ARCHITECTURAL STRUCTURES I: STATICS AND STRENGTH OF MATERIALS

ENDS 231
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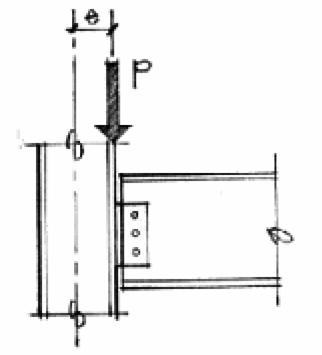
SUMMER 2006

lecture
twenty three

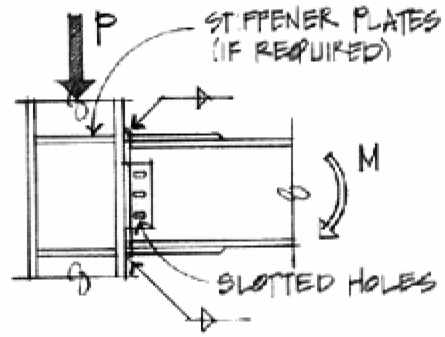
steel connections: bolts, welds & tension members

Connections

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



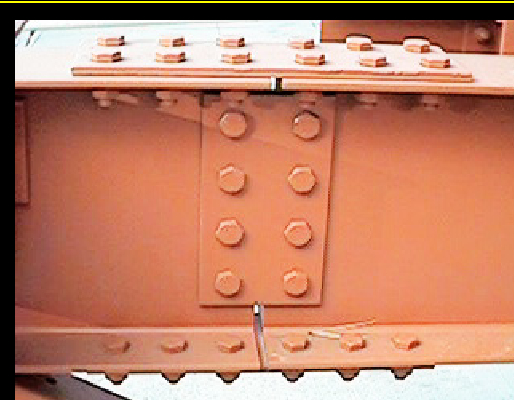
(a) Framed beam (shear) connection.
e = Eccentricity; M = P × e

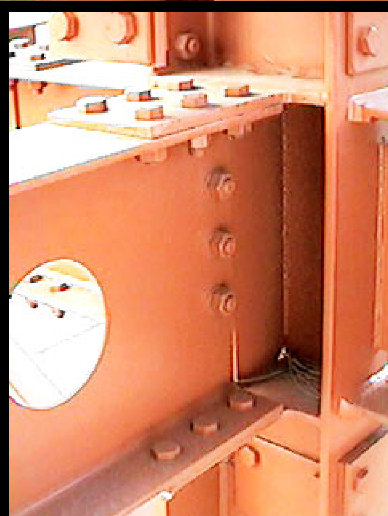


(b) Moment connection (rigid frame).
M = Moment due to beam bending

Bolts

- *bolted steel connections*



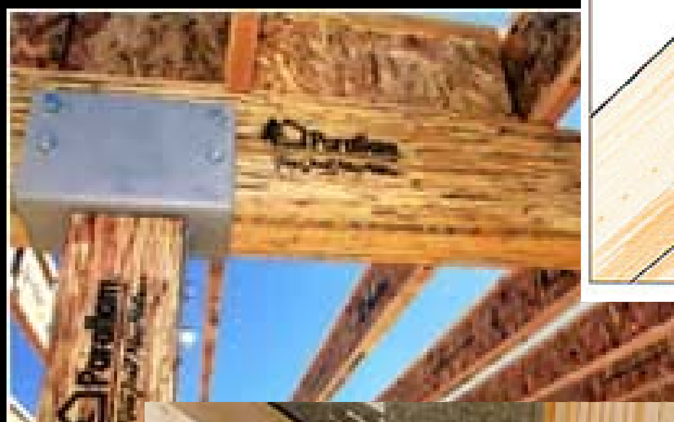


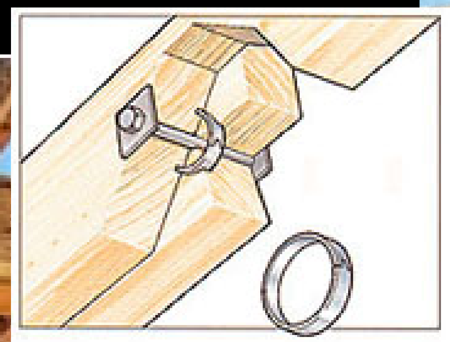
Welds

- *welded steel connections*

Fasteners

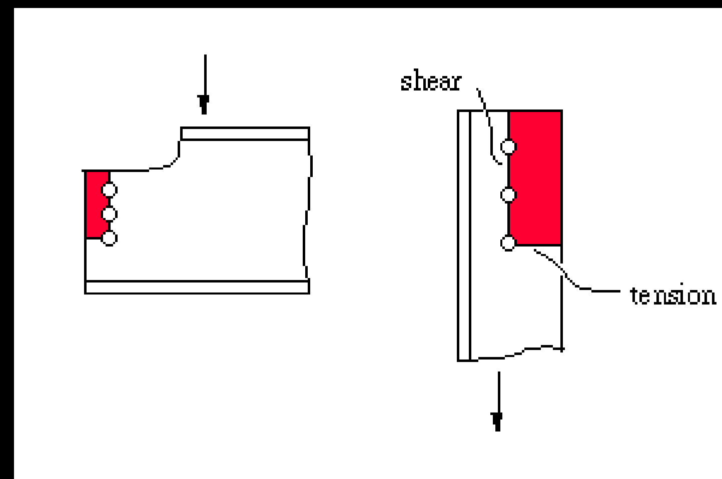
- *wood connections*

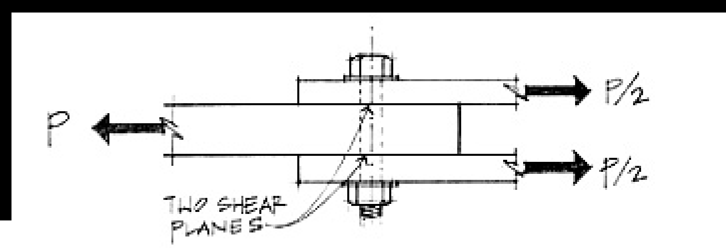


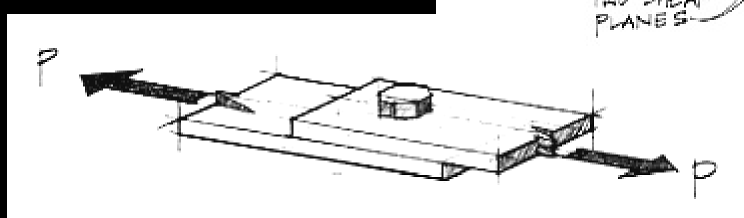


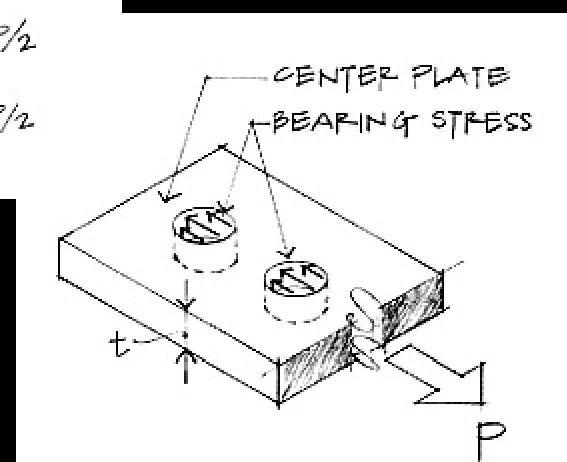
Bolted Connection Design

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









Bolted Connection Design

- *ASD steel*
  - *shear:*

$$f_v \leq F_v$$

    - *bolt strengths*
    - *single & double*
  - *bolt types*
    - *A325-SC, A490-SC*
    - *A325-N, A490-N*
    - *A325-X, A490-X*

BOLTS, THREADED PARTS AND RIVETS
Shear
Allowable load in kips

TABLE SHEAR

	ASTM Designation	Connection Type[a]	Hole Type[b]	F_v ksi	Loading[c]	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
						Area (Based on Nominal Diameter) in.^{2}							
						.3068	.4418	.6013	.7854	.9940	1.227	1.485	1.767
Bolts	A307	—	STD NSL	10.0	S	3.1	4.4	6.0	7.9	9.9	12.3	14.8	17.7
					D	6.1	8.8	12.0	15.7	19.9	24.5	29.7	35.3
	A325	SC[a] Class A	STD	17.0	S	5.22	7.51	10.2	13.4	16.9	20.9	25.2	30.0
					D	10.4	15.0	20.4	26.7	33.8	41.7	50.5	60.1
			OVS, SSL	15.0	S	4.60	6.63	9.02	11.8	14.9	18.4	22.3	26.5
					D	9.20	13.3	18.0	23.6	29.8	36.8	44.6	53.0
			LSL	12.0	S	3.68	5.30	7.22	9.42	11.9	14.7	17.8	21.2
					D	7.36	10.6	14.4	18.8	23.9	29.4	35.6	42.4
		N	STD, NSL	21.0	S	6.4	9.3	12.6	16.5	20.9	25.8	31.2	37.1
					D	12.9	18.6	25.3	33.0	41.7	51.5	62.4	74.2
		X	STD, NSL	30.0	S	9.2	13.3	18.0	23.6	29.8	36.8	44.5	53.0
					D	18.4	26.5	36.1	47.1	59.6	73.6	89.1	106.0
	A490	SC[a] Class A	STD	21.0	S	6.44	9.28	12.6	16.5	20.9	25.8	31.2	37.1
					D	12.9	18.6	25.3	33.0	41.7	51.5	62.4	74.2
			OVS, SSL	18.0	S	5.52	7.95	10.8	14.1	17.9	22.1	26.7	31.8
					D	11.0	15.9	21.6	28.3	35.8	44.2	53.5	63.6
			LSL	15.0	S	4.60	6.63	9.02	11.8	14.9	18.4	22.3	26.5
					D	9.20	13.3	18.0	23.6	29.8	36.8	44.6	53.0
		N	STD, NSL	28.0	S	8.6	12.4	16.8	22.0	27.8	34.4	41.6	49.5
					D	17.2	24.7	33.7	44.0	55.7	68.7	83.2	99.0
		X	STD, NSL	40.0	S	12.3	17.7	24.1	31.4	39.8	49.1	59.4	70.7
					D	24.5	35.3	48.1	62.8	79.6	98.2	119.0	141.0
Rivets	A502-1	—	STD	17.5	S	5.4	7.7	10.5	13.7	17.4	21.5	26.0	30.9
					D	10.7	15.5	21.0	27.5	34.8	42.9	52.0	61.8
	A502-2 A502-3	—	STD	22.0	S	6.7	9.7	13.2	17.3	21.9	27.0	32.7	38.9
					D	13.5	19.4	26.5	34.6	43.7	54.0	65.3	77.7
	A36 (F_u=58 ksi)	N	STD	9.9	S	3.0	4.4	6.0	7.8	9.8	12.1	14.7	17.5
					D	6.1	8.7	11.9	15.6	19.7	24.3	29.4	35.0
		X	STD	12.8	S	3.9	5.7	7.7	10.1	12.7	15.7	19.0	22.6

Bolted Connection Design

- *ASD steel*
  - *bearing:*
    - *bolts rarely fail by bearing*
    - *other part fails first*

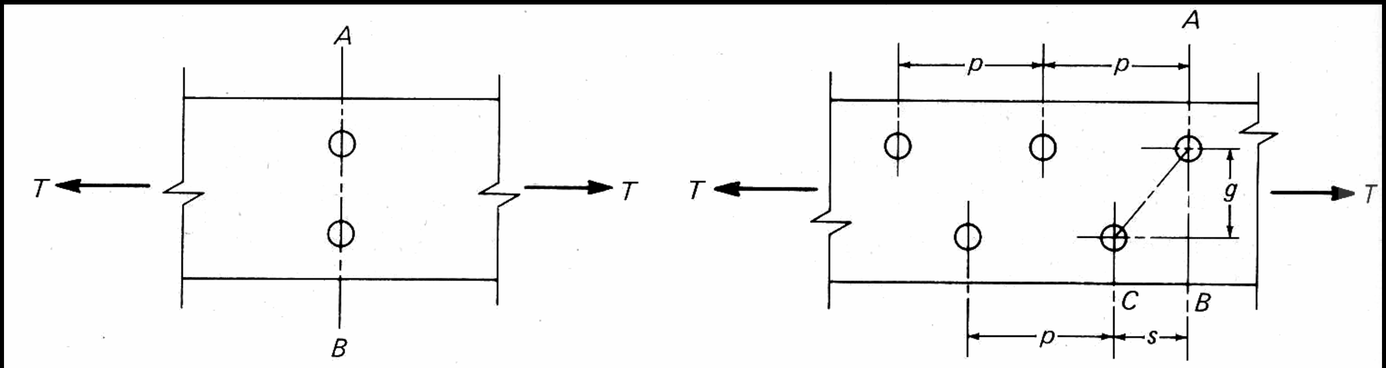
BOLTS AND THREADED PARTS
Bearing
Allowable loads in kips

TABLE BEARING
Slip-critical and Bearing-type Connections

Material Thickness	F_u = 58 ksi Bolt dia.			F_u = 65 ksi Bolt dia.			F_u = 70 ksi Bolt dia.			F_u = 100 ksi Bolt dia.		
	3/4	7/8	1	3/4	7/8	1	3/4	7/8	1	3/4	7/8	1
1/8	6.5	7.6	8.7	7.3	8.5	9.8	7.9	9.2	10.5	11.3	13.1	15.0
3/16	9.8	11.4	13.1	11.0	12.8	14.6	11.8	13.8	15.8	16.9	19.7	22.5
1/4	13.1	15.2	17.4	14.6	17.1	19.5	15.8	18.4	21.0	22.5	26.3	30.0
5/16	16.3	19.0	21.8	18.3	21.3	24.4	19.7	23.0	26.3	28.1	32.8	37.5
3/8	19.6	22.8	26.1	21.9	25.6	29.3	23.6	27.6	31.5	33.8	39.4	45.0
7/16	22.8	26.6	30.5	25.6	29.9	34.1	27.6	32.2	36.8		45.9	52.5
1/2	26.1	30.5	34.8	29.3	34.1	39.0	31.5	36.8	42.0			60.0
9/16	29.4	34.3	39.2	32.9	38.4	43.9		41.3	47.3			
5/8	32.6	38.1	43.5		42.7	48.8		45.9	52.5			
11/16		41.9	47.9		46.9	53.6			57.8			
3/4		45.7	52.2			58.5						
13/16			56.6									
7/8			60.9									
15/16												
1	52.2	60.9	69.6	58.5	68.3	78.0	63.0	73.5	84.0	90.0	105.0	120.0

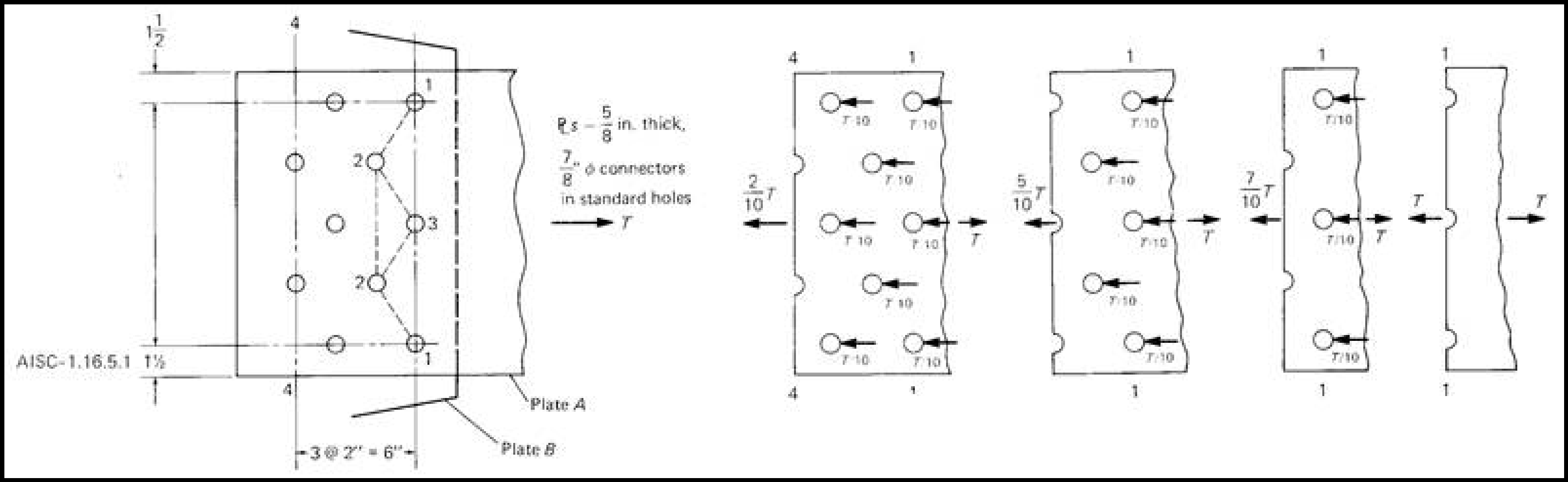
Tension Members

- steel members can have holes
- reduced area
- increased stress



Effective Net Area

- likely path to "rip" across
- bolts divide transferred force too



ASD – Tension Members

- non-pin connected members:
  - $F_t = 0.60F_y$ *on gross area*
  - $F_t = 0.50F_u$ *on net area*
- pin connected members:
  - $F_t = 0.45F_y$ *on net area*

- threaded rods of approved steel:
  - $F_t = 0.33F_u$ *on major diameter*
  - *(for static loading only)*

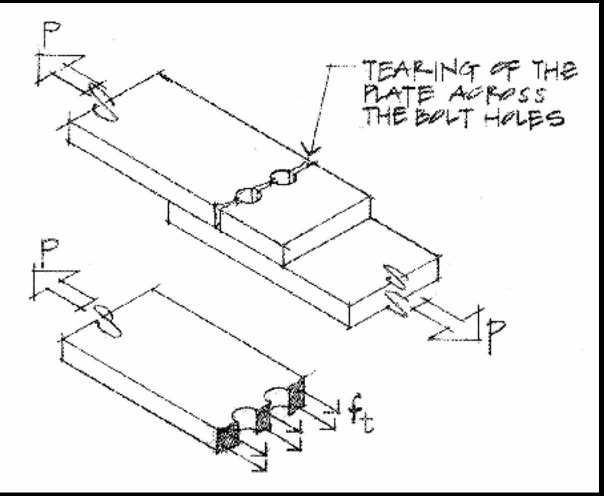
LRFD - Tension Members

- *limit states for failure* $P_u \leq \phi_t P_n$

1. yielding $\phi_t = 0.9 \quad P_n = F_y A_g$

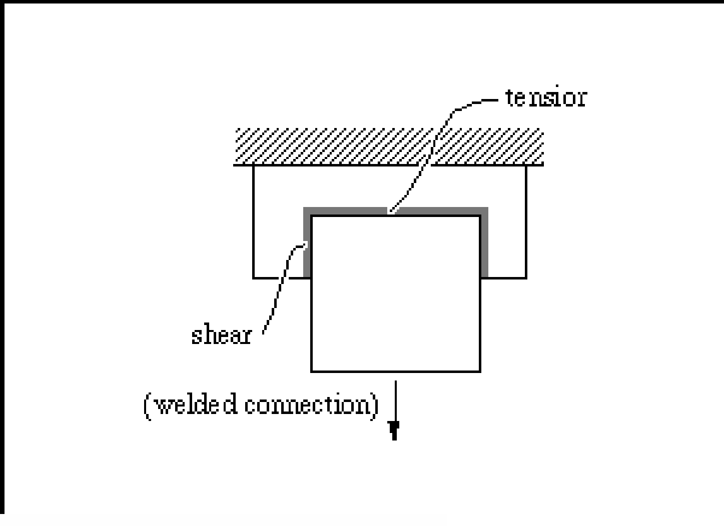
*2. rupture** $\phi_t = 0.75 \quad P_n = F_u A_e$

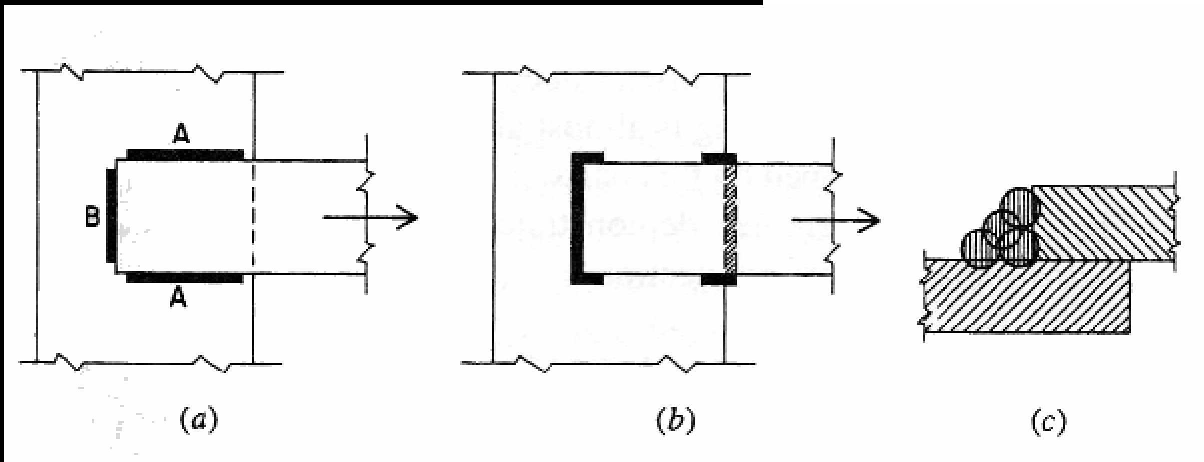
A_g - gross area
A_e - effective net area
F_u - tensile strength of the steel (ultimate)



Welded Connection Design

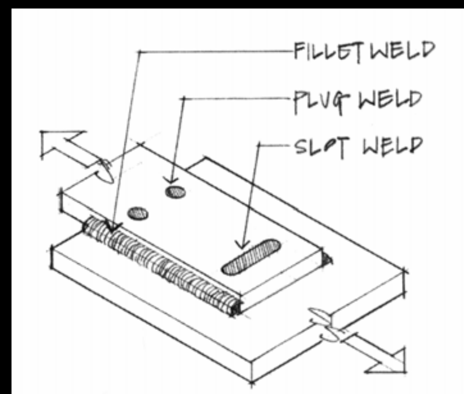
- considerations
  - shear stress
  - yielding
  - rupture

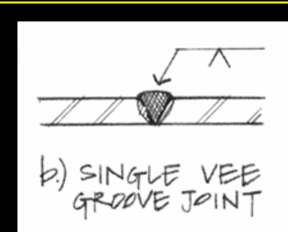


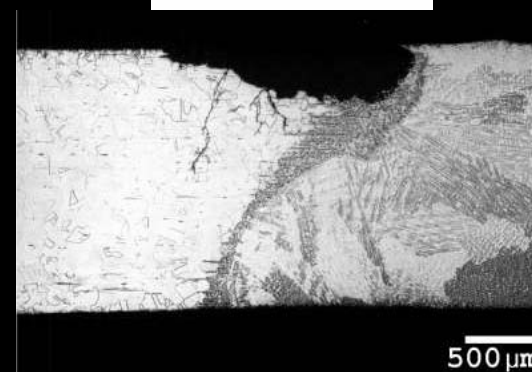


Welded Connection Design

- weld terms
  - butt weld
  - fillet weld
  - plug weld
  - throat







- weld materials
  - E60XX
  - E70XX
    $F_{EXX} = 70$ ksi

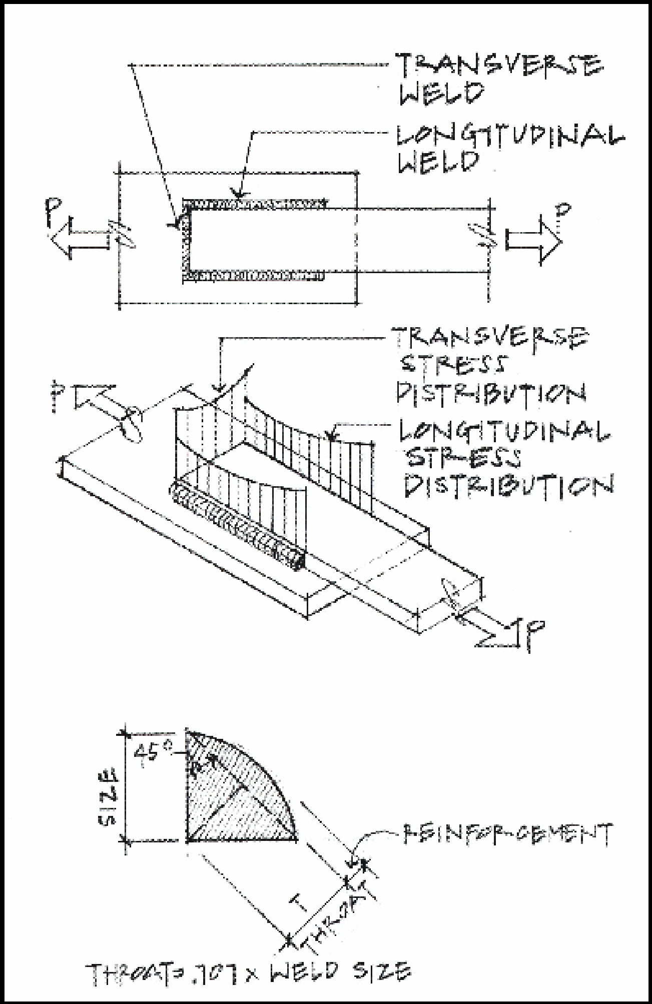
TABLE J2.4
Minimum Size of Fillet Welds

Material Thickness of Thicker Part Joined, in. (mm)	Minimum Size of Fillet Weld[a] in. (mm)
To $\frac{1}{4}$ (6) inclusive	$\frac{1}{8}$ (3)
Over $\frac{1}{4}$ (6) to $\frac{1}{2}$ (13)	$\frac{3}{16}$ (5)
Over $\frac{1}{2}$ (13) to $\frac{3}{4}$ (19)	$\frac{1}{4}$ (6)
Over $\frac{3}{4}$ (19)	$\frac{5}{16}$ (8)

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

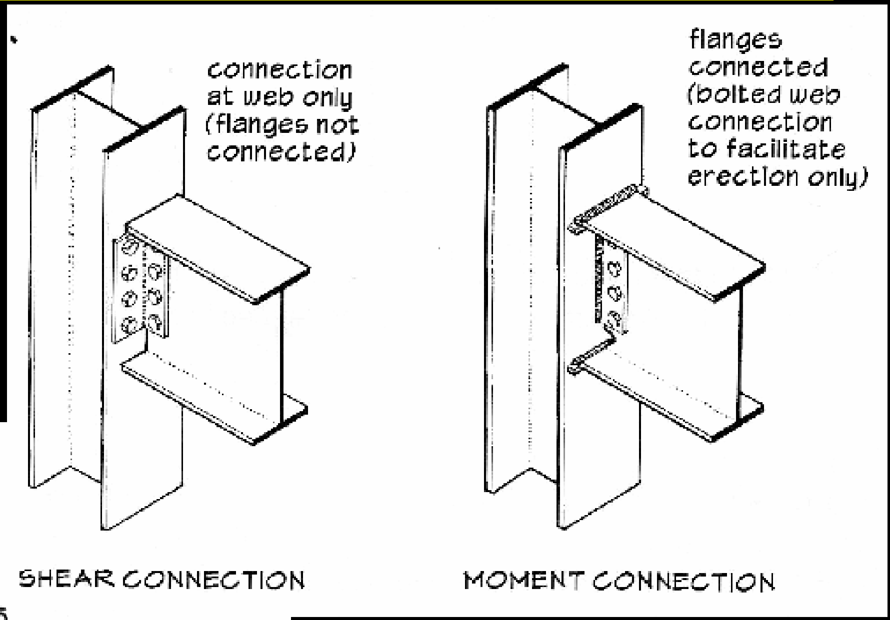
Welded Connection Design

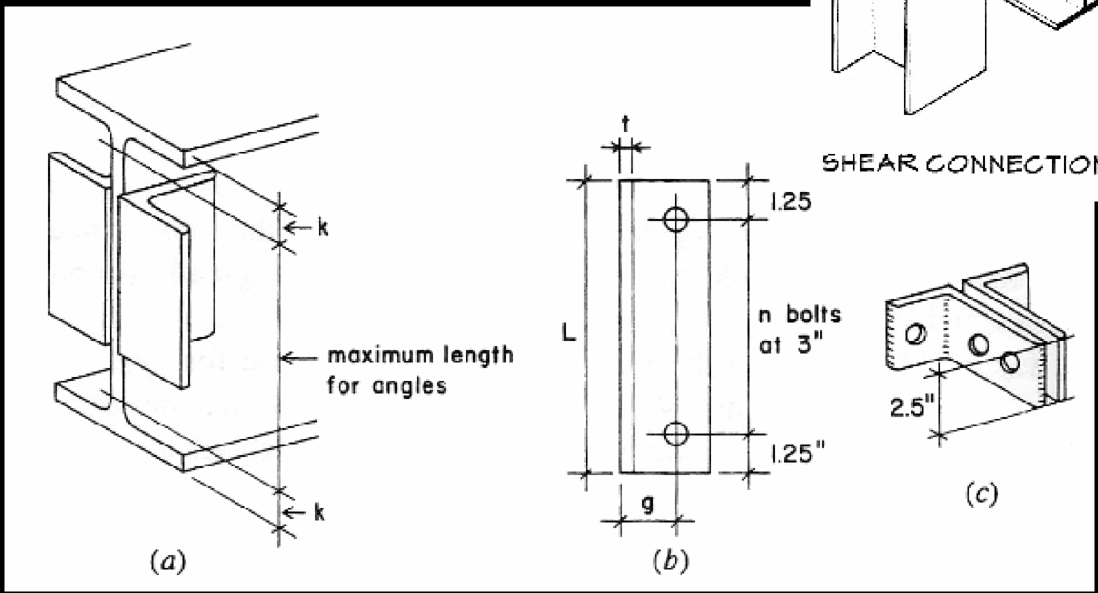
- ASD
  - shear $f_v \le F_v$
    - $F_v = 0.30F_{weld}$
  - throat
    - T =0.707 x weld size
  - area
    - A = T x length of weld
  - weld metal generally stronger than base metal (ex. F_y = 50 ksi)



Framed Beam Connections

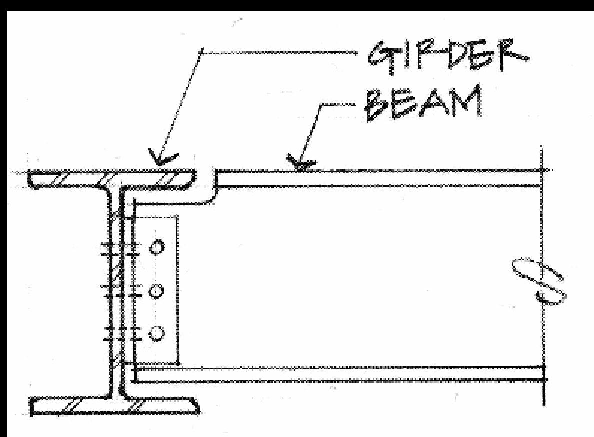
- angles
  - bolted
  - welded

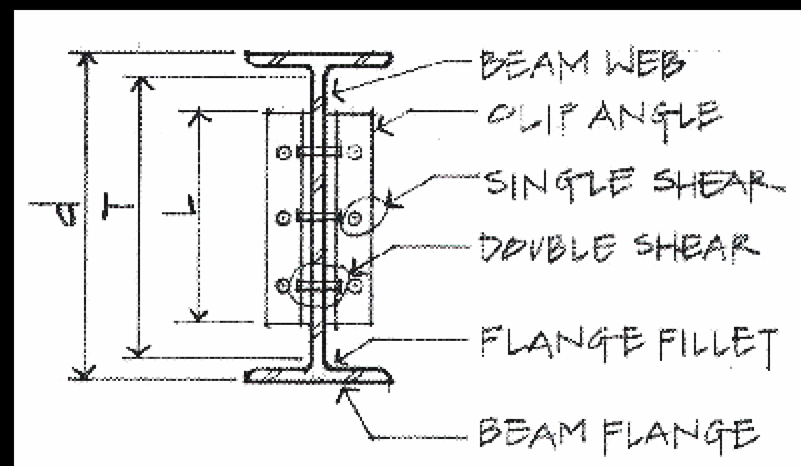




Framed Beam Connections

- *terms*
  - *coping*





Framed Beam Connections

- tables for standard bolt holes & spacings
- n = # bolts
- angle leg thickness
- length needed

FRAMED BEAM CONNECTIONS
Bolted
TABLE Allowable loads in kips

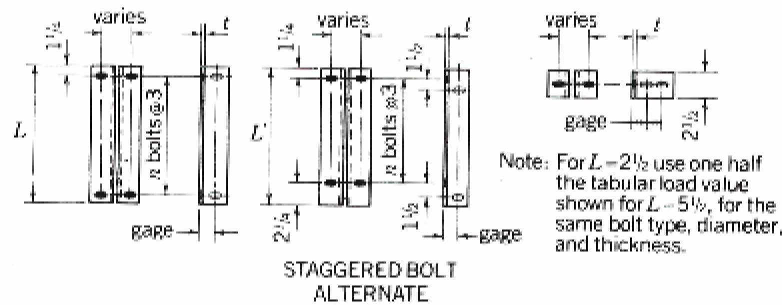
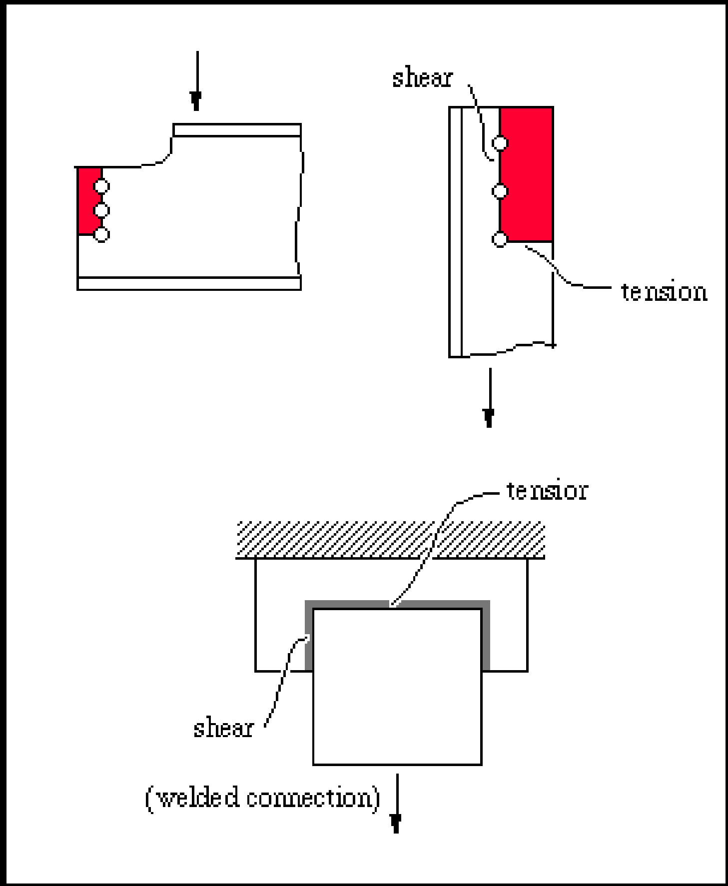


TABLE Bolt Shear[a]
For bolts in **bearing-type** connections with standard or slotted holes.

Bolt Type			A325-N			A490-N			A325-X			A490-X		
F_v, Ksi			21.0			28.0			30.0			40.0		
Bolt Dia., d In.			¾	⅞	1	¾	⅞	1	¾	⅞	1	¾	⅞	1
Angle Thickness t, In.			5/16	⅜	⅝	⅜	½	⅝	⅜	⅝	⅝	½	⅝	⅝
L In.	L' In.	n												
29½	31	10	186	253	330	247	337	440[b]	265	361	[c]	353	481	[c]
26½	28	9	167	227	297	223	303	396[b]	239	325	[c]	318	433	[c]
23½	25	8	148	202	264	198	269	352[b]	212	289	[c]	283	385	[c]
20½	22	7	130	177	231	173	236	308[b]	186	253	[c]	247	337	[c]
17½	19	6	111	152	198	148	202	264[b]	159	216	283	212	289	377
14½	16	5	92.8	126	165	124	168	220[b]	133	180	236	177	242	314
11½	13	4	74.2	101	132	99.0	135	176[b]	106	144	188	141	192	251

Beam Connections

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



Beam Connections

- *block shear rupture*
- *tension rupture*

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

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