Graphical Solution for Selection of Web Splice Bolts

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SELECTION OF the required number of bolts in the design of a web splice transmitting shear and moment is a trial and error procedure. A group of bolts is assumed and actual load on the bolt due to applied forces is calculated and then compared with the allowable load according to specifications. Curves are presented here that will assist the designer in making a rapid selection of the required number of bolts for a particular problem if shear and moment are known. The curves are developed in accordance with AASHO specifications, but can also be used for designs based on the AISC Specification. Contrary to the procedure of using effective eccentricity of the design shear in building construction in accordance with AISC Specification, actual eccentricity of the design shear with respect to the centroid of the bolt group is used when a web splice is designed according to AASHO specifications.

ASSUMPTIONS

Curves are developed using the following assumptions:

1. Bolts used are in double shear.
2. Vertical component of bolt load due to bending is small and neglected.
3. For use with the AASHO specifications, the ordinate (M_s') and abcissa (V) values are for ⅞-in. dia. ASTM A325 bolts having an allowable double shear value (R) of 16.24 kips.
4. For use with the AISC Specification, alternate scales for the ordinate and abcissa are provided. These scales generalize the curves so that they can be used for any bolt size or bolt strength if the applicable double shear value (R) is substituted in the ordinate (M_s'/R) and abcissa (V/R).
5. Dimensional nomenclature is shown in Fig. 1.

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BASIC EQUATIONS

The equation for R can be written as*:

$$R = \left\{\left[\frac{V}{mn} + \frac{6M_s a}{n(n^2b^2 + m^2a^2)}\right]^2 + \left[\frac{6M_s b}{m(n^2b^2 + m^2a^2)}\right]^2\right\}^{1/2} \quad (1)$$

With assumption 2, Eq. (1) becomes:

$$R = \left\{\left(\frac{V}{mn}\right)^2 + \left(\frac{6M_s b}{m(n^2b^2 + m^2a^2)}\right)^2\right\}^{1/2} \quad (1a)$$

Equation (1a) can also be written as:

$$M_s = \frac{b}{6}\left\{(Rmn^2)^2 - (Vn)^2\right\}^{1/2}\left(1 + \frac{m^2a^2}{n^2b^2}\right) \quad (1b)$$

Let $C = \left(1 + \dfrac{m^2a^2}{n^2b^2}\right)$ = moment adjustment factor

$$\therefore\ M_s = C\frac{b}{6}\left\{(Rmn^2)^2 - (Vn)^2\right\}^{1/2} \quad (1c)$$

Let $M_s' = M_s/C$

$$\therefore\ M_s' = \frac{b}{6}\left\{(Rmn^2)^2 - (Vn)^2\right\}^{1/2} \quad (1d)$$

Curves are developed for Eq. (1d) using R = 16.24 kips, for use with* the AASHO specifications.

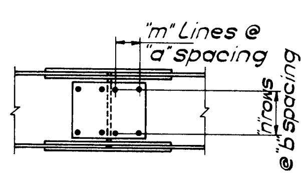

Figure 1

* *See* "Design of Steel Structures", *2nd Edition, by Bresler, Lin and Scalzi, John Wiley & Sons, Inc., New York, N.Y.*

USE OF CURVES

Curves are plotted for $b = 3$ in. spacing of horizontal rows of bolts and four different values of m, i.e., $m = 2$, 3, 4, and 5. To use these curves for AASHO specifications, assume the moment adjustment factor $C = 1.0$, and enter with the given values of M_s and V. The required number of bolts is represented by a line which falls at or above the point of intersection of M_s and V. Using this value of number of bolts, the actual value of moment adjustment factor C can be read from Chart 5. The required number of bolts is to be determined again using the given value of V and an adjusted value of

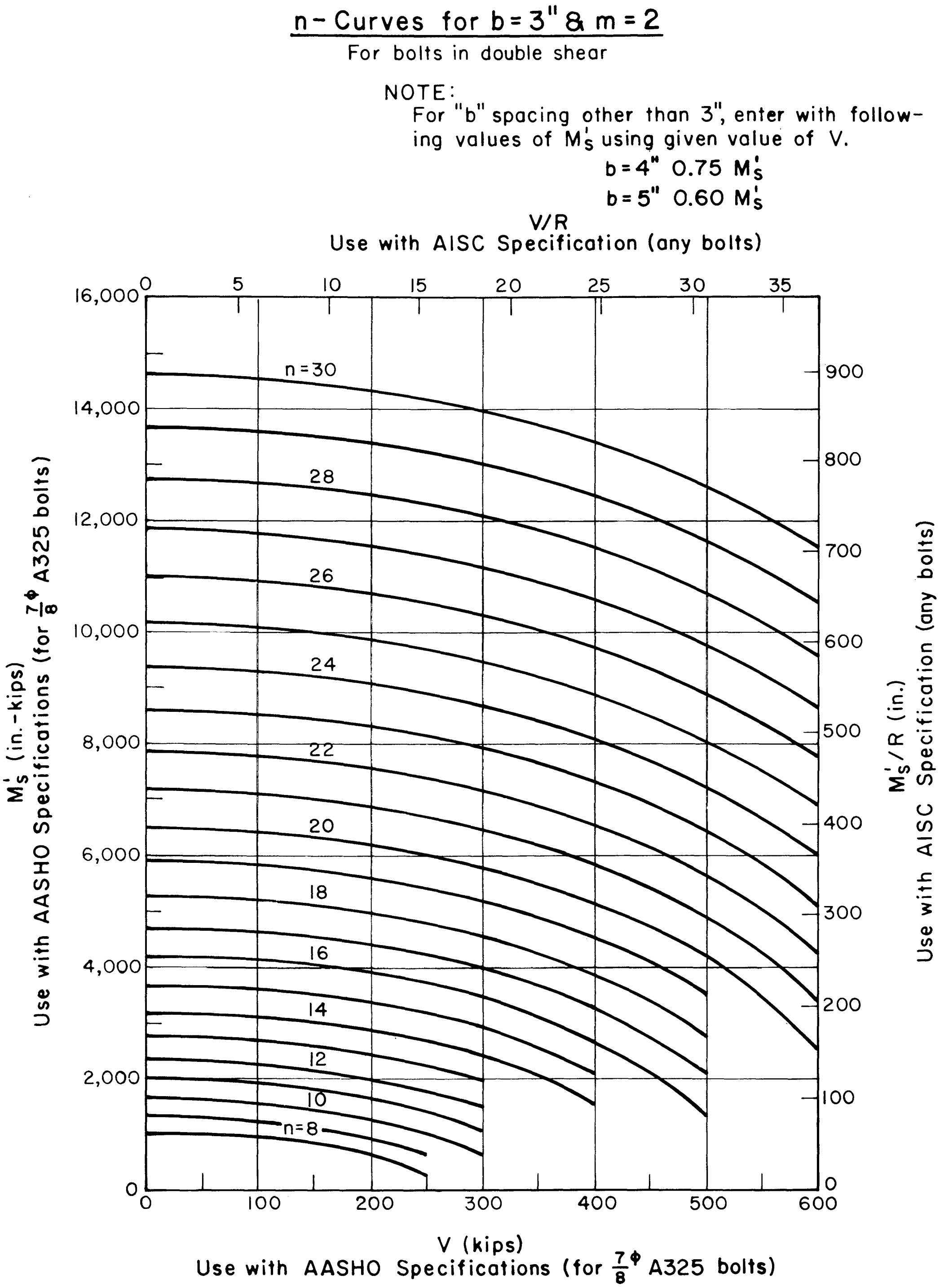

Chart 7

moment M_s' which is obtained by dividing the given value of M_s with the actual value of moment adjustment factor C.

To use the curves for the AISC Specification, the procedure is the same except that the right-hand ordinate and the upper abcissa are used, and the charts are entered with values of M_s/R, V/R, and M_s'/R, where R is the double shear value of the bolt under consideration.

For other values of b spacing enter the charts with the given value of V or V/R and the following M_s' or M_s'/R values.

For $b = 2\frac{3}{4}$ in.:	Use 1.09 M_s' or 1.09 M_s'/R
For $b = 4$ in.:	Use 0.75 M_s' or 0.75 M_s'/R
For $b = 5$ in.:	Use 0.60 M_s' or 0.60 M_s'/R

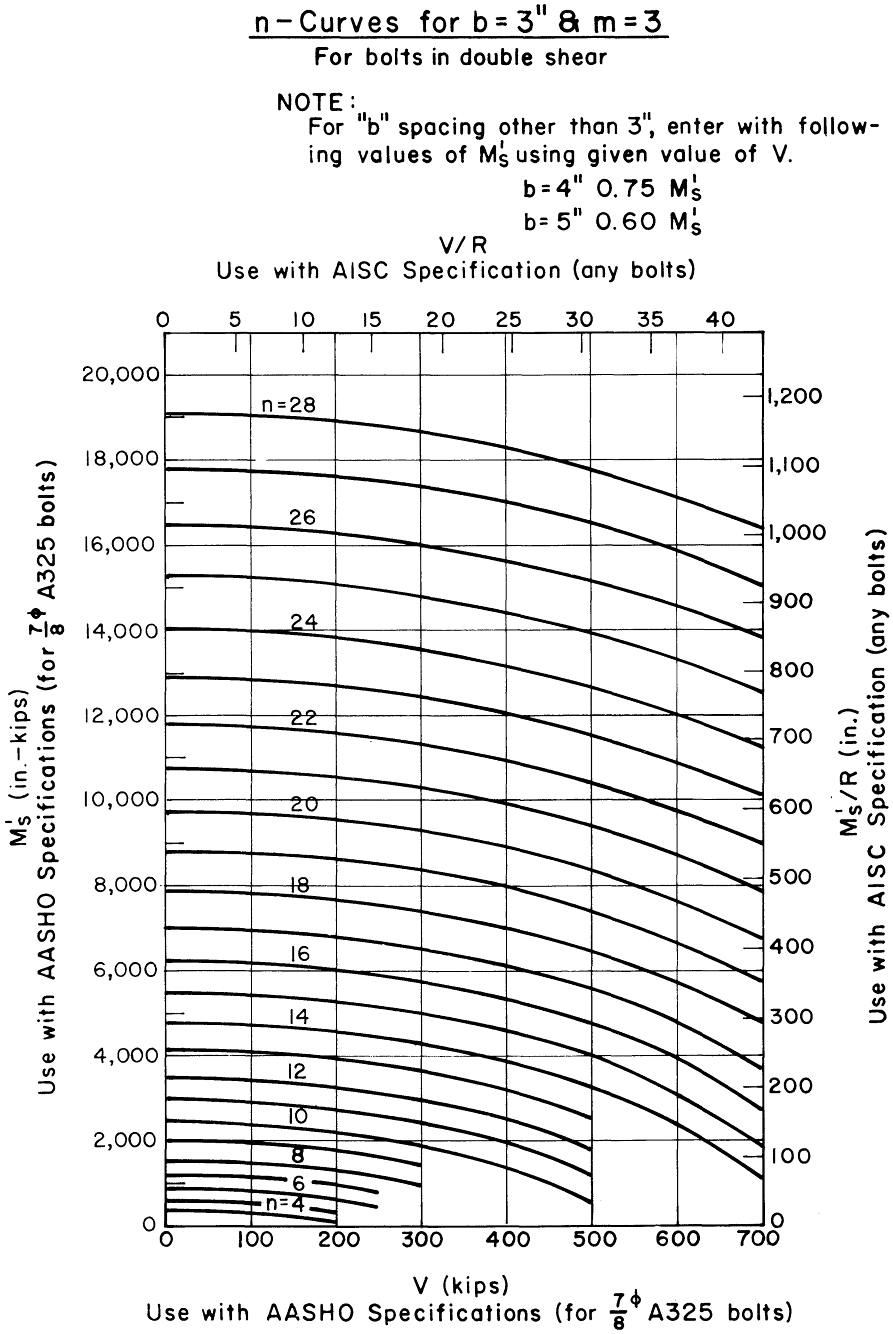

Chart 2

n – Curves for b = 3" & m = 4

For bolts in double shear

NOTE:
For "b" spacing other than 3", enter with following values of M_s' using given value of V.

b = 4" 0.75 M_s'

b = 5" 0.60 M_s'

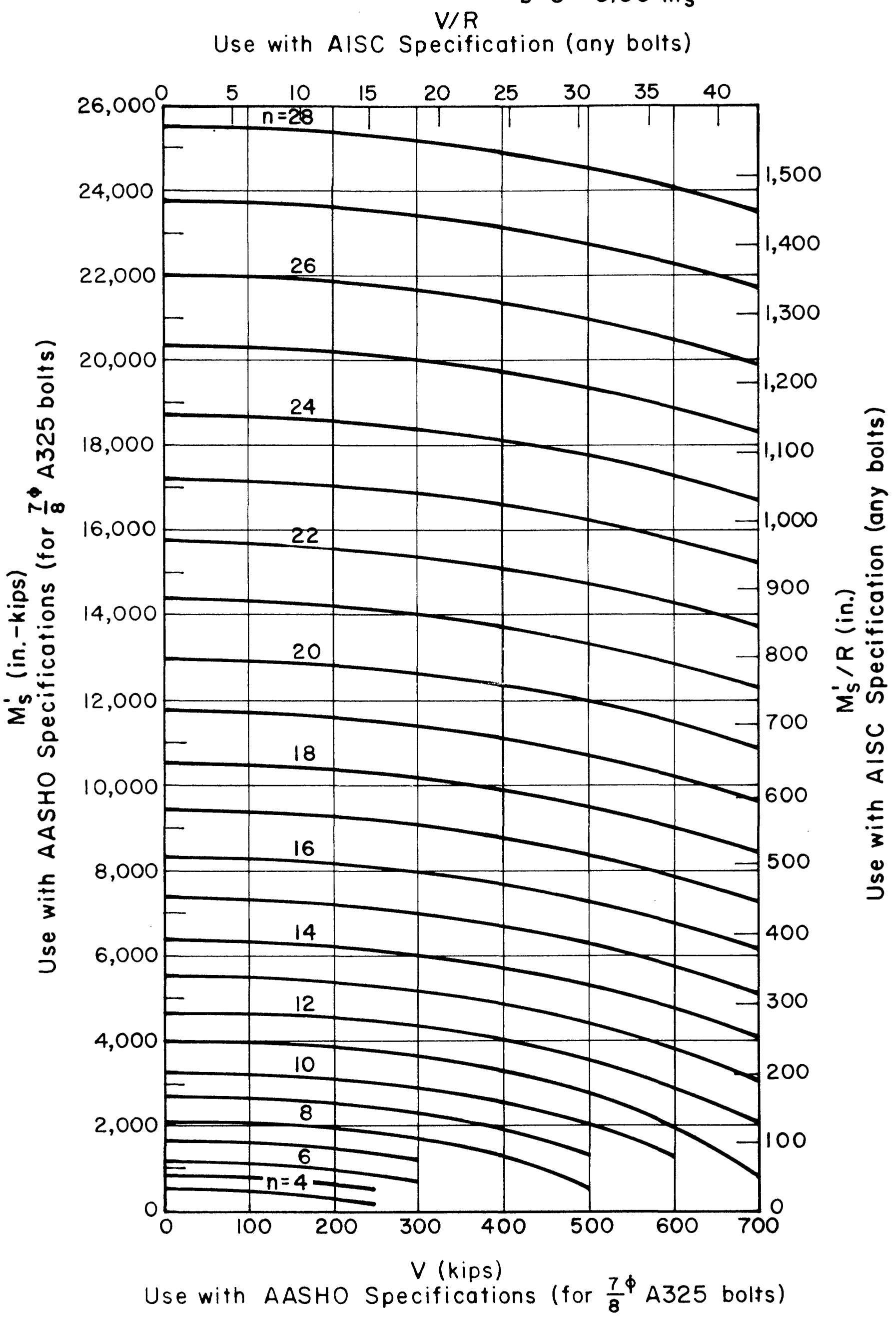

Chart 3

n−Curves for b = 3" & m = 5

For bolts in double shear

NOTE:
For "b" spacing other than 3", enter with following values of M'_s using given value of V.

b = 4" 0.75 M'_s

b = 5" 0.60 M'_s

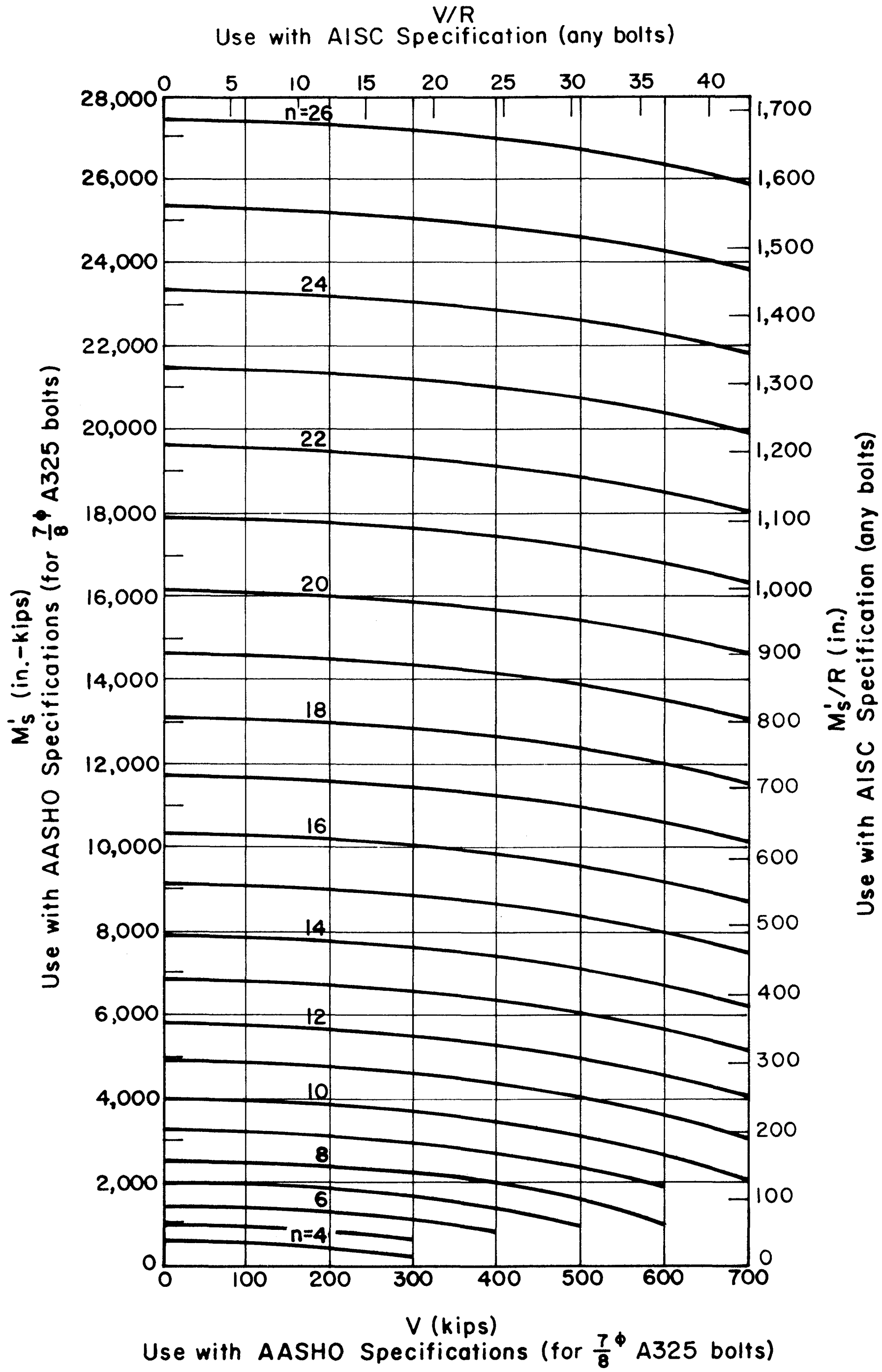

Chart 4

Moment Adjustment Factor "C" Curves

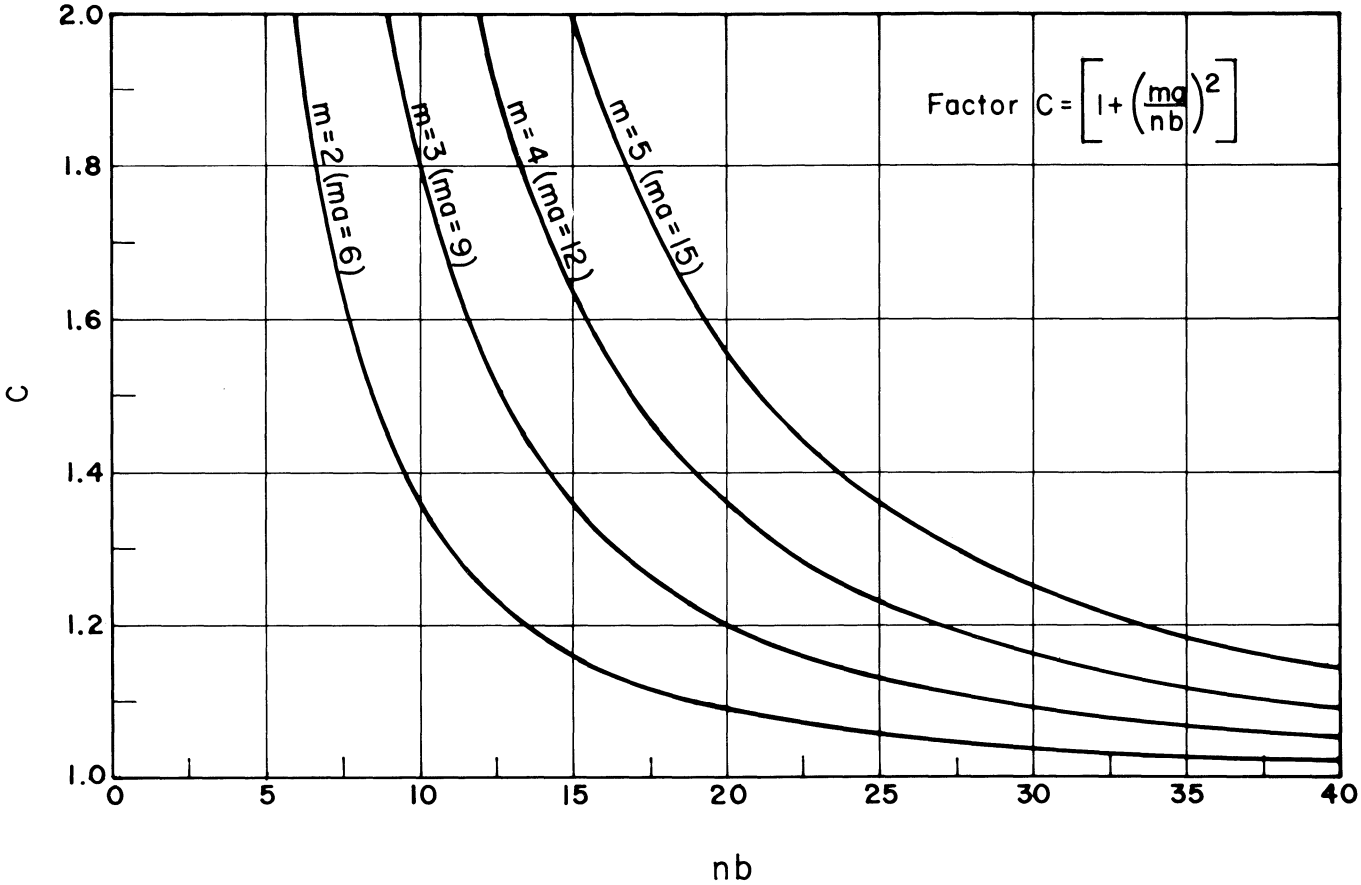

Chart 5

MOMENT ADJUSTMENT FACTOR *C*

In Chart 5, the moment adjustment factor C is plotted against nb for different values of ma. A commonly used value of 3 in. for the a spacing is used for developing the factor C curves. It is suggested that factor C should be used equal to 1.0 for all cases where the value of n is greater than three times the value of m. This will give a lower than allowable value of R. For the cases where $n < 3m$, it is suggested that the actual value of C be used.

NOMENCLATURE

A_f = Area of one flange, in.^{2}
A_w = Area of the web, in.^{2}
R = Allowable load on one bolt (double shear value), according to specification, kips
V = Design shear, kips
M = Design moment for the splice, in.-kips
M_s = Design moment for web splice, in.-kips. Can be estimated as $M_s = M_w + M_v$
M_s' = M_s/C
b = Spacing of horizontal rows of bolts, in.
n = Number of horizontal rows of bolts each side of center line of splice
m = Number of vertical lines of bolts each side of center line of splice
a = Spacing of vertical lines of bolts each side of center line of splice
e = Eccentricity of the design shear with respect to centroid of the bolt group, in.
C = Moment adjustment factor
M_w = Portion of the total moment at the splice assumed to be transmitted by the web splice, in.-kips
$= M(A_w/6)/(A_f + A_w/6)$
M_v = Moment due to the eccentricity of design shear, in.-kips
$= V(e)$

ILLUSTRATIVE EXAMPLES

Example 1 (See Fig. 2.)

Given:

M = 20,333 in.-kips
V = 260 kips
A_f = 18.00 in.^{2}
A_w = 21.00 in.^{2}
Use AASHO specifications; 7/8″ bolts (R = 16.24 kips)

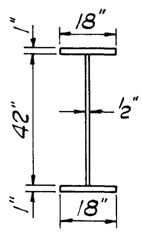

Figure 2

Solution:

Assume $C = 1.0$

Refer to Fig. 1. Assume $m = 4$ and let eccentricity e = 6.5 in. for this case.

M_v = 260 × 6.50 = 1690 in.-kips
$A_w/6$ = 21.00/6 = 3.50 in.^{2}
M_w = 20,333 × 3.50/(18.00 + 3.50)
= 3310 in.-kips
M_s = 3310 + 1690 = 5000 in.-kips
M_s' = M_s/C = 5000/1.0 = 5000 in.-kips

Assume b = 3 in.

From Chart 3 (n-curves for m = 4), using AASHO scales:

No. of 7/8″ bolts = 13

Enter Chart 5 with nb = 13 × 3 = 39 and read C = 1.09.

M_s' = 5000/1.09 = 4587 in.-kips

Enter Chart 3 with M_s' = 4587 in.-kips and V = 260 kips.

Required no. of 7/8″ bolts = 13

Example 2 (See Fig. 3.)

Given:

M = 11,180 in.-kips
V = 160 kips
A_f = 15.75 in.^{2}
A_w = 15.75 in.^{2}
Use AASHO specifications; 7/8″ bolts (R = 16.24 kips)

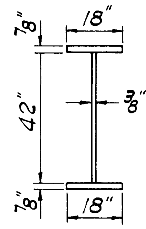

Figure 3

Solution:

Assume $C = 1.0$

Refer to Fig 1. Assume m = 3 and let eccentricity e = 5.00 in. for this case.

M_v = 160 × 5.00 = 800 in.-kips
$A_w/6$ = 15.75/6 = 2.63 in.^{2}
M_w = 11,180 × 2.63/(15.75 + 2.63)
= 1600 in.-kips
M_s = 1600 + 800 = 2400 in.-kips
M_s' = M_s/C = 2400/1.0 = 2400 in.-kips

Assume b = 4 in.

Enter Chart 2 (n-curves for m = 3) with 0.75 M_s', using AASHO scales.

0.75 × 2400 = 1800 in.-kips
V = 160 kips
No. of 7/8″ bolts = 9

Enter Chart 5 with nb = 9 × 4 = 36 and read C = 1.11.

M_s' = 1800/1.11 = 1622 in.-kips

Enter Chart 2 with M_s' = 1622 in.-kips and V = 160 kips.

Required no. of 7/8″ bolts = 9