ARCHITECTURAL STRUCTURES:
FORM, BEHAVIOR, AND DESIGN
ARCH 331
DR. ANNE NICHOLS
SUMMER 2013

lecture
eighteen

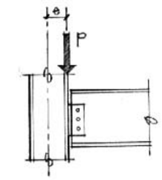
nrmc.org

# steel construction:
# bolts, welds & light gages

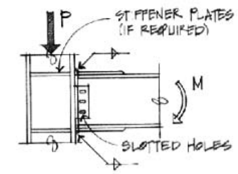


## Connections

- needed to:
  - support beams by columns
  - connect truss members
  - splice beams or columns
- transfer load
- subjected to
  - tension or compression
  - shear
  - bending




(a) Framed beam (shear) connection.
e = Eccentricity; M = P × e




(b) Moment connection (rigid frame).
M = Moment due to beam bending



## Bolts

- bolted steel connections

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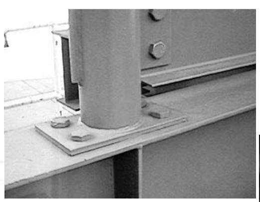
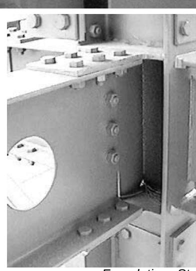
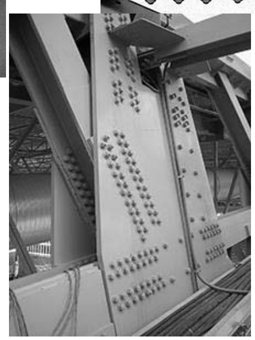
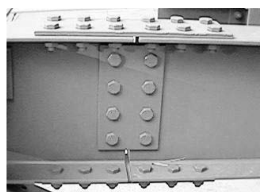

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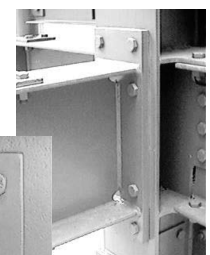
## Welds

- welded steel connections



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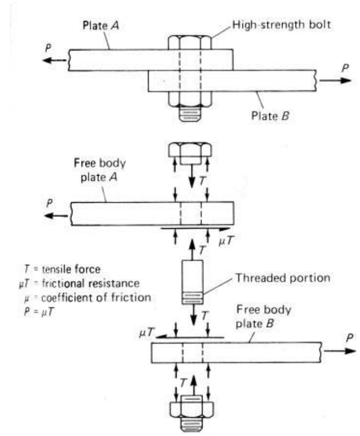
# Bolts

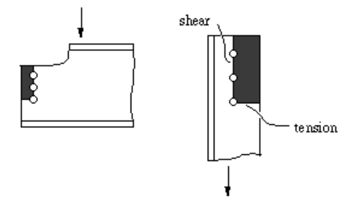
- *types*
  - *materials*
    - *high strength*
    - *A307, A325, A490*
  - *location of threads*
    - *included - N*
    - *excluded - X*
  - *friction or bearing (SC)*
    - *always tightened*

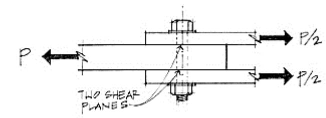


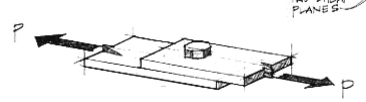


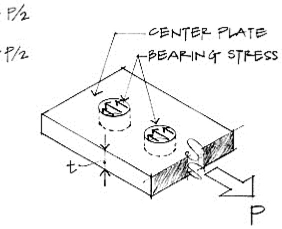

# Bolted Connection Design

- *considerations*
  - *bearing stress*
    - *yielding*
  - *shear stress*
    - *single & double*
  - *member*
    - *rupture*






# Bolts

- *rarely fail in bearing*
- *holes considered 1/8" larger*
- *shear & tension* $R_a \leq R_n / \Omega$ $\quad R_u \leq \phi_v R_n$

$$\phi_v = 0.75$$

  - *single shear or tension*

$$R_n = F_n A_b$$

  - *double shear*

$$R_n = F_n 2A_b$$



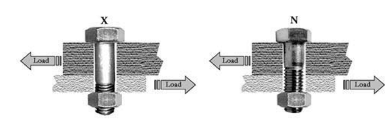
# Bolts

**Table 7-1**
**Available Shear Strength of Bolts, kips**

| Nominal Bolt Diameter, *d*, in. | | | | | 5/8 | | 3/4 | | 7/8 | | 1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nominal Bolt Area, in.² | | | | | 0.307 | | 0.442 | | 0.601 | | 0.785 | |
| ASTM Desig. | Thread Cond. | $F_{nv}/\Omega$ (ksi) ASD | $\phi F_{nv}$ (ksi) LRFD | Loading | $r_n/\Omega$ ASD | $\phi r_n$ LRFD | $r_n/\Omega$ ASD | $\phi r_n$ LRFD | $r_n/\Omega$ ASD | $\phi r_n$ LRFD | $r_n/\Omega$ ASD | $\phi r_n$ LRFD |
| Group A | N | 27.0 | 40.5 | S | 8.29 | 12.4 | 11.9 | 17.9 | 16.2 | 24.3 | 21.2 | 31.8 |
| | | | | D | 16.6 | 24.9 | 23.9 | 35.8 | 32.5 | 48.7 | 42.4 | 63.6 |
| | X | 34.0 | 51.0 | S | 10.4 | 15.7 | 15.0 | 22.5 | 20.4 | 30.7 | 26.7 | 40.0 |
| | | | | D | 20.9 | 31.3 | 30.1 | 45.1 | 40.9 | 61.3 | 53.4 | 80.1 |
| Group B | N | 34.0 | 51.0 | S | 10.4 | 15.7 | 15.0 | 22.5 | 20.4 | 30.7 | 26.7 | 40.0 |
| | | | | D | 20.9 | 31.3 | 30.1 | 45.1 | 40.9 | 61.3 | 53.4 | 80.1 |
| | X | 42.0 | 63.0 | S | 12.9 | 19.3 | 18.6 | 27.8 | 25.2 | 37.9 | 33.0 | 49.5 |
| | | | | D | 25.8 | 38.7 | 37.1 | 55.7 | 50.5 | 75.7 | 65.9 | 98.9 |
| A307 | – | 13.5 | 20.3 | S | 4.14 | 6.23 | 5.97 | 8.07 | 8.11 | 12.2 | 10.6 | 15.9 |
| | | | | D | 8.29 | 12.5 | 11.9 | 17.9 | 16.2 | 24.4 | 21.2 | 31.9 |
| Nominal Bolt Diameter, *d*, in. | | | | | 1 1/8 | | 1 1/4 | | 1 3/8 | | 1 1/2 | |
| Nominal Bolt Area, in.² | | | | | 0.994 | | 1.23 | | 1.48 | | 1.77 | |
| ASTM Desig. | Thread Cond. | $F_{nv}/\Omega$ (ksi) ASD | $\phi F_{nv}$ (ksi) LRFD | Loading | $r_n/\Omega$ ASD | $\phi r_n$ LRFD | $r_n/\Omega$ ASD | $\phi r_n$ LRFD | $r_n/\Omega$ ASD | $\phi r_n$ LRFD | $r_n/\Omega$ ASD | $\phi r_n$ LRFD |
| Group A | N | 27.0 | 40.5 | S | 26.8 | 40.3 | 33.2 | 49.8 | 40.0 | 59.9 | 47.8 | 71.7 |
| | | | | D | 53.7 | 80.5 | 66.4 | 99.6 | 79.9 | 120 | 95.6 | 143 |
| | X | 34.0 | 51.0 | S | 33.8 | 50.7 | 41.8 | 62.7 | 50.3 | 75.5 | 60.2 | 90.3 |
| | | | | D | 67.6 | 101 | 83.6 | 125 | 101 | 151 | 120 | 181 |
| Group B | N | 34.0 | 51.0 | S | 33.8 | 50.7 | 41.8 | 62.7 | 50.3 | 75.5 | 60.2 | 90.3 |
| | | | | D | 67.6 | 101 | 83.6 | 125 | 101 | 151 | 120 | 181 |
| | X | 42.0 | 63.0 | S | 41.7 | 62.6 | 51.7 | 77.5 | 62.2 | 93.2 | 74.3 | 112 |
| | | | | D | 83.5 | 125 | 103 | 155 | 124 | 186 | 149 | 223 |
| A307 | – | 13.5 | 20.3 | S | 13.4 | 20.2 | 16.6 | 25.0 | 20.0 | 30.0 | 23.9 | 35.9 |
| | | | | D | 26.8 | 40.4 | 33.2 | 49.9 | 40.0 | 60.1 | 47.8 | 71.9 |
| ASD | LRFD | For end loaded connections greater than 38 in., see AISC *Specification* Table J3.2 footnote b. | | | | | | | | | | |
| $\Omega = 2.00$ | $\phi = 0.75$ | | | | | | | | | | | |

**Table 7-2**
**Available Tensile Strength of Bolts, kips**

| Nominal Bolt Diameter, *d*, in. | | | 5/8 | | 3/4 | | 7/8 | | 1 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Nominal Bolt Area, in.² | | | 0.307 | | 0.442 | | 0.601 | | 0.785 | |
| ASTM Desig. | $F_{nt}/\Omega$ (ksi) ASD | $\phi F_{nt}$ (ksi) LRFD | $r_n/\Omega$ ASD | $\phi r_n$ LRFD | $r_n/\Omega$ ASD | $\phi r_n$ LRFD | $r_n/\Omega$ ASD | $\phi r_n$ LRFD | $r_n/\Omega$ ASD | $\phi r_n$ LRFD |
| Group A | 45.0 | 67.5 | 13.8 | 20.7 | 19.9 | 29.8 | 27.1 | 40.6 | 35.3 | 53.0 |
| Group B | 56.5 | 84.8 | 17.3 | 26.0 | 25.0 | 37.4 | 34.0 | 51.0 | 44.4 | 66.6 |
| A307 | 22.5 | 33.8 | 6.90 | 10.4 | 9.94 | 14.9 | 13.5 | 20.3 | 17.7 | 26.5 |
| Nominal Bolt Diameter, *d*, in. | | | 1 1/8 | | 1 1/4 | | 1 3/8 | | 1 1/2 | |
| Nominal Bolt Area, in.² | | | 0.994 | | 1.23 | | 1.48 | | 1.77 | |
| ASTM Desig. | $F_{nt}/\Omega$ (ksi) ASD | $\phi F_{nt}$ (ksi) LRFD | $r_n/\Omega$ ASD | $\phi r_n$ LRFD | $r_n/\Omega$ ASD | $\phi r_n$ LRFD | $r_n/\Omega$ ASD | $\phi r_n$ LRFD | $r_n/\Omega$ ASD | $\phi r_n$ LRFD |
| Group A | 45.0 | 67.5 | 44.7 | 67.1 | 55.2 | 82.8 | 66.8 | 100 | 79.5 | 119 |
| Group B | 56.5 | 84.8 | 56.2 | 84.2 | 69.3 | 104 | 83.9 | 126 | 99.8 | 150 |
| A307 | 22.5 | 33.8 | 22.4 | 33.5 | 27.6 | 41.4 | 33.4 | 50.1 | 39.8 | 59.6 |
| ASD | LRFD | | | | | | | | | |
| $\Omega = 2.00$ | $\phi = 0.75$ | | | | | | | | | |



## Bolts

- bearing

$$R_a \le R_n / \Omega \qquad R_u \le \phi R_n$$

$$\phi = 0.75$$

  - deformation is concern

$$R_n = 1.2 L_c t F_u \le 2.4 d t F_u$$

  - deformation isn't concern

$$R_n = 1.5 L_c t F_u \le 3.0 d t F_u$$

  - long slotted holes

$$R_n = 1.0 L_c t F_u \le 2.0 d t F_u$$

$L_c$ – clear length to edge or next hole (ex. 1¼", 3")



## Bolts

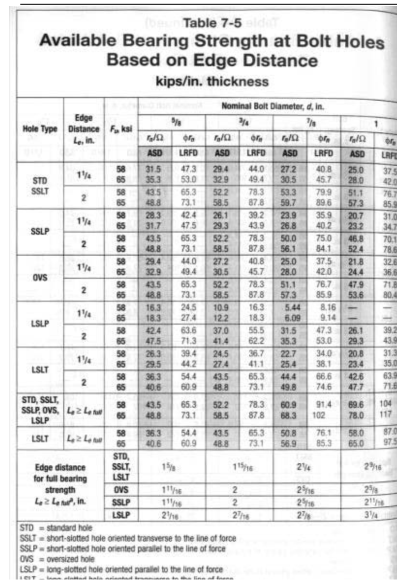


Table 7-5
**Available Bearing Strength at Bolt Holes Based on Edge Distance**
kips/in. thickness

| Hole Type | Edge Distance $L_e$, in. | $F_u$, ksi | 5/8 $r_n/\Omega$ ASD | 5/8 $\phi r_n$ LRFD | 3/4 $r_n/\Omega$ ASD | 3/4 $\phi r_n$ LRFD | 7/8 $r_n/\Omega$ ASD | 7/8 $\phi r_n$ LRFD | 1 $r_n/\Omega$ ASD | 1 $\phi r_n$ LRFD |
|---|---|---|---|---|---|---|---|---|---|---|
| STD SSLT | 1¼ | 58 | 31.5 | 47.3 | 29.4 | 44.0 | 27.2 | 40.8 | 25.0 | 37.5 |
| | | 65 | 35.3 | 53.0 | 32.9 | 49.4 | 30.5 | 45.7 | 28.0 | 42.0 |
| | 2 | 58 | 43.5 | 65.3 | 52.2 | 78.3 | 53.3 | 79.9 | 51.1 | 76.7 |
| | | 65 | 48.8 | 73.1 | 58.5 | 87.8 | 59.7 | 89.6 | 57.3 | 85.9 |
| SSLP | 1¼ | 58 | 28.3 | 42.4 | 26.1 | 39.2 | 23.9 | 35.9 | 20.7 | 31.0 |
| | | 65 | 31.7 | 47.5 | 29.3 | 43.9 | 26.8 | 40.2 | 23.2 | 34.7 |
| | 2 | 58 | 43.5 | 65.3 | 52.2 | 78.3 | 50.0 | 75.0 | 46.8 | 70.1 |
| | | 65 | 48.8 | 73.1 | 58.5 | 87.8 | 56.1 | 84.1 | 52.4 | 78.6 |
| OVS | 1¼ | 58 | 29.4 | 44.0 | 27.2 | 40.8 | 25.0 | 37.5 | 21.8 | 32.6 |
| | | 65 | 32.9 | 49.4 | 30.5 | 45.7 | 28.0 | 42.0 | 24.4 | 36.6 |
| | 2 | 58 | 43.5 | 65.3 | 52.2 | 78.3 | 51.1 | 76.7 | 47.9 | 71.8 |
| | | 65 | 48.8 | 73.1 | 58.5 | 87.8 | 57.3 | 85.9 | 53.6 | 80.4 |
| LSLP | 1¼ | 58 | 16.3 | 24.5 | 10.9 | 16.3 | 5.44 | 8.16 | — | — |
| | | 65 | 18.3 | 27.4 | 12.2 | 18.3 | 6.09 | 9.14 | — | — |
| | 2 | 58 | 42.4 | 63.6 | 37.0 | 55.5 | 31.5 | 47.3 | 26.1 | 39.2 |
| | | 65 | 47.5 | 71.3 | 41.4 | 62.2 | 35.3 | 53.0 | 29.3 | 43.9 |
| LSLT | 1¼ | 58 | 26.3 | 39.4 | 24.5 | 36.7 | 22.7 | 34.0 | 20.8 | 31.3 |
| | | 65 | 29.5 | 44.2 | 27.4 | 41.1 | 25.4 | 38.1 | 23.4 | 35.0 |
| | 2 | 58 | 36.3 | 54.4 | 43.5 | 65.3 | 44.4 | 66.6 | 42.6 | 63.9 |
| | | 65 | 40.6 | 60.9 | 48.8 | 73.1 | 49.8 | 74.6 | 47.7 | 71.6 |
| STD, SSLT, SSLP, OVS, LSLP | $L_e \ge L_{e\,full}$ | 58 | 43.5 | 65.3 | 52.2 | 78.3 | 60.9 | 91.4 | 69.6 | 104 |
| | | 65 | 48.8 | 73.1 | 58.5 | 87.8 | 68.3 | 102 | 78.0 | 117 |
| LSLT | $L_e \ge L_{e\,full}$ | 58 | 36.3 | 54.4 | 43.5 | 65.3 | 50.8 | 76.1 | 58.0 | 87.0 |
| | | 65 | 40.6 | 60.9 | 48.8 | 73.1 | 56.9 | 85.3 | 65.0 | 97.5 |

| Edge distance for full bearing strength $L_e \ge L_{e\,full}$[a], in. | Hole Type | 5/8 | 3/4 | 7/8 | 1 |
|---|---|---|---|---|---|
| | STD, SSLT, LSLT | 1 5/8 | 1 15/16 | 2 1/4 | 2 9/16 |
| | OVS | 1 11/16 | 2 | 2 5/16 | 2 5/8 |
| | SSLP | 1 11/16 | 2 | 2 5/16 | 2 11/16 |
| | LSLP | 2 1/16 | 2 7/16 | 2 7/8 | 3 1/4 |

STD = standard hole
SSLT = short-slotted hole oriented transverse to the line of force
SSLP = short-slotted hole oriented parallel to the line of force
OVS = oversized hole
LSLP = long-slotted hole oriented parallel to the line of force

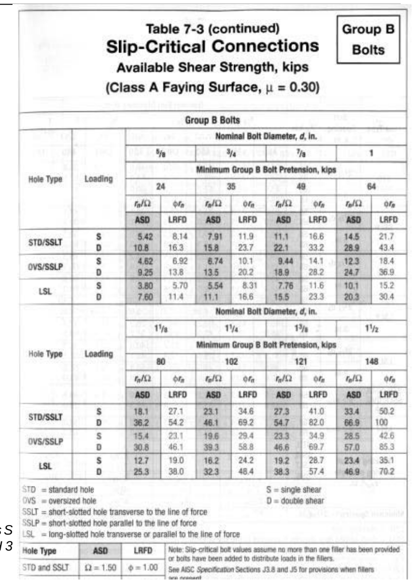


Table 7-3 (continued)
**Slip-Critical Connections**
Available Shear Strength, kips
(Class A Faying Surface, μ = 0.30)
Group B Bolts

| Hole Type | Loading | 5/8 (24 kips) $r_n/\Omega$ ASD | 5/8 (24 kips) $\phi r_n$ LRFD | 3/4 (35 kips) $r_n/\Omega$ ASD | 3/4 (35 kips) $\phi r_n$ LRFD | 7/8 (49 kips) $r_n/\Omega$ ASD | 7/8 (49 kips) $\phi r_n$ LRFD | 1 (64 kips) $r_n/\Omega$ ASD | 1 (64 kips) $\phi r_n$ LRFD |
|---|---|---|---|---|---|---|---|---|---|
| STD/SSLT | S | 5.42 | 8.14 | 7.91 | 11.9 | 11.1 | 16.6 | 14.5 | 21.7 |
| | D | 10.8 | 16.3 | 15.8 | 23.7 | 22.1 | 33.2 | 28.9 | 43.4 |
| OVS/SSLP | S | 4.62 | 6.92 | 6.74 | 10.1 | 9.44 | 14.1 | 12.3 | 18.4 |
| | D | 9.25 | 13.8 | 13.5 | 20.2 | 18.9 | 28.2 | 24.7 | 36.9 |
| LSL | S | 3.80 | 5.70 | 5.54 | 8.31 | 7.76 | 11.6 | 10.1 | 15.2 |
| | D | 7.60 | 11.4 | 11.1 | 16.6 | 15.5 | 23.3 | 20.3 | 30.4 |

| Hole Type | Loading | 1 1/8 (80 kips) $r_n/\Omega$ ASD | 1 1/8 (80 kips) $\phi r_n$ LRFD | 1 1/4 (102 kips) $r_n/\Omega$ ASD | 1 1/4 (102 kips) $\phi r_n$ LRFD | 1 3/8 (121 kips) $r_n/\Omega$ ASD | 1 3/8 (121 kips) $\phi r_n$ LRFD | 1 1/2 (148 kips) $r_n/\Omega$ ASD | 1 1/2 (148 kips) $\phi r_n$ LRFD |
|---|---|---|---|---|---|---|---|---|---|
| STD/SSLT | S | 18.1 | 27.1 | 23.1 | 34.6 | 27.3 | 41.0 | 33.4 | 50.2 |
| | D | 36.2 | 54.2 | 46.1 | 69.2 | 54.7 | 82.0 | 66.9 | 100 |
| OVS/SSLP | S | 15.4 | 23.1 | 19.6 | 29.4 | 23.3 | 34.9 | 28.5 | 42.6 |
| | D | 30.8 | 46.1 | 39.3 | 58.8 | 46.6 | 69.7 | 57.0 | 85.3 |
| LSL | S | 12.7 | 19.0 | 16.2 | 24.2 | 19.2 | 28.7 | 23.4 | 35.1 |
| | D | 25.3 | 38.0 | 32.3 | 48.4 | 38.3 | 57.4 | 46.9 | 70.2 |

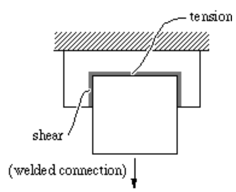
STD = standard hole
OVS = oversized hole
SSLT = short-slotted hole transverse to the line of force
SSLP = short-slotted hole parallel to the line of force
LSL = long-slotted hole transverse or parallel to the line of force
S = single shear
D = double shear

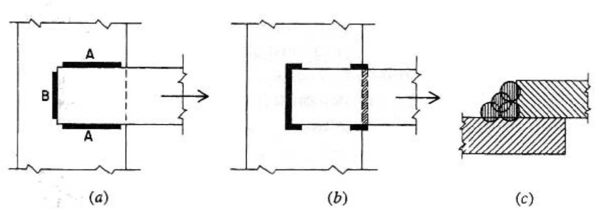
| Hole Type | ASD | LRFD |
|---|---|---|
| STD and SSLT | Ω = 1.50 | ϕ = 1.00 |

Note: Slip-critical bolt values assume no more than one filler has been provided or bolts have been added to distribute loads in the fillers.
See AISC *Specification* Sections J3.8 and J5 for provisions when fillers are present.

## Welded Connection Design

- considerations
  - shear stress
  - yielding
  - rupture

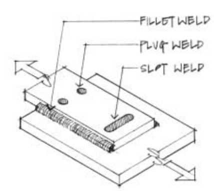





## Welded Connection Design

- weld terms
  - butt weld
  - fillet weld
  - plug weld
  - throat
- field welding
- shop welding

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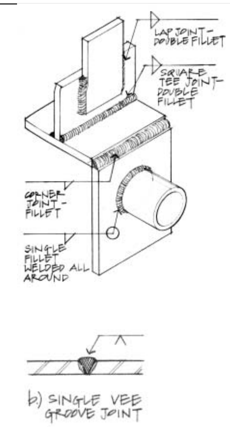
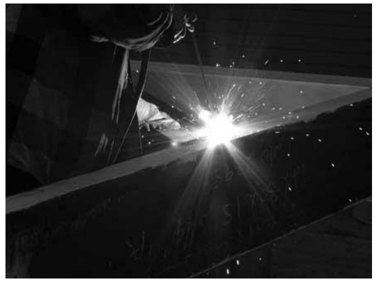
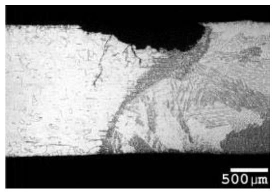


# Welded Connection Design

- *weld process*
  - *melting of material*
  - *melted filler - electrode*
  - *shielding gas / flux*
  - *potential defects*
- *weld materials*
  - *E60XX*
  - *E70XX*
    $F_{EXX}$ = 70 ksi

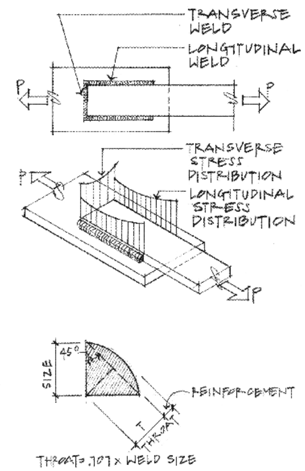







# Welded Connection Design

- *shear failure assumed*
- *throat*
  - *T = 0.707 x weld size*
- *area*
  - *A = T x length of weld*
- *weld metal generally stronger than base metal (ex. $F_y$ = 50 ksi)*






# Welded Connection Design

- *minimum*
  - *table*
- *maximum*
  - *material thickness ( to ¼")*
  - *1/16" less*
- *min. length*
  - *4 x size min.*
  - *≥ 1 ½"*

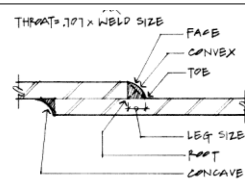



TABLE J2.4
Minimum Size of Fillet Welds

| Material Thickness of Thicker Part Joined, in. (mm) | Minimum Size of Fillet Weld[a] in. (mm) |
|---|---|
| To ¼ (6) inclusive | ⅛ (3) |
| Over ¼ (6) to ½ (13) | 3/16 (5) |
| Over ½ (13) to ¾ (19) | ¼ (6) |
| Over ¾ (19) | 5/16 (8) |

[a] Leg dimension of fillet welds. Single pass welds must be used.
[b] See Section J2.2b for maximum size of fillet welds.



# Welded Connection Design

- *shear*

$$R_a \le R_n / \Omega \qquad R_u \le \phi R_n$$
$$\phi = 0.75$$

$$R_n = 0.6F_{EXX}\underbrace{Tl}_{area} = Sl$$

  - *table for $\phi S$*

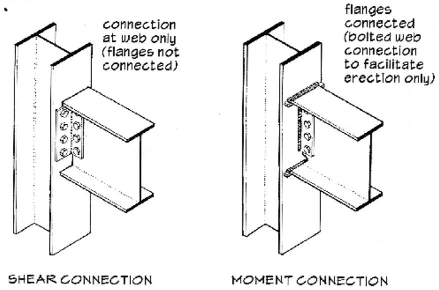
Available Strength of Fillet Welds per inch of weld ($\phi S$)

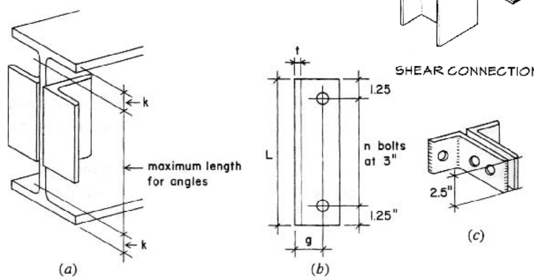
| Weld Size (in.) | E60XX (k/in.) | E70XX (k/in.) |
|---|---|---|
| 3/16 | 2.39 | 4.18 |
| ¼ | 4.77 | 5.57 |
| 5/16 | 5.97 | 6.96 |
| ⅜ | 7.16 | 8.35 |
| 7/16 | 5.57 | 9.74 |
| ½ | 8.35 | 11.14 |
| ⅝ | 11.93 | 13.92 |
| ¾ | 14.32 | 16.70 |

(not considering increase in throat with submerged arc weld process)

## Framed Beam Connections

- angles
  - bolted
  - welded

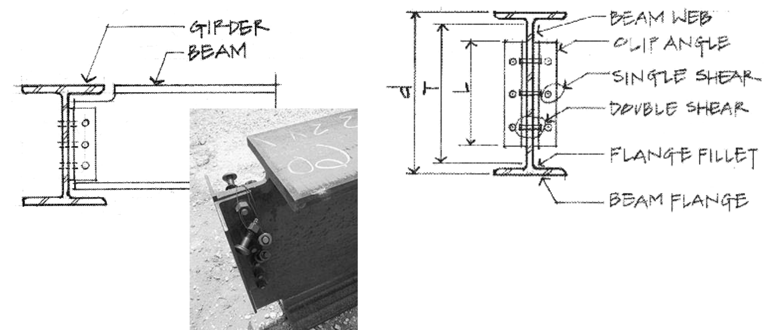





## Framed Beam Connections

- terms
  - coping

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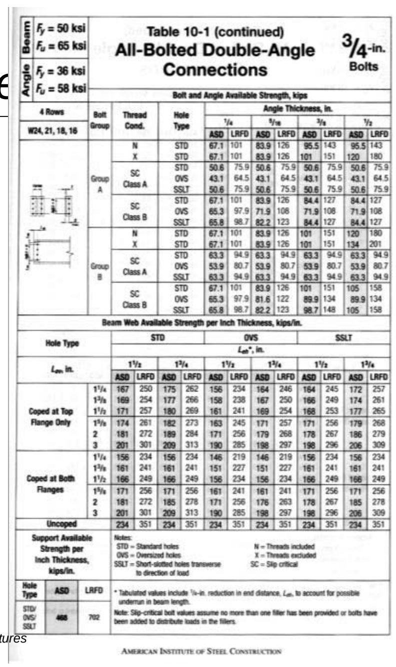
## Framed Beam Conne

- tables for standard bolt sizes & spacings
- # bolts
- bolt diameter, angle leg thickness
- bearing on beam web



Beam $F_y$ = 50 ksi, $F_u$ = 65 ksi
Angle $F_y$ = 36 ksi, $F_u$ = 58 ksi

Table 10-1 (continued)
All-Bolted Double-Angle Connections
3/4-in. Bolts

Bolt and Angle Available Strength, kips

| 4 Rows W24, 21, 18, 16 | Bolt Group | Thread Cond. | Hole Type | 1/4 ASD | 1/4 LRFD | 5/16 ASD | 5/16 LRFD | 3/8 ASD | 3/8 LRFD | 1/2 ASD | 1/2 LRFD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Group A | N | STD | 67.1 | 101 | 83.9 | 126 | 95.5 | 143 | 95.5 | 143 |
| | | X | STD | 67.1 | 101 | 83.9 | 126 | 101 | 151 | 120 | 180 |
| | | SC Class A | STD | 50.6 | 75.9 | 50.6 | 75.9 | 50.6 | 75.9 | 50.6 | 75.9 |
| | | | OVS | 43.1 | 64.5 | 43.1 | 64.5 | 43.1 | 64.5 | 43.1 | 64.5 |
| | | | SSLT | 50.6 | 75.9 | 50.6 | 75.9 | 50.6 | 75.9 | 50.6 | 75.9 |
| | | SC Class B | STD | 67.1 | 101 | 83.9 | 126 | 84.4 | 127 | 84.4 | 127 |
| | | | OVS | 65.3 | 97.9 | 71.9 | 108 | 71.9 | 108 | 71.9 | 108 |
| | | | SSLT | 65.8 | 98.7 | 82.2 | 123 | 84.4 | 127 | 84.4 | 127 |
| | Group B | N | STD | 67.1 | 101 | 83.9 | 126 | 101 | 151 | 120 | 180 |
| | | X | STD | 67.1 | 101 | 83.9 | 126 | 101 | 151 | 134 | 201 |
| | | SC Class A | STD | 63.3 | 94.9 | 63.3 | 94.9 | 63.3 | 94.9 | 63.3 | 94.9 |
| | | | OVS | 53.9 | 80.7 | 53.9 | 80.7 | 53.9 | 80.7 | 53.9 | 80.7 |
| | | | SSLT | 63.3 | 94.9 | 63.3 | 94.9 | 63.3 | 94.9 | 63.3 | 94.9 |
| | | SC Class B | STD | 67.1 | 101 | 83.9 | 126 | 101 | 151 | 105 | 158 |
| | | | OVS | 65.3 | 97.9 | 81.6 | 122 | 89.9 | 134 | 89.9 | 134 |
| | | | SSLT | 65.8 | 98.7 | 82.2 | 123 | 98.7 | 148 | 105 | 158 |

Beam Web Available Strength per Inch Thickness, kips/in.

| Hole Type | $L_{ev}$, in. | STD $L_{eh}$* 1 1/2 ASD | STD 1 1/2 LRFD | STD 1 3/4 ASD | STD 1 3/4 LRFD | OVS 1 1/2 ASD | OVS 1 1/2 LRFD | OVS 1 3/4 ASD | OVS 1 3/4 LRFD | SSLT 1 1/2 ASD | SSLT 1 1/2 LRFD | SSLT 1 3/4 ASD | SSLT 1 3/4 LRFD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coped at Top Flange Only | 1 1/4 | 167 | 250 | 175 | 262 | 156 | 234 | 164 | 246 | 164 | 245 | 172 | 257 |
| | 1 3/8 | 169 | 254 | 177 | 266 | 158 | 238 | 167 | 250 | 166 | 249 | 174 | 261 |
| | 1 1/2 | 171 | 257 | 180 | 269 | 161 | 241 | 169 | 254 | 168 | 253 | 177 | 265 |
| | 1 5/8 | 174 | 261 | 182 | 273 | 163 | 245 | 171 | 257 | 171 | 256 | 179 | 268 |
| | 2 | 181 | 272 | 189 | 284 | 171 | 256 | 179 | 268 | 178 | 267 | 186 | 279 |
| | 3 | 201 | 301 | 209 | 313 | 190 | 285 | 198 | 297 | 198 | 296 | 206 | 309 |
| Coped at Both Flanges | 1 1/4 | 156 | 234 | 156 | 234 | 146 | 219 | 146 | 219 | 156 | 234 | 156 | 234 |
| | 1 3/8 | 161 | 241 | 161 | 241 | 151 | 227 | 151 | 227 | 161 | 241 | 161 | 241 |
| | 1 1/2 | 166 | 249 | 166 | 249 | 156 | 234 | 156 | 234 | 166 | 249 | 166 | 249 |
| | 1 5/8 | 171 | 256 | 171 | 256 | 161 | 241 | 161 | 241 | 171 | 256 | 171 | 256 |
| | 2 | 181 | 272 | 185 | 278 | 171 | 256 | 176 | 263 | 178 | 267 | 185 | 278 |
| | 3 | 201 | 301 | 209 | 313 | 190 | 285 | 198 | 297 | 198 | 296 | 206 | 309 |
| Uncoped | | 234 | 351 | 234 | 351 | 234 | 351 | 234 | 351 | 234 | 351 | 234 | 351 |

Support Available Strength per Inch Thickness, kips/in.

| Hole Type | ASD | LRFD |
|---|---|---|
| STD/OVS/SSLT | 468 | 702 |

Notes:
STD = Standard holes
OVS = Oversized holes
SSLT = Short-slotted holes transverse to direction of load
N = Threads included
X = Threads excluded
SC = Slip critical

* Tabulated values include 1/4-in. reduction in end distance, $L_{eh}$, to account for possible underrun in beam length.

Note: Slip-critical bolt values assume no more than one filler has been provided or bolts have been added to distribute loads in the fillers.

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## Framed Beam Connections

- welded example (shear)

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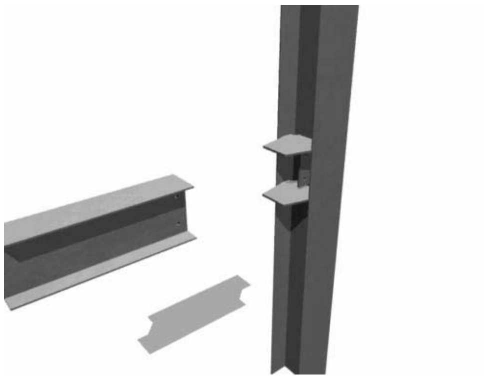
## Framed Beam Connections

- *welded moment example*



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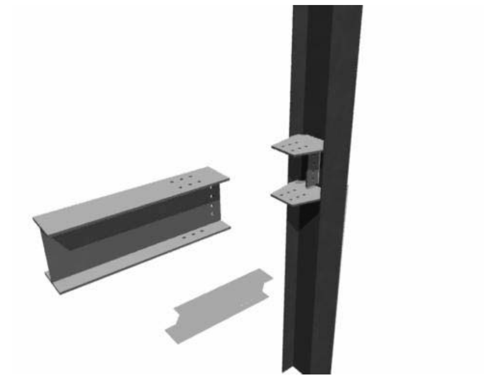
## Framed Beam Connections

- *welded/bolted moment example*



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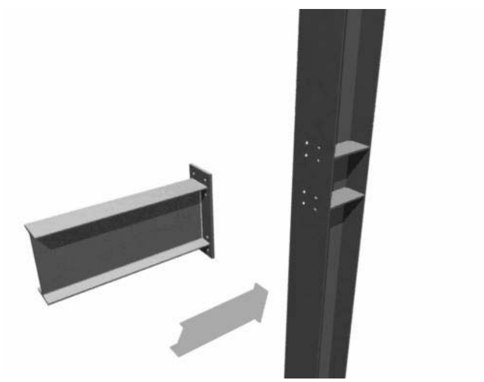
## Framed Beam Connections

- *welded/bolted moment example*



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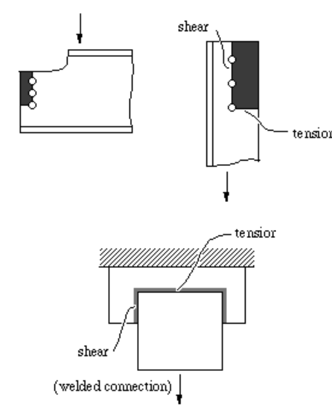
## Beam Connections

- *LRFD provisions*
  - *shear yielding*
  - *shear rupture*
  - *block shear rupture*
  - *tension yielding*
  - *tension rupture*
  - *local web buckling*
  - *lateral torsional buckling*



## Beam Connections

$\phi = 0.75$

$$R_n = 0.6F_uA_{nv} + U_{bs}F_uA_{nt} \le 0.6F_yA_{gv} + U_{bs}F_uA_{nt}$$

– where $U_{bs}$ is 1 for uniform tensile stress

Figure 2-1. Block Shear Rupture Limit State (Photo by J.A. Swanson and R. Leon, courtesy of Georgia Institute of Technology)

*block shear rupture*

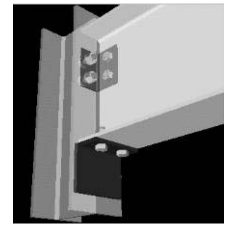
Figure 2-14. Tension Fracture Limit State (Photo by J.A. Swanson and R. Leon, courtesy of Georgia Institute of Technology)

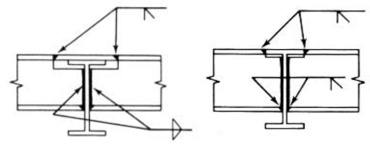
*tension rupture*



## Other Connections

- *seated beam*
- *continuous*
  - *beam to column*
  - *beam to beam*

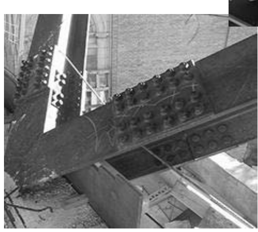






## Other Connections

- *splices*



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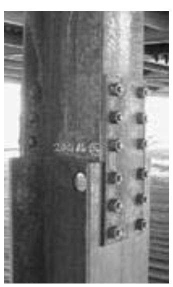

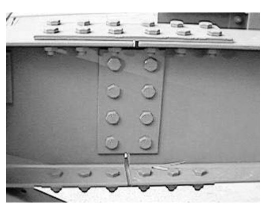

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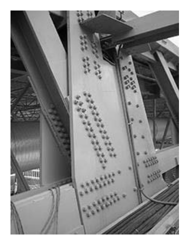
## Other Connections

- *rigid frame knees*
- *gussets & joints*



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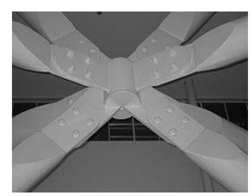
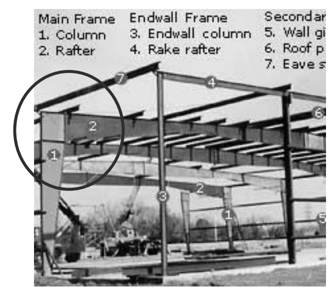
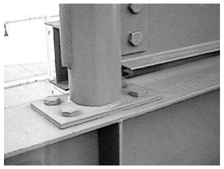





# Other Connections

- *base plates*
  - *anchor bolts*
  - *bearing on steel*
  - *bending of plate*



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