43
CLC/3	118.10	31.95	0.000	7.44	8.20	1.1022	Fig. 20	43
CLC/4	118.00	31.95	0.000	7.44	8.40	1.1290	Fig. 20	43
CLC/5	72.00	32.47	0.000	9.48	11.80	1.2447	Fig. 20	43
CLC/1-1	69.01	32.59	0.000	7.44	9.60	1.2903	Fig. 20	43
CLC/2-1	92.12	32.41	0.000	7.08	8.75	1.2359	Fig. 20	43
CLC/3-1	115.00	32.41	0.000	6.48	7.60	1.1728	Fig. 20	43
CLC/4-1	92.03	33.06	0.000	8.28	10.80	1.3043	Fig. 20	43
CLC/1-2	96.16	34.34	0.000	12.24	11.00	0.8986	Fig. 20	43
CLC/1-3	72.07	31.82	0.000	9.84	12.30	1.2500	Fig. 20	43
CLC/2-3	96.07	35.42	0.000	10.08	12.10	1.2004	Fig. 20	43
CLC/3-3	96.16	33.85	0.000	10.08	11.80	1.1706	Fig. 20	43
CLC/2.1	72.00	31.82	0.536	9.84	10.30	1.0467	Fig. 20	43

Table 43 (Continued)

Specimen	L (in.)	Fy (ksi)	Ex (in.)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
CLC/2.2	72.72	31.82	0.534	9.12	8.75	0.9594	Fig. 20	43
CLC/2.3	72.66	31.82	-0.982	5.40	6.75	1.2500	Fig. 20	43
CLC/2.4	72.00	32.47	0.212	12.48	12.40	0.9936	Fig. 20	43
CLC/2.1-3	96.03	33.06	0.521	12.24	12.50	1.0212	Fig. 20	43

Number of specimens	N = 18
Mean	Pm = 1.1489
Coefficient of variation	Vp = 0.10478

Note: Ex = Eccentricity in the x-direction

Table 44
Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Locally Stable Beam-Columns
Lipped Channel Sections Studied by Loh and Pekoz (1985)

Specimen	L (in.)	Fy (ksi)	Ex (in.)	Ey (in.)	$\frac{(Pu)test}{(Pu)pred}$	Cross Section	Reference
LC1-LS-1	39.0	45.5	1.50	0.00	1.13	Fig. 20	44
LC1-LS-2	51.0	45.5	1.50	0.00	1.05	Fig. 20	44
LC1-LS-3	63.0	45.5	1.50	0.00	0.94	Fig. 20	44
LC2-LS-1	36.6	41.9	-2.00	0.00	1.33	Fig. 20	44
LC2-LS-2	49.8	41.9	-2.25	0.00	1.27	Fig. 20	44
LC2-LS-3	60.6	41.9	-2.25	0.00	1.25	Fig. 20	44

Number of specimens	N = 6
Mean	Pm = 1.16
Coefficient of Variation	Vp = 0.13

Note: Ex = Eccentricity in the x-direction
Ey = Eccentricity in the y-direction = 0

Table 45
Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Locally Stable Beam-Columns
Lipped Channel Sections Studied by Loh and Pekoz (1985)

Specimen	L (in.)	Fy (ksi)	Ex (in.)	Ey (in.)	(Pu)test / (Pu)pred	Cross Section	Reference
LC3-LS-1	52.0	40.9	0.00	1.45	1.16	Fig. 20	44
LC3-LS-2	39.1	39.1	0.00	2.00	1.23	Fig. 20	44
LC3-LS-3	51.1	39.1	0.00	2.00	1.19	Fig. 20	44
LC3-LS-4	63.4	39.1	0.00	2.00	1.25	Fig. 20	44
LC4-LS-1	39.1	59.4	0.00	2.50	1.18	Fig. 20	44
LC4-LS-2	51.2	59.4	0.00	2.50	1.14	Fig. 20	44
LC5-LS-1	51.2	47.5	0.00	2.03	1.01	Fig. 20	44
LC5-LS-2	69.2	47.5	0.00	2.00	1.00	Fig. 20	44
LC6-LS-1	51.5	39.3	0.00	2.38	1.21	Fig. 20	44
LC6-LS-2	63.5	39.3	0.00	2.13	1.21	Fig. 20	44
LC7-LS-1	50.2	37.4	0.00	2.25	1.22	Fig. 20	44
LC7-LS-2	69.0	37.4	0.00	2.22	1.19	Fig. 20	44
LC8-LS-1	40.1	41.6	0.00	1.50	1.02	Fig. 20	44
LC8-LS-2	51.1	41.6	0.00	1.50	1.02	Fig. 20	44
LC8-LS-3	63.8	41.6	0.00	1.50	1.02	Fig. 20	44
LC8-LS-4	75.6	42.5	0.00	1.66	1.00	Fig. 20	44
LC8-LS-5	87.6	42.5	0.00	2.00	1.04	Fig. 20	44

Number of specimens	N = 17
Mean	Pm = 1.12
Coefficient of Variation	Vp = 0.09

Note: Ex = Eccentricity in the x-direction = 0
Ey = Eccentricity in the y-direction

Table 46
Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Locally Stable Beam-Columns
Lipped Channel Sections Studied by Loh and Pekoz (1985)

Specimen	L (in.)	Fy (ksi)	Ex (in.)	Ey (in.)	(Pu)test / (Pu)pred	Cross Section	Reference
LC9-LS-1	39.5	58.2	1.50	2.00	1.18	Fig. 20	44
LC9-LS-2	52.8	58.2	1.50	2.00	1.13	Fig. 20	44
LC9-LS-3	64.8	58.2	1.50	2.00	1.05	Fig. 20	44
LC9-LS-4#	62.6	65.3	-2.00	2.50	0.91	Fig. 20	44
LC10-LS-1*	39.2	54.9	-2.00	2.50	1.36	Fig. 20	44
LC10-LS-2*	51.2	54.9	-2.00	2.50	1.33	Fig. 20	44
LC10-LS-3	63.2	54.9	-2.00	2.50	1.30	Fig. 20	44
LC11-LS-1	39.0	48.8	2.00	2.50	1.28	Fig. 20	44
LC11-LS-2	49.5	48.8	2.50	2.00	1.27	Fig. 20	44
LC11-LS-3	61.3	48.8	2.00	2.50	1.16	Fig. 20	44

Number of specimens	N = 10
Mean	Pm = 1.23
Coefficient of Variation	Vp = 0.08

Premature failure of welds joining end plates to column. Excluded from statistical evaluation.
* Premature failure of welds joining end plates to column. Included in statistical evaluation.

Note: Ex = Eccentricity in the x-direction
Ey = Eccentricity in the y-direction

Table 47
Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Locally Unstable Beam-Columns
Lipped Channel Sections Studied by Loh and Pekoz (1985)

Specimen	L (in.)	Fy (ksi)	Ex (in.)	Ey (in.)	(Pu)test / (Pu)pred	Cross Section	Reference
LC1-LU-1	76.0	55.9	0.00	2.10	1.155	Fig. 20	44
LC1-LU-2	76.0	55.9	0.00	12.00	1.037	Fig. 20	44
LC1-LU-3	76.0	55.9	0.00	6.00	1.202	Fig. 20	44
LC2-LU-1	99.9	35.1	0.00	6.00	1.158	Fig. 20	44
LC2-LU-2	99.9	35.8	0.00	9.00	1.048	Fig. 20	44
LC3-LU-1	99.9	43.4	0.00	4.00	0.905	Fig. 20	44
LC3-LU-2	99.9	44.4	0.00	8.00	1.006	Fig. 20	44
LC3-LU-3	99.9	43.2	0.00	4.00	0.962	Fig. 20	44
LC4-LU-1	99.9	62.1	0.00	12.00	1.107	Fig. 20	44
LC4-LU-2	99.9	62.1	0.00	18.00	0.989	Fig. 20	44
LC4-LU-3	99.9	62.9	0.00	6.00	1.108	Fig. 20	44
LC5-LU-1	99.9	58.5	0.00	4.00	1.181	Fig. 20	44
LC5-LU-2	99.9	58.5	0.00	8.00	1.151	Fig. 20	44
LC5-LU-3	99.8	58.6	0.00	6.00	1.200	Fig. 20	44
LC5-LU-4	99.8	58.6	0.00	10.00	1.101	Fig. 20	44
LC6-LU-1	99.9	71.7	0.00	5.00	1.131	Fig. 20	44
LC6-LU-2	99.8	71.7	0.00	10.00	1.098	Fig. 20	44

Number of specimens	N = 17
Mean	Pm = 1.091
Coefficient of Variation	Vp = 0.0795

Note: Ex = Eccentricity in the x-direction = 0
Ey = Eccentricity in the y-direction

Table 48
Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Locally Unstable Beam-Columns
Lipped Channel Sections Studied by Loh and Pekoz (1985)

Specimen	L (in.)	Fy (ksi)	Ex (in.)	Ey (in.)	(Pu)test / (Pu)pred	Cross Section	Reference
LC8-LU-1	98.9	61.2	-1.00	2.00	1.206	Fig. 20	44
LC8-LU-2	99.2	61.2	-1.00	2.00	1.222	Fig. 20	44
LC8-LU-3	98.9	62.9	-1.00	4.00	1.217	Fig. 20	44
LC8-LU-4	98.9	62.9	-1.00	4.00	1.195	Fig. 20	44
LC8-LU-5	99.1	63.2	-1.00	6.00	1.177	Fig. 20	44
LC8-LU-6	98.7	63.2	-1.00	6.00	1.235	Fig. 20	44
LC9-LU-1	93.4	69.9	0.38	3.94	1.011	Fig. 20	44
LC9-LU-2	93.1	69.9	0.38	6.00	0.905	Fig. 20	44
LC9-LU-3	93.1	70.3	0.38	6.00	0.945	Fig. 20	44
LC9-LU-4	93.1	70.3	0.63	3.94	0.922	Fig. 20	44
LC10-LU-1	98.9	70.6	0.00	5.50	1.144	Fig. 20	44
LC10-LU-2	98.9	70.6	0.00	5.50	1.154	Fig. 20	44

Number of specimens	N = 12
Mean	Pm = 1.111
Coefficient of Variation	Vp = 0.1145

Note: Ex = Eccentricity in the x-direction
Ey = Eccentricity in the y-direction

Table 49
Comparison of Tested and Predicted Loads of Arc Spot Welds Failed in Shearing of the Weld

Specimen	(Pu)test (kips)	(Pu)pred (kips)	$\frac{(Pu)test}{(Pu)pred}$
A A/B 12/7 D(B-C)1	20.60	16.18	1.273
A A/B 12/7 D(B-C)2	24.80	17.15	1.446
A A/B 12/7 D(B-C)3	20.30	17.04	1.191
A A/B 12/7 D(F-C)1	24.10	17.15	1.405
A A/B 12/7 D(F-C)2	24.90	18.64	1.336
A A/B 12/7 D(E-C)1	24.10	18.64	1.293
A A/B 12/7 D(E-C)2	24.10	20.08	1.200
A A/B 12/7 D(AA-C)3	14.00	16.18	0.865
B A/B 14/7 D(A-C)1	17.20	16.03	1.073
B A/B 14/7 D(A-C)2	20.90	19.38	1.078
B A/B 14/7 D(D-C)1	16.10	17.46	0.922
B A/B 14/7 D(D-C)2	11.80	13.31	0.887
B A/B 14/7 D(F-C)1	14.80	15.55	0.952
B A/B 14/7 D(F-C)2	16.50	13.84	1.192
B A/B 14/7 D(D-E)1	38.90	23.98	1.622
B A/B 14/7 D(D-E)2	39.40	24.56	1.604
B A/B 18/7 C(D-AA)1	18.90	10.48	1.803
B A/B 18/7 C(D-AA)2	12.60	10.09	1.249
B A/B 14/7 D(E-D)1	18.80	20.13	0.934
B A/B 14/7 D(E-D)2	22.50	19.48	1.155
A A/B 12/7 C(E-AA)2	10.70	13.90	0.770
A A/B 10/7 D(E-CC)1	26.10	19.10	1.366
A A/B 10/7 D(E-CC)2	20.90	19.58	1.068
A A/B 10/7 D(E-E)1	34.50	24.54	1.406
A A/B 10/7 D(E-E)2	28.30	30.68	0.922
B A/B 18/7 D1S	12.70	11.71	1.085
B A/B 18/7 D2S	16.20	13.81	1.173
B A/B 18/7 D3S	15.40	13.38	1.151
B A/B 18/7 D4S	11.70	9.78	1.196
B A/B 18/7 D5S	8.60	13.81	0.623
B A/B 12/7 D2	6.00	4.68	1.282
B A/B 12/7 D3	5.00	4.93	1.014

Table 49 (Continued)

Number of specimens	N = 32
Mean	Pm = 1.173
Coefficient of Variation	Vp = 0.217

Note: The data selected were predicted in weld shear and are listed in Table 5 of Reference 45.

Table 50
Comparison of Tested and Predicted Loads of Arc Seam Welds
(Table 6 of Reference 45)

Specimen	(Pu)test (kips)	(Pu)pred (kips)	$\frac{(Pu)test}{(Pu)pred}$
Single Sheet Puddle Welds			
A A/B 18/7 X1	15.60	14.83	1.05
A A/B 18/7 X2	15.50	14.90	1.04
A A/B 18/7 X3	15.00	13.89	1.08
A A/B 18/7 Y1	13.10	11.90	1.10
A A/B 18/7 Y3	10.90	12.07	0.90
A A/B 22/7 X1	7.61	7.41	1.03
A A/B 22/7 X2	7.50	7.52	1.00
A A/B 22/7 X3	7.06	6.67	1.06
A A/B 22/7 Y1	3.90	5.57	0.70
A A/B 22/7 Y2	6.04	5.14	1.18
A A/B 22/7 Y3	4.76	5.49	0.87
Double Sheet Puddle Welds			
B A/B 18/7 X1	30.20	30.55	0.99
B A/B 18/7 X2	31.10	31.61	0.98
B A/B 18/7 X3	31.00	30.97	1.00
B A/B 18/7 Y1	23.90	24.99	0.95
B A/B 18/7 Y2	25.70	24.81	1.04
B A/B 18/7 Y3	24.90	24.88	1.00
B A/B 22/7 X1	15.60	14.34	1.09
B A/B 22/7 X2	15.10	14.52	1.04
B A/B 22/7 X3	15.40	14.63	1.05
B A/B 22/7 Y1	12.10	12.52	0.97
B A/B 22/7 Y2	12.40	11.70	1.06
B A/B 22/7 Y3	11.20	12.18	0.92
Number of specimens			N = 23
Mean			Pm = 1.004
Coefficient of Variation			Vp = 0.095

Table 51
Comparison of Tested and Predicted Loads of Flare Groove Welds
(Table 3 of Reference 45)

Specimen	(Pu)test (kips)	(Pu)pred (kips)	(Pu)test / (Pu)pred
Shop Welded Specimens			
E A/B 18/7 F1	7.04	7.88	0.89
E A/B 18/7 F2	9.58	7.82	1.22
E A/B 18/7 F3	7.82	7.98	0.98
E A/B 18/7 C1	2.66	4.94	0.53
E A/B 18/7 C2	3.70	4.58	0.80
E A/B 18/7 C3	4.70	4.94	0.95
E A/B 18/7 C4	2.84	4.48	0.63
E A/B 18/7 L1	16.20	16.11	1.01
E A/B 18/7 L2	16.60	15.81	1.05
E A/B 18/7 L3	16.60	15.55	1.06
E A/B 18/7 P1	20.80	20.28	1.02
E A/B 18/7 P2	21.50	21.33	1.01
E A/B 18/7 P3	20.50	20.96	0.98
E A/B 12/7 C1	9.50	8.36	1.14
E A/B 12/7 C2	8.94	7.48	1.19
E A/B 12/7 C3	9.44	10.23	0.92
E A/B 12/7 F1	13.00	13.29	0.98
E A/B 12/7 F2	10.80	13.51	0.80
E A/B 12/7 F3	14.56	13.69	1.06
E A/B 12/7 F4	14.30	13.29	1.07
E A/B 12/7 L1	27.50	26.49	1.04
E A/B 12/7 L2	27.50	26.40	1.04
E A/B 12/7 L3	27.50	26.58	1.03
E A/B 12/7 P1	33.10	35.20	0.94
E A/B 12/7 P2	32.90	35.11	0.93
E A/B 12/7 P3	33.30	34.78	0.96
Field Welded Specimens			
E A/B 12/7 P1	35.20	34.63	1.02
E A/B 12/7 P2	35.70	34.81	1.02

Table 51 (Continued)

Specimen	(Pu)test (kips)	(Pu)pred (kips)	$\frac{(Pu)test}{(Pu)pred}$
E A/B 12/7 P3	35.80	34.90	1.03
E A/B 12/7 C1	13.96	9.71	1.42
E A/B 12/7 C2	12.62	9.89	1.28
E A/B 12/7 C3	13.06	10.34	1.26
E A/B 12/7 C4	12.58	10.97	1.15
E A/B 12/7 C5	12.62	10.88	1.16
E A/B 18/7 P1	19.25	19.88	0.97
E A/B 18/7 P2	20.00	20.24	0.99
E A/B 18/7 P3	19.90	19.98	1.00
E A/B 18/7 C1	6.84	5.38	1.26
E A/B 18/7 C2	6.82	5.49	1.25
E A/B 18/7 C3	6.40	5.64	1.14
E A/B 18/7 C4	7.08	5.28	1.33
E A/B 18/7 C5	7.26	5.95	1.22

Number of specimens	N = 42
Mean	Pm = 1.040
Coefficient of Variation	Vp = 0.165

Table 52
Comparison of Tested and Predicted Loads of Longitudinal Flare Bevel Welds Failed in Tearing along Weld Contour

Specimen	(Pu)test (kips)	(Pu)pred (kips)	(Pu)test / (Pu)pred
Shop Welded Specimens			
D A/B 18/7 C1	17.60	15.88	1.108
D A/B 18/7 C2	19.40	15.88	1.222
D A/B 18/7 C3	21.20	17.33	1.223
D A/B 12/7 C1	28.50	30.03	0.949
D A/B 12/7 C2	25.20	28.71	0.878
D A/B 12/7 C3	29.00	29.37	0.987
D A/B 12/7 F6	35.50	46.86	0.758
Field Welded Specimens			
D A/B 12/7 C1	30.10	35.75	0.842
D A/B 12/7 C2	31.00	36.92	0.840
D A/B 12/7 C3	31.60	35.75	0.884
Number of specimens			N = 10
Mean			Pm = 0.969
Coefficient of Variation			Vp = 0.169

Note: The data selected were predicted for tearing along the weld contour and are listed in Table 4 of Reference 45.

Table 53
Comparison of Tested and Predicted Shear Strengths of Resistance Welds
(References 46 and 47)

Thickness of thinnest sheet (in.)	Shear strength per spot (lb) test	pred	(S)test / (S)pred
0.010	130	125.0	1.0400
0.022	550	550.4	0.9993
0.030	1000	1000.0	1.0000
0.036	1180	1255.0	0.9402
0.039	1400	1382.5	1.0127
0.052	1700	1775.0	0.9577
0.063	2500	2432.5	1.0277
0.078	3200	3220.0	0.9938
0.093	4200	4242.4	0.9900
0.108	5900	5876.3	1.0040
0.123	7200	7048.5	1.0215
0.188	10000	10000.0	1.0000
0.250	15000	15000.0	1.0000

Number of specimens	N = 13
Mean	Pm = 0.9990
Coefficient of Variation	Vp = 0.0266

Table 54

Comparison of Tested and Predicted Failure Loads of Bolted Connections for Shear Strength Study

Single Shear, with Washers, Fu/Fy $\geq$ 1.15

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	(Pu)t / (Pu)p	Reference
20A11SS	1/4	0.036	0.38	32.11	41.83	0.804	0.565	1.4237	49
20A21SS	1/4	0.036	0.63	32.11	41.83	1.210	0.941	1.2862	49
20A12SS	3/8	0.036	0.56	32.11	41.83	1.077	0.848	1.2702	49
20A22SS	3/8	0.036	0.94	32.11	41.83	1.759	1.413	1.2451	49
20A13SS	1/2	0.036	0.75	32.11	41.83	1.470	1.129	1.3019	49
20A14SS	5/8	0.036	0.94	32.11	41.83	1.762	1.413	1.2472	49
20A24SS	5/8	0.036	1.56	32.11	41.83	2.821	2.349	1.2009	49
20A15SS	3/4	0.036	1.13	32.11	41.83	2.284	1.702	1.3425	49
16C205SS	3/4	0.059	1.50	31.95	43.81	4.862	3.877	1.2539	49
14A11SS	1/4	0.080	0.38	29.81	43.40	1.606	1.302	1.2335	49
14A12SS	3/8	0.080	0.56	29.81	43.40	2.229	1.955	1.1403	49
14A22SS	3/8	0.080	0.94	29.81	43.40	3.893	3.257	1.1955	49
14A13SS	1/2	0.080	0.75	29.81	43.40	3.084	2.604	1.1843	49
14A23SS	1/2	0.080	1.25	29.81	43.40	4.909	4.340	1.1312	49

Table 54 (Continued)

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	(Pu)t / (Pu)p	Reference
12A11SS	1/4	0.093	0.38	25.60	41.15	1.813	1.435	1.2635	49
12A12SS	3/8	0.093	0.56	25.60	41.15	2.807	2.155	1.3029	49
12A14SS	5/8	0.093	0.94	26.65	41.40	4.448	3.611	1.2317	49
18E12SS	3/8	0.046	0.56	46.75	68.00	1.879	1.761	1.0670	50
18E22SS	3/8	0.046	0.94	46.75	68.00	3.409	2.934	1.1619	50
18E14SS	5/8	0.046	0.94	46.75	68.00	3.235	2.934	1.1025	50
14E13SS	1/2	0.078	0.75	54.44	70.40	4.341	4.118	1.0540	50
14E23SS	1/2	0.078	1.25	54.44	70.40	7.118	6.864	1.0369	50
14E15SS	3/4	0.078	1.13	54.44	70.40	6.991	6.205	1.1266	50
14E25SS	3/4	0.078	1.88	54.44	70.40	9.998	10.323	0.9684	50
10E15SS	3/4	0.143	1.13	59.47	76.84	11.508	12.417	0.9268	50
10E16SS	1/1	0.143	1.50	59.47	76.84	14.944	16.482	0.9066	50
8E15SS	3/4	0.190	1.13	56.45	76.98	15.262	16.528	0.9234	50
SS1	7/8	0.115	1.75	35.49	49.44	12.925	9.950	1.2990	51
SS1	7/8	0.115	1.75	35.49	49.44	12.925	9.950	1.2990	51
SS4	1/1	0.116	2.00	35.49	49.44	14.211	11.470	1.2390	51

Table 54 (Continued)

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	(Pu)t / (Pu)p	Reference
SS7	7/8	0.181	1.75	38.10	62.08	22.500	19.664	1.1442	51
SS10	1/1	0.184	2.00	38.10	62.08	25.300	22.845	1.1074	51
SS13	1/1	0.261	2.00	45.07	67.54	37.151	35.256	1.0537	51
----	1/2	0.051	0.97	40.60	50.10	3.420	2.478	1.3797	52
----	1/2	0.051	1.02	40.60	50.10	3.491	2.606	1.3395	52
----	1/2	0.061	1.03	50.50	74.10	5.280	4.656	1.1340	52
----	1/2	0.061	1.03	50.50	74.10	5.121	4.656	1.0999	52
B-1-1-1-0	1/4	0.027	0.38	44.06	53.25	0.560	0.539	1.0386	53
B-1-1-2-0	1/4	0.027	0.38	44.06	53.25	0.515	0.549	0.9378	53
B-1-1-3-T	1/4	0.027	0.38	44.06	53.25	0.586	0.539	1.0868	53
B-1-1-4-T	1/4	0.028	0.38	44.06	53.25	0.595	0.559	1.0642	53
B-1-2-1-0	3/8	0.027	0.95	44.06	53.25	1.370	1.370	0.9998	53
B-1-2-2-0	3/8	0.027	0.95	44.06	53.25	1.265	1.345	0.9407	53
B-1-2-3-T	3/8	0.027	0.94	44.06	53.25	1.263	1.324	0.9542	53
B-1-2-4-T	3/8	0.027	0.94	44.06	53.25	1.265	1.324	0.9557	53
B-0-1-1-0	1/4	0.027	0.38	44.06	53.25	0.520	0.539	0.9640	53

Table 54 (Continued)

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	(Pu)t / (Pu)p	Reference
B-0-1-2-0	1/4	0.027	0.38	44.06	53.25	0.560	0.539	1.0386	53
B-0-1-3-T	1/4	0.026	0.38	44.06	53.25	0.513	0.519	0.9880	53
B-0-1-4-T	1/4	0.026	0.38	44.06	53.25	0.513	0.519	0.9880	53

Number of specimens	N = 49
Mean	Pm = 1.1343
Coefficient of variation	Vp = 0.1216

Table 55

Comparison of Tested and Predicted Failure Loads of Bolted Connections for Shear Strength Study

Double Shear, with Washers, Fu/Fy ≥ 1.15

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	(Pu)t / (Pu)p	Reference
20A11DS	1/4	0.036	0.38	32.11	41.85	0.863	0.565	1.5269	49
20A21DS	1/4	0.036	0.63	32.11	41.85	1.285	0.942	1.3644	49
20A12DS	3/8	0.036	0.56	32.11	41.85	1.268	0.848	1.4943	49
20A13DS	1/2	0.036	0.75	32.11	41.85	1.520	1.130	1.3448	49
20A14DS	5/8	0.036	0.94	32.11	41.85	1.982	1.413	1.4025	49
20A15DS	3/4	0.036	1.13	32.11	41.85	2.395	1.695	1.4130	49
16C203DS	1/2	0.059	1.00	31.95	43.81	3.324	2.585	1.2861	49
14A11DS	1/4	0.080	0.38	29.81	43.40	1.567	1.302	1.2038	49
14A21DS	1/4	0.080	0.63	29.81	43.40	2.637	2.170	1.2153	49
14A12DS	3/8	0.080	0.56	29.81	43.40	2.504	1.955	1.2810	49
14A12SD	3/8	0.080	0.94	29.81	43.40	3.880	3.257	1.1913	49
14A13DS	1/2	0.080	0.75	29.81	43.40	3.276	2.604	1.2582	49
14A23DS	1/2	0.080	1.25	29.81	43.40	5.223	4.340	1.2035	49
12A11DS	1/4	0.093	0.38	26.00	41.15	1.911	1.435	1.3314	49

Table 55 (Continued)

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	(Pu)t / (Pu)p	Reference
12A21DS	1/4	0.093	0.63	26.00	41.15	3.134	2.392	1.3104	49
12A12DS	3/8	0.093	0.56	26.00	41.15	2.757	2.155	1.2794	49
12A22DS	3/8	0.093	0.94	26.00	41.15	4.687	3.590	1.3056	49
12A14DS	5/8	0.093	0.94	26.00	41.15	4.872	3.590	1.3572	49
12A24DS	5/8	0.093	1.56	26.00	41.15	7.424	5.982	1.2412	49
10A12DS	3/8	0.143	0.56	36.60	48.00	4.550	3.864	1.1773	49
10A22DS	3/8	0.143	0.94	36.60	48.00	7.162	6.438	1.1124	49
8B23DS	1/2	0.188	1.25	35.15	47.10	11.727	11.069	1.0594	49
8B25DS	3/4	0.188	1.88	35.15	47.10	18.212	16.647	1.0940	49
18E12DS	3/8	0.046	0.56	46.75	68.00	1.910	1.761	1.0844	50
18E22DS	3/8	0.046	0.94	46.75	68.00	3.198	2.934	1.0898	50
18E14DS	5/8	0.046	0.94	46.75	68.00	3.189	2.934	1.0868	50
18E24DS	5/8	0.046	1.56	46.75	68.00	4.944	4.889	1.0113	50
14E13DS	1/2	0.078	0.75	54.44	70.40	4.774	4.118	1.1591	50
14E13DS	1/2	0.078	1.25	54.44	70.40	7.445	6.864	1.0847	50
14E15DS	3/4	0.078	1.13	54.44	70.40	7.099	6.178	1.1491	50

Table 55 (Continued)

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	$\frac{(Pu)t}{(Pu)p}$	Reference
10E12DS	3/8	0.143	0.56	59.50	71.85	5.446	5.785	0.9414	50
10E13DS	1/2	0.143	0.75	59.50	71.85	7.658	7.706	0.9937	50
10E23DS	1/2	0.143	1.25	59.50	71.85	12.927	12.843	1.0065	50
10E15DS	3/4	0.143	1.13	59.50	71.85	13.026	11.610	1.1219	50
10E26DS	1/1	0.143	2.50	59.50	71.85	23.881	25.686	0.9297	50
8E15DS	3/4	0.190	1.13	56.45	76.98	15.525	16.454	0.9435	50
8E25DS	3/4	0.190	1.88	56.45	76.98	22.558	27.424	0.8226	50
16FAX-L14	1/2	0.062	1.25	30.10	45.90	3.150	3.557	0.8854	54
12FAX-L19	1/2	0.106	1.25	28.10	44.10	6.371	5.843	1.0902	54

Number of specimens	N = 39
Mean	Pm = 1.1757
Coefficient of variation	Vp = 0.1410

Table 56

Comparison of Tested and Predicted Failure Loads of Bolted Connections for Shear Strength Study

Single Shear, with Washers, Fu/Fy < 1.15

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	(Pu)t / (Pu)p	Reference
12Y-L10	5/8	0.106	2.11	72.40	72.80	13.515	16.282	0.8300	54
7Y-L1	3/4	0.183	0.62	83.10	83.80	8.510	9.508	0.8950	54
7Y-L2	3/4	0.183	0.69	83.10	83.80	8.784	10.581	0.8302	54
7Y-T3	3/4	0.183	0.62	86.40	91.30	8.029	10.359	0.7751	54
7Y-L4	3/4	0.183	1.00	83.10	83.80	13.341	15.336	0.8699	54
7Y-T4	3/4	0.183	1.00	86.40	91.30	14.000	16.708	0.8379	54
7Y-T5	3/4	0.183	1.75	86.40	91.30	25.529	29.239	0.8731	54

Number of specimens	N = 7
Mean	Pm = 0.8445
Coefficient of variation	Vp = 0.0466

Table 57

Comparison of Tested and Predicted Failure Loads of Bolted Connections for Shear Strength Study

Double Shear, with Washers, Fu/Fy < 1.15

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	(Pu)t / (Pu)p	Reference
7Y-L22	1/2	0.183	0.88	83.10	83.80	12.517	13.500	0.9272	54
7Y-L23	1/2	0.183	0.75	83.10	83.80	10.275	11.501	0.8934	54
7Y-L24	1/2	0.183	1.40	83.10	83.80	24.064	21.470	1.1208	54
7Y-L25	1/2	0.183	1.50	83.10	83.80	21.960	23.003	0.9547	54
20Z-L5	1/2	0.038	1.00	75.70	81.70	2.485	3.104	0.8006	54
20Z-L7	1/5	0.038	0.47	75.70	81.70	1.459	1.459	1.0000	54
1605X-L5	1/2	0.062	1.00	83.25	83.25	4.867	5.161	0.9430	54
1605X-L6	1/2	0.062	1.40	87.60	87.60	6.944	7.603	0.9133	54
1205X-L10	1/2	0.106	1.40	80.50	80.50	10.918	11.947	0.9139	54
7Y-L31	1/2	0.183	1.50	82.60	82.60	20.359	22.673	0.8979	54

Number of specimens	N = 10
Mean	Pm = 0.9365
Coefficient of variation	Vp = 0.0881

Table 58

Comparison of Tested and Predicted Failure Loads of Bolted Connections for Shear Strength Study

Single Shear, without Washers, $F_u/F_y \geq 1.15$

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	$\frac{(P_u)_t}{(P_u)_p}$	Reference
C-M/16-1	1/2	0.061	0.51	50.50	74.10	2.770	2.305	1.2016	52
C-M/16-2	1/2	0.061	0.52	50.50	74.10	3.090	2.350	1.3145	52
C-M/16-3	1/2	0.061	1.00	50.50	74.10	4.368	4.520	0.9663	52
C-M/16-4	1/2	0.061	1.00	50.50	74.10	4.499	4.520	0.9953	52
B-0-1-1-0	1/4	0.027	0.38	44.06	53.25	0.520	0.539	0.9640	53
B-0-1-2-0	1/4	0.027	0.38	44.06	53.25	0.560	0.539	1.0386	53
B-0-1-3-T	1/4	0.027	0.38	44.06	53.25	0.533	0.539	0.9880	53
B-0-1-4-T	1/4	0.027	0.38	44.06	53.25	0.533	0.539	0.9880	53

Number of specimens	N = 8
Mean	Pm = 1.0570
Coefficient of variation	Vp = 0.1148

Table 59

Comparison of Tested and Predicted Failure Loads of Bolted Connections for Shear Strength Study

Single Shear, without Washers, Fu/Fy < 1.15

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	$\frac{(Pu)t}{(Pu)p}$	Reference
C-M/20-1	1/2	0.037	1.00	53.50	58.90	2.390	2.179	1.0968	52
C-M/20-2	1/2	0.037	1.00	53.50	58:90	2.362	2.179	1.0840	52
C-M/20-3	1/2	0.037	0.50	53.50	58.90	1.680	1.090	1.5413	52
C-M/20-4	1/2	0.037	0.50	53.50	58.90	1.521	1.090	1.3954	52
C-M/20-5	1/2	0.037	1.00	53.50	58.90	2.157	2.179	0.9899	52
C-M/20-6	1/2	0.037	1.00	53.50	58.90	2.160	2.179	0.9913	52
C-M/20-7	1/2	0.037	1.00	53.50	58.90	2.190	2.179	1.0050	52
C-M/20-8	1/2	0.037	1.00	53.50	58.90	2.161	2.179	0.9917	52

Number of specimens	N = 8
Mean	Pm = 1.1369
Coefficient of variation	Vp = 0.1869

Table 60

Comparison of Tested and Predicted Ultimate Tensile Strengths of Bolted Connections

t < 3/16 in., Double Shear, with Washers

Specimen	d (in.)	t (in.)	s (in.)	Fy (ksi)	Fu (ksi)	$(\sigma_{net})_t$ (ksi)	$(\sigma_{net})_p$ (ksi)	$\frac{(\sigma_{net})_t}{(\sigma_{net})_p}$	Reference
20A21DS2	1/4	0.044	4.00	32.11	41.85	9.66	12.03	0.8029	49
20A22DS	3/8	0.033	4.00	32.11	41.85	14.85	15.96	0.9307	49
20A23DS1	1/2	0.035	4.00	32.11	41.85	20.80	19.88	1.0463	49
20A33DS1	1/2	0.036	4.00	32.11	41.85	23.60	19.88	1.1872	49
20A43DS	1/2	0.036	4.00	32.11	41.85	29.00	19.88	1.4588	49
20A34DS	5/8	0.035	4.00	32.11	41.85	35.81	23.80	1.5045	49
20A44DS1	5/8	0.036	4.00	32.11	41.85	34.56	23.80	1.4520	49
20A25DS	3/4	0.036	4.00	32.11	41.85	29.86	27.73	1.0770	49
20A35DS1	3/4	0.036	4.00	32.11	41.85	35.68	27.73	1.2869	49
16C403DS1	1/2	0.059	4.00	32.00	44.00	31.33	20.90	1.4990	49
16C503DS1	1/2	0.059	4.00	32.00	44.00	34.98	20.90	1.6737	49
14A43DS1	1/2	0.077	4.00	29.80	43.40	29.77	20.61	1.4441	49
14B25DS1	3/4	0.080	4.00	29.80	43.40	28.38	28.75	0.9870	49
14B35DS1	3/4	0.077	4.00	29.80	43.40	34.27	28.75	1.1919	49

Table 60 (Continued)

Specimen	d (in.)	t (in.)	s (in.)	Fy (ksi)	Fu (ksi)	$(\sigma_{net})_t$ (ksi)	$(\sigma_{net})_p$ (ksi)	$\frac{(\sigma_{net})_t}{(\sigma_{net})_p}$	Reference
14B26DS1	1/1	0.076	4.00	29.80	43.40	37.60	36.89	1.0192	49
14B36DS1	1/1	0.073	4.00	29.80	43.40	42.39	36.89	1.1491	49
12A34DS1	5/8	0.092	4.00	26.00	41.15	31.83	23.40	1.3600	49
12A44DS1	5/8	0.092	4.00	26.00	41.15	36.87	23.40	1.5754	49
8B45DS1	3/4	0.181	4.00	32.00	46.00	46.50	30.47	1.5258	49
18E34DS1	5/8	0.045	4.00	46.75	68.00	43.98	38.67	1.1372	50
18E44DS1	5/8	0.045	4.00	46.75	68.00	45.84	38.67	1.1853	50
14E25DS1	3/4	0.078	4.00	54.44	70.40	42.10	46.64	0.9027	50
14E45DS1	3/4	0.078	4.00	54.44	70.40	67.40	46.64	1.4451	50
10E25DS1	3/4	0.135	4.00	59.50	71.85	44.85	47.60	0.9422	50
10E16DS1	1/1	0.142	4.00	59.50	71.85	35.40	61.07	0.5796	50
10E46DS1	1/1	0.141	4.00	59.50	71.85	69.40	61.07	1.1364	50
14G25DS1	3/4	0.077	2.00	29.80	43.40	47.80	53.16	0.8991	50
14G35DS	3/4	0.076	2.00	29.80	43.40	48.30	53.16	0.9085	50
14G45DS	3/4	0.076	2.00	29.80	43.40	49.70	53.16	0.9348	50
20Z-L9	3/4	0.039	2.50	75.50	81.70	74.00	81.70	0.9058	54

Table 60 (Continued)

Specimen	d (in.)	t (in.)	s (in.)	Fy (ksi)	Fu (ksi)	$(\sigma_{net})_t$ (ksi)	$(\sigma_{net})_p$ (ksi)	$\frac{(\sigma_{net})_t}{(\sigma_{net})_p}$	Reference
20Z-T13	3/4	0.039	2.50	99.40	99.80	74.45	99.80	0.7460	54
1605X-L2	3/4	0.065	2.50	83.25	83.25	85.70	83.25	1.0294	54
1605X-L3	3/4	0.065	2.50	83.25	83.25	68.72	83.25	0.8255	54
1205X-L8	3/4	0.105	3.00	81.60	81.60	81.85	69.36	1.1801	54
1205X-L9	7/8	0.105	3.50	81.60	81.60	83.25	69.36	1.2003	54
1205X-L11	3/4	0.105	2.50	80.50	80.50	77.30	80.50	0.9602	54
7Y-L32	5/8	0.183	3.00	82.60	82.60	66.20	59.88	1.1055	54
16FAX-L12	3/4	0.060	2.50	30.10	45.90	46.00	45.90	1.0022	54
16FAX-L13	3/4	0.060	2.50	30.10	45.90	46.20	45.90	1.0065	54
16FAX-L15	1/2	0.060	2.50	31.10	45.90	43.87	32.13	1.3654	54
1610X-L18	3/4	0.060	2.50	78.40	81.50	84.32	81.50	1.0346	54
12FAX-L18	3/4	0.107	2.50	28.10	44.10	45.10	44.10	1.0227	54
12FAX-L20	1/2	0.107	2.50	28.10	44.10	41.10	30.87	1.3314	54
1210X-L32	3/4	0.107	2.50	70.10	72.80	77.70	72.80	1.0673	54
1210X-L25	1/2	0.107	2.00	70.10	72.80	77.10	61.88	1.2460	54
1215X-L26	3/4	0.107	2.50	65.20	69.30	66.00	69.30	0.9524	54

Table 60 (Continued)

Specimen	d (in.)	t (in.)	s (in.)	Fy (ksi)	Fu (ksi)	$(\sigma_{net})_t$ (ksi)	$(\sigma_{net})_p$ (ksi)	$\frac{(\sigma_{net})_t}{(\sigma_{net})_p}$	Reference
1215X-L29	1/2	0.107	2.00	65.20	69.30	69.83	58.90	1.1855	54
1215X-L30	3/4	0.107	2.50	36.60	50.00	53.61	50.00	1.0722	54
1225X-L31	1/2	0.107	2.50	36.60	50.00	42.40	35.00	1.2114	54
1225X-L32	1/2	0.107	2.50	36.60	50.00	42.50	35.00	1.2143	54
1225X-L33	1/2	0.107	2.00	36.60	50.00	51.50	42.50	1.2118	54

Number of specimens	N = 51
Mean	Pm = 1.1396
Coefficient of variation	Vp = 0.2020

Table 61

Comparison of Tested and Predicted Ultimate Tensile Strengths of Bolted Connections

t < 3/16 in., Single Shear, with Washers

Specimen	d (in.)	t (in.)	s (in.)	Fy (ksi)	Fu (ksi)	$(\sigma_{net})_t$ (ksi)	$(\sigma_{net})_p$ (ksi)	$\frac{(\sigma_{net})_t}{(\sigma_{net})_p}$	Reference
20A41SS1	1/4	0.035	4.00	32.11	41.85	15.50	12.03	1.2882	49
20A41SS2	1/4	0.035	4.00	32.11	41.85	14.87	12.03	1.2359	49
20A22SS1	3/8	0.035	4.00	32.11	41.85	13.50	15.96	0.8461	49
20A32SS1	3/8	0.034	4.00	32.11	41.85	14.74	15.96	0.9238	49
20A32SS2	3/8	0.034	4.00	32.11	41.85	19.94	15.96	1.2497	49
20A42SS1	3/8	0.035	4.00	32.11	41.85	14.35	15.96	0.8994	49
20A42SS3	3/8	0.036	4.00	32.11	41.85	13.10	15.96	0.8210	49
20A23SS1	1/2	0.035	4.00	32.11	41.85	17.15	19.88	0.8627	49
20A43SS1	1/2	0.035	4.00	32.11	41.85	17.19	19.88	0.8647	49
20A43SS3	1/2	0.036	4.00	32.11	41.85	20.55	19.88	1.0338	49
20A34SS	5/8	0.036	4.00	32.11	41.85	24.64	23.80	1.0352	49
20A44SS	5/8	0.035	4.00	32.11	41.85	21.90	23.80	0.9201	49
20A25SS1	3/4	0.036	4.00	32.11	41.85	25.30	27.73	0.9125	49
20A35SS1	3/4	0.036	4.00	32.11	41.85	25.13	27.73	0.9064	49

Table 61 (Continued)

Specimen	d (in.)	t (in.)	s (in.)	Fy (ksi)	Fu (ksi)	$(\sigma_{net})_t$ (ksi)	$(\sigma_{net})_p$ (ksi)	$\frac{(\sigma_{net})_t}{(\sigma_{net})_p}$	Reference
16C305SS	3/4	0.059	4.00	32.00	44.00	31.28	29.15	1.0731	49
16C505SS	3/4	0.059	4.00	32.00	44.00	30.32	29.15	1.0401	49
14A23SS1	1/2	0.083	4.00	29.80	43.40	17.97	20.61	0.8717	49
14B25SS1	3/4	0.080	4.00	29.80	43.40	25.12	28.75	0.8737	49
14B35SS1	3/4	0.077	4.00	29.80	43.40	23.79	28.75	0.8274	49
14B45SS	3/4	0.081	4.00	29.80	43.40	26.21	28.75	0.9116	49
14B26SS1	1/1	0.077	4.00	29.80	43.40	33.33	36.89	0.9035	49
14B36SS1	3/4	0.074	4.00	29.80	43.40	33.31	28.75	1.1585	49
14B46SS1	3/4	0.079	4.00	29.80	43.40	35.90	28.75	1.2486	49
12A34SS1	5/8	0.092	4.00	26.00	41.15	37.20	23.40	1.5895	49
12A44SS1	5/8	0.092	4.00	26.00	41.15	24.30	23.40	1.0383	49
8B45SS1	3/4	0.187	4.00	32.00	46.00	29.07	30.47	0.9539	49
18E42SS1	3/8	0.045	4.00	46.75	68.00	20.85	25.92	0.8042	50
18E24SS1	5/8	0.044	4.00	46.75	68.00	29.78	38.67	0.7700	50
18E34SS	5/8	0.044	4.00	46.75	68.00	37.80	38.67	0.9774	50
18E44SS1	5/8	0.045	4.00	46.75	68.00	35.04	38.67	0.9060	50

Table 61 (Continued)

Specimen	d (in.)	t (in.)	s (in.)	Fy (ksi)	Fu (ksi)	$(\sigma_{net})_t$ (ksi)	$(\sigma_{net})_p$ (ksi)	$\frac{(\sigma_{net})_t}{(\sigma_{net})_p}$	Reference
14E35SS1	3/4	0.079	4.00	54.44	70.40	47.95	46.64	1.0281	50
14E45SS1	3/4	0.078	4.00	54.44	70.40	55.45	46.64	1.1889	50
10E26SS1	1/1	0.146	4.00	59.50	71.85	55.25	61.07	0.9047	50
14G25SS	3/4	0.077	2.00	29.80	43.40	49.40	53.16	0.9292	50
14G35SS	3/4	0.075	2.00	29.80	43.40	47.00	53.16	0.8840	50
14G45SS	3/4	0.080	2.00	29.80	43.40	46.50	53.16	0.8746	50
12Y-L12	1/2	0.104	2.70	72.40	72.80	50.96	47.72	1.0678	54
12Y-L13	5/8	0.104	3.30	72.40	72.80	36.00	48.64	0.7401	54
12Y-L14	3/4	0.104	3.90	72.40	72.80	70.64	49.28	1.4334	54
12Y-L15	3/8	0.104	1.50	72.40	72.80	66.12	61.88	1.0685	54
12Y-L17	5/8	0.104	2.50	72.40	72.80	54.70	61.88	0.8840	54
12Y-L18	3/4	0.104	3.00	72.40	72.80	52.22	61.88	0.8439	54
12Y-L19	7/8	0.104	3.50	72.40	72.80	52.55	61.88	0.8492	54
7Y-T3	3/4	0.183	1.50	86.40	91.30	84.74	146.08	0.5801	54
7Y-L5	3/4	0.183	3.80	83.10	83.90	52.00	58.07	0.8955	54
7Y-L6	3/4	0.183	3.80	83.10	83.90	79.00	58.07	1.3605	54

Table 61 (Continued)

Specimen	d (in.)	t (in.)	s (in.)	Fy (ksi)	Fu (ksi)	$(\sigma_{net})_t$ (ksi)	$(\sigma_{net})_p$ (ksi)	$\frac{(\sigma_{net})_t}{(\sigma_{net})_p}$	Reference
12Y-L27	3/8	0.105	0.90	87.00	88.10	85.00	118.93	0.7147	54
12Y-L28	5/8	0.105	1.50	87.00	88.10	88.70	118.93	0.7458	54
7Y-T30	3/4	0.183	1.90	87.00	88.10	96.60	113.14	0.8538	54
7Y-L20	3/4	0.183	1.50	83.10	83.80	84.60	134.08	0.6310	54
7Y-L21	3/4	0.183	2.50	83.10	83.80	83.10	83.80	0.9916	54
20Z-L1	1/2	0.039	1.50	75.50	81.70	85.30	89.87	0.9491	54
20Z-L2	1/2	0.039	1.50	75.50	81.70	74.90	89.87	0.8334	54
20Z-L3	3/4	0.039	2.50	75.50	81.70	63.80	81.70	0.7809	54
20Z-T10	1/2	0.039	1.50	94.40	99.80	70.80	109.78	0.6449	54
20Z-T11	1/2	0.039	2.50	94.40	99.80	40.23	69.86	0.5759	54
1605X-L1	3/4	0.065	2.50	83.25	83.25	81.30	83.25	0.9766	54
16FAX-L16	1/2	0.060	2.50	30.10	45.90	41.30	32.13	1.2854	54

Number of specimens	N = 58
Mean	P_m = 0.9528
Coefficient of variation	V_p = 0.2101

Table 62

Comparison of Tested and Predicted Failure Loads of Bolted Connections for Bearing Strength Study

0.024 in. $\leq$ t < 3/16 in., Double Shear with Washers, Fu/Fy $\geq$ 1.15

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	$\frac{(Pu)t}{(Pu)p}$	Reference
20A41DS	1/4	0.036	1.13	32.11	41.85	1.857	1.252	1.4832	49
16C403DS	1/2	0.059	2.00	31.95	43.95	6.620	4.318	1.5330	49
16C503DS	1/2	0.059	2.50	31.95	43.95	7.200	4.318	1.6673	49
14E35DS	3/4	0.078	2.63	54.44	70.40	14.223	13.747	1.0352	50
10E36DS	1/1	0.143	3.50	59.50	71.85	28.507	34.165	0.8344	50
10E46DS	1/1	0.143	4.50	59.50	71.85	28.814	34.165	0.8434	50
16FAX-L15	1/2	0.062	1.75	30.10	45.90	5.016	4.731	1.0602	54
16FAX-L17	1/2	0.062	1.75	30.10	45.90	4.216	4.731	0.8911	54
12FAX-L20	1/2	0.106	1.75	28.10	44.10	8.438	7.772	1.0857	54
12FAX-L21	1/2	0.106	1.75	28.10	44.10	9.455	7.772	1.2165	54
DS1-1	7/8	0.116	3.06	35.49	49.44	16.400	16.686	0.9829	51
DS1-2	7/8	0.116	3.06	35.49	49.44	15.100	16.686	0.9050	51
DS2-1	1/1	0.115	3.50	35.49	49.44	16.000	18.905	0.8463	51
DS2-2	1/1	0.116	3.50	35.49	49.44	16.600	19.070	0.8705	51

Table 62 (Continued)

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	(Pu)t / (Pu)p	Reference
DS3-1	7/8	0.181	3.06	38.10	62.08	33.249	32.693	1.0170	51
DS3-2	7/8	0.180	3.06	38.10	62.08	30.892	32.512	0.9502	51
DS4-1	1/1	0.182	3.50	38.10	62.08	41.700	37.569	1.1100	51
DS4-2	1/1	0.181	3.50	38.10	62.08	40.501	37.362	1.0840	51

Number of specimens	N = 18
Mean	Pm = 1.0787
Coefficient of variation	Vp = 0.2300

Table 63

Comparison of Tested and Predicted Failure Loads of Bolted Connections for Bearing Strength Study

0.024 in. $\leq$ t < 3/16 in., Double Shear with Washers, Fu/Fy < 1.15

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	$\frac{(Pu)t}{(Pu)p}$	Reference
20Z-L8	1/5	0.038	0.66	75.70	81.70	1.566	1.861	0.8413	54
1205X-L7	3/4	0.106	2.63	81.60	81.60	20.034	19.442	1.0304	54
1205X-L8	3/4	0.106	2.63	81.60	81.60	18.762	19.442	0.9650	54
1205X-L9	7/8	0.106	3.06	81.60	81.60	22.445	22.682	0.9896	54
7Y-L32	5/8	0.183	2.19	81.60	81.60	28.251	27.971	1.0100	54

Number of specimens	N = 5
Mean	Pm = 0.9673
Coefficient of variation	Vp = 0.0689

Table 64

Comparison of Tested and Predicted Failure Loads of Bolted Connections for Bearing Strength Study

0.024 in. $\leq$ t < 3/16 in., Single Shear with Washers, Fu/Fy $\geq$ 1.15

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	$\frac{(Pu)t}{(Pu)p}$	Reference
20A41SS	1/4	0.036	1.13	32.11	41.83	1.875	1.128	1.6615	49
14A43SS	1/2	0.080	2.25	32.11	41.83	7.100	5.015	1.4159	49
10E36SS	1/1	0.143	3.50	59.47	76.84	24.632	32.931	0.7480	50
16FAX-L16	1/2	0.062	1.75	30.10	45.90	4.718	4.264	1.1064	54
SS2	7/8	0.116	3.06	35.49	49.44	16.095	15.039	1.0702	51
SS2-1	7/8	0.116	3.06	35.49	49.44	12.375	15.039	0.8228	51
SS3	7/8	0.116	4.40	35.49	49.44	15.153	15.039	1.0075	51
SS5	1/1	0.116	3.50	35.49	49.44	15.525	17.188	0.9033	51
SS5-1	1/1	0.116	3.50	35.49	49.44	13.643	17.188	0.7937	51
SS6	1/1	0.116	3.50	35.49	49.44	15.341	17.188	0.8925	51
SS8	7/8	0.181	3.06	38.10	62.08	33.001	29.466	1.1199	51
SS8-1	7/8	0.181	3.06	38.10	62.08	24.800	29.466	0.8416	51
SS9	7/8	0.185	4.38	38.10	62.08	32.751	30.117	1.0874	51
SS11	1/1	0.184	3.50	38.10	62.08	36.800	34.234	1.0750	51

Table 64 (Continued)

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	(Pu)t / (Pu)p	Reference
SS11-1	1/1	0.184	3.50	38.10	62.08	30.299	34.234	0.8851	51
SS12	1/1	0.184	5.00	38.10	62.08	35.300	34.234	1.0312	51
----	1/2	0.051	2.03	40.60	50.10	4.049	3.829	1.0576	52
----	1/2	0.051	2.03	40.60	50.10	4.230	3.829	1.1049	52
----	1/2	0.061	1.94	50.50	74.10	6.152	6.773	0.9082	52
B-1-8-1-T	3/8	0.025	1.31	45.00	52.00	1.370	1.461	0.9377	53
B-1-3-3-T	3/8	0.025	1.31	45.00	52.00	1.220	1.461	0.8350	53
B-1-9-1-T	3/8	0.024	1.66	45.00	52.00	1.440	1.403	1.0267	53
B-1-9-2-T	3/8	0.024	1.69	45.00	52.00	1.238	1.403	0.8827	53
B-1-9-3-T	3/8	0.024	1.69	45.00	52.00	1.712	1.403	1.2206	53

Number of specimens	N = 24
Mean	Pm = 1.0181
Coefficient of variation	Vp = 0.1966

Table 65

Comparison of Tested and Predicted Failure Loads of Bolted Connections for Bearing Strength Study

0.024 in. ≤ t < 3/16 in., Single Shear with Washers, Fu/Fy < 1.15

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	(Pu)t / (Pu)p	Reference
12Y-L7	1/2	0.106	1.75	72.40	72.80	12.667	11.564	1.0954	54
12Y-L8	3/8	0.106	1.50	72.40	72.80	9.739	8.673	1.1229	54
12Y-L9	1/2	0.106	1.75	72.40	72.80	14.151	11.564	1.2238	54
12Y-L11	3/8	0.106	1.49	72.40	72.80	8.586	8.673	0.9900	54
12Y-L12	1/2	0.106	1.75	72.40	72.80	11.183	11.564	0.9671	54
12Y-L15	3/8	0.106	1.50	72.40	72.80	7.711	8.673	0.8892	54
12Y-L16	1/2	0.106	1.75	72.40	72.80	11.183	11.564	0.9671	54
12Y-L18	3/4	0.106	2.65	72.40	72.80	12.163	17.345	0.7013	54
7Y-L6	3/4	0.183	3.75	83.10	83.80	42.136	34.470	1.2224	54
20Z-T12	1/5	0.038	0.66	99.40	99.80	1.976	2.273	0.8693	54
----	1/2	0.037	2.00	53.52	58.90	3.700	3.266	1.1330	52
----	1/2	0.037	2.00	53.50	58.90	3.659	3.266	1.1205	52
----	1/3	0.037	2.06	53.50	58.90	2.262	2.177	1.0390	52
----	1/3	0.037	2.04	53.50	58.90	2.348	2.177	1.0786	52

Table 65 (Continued)

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	(Pu)t / (Pu)p	Reference
----	1/2	0.037	2.50	53.50	58.90	3.841	3.266	1.1760	52
----	1/2	0.037	2.00	53.50	58.90	3.970	3.266	1.2157	52

Number of specimens	N = 16
Mean	Pm = 1.0507
Coefficient of variation	Vp = 0.1348

Table 66

Comparison of Tested and Predicted Failure Loads of Bolted Connections for Bearing Strength Study

0.036 in. ≤ t < 3/16 in., Single Shear without Washers, Fu/Fy ≥ 1.15

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	(Pu)t / (Pu)p	Reference
C-M/17-1	1/2	0.051	2.06	40.60	50.10	2.889	2.811	1.028	52
C-M/17-2	1/2	0.051	2.01	40.60	50.10	2.984	2.811	1.062	52
C-M/17-3	1/2	0.051	2.01	40.60	50.10	2.940	2.811	1.046	52
C-M/17-4	5/16	0.051	2.05	40.60	50.10	1.747	1.757	0.994	52
C-M/17-5	5/16	0.051	2.07	40.60	50.10	1.796	1.757	1.022	52
C-M/17-6	1/2	0.051	1.97	40.60	50.10	2.785	2.811	0.991	52
C-M/16-7	1/2	0.061	1.97	50.50	74.10	4.490	4.972	0.903	52
C-M/14-8	3/4	0.079	3.00	52.80	65.90	8.597	8.590	0.999	52
C-M/14-9	3/4	0.079	3.01	52.80	65.90	8.153	8.590	0.949	52
C-M/14-10	3/4	0.079	3.00	52.80	65.90	9.172	8.590	1.068	52
C-M/12-11	3/4	0.104	3.03	59.30	70.60	12.503	12.115	1.032	52
C-M/17-12	1/2	0.051	1.50	40.60	50.10	2.861	2.811	1.018	52
C-M/17-13	1/2	0.051	1.44	40.60	50.10	2.899	2.811	1.031	52

Table 66 (Continued)

Number of specimens	$N = 13$
Mean	$Pm = 1.011$
Coefficient of variation	$Vp = 0.043$

Table 67

Comparison of Tested and Predicted Failure Loads of Bolted Connections for Bearing Strength Study

0.036 in. ≤ t < 3/16 in., Double Shear without Washers, Fu/Fy ≥ 1.15

Specimen	d (in.)	t (in.)	e (in.)	Fy (ksi)	Fu (ksi)	(Pu)t (kips)	(Pu)p (kips)	$\frac{(Pu)t}{(Pu)p}$	Reference
B-0-5-1-T	1/2	0.046	1.72	43.83	55.73	2.533	2.820	0.900	53
B-0-5-2-T	1/2	0.046	1.72	43.83	55.73	2.645	2.820	0.938	53
B-0-5-3-T	1/2	0.046	1.75	43.83	55.73	2.628	2.820	0.932	53
B-0-5-4-T	1/2	0.047	1.75	43.83	55.73	2.868	2.881	0.995	53
B-0-5-5-T	1/2	0.047	1.75	43.83	55.73	2.830	2.881	0.992	53
B-0-6-1-T	1/2	0.046	2.25	43.83	55.73	2.675	2.820	0.949	53
B-0-6-2-T	1/2	0.046	2.25	43.83	55.73	2.405	2.820	0.853	53
B-0-6-3-T	1/2	0.046	2.25	43.83	55.73	2.470	2.820	0.876	53

Number of specimens	N = 8
Mean	Pm = 0.928
Coefficient of variation	Vp = 0.050

Table 68

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Transverse Stiffeners at Interior Support and Under Concentrated Load

Specimen	L (in.)	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
ITS-C-1-1	6.025	43.06	3.936	4.17	1.0595	Fig. 21	59
ITS-C-1-2	6.051	43.06	3.978	3.98	1.0005	Fig. 21	59
ITS-C-1-3	6.050	43.06	3.967	4.07	1.0260	Fig. 21	59
ITS-C-2-1	8.054	43.06	3.769	4.09	1.0852	Fig. 21	59
ITS-C-2-2	8.051	43.06	3.725	3.98	1.0685	Fig. 21	59
ITS-C-2-3	8.056	43.06	3.702	4.42	1.1939	Fig. 21	59
ITS-C-4-3	11.844	43.06	3.109	3.72	1.1965	Fig. 21	59
ITS-C-4-4	11.844	43.06	3.200	4.42	1.3813	Fig. 21	59
ITS-C-4-5	11.844	43.06	3.103	4.28	1.3793	Fig. 21	59
ITS-C-5-1	7.508	43.06	3.690	4.06	1.1003	Fig. 21	59
ITS-C-5-2	7.489	43.06	3.689	4.02	1.0897	Fig. 21	59
ITS-C-6-1	9.894	43.06	3.459	4.13	1.1940	Fig. 21	59
ITS-C-6-2	9.894	43.06	3.478	4.02	1.1558	Fig. 21	59
ITS-C-3-1	9.955	43.06	3.470	3.76	1.0836	Fig. 21	59

Table 68 (Continued)

Specimen	L (in.)	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
ITS-C-3-2	9.960	43.06	3.469	3.62	1.0435	Fig. 21	59
ITS-C-4-1	11.844	43.06	3.082	3.52	1.1421	Fig. 21	59
ITS-C-4-2	11.844	43.06	3.161	3.72	1.1768	Fig. 21	59
ITS-S-7-1	15.063	43.06	2.583	3.25	1.2582	Fig. 21	59
ITS-S-7-2	14.969	43.06	2.580	3.43	1.3295	Fig. 21	59
ITS-S-7-3	14.860	43.06	2.659	3.34	1.2561	Fig. 21	59
ITS-S-8-1	17.969	47.63	2.856	3.12	1.0924	Fig. 21	59
ITS-S-8-2	17.985	47.63	3.027	3.81	1.2587	Fig. 21	59
ITS-S-9-1	14.750	47.63	3.982	4.58	1.1502	Fig. 21	59
ITS-S-9-2	14.641	47.63	3.980	4.66	1.1709	Fig. 21	59
ITS-S-10-1	12.094	47.63	4.482	4.95	1.1044	Fig. 21	59
ITS-S-10-2	12.063	47.63	4.697	5.29	1.1263	Fig. 21	59
ITS-S-11-1	21.094	47.63	2.392	3.01	1.2584	Fig. 21	59
ITS-S-11-2	21.063	47.63	2.387	2.90	1.2149	Fig. 21	59
ITS-S-11-3	21.031	47.63	2.378	2.96	1.2447	Fig. 21	59
ITS-S-12-1	18.063	47.63	3.272	3.98	1.2164	Fig. 21	59

Table 68 (Continued)

Specimen	L (in.)	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
ITS-S-12-2	18.047	47.63	2.768	3.85	1.3909	Fig. 21	59
ITS-S-13-1	14.963	47.63	4.426	5.22	1.1794	Fig. 21	59
ITS-S-13-2	14.969	47.63	4.319	5.12	1.1855	Fig. 21	59

Number of specimens	N = 33
Mean	Pm = 1.1762
Coefficient of variation	Vp = 0.08658

Table 69

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Transverse Stiffeners at End Support

Specimen	L (in.)	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
ETS-C-1-1	6.059	43.06	3.524	3.68	1.0443	Fig. 21	59
ETS-C-1-2	6.059	43.06	3.559	3.76	1.0565	Fig. 21	59
ETS-C-2-1	8.035	43.06	3.389	3.79	1.1183	Fig. 21	59
ETS-C-2-2	8.022	43.06	3.370	3.57	1.0593	Fig. 21	59
ETS-C-3-3	9.970	43.06	3.104	3.77	1.2146	Fig. 21	59
ETS-C-4-3	11.844	43.06	2.854	3.52	1.2334	Fig. 21	59
ETS-C-5-1	7.509	43.06	3.229	3.88	1.2016	Fig. 21	59
ETS-C-5-2	7.506	43.06	3.172	3.93	1.2390	Fig. 21	59
ETS-C-6-1	9.902	43.06	2.996	3.70	1.2350	Fig. 21	59
ETS-C-6-2	9.852	43.06	2.994	3.91	1.3059	Fig. 21	59
ETS-C-3-1	9.997	43.06	3.182	3.43	1.0779	Fig. 21	59
ETS-C-3-2	9.984	43.06	3.186	3.40	1.0672	Fig. 21	59
ETS-C-4-1	11.844	43.06	2.871	3.37	1.1738	Fig. 21	59
ETS-C-4-2	11.844	43.06	2.873	3.24	1.1277	Fig. 21	59

Table 69 (Continued)

Specimen	L (in.)	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
ETS-S-7-1	14.844	43.06	2.494	2.99	1.1989	Fig. 21	59
ETS-S-7-2	14.953	43.06	2.464	3.06	1.2419	Fig. 21	59
ETS-S-8-1	17.969	47.63	2.661	3.30	1.2401	Fig. 21	59
ETS-S-8-2	17.975	47.63	2.276	3.29	1.4455	Fig. 21	59
ETS-S-9-1	14.531	47.63	3.472	4.20	1.2097	Fig. 21	59
ETS-S-9-2	14.516	47.63	3.369	4.00	1.1873	Fig. 21	59
ETS-S-10-1	11.915	47.63	4.222	4.70	1.1132	Fig. 21	59
ETS-S-10-2	12.047	47.63	4.135	4.69	1.1342	Fig. 21	59
ETS-S-11-1	21.047	47.63	1.837	2.63	1.4317	Fig. 21	59
ETS-S-11-2	21.079	47.63	1.766	2.50	1.4156	Fig. 21	59
ETS-S-12-1	18.047	47.63	2.799	3.67	1.3112	Fig. 21	59
ETS-S-12-2	18.025	47.63	2.596	3.35	1.2904	Fig. 21	59
ETS-S-13-1	14.969	47.63	3.570	4.56	1.2773	Fig. 21	59
ETS-S-13-2	15.032	47.63	3.683	4.51	1.2245	Fig. 21	59

Table 69 (Continued)

Number of specimens	$N = 28$
Mean	$P_m = 1.2099$
Coefficient of variation	$V_p = 0.09073$

Table 70

Comparison of Tested and Predicted Failure Shear Forces of Cold-Formed Steel Beams with Shear Stiffeners

Specimen	h/t	Fy (ksi)	(Vu)pred (kips)	(Vu)test (kips)	(Vu)test / (Vu)pred	Cross Section	Reference
S-1-1(A)	145.31	44.80	8.709	14.01	1.6087	Fig. 22	59
S-1-2(A)	145.18	44.80	11.180	15.14	1.3542	Fig. 22	59
S-1-3(A)	146.19	44.80	8.368	13.02	1.5559	Fig. 22	59
S-1-4(A)	144.30	44.80	6.735	11.58	1.7194	Fig. 22	59
S-1-5(A)	145.51	44.80	5.912	10.11	1.7101	Fig. 22	59
S-2-1(A)	152.06	44.07	4.799	8.15	1.6983	Fig. 22	59
S-2-2(A)	153.18	44.07	4.797	7.80	1.6260	Fig. 22	59
S-2-3(B)	155.41	44.07	4.799	7.70	1.6045	Fig. 22	59
S-2-4(B)	158.13	44.07	4.814	8.17	1.6971	Fig. 22	59
S-3-1(A)	151.65	33.46	6.941	9.52	1.3716	Fig. 22	59
S-3-2(A)	152.72	33.46	6.844	9.81	1.4334	Fig. 22	59
S-3-3(C)	155.05	33.46	6.901	9.56	1.3853	Fig. 22	59
S-3-4(C)	154.70	33.46	6.949	9.79	1.4088	Fig. 22	59
S-3-5(D)	152.49	33.46	4.227	6.13	1.4502	Fig. 22	59

Table 70 (Continued)

Specimen	h/t	Fy (ksi)	(Vu)pred (kips)	(Vu)test (kips)	(Vu)test / (Vu)pred	Cross Section	Reference
S-3-6(D)	154.35	33.46	4.204	6.76	1.6080	Fig. 22	59
S-3-7(D)	150.15	33.46	4.446	6.83	1.5362	Fig. 22	59
S-4-1(B)	157.76	44.07	4.739	8.15	1.7198	Fig. 22	59
S-4-2(B)	157.08	44.07	4.737	7.99	1.6867	Fig. 22	59
S-4-3(B)	155.59	44.07	4.782	7.77	1.6248	Fig. 22	59
S-4-4(B)	149.70	44.07	5.011	8.33	1.6627	Fig. 22	59
S-5-1(B)	210.45	44.07	3.500	8.69	2.4829*	Fig. 22	59
S-5-2(B)	210.31	44.07	3.511	9.37	2.6688*	Fig. 22	59
S-6-1(B)	259.78	44.07	2.200	8.01	3.6409*	Fig. 22	59
S-6-2(B)	263.08	44.07	2.145	8.07	3.7622*	Fig. 22	59
S-7-1(B)	258.37	44.07	2.831	10.68	3.7725*	Fig. 22	59
S-7-2(B)	260.37	44.07	2.790	10.53	3.7742*	Fig. 22	59
S-7-3(B)	256.31	44.07	7.992	14.69	1.8381	Fig. 22	59
S-7-4(B)	251.53	44.07	8.343	15.53	1.8614	Fig. 22	59
S-8-1(A)	209.27	51.24	4.019	10.11	2.5156*	Fig. 22	59
S-8-2(A)	213.72	51.24	3.819	10.46	2.7389*	Fig. 22	59

Table 70 (Continued)

Specimen	L (in.)	Fy (ksi)	(Vu)pred (kips)	(Vu)test (kips)	(Vu)test / (Vu)pred	Cross Section	Reference
S-9-1(B)	303.33	44.07	2.410	11.34	4.7054*	Fig. 22	59
S-9-2(B)	305.97	44.07	2.335	11.35	4.8608*	Fig. 22	59

Number of specimens	N = 22
Mean	Pm = 1.5982
Coefficient of variation	Vp = 0.09150

* Data not included in the statistic analysis because of high postbuckling strength

Table 71

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Wall Studs in Compression

Specimen	L (in.)	Fy (ksi)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
1A	144.0	58.0	10.658	11.5	1.0790	Fig. 23	60
2A	144.0	58.0	9.353	10.6	1.1333	Fig. 23	60
5B	144.0	53.0	18.068	23.4	1.2951	Fig. 23	60
6C	144.0	53.0	12.490	15.5	1.2410	Fig. 23	60
7C	144.0	53.0	20.396	23.7	1.1620	Fig. 23	60
8D	144.0	53.0	27.066	26.5	0.9791	Fig. 23	60
9D	144.0	53.0	25.266	26.9	1.0647	Fig. 23	60

Number of specimens	N = 7
Mean	Pm = 1.1363
Coefficient of variation	Vp = 0.0950

Table 72

Comparison of Tested and Predicted Ultimate Moments of Cold-formed Steel Wall Studs in Bending

Specimen	w/t	Fy (ksi)	(Mu)pred (in.-kips)	(Mu)test (in.-kips)	$\frac{(Mu)test}{(Mu)pred}$	Cross Section	Reference
4	14.81	50.16	66.167	83.34	1.2595	Fig. 24	61
10	14.81	50.16	66.167	84.20	1.2725	Fig. 24	61

Number of specimens	N = 2
Mean	Pm = 1.2660
Coefficient of variation	Vp = 0.0073

Table 73

Comparison of Tested and Predicted Failure Loads of Cold-Formed Steel Wall Studs with Combined Axial Load and Bending

Specimen	L (in.)	Fy (ksi)	(Mu)test (in.-kips)	(Pu)pred (kips)	(Pu)test (kips)	(Pu)test / (Pu)pred	Cross Section	Reference
1	192.0	50.16	1.922	12.355	15.80	1.2788	Fig. 24	61
2	192.0	50.16	3.844	16.294	20.80	1.2765	Fig. 24	61
3	192.0	50.16	3.844	16.294	22.00	1.3502	Fig. 24	61
5	192.0	50.16	1.781	17.641	16.00	0.9070	Fig. 24	61
6	192.0	50.16	13.229	10.035	12.50	1.2456	Fig. 24	61
7	96.0	50.16	0.445	25.266	23.14	0.9159	Fig. 24	61
8	96.0	50.16	3.307	23.012	25.96	1.1281	Fig. 24	61
9	192.0	50.16	13.229	10.035	12.94	1.2895	Fig. 24	61
11	192.0	50.16	6.360	13.986	18.30	1.3085	Fig. 24	61
12	192.0	50.16	1.781	17.641	20.74	1.1757	Fig. 24	61

Number of specimens	N = 10
Mean	Pm = 1.1876
Coefficient of variation	Vp = 0.1338

Table 74

Computed Safety Index β for Section Bending Strength of Beams

Case	No. of Tests	M_m	V_M	F_m	V_F	P_m	V_P	β
Stiffened Compression Flanges (ϕ = 0.95)								
FF. FW.	8	1.10	0.10	1.0	0.05	1.10543	0.03928	2.76
PF. FW.	30	1.10	0.10	1.0	0.05	1.11400	0.08889	2.65
PF. PW.	5	1.10	0.10	1.0	0.05	1.08162	0.09157	2.53
Unstiffened Compression Flanges (ϕ = 0.90)								
FF. FW.	3	1.10	0.10	1.0	0.05	1.43330	0.04337	4.05
PF. FW.	40	1.10	0.10	1.0	0.05	1.12384	0.13923	2.67
PF. PW.	10	1.10	0.10	1.0	0.05	1.03162	0.05538	2.66

Note: FF. = Fully effective flanges
PF. = Partially effective flanges
FW. = Fully effective webs
PW. = Partially effective webs

Table 75
Computed Safety Index β for Lateral Buckling Strength of Bending
(ϕ = 0.90)

Case	No. of Tests	M_m	V_M	F_m	V_F	P_m	V_P	β
1	47	1.0	0.06	1.0	0.05	2.5213	0.30955	3.79
2	47	1.0	0.06	1.0	0.05	1.2359	0.19494	2.48
3	47	1.0	0.06	1.0	0.05	1.1800	0.19000	2.35
4	47	1.0	0.06	1.0	0.05	1.7951	0.21994	3.53
5	47	1.0	0.06	1.0	0.05	1.8782	0.20534	3.80

Note: Case 1 = AISI approach
Case 2 = Theoretical approach with J = 0.0026 in.^{4}
Case 3 = SSRC approach with J = 0.0026 in.^{4}
Case 4 = Theoretical approach with J = 0.0008213 in.^{4}
Case 5 = SSRC approach with J = 0.0008213 in.^{4}

Table 76

Computed Safety Index β for Web Crippling Strength of Beams

Case	No. of Tests	M_m	V_M	F_m	V_F	P_m	V_P	β
Single, Unreinforced Webs (ϕ = 0.75)								
1(SF)	68	1.10	0.10	1.0	0.05	1.00	0.12	3.01
1(UF)	30	1.10	0.10	1.0	0.05	1.00	0.16	2.80
2(UMR)	54	1.10	0.10	1.0	0.05	0.99	0.11	3.02
2(CA)	38	1.10	0.10	1.0	0.05	0.86	0.14	2.36
2(SUM)	92	1.10	0.10	1.0	0.05	0.94	0.14	2.67
3(UMR)	26	1.10	0.10	1.0	0.05	0.99	0.09	3.11
3(CA)	63	1.10	0.10	1.0	0.05	1.72	0.26	3.80
3(SUM)	89	1.10	0.10	1.0	0.05	1.51	0.34	2.95
4(UMR)	26	1.10	0.10	1.0	0.05	0.98	0.10	3.03
4(CA)	70	1.10	0.10	1.0	0.05	1.04	0.26	2.39
4(SUM)	96	1.10	0.10	1.0	0.05	1.02	0.23	2.49
I-Sections (ϕ = 0.80)								
1	72	1.10	0.10	1.0	0.05	1.10	0.19	2.74
2	27	1.10	0.10	1.0	0.05	0.96	0.13	2.57
3	53	1.10	0.10	1.0	0.05	1.01	0.13	2.76
4	62	1.10	0.10	1.0	0.05	1.02	0.11	2.89

Note: Case 1 = End one-flange loading

Case 2	=	Interior one-flange loading
Case 3	=	End two-flange loading
Case 4	=	Interior two-flange loading
SF	=	Stiffened flanges
UF	=	Unstiffened flanges
UMR	=	UMR tests only
CA	=	Canadian tests only
SUM	=	Combine UMR and Canadian tests together

Table 77

Computed Safety Index β for Combined Bending and Web Crippling

Case	No. of Tests	M_m	V_M	F_m	V_F	P_m	V_P	β
Single, Unreinforced Webs (Interior one-flange loading) (Based on $\phi_w = 0.75$)								
1	74	1.10	0.10	1.0	0.05	1.01	0.07	3.27
2	202	1.10	0.10	1.0	0.05	0.87	0.13	2.45
3	103	1.10	0.10	1.0	0.05	0.95	0.10	2.91
4	66	1.10	0.10	1.0	0.05	1.03	0.18	2.79
5	445	1.10	0.10	1.0	0.05	0.94	0.14	2.68
I-Sections (Interior one-flange loading) (Based on $\phi_w = 0.80$)								
1	106	1.10	0.10	1.0	0.05	1.06	0.12	2.99

Note: Case 1 = UMR and Cornell tests only
Case 2 = Canadian brake-formed section tests only
Case 3 = Canadian roll-formed section tests only
Case 4 = Hoglund's tests only
Case 5 = Combine all tests together

Table 78
Computed Safety Index β for Concentrically Loaded Compression Members
(ϕ = 0.85)

Case	No. of Tests	M_m	V_M	F_m	V_F	P_m	V_P	β
1	5	1.10	0.10	1.0	0.05	1.14610	0.10452	3.13
2	24	1.10	0.10	1.0	0.05	1.05053	0.07971	2.89
3	15	1.10	0.10	1.0	0.05	1.05523	0.07488	2.93
4	3	1.10	0.10	1.0	0.05	1.10550	0.07601	3.11
5	28	1.10	0.10	1.0	0.05	1.04750	0.11072	2.76
6	25	1.10	0.10	1.0	0.05	1.22391	0.21814	2.72
7	9	1.00	0.06	1.0	0.05	0.96330	0.04424	2.39
8	41	1.10	0.10	1.0	0.05	1.19620	0.09608	3.34
9	18	1.10	0.10	1.0	0.05	1.02900	0.08131	2.81
10	12	1.10	0.11	1.0	0.05	1.06180	0.11062	2.77
11	8	1.00	0.06	1.0	0.05	1.15290	0.10544	2.92
12	30	1.10	0.10	1.0	0.05	1.07960	0.15061	2.68
13	14	1.10	0.10	1.0	0.05	1.07930	0.08042	3.00
14	32	1.10	0.10	1.0	0.05	1.08050	0.10772	2.89

Note: Case 1 = Stub columns having unstiffened compression flanges with fully effective widths
Case 2 = Stub columns having unstiffened compression flanges with partially effective widths
Case 3 = Thin plates with partially effective widths
Case 4 = Stub columns having stiffened compression flanges with fully effective flanges and webs
Case 5 = Stub columns having stiffened compression flanges with partially effective flanges and fully effective webs

Case 6 = Stub columns having stiffened compression flanges with partially effective flanges and partially effective webs
Case 7 = Long columns having unstiffened compression flanges subjected to elastic flexural buckling
Case 8 = Long columns having unstiffened compression flanges subjected to inelastic flexural buckling
Case 9 = Long columns having stiffened compression flanges subjected to inelastic flexural buckling
Case 10 = Long columns subjected to inelastic flexural buckling (including cold-work)
Case 11 = Long columns subjected to elastic torsional-flexural buckling
Case 12 = Long columns subjected to inelastic torsional-flexural buckling
Case 13 = Stub columns with circular perforations
Case 14 = Long columns with circular perforations

Table 79
Computed Safety Index β for Combined Axial Load and Bending

Case	No. of Tests	M_m	V_M	F_m	V_F	P_m	V_P	β
1	18	1.05	0.10	1.0	0.05	1.0367	0.06619	2.70
2	13	1.05	0.10	1.0	0.05	1.0509	0.07792	2.72
3	33	1.05	0.10	1.0	0.05	1.1028	0.09182	2.86
4	18	1.05	0.10	1.0	0.05	1.1489	0.10478	2.96
5	6	1.05	0.10	1.0	0.05	1.1600	0.13000	2.87
6	17	1.05	0.10	1.0	0.05	1.1200	0.09000	2.92
7	10	1.05	0.10	1.0	0.05	1.2300	0.08000	3.34
8	17	1.05	0.10	1.0	0.05	1.0910	0.07950	2.86
9	12	1.05	0.10	1.0	0.05	1.1110	0.11450	2.79

* β values were determined based on $\phi_c = 0.85$

Note: Case 1 = Locally stable beam-columns, hat sections of Pekoz and Winter (1967)

Case 2 = Locally unstable beam-columns, lipped channel sections of Thomasson (1978)

Case 3 = Locally unstable beam-columns, lipped channel sections of Loughlan (1979)

Case 4 = Locally unstable beam-columns, lipped channel sections of Mulligan and Pekoz (1983)

Case 5 = Locally stable beam-columns, lipped channel sections of Loh and Pekoz (1985) with $e_x \neq 0$ and $e_y = 0$

Case 6 = Locally stable beam-columns, lipped channel sections of Loh and Pekoz (1985) with $e_x = 0$ and $e_y \neq 0$

Case 7 = Locally stable beam-columns, lipped channel sections of Loh and Pekoz (1985) with $e_x \neq 0$ and $e_y \neq 0$

Case 8 = Locally unstable beam-columns, lipped channel sections of Loh and Pekoz (1985) with $e_x=0$ and $e_y\neq0$

Case 9 = Locally unstable beam-columns, lipped channel sections of Loh and Pekoz (1985) with $e_x\neq0$ and $e_y\neq0$

Table 80

Computed Safety Index β for Plate Failure in Welded Connections

Case	M_m	V_M	F_m	V_F	P_m	V_P	ϕ	β
Arc Spot Welds								
1	1.10	0.08	1.00	0.15	1.10	0.17	0.60	3.52
2	1.10	0.08	1.00	0.15	0.98	0.18	0.50	3.64
Fillet Welds								
3	1.10	0.08	1.00	0.15	1.01	0.08	0.60	3.65
4	1.10	0.08	1.00	0.15	0.89	0.09	0.55	3.59
5	1.10	0.08	1.00	0.15	1.05	0.11	0.60	3.72

Note: Case 1 = For $d_a/t \le 0.815\sqrt{(E/F_u)}$
Case 2 = For $d_a/t > 1.397\sqrt{(E/F_u)}$
Case 3 = Longitudinal Loading, $L/t < 25$
Case 4 = Longitudinal Loading, $L/t \ge 25$
Case 5 = Transverse Loading

Table 81

Computed Safety Index β for Bolted Connections

Case	M_m	V_M	F_m	V_F	P_m	V_P	ϕ	β
Minimum Spacing and Edge Distance								
1	1.10	0.08	1.00	0.05	1.13	0.12	0.70	3.75
2	1.10	0.08	1.00	0.05	1.18	0.14	0.70	3.84
3	1.10	0.08	1.00	0.05	0.84	0.05	0.60	3.61
4	1.10	0.08	1.00	0.05	0.94	0.09	0.60	3.90
5	1.10	0.08	1.00	0.05	1.06	0.11	0.70	3.62
6	1.10	0.08	1.00	0.05	1.14	0.19	0.60	3.87
Tension Stress on Net Section								
7	1.10	0.08	1.00	0.05	1.14	0.20	0.65	3.53
8	1.10	0.08	1.00	0.05	0.95	0.21	0.55	3.41
9	1.10	0.08	1.00	0.05	1.04	0.14	0.65	3.63
Bearing Stress on Bolted Connections								
10	1.10	0.08	1.00	0.05	1.08	0.23	0.55	3.65
11	1.10	0.08	1.00	0.05	0.97	0.07	0.65	3.80
12	1.10	0.08	1.00	0.05	1.02	0.20	0.60	3.43
13	1.10	0.08	1.00	0.05	1.05	0.13	0.60	4.06
14	1.10	0.08	1.00	0.05	1.01	0.04	0.70	3.71

Table 81 (Continued)

Case	M_m	V_M	F_m	V_F	P_m	V_P	ϕ	β
15	1.10	0.08	1.00	0.05	0.93	0.05	0.65	3.70
Shear Strength on A307 Bolts								
16	1.28	0.08	1.00	0.05	0.68	0.11	0.65	4.73
17	1.13	0.08	1.00	0.05	0.60	0.10	0.65	3.85
18	1.28	0.08	1.00	0.05	0.75	0.10	0.65	5.23
19	1.36	0.08	1.00	0.05	0.63	0.06	0.65	4.49
20	1.13	0.08	1.00	0.05	0.76	0.06	0.65	5.09

Note: Case 1 = Single shear, with washers, $F_u/F_y \geq 1.15$
Case 2 = Double shear, with washers, $F_u/F_y \geq 1.15$
Case 3 = Single shear, with washers, $F_u/F_y < 1.15$
Case 4 = Double shear, with washers, $F_u/F_y < 1.15$
Case 5 = Single shear, without washers, $F_u/F_y \geq 1.15$
Case 6 = Single shear, without washers, $F_u/F_y < 1.15$
Case 7 = $t < 3/16$ in., double shear, with washers
Case 8 = $t < 3/16$ in., single shear, with washers
Case 9 = $t < 3/16$ in., single shear, without washers
Case 10 = $0.024 \leq t < 3/16$ in., double shear, with washers, $F_u/F_y \geq 1.15$
Case 11 = $0.024 \leq t < 3/16$ in., double shear, with washers, $F_u/F_y < 1.15$
Case 12 = $0.024 \leq t < 3/16$ in., single shear, with washers, $F_u/F_y \geq 1.15$
Case 13 = $0.024 \leq t < 3/16$ in., single shear, with washers, $F_u/F_y < 1.15$
Case 14 = $0.036 \leq t < 3/16$ in., single shear, without washers, $F_u/F_y \geq 1.15$
Case 15 = $0.036 \leq t < 3/16$ in., double shear, without washers, $F_u/F_y \geq 1.15$

Case 16 = Double shear, with washers, 3/8 in. diameter
Case 17 = Double shear, with washers, 3/4 in. diameter
Case 18 = Single shear, with washers, 3/8 in. diameter
Case 19 = Single shear, with washers, 1/2 in. diameter
Case 20 = Single shear, with washers, 3/4 in. diameter

Table 82
Computed Safety Index β for Transverse Stiffeners
(ϕ_c = 0.85)

Case	No. of Tests	M_m	V_M	F_m	V_F	P_m	V_P	β
1	33	1.10	0.10	1.0	0.05	1.1762	0.08658	3.32
2	28	1.10	0.10	1.0	0.05	1.2099	0.09073	3.41
3	61	1.10	0.10	1.0	0.05	1.1916	0.08897	3.36

Note: Case 1 = Transverse stiffeners at interior support and under concentrated load
Case 2 = Transverse stiffeners at end support
Case 3 = Sum of Cases 1 and 2

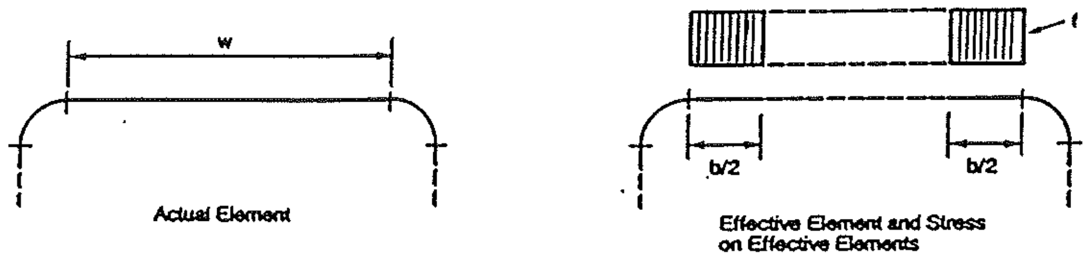

Fig. 1. Stiffened Elements with Uniform Compression

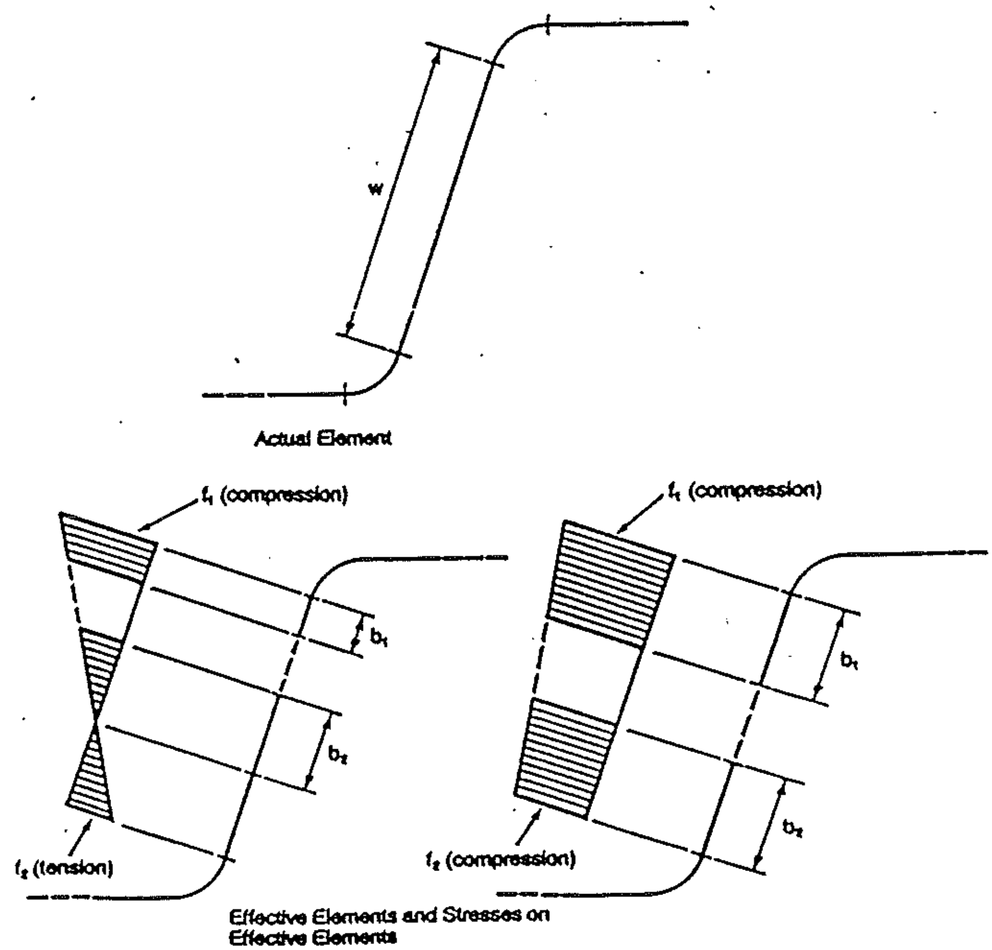

Fig. 2. Stiffened Elements with Stress Gradient and Webs

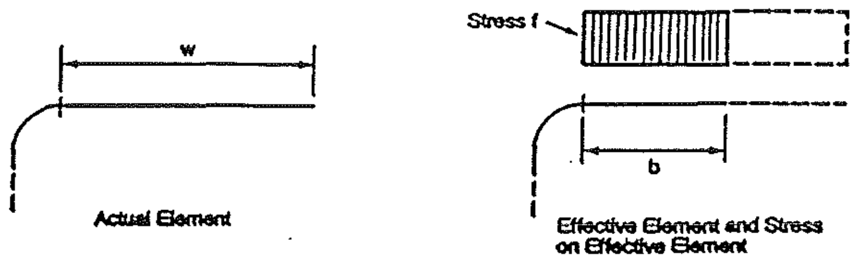

Fig. 3. Unstiffened Element with Uniform Compression

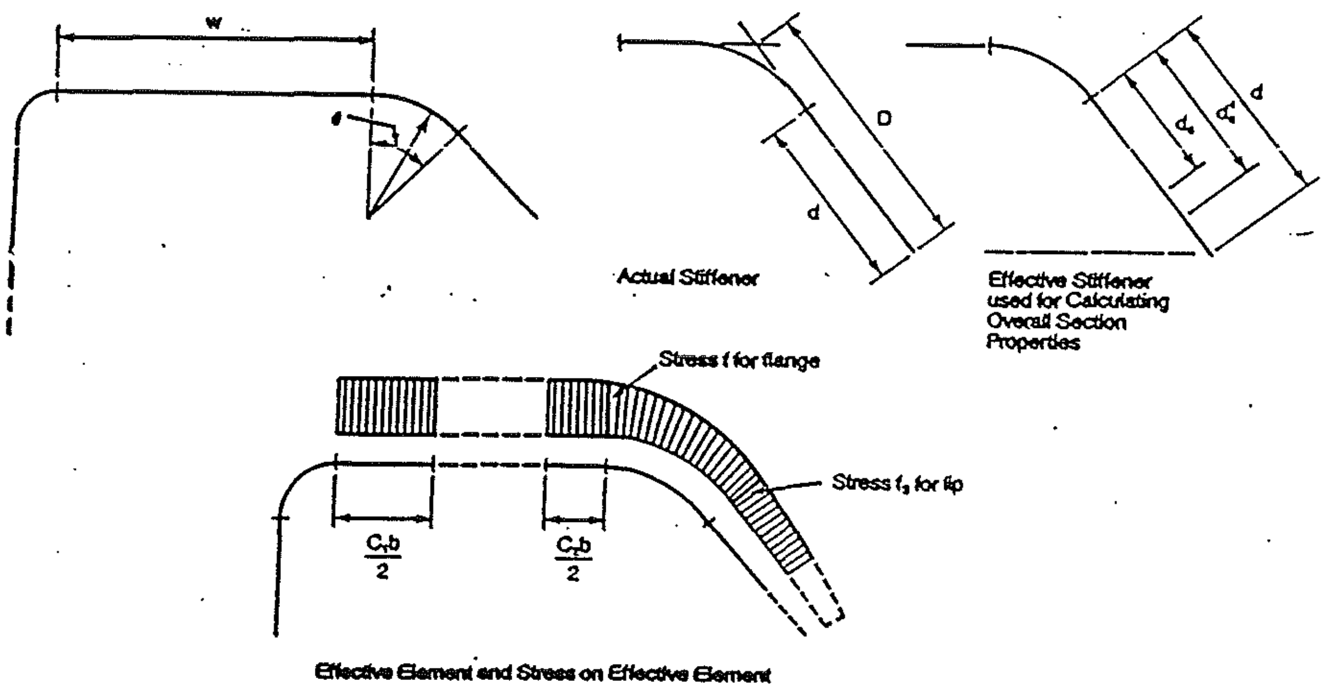

Fig. 4. Elements with Edge Stiffener

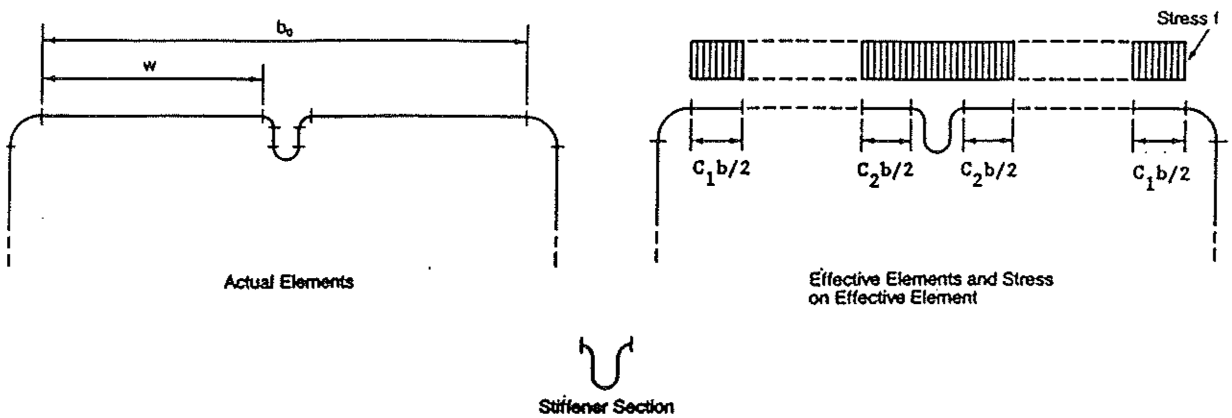

Fig. 5. Elements with Intermediate Stiffener

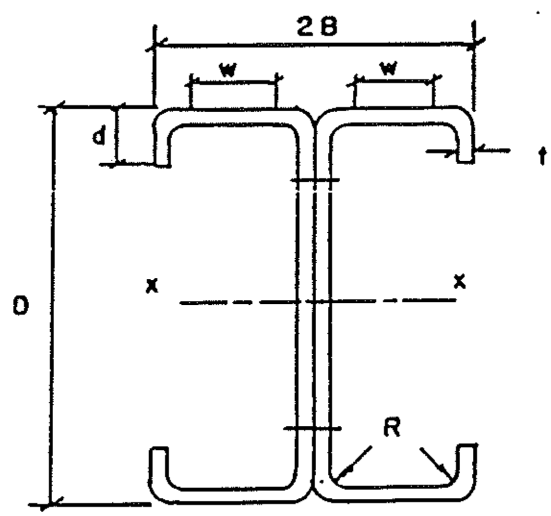

Fig. 6. I-Section Composed of Two Channels

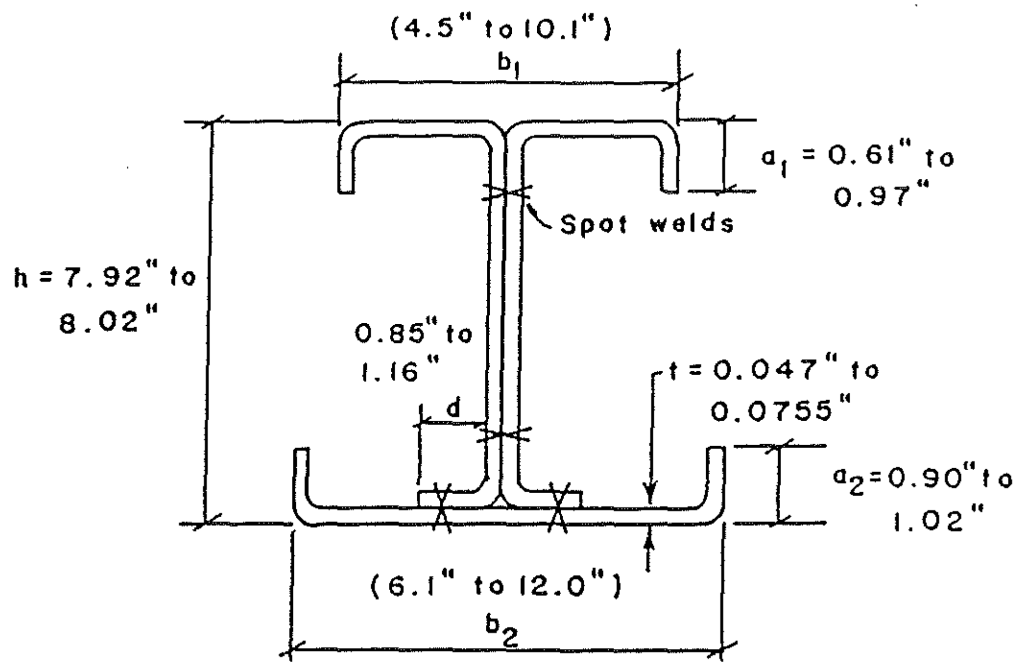

Fig. 7. I-Section Composed of Three Channels

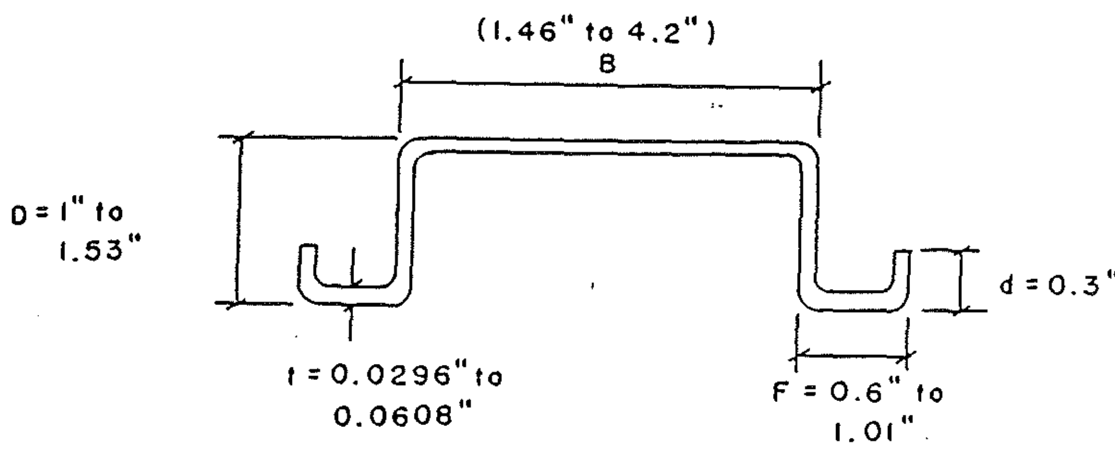

Fig. 8. Hat Section with Lips

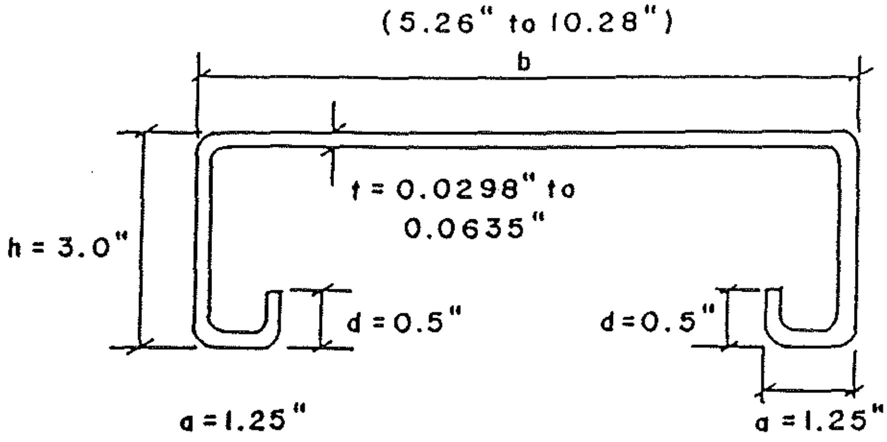

Fig. 9. Track Section

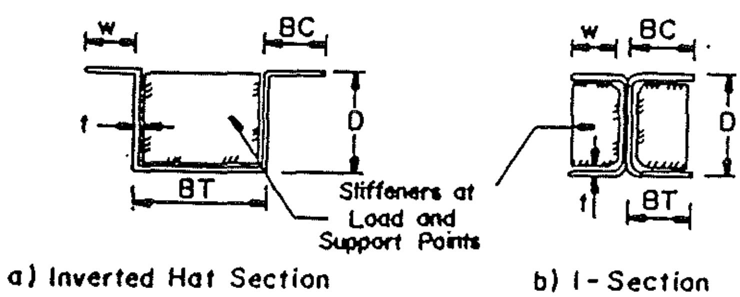

Fig. 10. Cross Section of Specimens Used in Reference 21

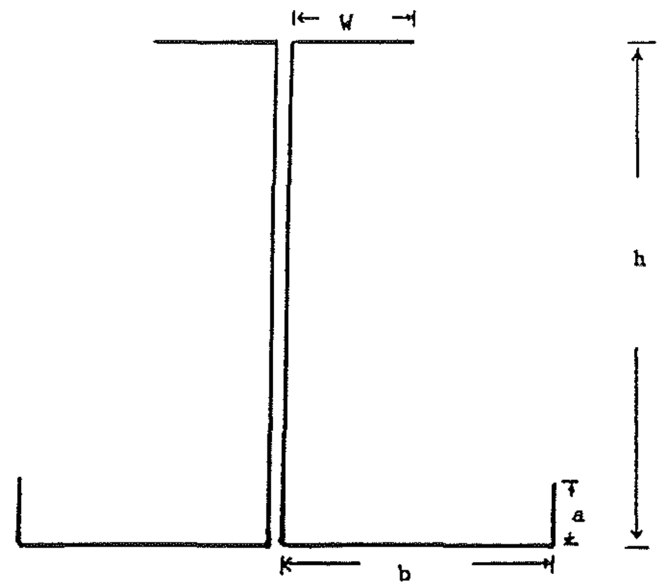

Fig. 11. Midline Dimensions of the Specimens Used in Reference 22

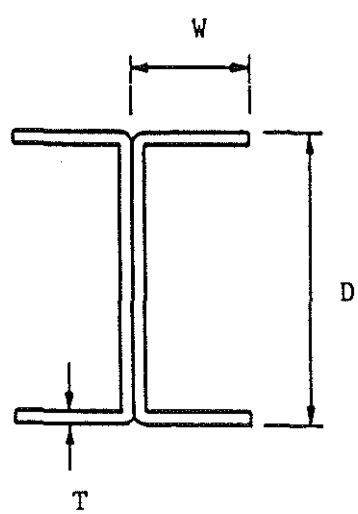

Fig. 12. I-Section with Unstiffened Flanges

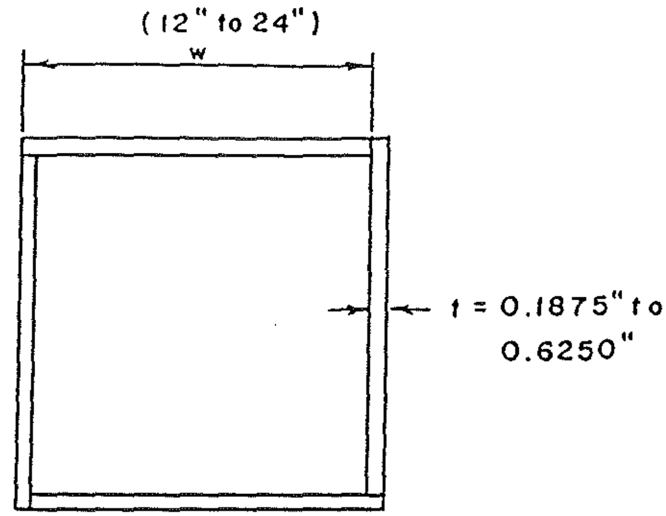

Fig. 13. Square Box Section

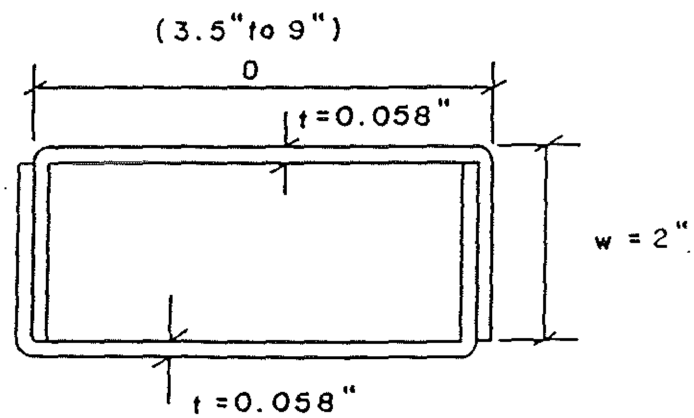

Fig. 14. Rectangular Box Section

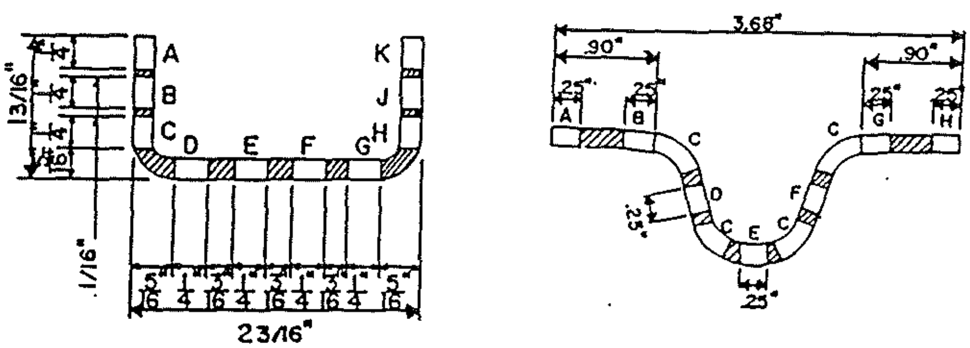

Fig. 15. Cross Section of Specimens Used in Reference 36

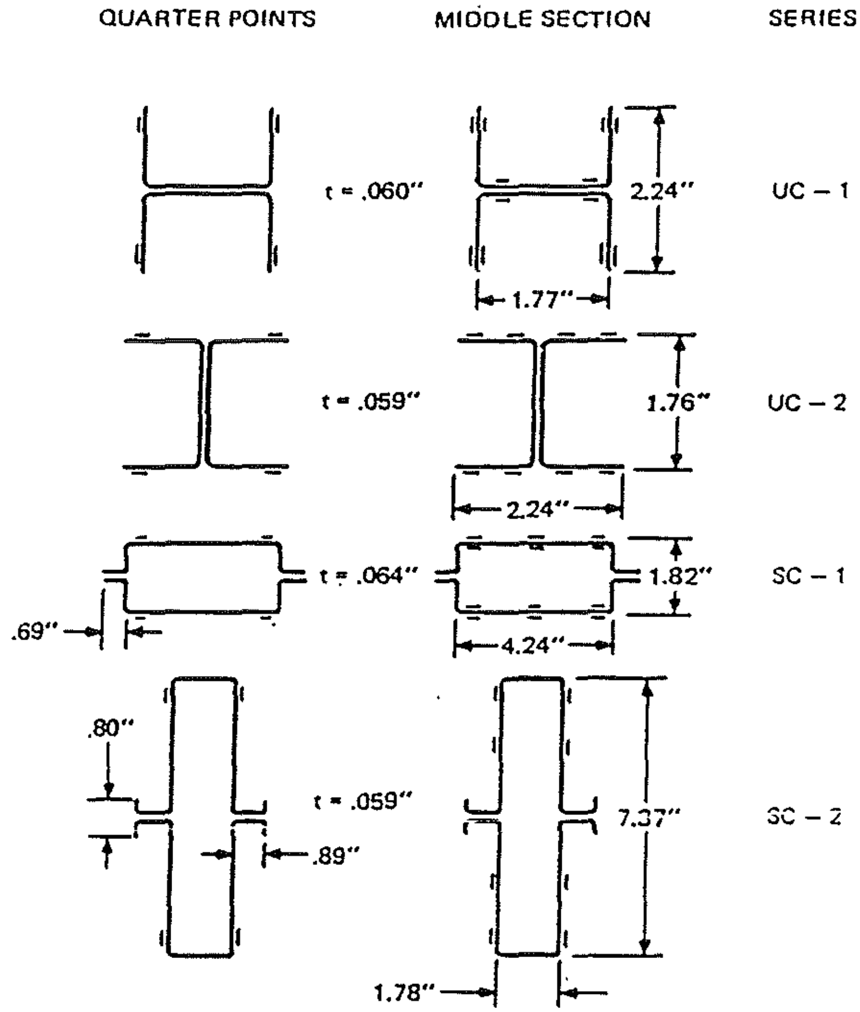

Fig. 16. Cross Section of Specimens Used in Reference 37

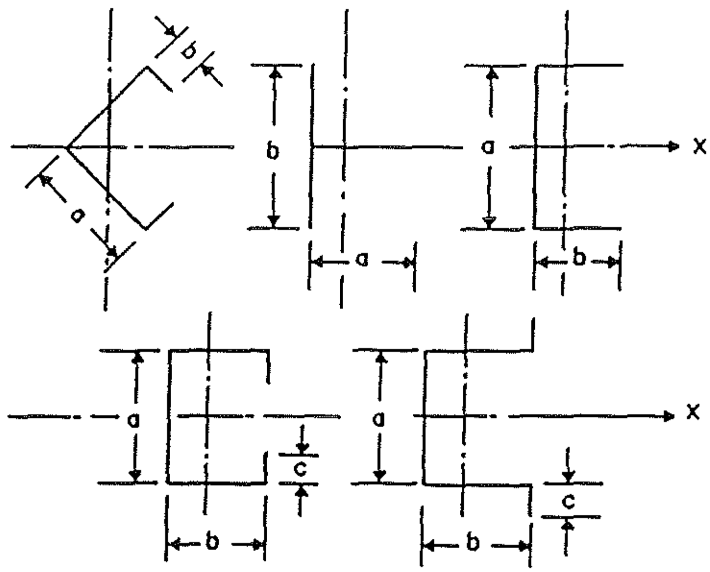

Fig. 17. Cross Section of Specimens Used in Reference 38

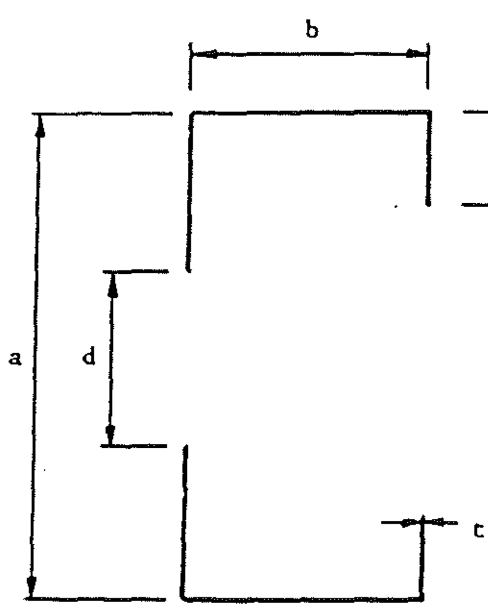

Fig. 18. Cross Section of the Lipped Channels
with Circular Perforations

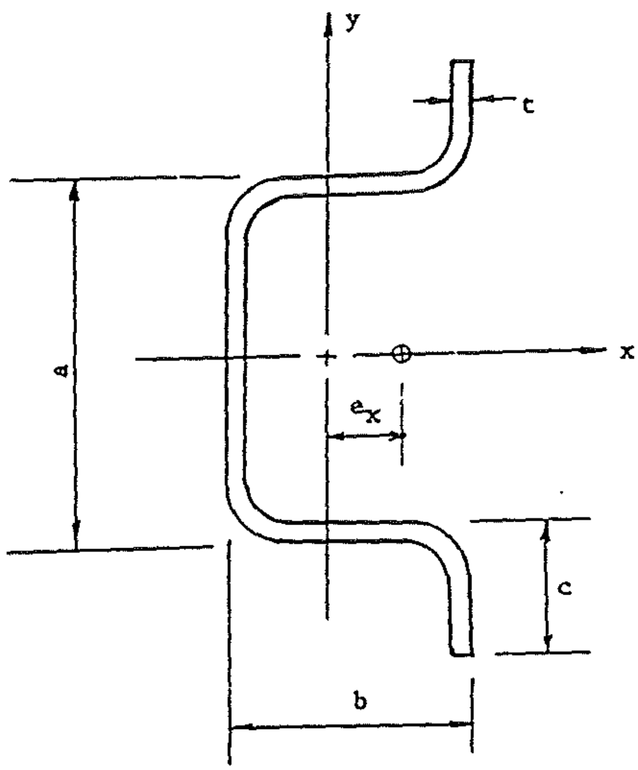

Fig. 19. Cross Section of Hat Sections for Beam-Column Tests

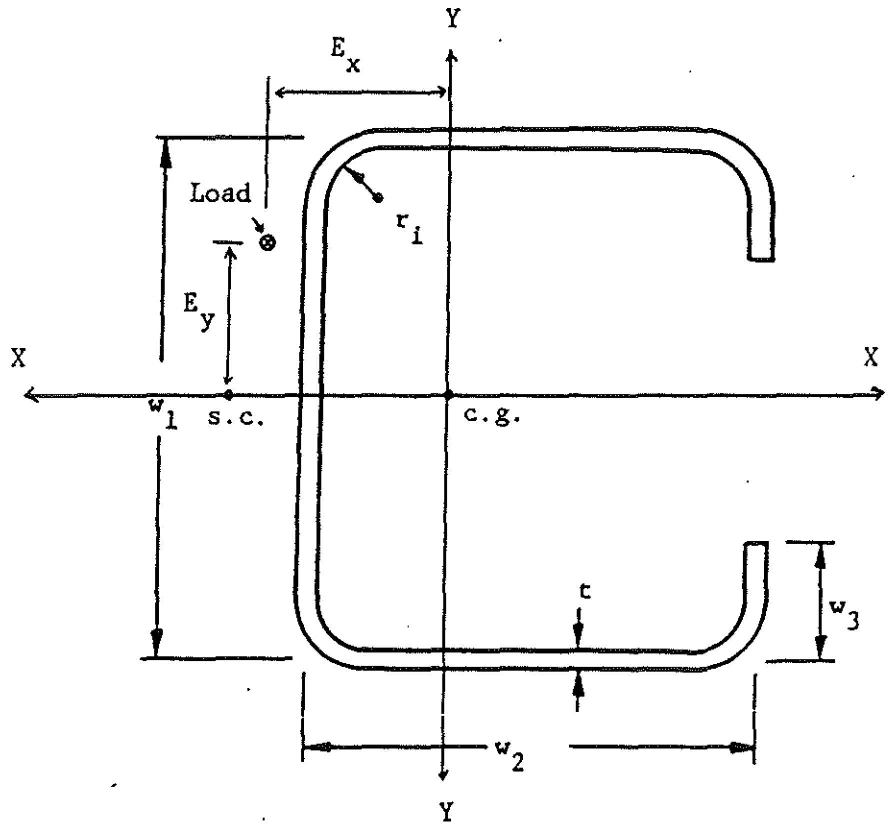

Fig. 20. Cross Section of Lipped Channels for Beam-Column Tests

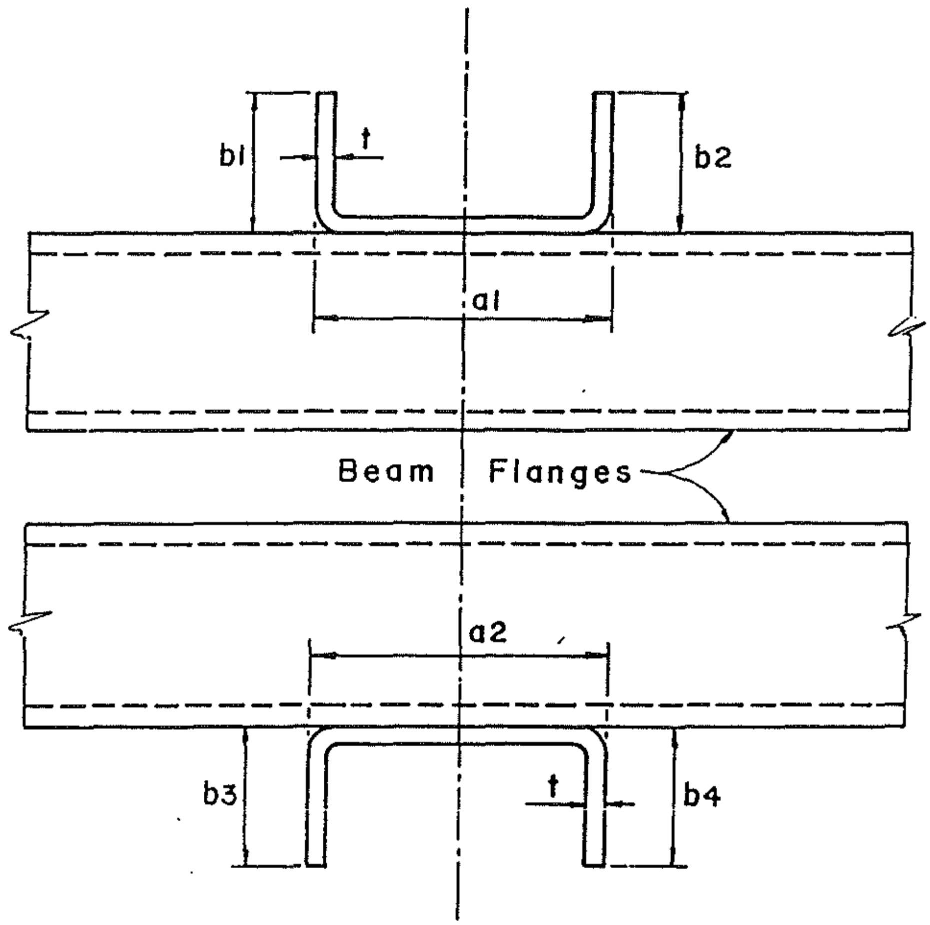

Fig. 21. Dimensions of Cold-Formed Steel Transverse Stiffeners

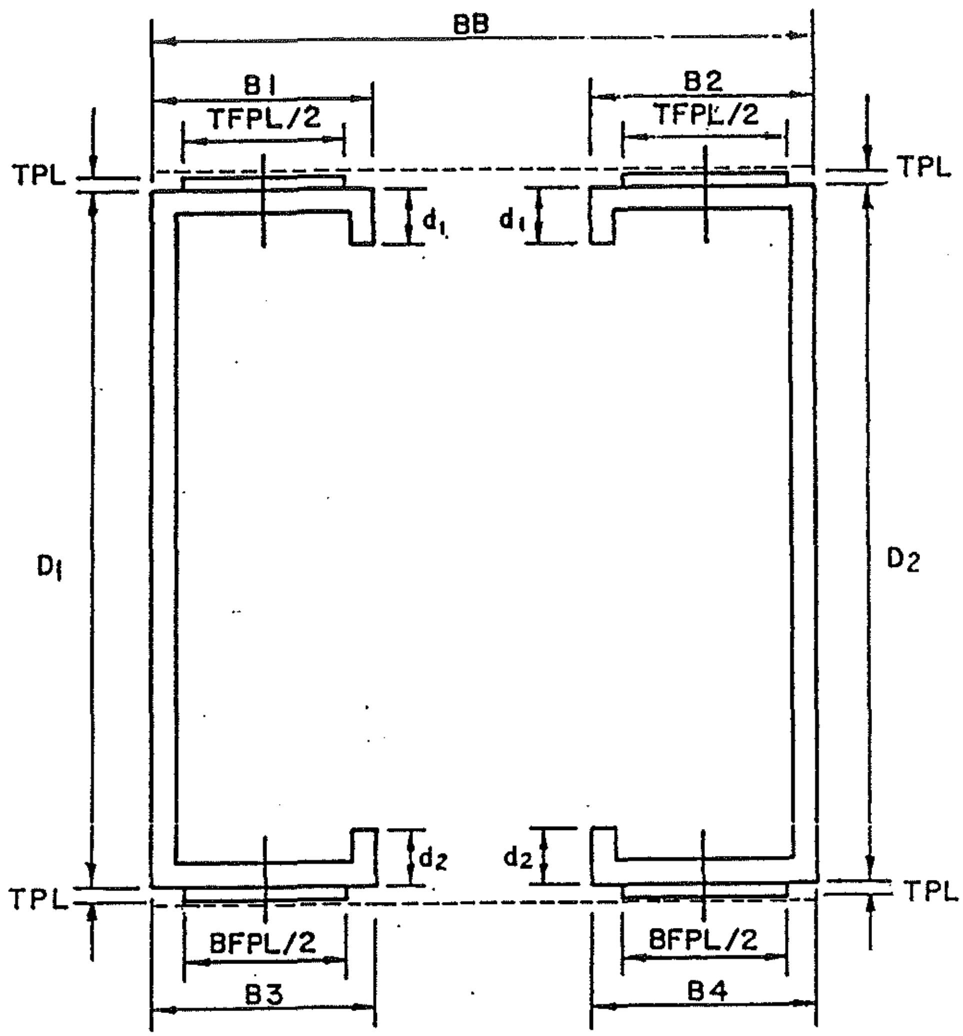

Fig. 22. Dimensions of Shear Test Specimens with Shear Stiffeners

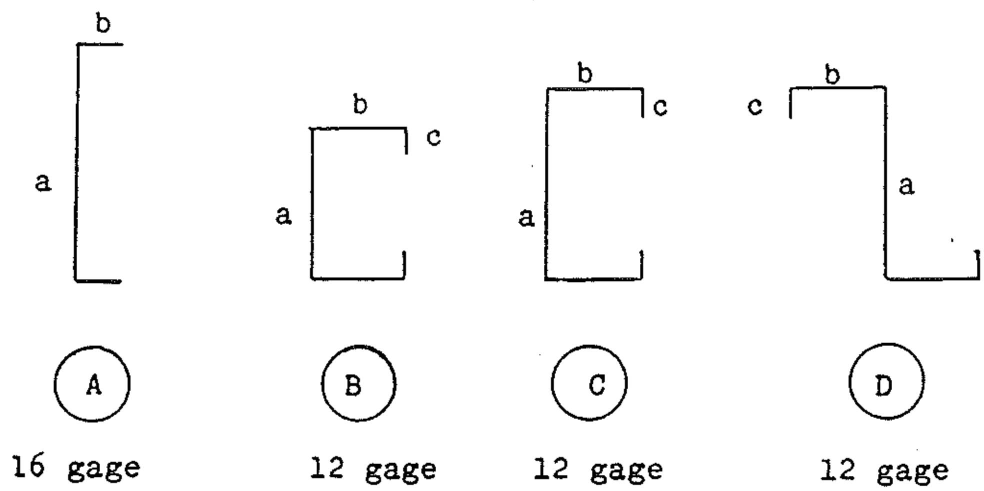

Fig. 23. Specimens Used in Reference 60

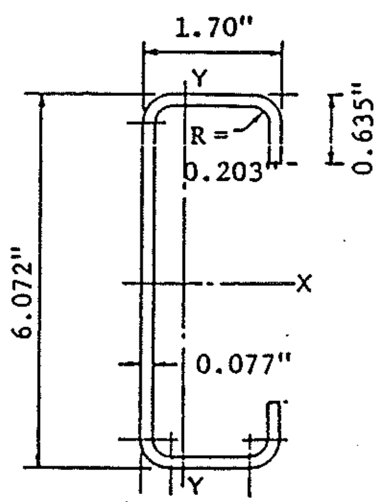

Fig. 24. Channel Sections Used in Reference 61