1989 AISC Specification (Ninth Edition) Allowable Bending Stress Design Aid

ALLEN J. HULSHIZER

SYNOPSIS

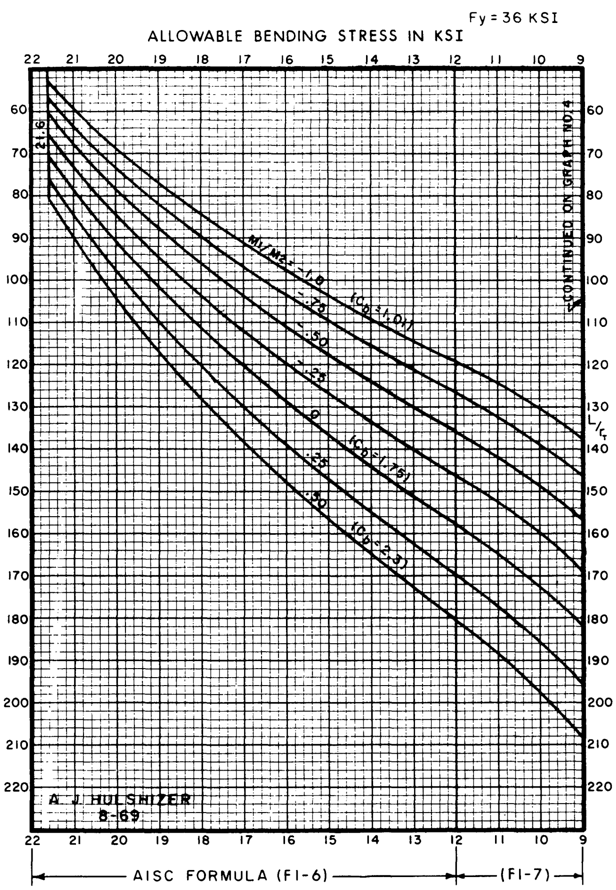
Simple to use, accurate graphic solutions to compressive bending stress equations are provided to readily facilitate taking full advantage of actual bracing and continuity conditions to achieve design time and material efficiencies.

INTRODUCTION

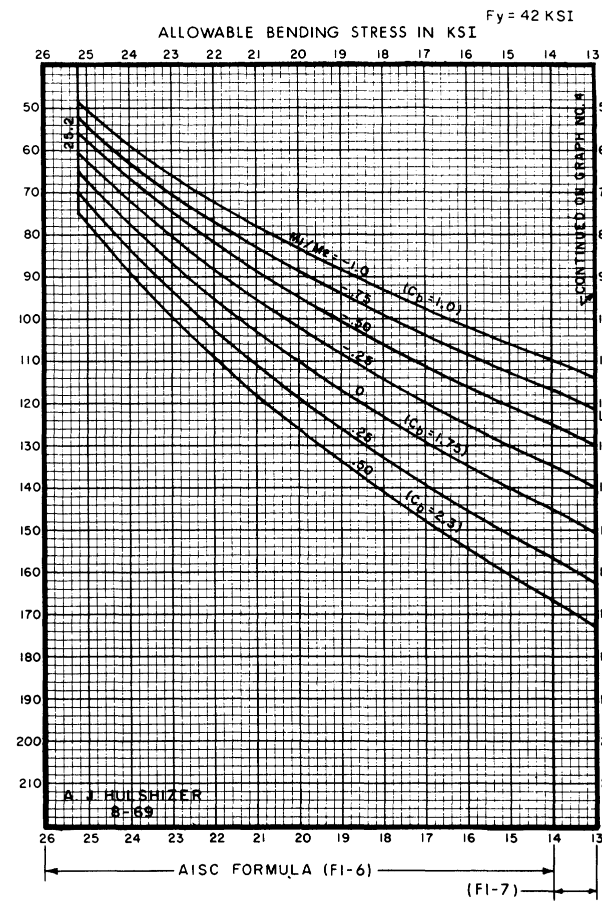
The 1969 AISC Specification introduced two new allowable compressive bending stress equations and a means of accounting for reduced buckling behavior associated with member continuity and/or bracing conditions. These provisions offered higher allowable stresses (economies) under certain conditions. The 1969 equations, designated formulas 1.5-6a and 1.5-6b through the eighth edition, have now been identified in the ninth edition as Formulas F1-6 and F1-7 respectively, while the continuity/bracing relationship (C_b) remains as termed in 1969. The earliest AISC equation for allowable compressive stress which was designated as Formula 1.5-7 in 1969 has been now identified as Formula F1-8.

For the most part, the advantageous use of Formulas F1-6 and F1-7 for rolled shapes is with lighter members (as W24×55, W18×35, W12×14 and W8×10) where C_b values approach or are equal to one. High strength steels will provide even greater efficiencies for parameters with the Formula F1-6 range since Formulas F1-7 and F1-8 do not involve yield values. Due to the linear influence of C_b in Formula F1-8, the allowable stress advantage obtained by the use of

Allen J. Hulshizer is consulting structural engineer, United Engineers & Constructors, Inc. Philadelphia, PA.



Graph 1



Graph 2

the more complex equation (F1-6) decreases with an increase in the value of C_b. On the other hand, Formula F1-8 becomes extremely conservative for members with large *d/Af* properties, such as plate girders which will generally find their greatest stress economies through the use of Formulas F1-6 and F1-7 (see Plate Girder Examples).

F1-6 AND F1-7 GRAPHIC SOLUTION

In order to conveniently take advantage of actual continuity and bracing conditions and the resulting higher allowable stresses, a simple graphic solution to F1-6 and F1-7 has been developed to solve for allowable bending stress in terms of M_1/M_2 and L/r_t to cover yield values 36, 42, and 50 ksi. These plots are essentially self-explanatory and are included as Graphs 1 through 4. These two equations (F1-6 and F1-7) are actually continuous curves and therefore when plotted together, the tests for equation boundary conditions are no longer required. The solution for F_b (F1-6 and F1-7) is obtained solely by entering the graphs with the values of M_1/M_2 and L/r_t. The graphs are plotted on 200 psi grids and, as presented, are large enough to enable allowable stress values to be readily interpolated within 100 psi.

Graphs 1 and 2 are plotted for yield stresses of $F_y = 36$ and 42 ksi respectively for Formula F1-6 with a small section of Formula F1-7 (extension of Graph 4) indicating the point of intersection of the two equations.

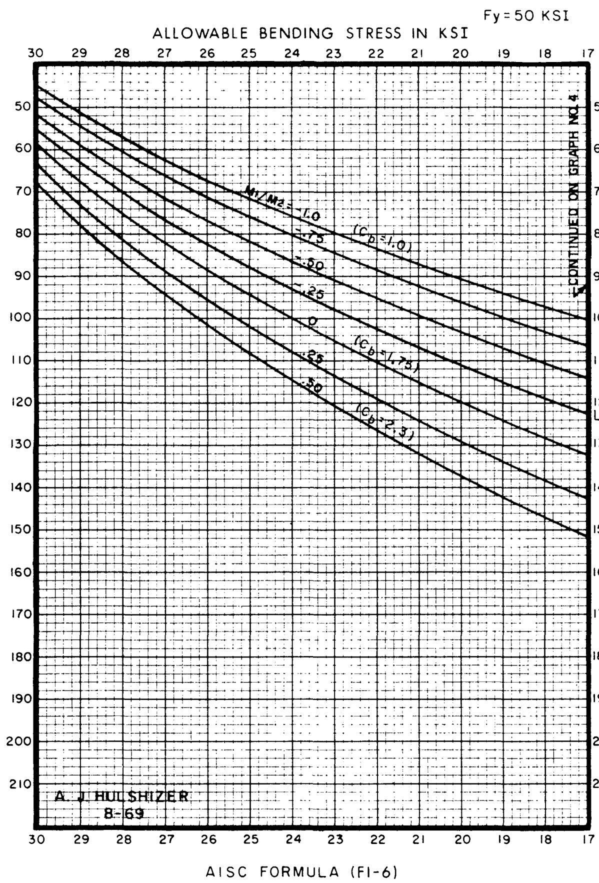
Graph 3 is plotted for Formula F1-6 for a yield stress of $F_y = 50$ ksi with the lower stress range of the formula completed on Graph 4.

Graph 4 is plotted for Formula F1-7 for yield stresses of $F_y = 36$, 42, and 50 ksi with indicated limits for each stress grade range. Formula F1-7 for the yield stress of $F_y = 50$ ksi is also completed on the graph.

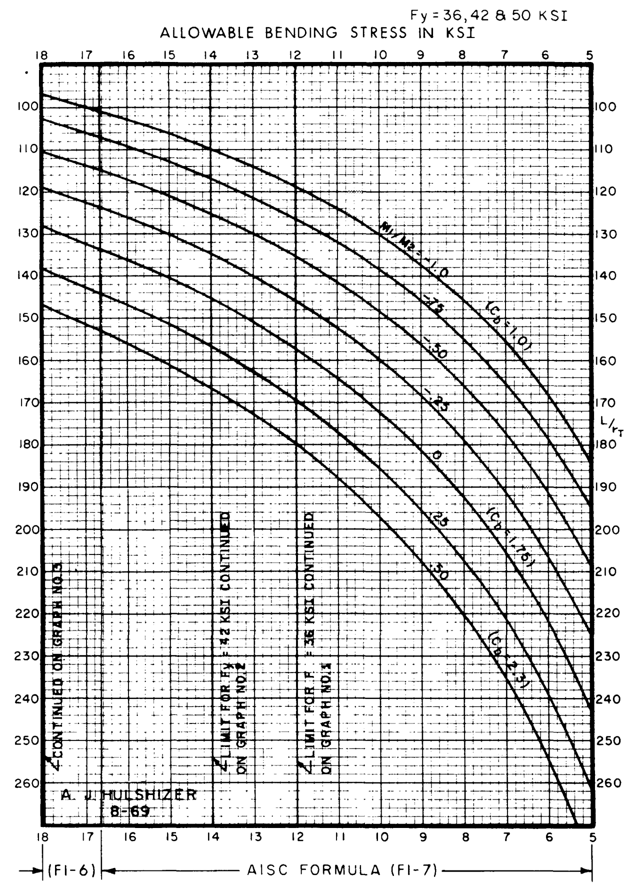
COMPARISON OF SIMPLIFIED APPROACH AND DIRECT APPROACH

The AISC Specification, in order to simplify the use of Formulas F1-6 and F1-7, suggests that C_b can be conservatively taken as unity (i.e., ignore bracing and/or continuity stress reducing conditions). This approach is equivalent to the extreme single curvature and moment ratio of -1 or the condition where moment within the unbraced length is greater than the end moments. For actual end moment rotations less than -1.0 ($C_b = 1.0$), the simplified use of $C_b = 1.0$ produces a degree of conservatism which increases with a decrease in the end moment ratio and when using Formulas F1-6 or F1-7 and an increase in the L/r_t.

Table 1 presents allowable bending stresses for various



Graph 3

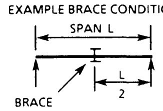


Graph 4

Table 1.
Relative Allowable Bending Stresses From Framing Examples Considering C_b = 1.0, 1.75, and 2.3

Beam Size	d/A_f	r_t	Span L	$\frac{L}{2r_t}$	F_b from Graphs Based on F1-6 and F1-7 ( ) = F_b Utilizing Formula F1-8: C_b =1.0, M_1/M_2 =−1	C_b =1.75, M_1/M_2 =0	C_b =2.3, M_1/M_2 =+0.5	% Increase Relative to C_b = 1.0 for: C_b =1.75	C_b =2.3	F_y
W30×99	4.23	2.57	52-0	121	11.6 (9.1)	16.9 (15.9)	18.7 (20.9)	46% (*)	61% (*)	36 ksi
W24×55	6.66	1.68	40-0	143	8.3 (7.5)	14.2 (13.1)	16.5 (17.3)	71% (*)	99% (*)	36 ksi
W18×35	6.94	1.49	32-0	129	10.1 (9.1)	15.9 (15.8)	17.9 (20.9)	57% (*)	77% (*)	36 ksi
W12×14	13.3	0.95	20-0	126	10.6 (7.5)	16.3 (13.2)	18.2 (17.3)	54% (*)	72% (*)	36 ksi
W10×12	11.9	0.96	16-0	100	15.6 (10.5)	19.1 (18.4)	20.3 (21.6)	22% (*)	30% (*)	36 ksi
W8×10	9.77	0.99	14-0	85	17.8 (14.6)	20.5 (21.6)	21.3 (21.6)	15% (*)	20% (*)	36 ksi
W30×99	4.23	2.57	52-0	121	11.6 (9.1)	19.8 (15.9)	23.0 (20.9)	71% (*)	98% (*)	50 ksi
W12×14	13.3	0.95	20-0	126	10.6 (7.5)	18.6 (13.2)	22.1 (17.3)	75% (*)	108% (*)	50 ksi

EXAMPLE BRACE CONDITIONS



F_b based simplified Use of C_b = 1.0 for mid-span braced condition

F_b based on actual mid-span braced condition C_b = 1.75

F_b based on end continuity where M_1/M_2 = 0.5

* = % increase of 75% and 130% for Formula F1-8 relative to C_b = 1.75 and 2.30 respectively

beam sizes based on selected spans and bracing/continuity conditions for C_b equal to 1.0, 1.75, and 2.3. The percent difference in allowable stresses (F_b) is tabulated to portray the penalty that occurs when C_b is used as one when, in fact, different bracing/continuity conditions actually exist. The example mid-span braced condition is specifically illustrative of the typical situations where C_b is equal to 1.75 but the simplified approach utilizes C_b equal to one. This also applies to utilizing the AISC Allowable Moments in Beams Graphs when C_b is greater than one.

CONCLUSION

By eliminating the mechanics of an algebraic solution through means of the continuous graphic solution, the simplified use of C_b = 1 is no longer necessary since Formulas F1-6 and F1-7 can be readily and accurately used with a minimum of effort. In many cases, the proper use of these formulas will provide a more efficient use of material through higher allowable stresses. Even greater efficiencies exist when using high strength steels for ranges where Formula F1-6 is applicable.

PLATE GIRDER EXAMPLE

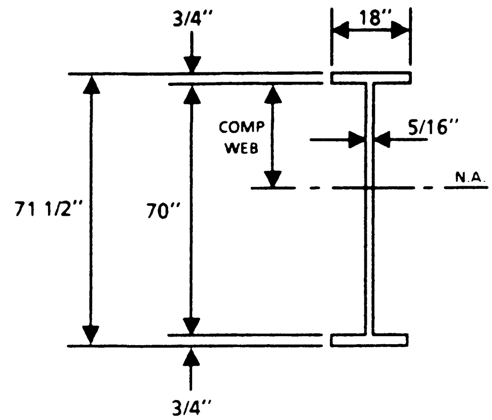
Find the allowable compressive bending stress for the plate girder shown with the following span and bracing conditions

Area of flange (A_f) $= 0.75 \times 18 = 13.50$ in.^{2}
Area of web (A_w) $= 70 \times 0.3125 = 21.88$ in.^{2}

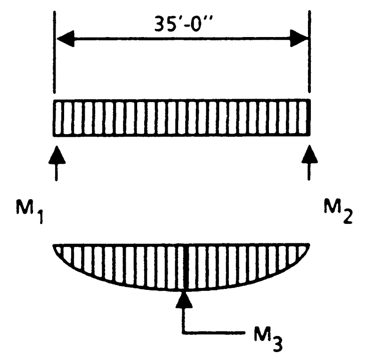
$$I_y = \frac{2 \times 0.75 \times 18^3}{12} = 729 \text{ in.}^4$$

$$d/A_f = \frac{71.5}{13.75} = 5.2$$

$$r_t = \sqrt{\frac{I_y}{2(A_f + A_w/6)}} = \sqrt{\frac{729}{2\left(13.5 + \frac{21.88}{6}\right)}} = 4.61 \text{ in.}$$



Condition 1



$M_3 > M_1$ & M_2
$\therefore C_b = 1.0$ & $M_1/M_2 = -1.0$

Formula F1-8

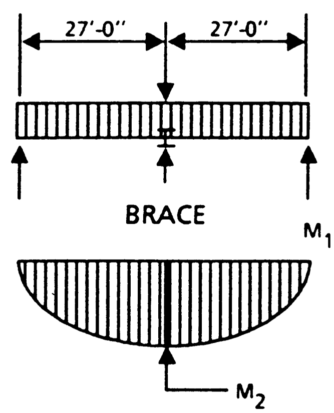
$$F_b = \frac{12 \times 10^3 \times 1.0}{35 \times 12 \times 5.2} = 5.5 \text{ ksi}$$

Formulas F1-6 and F1-7 (Graph)

$$\frac{L}{r_t} = \frac{35 \times 12}{4.61} = 91.1 \qquad \textbf{Use 91}$$

With $M_1/M_2 = -1$ and $L/r_t = 91$
From Graph 1: $F_b = 17.0$ ksi for $F_y = 36$ ksi
From Graph 2: $F_b = 22.6$ ksi for $F_y = 42$ ksi

Condition 2



$M_1/M_2 = 0/1 = 0$
$\therefore C_b = 1.75$

Formula F1-8

$$F_b = \frac{12 \times 10^3 \times 1.75}{27 \times 12 \times 5.2} = 12.5 \text{ ksi}$$

Formulas F1-6 and F1-7 (Graph)

$$\frac{L}{r_t} = \frac{27 \times 12}{4.61} = 70.3 \qquad \textbf{Use 70}$$

With $M_1/M_2 = 0$ and $L/r_t = 70$
From Graph 1: $F_b = 21.6$ ksi for $F_y = 36$ ksi
From Graph 2: $F_b = 24.8$ ksi for $F_y = 42$ ksi