## **Connections and Tension Member Design**

### Connections

Connections must be able to transfer any axial force, shear, or moment from member to member or from beam to column.

Steel construction accomplishes this with bolt and welds. Wood construction uses nails, bolts, shear plates, and split-ring connectors.

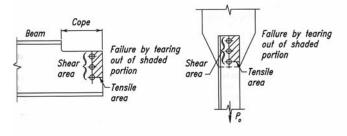
### Bolted and Welded Connections

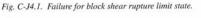
The limit state for connections depends on the loads:

- 1. tension yielding
- 2. shear yielding
- 3. bearing yielding
- 4. bending yielding due to eccentric loads
- 5. rupture

Welds must resist tension AND shear stress. The design strengths depend on the weld materials.

## **Bolted Connection Design**





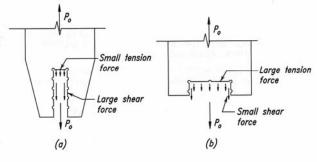


Fig. C-J4.2. Block shear rupture in tension

# Bolt designations signify material and type of connection where

SC: slip critical

- N: bearing-type connection with bolt threads *included* in shear plane
- X: bearing-type connection with bolt threads *excluded* from shear plane

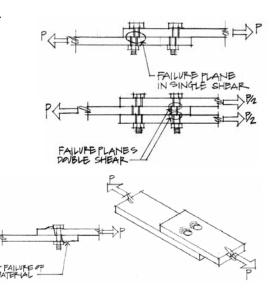
Bolts rarely fail in \_\_\_\_\_\_. The material with the hole will more likely yield first.

Standard bolt holes are 1/16" larger than the bolt diameter.

## ASD

Allowable shear values are given by bolt type, connection type, hole type, diameter, and loading (Single or Double shear) in AISC manual tables.

Allowable bearing force values are given by bolt diameter, ultimate tensile strength,  $F_u$ , of the connected part, and thickness of the connected part in AISC manual tables.



1

BOLTS, THREADED PARTS AND RIVETS Shear Allowable load in kips

ASTM         Contr         Hole $F_{V}$ Load $\frac{5}{7}$ Anominal Diameter d, in.           A307         —         Type*         ksi         ing $\frac{5}{7}$ $\frac{5}{7}$ $\frac{5}{7}$ $\frac{1}{7}$ <th>KIM beg         Conv reduin         Hels Type         Fx ks         Top         Monimal Damenet         Monimal Damenet<!--</th--><th>SIM begin         Corr begin         Hole for the form         Fx the for the for         Least the for the for         Fx the for the for         Least the for the for         Anomal the for the for         Anomal the for         Interest the for         Anomal the for         Interest the for         Interest for         Interest the for         In</th><th></th><th></th><th></th><th></th><th>TABLE</th><th>÷.</th><th>-D. S</th><th>SHEAR</th><th>щ</th><th></th><th></th><th></th><th></th><th></th></th>	KIM beg         Conv reduin         Hels Type         Fx ks         Top         Monimal Damenet         Monimal Damenet </th <th>SIM begin         Corr begin         Hole for the form         Fx the for the for         Least the for the for         Fx the for the for         Least the for the for         Anomal the for the for         Anomal the for         Interest the for         Anomal the for         Interest the for         Interest for         Interest the for         In</th> <th></th> <th></th> <th></th> <th></th> <th>TABLE</th> <th>÷.</th> <th>-D. S</th> <th>SHEAR</th> <th>щ</th> <th></th> <th></th> <th></th> <th></th> <th></th>	SIM begin         Corr begin         Hole for the form         Fx the for the for         Least the for the for         Fx the for the for         Least the for the for         Anomal the for the for         Anomal the for         Interest the for         Anomal the for         Interest the for         Interest for         Interest the for         In					TABLE	÷.	-D. S	SHEAR	щ					
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	ASTM Molicity         Hole Type         Fv Instruction         Load Hole Type         Hole Molicity         Fv Instruction         Load Hole Hole Hole         Fv Instruction         Lease Hole Hole Hole         Fv Instruction         Lease Hole Hole Hole Hole         Fv Instruction         Lease Hole Hole Hole Hole Hole Hole Hole Hol	ASTM biol         Com- type         Hole biol         FV biol         Load biol         FV biol         FV biol         Load biol         FV biol         FV biol <thfv biol         <thfv biol         <thfv< th=""><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th>Nor</th><th>ninal Dia</th><th>meter d</th><th></th><th></th><th></th></thfv<></thfv </thfv 									Nor	ninal Dia	meter d			
Unset mation         Type <sup>1</sup> Type <sup>1</sup> isi isi SC <sup>1</sup> isi SC <sup>1</sup> isi SC <sup>1</sup> <th>Unside         Type         Isia         ing         Analytic         Test of the initial intent in the initial intent initial intent initial initi initini inital initial initiali initial initial initininitiali</th> <th>Unside         Type         Isia         Ing         Analy         Total         To</th> <th></th> <th>ASTM</th> <th>Con</th> <th>Hole</th> <th>Ľ,</th> <th>Load-</th> <th>5/8</th> <th>3/4</th> <th>3/8</th> <th>-</th> <th>11/8</th> <th>11/4</th> <th>13/8</th> <th>11</th>	Unside         Type         Isia         ing         Analytic         Test of the initial intent in the initial intent initial intent initial initi initini inital initial initiali initial initial initininitiali	Unside         Type         Isia         Ing         Analy         Total         To		ASTM	Con	Hole	Ľ,	Load-	5/8	3/4	3/8	-	11/8	11/4	13/8	11
Intercond         Type         No	Math         Type         X 2006         Atts         Solid         244         Solid         236         2418         Solid         127         1446         127         1448         123         1441         255         2441         255         2441         255         2441         255         2445         255         245         255         245         255         245         255 <th255< th=""> <th255< th=""> <th255< th=""></th255<></th255<></th255<>	mature         Type         T         300         T         306         4418         6013         784         99         1227         1448         1237         1448         1237         1448         1237         1448         1237         1448         1237         1448         1237         1448         1237         1448         1237         1448         1237         1549         1237         1549         1237         1549         1237         1549         1237         1549         134         1237         1348         1237         1348         1323         1347         1368         134         1416         135         134         1356         134		Desig-	ection	Type <sup>b</sup>	ksi	'ng		Are	a (Base	d on Not	ninal Di	ameter)	in.2	
A307         -         NSID         10.0         5         3.1         8.4         6.0         7.7         9.9         12.3         14.9         23.5         24.5         29.4         5         27.5         10.0         7         9.9         12.3         14.9         25.5         24.5         29.5         24.5         23.5         24.5         23.5         24.5         23.5         24.5         23.5         24.5         23.5         24.5         23.5         24.5         23.5         24.5         23.5         24.5         23.5         24.5         23.5         24.5         23.5         24.5         23.5         24.5         23.5	A307         -         STD         100         D         8,1         8,4         600         7,9         12,3         13,0         23,1	A007         —         SID         100         D         31         84         120         123         144         65         252         251         751         753         265		nation	adki				3068	.4418	.6013	.7854	.9940	1.227	1.485	1.7
AD25         STD         17.0         5         5.2         15.1         10.2         15.3         15.6         25.5         15.5	Str         Str         17.0         5         5.5         15         10.2         15.6         20.4         15.6         20.4         15.7         50.5         15.6         20.4         15.7         50.5         15.6         20.4         15.7         50.5         15.6         20.4         15.6         20.4         15.7         50.5         15.7         50.5         15.8         15.9         21.4         15.8         15.9         21.4         15.8         15.9         21.4         15.8 <th15.8< th=""> <th15.8< th=""> <th15.8< th=""></th15.8<></th15.8<></th15.8<>	Str         T70         T         T21         T25         T25 <tht25< th=""> <tht25< th=""> <tht25< th=""></tht25<></tht25<></tht25<>	-	A307	I	STD	10.0	ωD	3.1	4.4 8.8	6.0	7.9	9.9 19.9	12.3 24.5	14.8 29.7	35
Accs         ONG, SSC         Total SSC         ONG, SSC         Total SSC         Accs         Acc	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $				STD	17.0	sα	5.22 10.4		10.2	13.4 26.7	16.9 33.8	20.9	25.2	88
A326         5.30         7.22         9.42         1.94         7.56         6.56         4.42         1.95         1.94         7.56         6.54         3.55         3.56         3.55         3.56         3.55 <td>A225 To the set of th</td> <td>A225         Total         LSL         12.0         5         36         15.6         14.4         18.8         23.9         24.3         15.6         62.4         35.6         35.1         35.1         55.1         55.2         35.2         35.2         35.1         35.1         55.1         55.2         35.</td> <td></td> <td></td> <td>Class</td> <td>OVS, SSL</td> <td>15.0</td> <td>ഗവ</td> <td>4.60</td> <td>-</td> <td>9.02 18.0</td> <td>11.8 23.6</td> <td>14.9 29.8</td> <td>18.4 36.8</td> <td>22.3</td> <td>28</td>	A225 To the set of th	A225         Total         LSL         12.0         5         36         15.6         14.4         18.8         23.9         24.3         15.6         62.4         35.6         35.1         35.1         55.1         55.2         35.2         35.2         35.1         35.1         55.1         55.2         35.			Class	OVS, SSL	15.0	ഗവ	4.60	-	9.02 18.0	11.8 23.6	14.9 29.8	18.4 36.8	22.3	28
N         STD, NSL         21.0         5         6.4         8.6         5.6.5         5.5.6         5.6.5         5.5.6         5.7.5         5.6.4         5.5.5         5.7.5         5.6.4         5.5.5         5.7.5 <td>N         STD, NSL         21.0         5         5.4         18.0         23.5         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         31.2         5.5         31.2</td> <td><math display="block"> \begin{array}{ c c c c c c c c c c c c c c c c c c c</math></td> <td></td> <td>A325</td> <td>:</td> <td>rsl</td> <td>12.0</td> <td>sο</td> <td>3.68</td> <td></td> <td>7.22</td> <td>9.42 18.8</td> <td>11.9</td> <td>14.7 29.4</td> <td>17.8</td> <td>24</td>	N         STD, NSL         21.0         5         5.4         18.0         23.5         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         5.5         31.2         31.2         5.5         31.2	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$		A325	:	rsl	12.0	sο	3.68		7.22	9.42 18.8	11.9	14.7 29.4	17.8	24
X         STD, NSL         30.0         5         39.2         13.3         160         27.6         36.4         47.1         59.6         84.4         51.5         56.2         36.1         47.1         59.6         84.4         51.5         56.2         36.1         47.1         51.5         62.4         31.2         51.5         56.2         36.1         47.1         51.5         62.4         31.2         51.5         56.7         51.5         56.7         56	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$			z	STD, NSL	21.0	ഗവ	6.4 12.9	9.3 18.6	12.6 25.3	16.5 33.0	20.9	25.8	31.2 62.4	50
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	AB0         STD         21.0         5         55.4         15.5         15.5         25.6         31.2         25.4         25.5         31.2         25.5         31.2         25.5         31.2         25.5         31.2         25.5         31.5         35.5         31.5         35.5	91100		×	STD, NSL	30.0	ഗവ	9.2	13.3 26.5	18.0	23.6 47.1	29.8	36.8	44.5	8.5
A490         A202         A80         552         552         552         552         552         553 </td <td>Also         SSL         OVS         18.0         5.52         7.95         10.8         14.1         17.9         22.1         26.5           Also         LSL         15.0         D         3.50         13.3         18.0         23.5         23.5         35.5         35.5         35.5         35.5         35.5         35.4         44.1         25.5         35.7         44.0         55.7         86.8         44.5         55.7         86.8         44.5         55.7         86.8         44.5         55.7         86.8         45.5         35.7         24.1         31.7         24.1         31.7         28.1         33.7         44.0         55.7         86.8         45.5         55.7         86.7         55.7         86.7         55.7         86.7         55.7         86.7         55.7         38.7         45.5         55.2         26.9         45.7         55.2         26.7         35.7         35.7         34.4         25.5         26.0         35.7         35.7         34.8         55.7         35.9         45.5         55.0         35.7         35.9         45.7         55.9         45.5         36.7         35.9         45.5         36.7         35.9         45.5<td>Also         SSC         OVS         18.0         5.52         1.53         5.02         1.10         1.53         2.11         1.73         2.21         2.83         3.53         4.43         3.53         4.43         3.53         4.43         4.43         4.43         4.43         4.43         4.43         4.43         4.43         4.43         4.43         4.43         5.53         5</td><td>8</td><td></td><td></td><td>STD</td><td>21.0</td><td>ωD</td><td>6.44</td><td></td><td></td><td>16.5 33.0</td><td>20.9</td><td>25.8</td><td>31.2 62.4</td><td>54</td></td>	Also         SSL         OVS         18.0         5.52         7.95         10.8         14.1         17.9         22.1         26.5           Also         LSL         15.0         D         3.50         13.3         18.0         23.5         23.5         35.5         35.5         35.5         35.5         35.5         35.4         44.1         25.5         35.7         44.0         55.7         86.8         44.5         55.7         86.8         44.5         55.7         86.8         44.5         55.7         86.8         45.5         35.7         24.1         31.7         24.1         31.7         28.1         33.7         44.0         55.7         86.8         45.5         55.7         86.7         55.7         86.7         55.7         86.7         55.7         86.7         55.7         38.7         45.5         55.2         26.9         45.7         55.2         26.7         35.7         35.7         34.4         25.5         26.0         35.7         35.7         34.8         55.7         35.9         45.5         55.0         35.7         35.9         45.7         55.9         45.5         36.7         35.9         45.5         36.7         35.9         45.5 <td>Also         SSC         OVS         18.0         5.52         1.53         5.02         1.10         1.53         2.11         1.73         2.21         2.83         3.53         4.43         3.53         4.43         3.53         4.43         4.43         4.43         4.43         4.43         4.43         4.43         4.43         4.43         4.43         4.43         5.53         5</td> <td>8</td> <td></td> <td></td> <td>STD</td> <td>21.0</td> <td>ωD</td> <td>6.44</td> <td></td> <td></td> <td>16.5 33.0</td> <td>20.9</td> <td>25.8</td> <td>31.2 62.4</td> <td>54</td>	Also         SSC         OVS         18.0         5.52         1.53         5.02         1.10         1.53         2.11         1.73         2.21         2.83         3.53         4.43         3.53         4.43         3.53         4.43         4.43         4.43         4.43         4.43         4.43         4.43         4.43         4.43         4.43         4.43         5.53         5	8			STD	21.0	ωD	6.44			16.5 33.0	20.9	25.8	31.2 62.4	54
A490         LSL         15.0         5         4.60         15.3         18.0         25.3         18.0         21.8         14.9         18.4         22.3           N STD         28.0         5         3.5         13.3         18.0         25.6         29.8         36.8         44.4         51.5           N STD         28.0         5         3.6         12.4         33.7         44.0         55.7         83.7         84.1         53.8         86.1         44.16         55.7         83.2         119.0         119.4         146         55.7         83.2         119.1         119.4         156         22.0         55.1         119.1         55.7         84.1         62.8         32.1         119.1         15.6         119.4         147         147         147         147         25.0         32.7         32.0	A490         LSL         15.0         5         4.50         13.3         18.0         2.23         18.4         2.23           N         STD         28.0         D         17.2         24.7         33.7         44.0         55.7         83.4         44.6           NSL         NSL         28.0         D         17.2         24.7         33.4         43.6         55.7         83.7         83.2         113.9         113.7         17.4         21.5         83.2         113.7         17.4         21.5         25.0         23.9         84.1         15.5         86.1         84.1         15.5         86.1         14.4         15.5         25.0         23.1         13.7         13.1         23.1         23.1         23.1         23.1         23.1         23.1         23.1         23.1         24.1         13.7         24.0         55.7         24.0         55.3         24.0         55.3         24.0         55.3         24.0         55.3         24.0         55.3         24.0         55.3         24.0         55.3         24.0         55.3         24.0         55.3         24.0         55.3         24.0         55.3         24.0         55.3         24.0	A490         LSL         15.0         5         4.60         6.63         9.02         11.8         14.9         18.4         2.2.3           A400         NSL         28.0         5         3.1         13.3         18.0         25.5         23.9         38.8         44.4         5.3           A502-1         NSL         28.0         5         3.5         3.3         13.7         7.4         21.5         33.4         43.9         53.9         42.1         53.7         53.0         13.7         7.7         21.5         33.4         43.9         53.9         42.1         53.7         23.0         55.7         53.1         13.7         7.7         21.5         33.4         43.6         55.7         53.0         53.7         54.0         55.7         54.0         55.7         54.0         55.7         54.0         55.7         54.0         55.7         54.0         55.7         54.0         55.7         54.0         55.7         54.0         55.7         54.0         55.7         54.0         55.7         54.0         55.7         54.0         55.7         54.0         55.7         54.0         55.7         54.0         55.7         34.0         55.7 <t< td=""><td></td><td></td><td>SC<sup>a</sup></td><td>OVS, SSL</td><td>18.0</td><td>ωD</td><td>5.52</td><td></td><td></td><td>14.1 28.3</td><td>17.9</td><td>22.1</td><td>26.7 53.5</td><td>59</td></t<>			SC <sup>a</sup>	OVS, SSL	18.0	ωD	5.52			14.1 28.3	17.9	22.1	26.7 53.5	59
N         STD, NSL         280         5         3.6         1.2         4.6         2.6         2.8         4.1         5.7         8.7         8.1         5.7         8.7         8.1         5.7         8.7         8.1         5.3         5.4         4.15         5.9.4         4.16         5.9.4         4.15         5.9.5         8.7         8.7         8.7         8.7         8.7         8.7         8.7         8.7         8.7         8.7         8.7         8.7         8.7         8.7         1.9.5         9.8         4.1         5.5         8.7         9.7         1.0         7.7         1.0         1.7         2.5         9.2         1.3         7.7         1.0         1.7         2.5         9.2         1.3         7.7         1.0         1.7         2.5         9.2         1.3         1.7         2.1         1.3         1.7         2.1         1.4         2.0         3.2         3.4         3.2         3.4         3.2         3.4         3.2         3.4         3.2         3.4         3.2         3.4         3.2         3.4         3.2         3.4         3.2         3.4         3.6         3.2         3.2         3.4         3.2	N         STD, NSL         280         5         35         12.2         16.8         22.0         27.8         33.4         41.5         54.4         41.6         55.8         34.4         55.4         31.7         77.8         54.7         55.9         54.1         53.6         36.1         59.0         113.0         11.7         55.3         34.1         55.4         31.7         77.7         115.5         31.2         77.7         21.5         21.0         27.7         31.5         77.7         115.5         13.2         17.4         21.5         26.0         32.7           A502.23         -         -         STD         2.9         5.7         9.7         10.5         11.7         5.5         9.2         7.7         10.5         11.4         38.0         45.1         52.0         32.7         34.4         25.6         32.7         34.4         25.9         52.0         32.7         34.6         52.0         32.7         34.6         52.0         32.7         34.6         52.0         32.7         32.4         34.7         35.0         34.7         35.0         34.7         35.0         35.7         32.7         32.1         32.1         32.1         35.7	N         STD, NSL         28.0         5         3.6         12.2         16.8         22.0         27.8         34.4         41.6         59.4         41.5         41.0         55.7         83.7         83.1         59.4         41.6         59.4         41.6         59.4         41.6         59.4         41.6         59.4         41.0         55.7         83.7         83.7         83.7         83.7         83.6         83.2         59.2         119.0         11         59.4         11.9         11.0         11.1         59.7         11.2         11.		A490	¢	rsl	15.0	ωD	4.60				14.9	18.4	22.3	88
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	X         STD, NSL         400         S         12.3         17.7         24.1         31.4         36.8         49.1         59.4         159.4         1           A502-1         —         STD         17.5         S         5.4         7.7         0.5         13.7         12.4         5.8         80.2         159.0         15.2         50.0         57.5         34.8         42.9         52.0         52.0         57.5         34.8         42.9         52.0         55.0         52.1         52.0         52.1         52.0	X         STD, NSC         40.0         S         12.3         17.7         24.1         31.4         30.8         49.1         59.4         159.4         1           A502-1         -         STD         17.5         D         10.7         15.5         21.0         27.5         34.8         42.9         52.0         52.0         27.5         34.8         42.9         52.0			z	STD, NSL	28.0	ωD	8.6	12.4 24.7	16.8	22.0	27.8	34.4 68.7	41.6	48
A502-1         —         STD         17.5         5.4         7.7         10.5         13.7         77.4         21.5         28.0           A502-3         —         STD         27.0         5         5.7         9.7         5.7         37.4         21.5         28.0         32.0         32.0         32.0         32.7         32.4         27.5         34.8         27.9         32.7         32.7         32.4         23.7         32.0         32.7         32.7         32.0         32.7         32.7         32.0         32.7         32.7         32.0         32.7         32.7         32.0         32.7         32.0         32.7         32.0         52.0         32.7         32.0         52.0         32.7         32.0         52.0         32.7         32.0         52.0         32.7         32.0         52.0         32.7         32.0         52.0         32.7         32.0         52.0         32.7         32.0         52.0         32.7         32.0         52.0         32.7         32.0         52.7         32.0         52.7         32.0         52.7         32.0         52.7         32.0         52.7         32.0         52.7         32.0         52.7         32.0	A502-1         —         STD         17.5         5.4         7.7         10.5         13.7         17.4         21.5         26.0         25	A502-1         —         STD         17.5         5.4         7.7         10.5         13.7         77.4         21.5         38.0         22.0         55.4         10.7         15.5         21.0         21.9         22.0         65.3         32.0         65.3         34.6         21.9         21.9         22.0         65.3         34.6         61.7         51.9         21.9         21.9         23.0         65.3         34.6         61.7         51.9         21.0         13.7         51.9         21.0         65.3         32.9         65.7         71.9         15.6         61.3         23.9         61.7         15.7         10.1         12.7         14.7         13.0         65.3         23.0         65.7         23.1         24.4         60.7         24.3         24.0         65.3         38.0         11.1         13.9         14.7         11.0         15.4         23.1         23			×	STD, NSL	40.0	δ	12.3	17.7	24.1 48.1	31.4 62.8	39.8	49.1	59.4 119.0	14 1
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	534	A502-1	I	STD	17.5	ωD	5.4	7.7	10.5 21.0	13.7 27.5	17.4	21.5	26.0 52.0	89
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	AB6 (F <sub>a</sub> =58 ks)         N         STD         9.9         5         3.0         8.4         6.0         7.8         9.8         12.1         13.7           (F <sub>a</sub> =58 ks)         X         STD         12.8         5         3.0         8.4         6.0         7.8         3.9         13.1         15.7         19.0         15.6         19.7         13.1         15.4         3.0         14.7         16.0         15.6         19.0         15.7         13.0         15.7         13.0         15.5         13.0         3.0         14.8         16.5         13.1         3.0         14.8         16.5         13.0         14.5         15.2         15.4         20.1         35.6         13.2         3.0         14.5         16.5         13.0         3.0         14.5         16.5         16.5         33.0         16.5         13.2         3.0         3.0         14.7         16.5         14.5         38.0         14.5         16.5         31.2         13.2         13.2         13.2         13.2         23.2         32.2         33.2         32.2         35.2         35.2         35.2         35.2         35.2         35.2         35.2         35.2         35.2         35.2	AB6 (F <sub>a</sub> =56 ksi)         N         STD         9.9         5         3.0         8.4         6.0         7.8         9.8         12.1         13.7           (F <sub>a</sub> =56 ksi)         X         STD         12.8         5         3.9         5.7         10.1         12.7         15.7         19.0         15.6         19.2         3.1.4         38.0           A572         Gr. 50         N         STD         11.1         D         6.8         9.8         11.2         15.7         13.1         3.8         0.8         11.2         7         3.1         3.80         0         3.8         13.1         15.4         20.1         25.6         3.9.1         3.80         0         14.5         3.80         0         14.5         3.80         0         14.5         3.80         0         15.6         13.7         2.12         2.12         3.30         15.4         2.13         3.30         15.4         2.12         2.12         3.30         3.7         3.5         3.5         3.5         3.5         3.5         3.5         3.5         3.5         3.5         3.5         3.5         3.5         3.5         3.5         3.5         3.5         3.5         3.5 <td>HIM</td> <td>A502-2 A502-3</td> <td>1</td> <td>STD</td> <td>22.0</td> <td>sο</td> <td>6.7 13.5</td> <td>9.7 19.4</td> <td>13.2 26.5</td> <td>17.3 34.6</td> <td>21.9</td> <td>27.0</td> <td>32.7 65.3</td> <td>38</td>	HIM	A502-2 A502-3	1	STD	22.0	sο	6.7 13.5	9.7 19.4	13.2 26.5	17.3 34.6	21.9	27.0	32.7 65.3	38
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	X         STD         12.8         S         3.9         5.7         7.7         10.1         12.7         15.6         15.4         15.6         16.5         16.5         16.5         16.5         16.5         16.5         16.5         15.2         15.6         15.2         15.2         33.0         16.7         35.1         22.1         23.7         35.1         22.1         23.7         35.1         23.7         35.1         23.7         35.3         13.7         23.7         35.1         42.5         35.3         13.7         13.2 <th13.6< th=""> <th13.5< th=""> <th13.6< th=""></th13.6<></th13.5<></th13.6<>	X         STD         12.8         S         3.9         5.7         7.7         10.1         12.7         15.2         15.2         25.3         35.3         15.7         15.2         25.2         23.4         15.5         15.2         25.2         23.4         25.3         15.3         15.7         12.5         35.3         13.7         42.5         35.3         13.7         42.5         35.3         14.2         15.7         15.2         23.1         23.2         23.2         23.2         35.3		A36 (F <sub>c</sub> =58 ksi)	z	STD	9.9	sο	3.0	4.4	6.0	7.8	9.8	12.1 24.3	14.7 29.4	17.5 35.0
	M572.         Gr. 50         N         STD         11.1         5         3.4         4.9         6.7         8.7         11.0         13.5         14.6         13.7         17.7         27.2         23.0         17.7         23.1         17.4         22.1         27.2         23.0         17.7         23.1         24.2         17.7         23.1         24.2         17.7         23.1         24.2         17.7         23.1         24.2         17.7         24.2         37.1         31.0         31.1         31.5         31.2         13.2         13.2         14.2         35.1         42.5         35.1         42.5         35.1         42.5         35.1         42.5         35.1         42.5         35.1         42.5         35.1         42.5         35.1         42.5         35.1         42.5         35.1         42.5         35.1         42.5         35.3         35.1         42.5         35.3         35.1         42.5         35.3         35.1         42.5         35.3         35.1         42.5         35.3         35.1         43.5         35.7         35.2         35.2         35.2         35.3         35.3         35.1         35.1         35.1         35.1         35.1 <td>AF72.         Gr. 50         N         STD         11.1         5         3.4         4.9         6.7         8.7         11.0         13.5         14.2         13.7         13.7         12.7         13.5         14.5         14.2         17.7         21.7         21.2         <th21.2< th=""> <th22.2< th=""> <th23.3< th=""></th23.3<></th22.2<></th21.2<></td> <td>81</td> <td></td> <td>×</td> <td>STD</td> <td>12.8</td> <td>sο</td> <td>3.9</td> <td>5.7</td> <td>7.7</td> <td>10.1</td> <td>12.7 25.4</td> <td>15.7</td> <td>19.0 38.0</td> <td>24</td>	AF72.         Gr. 50         N         STD         11.1         5         3.4         4.9         6.7         8.7         11.0         13.5         14.2         13.7         13.7         12.7         13.5         14.5         14.2         17.7         21.7         21.2 <th21.2< th=""> <th22.2< th=""> <th23.3< th=""></th23.3<></th22.2<></th21.2<>	81		×	STD	12.8	sο	3.9	5.7	7.7	10.1	12.7 25.4	15.7	19.0 38.0	24
X         STD         14.3         5         4.4         6.3         8.6         11.2         14.2         15.5         14.2         15.5         12.5           A586         N         STD         11.9         5         3.7         5.3         15.6         17.2         13.6         17.5         14.2         15.5         14.2         15.5         14.2         15.5         14.2         15.5         14.2         15.5         14.2         15.7         14.2         15.7         14.2         15.7         14.2         15.7         14.2         15.7         14.2         15.7         14.2         15.7         14.2         15.7         14.2         15.7         14.2         15.7         14.2         15.7         14.2         15.7         14.2         15.7         14.2         15.7         14.2         15.7         15.2         15.3 <th< td=""><td>X         STD         14.3         S         4.4         15.3         8.6         11.2         14.2         15.7         21.2           A58         N         STD         11.9         S         3.7         5.3         15.2         13.5         13.6         17.5         21.2           A58         N         STD         11.9         S         3.7         5.3         15.2         13.7         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.7         23.7         23.2         33.3         33.7         13.7         13.5</td><td>X         STD         14.3         S         44.4         6.3         8.6         11.2         14.2         15.5         28.4         17.5         21.2         13.5</td></th<> <td>N Pa</td> <td></td> <td>z</td> <td>STD</td> <td>11.1</td> <td>sο</td> <td>3.4 6.8</td> <td>4.9 9.8</td> <td>6.7 13.3</td> <td>8.7 17.4</td> <td>11.0</td> <td>13.6 27.2</td> <td>16.5 33.0</td> <td>5°</td>	X         STD         14.3         S         4.4         15.3         8.6         11.2         14.2         15.7         21.2           A58         N         STD         11.9         S         3.7         5.3         15.2         13.5         13.6         17.5         21.2           A58         N         STD         11.9         S         3.7         5.3         15.2         13.7         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.5         13.7         23.7         23.2         33.3         33.7         13.7         13.5	X         STD         14.3         S         44.4         6.3         8.6         11.2         14.2         15.5         28.4         17.5         21.2         13.5	N Pa		z	STD	11.1	sο	3.4 6.8	4.9 9.8	6.7 13.3	8.7 17.4	11.0	13.6 27.2	16.5 33.0	5°
A586 N STD 11.9 S 3.7 5.3 7.2 9.3 11.8 14.6 17.7 (f <sub>a</sub> =70 ks) X STD 15.4 S 47.6 8 9.3 12.1 23.7 29.2 35.3 (f <sub>a</sub> =70 ks) X STD 15.4 S 4.7 16.8 9.3 12.1 15.3 18.9 22.9 4.5 15.4 13.6 18.5 24.2 30.6 37.8 45.7	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	A58 ( $F_{s}^{-1}$ O ks)         N         STD         11.9         S         3.7         15.3         17.3         18.7         23.2         13.5         14.5         17.7           ( $F_{s}^{-1}$ O ks)         X         STD         15.4         S         3.7         10.5         14.3         18.7         23.2         23.5         35.3           ( $F_{s}^{-1}$ O ks)         X         STD         15.4         D         9.3         12.1         18.5         24.2         18.5         18.3         23.7         8         35.3         35.5         36.6         37.8         45.7 <td>opeou</td> <td></td> <td>×</td> <td>STD</td> <td>14.3</td> <td>sο</td> <td>4.4</td> <td>6.3 12.6</td> <td>8.6</td> <td>11.2</td> <td>14.2</td> <td>17.5 35.1</td> <td>21.2</td> <td>ã is</td>	opeou		×	STD	14.3	sο	4.4	6.3 12.6	8.6	11.2	14.2	17.5 35.1	21.2	ã is
X STD 15.4 S 4.7 6.8 9.3 12.1 15.3 18.9 22.9 9.4 13.6 18.5 24.2 30.6 37.8 45.7	X         STD         15.4         S         4.7         6.8         9.3         12.1         15.3         18.9         22.9           Silp critical connection with threads included in shear plane.         ing-type connection with threads included in shear plane.         OVS: Oversize round holes         45.7           Standard round holes (d+'hin.)         OVS: Oversize round holes         OVS: Oversize round holes         45.7           Long-or short-slotted hole mormal to load direction         SSL: Short-slotted holes         0         SSL: Short-slotted holes           Long-or short-slotted hole mormal to load direction         SSL: Short-slotted holes         0         0           Long-or short-slotted hole mormal to load direction         SSL: Short-slotted holes         0         0           Long-or short-slotted hole mormal to load direction         SSL: Short-slotted holes         0         0           Long-or short-slotted hole morection.         SSL: Short-slotted holes         0         0         0           Reading in the main to load direction         SSL: Short-slotted holes         0         0         0           Long-or short-slotted hole morection.         SSL: Short-slotted holes         0         0         0         0         0         0         0         0         0         0         0         0	X         STD         15.4         S         9.3         12.1         15.3         18.9         22.9           Silp critical connection.         indy-type connection with threads included in shear plane.         24.2         30.6         37.8         45.7           indy-type connection with threads included from shear plane.         OVS: Oversize round holes         45.7           indy-type connection with threads included from shear plane.         OVS: Oversize round holes         45.7           indy-type connection with threads included from shear plane.         OVS: Oversize round holes         45.7           indy-type connection with threads excluded from shear plane.         OVS: Oversize round holes         45.7           indy-type connection.         SSL: Short-slotted holes         95.8           indy-type connection.         SSL: Short-slotted holes         46.7           indy-type connection.         SSL: Short-slotted holes         46.7           indy-type connection.         SSL: Short-slotted holes         46.4           indy-type connection.         SSL: Short-slotted holes         4.4           indy-type state state of the st	41		z	STD	11.9	sο	3.7	5.3 10.5	7.2	9.3	11.8	14.6 29.2	17.7 35.3	04
	% = Sip critical connection. R Bearing-type connection with threads <i>included</i> in shear plane. R Bearing-type connection with threads <i>accluded</i> from shear plane. R Standard courd noise ( $d + 1/\kappa_{\rm in}$ ). CNS: Standard courd noise ( $d + 1/\kappa_{\rm in}$ ). CNS: Congor short-stotted holes ormal to load direction R: Long-or short-stotted holes from and to load direction (required in bearing-type connection). % Single shear. Plane D: 2.2, when threads are excluded from a shear plane. bear of $F_{a} = 0.22F_{a}$ when threads are excluded from a shear plane.	Sr. = Sip critical connection. Restring-type connection with threads <i>included</i> in shear plane. Restring-type connection with threads <i>sociuded</i> from shear plane. The standard cound holes (4 + 1/s in.) Standard cound holes normal to load direction St. Cong-storted holes normal to load direction (required) in baaring-type connection). St. Stort-slotted holes (required) in baaring-type connection). St. Stort-slotted holes (required) reading are excluded from a shear plane. Readed parts of materials not listed, use F, = 0.17F, when threads are included in a shear plane. Readed parts of materials not listed, use F, = 0.17F, when threads are included in a shear plane. Readed parts of materials not listed, use F, = 0.17F, when threads are excluded from Readed parts of materials not listed, use F, = 0.17F, when threads are included in a shear plane.			×	STD	15.4	sο	4.7	6.8 13.6	9.3 18.5	12.1 24.2	15.3	18.9 37.8	22.9 45.7	6.0
	pane, and $F_v = 0.22F_v$ when threads are excluded from a shear plane. To they pretension bolts 11%-in. dia. and greater, special impact wrenches may be required.	per, and f, = 0.22f, when threads are excluded from a shear plane. This preension bolts 1%-in. dia. and greater, prepaid imperativent wenches may be required. Wen bearing-type connections used to splice tension members have a flastener pattern whose length, meaved parallel to the line of horce, exceeds 50 in, tabulated values shall be reduced by 20%. See	-	or only in surear For threaded parts o	of materi	als not	listed, t	JS6 F	= 0.17/	F, wher	thread	ds are it	ncludec	linas	hear	
is single snear $D$ : Loudele snear. For threaded parts of materials not listed, use $F_v = 0.17F_v$ when threads are included in a shear		Men bearing-type connections used to splice tension members have a fastener pattern whose length, measured parallel to the line of force, exceeds 50 in, tabulated values shall be reduced by 20%. See	-	plane, and $F_v = 0.2$ . To fully pretension b	2F <sub>v</sub> whe olts 1%	in threa	ds are and gre	exclude eater, s	pecial i.	a shea mpact v	r plane wrench	es may	be red	uired.		

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BOLTS AND THREADED PARTS Bearing Allowable loads in kips

	Si	-	15.0 22.5	30.0 37.5 45.0 52.5	60.0	-10	120.0	-in. -in. wrk- wrk- the ary un- der
	$F_{\nu} = 100 \text{ ksi}$ Bolt dia.	8/2	13.1 19.7	26.3 32.8 39.4 45.9			105.0 120.0	9-type of ally % ally % % % % allip at wo anter of i anter of i the cent or the cent of the u
suc	۳. ۳	3/4	11.3 16.9	22.5 28.1 33.8			90.06	I bearing tr nomir uced 20 blied in xis of th gainst s ASD Co he just al value
TABLE I-E. BEARING Slip-critical and Bearing-type Connections	si	-	10.5 15.8	21.0 26.3 31.5 36.8	42.0 47.3 52.5 57.8		84.0	itcal and diamete trreme fa l be red oad apj oad abj oad abj a
Sola	$F_{u} = 70$ ksi Bolt dia.	3/8	9.2 13.8	18.4 23.0 27.6 32.2	36.8 41.3 45.9		73.5	slip-crit ave a crit bart. d part. een ext een ext een ext f and th d and th d and th d and th d and th f A490- f A490- ilying th
EARII	<i>.</i> ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	3/4	7.9 11.8	15.8 19.7 23.6 27.6	31.5		63.0	in both shall h is shall h is shall h in betweed value oles win oles win ol
TABLE I-E. BEARING I and Bearing-type Co	si	-	9.8 14.6	19.5 24.4 29.3 34.1	39.0 43.9 48.8 53.6	58.5	78.0	steners steners $\gamma_{va}$ in.) = 1.2 i = 1.2 i = 1.2 i = 1.2 i soluted 7 soluted 7 soluted 7 soluted 7 soluted 1 soluted 1 solut
LE - d Be	$F_{u} = 65$ ksi Bolt dia.	7/8	8.5 12.8	17.1 21.3 25.6 29.9	34.1 38.4 42.7 46.9	•	68.3	nnical fa er $(d + + d \text{ on } F_p$ er $(d + + d \text{ on } F_p$ ength of ength of s 50 in s 50 in s 50 in s 120 Sp SSD Sp SSD Sp statace d in tholt i reater the ear bea
TAB al an	<i>ч</i> , п	3/4	7.3 11.0	14.6 18.3 21.9 25.6	29.3 32.9		58.5	Notes: Notes: This table is applicable to all mechanical fasteners in bot nections utilizing standard holes. Standard holes shall arger than the nominal bolt diameter ( $d + \gamma_{ve}$ in.). Tabulated bearing values are based on $F_p = 1.2 F_v$ . $F_v =$ specified minimum tensile strength of the connect in connections transmitting axial force whose length bet connections using high-strength bolts in slotted holes connections with bolts in oversize holes shall be designed to gload in accordance with AISC ASD Specification Se Tabulated values apply when the distance <i>t</i> parallel to the connections, with bolts in oversize holes shall be designed to the edge of the connected part is not less than 1% of to the edge of the connected part is not less than 1% Jabues are limited to the double-shear bearing capacity values are limited to the double-shear bearing capacity values are limited to the double-shear bearing capacity values for decimal thicknesses may be obtained by mult
critic	si	۲	8.7 13.1	17.4 21.8 26.1 30.5	34.8 39.2 43.5 47.9	52.2 56.6 60.9	69.69	ble to al andard andard f force a if force a ligh-stra nutting r force with r ove ts in ove the ove ts in
Slip	u = 58 ksi Bolt dia.	7/8	7.6 11.4	15.2 19.0 22.8 26.6	30.5 34.3 38.1 41.9	45.7	60.9	applical applical string str atring v and mining and and atring v astrong i using i using i using i using i using i using i using i using i tho bol vith bol gige of th be condin the centin the centi
	Ľ, m	3/4	6.5 9.8	13.1 16.3 19.6 22.8	26.1 29.4 32.6		52.2	Notes: This table is applicable to all mechanical fasteners in both slip-critical and bearing-type con- nections utilizing standard holes. Standard holes shall have a diameter nominally <i>y</i> <sub>ie</sub> h. Tabulated bearing values are based on $F_p = 1.2 F_c$ . $F_u =$ specified minimum tensile strength of the connected part. $F_u =$ specified minimum tensile strength bott econnected part. To connections using high-strength botts in slotted holes with the load applied in a direction other than approximately normal (between 80 and 100 degrees) to the axis of the hole and connections using high-strength bolts in slotted holes with the load applied in a direction other than approximately normal (between 80 and 100 degrees) to the axis of the hole and connections with bolts in oversize holes shall be redicted for the sais of the hole and connections with bolts in oversize holes shall be designed for resistance against slip at work. Tabulated values apply when the distance <i>l</i> parallel to the line of force from the center of the bolt to the edge of the connected part is not less than $1y_2 d$ and the distance from the center of a bolt to the edge of the connected part is not less than $3d$ . See AISC ASD Commentary 3.3. Under certain conditions, values greater than the tabulated values may be justified under gorefication Sect. $.3.7$ . Values are limited to the double-shear bearing capacity of A490-X bolts. Values for decimal thicknesses may be obtained by multiplying the decimal value of the un- values for decimal thicknesses may be obtained by multiplying the decimal value of the un-
	Mate- rial	-unice-	1/8 3/16	% 5∕16 %8 7∕16	1/2 9/16 5/8 11/16	3/4 13/16 7/8 15/16	-	Notes: This team of the second secon

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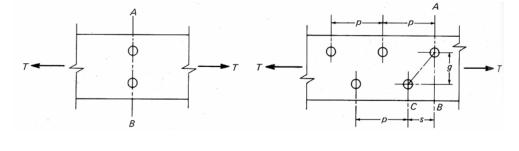
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## **Tension Member Design**

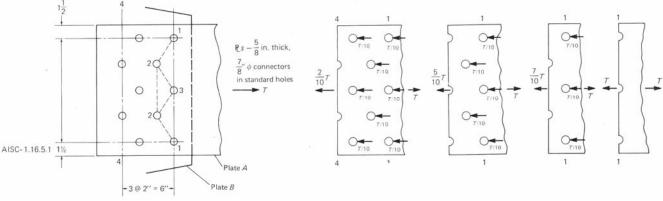
In steel tension members, there may be bolt holes that reduce the size of the cross section.

Effective Net Area:

The smallest effective are must be determined by subtracting the bolt hole areas. With staggered holes, the shortest length must be evaluated.



A series of bolts can also transfer a portion of the tensile force, and some of the effective net areas see reduced stress.



## <u>ASD</u>

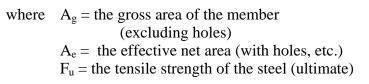
For other than pin connected members:	$F_t = 0.60 F_y$ on gross area
	$F_t = 0.50F_u$ on net area
For pin connected members:	$F_t = 0.45 F_y$ on net area
For threaded rods of approved steel:	$F_t = 0.33F_u$ on major diameter (static loading only)

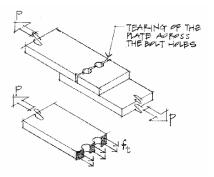
 $P_{u} \leq \phi_{t} P_{n}$ 

## <u>LRFD</u>

The limit state for tension members are:

- 1. yielding  $\phi_t = 0.9 \quad P_n = F_v A_g$
- 2. rupture  $\phi_t = 0.75 \quad P_n = F_u A_e$





## Welded Connections

Weld designations include the strength in the name, i.e. E70XX has  $F_y = 70$  ksi.

The throat size, T, of a fillet weld is determined trigonometry by:  $T = 0.707 \times weld$  size

## ASD

Allowable shear stress of a weld is limited to 30% of the nominal strength.

 $F_v = 18$  ksi for E60XX  $F_v = 21$  ksi for E70XX

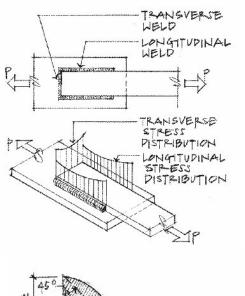
Weld sizes are limited by the size of the parts being put together and are given in AISC manual table J2.4 along with the allowable strength per length of fillet weld, referred to as *S*.

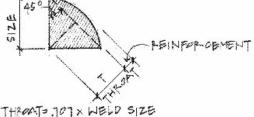
The maximum size of a fillet weld:

- a) can't be greater than the material thickness if it
  - is  $\frac{1}{4}$  or less
- b) is permitted to be 1/16" less than the thickness of the material if it is over 1/4"

The *minimum length* of a fillet weld is 4 times the nominal size. If it is not, then the weld size used for design is  $\frac{1}{4}$  the length.

Intermittent fillet welds can not be less that four times the weld size, not to be less than  $1 \frac{1}{2}$ ".





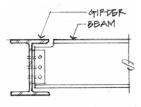
Allowable	e Strength of Fil	llet Welds
pe	r inch of weld (	(S)
Weld Size	E60XX	E70XX
(in.)	(k/in.)	(k/in.)
3/16	2.39	2.78
1⁄4	3.18	3.71
5/16	3.98	4.64
3/8	4.77	5.57
7/16	5.57	6.94
1/2	6.36	7.42
5/8	7.95	9.27
3⁄4	9.55	11.13

TABLE J2.4
Minimum Size of Fillet Welds

Material Thickness of Thicker	Minimum Size of Fillet
Part Joined (in.)	Weld <sup>a</sup> (in.)
To 1/4 inclusive	1/8
Over 1/4 to 1/2	3⁄16
Over 1/2 to 3/4	1/4
Over 3/4	5⁄16

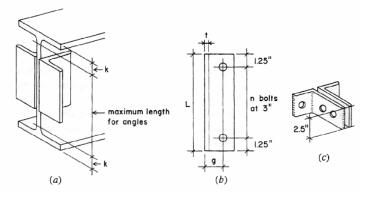
American Institute of Steel Construction

### **Framed Beam Connections**



*Coping* is the term for cutting away part of the flange to connect a beam to another beam using welded or bolted angles.

AISC provides tables that give angle sizes knowing bolt type, bolt diameter, angle leg thickness, and number of bolts (determined by *shear* capacity).



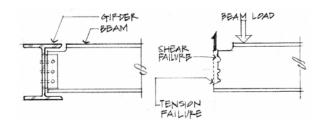
## Load and Factor Resistance Design

In addition to resisting shear and tension in bolts and shear in welds, the connected materials may be subjected to shear, bearing, tension, flexure and even prying action. Coping can significantly reduce design strengths and may require web reinforcement. All the following must be considered:

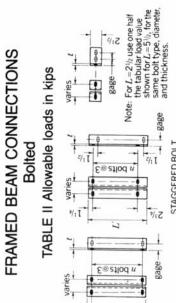
- shear yielding
- shear rupture
- block shear rupture -

failure of a block at a beam as a result of shear and tension

- tension yielding
- tension rupture
- local web buckling
- lateral torsional buckling



FRAMED BEAM CONNECTION Bolted         Bolted         TABLE II Allowable loads in kips         L       Table II Allowable loads in kips	TABLE II-A Bolt Shear For bolts in <b>bearing-type</b> connections with standard or slotted h	a A325-N A490-N A	F <sub>v</sub> , Ksi         21.0         28.0         30.0           Bolt Dia., $d$ $3_4$ $7_{68}$ 1 $3_4$ $7_{88}$ 1           In. $3_4$ $7_{68}$ 1 $3_4$ $7_{88}$ 1	t el	330         247         337         440         265           297         223         303         396         239	23%         25         8         148         202         264         198         269         352         212         289           20%         22         7         130         177         231         173         236         306         186         253           17%         19         6         111         152         198         148         202         264         159         216         233           17%         19         6         111         152         198         148         202         204         159         216           11%         13         4         74.2         101         132         99.0         136         136         138         180           8%         10         3         55.7         75.8         99.0         74.2         101         132         79.5         108         141           5%         7         2         37.1         50.5         66.0         49.5         67.3         80.0         52.0         141	Tabulated load values are based on double shear of bolts. Shaded values are based on double shear of the bolts; however, for length <i>L</i> , the angle thickness specified is critical. See Table II-C.	For shaded cells without values, shear rupture is critical for lengths L and L' c specified. See Table II-C.	
FRAMED BEAM CONNECTIONS Bolted TABLE II Allowable loads in kips	TABLE II-A Bolt Shear <sup>a</sup> For A307 bolts in standard or stotted holes and tor A325 and A490 bolts in <b>silp-critical</b> connections with standard holes and Class A, clean mill scale surface condition.	a A307 A325-SC A	F,, Ksi         10.0         17.0         21.0         Note:           Bat Dia, d         3/4         7/6         1         3/4         7/6         1	NA         NA         NA         SA         SA<	n 10 88.4 120 157 150 204 267 186 9 79.5 108 141 135 184 240 167	25         8         70.7         96.2         126         120         164         214         148         202           22         7         61.9         84.2         110         105         143         187         130         177           19         6         53.0         72.2         94.2         110         105         143         187         130         177           16         5         53.0         72.2         94.2         55.1         102         134         92.8         126           13         4         35.5         36.1         77.1         80.1         82.4         101           10         3         26.5         36.1         47.1         84.1         63.8         80.1         55.7         76.8           7         2         17.7         24.1         31.4         30.0         40.9         53.4         37.1         50.5	Notes: Tabulated load values are based on double shear of botts unless noted. See RCSC Specifi- cation for other surface conditions.	*Capacity shown is based on double shear of the bolts; however, for length L, net shear on the angle thickness specified is critical. See Table II-C.	



	1	A325-N			A490-N	7		A325-X			A490-X	
Fv, KSI		21.0			28.0			30.0			40.0	
Bolt Dia., d In.	3/4	3/8	-	3/4	3/8	-	3/4	3/8	-	3/4	3/8	-
Angle Thickness t, In.	5/16	3⁄8	5/8	3/8	1/2	5/8	3/8	5/8	5/8	1/2	5/8	*
$\vdash$												
In. In. n												
29½ 31 10 1	186	253	330	247	337	440	265	361		353		
28 9	167	227	297	223	303		239	325		318		
25 8	148		264	198	269	352	212			283	C A	
22 7	130	171	231	173	236		186		A BUNNIN	247		
19 6	E	152	198	148	202		159			212	289	
16 5	92.8	126	165	124	168		133	0.00		171	242	
4	74.2	101	132	0.99	135		106			141	192	
10 3	55.7	75.8	0.99	74.2	101	132	79.5	-	141	106	4	
7 2	37.1	50.5	66.0	49.5	67.3	88.0	53.0			7.07	8	
Tabulated load values are based on double shear of bolts.	value	es are t	ased o	n dout	ole she	ar of bo	olts.					
Shaded values are based on double shear of the bolts; however, for length L, net shear on the angle thickness specified is critical. See Table II-C.	are t	pased c specifie	on doub	ole shei tical. S	ar of th ee Tab	le bolts: le II-C.	hower	rer, for l	ength	L, net s	hear o	~
For shaded cells without values, shear rupture is critical for lengths L and L' on angle thickness	lls with	hout va	lues, s	hear ru	pture is	s critica	I for ler	ngths L	and L'	on ang	jle thid	cness
specified. See Table II-C.	Table	⊢										

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### Example 1

**10.2** The butt splice shown in Figure 10.22 uses two  $8 \times \frac{3}{6}$ " plates to "sandwich" in the  $8 \times \frac{1}{2}$ " plates being joined. Four  $\frac{7}{6}$ "  $\phi$  A325-SC bolts are used on both sides of the splice. Assuming A36 steel and standard round holes, determine the allowable capacity of the connection.

#### Solution:

Shear, bearing, and net tension will be checked to determine the critical condition that governs the capacity of the connection. (Table I-D)

*Shear:* Using the AISC allowable shear in Table 10.1:

 $P_v = 20.4 \text{ k/bolt} \times 4 \text{ bolts} = 81.6 \text{ k}$  (double shear) (Table I-E)

*Bearing:* Using the AISC bearing in Table 10.2:

The thinner material with the largest proportional load governs, therefore, the  $\frac{1}{2}$ " center plate governs. Assume the bolts are at a *3d* spacing, center to center.

 $P_b = 30.5 \text{ k/bolt} \times 4 \text{ bolts} = 122 \text{ k}$ 

*Tension:* The center plate is critical since its thickness is less than the combined thickness of the two outer plates.

Hole diameter = (bolt diameter) +  $\frac{1}{16''} = \frac{7}{8''} + \frac{1}{16''} = \frac{15}{16''}$ .

 $A_{net} = (8'' - 2 \times \frac{15}{16}'') \times (\frac{1}{2}'') = 3.06 \text{ in.}^2$ 

 $P_t = F_t \times A_{net}$ 

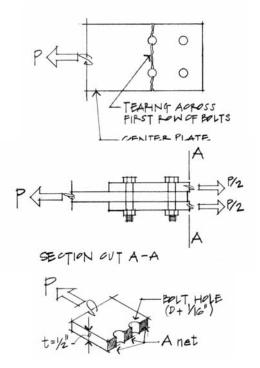
where:

 $F_t = 0.5F_u = 0.5(58 \, \text{ksi}) = 29 \, \text{ksi}$ 

 $P_t = 29 \,\mathrm{k/in.^2} \times 3.06 \,\mathrm{in.^2} = 88.7 \,\mathrm{k}$ 

The maximum connection capacity is governed by shear.

 $P_{\text{allow}} = 81.6 \text{ k}$ 



### Example 2

**10.7** Determine the capacity of the connection in Figure 10.44 assuming A36 steel with E70XX electrodes.

#### Solution:

Capacity of weld:

For a  $\frac{5}{16''}$  fillet weld, S = 4.64 k/in

Weld length = 22''

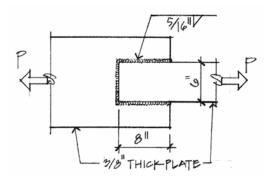
Weld capacity =  $22'' \times 4.64$  k/in = 102.1 k

Capacity of plate:

 $F_t = 0.6F_y = 22 \,\mathrm{ksi}$ 

Plate capacity =  $\frac{3}{2}$  × 6" × 22 k/in.<sup>2</sup> = 49.5 k

: Plate capacity governs,  $P_{\text{allow}} = 49.5 \text{ k}$ 



The weld size used is obviously too strong. What size, then, can the weld be reduced to so that the weld strength is more compatible to the plate capacity? To make the weld capacity  $\approx$  plate capacity:

 $22'' \times (weld capacity per in.) = 49.5 k$ 

Weld capacity per inch =  $\frac{49.5 \text{ k}}{22 \text{ in.}} = 2.25 \text{ k/in.}$ (page 4)

From Table 10.5, use  $\frac{3}{16}''$  weld (*S* = 2.78 k/in.).

Minimum size fillet =  $\frac{3}{16}$ " based on a  $\frac{3}{8}$ " thick plate.

TIONS kips	for A36 Material	٠	Va 5/16 3/8 1/2 %		205 246 328 184 221 295 163 196 261 142 170 227 8 121 145 194 9 99.9120 160	63.1         78.8         94.6126         158           46.2         57.8         69.3         92.4116           29.4         36.7         44.0         58.7         734		177         222         266         355         44           160         201         241         321         401           144         179         215         287         359           112         158         155         287         359           317         158         190         253         317           110         137         155         262         225         330           330         1165         190         233         317         156         226         275           330         1167         139         165         220         275         266         276 <td< th=""><th>Table based on an allowable shear of <math>0.3F_{\nu}</math> (17.4 ksi for A36 angles) of the net section of two angles. Net section based on diameter of fastener + <math>\gamma_{\rm A6}</math> in. American Institute of Street Construction</th></td<>	Table based on an allowable shear of $0.3F_{\nu}$ (17.4 ksi for A36 angles) of the net section of two angles. Net section based on diameter of fastener + $\gamma_{\rm A6}$ in. American Institute of Street Construction
IECTI Is in ki	C Angles for		8/8			169 124 78.8		470 1 425 1 381 1 336 1 291 1 291 1 291 1 156 1 111	17.4 ksi fo We in.
BEAM CONNECTIONS BOLTED I Allowable loads in kips	n Ang	9/2	%8 ½2			01 135 74.2 99.0 47.3 63.1		82 376 55 340 28 305 01 269 75 233 75 233 75 233 76 233 76 233 78 197 21 161 93.8 125 66.9 89.2	an allowable shear of 0.3 <i>F</i> <sub>u</sub> (17.4 ksi for angles. sed on diameter of fastener + <i>V</i> <sub>16</sub> in.
BOLTED BOLTED Allowable I	TABLE II- Connection	2	5/16 3		219 196 174 152 152 129 107	84.31 61.9 39.4		235 22 213 22 190 22 168 21 145 11 145 11 145 11 101 11 78.2 55.7	Table based on an allowable shear of 0.3 <i>F</i> <sub>u</sub> (section of two angles. Net section based on diameter of fastener + American Institute of Street Co
			*		175 157 139 121 121 103 85.4	67.4 49.5 31.5		188 170 152 134 116 98.4 80.5 62.5 62.5	lowab i diam
FRAMED TABLE I	ear in		1/2		372 334 296 258 258 258	144 1 105 67.4		398 360 322 284 284 284 208 170 7 132	Table based on an all section of two angles Net section based on Ametro
TA TA	Shear	**	3/8			108 79.1 50.6		299 270 241 241 241 184 156 127 98. 98. 70.	of two ition be
ш	able	6.	5/16		00	89.7 65.9 42.1		249 225 201 177 154 154 154 130 106 82.2 58.5	ble ba
	Allowable		**		186 167 148 148 129 110 90.8	71.8 52.7 33.7		199 161 142 142 123 123 84.8 84.8 65.8 46.8	
	A	đ	e ż.	C	10 9 6 7 0 7 0	4 6 0	C	10 90 00 00 00 00 00 00 00 00 00 00 00 00	NOTES
		Bolt Dia., In.	Angle Thick- ness, t In.	Ч. Ц	29½ 26½ 23½ 23½ 20½ 17½ 14½	11½ 8½ 5½	, i i	31 28 25 22 19 16 10 10	z

### Example 3

The steel used in the connection and beams is A992 with  $F_y = 50$  ksi, and  $F_u = 65$  ksi. Using A490-N bolt material, determine the maximum capacity of the connection based on shear in the bolts, bearing in all materials and pick the number of bolts and angle length (not staggered). Use A36 steel for the angles.

W21x93: d = 21.62 in,  $t_w = 0.58$  in,  $t_f = 0.93$  in W10x54:  $t_f = 0.615$  in

#### SOLUTION:

The maximum length the angles can be depends on how it fits between the top and bottom flange with some clearance allowed for the fillet to the flange, and getting an air wrench in to tighten the bolts. This example uses 1" of clearance:

Available length = beam depth - both flange thicknesses - 1" clearance at top & 1" at bottom

$$= 21.62 \text{ in } - 2(0.93 \text{ in}) - 2(1 \text{ in}) = 17.76 \text{ in}.$$

The standard lengths for non-staggered holes (L) and staggered holes (L') are shown in Table II-A. The closest size within the available length is  $17 \frac{1}{2}$  in. This will fit 6 bolts (n) with a standard spacing.

We have a choice of bolt diameters of  $\frac{34}{7}$ ,  $\frac{7}{8}$  and 1" in Table II-A. These have allowable loads for **shear** (double) of 148 kips, 202 kips, and 264 kips. But the last two values are shaded and the note says that "net shear on the angle thickness specified is critical" and to see Table II-C. The angle thickness (t) is listed below the bolt diameter.

Table II-C gives a value of 207 kips for a 7/8" bolt diameter,  $\frac{1}{2}$ " angle thickness, and 17.5" length. It gives a value of 242 kips for a 1" bolt diameter, 5/8" angle thickness, and 17.5" length. Therefore, 242 kips is the maximum value limited by shear in the *angle*.

 $P_p = 264$  kips for double shear of 1" bolts (Table I-D: 6 bolts · (44 k/bolt) = 264 kips)

 $P_v = 242$  kips for net shear in angle

We also need to evaluate **bearing** of bolts on the angles, beam web, and column flange where there are bolt holes. Table I-E provides allowable bearing load for the material type, bolt diameter and some material thicknesses. The last note states that "Values for decimal thicknesses may be obtained by multiplying the decimal value of the unlisted thickness by the value given for a 1-in. thickness". This comes from the definition for bearing stress:

$$f_P = \frac{P}{td} \le F_p$$
, where  $P_p = t \cdot d \cdot F_p$  at the allowable bearing stress

For a constant diameter and allowable stress, the allowable load depends only on the thickness.

a) Bearing for 5/8" thick angle: There are 12 bolt holes through two angle legs to the column, and 12 bolt holes through two angle legs either side of the beam. The material is A36 ( $F_u = 58$  ksi), with 1" bolt diameters.

b) Bearing for column flange: There are 12 bolt holes through two angle legs to the column. The material is A992 ( $F_u = 65$  ksi), 0.615" thick, with 1" bolt diameters.

c) Bearing for beam web: There are 6 bolt holes through two angle legs either side of the beam. The material is A992 ( $F_u = 65$  ksi), 0.58" thick, with 1" bolt diameters

Although, the bearing in the beam web is the smallest at 271 kips, with the shear on the bolts even smaller at 264 kips, *the maximum capacity for the simple-shear connector is 242 kips* limited by net shear in the angles.

