Stiffened Seat Brackets

1. ANALYSIS OF STIFFENER AT RIGHT ANGLES TO BEAM WEB

When the reaction load (R) requires a thickness of angle greater than the available sections, a stiffened seat bracket may be used. There are two analyses: (A) in which the seat stiffener is at right angles to the web of the beam, and (B) in which the seat stiffener is in line with the web of the beam.

For analysis, the stiffener of Type (A) is considered an eccentrically loaded column with the reaction load applied at a fixed point. The *maximum stress is the* sum of the direct load and bending effects. The line of action of the compressive load is approximately parallel to the outer edge of the stiffener. The critical cross-section of the stiffener (to be used for the area and section modulus) is at right angles to the line of action of the load.

The area and section modulus are—

$$A = t\,X = t\,L_h \sin\phi$$

$$S = \frac{t\,X^2}{6} = \frac{t\,L_h^2 \sin^2\phi}{6}$$

$$a = \left(e_s - \frac{L_h}{2}\right)\sin\phi$$

$$X = L_h\ \mathit{sin}\ \phi$$

Since the maximum stress,

$$\sigma = \frac{F}{A} + \frac{M}{S} = \frac{F}{A} + \frac{F\,a}{S}$$

$$= \frac{R}{t\,L_h^2 \sin^2\phi} + \frac{6R\left(e_s - \frac{L_h}{2}\right)\sin\phi}{t\,L_h^2 \sin^3\phi}$$

$$= \frac{R(6e_s - 2L_h)}{t\,L_h \sin^2\phi}$$

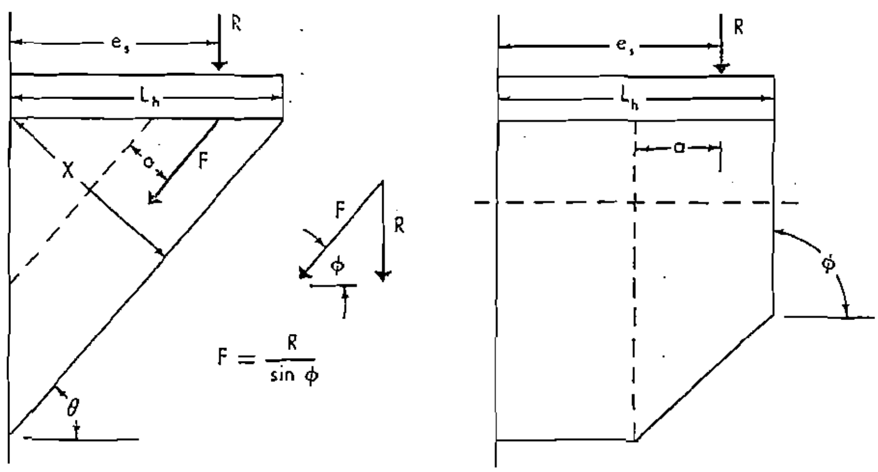
the required thickness of the bracket web is—

$$\boxed{t = \frac{R(6e_s - 2L_h)}{\sigma\,L_h^2 \sin^2\phi}} \quad \cdots\cdots\cdots\cdots (1)$$

The thickness of the bracket web can be determined quickly from Nomograph No. 4 (Fig. 2) for A36 steel; this is based on formula #1. The vertical line at the left is for values of load eccentricity (e_s) and length of outstanding bracket leg (L_h). The next line is for the angle between the side of the bracket web and the horizontal. A line is drawn through these two values to the pivot line (C). From this pivot point, a line is drawn through the reaction value (R) and the required thickness of bracket web (t) is read on the extreme right-hand line.

*The above analysis of bracket web thickness requirement is based upon "Welded Structural Brackets", Cyril D. Jensen, AWS Welding Journal, Oct. 1936.

FIGURE 1



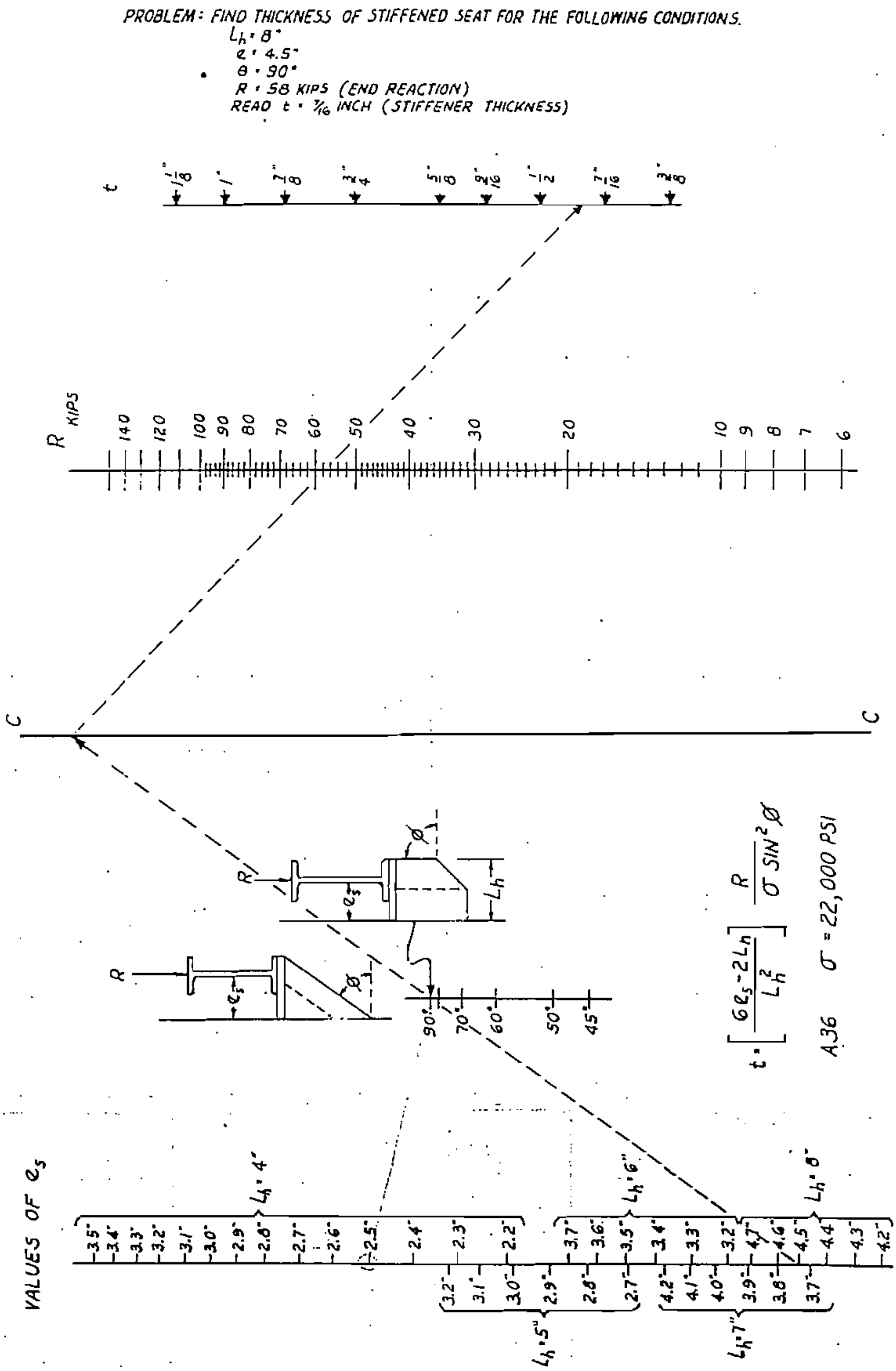


FIGURE 2—Thickness of Stiffened Seat For A36 Steel

NOMOGRAPH NO. 4

2. ANALYSIS OF STIFFENER IN LINE WITH BEAM WEB

If the beam rests in line with the bracket stiffener, Type B, Figure 3, the bearing length (N) of the beam (AISC Sec 1.10.10) is—

$$\boxed{N = \frac{R}{t_w\ (.75\ \sigma_y)} - K} \qquad (2)$$

and this would be the minimum value allowed.

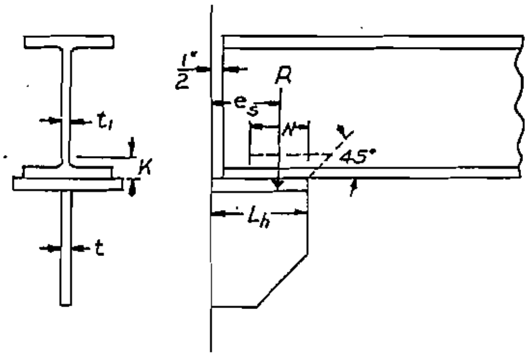


FIGURE 3

The eccentricity (e_s) of the reaction load is—

$$\boxed{e_s = L_h - \frac{N}{2}} \qquad (3)$$

This value of load eccentricity (e_s) can be quickly found by using Nomograph No. 1 (Fig. 4 in previous Sect. 5.2). Sometimes it is figured as 80% of the bracket's outstanding leg length (L_h).

The eccentrically loaded column formula (#1) is seldom used in this case because it will result in an excessively thick bracket web or stiffener. This is because the formula is based upon stress only and does not take into consideration some yielding of the bracket which will cause the point of application of the load to shift in toward the support, thus reducing the moment arm and bending stress.

AISC Manual, page 4-39 recommends for A36 bracket material that the bracket web's thickness be at least equal to 1.33 times the required fillet weld size (E70 welds). Also it should not be less than the supported beam web thickness for A7, A373 and A36 beams, and not less than 1.4 times the beam web thickness for A242 and A441 beams.

For stiffened seats in line on opposite sides of the column web, the fillet weld size should not exceed ¾ the column web thickness when determining its length (L_v).

3. WELDING OF BRACKETS

If the bracket is made up of plates, AISC recommends that the welds connecting the top plate to the web of the stiffener should have strength equivalent to the horizontal welds between the bracket and the column support.

The depth of the stiffener is determined by the vertical length of weld (L_v) required to connect the bracket.

The length of the bracket top plate (L_h) should be sufficient for it to extend at least beyond the bearing length of the beam (N).

The stiffened seat bracket is shop welded to the supporting member in the flat or downhand position. Usually the top portion of the bracket is welded on the underside only, and the web of the stiffener is welded both sides, full length. By placing the weld on the underside of the bracket, it does not interfere in any way with the beam which it supports.

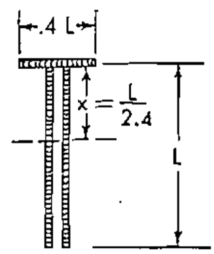
Some engineers do not like the notch effect of this fillet weld's root to be at the outer fiber of the connection, and would prefer to place this fillet weld on top of the bracket; this can be done.

4. WELD SIZE AND LENGTH

The following method is used to determine the leg size of the connecting fillet weld (ω). For simplicity the length of the horizontal top weld is assumed to be a certain percentage of the vertical weld length (L_v). The top weld length is usually less than the bracket width, and the vertical weld length is assumed equal to the vertical length of the bracket.

This analysis uses the value of 0.4 L_v for the top weld as it is a more commonly used value, although any reasonable value might be used, Figure 4.

FIGURE 4



Thus it can be shown that:

neutral axis of connecting weld

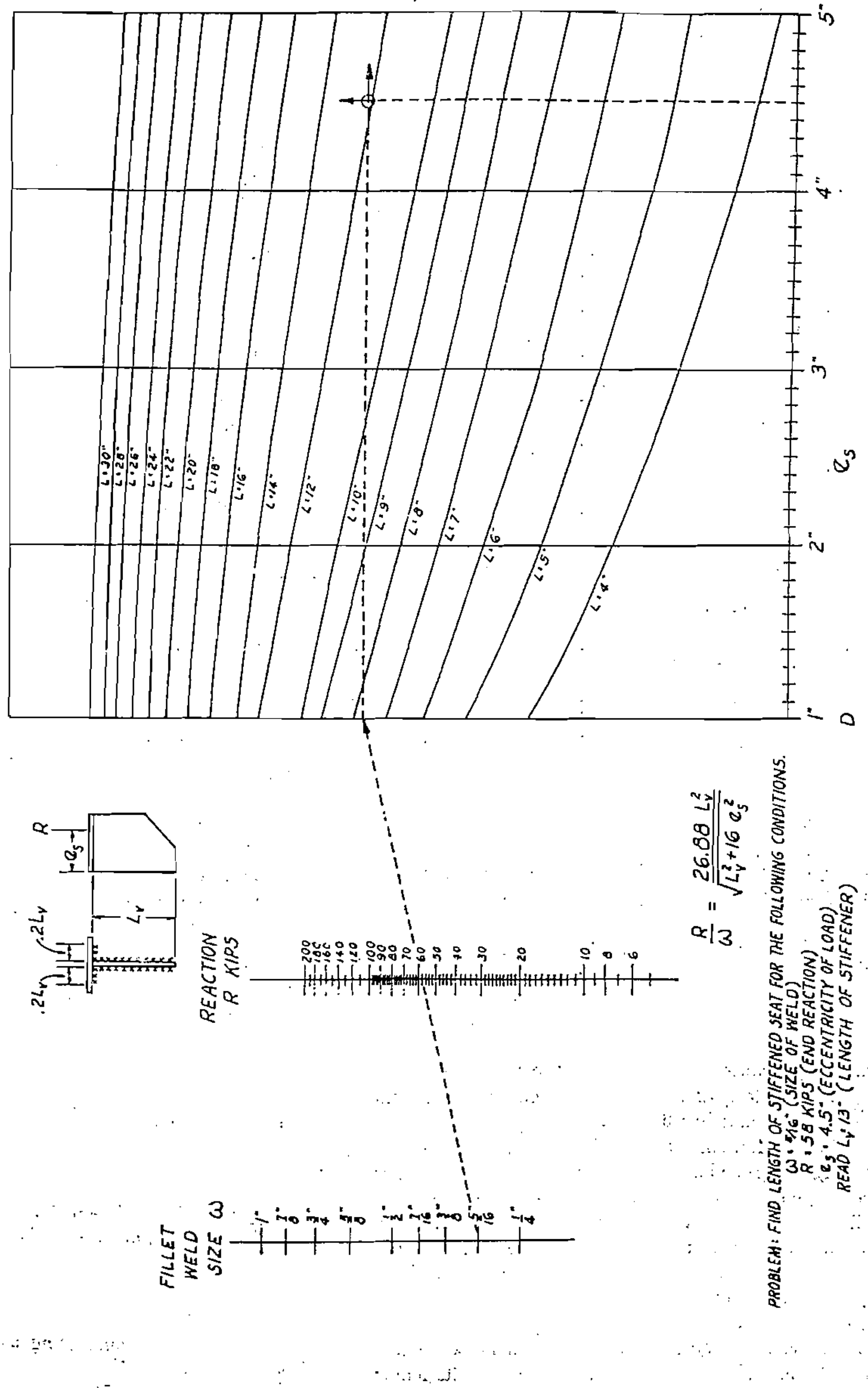
$$x = \frac{L_v}{2.4}$$

section modulus of connecting weld

$$S_w = 0.6\ L_v^2$$
(top)

FIGURE 5—Length of Stiffener and Size of Weld for Stiffened Seat
For A36 Steel & E70 Welds

NOMOGRAPH NO. 5



length of connecting weld

$$A_w = 2.4\ L_v$$

bending force on weld

$$f_b = \frac{M}{S_w} = \frac{R\ e_s}{.6\ L_v^2}$$

vertical shear on weld

$$f_s = \frac{R}{A_w} = \frac{R}{2.4\ L_v}$$

resultant force on weld

$$f_r = \sqrt{f_b^2 + f_s^2} = \sqrt{\left(\frac{R\ e_s}{.6\ L_v^2}\right)^2 + \left(\frac{R}{2.4\ L_v}\right)^2}$$

or

$$\boxed{f_r = \frac{R}{2.4\ L_v^2}\sqrt{L_v^2 + 16\ e_s^2}} \quad \text{............(4)}$$

leg size of fillet weld

$$\omega = \frac{\text{actual force}}{\text{allowable force}} \qquad \text{or}$$

A7, A373 Steel; E60 Welds	A36 Steel; E70 Welds
$\frac{R}{\omega} = \frac{23.04\ L_v^2}{\sqrt{L_v^2 + 16\ e_s^2}}$	$\frac{R}{\omega} = \frac{26.88\ L_v^2}{\sqrt{L_v^2 + 16\ e_s^2}}$

vertical weld length (L_v)

$$\boxed{L_v = \sqrt{\frac{B}{2}\left[B + \sqrt{B^2 + 64\ e_s^2}\right]}} \quad \text{.........(6)}$$

where:

A7, A373 Steel; E60 Welds	A36 Steel; E70 Welds
$B = \frac{R}{23.04\ \omega}$	$B = \frac{R}{26.88\ \omega}$

By knowing the value of B and e_s, the engineer may solve directly for L_v.

The length of connecting vertical weld (L_v) may be determined quickly from Nomograph No. 5 (Fig. 5) for A36 steel and E70 welds; this is based on formula #7. The welded connection is assumed to extend horizontally 0.2 L on each side of the bracket web. The maximum leg size of fillet weld (ω) is held to ¾ of the stiffener thickness. Draw a line from weld size (ω) through the reaction (R) to the vertical line (D). The required length of weld (L_v), = vertical length of stiffener (L), is found at the intersection of a horizontal line through (D) and a vertical line through the given value of (e_s).

For stiffener brackets which have a top width (b) other than 40% of the depth (L_v), the Table I formulas may be used.

Problem 1

Design a bracket to support a beam with an end reaction of 58 kips. The beam lies at right angles to the bracket. Use A36 steel and E70 welds. See Figure 6.

Using Nomograph No. 4:

$L_b = 8''$

$e_s = 4.5''$

$\theta = 90°$

$R = 58$ kips

TABLE 1—Fillet Weld Leg Sizes

Bracket Width	A7, A373 Steel & E60 Welds	A36 Steel & E70 Welds
$b = 0.4\ L_v$	$\omega = \frac{R}{23.04\ L_v^2}\sqrt{L_v^2 + 16.00\ e_s^2}$	$\omega = \frac{R}{26.88}\sqrt{L_v^2 + 16.00 + e_s^2}$
$b = 0.5\ L_v$	$\omega = \frac{R}{24.00\ L_v^2}\sqrt{L_v^2 + 14.06\ e_s^2}$	$\omega = \frac{R}{28.00}\sqrt{L_v^2 + 14.06 + e_s^2}$
$b = 0.6\ L_v$	$\omega = \frac{R}{24.96\ L_v^2}\sqrt{L_v^2 + 12.57\ e_s^2}$	$\omega = \frac{R}{29.12}\sqrt{L_v^2 + 12.57 + e_s^2}$
$b = 0.7\ L_v$	$\omega = \frac{R}{25.92\ L_v^2}\sqrt{L_v^2 + 11.37\ e_s^2}$	$\omega = \frac{R}{30.24}\sqrt{L_v^2 + 11.37 + e_s^2}$
$b = 0.8\ L_v$	$\omega = \frac{R}{26.88\ L_v^2}\sqrt{L_v^2 + 10.44\ e_s^2}$	$\omega = \frac{R}{31.36}\sqrt{L_v^2 + 10.44 + e_s^2}$
$b = 0.9\ L_v$	$\omega = \frac{R}{27.84\ L_v^2}\sqrt{L_v^2 + 9.65\ e_s^2}$	$\omega = \frac{R}{32.48}\sqrt{L_v^2 + 9.65 + e_s^2}$
$b = 1.0\ L_v$	$\omega = \frac{R}{28.80\ L_v^2}\sqrt{L_v^2 + 9.00\ e_s^2}$	$\omega = \frac{R}{33.60}\sqrt{L_v^2 + 9.00 + e_s^2}$

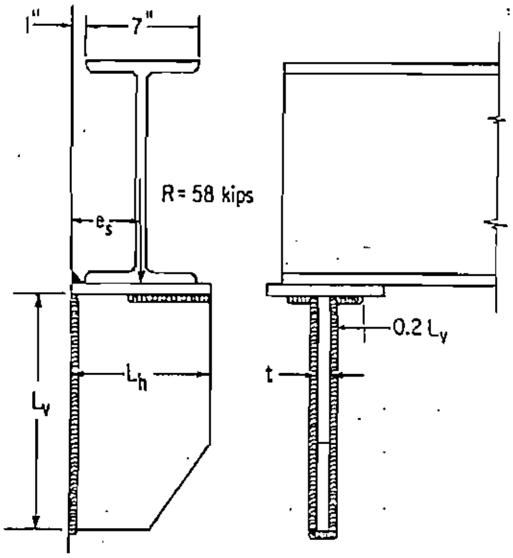


FIGURE 6

read the required stiffener thickness as—

$t = \frac{7}{16}''$

Using Nomograph No. 5:

$\omega = \frac{5}{16}''$ $\quad (t = \frac{7}{16}'')$

$R = 58$ kips

$e_s = 4.5''$

read the required vertical length of the stiffener as—

$L_v = \underline{13''}$

Problem 2

Design a bracket to support a 20″, 85# I-beam with an end reaction of 58 kips. The beam lies in line with the bracket. Use A36 steel and E70 welds.

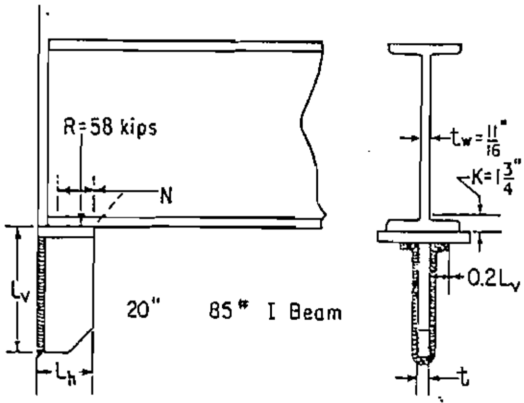


FIGURE 7

Using Nomograph No. 1 (Fig. 4, Sect. 5.2):

$R = 58$ kips

$t = \frac{11}{16}''$

$K = 1\frac{3}{4}''$

read the bearing length and load eccentricity as—

$\left.\begin{array}{l} N = 1.54'' \\ e_s = 3.23'' \end{array}\right\} \text{(if } L_h = 4'')$

Since $t = \frac{11}{16}''$, use $t = \frac{3}{4}''$ plate.

Using Nomograph No. 5:

$R = 58$ kips

$e_s = 3.37''$

for $\omega = \frac{3}{8}''$, read $L_v = 10''$

for $\omega = \frac{5}{16}''$, read $L_v = 11''$

Use the $\frac{5}{16}''$ fillet weld with a length of 11″.

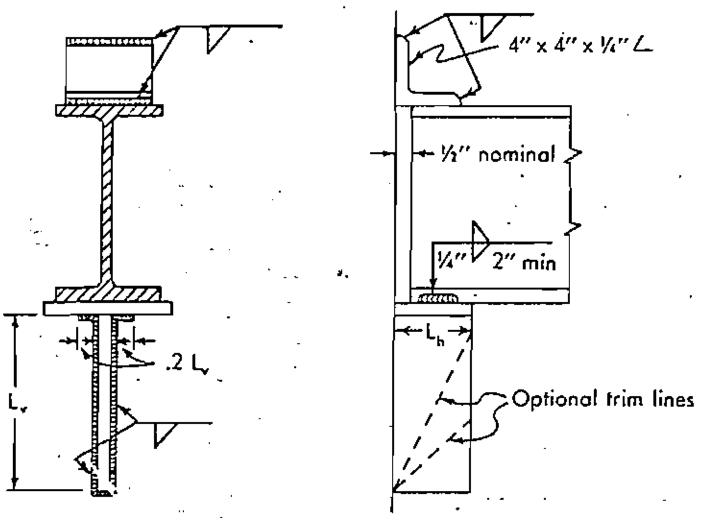


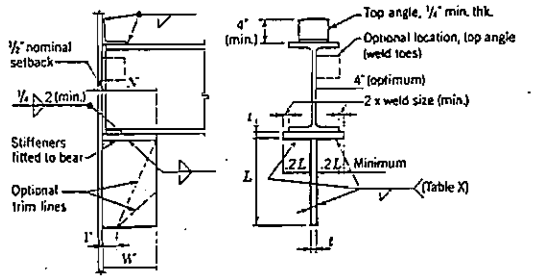
FIGURE 8

5. STANDARD SEAT BRACKET CONNECTIONS

(From American Institute of Steel Construction)

STIFFENED SEATED BEAM CONNECTIONS
Welded—E60XX or E70XX electrodes

TABLE X



Allowable loads in Table X are based on the use of E60XX electrodes. For E70XX electrodes, multiply tabular loads by 1.16, or enter the table with 86% of the given reaction. Note: Advantage may be taken of the higher allowable unit stress of E70XX electrodes only if both bracket and supporting members are ASTM A36, A242 or A441 material.

L in.	W = 4, Weld Size, Inches ¼	4: 5/16	4: 3/8	4: 7/16	W = 5, Weld Size, Inches 5/16	5: 3/8	5: 7/16	5: ½	W = 6, Weld Size, Inches 5/16	6: 3/8	6: 7/16	6: ½
6	14.7	18.4	22.0	25.7	15.2	18.2	21.2	24.2				20.6
7	19.4	24.2	29.0	33.9	20.2	24.2	28.3	32.3		20.7	24.2	27.6
8	24.4	30.6	36.7	42.8	25.8	30.9	36.1	41.2	22.2	26.6	31.0	35.4
9	29.8	37.3	44.7	52.2	31.8	38.1	44.5	50.8	27.5	33.0	38.5	44.0
10	35.5	44.4	53.2	62.1	38.2	45.8	53.4	61.0	33.3	39.9	46.6	53.2
11	41.3	51.6	61.9	72.2	44.9	53.8	62.8	71.8	39.4	47.2	55.1	63.0
12	47.3	59.1	70.9	82.7	51.9	62.2	72.6	83.0	45.8	55.0	64.1	73.3
13		66.7	80.0	93.4	59.0	70.8	82.6	94.4	52.5	63.0	73.5	84.0
14		74.4	89.3	104.	66.4	79.7	93.0	106.	59.4	71.3	83.2	95.0
15		82.2	96.6	115.	73.9	88.6	103.	118.	66.5	79.8	93.1	106.
16		90.0	109.	126.	81.5	97.7	114.	130.	73.8	88.5	103.	118.
17		97.8	117.	137.	89.2	107.	125.	143.	81.2	97.4	114.	130.
18		106.	127.	149.	96.9	116.	136.	155.	88.7	106.	124.	142.
19		113.	136.	159.	105.	126.	147.	167.	95.2	115.	135.	154.
20		121.	146.	170.	112.	135.	157.	180.	104.	125.	145.	166.
21		129.	155.	181.	120.	144.	168.	192.	112.	134.	156.	179.
22		137.	164.	192.	128.	154.	179.	205.	119.	143.	167.	191.
23		145.	174.	203.	136.	163.	190.	218.	127.	153.	178.	203.
24		152.	183.	213.	144.	173.	201.	230.	135.	162.	189.	216.
25		160.	192.	224.	152.	182.	212.	243.	143.	171.	200.	228.
26		168.	202.	235.	159.	191.	223.	255.	151.	181.	211.	241.
27		176.	211.	246.	167.	201.	234.	268.	158.	190.	222.	254.

Note 1: Loads shown above apply to welds made with E60XX electrodes. For E70XX electrodes, multiply tabular loads by 1.16, or enter the table with 86% of the given reaction. Increased values are applicable only when E70XX electrodes are used with ASTM A36, A242 or A441 material.

Based on ASTM A36 bracket material, minimum stiffener plate thickness, t, shall not be less than the supported beam web thickness for ASTM A7, A373 and A36 beams, and not less than 1.4 times the beam web thickness for ASTM A242 and A441 beams. Based on ASTM A242 or A441 bracket material, t shall not be less than the beam web thickness, regardless of beam material. Minimum stiffener plate thickness, t, shall be at least 1.33 times the required weld size.

Thickness, t, of the horizontal seat plate, or flange of tee, shall not be less than the thickness of the stiffener.

If seat and stiffener are separate plates, fit stiffener to bear against seat. Welds connecting the two plates shall have a strength equal to or greater than the horizontal welds to the support under the seat plate.

Welds attaching beam to seat may be replaced by bolts or rivets, providing the limitations on the use of ASTM A307 bolts, stipulated in AISC Specification, Sect. 1.15.12, are observed.

For stiffened seats in line on opposite sides of a column web, select a weld size no greater than ½ of the column web thickness.

Should combinations of material thickness and weld size selected from Table X, or shown in the sketch above, exceed the limits set by AISC Specification, Sect. 1.17.4 and 1.17.5, increase the weld size or material thickness as required.

In addition to the welds shown, temporary erection bolts may be used to attach beams to seats (optional).

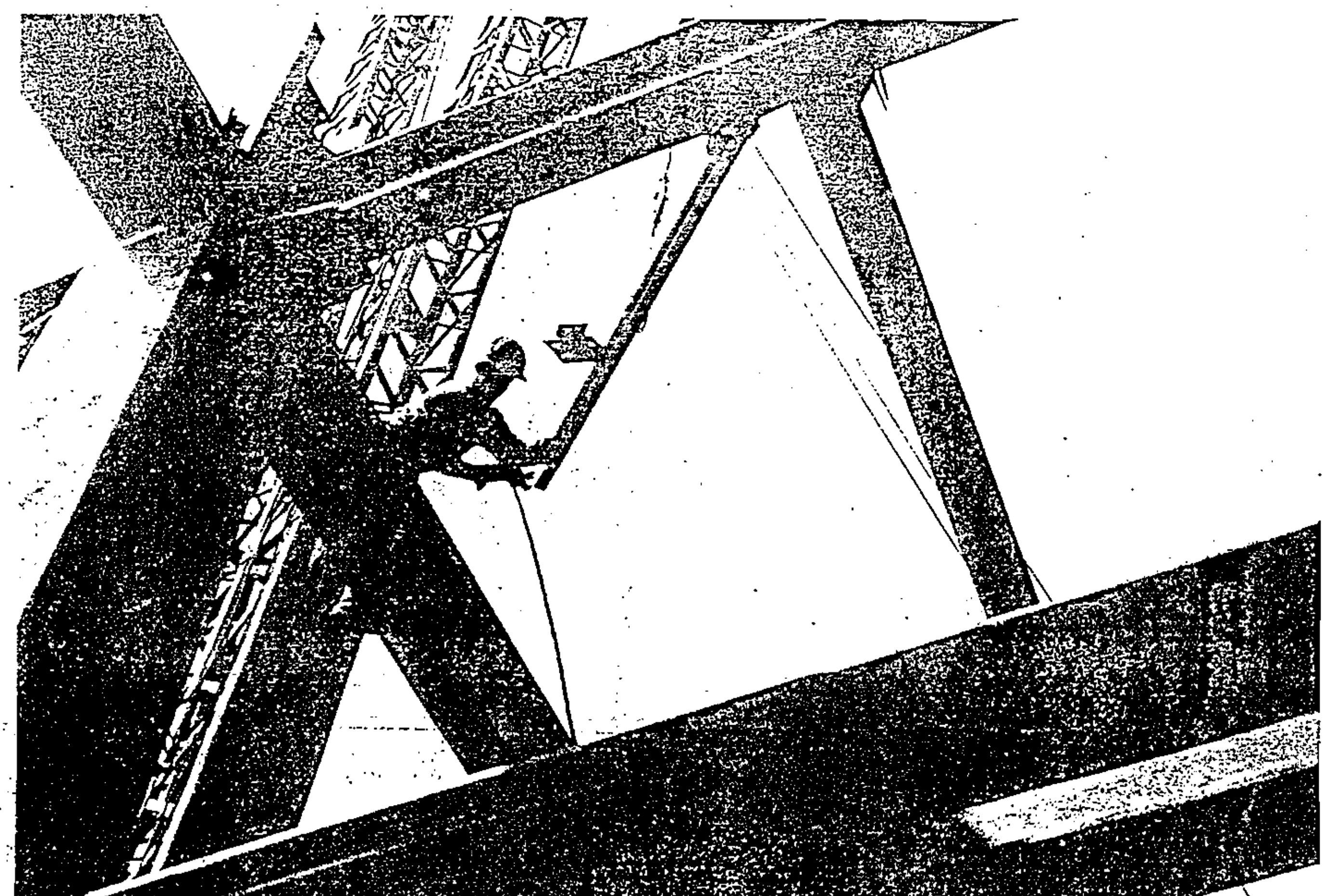
Seated connections are to be used only when the beam is supported by a top angle placed as sketched above, or in the optional location, as indicated.

If the reaction values of a beam are not shown on contract drawings, the connections shall be selected to support half the total uniform load capacity tabulated in the beam load tables for the given shape, span and steel specification of the beam in question. The effect of concentrated loads near an end connection shall also be considered.

L in.	W = 7, Weld Size, Inches 5/16	7: 3/8	7: 7/16	7: ½	W = 8, Weld Size, Inches 5/16	8: 3/8	8: ½	8: 5/8	W = 9, Weld Size, Inches 5/16	9: 3/8	9: ½	9: 5/8
11	34.9	41.9	48.9	55.8				62.5				
12	40.8	49.0	57.1	65.3			58.6	73.3				
13	47.0	56.4	65.8	75.2			67.8	84.8				77.0
14	53.4	64.1	74.8	85.4		58.0	77.4	96.7				88.1
15	60.1	72.1	84.1	96.2	54.6	65.5	87.4	109.			79.8	99.8
16	67.0	80.3	93.7	107.	61.1	73.3	97.7	122.			89.5	112.
17	74.0	88.8	104.	118.	67.7	81.2	108.	135.		74.6	99.5	124.
18	81.2	97.4	114.	130.	74.6	89.5	119.	149.		82.4	110.	137.
19	88.5	106.	124.	142.	81.6	97.9	130.	163.	75.4	90.4	121.	151.
20	95.9	115.	134.	153.	88.7	106.	142.	177.	82.2	98.6	131.	164.
21	103.	124.	145.	165.	95.9	115.	153.	192.	89.1	107.	143.	178.
22	111.	133.	155.	178.	103.	124.	165.	207.	96.2	115.	154.	192.
23	119.	142.	166.	190.	111.	133.	177.	221.	103.	124.	165.	207.
24	126.	152.	177.	202.	118.	142.	189.	236.	111.	133.	177.	221.
25	134.	161.	188.	214.	126.	151.	201.	252.	118.	142.	189.	236.
26	142.	170.	199.	227.	133.	160.	213.	267.	125.	151.	201.	251.
27	150.	180.	209.	239.	141.	169.	226.	282.	133.	160.	213.	266.
28	157.	189.	220.	252.	149.	179.	238.	298.	141.	169.	225.	281.
29	165.	198.	231.	264.	157.	188.	250.	313.	148.	178.	237.	296.
30	173.	208.	242.	277.	164.	197.	263.	329.	156.	187.	249.	312.
31	181.	217.	253.	289.	172.	207.	275.	344.	164.	196.	262.	327.
32	189.	227.	264.	302.	180.	216.	288.	360.	171.	206.	274.	343.

Note 1: Loads shown above apply to welds made with E60XX electrodes. For E70XX electrodes, multiply tabular loads by 1.16, or enter the table with 86% of the given reaction. Increased values are applicable only when E70XX electrodes are used with ASTM A36, A242 or A441 material.

Beam-to-column connection being made on the Colorado State Services Building in Denver. Operator is anchoring the beam to a stiffened seat bracket by downhand welding, using iron powder electrode.



Extensive use of modern structural techniques and welding processes speeded erection of Detroit Bank & Trust Co. Building. Stiffened seat bracket can be seen at upper left. Angle clip to facilitate field splicing of column lengths shows immediately above.