Chapter **IV**

Check/Design for AISC-ASD89

This chapter describes the details of the structural steel design and stress check algorithms that are used by the program when the user selects the AISC-ASD89 design code (AISC 1989). Various notations used in this chapter are described in Table III-1.

For referring to pertinent sections and equations of the original ASD code, a unique prefix “ASD” is assigned. However, all references to the “Specifications for Allowable Stress Design of Single-Angle Members” carry the prefix of “ASD SAM”.

The design is based on user-specified loading combinations. But the program provides a set of default load combinations that should satisfy requirements for the design of most building type structures.

In the evaluation of the axial force/biaxial moment capacity ratios at a station along the length of the member, first the actual member force/moment components and the corresponding capacities are calculated for each load combination. Then the capacity ratios are evaluated at each station under the influence of all load combinations using the corresponding equations that are defined in this chapter. The controlling capacity ratio is then obtained. A capacity ratio greater than 1.0 indicates overstress. Similarly, a shear capacity ratio is also calculated separately.

A	=	Cross-sectional area, in^2
A_e	=	Effective cross-sectional area for slender sections, in^2
A_f	=	Area of flange , in^2
A_g	=	Gross cross-sectional area, in^2
A_{v2}, A_{v3}	=	Major and minor shear areas, in^2
A_w	=	Web shear area, dt_w, in^2
C_b	=	Bending Coefficient
C_m	=	Moment Coefficient
C_w	=	Warping constant, in^6
D	=	Outside diameter of pipes, in
E	=	Modulus of elasticity, ksi
F_a	=	Allowable axial stress, ksi
F_b	=	Allowable bending stress, ksi
F_{b33}, F_{b22}	=	Allowable major and minor bending stresses, ksi
F_{cr}	=	Critical compressive stress, ksi
F_{e33}	=	$\dfrac{12 \quad ^2 E}{23 \;\; K_{33} l_{33} / r_{33} \quad ^2}$
F_{e22}	=	$\dfrac{12 \quad ^2 E}{23 \;\; K_{22} l_{22} / r_{22} \quad ^2}$
F_v	=	Allowable shear stress, ksi
F_y	=	Yield stress of material, ksi
K	=	Effective length factor
K_{33}, K_{22}	=	Effective length K-factors in the major and minor directions
M_{33}, M_{22}	=	Major and minor bending moments in member, kip-in
M_{ob}	=	Lateral-torsional moment for angle sections, kip-in
P	=	Axial force in member, kips
P_e	=	Euler buckling load, kips
Q	=	Reduction factor for slender section, = $Q_a Q_s$
Q_a	=	Reduction factor for stiffened slender elements
Q_s	=	Reduction factor for unstiffened slender elements
S	=	Section modulus, in^3
S_{33}, S_{22}	=	Major and minor section moduli, in^3

Table IV-1

AISC-ASD Notations

$S_{eff,33}, S_{eff,22}$	=	Effective major and minor section moduli for slender sections, in^3
S_c	=	Section modulus for compression in an angle section, in^3
V_2, V_3	=	Shear forces in major and minor directions, kips
b	=	Nominal dimension of plate in a section, in longer leg of angle sections, $b_f \quad 2t_w$ for welded and $b_f \quad 3t_w$ for rolled box sections, etc.
b_e	=	Effective width of flange, in
b_f	=	Flange width, in
d	=	Overall depth of member, in
f_a	=	Axial stress either in compression or in tension, ksi
f_b	=	Normal stress in bending, ksi
f_{b33}, f_{b22}	=	Normal stress in major and minor direction bending, ksi
f_v	=	Shear stress, ksi
f_{v2}, f_{v3}	=	Shear stress in major and minor direction bending, ksi
h	=	Clear distance between flanges for I shaped sections $(d \quad 2t_f)$, in
h_e	=	Effective distance between flanges less fillets, in
k	=	Distance from outer face of flange to web toe of fillet , in
k_c	=	Parameter used for classification of sections, $\frac{4.05}{h/t_w{}^{0.46}}$ if $h/t_w \quad 70$, 1 if $h/t_w \quad 70$.
l_{33}, l_{22}	=	Major and minor direction unbraced member lengths, in
l_c	=	Critical length, in
r	=	Radius of gyration, in
r_{33}, r_{22}	=	Radii of gyration in the major and minor directions, in
r_z	=	Minimum Radius of gyration for angles, in
t	=	Thickness of a plate in I, box, channel, angle, and T sections, in
t_f	=	Flange thickness, in
t_w	=	Web thickness, in
$_w$	=	Special section property for angles, in

Table IV-1

AISC-ASD Notations (cont.)

English as well as SI and MKS metric units can be used for input. But the code is based on Kip-Inch-Second units. For simplicity, all equations and descriptions presented in this chapter correspond to **Kip-Inch-Second** units unless otherwise noted.

Design Loading Combinations

The design load combinations are the various combinations of the load cases for which the structure needs to be checked. For the AISC-ASD89 code, if a structure is subjected to dead load (DL), live load (LL), wind load (WL), and earthquake induced load (EL), and considering that wind and earthquake forces are reversible, then the following load combinations may have to be defined (ASD A4):

DL (ASD A4.1)
DL + LL (ASD A4.1)

DL WL (ASD A4.1)
DL + LL WL (ASD A4.1)

DL EL (ASD A4.1)
DL + LL EL (ASD A4.1)

These are also the default design load combinations in the program whenever the AISC-ASD89 code is used. The user should use other appropriate loading combinations if roof live load is separately treated, if other types of loads are present, or if pattern live loads are to be considered.

When designing for combinations involving earthquake and wind loads, allowable stresses are increased by a factor of 4/3 of the regular allowable value (ASD A5.2).

Live load reduction factors can be applied to the member forces of the live load case on an element-by-element basis to reduce the contribution of the live load to the factored loading.

Classification of Sections

The allowable stresses for axial compression and flexure are dependent upon the classification of sections as either Compact, Noncompact, Slender, or Too Slender. The program classifies the individual members according to the limiting width/thickness ratios given in Table III-2 (ASD B5.1, F3.1, F5, G1, A-B5-2). The definition of the section properties required in this table is given in Figure III-1 and Table III-1.

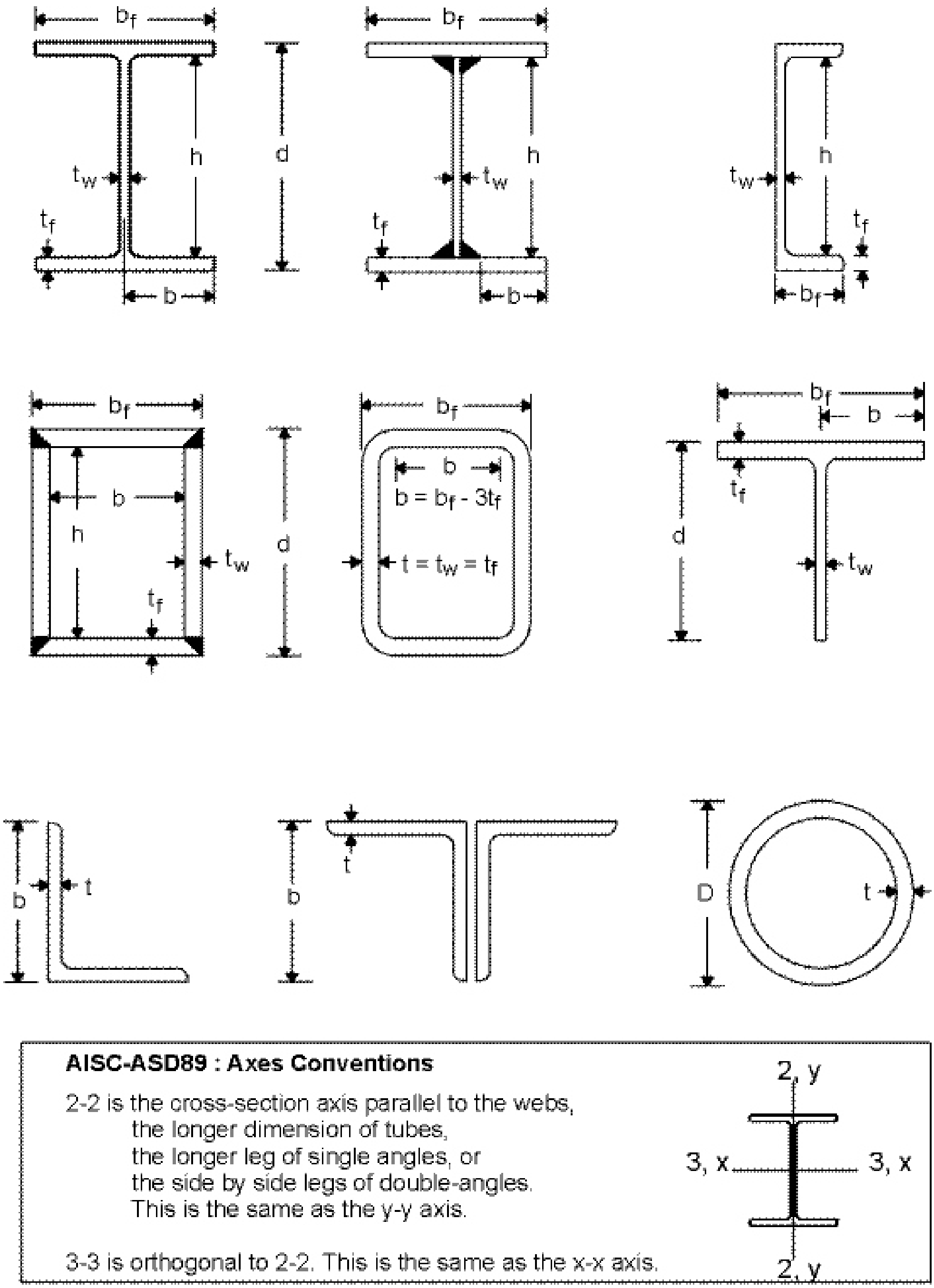

Figure IV-1

AISC-ASD Definition of Geometric Properties

Section Description	Ratio Checked	Compact Section	Noncompact Section	Slender Section
I-SHAPE	$b_f / 2t_f$ (rolled)	$65 / \sqrt{F_y}$	$95 / \sqrt{F_y}$	No limit
	$b_f / 2t_f$ (welded)	$65 / \sqrt{F_y}$	$95 / \sqrt{F_y / k_c}$	No limit
	d / t_w	For $f_a / F_y \quad 0.16$ $\frac{640}{\sqrt{F_y}}(1 \quad 3.74 \frac{f_a}{F_y})$, For $f_a / F_y \quad 0.16$ $257 / \sqrt{F_y}$.	No limit	No limit
	h / t_w	No limit	If compression only, $253 / \sqrt{F_y}$ otherwise $760 / \sqrt{F_b}$	$\frac{14000}{\sqrt{F_y \quad F_y \quad 16.5}}$ 260
BOX	b / t_f	$190 / \sqrt{F_y}$	$238 / \sqrt{F_y}$	No limit
	d / t_w	As for I-shapes	No limit	No limit
	h / t_w	No limit	As for I-shapes	As for I-shapes
	Other	$t_w \quad t_f / 2$, $d_w \quad 6b_f$	None	None
CHANNEL	b / t_f	As for I-shapes	As for I-shapes	No limit
	d / t_w	As for I-shapes	No limit	No limit
	h / t_w	No limit	As for I-shapes	As for I-shapes
	Other	No limit	No limit	If welded $b_f / d_w \quad 0.25$, $t_f / t_w \quad 3.0$ If rolled $b_f / d_w \quad 0.5$, $t_f / t_w \quad 2.0$

Table IV-2

Limiting Width-Thickness Ratios for
Classification of Sections Based on AISC-ASD

Section Description	Ratio Checked	Compact Section	Noncompact Section	Slender Section
T-SHAPE	$b_f / 2t_f$	$65 / \sqrt{F_y}$	$95 / \sqrt{F_y}$	No limit
	d / t_w	Not applicable	$127 / \sqrt{F_y}$	No limit
	Other	No limit	No limit	If welded b_f / d_w 0.5, t_f / t_w 1.25 If rolled b_f / d_w 0.5, t_f / t_w 1.10
DOUBLE ANGLES	b / t	Not applicable	$76 / \sqrt{F_y}$	No limit
ANGLE	b / t	Not applicable	$76 / \sqrt{F_y}$	No limit
PIPE	D / t	$3{,}300 / F_y$	$3{,}300 / F_y$	$13{,}000 / F_y$ (Compression only) No limit for flexure
ROUND BAR		Assumed Compact		
RECTANGLE		Assumed Noncompact		
GENERAL		Assumed Noncompact		

Table IV-2

Limiting Width-Thickness Ratios for Classification of Sections Based on AISC-ASD (Cont.)

If the section dimensions satisfy the limits shown in the table, the section is classified as either Compact, Noncompact, or Slender. If the section satisfies the criteria for Compact sections, then the section is classified as Compact section. If the section does not satisfy the criteria for Compact sections but satisfies the criteria for Noncompact sections, the section is classified as Noncompact section. If the section does not satisfy the criteria for Compact and Noncompact sections but satisfies the criteria for Slender sections, the section is classified as Slender section. If the limits for Slender sections are not met, the section is classified as Too Slender. **Stress check of Too Slender sections is beyond the scope of SAP2000.**

In classifying web slenderness of I-shapes, Box, and Channel sections, it is assumed that there are no intermediate stiffeners (ASD F5, G1). Double angles are conservatively assumed to be separated.

Calculation of Stresses

The stresses are calculated at each of the previously defined stations. The member stresses for non-slender sections that are calculated for each load combination are, in general, based on the gross cross-sectional properties.:

$$f_a = P/A$$
$$f_{b33} = M_{33}/S_{33}$$
$$f_{b22} = M_{22}/S_{22}$$
$$f_{v2} = V_2/A_{v2}$$
$$f_{v3} = V_3/A_{v3}$$

If the section is slender with slender stiffened elements, like slender web in I, Channel, and Box sections or slender flanges in Box, effective section moduli based on reduced web and reduced flange dimensions are used in calculating stresses.

$$f_a = P/A \qquad \text{(ASD A-B5.2d)}$$
$$f_{b33} = M_{33}/S_{eff,33} \qquad \text{(ASD A-B5.2d)}$$
$$f_{b22} = M_{22}/S_{eff,22} \qquad \text{(ASD A-B5.2d)}$$
$$f_{v2} = V_2/A_{v2} \qquad \text{(ASD A-B5.2d)}$$
$$f_{v3} = V_3/A_{v3} \qquad \text{(ASD A-B5.2d)}$$

The flexural stresses are calculated based on the properties about the principal axes. For I, Box, Channel, T, Double-angle, Pipe, Circular and Rectangular sections, the principal axes coincide with the geometric axes. For Single-angle sections, the design considers the principal properties. For general sections it is assumed that all section properties are given in terms of the principal directions.

For Single-angle sections, the shear stresses are calculated for directions along the geometric axes. For all other sections the shear stresses are calculated along the geometric and principle axes.

Calculation of Allowable Stresses

The allowable stresses in compression, tension, bending, and shear are computed for Compact, Noncompact, and Slender sections according to the following subsections. The allowable flexural stresses for all shapes of sections are calculated based on their principal axes of bending. For the I, Box, Channel, Circular, Pipe, T, Double-angle and Rectangular sections, the principal axes coincide with their geometric axes. For the Angle sections, the principal axes are determined and all computations related to flexural stresses are based on that.

*If the user specifies nonzero allowable stresses for one or more elements in the program "Overwrites Element Design Data" form, these values **will override the above mentioned calculated values for those elements** as defined in the following subsections. The specified allowable stresses should be based on the principal axes of bending.*

Allowable Stress in Tension

The allowable axial tensile stress value F_a is assumed to be 0.60 F_y.

$$F_a = 0.6 F_y \qquad \text{(ASD D1, ASD SAM 2)}$$

It should be noted that net section checks are not made. For members in tension, if l/r is greater than 300, a message to that effect is printed (ASD B7, ASD SAM 2). For single angles, the minimum radius of gyration, r_z, is used instead of r_{22} and r_{33} in computing l/r.

Allowable Stress in Compression

The allowable axial compressive stress is the minimum value obtained from flexural buckling and flexural-torsional buckling. The allowable compressive stresses are determined according to the following subsections.

For members in compression, if Kl/r is greater than 200, a warning message is printed (ASD B7, ASD SAM 4). For single angles, the minimum radius of gyration, r_z, is used instead of r_{22} and r_{33} in computing Kl/r.

Flexural Buckling

The allowable axial compressive stress value, F_a, depends on the slenderness ratio Kl/r based on gross section properties and a corresponding critical value, C_c, where

$$\frac{Kl}{r} = \max\left\{\frac{K_{33}\, l_{33}}{r_{33}}, \frac{K_{22}\, l_{22}}{r_{22}}\right\}, \text{ and}$$

$$C_c = \sqrt{\frac{2\pi^2 E}{F_y}}. \qquad \text{(ASD E2, ASD SAM 4)}$$

For single angles, the minimum radius of gyration, r_z, is used instead of r_{22} and r_{33} in computing Kl/r.

For Compact or Noncompact sections F_a is evaluated as follows:

$$F_a = \frac{\left\{1.0 - \frac{(Kl/r)^2}{2C_c^2}\right\} F_y}{\frac{5}{3} + \frac{3}{8}\left(\frac{Kl/r}{C_c}\right) - \frac{(Kl/r)^3}{8C_c^3}}, \text{ if } \frac{Kl}{r} \le C_c, \qquad \text{(ASD E2-1, SAM 4-1)}$$

$$F_a = \frac{12\pi^2 E}{23(Kl/r)^2}, \qquad \text{if } \frac{Kl}{r} > C_c. \qquad \text{(ASD E2-2, SAM 4-2)}$$

If Kl/r is greater than 200, then the calculated value of F_a is taken not to exceed the value of F_a calculated by using the equation ASD E2-2 for Compact and Noncompact sections (ASD E1, B7).

For Slender sections, except slender Pipe sections, F_a is evaluated as follows:

$$F_a = Q\, \frac{\left\{1.0 - \frac{(Kl/r)^2}{2C_c'^2}\right\} F_y}{\frac{5}{3} + \frac{3}{8}\left(\frac{Kl/r}{C_c'}\right) - \frac{(Kl/r)^3}{8C_c'^3}}, \text{ if } \frac{Kl}{r} \le C_c', \qquad \text{(ASD A-B5-11, SAM 4-1)}$$

$$F_a = \frac{12\pi^2 E}{23(Kl/r)^2}, \qquad \text{if } \frac{Kl}{r} > C_c'. \qquad \text{(ASD A-B5-12, SAM 4-2)}$$

where,

$$C_c' = \sqrt{\frac{2\pi^2 E}{Q F_y}}. \qquad \text{(ASD A-B5.2c, ASD SAM 4)}$$

For slender sections, if Kl/r is greater than 200, then the calculated value of F_a is taken not to exceed its value calculated by using the equation ASD A-B5-12 (ASD B7, E1).

For slender Pipe sections F_a is evaluated as follows:

$$F_a = \frac{662}{D/t} \quad 0.40 F_y \qquad \text{(ASD A-B5-9)}$$

The reduction factor, Q, for all compact and noncompact sections is taken as 1. For slender sections, Q is computed as follows:

$$Q \quad Q_s Q_a \text{, where} \qquad \text{(ASD A-B5.2.c, SAM 4)}$$

Q_s = reduction factor for unstiffened slender elements, and (ASD A-B5.2.a)

Q_a = reduction factor for stiffened slender elements. (ASD A-B5.2.c)

The Q_s factors for slender sections are calculated as described in Table III-4 (ASD A-B5.2a, ASD SAM 4). The Q_a factors for slender sections are calculated as the ratio of effective cross-sectional area and the gross cross-sectional area.

$$Q_a \quad \frac{A_e}{A_g} \qquad \text{(ASD A-B5-10)}$$

The effective cross-sectional area is computed based on effective width as follows:

$$A_e \quad A_g \qquad b \quad b_e \quad t$$

b_e for unstiffened elements is taken equal to b, and b_e for stiffened elements is taken equal to or less than b as given in Table III-5 (ASD A-B5.2b). For webs in I, box, and Channel sections, h_e is used as b_e and h is used as b in the above equation.

Flexural-Torsional Buckling

The allowable axial compressive stress value, F_a, determined by the limit states of torsional and flexural-torsional buckling is determined as follows (ASD E3, C-E3):

$$F_a = Q \frac{1.0 \quad \dfrac{Kl/r_{e}^{\;2}}{2C_c^{\,2}} \quad F_y}{\dfrac{5}{3} + \dfrac{3 \;\; Kl/r_{e}}{8\, C_c} \quad \dfrac{Kl/r_{e}^{\;3}}{8\, C_c^{\,3}}} \text{, if } Kl/r_{e} \quad C_c, \qquad \text{(E2-1, A-B5-11)}$$

Section Type	Reduction Factor for Unstiffened Slender Elements (Q_s)	Equation Reference
I-SHAPE	$Q_s \quad \begin{array}{lll} 1.0 & \textit{if} & b_f/2t_f \quad 95/\sqrt{F_y/k_c}, \\ 1.293 \quad 0.00309\, b_f/2t_f \sqrt{F_y/k_c} & \textit{if} & 95/\sqrt{F_y/k_c} \quad b_f/2t_f \quad 195/\sqrt{F_y/k_c}, \\ 26{,}200\, k_c / \quad b_f/2t_f \;^2 F_y & \textit{if} & b_f/2t_f \quad 195/\sqrt{F_y/k_c}. \end{array}$	ASD A-B5-3, ASD A-B5-4
BOX	$Q_s \quad 1$	ASD A-B5.2c
CHANNEL	As for I-shapes with $b_f/2t_f$ replaced by b_f/t_f.	ASD A-B5-3, ASD A-B5-4
T-SHAPE	For flanges, as for flanges in I-shapes. For web see below. $Q_s \quad \begin{array}{lll} 1.0\,, & \textit{if} & d/t_w \quad 127/\sqrt{F_y}, \\ 1.908 \quad 0.00715\, d/t_w \sqrt{F_y}, & \textit{if} & 127/\sqrt{F_y} \quad d/t_w \quad 176/\sqrt{F_y}, \\ 20{,}000/ \quad d/t_w \;^2 F_y \;, & \textit{if} & d/t_w \quad 176/\sqrt{F_y}. \end{array}$	ASD A-B5-3, ASD A-B5-4, ASD A-B5-5, ASD A-B5-6
DOUBLE-ANGLE	$Q_s \quad \begin{array}{lll} 1.0\;, & \textit{if} & b/t \quad 76/\sqrt{F_y}, \\ 1.340 \quad 0.00447\, b/t \sqrt{F_y}, & \textit{if} & 76/\sqrt{F_y} \quad b/t \quad 155/\sqrt{F_y}, \\ 15{,}500/ \quad b/t \;^2 F_y \;, & \textit{if} & b/t \quad 155/\sqrt{F_y}. \end{array}$	ASD A-B5-1, ASD A-B5-2, SAM 4-3
ANGLE	$Q_s \quad \begin{array}{lll} 1.0\;, & \textit{if} & b/t \quad 76/\sqrt{F_y}, \\ 1.340 \quad 0.00447\, b/t \sqrt{F_y}, & \textit{if} & 76/\sqrt{F_y} \quad b/t \quad 155/\sqrt{F_y}, \\ 15{,}500/ \quad b/t \;^2 F_y \;, & \textit{if} & b/t \quad 155/\sqrt{F_y}. \end{array}$	ASD A-B5-1, ASD A-B5-2, SAM 4-3
PIPE	$Q_s \quad 1$	ASD A-B5.2c
ROUND BAR	$Q_s \quad 1$	ASD A-B5.2c
RECTAN-GULAR	$Q_s \quad 1$	ASD A-B5.2c
GENERAL	$Q_s \quad 1$	ASD A-B5.2c

Table IV-3

Reduction Factor for Unstiffened Slender Elements, Q_s

Section Type	Effective Width for Stiffened Sections	Equation Reference
I-SHAPE	$h_e \quad \begin{array}{ll} h, & if \ \frac{h}{t_w} \quad \frac{195.74}{\sqrt{f}}, \\ \frac{253\,t_w}{\sqrt{f}} \ 1 \quad \frac{44.3}{(h/t_w)\sqrt{f}} \ , & if \ \frac{h}{t_w} \quad \frac{195.74}{\sqrt{f}}. \end{array}$ (compression only, $f \quad \frac{P}{A_g}$)	ASD A-B5-8
BOX	$h_e \quad \begin{array}{ll} h, & if \ \frac{h}{t_w} \quad \frac{195.74}{\sqrt{f}}, \\ \frac{253\,t_w}{\sqrt{f}} \ 1 \quad \frac{44.3}{(h/t_w)\sqrt{f}} \ , & if \ \frac{h}{t_w} \quad \frac{195.74}{\sqrt{f}}. \end{array}$ (compression only, $f \quad \frac{P}{A_g}$) $b_e \quad \begin{array}{ll} b, & if \ \frac{b}{t_f} \quad \frac{183.74}{\sqrt{f}}, \\ \frac{253\,t_f}{\sqrt{f}} \ 1 \quad \frac{50.3}{(h/t_f)\sqrt{f}} \ , & if \ \frac{b}{t} \quad \frac{183.74}{\sqrt{f}}. \end{array}$ (compr., flexure, $f \quad 0.6F_y$)	ASD A-B5-8 ASD A-B5-7
CHANNEL	$h_e \quad \begin{array}{ll} h, & if \ \frac{h}{t_w} \quad \frac{195.74}{\sqrt{f}}, \\ \frac{253\,t_w}{\sqrt{f}} \ 1 \quad \frac{44.3}{(h/t_w)\sqrt{f}} \ , & if \ \frac{h}{t_w} \quad \frac{195.74}{\sqrt{f}}. \end{array}$ (compression only, $f \quad \frac{P}{A_g}$)	ASD A-B5-8
T-SHAPE	$b_e \quad b$	ASD A-B5.2c
DOUBLE-ANGLE	$b_e \quad b$	ASD A-B5.2c
ANGLE	$b_e \quad b$	ASD A-B5.2c
PIPE	$Q_a \quad 1$, (However, special expression for allowable axial stress is given.)	ASD A-B5-9
ROUND BAR	Not applicable	
RECTAN-GULAR	$b_e \quad b$	ASD A-B5.2c
GENERAL	Not applicable	

Table IV-4

Effective Width for Stiffened Sections

$$F_a = \frac{12 \quad {}^2 E}{23 \quad Kl/r \quad {}_e^{\;2}}, \qquad \text{if} \quad Kl/r \quad {}_e \qquad C_c. \qquad \text{(E2-2, A-B5-12)}$$

where,

$$C_c = \sqrt{\frac{2 \quad {}^2 E}{Q\, F_y}}, \ \text{and} \qquad \text{(ASD E2, A-B5.2c, SAM 4)}$$

$$Kl/r \quad {}_e = \sqrt{\frac{{}^2 E}{F_e}}. \qquad \text{(ASD C-E2-2, SAM 4-4)}$$

ASD Commentary (ASD C-E3) refers to the 1986 version of the AISC-LRFD code for the calculation of F_e. The 1993 version of the AISC-LRFD code is the same as the 1986 version in this respect. F_e is calculated in the program as follows:

- For Rectangular, I, Box, and Pipe sections:

$$F_e \qquad \frac{{}^2 E C_w}{K_z l_z \quad {}^2} \quad GJ \quad \frac{1}{I_{22} \quad I_{33}} \qquad \text{(LRFD A-E3-5)}$$

- For T-sections and Double-angles:

$$F_e = \frac{F_{e22} \quad F_{ez}}{2H} \qquad 1 \quad \sqrt{1 \quad \frac{4\, F_{e22} F_{ez} H}{(F_{e22} \quad F_{ez})^2}} \qquad \text{(LRFD A-E3-6)}$$

- For Channels:

$$F_e = \frac{F_{e33} \quad F_{ez}}{2H} \qquad 1 \quad \sqrt{1 \quad \frac{4\, F_{e33} F_{ez} H}{(F_{e33} \quad F_{ez})^2}} \qquad \text{(LRFD A-E3-6)}$$

- For Single-angle sections with equal legs:

$$F_e = \frac{F_{e33} \quad F_{ez}}{2H} \qquad 1 \quad \sqrt{1 \quad \frac{4\, F_{e33} F_{ez} H}{(F_{e33} \quad F_{ez})^2}} \qquad \text{(ASD SAM C-C4-1)}$$

- For Single-angle sections with unequal legs, F_e is calculated as the minimum real root of the following cubic equation (ASD SAM C-C4-2, LRFD A-E3-7):

$$(F_e \quad F_{e33})(F_e \quad F_{e22})(F_e \quad F_{ez}) \quad F_e^2(F_e \quad F_{e22})\frac{x_0^2}{r_0^2} \quad F_e^2(F_e \quad F_{e33})\frac{y_0^2}{r_0^2} \quad 0\,,$$

where,

x_0, y_0 are the coordinates of the shear center with respect to the centroid, $x_0 \quad 0$ for double-angle and T-shaped members (y-axis of symmetry),

$r_0 \quad \sqrt{x_0^2 \quad y_0^2 \quad \frac{I_{22} \quad I_{33}}{A_g}}$ = polar radius of gyration about the shear center,

$$H \quad 1 \quad \frac{x_0^2 \quad y_0^2}{r_0^2}\,, \qquad \text{(LRFD A-E3-9)}$$

$$F_{e33} \quad \frac{{}^2E}{K_{33}l_{33}/r_{33}\;{}^2}\,, \qquad \text{(LRFD A-E3-10)}$$

$$F_{e22} \quad \frac{{}^2E}{K_{22}l_{22}/r_{22}\;{}^2}\,, \qquad \text{(LRFD A-E3-11)}$$

$$F_{ez} \quad \frac{{}^2EC_w}{K_zl_z\;{}^2} \quad GJ \quad \frac{1}{Ar_0^2}\,, \qquad \text{(LRFD A-E3-12)}$$

K_{22}, K_{33} are effective length factors in minor and major directions,

K_z is the effective length factor for torsional buckling, and it is taken equal to K_{22} in the program,

l_{22}, l_{33} are effective lengths in the minor and major directions,

l_z is the effective length for torsional buckling, and it is taken equal to l_{22}.

For angle sections, the principal moment of inertia and radii of gyration are used for computing F_e (ASD SAM 4). Also, the maximum value of Kl, i.e, $\max(K_{22}l_{22}, K_{33}l_{33})$, is used in place of $K_{22}l_{22}$ or $K_{33}l_{33}$ in calculating F_{e22} and F_{e33} in this case.

Allowable Stress in Bending

The allowable bending stress depends on the following criteria: the geometric shape of the cross-section, the axis of bending, the compactness of the section, and a length parameter.

I-sections

For I-sections the length parameter is taken as the laterally unbraced length, l_{22}, which is compared to a critical length, l_c. The critical length is defined as

$$l_c \quad \min \quad \frac{76\, b_f}{\sqrt{F_y}}, \frac{20{,}000\, A_f}{d\, F_y} \quad \text{, where} \qquad \text{(ASD F1-2)}$$

A_f is the area of compression flange,

Major Axis of Bending

If l_{22} is less than l_c, the major allowable bending stress for Compact and Noncompact sections is taken depending on whether the section is welded or rolled and whether f_y is greater than 65 ksi or not.

For Compact sections:

$$F_{b33} = 0.66\, F_y \qquad \text{if } f_y \quad 65 \text{ ksi}, \qquad \text{(ASD F1-1)}$$

$$F_{b33} = 0.60\, F_y \qquad \text{if } f_y \quad 65 \text{ ksi}, \qquad \text{(ASD F1-5)}$$

For Noncompact sections:

$$F_{b33} = \quad 0.79 \quad 0.002 \frac{b_f}{2t_f} \sqrt{F_y} \quad F_y \text{, if rolled and } f_y \quad 65 \text{ ksi}, \qquad \text{(ASD F1-3)}$$

$$F_{b33} = \quad 0.79 \quad 0.002 \frac{b_f}{2\,t_f} \sqrt{\frac{F_y}{k_c}} \quad F_y \text{, if welded and } f_y \quad 65 \text{ ksi}, \qquad \text{(ASDF1-4)}$$

$$F_{b33} = 0.60\, F_y \qquad \text{if } f_y \quad 65 \text{ ksi..} \qquad \text{(ASD F1-5)}$$

If the unbraced length l_{22} is greater than l_c, then for both Compact and Noncompact I-sections the allowable bending stress depends on the l_{22}/r_T ratio.

For $\frac{l_{22}}{r_T} \quad \sqrt{\frac{102{,}000\, C_b}{F_y}}$,

$$F_{b33} \quad 0.60 F_y \,, \tag{ASD F1-6}$$

for $\sqrt{\frac{102{,}000\ C_b}{F_y}} \quad \frac{l_{22}}{r_T} \quad \sqrt{\frac{510{,}000\ C_b}{F_y}}$,

$$F_{b33} \quad \frac{2}{3} \quad \frac{F_y (l_{22} / r_T)^2}{1530{,}000\ C_b} \quad F_y \qquad 0.60 F_y \,, \text{ and} \tag{ASD F1-6}$$

for $\frac{l_{22}}{r_T} \quad \sqrt{\frac{510{,}000\ C_b}{F_y}}$,

$$F_{b33} \quad \frac{170{,}000\, C_b}{(l_{22} / r_T)^2} \quad 0.60 F_y \,, \tag{ASD F1-7}$$

and F_{b33} is taken not to be less than that given by the following formula:

$$F_{b33} = \frac{12{,}000\, C_b}{l_{22} \quad d / A_f} \quad 0.6 F_y \tag{ASD F1-8}$$

where,

r_T is the radius of gyration of a section comprising the compression flange and $1/3$ the compression web taken about an axis in the plane of the web,

$$C_b = 1.75 + 1.05 \quad \frac{M_a}{M_b} \quad + 0.3 \quad \frac{M_a}{M_b} \quad ^2 \qquad 2.3, \text{ where} \tag{ASD F1.3}$$

M_a and M_b are the end moments of any unbraced segment of the member and M_a is numerically less than M_b; M_a / M_b being positive for double curvature bending and negative for single curvature bending. Also, if any moment within the segment is greater than M_b, C_b is taken as 1.0. Also, C_b is taken as 1.0 for cantilevers and frames braced against joint translation (ASD F1.3). The program defaults C_b to 1.0 if the unbraced length, l_{22}, of the member is redefined by the user (i.e. it is not equal to the length of the member). The user can overwrite the value of C_b for any member by specifying it.

The allowable bending stress for Slender sections bent about their major axis is determined in the same way as for a Noncompact section. Then the following additional considerations are taken into account.

If the web is slender, then the previously computed allowable bending stress is reduced as follows:

$$F_{b33} = R_{PG} R_e \, F_{b33} \text{ , where} \qquad \text{(ASD G2-1)}$$

$$R_{PG} \quad 1.0 \quad 0.0005 \frac{A_w}{A_f} \quad \frac{h}{t} \quad \frac{760}{\sqrt{F_{b33}}} \quad 1.0 \text{,} \qquad \text{(ASD G2)}$$

$$R_e \quad \frac{12 \quad 3 \qquad {}^3 \; \frac{A_w}{A_f}}{12 \quad 2 \frac{A_w}{A_f}} \quad 1.0 \text{, (hybrid girders)} \qquad \text{(ASD G2)}$$

$$R_e \quad 1.0 \text{,} \qquad \text{(non-hybrid girders)} \qquad \text{(ASD G2)}$$

A_w = Area of web, in^2,

A_f = Area of compression flange, in^2,

$$\frac{0.6 F_y}{F_{b33}} \quad 1.0 \qquad \text{(ASD G2)}$$

F_{b33} = Allowable bending stress assuming the section is non-compact, and

F_{b33} = Allowable bending stress after considering web slenderness.

In the above expressions, R_e is taken as 1, because currently the program deals with only non-hybrid girders.

If the flange is slender, then the previously computed allowable bending stress is taken to be limited as follows.

$$F_{b33} \quad Q_s \; 0.6 F_y \text{ , where} \qquad \text{(ASD A-B5.2a, A-B5.2d)}$$

Q_s is defined earlier.

Minor Axis of Bending

The minor direction allowable bending stress F_{b22} is taken as follows:

For Compact sections:

$$F_{b22} = 0.75\, F_y \qquad \text{if } f_y \quad 65\,\text{ksi}, \qquad \text{(ASD F2-1)}$$

$$F_{b22} = 0.60\, F_y \qquad \text{if } f_y \quad 65\,\text{ksi}, \qquad \text{(ASD F2-2)}$$

For Noncompact and Slender sections:

$$F_{b22} = \quad 1.075 \quad 0.005 \frac{b_f}{2t_f} \sqrt{F_y} \quad F_y, \quad \text{if } f_y \quad 65\,\text{ksi}, \qquad \text{(ASD F2-3)}$$

$$F_{b22} = 0.60\, F_y \qquad \text{if } f_y \quad 65\,\text{ksi..} \qquad \text{(ASD F2-2)}$$

Channel sections

For Channel sections the length parameter is taken as the laterally unbraced length, l_{22}, which is compared to a critical length, l_c. The critical length is defined as

$$l_c \quad \min \quad \frac{76\, b_f}{\sqrt{F_y}}, \frac{20,000\, A_f}{d\, F_y} \quad \text{, where} \qquad \text{(ASD F1-2)}$$

A_f is the area of compression flange,

Major Axis of Bending

If l_{22} is less than l_c, the major allowable bending stress for Compact and Noncompact sections is taken depending on whether the section is welded or rolled and whether f_y is greater than 65 ksi or not.

For Compact sections:

$$F_{b33} = 0.66\, F_y \qquad \text{if } f_y \quad 65\,\text{ksi}, \qquad \text{(ASD F1-1)}$$

$$F_{b33} = 0.60\, F_y \qquad \text{if } f_y \quad 65\,\text{ksi}, \qquad \text{(ASD F1-5)}$$

For Noncompact sections:

$$F_{b33} = \quad 0.79 \quad 0.002 \frac{b_f}{t_f} \sqrt{F_y} \quad F_y, \text{ if rolled and } f_y \quad 65\,\text{ksi}, \qquad \text{(ASD F1-3)}$$

$$F_{b33} = \quad 0.79 \quad 0.002 \frac{b_f}{t_f} \sqrt{\frac{F_y}{k_c}} \quad F_y \text{, if welded and } f_y \quad 65 \text{ ksi,} \qquad \text{(ASD F1-4)}$$

$$F_{b33} = 0.60 \, F_y \qquad \text{if } f_y \quad 65 \text{ ksi..} \qquad \text{(ASD F1-5)}$$

If the unbraced length l_{22} is greater than l_c, then for both Compact and Noncompact Channel sections the allowable bending stress is taken as follows:

$$F_{b33} = \frac{12{,}000 \, C_b}{l_{22} \quad d \, / \, A_f} \qquad 0.6 \, F_y \qquad \text{(ASD F1-8)}$$

The allowable bending stress for Slender sections bent about their major axis is determined in the same way as for a Noncompact section. Then the following additional considerations are taken into account.

If the web is slender, then the previously computed allowable bending stress is reduced as follows:

$$F_{b33} = R_e R_{PG} \, F_{b33} \qquad \text{(ASD G2-1)}$$

If the flange is slender, the previously computed allowable bending stress is taken to be limited as follows:

$$F_{b33} \qquad Q_s \quad 0.6 F_y \qquad \text{(ASD A-B5.2a, A-B5.2d)}$$

The definition for $r_T, C_b, A_f, A_w, R_e, R_{PG}, Q_s, F_{b33}$, and F_{b33} are given earlier.

Minor Axis of Bending

The minor direction allowable bending stress F_{b22} is taken as follows:

$$F_{b22} = 0.60 \, F_y \qquad \text{(ASD F2-2)}$$

T-sections and Double angles

For T sections and Double angles, the allowable bending stress for both major and minor axes bending is taken as,

$$F_b = 0.60 \, F_y \ .$$

Box Sections and Rectangular Tubes

For all Box sections and Rectangular tubes, the length parameter is taken as the laterally unbraced length, l_{22}, measured compared to a critical length, l_c. The critical length is defined as

$$l_c \quad \max \quad (1950 \quad 1200\, M_a / M_b)\frac{b}{F_y}, \frac{1200\, b}{F_y} \qquad \text{(ASD F3-2)}$$

where M_a and M_b have the same definition as noted earlier in the formula for C_b. If l_{22} is specified by the user, l_c is taken as $\frac{1200\, b}{F_y}$ in the program.

Major Axis of Bending

If l_{22} is less than l_c, the allowable bending stress in the major direction of bending is taken as:

$$F_{b33} = 0.66\, F_y \quad \text{(for Compact sections)} \qquad \text{(ASD F3-1)}$$

$$F_{b33} = 0.60\, F_y \quad \text{(for Noncompact sections)} \qquad \text{(ASD F3-3)}$$

If l_{22} exceeds l_c, the allowable bending stress in the major direction of bending for both Compact and Noncompact sections is taken as:

$$F_{b33} = 0.60\, F_y \qquad \text{(ASD F3-3)}$$

The major direction allowable bending stress for Slender sections is determined in the same way as for a Noncompact section. Then the following additional consideration is taken into account. If the web is slender, then the previously computed allowable bending stress is reduced as follows:

$$F_{b33} = R_e R_{PG}\, F_{b33} \qquad \text{(ASD G2-1)}$$

The definition for R_e, R_{PG}, F_{b33}, and F_{b33} are given earlier.

If the flange is slender, no additional consideration is needed in computing allowable bending stress. However, effective section dimensions are calculated and the section modulus is modified according to its slenderness.

Minor Axis of Bending

If l_{22} is less than l_c, the allowable bending stress in the minor direction of bending is taken as:

$$F_{b22} = 0.66\, F_y \quad \text{(for Compact sections)} \qquad \text{(ASD F3-1)}$$

$$F_{b22} = 0.60\, F_y \quad \text{(for Noncompact and Slender sections)} \qquad \text{(ASD F3-3)}$$

If l_{22} exceeds l_c, the allowable bending stress in the minor direction of bending is taken, irrespective of compactness, as:

$$F_{b22} = 0.60\, F_y \qquad \text{(ASD F3-3)}$$

Pipe Sections

For Pipe sections, the allowable bending stress for both major and minor axes of bending is taken as

$$F_b = 0.66\, F_y \quad \text{(for Compact sections), and} \qquad \text{(ASD F3-1)}$$

$$F_b = 0.60\, F_y \quad \text{(for Noncompact and Slender sections).} \qquad \text{(ASD F3-3)}$$

Round Bars

The allowable stress for both the major and minor axis of bending of round bars is taken as,

$$F_b = 0.75\, F_y\ . \qquad \text{(ASD F2-1)}$$

Rectangular and Square Bars

The allowable stress for both the major and minor axis of bending of solid square bars is taken as,

$$F_b = 0.75\, F_y\ . \qquad \text{(ASD F2-1)}$$

For solid rectangular bars bent about their major axes, the allowable stress is given by

$$F_b = 0.60\, F_y,\ \text{And}$$

the allowable stress for minor axis bending of rectangular bars is taken as,

$$F_b = 0.75\, F_y\ . \qquad \text{(ASD F2-1)}$$

Single-Angle Sections

The allowable flexural stresses for Single-angles are calculated based on their principal axes of bending (ASD SAM 5.3).

Major Axis of Bending

The allowable stress for major axis bending is the minimum considering the limit state of lateral-torsional buckling and local buckling (ASD SAM 5.1).

The allowable major bending stress for Single-angles for the limit state of lateral-torsional buckling is given as follows (ASD SAM 5.1.3):

$$F_{b,major} = \left(0.55 - 0.10\frac{F_{ob}}{F_y}\right) F_{ob}, \qquad \text{if } F_{ob} \le F_y \qquad \text{(ASD SAM 5-3a)}$$

$$F_{b,major} = \left(0.95 - 0.50\sqrt{\frac{F_y}{F_{ob}}}\right) F_y \le 0.66F_y, \quad \text{if } F_{ob} > F_y \qquad \text{(ASD SAM 5-3b)}$$

where, F_{ob} is the elastic lateral-torsional buckling stress as calculated below.

The elastic lateral-torsional buckling stress, F_{ob}, for equal-leg angles is taken as

$$F_{ob} = C_b \frac{28{,}250}{l/t}, \qquad \text{(ASD SAM 5-5)}$$

and for unequal-leg angles F_{ob} is calculated as

$$F_{ob} = 143{,}100\, C_b \frac{I_{min}}{S_{major}\, l^2}\left[\sqrt{\beta_w^2 + 0.052(lt/r_{min})^2} + \beta_w\right], \qquad \text{(ASD SAM 5-6)}$$

where,

$t = \min\{t_w, t_f\}$,

$l = \max\{l_{22}, l_{33}\}$,

I_{min} = minor principal moment of inertia,

I_{max} = major principal moment of inertia,

S_{major} = major section modulus for compression at the tip of one leg,

r_{min} = radius of gyration for minor principal axis,

$$\beta_w = \frac{1}{I_{max}} \int_A z(w^2 + z^2)\, dA - 2z_0 \,, \qquad \text{(ASD SAM 5.3.2)}$$

z = coordinate along the major principal axis,

w = coordinate along the minor principal axis, and

z_0 = coordinate of the shear center along the major principal axis with respect to the centroid.

β_w is a special section property for angles. It is positive for short leg in compression, negative for long leg in compression, and zero for equal-leg angles (ASD SAM 5.3.2). However, for conservative design in the program, it is always taken as negative for unequal-leg angles.

In the above expressions C_b is calculated in the same way as is done for I sections with the exception that the upper limit of C_b is taken here as 1.5 instead of 2.3.

$$C_b = 1.75 + 1.05 \left(\frac{M_a}{M_b}\right) + 0.3 \left(\frac{M_a}{M_b}\right)^2 \leq 1.5 \qquad \text{(ASD F1.3, SAM 5.2.2)}$$

The allowable major bending stress for Single-angles for the limit state of local buckling is given as follows (ASD SAM 5.1.1):

$$F_{b,major} = 0.66\, F_y \,, \qquad \text{if} \quad \frac{b}{t} \leq \frac{65}{\sqrt{F_y}} \,, \qquad \text{(ASD SAM 5-1a)}$$

$$F_{b,major} = 0.60\, F_y \,, \qquad \text{if} \quad \frac{65}{\sqrt{F_y}} < \frac{b}{t} \leq \frac{76}{\sqrt{F_y}} \,, \qquad \text{(ASD SAM 5-1b)}$$

$$F_{b,major} = Q\,(0.60\, F_y) \,, \qquad \text{if} \quad \frac{b}{t} > \frac{76}{\sqrt{F_y}} \,, \qquad \text{(ASD SAM 5-1c)}$$

where,

t = thickness of the leg under consideration,

b = length of the leg under consideration, and

Q = slenderness reduction factor for local buckling. (ASD A-B5-2, SAM 4)

In calculating the allowable bending stress for Single-angles for the limit state of local buckling, the allowable stresses are calculated considering the fact that either of the two tips can be under compression. The minimum allowable stress is considered.

Minor Axis of Bending

The allowable minor bending stress for Single-angles is given as follows (ASD SAM 5.1.1, 5.3.1b, 5.3.2b):

$$F_{b,minor} = 0.66\, F_y \ , \qquad \text{if} \qquad \frac{b}{t} \quad \frac{65}{\sqrt{F_y}}, \qquad \text{(ASD SAM 5-1a)}$$

$$F_{b,minor} = 0.60\, F_y \ , \qquad \text{if} \quad \frac{65}{\sqrt{F_y}} \quad \frac{b}{t} \quad \frac{76}{\sqrt{F_y}}, \qquad \text{(ASD SAM 5-1b)}$$

$$F_{b,minor} = Q \quad 0.60\, F_y \ , \qquad \text{if} \qquad \frac{b}{t} \quad \frac{76}{\sqrt{F_y}}, \qquad \text{(ASD SAM 5-1c)}$$

In calculating the allowable bending stress for Single-angles it is assumed that the sign of the moment is such that both the tips are under compression. The minimum allowable stress is considered.

General Sections

For General sections the allowable bending stress for both major and minor axes bending is taken as,

$$F_b = 0.60\, F_y \ .$$

Allowable Stress in Shear

The shear stress is calculated along the geometric axes for all sections. For I, Box, Channel, T, Double angle, Pipe, Circular and Rectangular sections, the principal axes coincide with their geometric axes. For Single-angle sections, principal axes do not coincide with the geometric axes.

Major Axis of Bending

The allowable shear stress for all sections except I, Box and Channel sections is taken in the program as:

$$F_v \quad 0.40\,F_y \qquad \text{(ASD F4-1, SAM 3-1)}$$

The allowable shear stress for major direction shears in I-shapes, boxes and channels is evaluated as follows:

$$F_v \quad 0.40\,F_y \;, \qquad \text{if } \frac{h}{t_w} \quad \frac{380}{\sqrt{F_y}}\text{, and} \qquad \text{(ASD F4-1)}$$

$$F_v \quad \frac{C_v}{2.89} F_y \quad 0.40\,F_y \;, \quad \text{if } \frac{380}{\sqrt{F_y}} \quad \frac{h}{t_w} \quad 260\,. \qquad \text{(ASD F4-2)}$$

where,

$$C_v \quad \begin{matrix} \dfrac{45{,}000\,k_v}{F_y \;\; h/t_w \;\;^{2}}, & \textit{if} \;\; \dfrac{h}{t_w} \quad 56{,}250\dfrac{k_v}{F_y}\;, \\ \dfrac{190}{h/t_w}\sqrt{\dfrac{k_v}{F_y}}\,, & \textit{if} \;\; \dfrac{h}{t_w} \quad 56{,}250\dfrac{k_v}{F_y}\;, \end{matrix} \qquad \text{(ASD F4)}$$

$$k_v \quad \begin{matrix} 4.00 \quad \dfrac{5.34}{a/h \;\;^{2}}, & \textit{if} \;\; \dfrac{a}{h} \quad 1\,, \\ 5.34 \quad \dfrac{4.00}{a/h \;\;^{2}}, & \textit{if} \;\; \dfrac{a}{h} \quad 1\,, \end{matrix} \qquad \text{(ASD F4)}$$

t_w = Thickness of the web,

a = Clear distance between transverse stiffeners, in. Currently it is taken conservatively as the length, l_{22}, of the member in the program,

h = Clear distance between flanges at the section, in.

Minor Axis of Bending

The allowable shear stress for minor direction shears is taken as:

$$F_v \quad 0.40\,F_y \qquad \text{(ASD F4-1, SAM 3-1)}$$

Calculation of Stress Ratios

In the calculation of the axial and bending stress capacity ratios, first, for each station along the length of the member, the actual stresses are calculated for each load combination. Then the corresponding allowable stresses are calculated. Then, the capacity ratios are calculated at each station for each member under the influence of each of the design load combinations. The controlling capacity ratio is then obtained, along with the associated station and load combination. A capacity ratio greater than 1.0 indicates an overstress.

During the design, the effect of the presence of bolts or welds is not considered. Also, the joints are not designed.

Axial and Bending Stresses

With the computed allowable axial and bending stress values and the factored axial and bending member stresses at each station, an interaction stress ratio is produced for each of the load combinations as follows (ASD H1, H2, SAM 6):

- If f_a is compressive and $f_a / F_a \quad 0.15$, the combined stress ratio is given by the larger of

$$\frac{f_a}{F_a} + \frac{C_{m33}\, f_{b33}}{1 \quad \dfrac{f_a}{F'_{e33}} \quad F_{b33}} + \frac{C_{m22}\, f_{b22}}{1 \quad \dfrac{f_a}{F'_{e22}} \quad F_{b22}}, \text{ and} \qquad \text{(ASD H1-1, SAM 6.1)}$$

$$\frac{f_a}{Q \quad 0.60\, F_y} \quad \frac{f_{b33}}{F_{b33}} \quad \frac{f_{b22}}{F_{b22}}, \text{ where} \qquad \text{(ASD H1-2, SAM 6.1)}$$

f_a, f_{b33}, f_{b22}, F_a, F_{b33}, and F_{b22} are defined earlier in this chapter,

C_{m33} and C_{m22} are coefficients representing distribution of moment along the member length.

$$C_m \quad \begin{array}{ll} 1.00\,, & \text{if length is overwritten,} \\ 1.00\,, & \text{if tension member,} \\ 0.85\,, & \text{if sway frame,} \\ 0.6 \quad 0.4\dfrac{M_a}{M_b}\,, & \text{if nonsway, no transverse loading,} \\ 0.85\,, & \text{if nonsway, trans. load, end restrained,} \\ 1.00\,, & \text{if nonsway, trans. load, end unrestrained.} \end{array} \qquad \text{(ASD H1)}$$

For sway frame $C_m \quad 0.85$, for nonsway frame without transverse load $C_m \quad 0.6 \quad 0.4 M_a / M_b$, for nonsway frame with transverse load and end restrained compression member $C_m \quad 0.85$, and for nonsway frame with transverse load and end unrestrained compression member $C_m \quad 1.00$ (ASD H1), where M_a / M_b is the ratio of the smaller to the larger moment at the ends of the member, M_a / M_b being positive for double curvature bending and negative for single curvature bending. When M_b is zero, C_m is taken as 1.0. The program defaults C_m to 1.0 if the unbraced length factor, l, of the member is redefined by either the user or the program, i.e., if the unbraced length is not equal to the length of the member. The user can overwrite the value of C_m for any member. C_m assumes two values, C_{m22} and C_{m33}, associated with the major and minor directions.

F_e is given by

$$F_e \quad \frac{12 \quad ^2 E}{23(Kl/r)^2}\,. \qquad \text{(ASD H1)}$$

A factor of 4/3 is applied on F_e and $0.6F_y$ if the load combination includes any wind load or seismic load (ASD H1, ASD A5.2).

- If f_a is compressive and $f_a / F_a \quad 0.15$, a relatively simplified formula is used for the combined stress ratio.

$$\frac{f_a}{F_a} + \frac{f_{b33}}{F_{b33}} + \frac{f_{b22}}{F_{b22}} \qquad \text{(ASD H1-3, SAM 6.1)}$$

- If f_a is tensile or zero, the combined stress ratio is given by the larger of

$$\frac{f_a}{F_a} \qquad \frac{f_{b33}}{F_{b33}} \qquad \frac{f_{b22}}{F_{b22}}\,, \text{ and} \qquad \text{(ASD H2-1, SAM 6.2)}$$

$$\frac{f_{b33}}{F_{b33}} \quad \frac{f_{b22}}{F_{b22}}, \text{ where}$$

f_a, f_{b33}, f_{b22}, F_a, F_{b33}, and F_{b22} are defined earlier in this chapter. However, either F_{b33} or F_{b22} need not be less than $0.6F_y$ in the first equation (ASD H2-1). The second equation considers flexural buckling without any beneficial effect from axial compression.

For circular and pipe sections, an SRSS combination is first made of the two bending components before adding the axial load component, instead of the simple addition implied by the above formulae.

For Single-angle sections, the combined stress ratio is calculated based on the properties about the principal axis (ASD SAM 5.3, 6.1.5). For I, Box, Channel, T, Double-angle, Pipe, Circular and Rectangular sections, the principal axes coincide with their geometric axes. For Single-angle sections, principal axes are determined in the program. For general sections no effort is made to determine the principal directions.

When designing for combinations involving earthquake and wind loads, allowable stresses are increased by a factor of 4/3 of the regular allowable value (ASD A5.2).

Shear Stresses

From the allowable shear stress values and the factored shear stress values at each station, shear stress ratios for major and minor directions are computed for each of the load combinations as follows:

$$\frac{f_{v2}}{F_v}, \quad \text{and}$$

$$\frac{f_{v3}}{F_v}.$$

For Single-angle sections, the shear stress ratio is calculated for directions along the geometric axis. For all other sections the shear stress is calculated along the principle axes which coincide with the geometric axes.

When designing for combinations involving earthquake and wind loads, allowable shear stresses are increased by a factor of 4/3 of the regular allowable value (ASD A5.2).