Practical Design Considerations
For Tee Framing Shear Connections

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Tee framing connections are listed as one of the acceptable shear connections in the AISC Manual and are typically used in structures as simple connections. The connection type where the tee section is bolted to a beam web and welded to the support is the most popular and efficient one among all types of tee framing connections. This thesis describes the design process and the practical application of this type of connection including proposed design procedures, the process for calculating and developing design tables, the directions for use of the design tables and conclusions. All structural tee sections listed in the AISC Manual that could be used in this connection configuration are presented in six design tables. Using these tables, both the tee section and associated connectors (bolts and fillet welds) can be selected for a given service load considering the loading on the bolt line to be eccentric or not.

NOMENCLATURE

a	Distance between bolt line and weld line, in.
A_{ns}	Net area in shear, in.^{2}
A_{nse}	Effective net area in shear, in.^{2}
A_{vg}	Gross area of tee stem in shear, in^2
A_{vgf}	Gross area of tee flange in shear, in.^{2}
b_f	Width of tee flange, in.
C	Coefficient in the AISC Manual, Tables X and XIX
C_1	Cooefficient in the AISC Manual, Table XIX
d_b	Diameter of bolt, in.
D_{16}	Number of sixteenths of an inch in fillet weld size
e	Eccentricity of reaction,in.
e_b	Eccentricity of beam reaction from bolt line, in.
e_w	Eccentricity of beam reaction from weld line, in.
f_{vu}	Shear stress applied to net area, ksi
f_{vy}	Shear stress applied to gross area, ksi
F_u	Specified minimum tensile strength of steel, ksi
F_{vu}	Allowable ultimate shear strength = $0.30F_u$, ksi
F_{vy}	allowable shear stress for plate in yielding = $0.40F_y$, ksi
F_y	Specified yield stress of steel, ksi
k	Coefficient in the AISC Manual, Table XIX

L_h	Horizontal edge distance of bolts, in.
L_v	Vertical edge distance of bolts, in.
L_t	Length of tee, in.
n	Number of bolts
R_v	Allowable shear strength of one bolt, kips.
R_1	Service load reaction of the beam, kips. assuming eccentricity
R_2	Service load reaction of the beam, kips. assuming no eccentricity
R_{ns}	Allowable shear strength of net area, kips.
R_{nse}	Allowable shear strength of effective net area, kips.
R_o	Allowable shear yield strength of plate, kips.
t_f	Thickness of tee flange, in.
t_{fc}	Thickness of column flange, in.
t_s	Thickness of tee stem, in.
t_w	Thickness of beam web, in.

Chapter 1

INTRODUCTION

Tee framing connections are listed as one of the acceptable shear connections in the AISC Manual(1) and are used in steel structures as simple connections(See Figure 1). The type where the tee section is bolted to the beam web and welded to the support is the most popular and efficient one among all types of tee framing connections. However, the published information on the actual behavior and design of this type of connection is very limited. This thesis describes the design and application of this type of connection, based on recent research at the University of California-Berkeley.(2) According to the recommended design procedures in the article"Design of Tee Framing Shear Connections" by Abolhassan Astaneh and Marwan N. Nader,(2) all structure tee sections listed in the AISC Manual(1) that could be used in this connection configuration are presented in six design tables. Using these tables, both tee sections and associated connectors (bolts and fillet welds) can be selected for a given service load considering the loading on the bolt line to be eccentric or not.

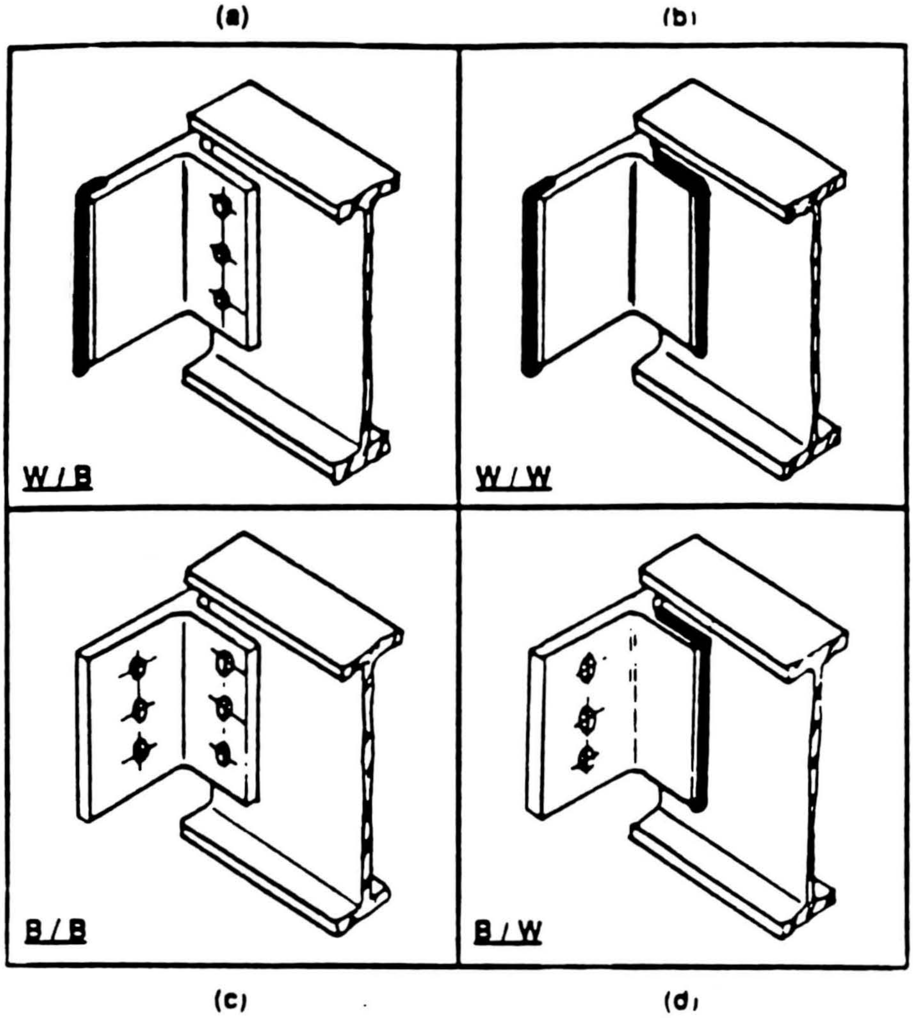


Figure 1. Types of Tee Framing Connections (Ref. 2)

Chapter 2

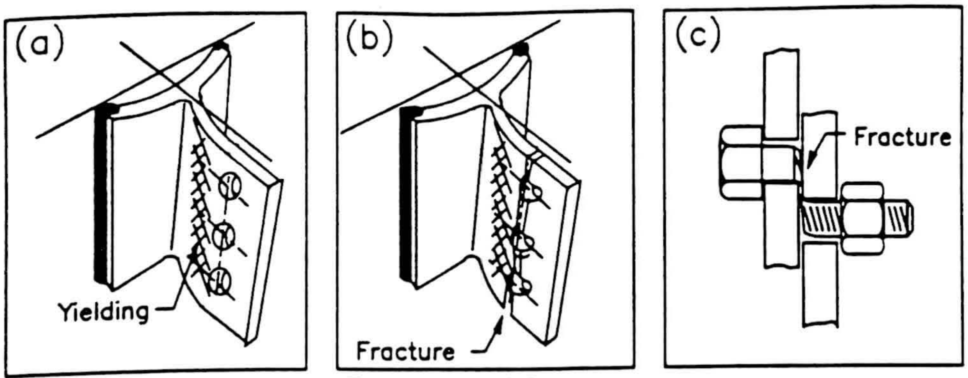
PROPOSED DESIGN PROCEDURES

According to test results, Astaneh and Nader(2) found that there are six possible failure modes in this tee connection. They are(see Figure 2) listed in order of their desirability in design as follows:

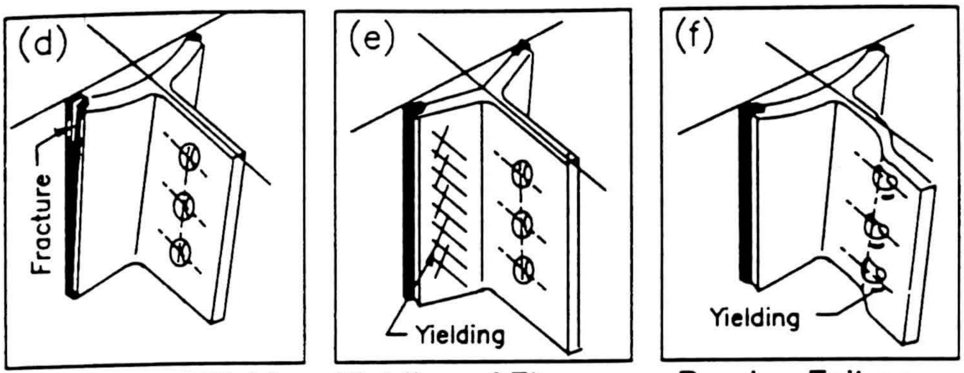
a. Shear yielding of gross area of stem
b. Yielding of tee flange
c. Bearing failure of beam web as well as tee stem
d. Shear fracture of net area of stem
e. Fracture of bolts connecting tee stem to beam web
f. Fracture of welds connecting tee flange to support

The limit states (a) and (b) are the most desirable limit states since they correspond to yielding of steel which is ductile and, therefore, the most reliable. The limit states (e) and (f) are the least desirable since they are associated with brittle fracture and thus,less reliable than yielding.

The design interpretations of these limit states are as follows(See Figure 3 for tee dimensions):



Yielding of Stem **Fracture of Stem** **Bolt Failure**



Fracture of Weld **Yielding of Flange** **Bearing Failure**

Figure 2. Typical Failure Modes of Tee Connections. (Ref. 2)

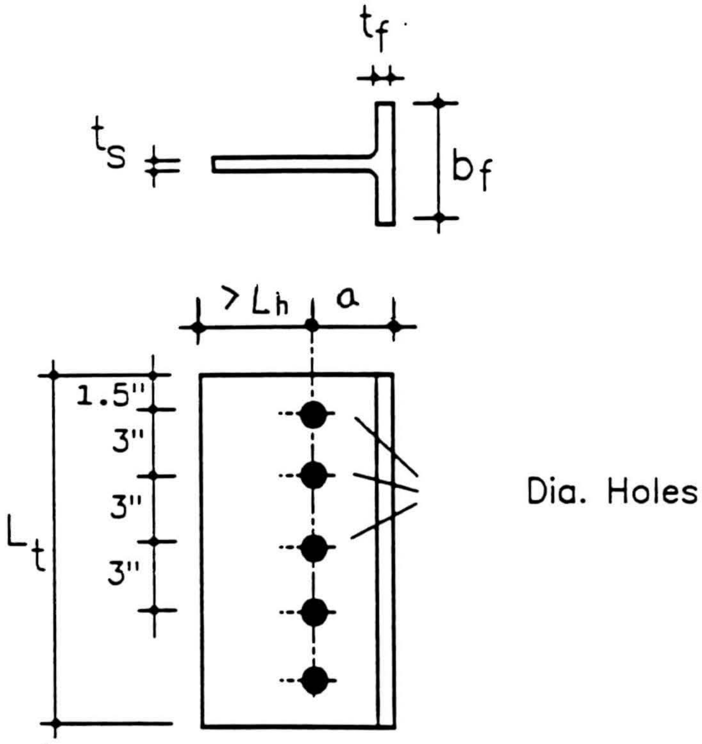


Figure 3. Tee Dimensions.

a. Shear Yielding of Gross Area of Tee Stem

The stem of the tee in tee framing connections is subjected to shear and a small bending moment. In the proposed design equations, only the shear force is considered and the effects of the small bending moment are neglected. The equation defining this limit state is:

$$f_{vy} \leq F_{vy} \qquad (1)$$

where,

$$f_{vy} = R/A_{vg} \qquad (2)$$

$$F_{vy} = 0.40F_y \qquad (3)$$

$$A_{vg} = L_t t_s \qquad (4)$$

b. Yielding of Tee Flange

If thickness of the tee flange is less than the thickness of the stem, this limit state may be reached before limit state (a) is reached. The equation defining this limit state is:

$$f_{vy} \leq F_{vy} \qquad (5)$$

where,

$$f_{vy} = R/2A_{vgf} \qquad (6)$$

$$F_{vy} = 0.40F_y \qquad (7)$$

$$A_{vgf} = L_t t_f \qquad (8)$$

c. Bearing Failure of Tee Stem or Beam Web

Large bearing deformations can result in failure of the connection due to fracture. It is recommended that the horizontal and vertical edge distances be at least equal to 1.5 times the bolt diameter. Meanwhile, the bolt spacings should satisfy requirements of the AISC-ASD Specification. It is recommended that the bolt spacing be kept equal to 3 in. for the bolts considered in this study (3/4, 7/8 and 1 inch dia.).

d. Shear Fracture of Net Area of Tee Stem

This limit state is reached when the critical net section of tee stem fractures in shear. The research(2) indicated that the critical net section in shear is located close to the edge of bolt holes and not along the centerline of the bolt holes. The following equations define this limit state where the effective net area in shear is used.

$$f_{vu} \leq F_{vu} \tag{9}$$

where,

$$f_{vu} = R_o/A_{nse} \tag{10}$$

$$F_{vu} = 0.30F_u \tag{11}$$

$$A_{nse} = [L_t-n(1/2)(d_b+1/16)]t_s \tag{12}$$

The factor 1/2 in Eq.(12) reflects an averaging of the net area and gross area of the stem in order to obtain the effective net area in shear. Currently, the AISC Specification recommends use of the following equation in calculation of net area in shear:

$$A_{nse} = [L_t - n(d_b = 1/16)]t_s \qquad (12a)$$

e. Shear Failure of Bolts

The bolts are proposed to be designed for a direct shear equal to the end reaction of the beam. The eccentricity, e_b, for tee connections is negligible when the supporting member is a rigid element. For rotationally flexible supports, it can be assumed that point of inflection is at the weld line and the bolts are subjected to direct shear and a bending moment equal to the shear force multiplied by the distance between bolt and weld lines(a). The eccentricity e_b can be obtained from:

$$e_b = 0.0 \text{ (for rotationally rigid supports)} \qquad (13)$$

and

$$e_b = a \text{ (for rotationally flexible supports)} \qquad (14)$$

By using Tables X of the AISC Manual(1), the bolts are then designed for the combined effects of shear R and moment equal to Re_b.

f. Weld Failure

The welds connecting the tee to the support are proposed to be designed for the combined effects of direct shear and a moment due to the eccentricity of the reaction from the weld line. The eccentricity e_w is conservatively equal to the distance between bolt and weld lines.

$$e_w = a \tag{15}$$

By using Table XIX of the AISC Manual$^{(1)}$, the fillet welds are designed for the combined effects of shear equal to R and moment equal to Re_w.

In the design of tee framing connections,the following requirements should be satisfied (Again, See Figure 3 for dimension details):

1. Material for the tee should be A36 steel.
2. The ratio of L_t/a of the tee stem should be more than 2.
3. Either ASTM A325 or A490 bolts may be used. Fully tightened as well as snug tight bolts are permitted, but snug tight bolts are preferred. If for erection purposes some bolts need to be tightened, one or two bolts at the bottom of connection can be tightened and the rest left snug tight. The bolts should be used in only one vertical row. Standard or short-slotted punched or drilled holes are permitted. The number of bolts should not be more than seven or less than two. The procedure is not applicable to oversized and long

slotted bolt holes.

4. Welds are fillet welds using E70XX or E60XX electrodes.
5. Vertical center-to-center spacing between the bolt holes is equal to 3 in.
6. To ensure connection flexibility, the $b_f/2t_f$ ratio of tee flange should be more than 6.5 .
7. The ratio of L_t/b_f of the tee should not exceed 3.5 .
8. The end returns at the top of the fillet welds should be at least 2 times weld size.
9. If tee is welded to a column flange, it is recommended that t_{fc} of the column be greater than t_f of the tee.
10. The ratio $(t_s/d_b)/(t_f/t_s)$ is preferred to be about 1/4 to facilitate ductile behavior of tee stem.

For the practical design of tee framing connections, the following specific steps were taken:

1. Select both number and type of bolts for a given beam end reaction R by using the allowable single shear load of the given fastener:
   (a) Assuming an eccentricity:
       $R_1 \leq CR_v$ where C is taken from Table XI in AISC Manual(1).
       R_v is allowable single shear strength of one bolt, kips.
   (b) Assuming no eccentricity:

$R_2 \leq nR_v$ where n is number of bolts,

2. Taking into consideration the shear yielding of the gross area of tee stem, calculate required gross area of the tee stem:

   $A_{vg}=R/(0.4F_y)$, R is either R_1 or R_2.

3. Using A36 steel, select a tee to satisfy the following requirements:

   a. To ensure connection flexibility:

      $b_f/2t_f \geq 6.5$

   b. To obtain a flexible and ductile connection:

      $d_b/t_s \geq 2.0$

   c. Check bearing failure of tee stem or beam web:

      (1) L_h and $L_v \geq 1.50d_b$ where d_b is the bolt diameter(in.)

      (2) Depth of tee d $\geq k+2L_h$, k is taken from STRUCTURAL TEES TABLES of the AISC Manual(1).

   d. To satisfy the AISC preferred bolt spacing requirement:

      Bolt spacings = 3 in. (good for 3/4, 7/8 or 1 in. dia. bolts)

   e. Check shear yielding of gross area of tee stem:

      $L_t t_s \geq A_{vg}$

   f. To avoid sudden fracture of the welds in tee section:

      $L_t/b_f \leq 3.5$

   g. To satisfy design requirement 9 given earlier:

$t_{fc} > t_f$

h. To facilitate ductile behavior of the tee stem:

$(t_s/d_b)/(t_f/t_s) \simeq 0.25$, In actual design, selection usually ranges from 0.23 to 0.28.

4. Calculate the actual allowable shear yield capacity of the gross area of stem:

$$R_o = (L_t t_s)(0.4F_y)$$

5. Check capacity of effective net area of the stem (shear fracture):

a. $R_{nse} = [L_t - (n/2)(d_b + 1/16)](t_s)(0.3F_u) \geq R_o$

b. Or by using net area in shear as defined by the AISC:

$R_{ns} = [L_t - n(d_b + 1/16)](t_s)(0.3F_u) \geq R$

6. Check shear yielding of tee flange:

$$2L_t t_f(0.4F_y) \geq R$$

7. Design the fillet welds at the support for the combined effects of shear and moment using AISC Table XIX$^{(1)}$:

a. $e \geq k + L_h$, e is sum of k and L_h rounded up to the next largest 1/2 in.

For example: $k+L_h=2.75$ in., $e=3$ in.

$k+L_h=2.25$in., $e=2.5$ in.

b. $a=e/L_t$, obtain C from AISC Table XIX$^{(1)}$ ($k=0$, $C_1=0$)

c. $D_{16} = R_o / C C_1 L_t$ (E70 fillet welds)

8. Check bearing capacity:

$$n(t_s)(d_b)(1.2F_u) \geq R$$

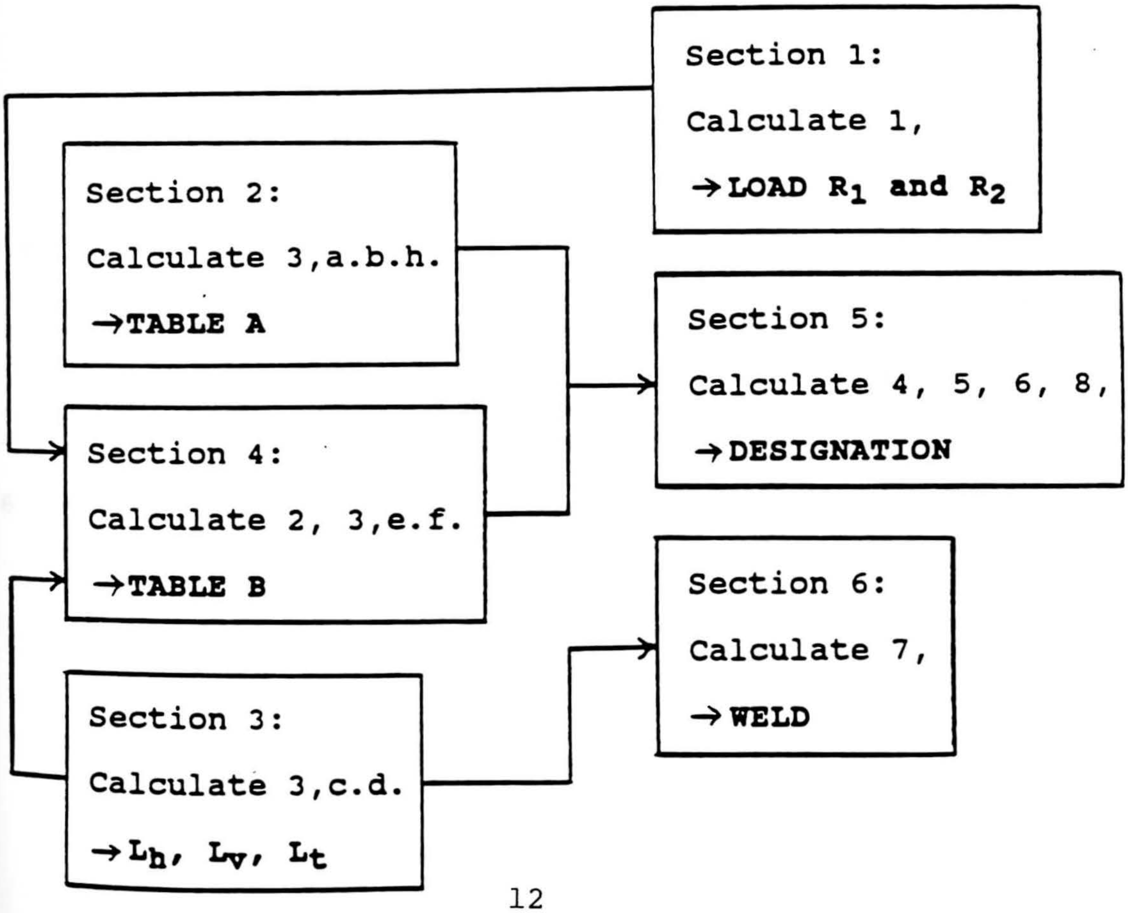
9. If beam is coped, check for block shear failure in the beam web.

Chapter 3

PROCEDURE FOR CALCULATING AND DEVELOPING DESIGN TABLES

Using the proposed design procedures, all the WT sections listed in the AISC Manual were checked for application in a tee framing connection and six design tables were obtained. Because the calculations are very extensive and complicated, various mathematical and analytical techniques had to be employed. All these design procedures were divided into six major sections. The actual calculation procedures are as follows:

CALCULATION PROCEDURE



where 1,2,3,...... etc. are the design step numbers outlined in the previous section.

Detailed computations used in the six sections are as follows:

Section 1:

Consider the number of bolts and determine R :

(I) $R_1 \leq CR_v$ (assuming eccentricity)

(II) $R_2 \leq nR_v$ (assuming no eccentricity)

Based on the AISC specification, R_v is as follow:

Description	R_v		
Bolt Size, in.	3/4	7/8	1
A325-N	9.3k	12.6k	16.5k
A490-N	12.4k	16.8k	22.0k

Meanwhile, the selection of $R_1 \leq CR_v$ is obtained using AISC Table X(1).

n=2

	A325-N		A490-N
3/4	$R_1 \leq 8.2k$, $R_2 \leq 18.6k$	3/4	$R_1 \leq 10.9k$, $R_2 \leq 24.8k$
7/8	$R_1 \leq 11.1k$, $R_2 \leq 25.2k$	7/8	$R_1 \leq 14.8k$, $R_2 \leq 33.6k$
1	$R_1 \leq 14.5k$, $R_2 \leq 33.0k$	1	$R_1 \leq 19.4k$, $R_2 \leq 44.0k$

n=3

	A325-N		A490-N
3/4	$R_1 \le 16.3k$, $R_2 \le 27.9k$	3/4	$R_1 \le 21.7k$, $R_2 \le 37.2k$
7/8	$R_1 \le 22.1k$, $R_2 \le 37.8k$	7/8	$R_1 \le 29.4k$, $R_2 \le 50.4k$
1	$R_1 \le 28.9k$, $R_2 \le 49.5k$	1	$R_1 \le 38.5k$, $R_2 \le 66.0k$

n=4

	A325-N		A490-N
3/4	$R_1 \le 26.1k$, $R_2 \le 37.2k$	3/4	$R_1 \le 34.8k$, $R_2 \le 49.6k$
7/8	$R_1 \le 35.4k$, $R_2 \le 50.4k$	7/8	$R_1 \le 47.2k$, $R_2 \le 67.2k$
1	$R_1 \le 46.4k$, $R_2 \le 66.0k$	1	$R_1 \le 61.8k$, $R_2 \le 88.0k$

n=5

	A325-N		A490-N
3/4	$R_1 \le 36.3k$, $R_2 \le 46.5k$	3/4	$R_1 \le 48.4k$, $R_2 \le 62.0k$
7/8	$R_1 \le 49.1k$, $R_2 \le 63.0k$	7/8	$R_1 \le 65.5k$, $R_2 \le 84.0k$
1	$R_1 \le 64.4k$, $R_2 \le 82.5k$	1	$R_1 \le 85.8k$, $R_2 \le 110.0k$

n=6

	A325-N		A490-N
3/4	$R_1 \le 46.3k$, $R_2 \le 55.8k$	3/4	$R_1 \le 61.8k$, $R_2 \le 74.4k$
7/8	$R_1 \le 62.7k$, $R_2 \le 75.6k$	7/8	$R_1 \le 83.7k$, $R_2 \le 100.8k$
1	$R_1 \le 82.2k$, $R_2 \le 99.0k$	1	$R_1 \le 110k$, $R_2 \le 132k$

n=7

	A325-N		A490-N
3/4	$R_1 \le 56.4k$, $R_2 \le 65.1k$	3/4	$R_1 \le 75.1k$, $R_2 \le 86.8k$
7/8	$R_1 \le 76.4k$, $R_2 \le 88.2k$	7/8	$R_1 \le 102k$, $R_2 \le 117.6k$
1	$R_1 \le 100k$, $R_2 \le 115.5k$	1	$R_1 \le 133k$, $R_2 \le 154.0k$

Section 2:

Using design procedures 3a,b and h, applicable tee sections can be selected which satisfy the geometric requirements for both the tee sections and bolts.

where:

$b_f/2t_f$ of the tee ≥ 6.5

$d_b/t_s \geq 2.0; \quad t_w = t_s \leq 0.5d_b$

$(t_s/d_b)/(t_f/t_s) \simeq 0.25$

The resulting tee sections are presented in TABLE A.

TABLE A. Suitable Tees

1. d_b = 3/4 in.

Designation	$b_f/2t_f \geq 6.5$	$(t_s/d_b)/(t_f/t_s)$	$t_w \leq 0.375$ (in.)	b_f (in.)	t_f (in.)
WT9x17.5	7.06	0.28	0.3	6.0	0.425
WT8x20	6.93	0.25	0.305	7.00	0.505
WT8x18	8.12	0.27	0.295	6.99	0.430
WT8x13	7.97	0.24	0.25	5.5	0.345
WT7x24	6.75	0.26	0.34	8.03	0.595
WT7x21.5	7.54	0.23	0.305	8.00	0.53
WT7x19	6.57	0.25	0.31	6.77	0.515
WT7x17	7.41	0.24	0.285	6.75	0.455
WT7x15	8.74	0.25	0.27	6.73	0.385
WT6x29	7.82	0.27	0.36	10.01	0.64
WT6x26.5	8.69	0.28	0.345	10.00	0.575
WT6x22.5	7.00	0.26	0.335	8.05	0.575
WT6x20	7.77	0.23	0.295	8.01	0.515
WT6x8	7.53	0.24	0.22	3.99	0.265
WT6x7	8.82	0.24	0.2	3.97	0.225
WT5x24.5	8.93	0.275	0.34	10.00	0.56
WT4x17.5	8.10	0.26	0.31	8.02	0.495

2. d_b = 7/8 in. TABLE A (Con't)

Designation	$b_f/2t_f \geq 6.5$	$(t_s/d_b)/(t_f/t_s)$	$t_w \leq 0.438$ (in.)	b_f (in.)	t_f (in.)
WT9x25	6.57	0.25	0.355	7.50	0.57
WT9x17.5	7.06	0.24	0.3	6.00	0.425
WT8x33.5	7.70	0.27	0.395	10.24	0.665
WT8x18	8.12	0.23	0.295	6.99	0.430
WT7x34	6.97	0.27	0.415	10.04	0.72
WT7x30.5	7.75	0.25	0.375	10.00	0.645
WT6x29	7.82	0.23	0.36	10.01	0.64
WT6x26.5	8.69	0.24	0.345	10.00	0.575
WT5x27	8.15	0.25	0.37	10.03	0.615
WT5x24.5	8.93	0.24	0.34	10.00	0.56

3. d_b = 1 in. TABLE A (Con't)

Designation	$b_f/2t_f \geq 6.5$	$(t_s/d_b)/(t_f/t_s)$	$t_w \leq 0.5$ (in.)	b_f (in.)	t_f (in.)
WT10.5x31	6.7	0.26	0.4	8.24	0.615
WT10.5x22	7.22	0.27	0.35	6.50	0.45
WT9x38	8.11	0.27	0.425	11.04	0.68
WT8x38.5	6.77	0.27	0.455	10.30	0.76
WT8x33.5	7.70	0.23	0.395	10.24	0.665
WT7x45	10.23	0.27	0.44	14.52	0.71
WT7x34	6.97	0.24	0.415	10.04	0.72
WT6x36	8.99	0.28	0.43	12.04	0.67
WT6x32.5	9.92	0.25	0.39	12.00	0.605
WT5x30	7.41	0.26	0.42	10.08	0.68

The following computations are some examples of how the sections in TABLE A were selected.

1. Considering 3a($b_f/2t_f \geq 6.5$), all 207 WT sections listed in the AISC Manual(1) were checked for compliance. For example, from p.1-66 in the AISC Manual(1), the following typical selections were made:

WT8x38.5 b_f=10.295in. t_f=0.760in. $b_f/2t_f$=6.77>6.5 OK.
WT8x28.5 b_f= 7.120in. t_f=0.715in. $b_f/2t_f$=4.98<6.5 NO GO.
WT8x25 b_f= 7.07 in. t_f=0.630in. $b_f/2t_f$=5.61<6.5 NO GO.
WT8x22.5 b_f= 7.035in. t_f=0.565in. $b_f/2t_f$=6.23<6.5 NO GO.
WT8x20 b_f= 6.995in. t_f=0.505in. $b_f/2t_f$=6.93>6.5 OK.
WT8x18 b_f= 6.985in. t_f=0.430in. $b_f/2t_f$=8.12>6.5 OK.
WT8x15.5 b_f= 5.525in. t_f=0.440in. $b_f/2t_f$=6.28<6.5 NO GO.
WT8x13 b_f= 5.5 in. t_f=0.345in. $b_f/2t_f$=7.97>6.5 OK.

2. Considering 3b($d_b/t_s \geq 2.0$), the 84 WT sections which satisfied $b_f/2t_f \geq 6.5$ were further examined for this addtional restriction. Sample calculations are as follows:

WT8x38.5 d_b=7/8", t_s=0.455", d_b/t_s=1.92<2.0 NO GO.
WT8x20 d_b=7/8", t_s=0.305", d_b/t_s=2.87>2.0 OK.
WT8x18 d_b=7/8", t_s=0.295", d_b/t_s=2.97>2.0 OK.
WT8x13 d_b=7/8", t_s=0.250", d_b/t_s=3.50>2.0 OK.

3. Considering 3h$(t_s/d_b)/(t_f/t_s) \simeq 0.25$. The range selected was

from 0.23 to 0.28. This design restriction further reduced the applicable sections as the following sampling shows;

WT8x20, d_b=7/8",t_s=0.305",t_f=0.505",$(t_s/d_b)/(t_f/t_s)$=0.21 NO GO.

WT8x18, d_b=7/8",t_s=0.295",t_f=0.43", $(t_s/d_b)/(t_f/t_s)$=0.23 OK.

WT8x13, d_b=7/8",t_s=0.25", t_f=0.345",$(t_s/d_b)/(t_f/t_s)$=0.21 NO GO.

The original 207 sections were reduced to 17 applicable sections for d_b=3/4 in., 10 sections for d_b=7/8 in. and 10 sections for d_b= 1 in.

Section 3:

Considering design procedures

3c. L_h and $L_v \geq 1.50\ d_b$

3d. Bolt center-to-center spacings of 3d to satisfy the AISC Specification.

3c. (1) d_b = 3/4 in.

$L_h=L_v=1.50d_b=1.50(3/4)=1.125$in.

USE: $L_h=L_v=1.5$in.

(2) d_b = 7/8 in.

$L_h=L_v=1.50d_b=1.50(7/8)=1.32$in.

USE: $L_h=L_v=1.5$in.

(3) d_b = 1 in.

$L_h=L_v=1.50d_b=1.5$in.

USE: $L_h=L_v=1.5$in.

USE:$=L_h=L_v=1.5$in.
for all bolt dia.

3d. Bolt Spacing=3d=3 in. (satisfies the AISC Specification for d_b = 3/4 = 7/8 = 1 in.)

$\therefore L_t=(n-1)(3)+2(1.5)=3n$

section 4:

Using design procedures 2, 3e and f, the design parameters in TABLE B(a) (considering the bolt line to be eccentrically loaded) and TABLE B(b) (assuming no eccentricity on the bolt line) can be obtained. For the different cases of R_1, R_2, n and d_b, there are different requirements for L_t, t_w, and b_f.

(a). Considering the bolt line to be eccentrically loaded and each design procedure:

2. $A_{vg} = R_1/(0.4F_y)$

3e. $L_t = 3n$

$t_w = t_s \geq A_{vg}/L_t$

3f. $L_t/b_f \leq 3.5 \quad b_f \geq L_t/3.5$

(b). Ignoring the eccentricity on the bolt line and repeating the calcutations:

2. $A_{vg} = R_2/(0.4F_y)$

3e. $L_t = 3n$

$t_w = t_s \geq A_{vg}/L_t$

3f. $L_t/b_f \leq 3.5 \quad b_f \geq L_t/3.5$

TABLE B(a). Tee Design Parameters

Bolt Type	n	d_b (in.)	R_1 (in.)	A_{vg} (in.^{2})	L_t (in.)	$t_w \geq A_{vg}/L_t$ (in.)	$b_f \geq L_t/3.5$ (in.)
A325-N	2	3/4	8.2	0.569	6	0.095	1.714
		7/8	11.1	0.771	6	0.128	1.714
		1	14.5	1.007	6	0.168	1.714
A490-N		3/4	10.9	0.757	6	0.126	1.714
		7/8	14.8	1.028	6	0.171	1.714
		1	19.4	1.347	6	0.225	1.714
A325-N	3	3/4	16.3	1.132	9	0.126	2.571
		7/8	22.1	1.535	9	0.171	2.571
		1	28.9	2.007	9	0.223	2.571
A490-N		3/4	21.7	1.507	9	0.167	2.571
		7/8	29.4	2.042	9	0.227	2.571
		1	38.5	2.674	9	0.297	2.571
A325-N	4	3/4	26.1	1.813	12	0.151	3.429
		7/8	35.4	2.458	12	0.205	3.429
		1	46.4	3.222	12	0.269	3.429
A490-N		3/4	34.8	2.417	12	0.201	3.429
		7/8	47.2	3.278	12	0.273	3.429
		1	61.8	4.292	12	0.358	3.429

TABLE B(a). Tee Design Parameters

Bolt Type	n	d_b (in.)	R_1 (in.)	A_{vg} (in.^{2})	L_t (in.)	$t_w \geq A_{vg}/L_t$ (in.)	$b_f \geq L_t/3.5$ (in.)
A325-N	5	3/4	36.3	2.521	15	0.168	4.286
		7/8	49.1	3.410	15	0.227	4.286
		1	64.4	4.472	15	0.298	4.286
A490-N		3/4	48.4	3.361	15	0.224	4.286
		7/8	65.5	4.549	15	0.303	4.286
		1	85.8	5.958	15	0.397	4.286
A325-N	6	3/4	46.3	3.215	18	0.179	5.143
		7/8	62.7	4.354	18	0.242	5.143
		1	82.2	5.708	18	0.317	5.143
A490-N		3/4	61.8	4.292	18	0.238	5.143
		7/8	83.7	5.813	18	0.323	5.143
		1	110	7.639	18	0.424	5.143
A325-N	7	3/4	56.4	3.917	21	0.187	6
		7/8	76.4	5.306	21	0.253	6
		1	100	6.944	21	0.331	6
A490-N		3/4	75.1	5.215	21	0.248	6
		7/8	102	7.083	21	0.337	6
		1	133	9.236	21	0.440	6

TABLE B(b). Tee Design Parameters

Bolt Type	n	d_b (in.)	R_2 (in.)	A_{vg} (in.^{2})	L_t (in.)	$t_w \geq A_{vg}/L_t$ (in.)	$b_f \geq L_t/3.5$ (in.)
A325-N	2	3/4	18.6	1.29	6	0.215	1.714
		7/8	25.2	1.75	6	0.292	1.714
		1	33.0	2.29	6	0.382	1.714
A490-N		3/4	24.8	1.72	6	0.287	1.714
		7/8	33.6	2.33	6	0.389	1.714
		1	44.0	3.06	6	0.509	1.714
A325-N	3	3/4	27.9	1.94	9	0.215	2.571
		7/8	37.8	2.63	9	0.292	2.571
		1	49.5	3.44	9	0.382	2.571
A490-N		3/4	37.2	2.58	9	0.287	2.571
		7/8	50.4	3.50	9	0.389	2.571
		1	66.0	4.58	9	0.509	2.571
A325-N	4	3/4	37.2	2.58	12	0.215	3.429
		7/8	50.4	3.50	12	0.292	3.429
		1	66.0	4.58	12	0.382	3.429
A490-N		3/4	49.6	3.44	12	0.287	3.429
		7/8	67.2	4.67	12	0.389	3.429
		1	88.0	6.11	12	0.509	3.429

TABLE B(b). Tee Design Paramater

Bolt Type	n	d_b (in.)	R_2 (in.)	A_{vg} (in.^{2})	L_t (in.)	$t_w \geq A_{vg}/L_t$ (in.)	$b_f \geq L_t/3.5$ (in.)
A325-N	5	3/4	46.5	3.23	15	0.215	4.286
		7/8	63.0	4.38	15	0.292	4.286
		1	82.5	5.73	15	0.382	4.286
A490-N		3/4	62.0	4.31	15	0.287	4.286
		7/8	84.0	5.83	15	0.389	4.286
		1	110	7.64	15	0.509	4.286
A325-N	6	3/4	55.8	3.88	18	0.215	5.143
		7/8	75.6	5.25	18	0.292	5.143
		1	99.0	6.88	18	0.382	5.143
A490-N		3/4	74.4	5.17	18	0.287	5.143
		7/8	101	7.00	18	0.389	5.143
		1	132	9.17	18	0.509	5.143
A325-N	7	3/4	65.1	4.52	21	0.215	6
		7/8	88.2	6.13	21	0.292	6
		1	116	8.02	21	0.382	6
A490-N		3/4	86.8	6.03	21	0.287	6
		7/8	118	8.17	21	0.389	6
		1	154	10.7	21	0.509	6

Section 5:

The design parameters in Table A must be matched with those in Table B in order to select those tee sections which satisfied both sets of requirements. After this match, design procedures 4, 5, 6 and 8, must be implemented in order to obtain the final suitable WT sections. Reviewing these design procedures yields:

4. $R_o=L_t t_s(0.4F_y)$
5. $R_{nse}=[L_t-(n/2)(d_b+1/16)](t_s)(0.3F_u)\geq R_o$

   or $R_{ns}=[L_t-n(d_b+1/16)](t_s)(0.3F_u)\geq R$
6. $2L_t t_f(0.4F_y)\geq R$
8. $n(t_w)(d_b)(1.2F_u)\geq R_o$ where: F_y = 36 ksi and F_u = 58 ksi

Consider the following example of this selection procedure:

Given: n=5, L_t=15", A325-N Bolt dia.=7/8". Assume no bolt line eccentricity.

Find: Suitable WT sections

Solution: From Table B(b) (no eccentricity):

R_2=63.0k, $t_w\geq$0.292", $b_f\geq$4.286"

Compare with Table A (d_b=7/8in.):

1. Try WT9x25:

   t_w=0.355" > 0.292" OK.

   b_f=7.495" > 4.286" OK.

Checking design procedure 4:

$R_o=L_t t_s(0.4F_y)=15(0.355)(0.4)(36)=76.68$ kips.

Checking design procedure 5:

$R_{nse}=[L_t-(n/2)(d_b+1/16)](t_s)(0.3F_u)$

$=[15-(5/2)(7/8+1/16)](0.355)(0.3)(58)$

$=78.18$ kips. $> R_o$ OK.

$R_{ns}=[L_t-n(d_b+1/16)](t_s)(0.3F_u)$

$=[15-5(7/8+1/16)](0.355)(0.3)(58)$

$=63.7$ kips. $> R(=63.0$ kips.$)$ OK.

Checking design procedure 6:

$2L_t t_f(0.4F_y)=2(15)(0.57)(0.4)(36)=246.2$kips.$>R$ OK.

Checking design procedure 8:

$n(t_w)(d_b)(1.2F_u)=5(0.355)(7/8)(1.2)(58)$

$=108$ kips.$>R_o(=76.68$kips.$)$ OK.

$\therefore$ WT9x25 is suitable.

2. Try WT9x17.5:

$t_w=0.300" > 0.292"$ OK.

$b_f=6.00" > 4.286"$ OK.

Checking design procedure 4:

$R_o=L_t t_s(0.4F_y)=64.8$ kips.

Checking design procedure 5:

$R_{nse}=[15-(5/2)(7/8+1/16)](0.3)(0.3)(58)$

$=66.07$ kips.$>R_o$ OK.

$R_{ns}=[15-5(7/8+1/16)](0.3)(0.3)(58)$

$=53.83$ kips.$<R(=63.0$ kips.) NO GO.

∴ WT9x17.5 is not suitable.

Section 6:

The design of the fillet welds is accomplished using design precedure 7. Continuing :

a. $e \geq k+L_h$

b. Using AISC TABLE XIX (1), $a=e/L_t$, $k=0$, $C_1=0$,
and obtain C from AISC Table XIX.

c. $D_{16}=R_o/CC_1L_t$ (E70 fillet welds)

Example 1:

Given: WT9x17.5, $n=2$, $L_t=6"$

Solution: From p.1-66 in AISC Manual(1):

$k=9/8"$, $t_w=t_s=0.3"$

$R_o=(L_tt_s)(0.4F_y)=6(0.3)(0.4)(36)=25.92$ kips.

a. $k+L_h=9/8+1.5=2.625"$ rounding up to $e=3"$

b. $a=e/L_t=3/6=0.5$, $k=0$, $C_1=0$,
From Table XIX p.4-75 in AISC Manual: $C=0.787$

c. $D_{16}=R_o/CC_1L_t=25.92/0.787(6)=5.49 = 6$
$6/16=3/8$

∴ USE: 3/8 in. E70 Fillet welds.

Example 2:

Given: WT5x24.5, $n=5$, $L_t=15''$

Solution: From p.1-73 in AISC Manual(1):

$k=19/16''$, $t_w=t_s=0.34''$

$R_o=(L_t t_s)(0.4F_u)=15(0.34)(0.4)(36)=73.44$ kips.

a. $k+L_h=19/16+1.5=2.69''$ rounding up to $e=3''$

b. $a=e/L_t=3/15=0.2$, $k=0$, $C_1=0$,

From Table XIX p.4-75 in AISC Manual: $C=1.39$

c. $D_{16}=R_o/CC_iL_t=73.44/1.39(15)=3.52 = 4$

$4/16=1/4$

∴ USE: 1/4 in. E70 fillet welds.

Chapter 4

DIRECTIONS FOR USE OF DESIGN TABLES

DESIGN ASSUMPTIONS

The design assumption associated with the design tables are as follows:

1. Single bolt row: $2 \leq n \leq 7$ where n = the number of bolts
2. Bolt pitch=3 in.
3. Vertical edge distance=1.5 in.(L_v)
4. Distance from the weld line to the bolt line = 3 in.
5. F_y = 36 ksi(Tee material)
6. Fillet welds are E70 electrodes
7. $t_s \leq 0.5 d_b$
8. $b_f/2t_f \geq 6.5$
9. $L_t/b_f \leq 3.5$
10. $t_{fc} \geq t_f$

Design Example 1:

Given: Beam: W27x114, t_w=0.570 in.

Material: A36 Steel (Beam and Tee)

Support: Flange of W10x77 column, t_{fc}=0.87in.

Reaction: 88 kips.(assuming no eccentricity)

Bolts: 7/8 in.dia. A325-N(snug tight)

Bolt Spacing: 3 in.

Welds: E70XX fillet welds

Find: A tee framing connection to transfer the beam reaction to the supporting column.

Solution: From Table F,

7-A325-N bolts with WT9x25 (L_t=21") and 1/4 in. fillet welds with a total capacity of 88.2 kips.

Design Example 2:

Given: Beam: W16x31, t_w=0.275in.

Material: A36 Steel (Beam and Tee)

Support: Web of W8x58 column, t_w=0.51 in.

Reaction: 25 kips.(assuming eccentricity)

Bolts: 3/4 in.dia. A325-N(Tight Bolts)

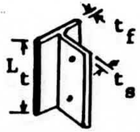
Bolt Spacing: 3 in.

Welds: E70XX fillet welds

Find: A tee framing connection to transfer the beam reaction to the supporting column.

Solution: From Table D,

4-A325-N bolts with WT8x13 (L_t=12") and 3/16 in. fillet welds with a total capacity of 26.1 kips.



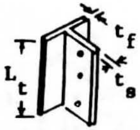
TEE FRAMING SHEAR CONNECTIONS

TABLE A Allowable Loads in Kips

$n = 2$ $L_t = 6"$

ASTM Designation	Bolt Size. 3/4 in.						Bolt Size, 7/8 in.						Bolt Size, 1 in.					
	Designation	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)	Designation	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)	Designation	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)
A325-N	WT 9x17.5	8.2	18.6	3/8	0.3	0.425	WT 9x25	11.1	25.2	7/16	0.355	0.57	WT 10.5x31	14.5	--	1/2	0.4	0.615
	WT 8x20	8.2	18.6	3/8	0.305	0.505	WT 9x17.5	11.1	--	3/8	0.3	0.425	WT 10.5x22	14.5	--	7/16	0.35	0.45
	WT 8x18	8.2	18.6	3/8	0.295	0.43	WT 8x33.5	11.1	25.2	1/2	0.395	0.665	WT 9x38	14.5	28.6	1/2	0.425	0.68
	WT 8x13	8.2	18.6	5/16	0.25	0.345	WT 8x18	11.1	--	3/8	0.295	0.43	WT 8x38.5	14.5	30.6	9/16	0.455	0.76
	WT 7x24	8.2	18.6	7/16	0.34	0.595	WT 7x34	11.1	25.2	1/2	0.415	0.72	WT 8x33.5	14.5	--	1/2	0.395	0.665
	WT 7x21.5	8.2	18.6	3/8	0.305	0.53	WT 7x30.5	11.1	25.2	7/16	0.375	0.645	WT 7x45	14.5	29.6	9/16	0.44	0.71
	WT 7x19	8.2	18.6	3/8	0.31	0.515	WT 6x29	11.1	25.2	7/16	0.36	0.64	WT 7x34	14.5	27.9	1/2	0.415	0.72
	WT 7x17	8.2	18.6	1/4	0.285	0.455	WT 6x26.5	11.1	--	7/16	0.345	0.575	WT 6x36	14.5	28.9	1/2	0.43	0.67
	WT 7x15	8.2	18.6	5/16	0.27	0.385	WT 5x27	11.1	25.2	7/16	0.37	0.615	WT 6x32.5	14.5	--	1/2	0.39	0.605
	WT 6x29	8.2	18.6	7/16	0.36	0.64	WT 5x24.5	11.1	--	7/16	0.34	0.56	WT 5x30	14.5	28.3	1/2	0.42	0.68
	WT 6x26.5	8.2	18.6	7/16	0.345	0.575												
	WT 6x22.5	8.2	18.6	7/16	0.335	0.575												
	WT 6x20	8.2	18.6	3/8	0.295	0.515												
	WT 6x8	8.2	--	1/4	0.22	0.265												
	WT 6x7	8.2	--	1/4	0.2	0.225												
	WT 5x24.5	8.2	18.6	7/16	0.34	0.56												
	WT 4x17.5	8.2	18.6	5/16	0.31	0.495												
A490-N	WT 9x17.5	10.9	--	3/8	0.3	0.425	WT 9x25	14.8	25.4	7/16	0.355	0.57	WT 10.5x31	19.4	--	1/2	0.4	0.615
	WT 8x20	10.9	--	3/8	0.305	0.505	WT 9x17.5	14.8	--	3/8	0.3	0.425	WT 10.5x22	19.4	--	7/16	0.35	0.45
	WT 8x18	10.9	--	3/8	0.295	0.43	WT 8x33.5	14.8	28.3	1/2	0.395	0.665	WT 9x38	19.4	28.6	1/2	0.425	0.68
	WT 8x13	10.9	--	5/16	0.25	0.345	WT 8x18	14.8	--	3/8	0.295	0.43	WT 8x38.5	19.4	30.6	9/16	0.455	0.76
	WT 7x24	10.9	24.8	7/16	0.34	0.595	WT 7x34	14.8	29.7	1/2	0.415	0.72	WT 8x33.5	19.4	--	1/2	0.395	0.665
	WT 7x21.5	10.9	--	3/8	0.305	0.53	WT 7x30.5	14.8	26.9	7/16	0.375	0.645	WT 7x45	19.4	29.6	9/16	0.44	0.71
	WT 7x19	10.9	23.6	3/8	0.31	0.515	WT 6x29	14.8	25.8	7/16	0.36	0.64	WT 7x34	19.4	27.9	1/2	0.415	0.72
	WT 7x17	10.9	--	1/4	0.285	0.455	WT 6x26.5	14.8	--	7/16	0.345	0.575	WT 6x36	19.4	28.9	1/2	0.43	0.67
	WT 7x15	10.9	--	5/16	0.27	0.385	WT 5x27	14.8	26.5	7/16	0.37	0.615	WT 6x32.5	19.4	--	1/2	0.39	0.605
	WT 6x29	10.9	24.8	7/16	0.36	0.64	WT 5x24.5	14.8	--	7/16	0.34	0.56	WT 5x30	19.4	28.3	1/2	0.42	0.68
	WT 6x26.5	10.9	24.8	7/16	0.345	0.575												
	WT 6x22.5	10.9	24.8	7/16	0.335	0.575												
	WT 6x20	10.9	--	3/8	0.295	0.515												
	WT 6x8	10.9	--	1/4	0.22	0.265												
	WT 6x7	10.9	--	1/4	0.2	0.225												
	WT 5x24.5	10.9	24.8	7/16	0.34	0.56												
	WT 4x17.5	10.9	--	5/16	0.31	0.495												

** R_1: Assuming eccentricity. R_2: Assuming no eccentricity. t_w: Minimum thickness of beam web. t_{fc}: Minimum thickness of column flange.



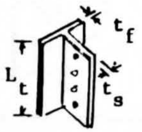
TEE FRAMING SHEAR CONNECTIONS

TABLE B Allowable Loads in Kips

n = 3 L_t = 9"

ASTM Designation	Bolt Size, 3/4 in.						Bolt Size, 7/8 in.						Bolt Size, 1 in.					
	Designation	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)	Designation	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)	Designation	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)
A325-N	WT 9x17.5	16.3	27.9	5/16	0.3	0.425	WT 9x25	22.1	37.8	5/16	0.355	0.57	WT 10.5x31	28.9	--	3/8	0.4	0.615
	WT 8x20	16.3	27.9	5/16	0.305	0.505	WT 9x17.5	22.1	--	5/16	0.3	0.425	WT 10.5x22	28.9	--	5/16	0.35	0.45
	WT 8x18	16.3	27.9	1/4	0.295	0.43	WT 8x33.5	22.1	37.8	3/8	0.395	0.665	WT 9x38	28.9	42.9	3/8	0.425	0.68
	WT 8x13	16.3	27.9	1/4	0.25	0.345	WT 8x18	22.1	--	1/4	0.295	0.43	WT 8x38.5	28.9	46.0	7/16	0.455	0.76
	WT 7x24	16.3	27.9	5/16	0.34	0.595	WT 7x34	22.1	37.8	3/8	0.415	0.72	WT 8x33.5	28.9	--	3/8	0.395	0.665
	WT 7x21.5	16.3	27.9	5/16	0.305	0.53	WT 7x30.5	22.1	37.8	3/8	0.375	0.645	WT 7x45	28.9	44.5	3/8	0.44	0.71
	WT 7x19	16.3	27.9	5/16	0.31	0.515	WT 6x29	22.1	37.8	5/16	0.36	0.64	WT 7x34	28.9	41.9	3/8	0.415	0.72
	WT 7x17	16.3	27.9	1/4	0.285	0.455	WT 6x26.5	22.1	--	5/16	0.345	0.575	WT 6x36	28.9	43.4	3/8	0.43	0.67
	WT 7x15	16.3	27.9	1/4	0.27	0.385	WT 5x27	22.1	37.8	5/16	0.37	0.615	WT 6x32.5	28.9	--	3/8	0.39	0.605
	WT 6x29	16.3	27.9	5/16	0.36	0.64	WT 5x24.5	22.1	--	5/16	0.34	0.56	WT 5x30	28.9	42.4	3/8	0.42	0.68
	WT 6x26.5	16.3	27.9	5/16	0.345	0.575												
	WT 6x22.5	16.3	27.9	5/16	0.335	0.575												
	WT 6x20	16.3	27.9	1/4	0.295	0.515												
	WT 6x8	16.3	--	3/16	0.22	0.265												
	WT 6x7	16.3	--	3/16	0.2	0.225												
	WT 5x24.5	16.3	27.9	5/16	0.34	0.56												
	WT 4x17.5	16.3	27.9	1/4	0.31	0.495												
A490-N	WT 9x17.5	21.7	--	5/16	0.3	0.425	WT 9x25	29.4	38.2	5/16	0.355	0.57	WT 10.5x31	38.5	--	3/8	0.4	0.615
	WT 8x20	21.7	--	5/16	0.305	0.505	WT 9x17.5	29.4	--	5/16	0.3	0.425	WT 9x38	38.5	43.0	3/8	0.425	0.68
	WT 8x18	21.7	--	1/4	0.295	0.43	WT 8x33.5	29.4	42.5	3/8	0.395	0.665	WT 8x38.5	38.5	46.0	7/16	0.455	0.76
	WT 8x13	21.7	--	1/4	0.25	0.345	WT 8x18	29.4	--	1/4	0.295	0.43	WT 8x33.5	38.5	--	3/8	0.395	0.665
	WT 7x24	21.7	37.2	5/16	0.34	0.595	WT 7x34	29.4	44.6	3/8	0.415	0.72	WT 7x45	38.5	44.5	3/8	0.44	0.71
	WT 7x21.5	21.7	--	5/16	0.305	0.53	WT 7x30.5	29.4	40.3	3/8	0.375	0.645	WT 7x34	38.5	42.0	3/8	0.415	0.72
	WT 7x19	21.7	35.4	5/16	0.31	0.515	WT 6x29	29.4	38.7	5/16	0.36	0.64	WT 6x36	38.5	43.5	3/8	0.43	0.67
	WT 7x17	21.7	--	1/4	0.285	0.455	WT 6x26.5	29.4	--	5/16	0.345	0.575	WT 6x32.5	38.5	--	3/8	0.39	0.605
	WT 7x15	21.7	--	1/4	0.27	0.385	WT 5x27	29.4	39.8	5/16	0.37	0.615	WT 5x30	38.5	42.5	3/8	0.42	0.68
	WT 6x29	21.7	37.2	5/16	0.36	0.64	WT 5x24.5	29.4	--	5/16	0.34	0.56						
	WT 6x26.5	21.7	37.2	5/16	0.345	0.575												
	WT 6x22.5	21.7	37.2	5/16	0.335	0.575												
	WT 6x20	21.7	--	1/4	0.295	0.515												
	WT 6x8	21.7	--	3/16	0.22	0.265												
	WT 6x7	21.7	--	3/16	0.2	0.225												
	WT 5x24.5	21.7	37.2	5/16	0.34	0.56												
	WT 4x17.5	21.7	--	1/4	0.31	0.495												

** R_1: Assuming eccentricity. R_2: Assuming no eccentricity. t_w: Minimum thickness of beam web. t_{fc}: Minimum thickness of column flange.



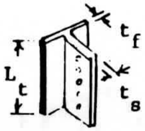
TEE FRAMING SHEAR CONNECTIONS

TABLE C Allowable Loads in Kips

$n = 4$ $L_t = 12"$

ASTM Designation	Bolt Size, 3/4 in.						Bolt Size, 7/8 in.						Bolt Size, 1 in.					
	Designation	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)	Designation	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)	Designation	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)
A325-N	WT 9x17.5	26.1	37.2	1/4	0.3	0.425	WT 9x25	35.4	50.4	5/16	0.355	0.57	WT 10.5x31	46.4	--	5/16	0.4	0.615
	WT 8x20	26.1	37.2	1/4	0.305	0.505	WT 9x17.5	35.4	--	1/4	0.3	0.425	WT 10.5x22	46.4	--	1/4	0.35	0.45
	WT 8x18	26.1	37.2	1/4	0.295	0.43	WT 8x33.5	35.4	50.4	5/16	0.395	0.665	WT 9x38	46.4	57.3	5/16	0.425	0.68
	WT 8x13	26.1	37.2	3/16	0.25	0.345	WT 8x18	35.4	--	1/4	0.295	0.43	WT 8x38.5	46.4	61.3	3/8	0.455	0.76
	WT 7x24	26.1	37.2	1/4	0.34	0.595	WT 7x34	35.4	50.4	5/16	0.415	0.72	WT 8x33.5	46.4	--	5/16	0.395	0.665
	WT 7x21.5	26.1	37.2	1/4	0.305	0.53	WT 7x30.5	35.4	50.4	5/16	0.375	0.645	WT 7x45	46.4	59.3	3/8	0.44	0.71
	WT 7x19	26.1	37.2	1/4	0.31	0.515	WT 6x29	35.4	50.4	5/16	0.36	0.64	WT 7x34	46.4	55.9	5/16	0.415	0.72
	WT 7x17	26.1	37.2	3/16	0.285	0.455	WT 6x26.5	35.4	--	1/4	0.345	0.575	WT 6x36	46.4	57.9	5/16	0.43	0.67
	WT 7x15	26.1	37.2	3/16	0.27	0.385	WT 5x27	35.4	50.4	5/16	0.37	0.615	WT 6x3 ..5	46.4	--	5/16	0.39	0.605
	WT 6x29	26.1	37.2	5/16	0.36	0.64	WT 5x24.5	35.4	--	1/4	0.34	0.56	WT 5x30	46.4	56.6	5/16	0.42	0.68
	WT 6x26.5	26.1	37.2	1/4	0.345	0.575												
	WT 6x22.5	26.1	37.2	1/4	0.335	0.575												
	WT 6x20	26.1	37.2	1/4	0.295	0.515												
	WT 6x8	26.1	--	3/16	0.22	0.265												
	WT 6x7	26.1	--	3/16	0.2	0.225												
	WT 5x24.5	26.1	37.2	1/4	0.34	0.56												
	WT 4x17.5	26.1	37.2	1/4	0.31	0.495												
A490-N	WT 9x17.5	34.8	--	1/4	0.3	0.425	WT 9x25	47.2	50.9	5/16	0.355	0.57	WT 9x38	57.3	57.3	5/16	0.425	0.68
	WT 8x20	34.8	--	1/4	0.305	0.505	WT 8x33.5	47.2	56.7	5/16	0.395	0.665	WT 8x38.5	61.3	61.3	3/8	0.455	0.76
	WT 8x18	34.8	--	1/4	0.295	0.43	WT 7x34	47.2	59.5	5/16	0.415	0.72	WT 7x45	59.3	59.3	3/8	0.44	0.71
	WT 8x13	34.8	--	3/16	0.25	0.345	WT 7x30.5	47.2	53.8	5/16	0.375	0.645	WT 7x34	55.9	55.9	5/16	0.415	0.72
	WT 7x24	34.8	49.6	1/4	0.34	0.595	WT 6x29	47.2	51.6	5/16	0.36	0.64	WT 6x36	57.9	57.9	5/16	0.43	0.67
	WT 7x21.5	34.8	--	1/4	0.305	0.53	WT 6x26.5	47.2	--	1/4	0.345	0.575	WT 5x30	56.6	56.6	5/16	0.42	0.68
	WT 7x19	34.8	47.2	1/4	0.31	0.515	WT 5x27	47.2	53.1	5/16	0.37	0.615						
	WT 7x17	34.8	--	3/16	0.285	0.455	WT 5x24.5	47.2	--	1/4	0.34	0.56						
	WT 7x15	34.8	--	3/16	0.27	0.385												
	WT 6x29	34.8	49.6	5/16	0.36	0.64												
	WT 6x26.5	34.8	49.6	1/4	0.345	0.575												
	WT 6x22.5	34.8	49.6	1/4	0.335	0.575												
	WT 6x20	34.8	--	1/4	0.295	0.515												
	WT 6x24.5	34.8	49.6	1/4	0.34	0.56												
	WT 4x17.5	34.8	--	1/4	0.31	0.495												

** R_1: Assuming eccentricity. R_2: Assuming no eccentricity. t_w: Minmum thickness of beam web. t_{fc}: Minimum thickness of column flange.



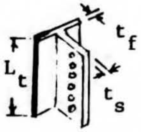
TEE FRAMING SHEAR CONNECTIONS

TABLE D Allowable Loads in Kips

$n = 5 \quad L_t = 15''$

ASTM Designation	Bolt Size, 3/4 in.						Bolt Size, 7/8 in.						Bolt Size, 1 in.					
	Designation	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)	**Designation**	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)	Designation	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)
A325-N	WT 9x17.5	36.3	46.5	1/4	0.3	0.425	WT 9x25	49.1	63.0	1/4	0.355	0.57	WT 10.5x31	64.4	--	5/16	0.4	0.615
	WT 8x20	36.3	46.5	1/4	0.305	0.505	WT 9x17.5	49.1	--	1/4	0.3	0.425	WT 9x38	64.4	71.6	5/16	0.425	0.68
	WT 8x18	36.3	46.5	1/4	0.295	0.43	WT 8x33.5	49.1	63.0	5/16	0.395	0.665	WT 8x38.5	64.4	76.6	5/16	0.455	0.76
	WT 8x13	36.3	46.5	3/16	0.25	0.345	WT 8x18	49.1	--	1/4	0.295	0.43	WT 8x33.5	64.4	--	5/16	0.395	0.665
	WT 7x24	36.3	46.5	1/4	0.34	0.595	WT 7x34	49.1	63.0	5/16	0.415	0.72	WT 7x45	64.4	74.1	5/16	0.44	0.71
	WT 7x21.5	36.3	46.5	1/4	0.305	0.53	WT 7x30.5	49.1	63.0	1/4	0.375	0.645	WT 7x34	64.4	69.9	5/16	0.415	0.72
	WT 7x19	36.3	46.5	1/4	0.31	0.515	WT 6x29	49.1	63.0	1/4	0.36	0.64	WT 6x36	64.4	72.4	5/16	0.43	0.67
	WT 7x17	36.3	46.5	3/16	0.285	0.455	WT 6x26.5	49.1	--	1/4	0.345	0.575	WT 6x32.5	64.4	--	5/16	0.39	0.605
	WT 7x15	36.3	46.5	3/16	0.27	0.385	WT 5x27	49.1	63.0	1/4	0.37	0.615	WT 5x30	64.4	70.8	5/16	0.42	0.68
	WT 6x29	36.3	46.5	1/4	0.36	0.64	WT 5x24.5	49.1	--	1/4	0.34	0.56						
	WT 6x26.5	36.3	46.5	1/4	0.345	0.575												
	WT 6x22.5	36.3	46.5	1/4	0.335	0.575												
	WT 6x20	36.3	46.5	1/4	0.295	0.515												
	WT 5x24.5	36.3	46.5	1/4	0.34	0.56												
	WT 4x17.5	36.3	46.5	1/4	0.31	0.495												
A490-N	WT 9x17.5	48.5	--	1/4	0.3	0.425	WT 8x33.5	65.5	70.8	5/16	0.395	0.665	WT 9x38	71.6	71.6	5/16	0.425	0.68
	WT 8x20	48.5	--	1/4	0.305	0.505	WT 7x34	65.5	74.4	5/16	0.415	0.72	WT 8x38.5	76.6	76.6	5/16	0.455	0.76
	WT 8x18	48.5	--	1/4	0.295	0.43	WT 7x30.5	65.5	67.3	1/4	0.375	0.645	WT 7x45	74.1	74.1	5/16	0.44	0.71
	WT 7x24	48.5	62.0	1/4	0.34	0.595	WT 5x27	65.5	66.4	1/4	0.37	0.615	WT 7x34	69.9	69.9	5/16	0.415	0.72
	WT 7x21.5	48.5	--	1/4	0.305	0.53	WT 6x29	64.5	64.6	1/4	0.36	0.64	WT 6x36	72.4	72.4	5/16	0.43	0.67
	WT 7x19	48.5	59.0	1/4	0.31	0.515	WT 9x25	63.7	63.7	1/4	0.355	0.57	WT 5x30	70.7	70.7	5/16	0.42	0.68
	WT 7x17	48.5	--	3/16	0.285	0.455												
	WT 7x15	48.5	--	3/16	0.27	0.385												
	WT 6x29	48.5	62.0	1/4	0.36	0.64												
	WT 6x26.5	48.5	62.0	1/4	0.345	0.575												
	WT 6x22.5	48.5	62.0	1/4	0.335	0.575												
	WT 6x20	48.5	--	1/4	0.295	0.515												
	WT 5x24.5	48.5	62.0	1/4	0.34	0.56												
	WT 4x17.5	48.5	--	1/4	0.31	0.495												

** R_1: Assuming eccentricity. R_2: Assuming no eccentricity. t_w: Minimum thickness of beam web. t_{fc}: Minimum thickness of column flange.



TEE FRAMING SHEAR CONNECTIONS

TABLE E Allowable Loads in Kips

n = 6 L_t= 18"

ASTM Designation	Bolt Size, 3/4 in.						Bolt Size, 7/8 in.						Bolt Size, 1 in.					
	Designation	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)	**Designation**	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)	**Designation**	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)
A325-N	WT 9x17.5	46.3	55.8	3/16	0.3	0.425	WT 9x25	62.7	75.6	1/4	0.355	0.57	WT 9x38	82.2	85.9	5/16	0.425	0.68
	WT 8x20	46.3	55.8	3/16	0.305	0.505	WT 9x17.5	62.7	--	3/16	0.3	0.425	WT 8x38.5	82.2	92.0	5/16	0.455	0.76
	WT 8x18	46.3	55.8	3/16	0.295	0.43	WT 8x33.5	62.7	75.6	1/4	0.395	0.665	WT 7x45	82.2	89.0	5/16	0.44	0.71
	WT 8x13	46.3	55.8	3/16	0.25	0.345	WT 8x18	62.7	--	3/16	0.295	0.43	WT 7x34	82.2	83.9	5/16	0.415	0.72
	WT 7x24	46.3	55.8	1/4	0.34	0.595	WT 7x34	62.7	75.6	5/16	0.415	0.72	WT 6x36	82.2	86.9	5/16	0.43	0.67
	WT 7x21.5	46.3	55.8	3/16	0.305	0.53	WT 7x30.5	62.7	75.6	1/4	0.375	0.645	WT 5x30	82.2	84.9	5/16	0.42	0.68
	WT 7x19	46.3	55.8	1/4	0.31	0.515	WT 6x29	62.7	75.6	1/4	0.36	0.64						
	WT 7x17	46.3	55.8	3/16	0.285	0.455	WT 6x26.5	62.7	--	1/4	0.345	0.575						
	WT 7x15	46.3	55.8	3/16	0.27	0.385	WT 5x27	62.7	75.6	1/4	0.37	0.615						
	WT 6x29	46.3	55.8	1/4	0.36	0.64	WT 5x24.5	62.7	--	1/4	0.34	0.56						
	WT 6x26.5	46.3	55.8	1/4	0.345	0.575												
	WT 6x22.5	46.3	55.8	1/4	0.335	0.575												
	WT 6x20	46.3	55.8	3/16	0.295	0.515												
	WT 5x24.5	46.3	55.8	1/4	0.34	0.56												
	WT 4x17.5	46.3	55.8	3/16	0.31	0.495												
A490-N	WT 9x17.5	61.8	--	3/16	0.3	0.425	WT 8x33.5	83.7	85.0	1/4	0.395	0.665	WT 9x38	85.9	85.9	5/16	0.425	0.68
	WT 8x20	61.8	--	3/16	0.305	0.505	WT 7x34	83.7	89.3	5/16	0.415	0.72	WT 8x38.5	92.0	92.0	5/16	0.455	0.76
	WT 8x18	61.8	--	3/16	0.295	0.43	WT 7x30.5	80.7	80.7	1/4	0.375	0.645	WT 7x45	89.0	89.0	5/16	0.44	0.71
	WT 8x13	61.8	--	3/16	0.25	0.345	WT 5x27	79.6	79.6	1/4	0.37	0.615	WT 7x34	83.9	83.9	5/16	0.415	0.72
	WT 7x24	61.8	74.4	1/4	0.34	0.595	WT 6x29	77.5	77.5	1/4	0.34	0.56	WT 6x36	86.9	86.9	5/16	0.43	0.67
	WT 7x21.5	61.8	--	3/16	0.305	0.53	WT 9x25	76.4	76.4	1/4	0.355	0.57	WT 5x30	84.9	84.9	5/16	0.42	0.68
	WT 7x19	61.8	70.8	1/4	0.31	0.515												
	WT 7x17	61.8	--	3/16	0.285	0.455												
	WT 7x15	61.8	--	3/16	0.27	0.385												
	WT 6x29	61.8	74.4	1/4	0.36	0.64												
	WT 6x26.5	61.8	74.4	1/4	0.345	0.575												
	WT 6x22.5	61.8	74.4	1/4	0.335	0.575												
	WT 6x20	61.8	--	3/16	0.295	0.515												
	WT 5x24.5	61.8	74.4	1/4	0.34	0.56												
	WT 4x17.5	61.8	--	3/16	0.31	0.495												

**R_1: Assuming eccentricity. R_2: Assuming no eccentricity. t_w: Minimum thickness of beam web. t_{fc}: Minimum thickness of column flange.

TEE FRAMING SHEAR CONNECTIONS

TABLE F Allowable Loads in Kips

$n = 7 \quad L_t = 21''$

ASTM Designation	Bolt Size, 3/4 in.						Bolt Size, 7/8 in.						Bolt Size, 1 in.					
	Designation	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)	Designation	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)	Designation	Load R_1 (Kips)	Load R_2 (Kips)	Weld (in)	Min. t_w (in)	Min. t_{fc} (in)
A325-N	WT 9x17.5	56.4	65.1	3/16	0.3	0.425	WT 9x25	76.4	88.2	1/4	0.355	0.57	WT 9x38	100.0	100.3	5/16	0.425	0.68
	WT 8x20	56.4	65.1	3/16	0.305	0.505	WT 8x33.5	76.4	88.2	1/4	0.395	0.665	WT 8x38.5	100.0	107.3	5/16	0.455	0.76
	WT 8x18	56.4	65.1	3/16	0.295	0.43	WT 7x34	76.4	88.2	1/4	0.415	0.72	WT 7x45	100.0	103.8	5/16	0.44	0.71
	WT 7x24	56.4	65.1	1/4	0.34	0.595	WT 7x30.5	76.4	88.2	1/4	0.375	0.645	WT 6x36	100.0	101.4	5/16	0.43	0.67
	WT 7x21.5	56.4	65.1	3/16	0.305	0.53	WT 6x29	76.4	88.2	1/4	0.36	0.64	WT 5x30	99.1	99.1	1/4	0.42	0.68
	WT 7x19	56.4	65.1	3/16	0.31	0.515	WT 6x26.5	76.4	--	1/4	0.345	0.575	WT 7x34	97.9	97.9	1/4	0.415	0.72
	WT 7x17	56.4	65.1	3/16	0.285	0.455	WT 5x27	76.4	88.2	1/4	0.37	0.615						
	WT 7x15	56.4	65.1	3/16	0.27	0.385	WT 5x24.5	76.4	--	1/4	0.34	0.56						
	WT 6x29	56.4	65.1	1/4	0.36	0.64												
	WT 6x26.5	56.4	65.1	1/4	0.345	0.575												
	WT 6x22.5	56.4	65.1	1/4	0.335	0.575												
	WT 6x20	56.4	65.1	3/16	0.295	0.515												
	WT 5x24.5	56.4	65.1	1/4	0.34	0.56												
	WT 4x17.5	56.4	65.1	3/16	0.31	0.495												
A490-N	WT 9x17.5	75.1	--	3/16	0.3	0.425	WT 7x34	102.0	104.2	1/4	0.415	0.72	WT 8x38.5	107.3	107.3	5/16	0.455	0.76
	WT 8x20	75.1	--	3/16	0.305	0.505	WT 8x33.5	99.2	99.2	1/4	0.395	0.665	WT 7x45	103.8	103.8	5/16	0.44	0.71
	WT 8x18	75.1	--	3/16	0.295	0.43	WT 7x30.5	94.2	94.2	1/4	0.375	0.645	WT 6x36	101.4	101.4	5/16	0.43	0.67
	WT 7x24	75.1	86.8	1/4	0.34	0.595	WT 5x27	92.9	92.9	1/4	0.37	0.615	WT 9x38	100.2	100.2	5/16	0.425	0.68
	WT 7x21.5	75.1	--	3/16	0.305	0.53	WT 6x29	90.4	90.4	1/4	0.36	0.64	WT 5x30	99.1	99.1	1/4	0.42	0.68
	WT 7x19	75.1	82.6	3/16	0.31	0.515	WT 9x25	89.1	89.1	1/4	0.355	0.57	WT 7x34	97.9	97.9	1/4	0.415	0.72
	WT 7x17	75.1	--	3/16	0.285	0.455												
	WT 6x29	75.1	86.8	1/4	0.36	0.64												
	WT 6x26.5	75.1	86.8	1/4	0.345	0.575												
	WT 6x22.5	75.1	86.8	1/4	0.335	0.575												
	WT 6x20	75.1	--	3/16	0.295	0.515												
	WT 5x24.5	75.1	86.8	1/4	0.34	0.56												
	WT 4x17.5	75.1	--	3/16	0.31	0.495												

**R_1: Assuming eccentricity. R_2: Assuming no eccentricity. t_w: Minimum thickness of beam web. t_{fc}: Minimum thickness of column flange.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

Based upon test results and recommended design procedures for tee framing shear connections, the following conclusions and recommendations were reached:

1. Because the design procedures are based on research conducted at the University of California-Berkeley, the use of A36 steel only is recommended for the tee sections in order to comform with the test data of that research.
2. Although there are 207 actual WT sections listed in the AISC Manual, the number of applicable selections is relatively limited when all the design procedures are implemented. There are only 17 suitable WT sections for $d_b=3/4$ in. and 10 sections for $d_b=7/8$ in. and $d_b=1$ in.
3. Service loading on the bolt line can be assumed to be eccentric or not. If the support is rotationally flexible, the eccentricity has to be considered.
4. The number of bolts considered in this study ranged from 2 to 7. This corresponds to a maximum service load reaction for the beam of 107.3 kips.(Use 7-A490-N bolts with WT8x38.5

tee and 5/16 in. fillet welds)

5. If beam is coped, the block shear failure of the beam web has to be checked independently.

As can be seen from the recommended design procedure, the design process for a tee framing connection is cumbersome and tedious. The design steps are numerous and the number of actual tee sections that can be used is extremely limited. The design tables make these computations and selections almost effortless. Since the use of a coped beam is quite possible, it is recommended that a new set of design tables could be constructed to incorporate block shear. It is also recommended that the question of support located flexibility be examined since it is this factor which determines whether the bolt line can be assumed to be eccentric or not.

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