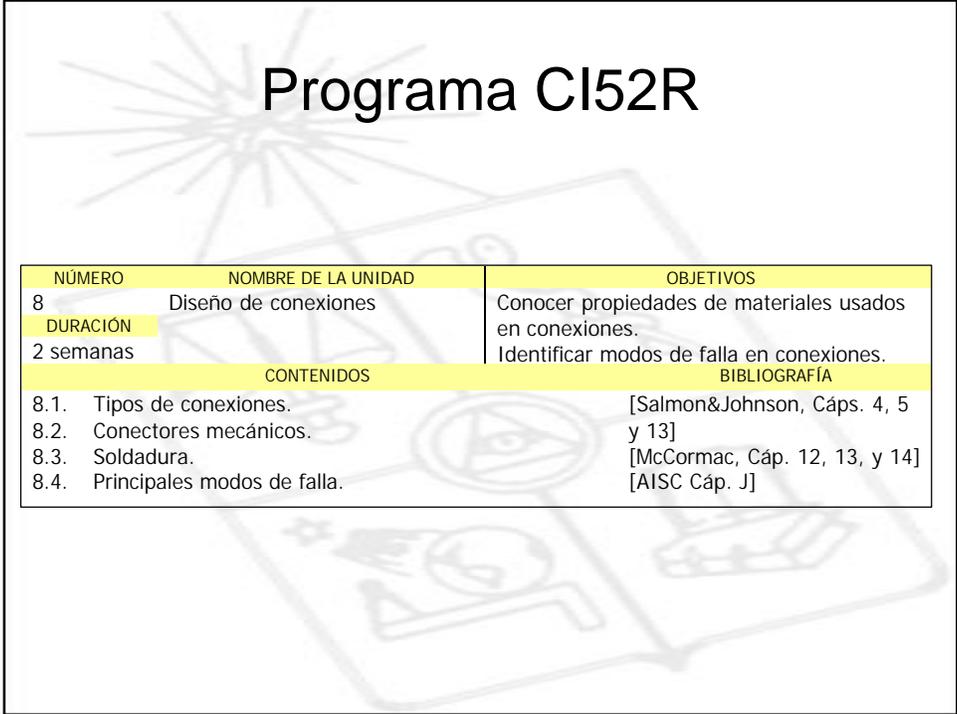
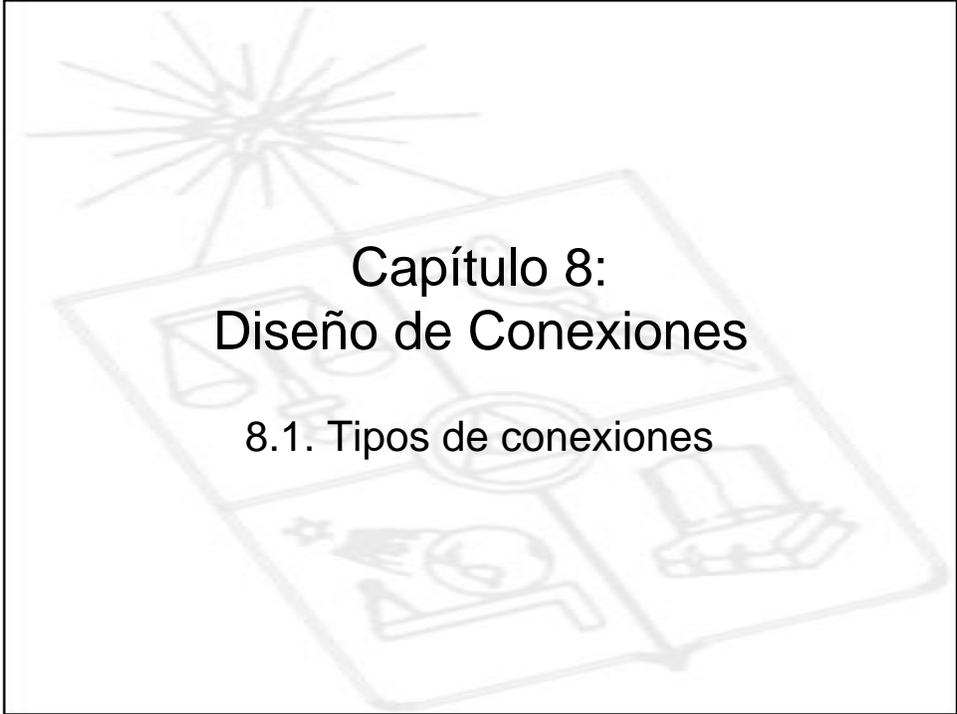


Capítulo 8: Diseño de Conexiones



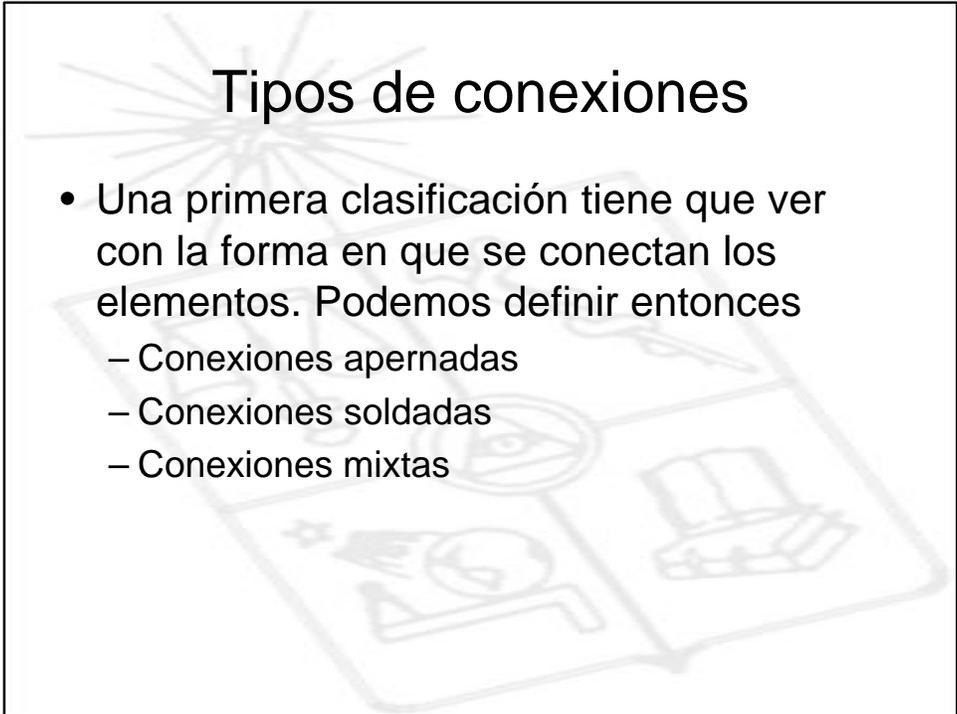
Programa CI52R

NÚMERO	NOMBRE DE LA UNIDAD	OBJETIVOS
8	Diseño de conexiones	Conocer propiedades de materiales usados en conexiones.
DURACIÓN		Identificar modos de falla en conexiones.
2 semanas		
CONTENIDOS		BIBLIOGRAFÍA
8.1.	Tipos de conexiones.	[Salmon&Johnson, Cáp. 4, 5 y 13]
8.2.	Conectores mecánicos.	[McCormac, Cáp. 12, 13, y 14]
8.3.	Soldadura.	[AISC Cáp. J]
8.4.	Principales modos de falla.	



Capítulo 8: Diseño de Conexiones

8.1. Tipos de conexiones



Tipos de conexiones

- Una primera clasificación tiene que ver con la forma en que se conectan los elementos. Podemos definir entonces
 - Conexiones apernadas
 - Conexiones soldadas
 - Conexiones mixtas

Tipos de conexiones

– Conexiones apernadas



Tipos de conexiones

– Conexiones soldadas



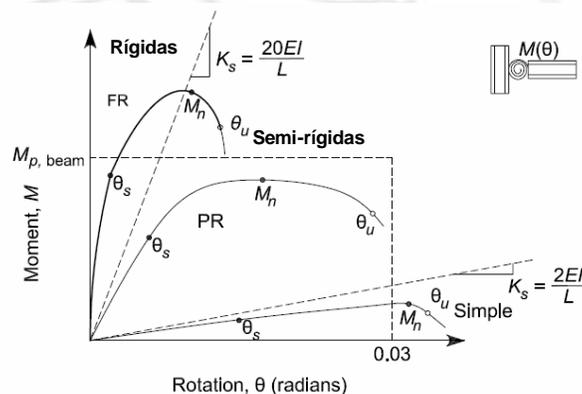
Tipos de conexiones

– Conexiones mixtas



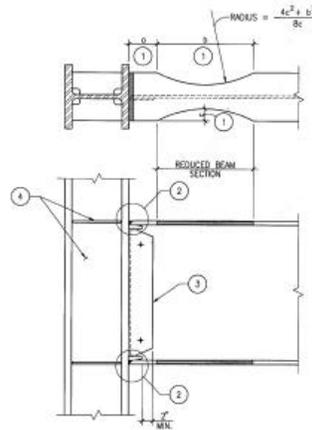
Tipos de conexiones

- Otra clasificación tiene que ver con los esfuerzos que la conexión debe transmitir.



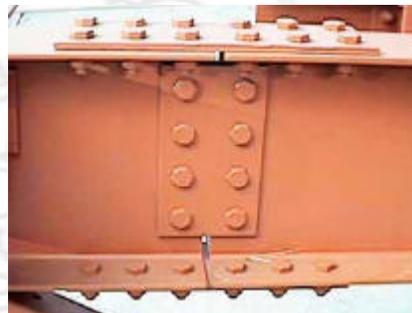
Tipos de conexiones

– Conexiones rígidas



Tipos de conexiones

– Conexiones rígidas



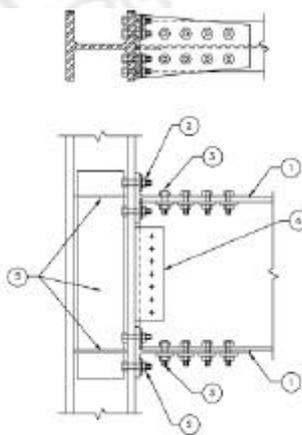
Tipos de conexiones

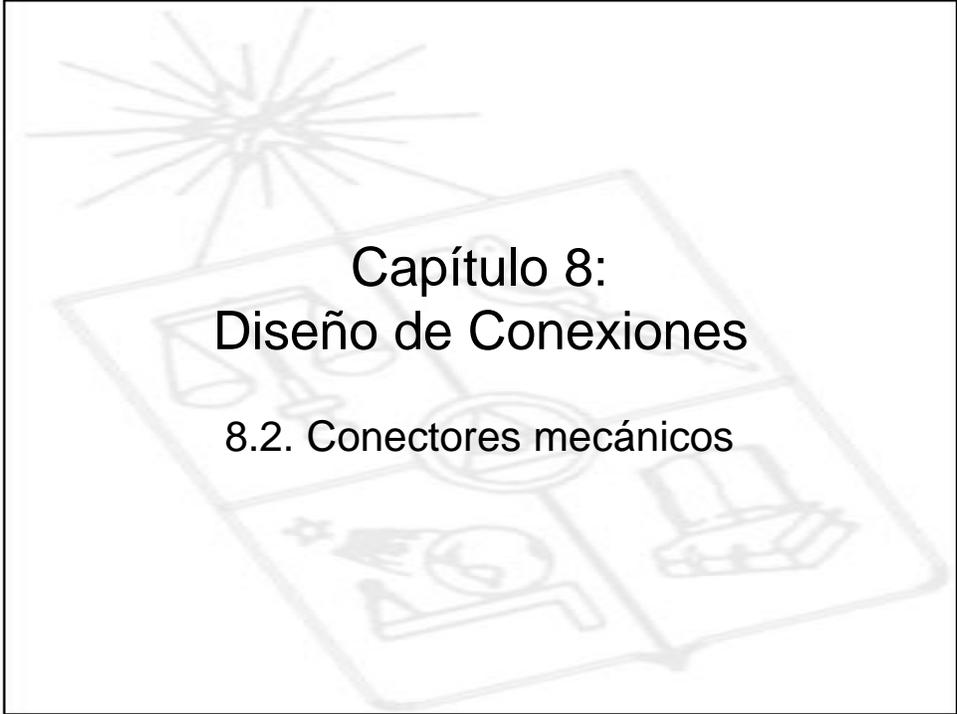
– Conexiones simples



Tipos de conexiones

– Conexiones semi-rígidas





Capítulo 8:
Diseño de Conexiones
8.2. Conectores mecánicos



Conectores mecánicos



Propiedades de pernos

ASTM designation	Bolt diameter in. (mm)	Proof load, ^a length measurement ^b method, ksi (MPa)	Proof load, ^c yield strength ^d method, ksi (MPa)	Minimum tensile strength, ksi (MPa)
A307 [2.4], low-carbon steel Grades A and B	$\frac{1}{2}$ to 4 (6.35 to 104)	—	—	60
A325 [2.5], high-strength steel Types 1, 2, and 3	$\frac{1}{2}$ to 1 (12.7 to 25.4)	85 (585)	92 (635)	120 (825)
Types 1, 2, and 3	$1\frac{1}{2}$ to $1\frac{1}{2}$ (28.6 to 38.1)	74 (510)	81 (560)	105 (725)
A449 [2.7], quenched and tempered steel (Note: AISC ^e permits use only for bolts larger than $1\frac{1}{2}$ in. and for threaded rods and anchor bolts)	$\frac{1}{2}$ to 1 (6.35 to 25.4)	85 (585)	92 (635)	120 (825)
	$1\frac{1}{2}$ to $1\frac{1}{2}$ (28.6 to 38.1)	74 (510)	81 (560)	105 (725)
	$1\frac{1}{2}$ to 3 (6.35 to 76.2)	55 (380)	58 (400)	90 (620)
A490 [2.8], quenched and tempered alloy steel	$\frac{1}{2}$ to $1\frac{1}{2}$ (12.7 to 38.1)	120 (825)	130 (895)	150 (1035)

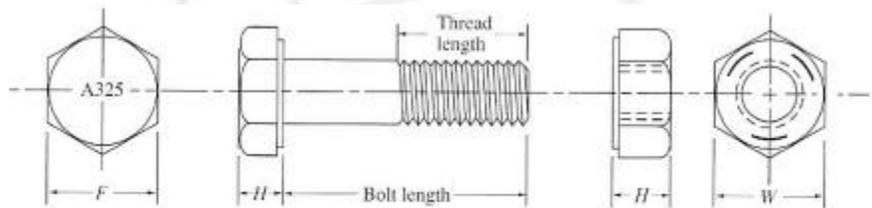
^a Actual proof load and tensile load obtained by multiplying given stress value by the tensile stress area A_s ; $A_s = 0.785 [d_n - 0.9743/n]^2$, where A_s = stress area in square inches, d_n = nominal diameter of bolt in inches, and n = number of threads per inch.

^b 0.5% extension under load.

^c 0.2% offset value.

^d LRFD and ASD-A5.3 and J3.

Propiedades de pernos



Nut may be chamfered
on both faces

Propiedades de pernos

Type	A325		A490	
	Bolt	Nut	Bolt	Nut
1	(1) 	(1)  MFG identification (typical) Arcs indicate Grade C		 DH or 2H (2)
2	 Note mandatory 3 radial lines at 60°	Same as Type 1	 Note mandatory 6 radial lines at 30°	Same as Type 1
3	(3)  Note mandatory underline	(3) 	(3)  Note mandatory underline	(3) 

(1) Additional optional 3 radial lines at 120° may be added.
 (2) Type 3 also acceptable.
 (3) Additional optional mark indicating weathering grade may be added.

Instalación de pernos

- Hay dos categorías:
 - Apretado (“snug tight”): instalado usando pocos impactos de una llave de impacto o manualmente.
 - Pretensado: instalado por métodos mas controlados
 - Vuelta de tuerca
 - Llave calibrada
 - Pernos especiales
 - Indicadores de tensión

Instalación de pernos

- Pretensión mínima

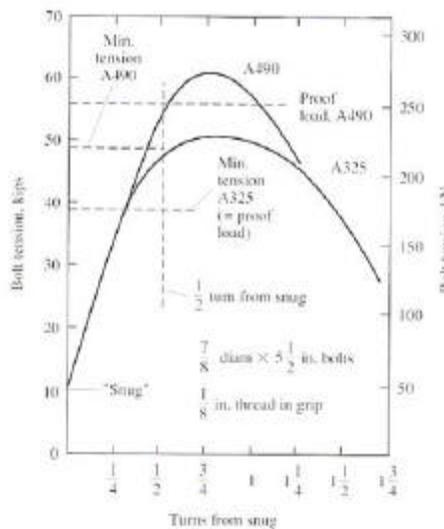
Minimum Bolt Pretension, kips*		
Bolt Size, in.	A325 Bolts	A490 Bolts
1/2	12	15
5/8	19	24
3/4	28	35
7/8	39	49
1	51	64
1 1/8	56	80
1 1/4	71	102
1 3/8	85	121
1 1/2	103	148

Minimum Bolt Pretension, kN*		
Bolt Size, mm	A325M Bolts	A490M Bolts
M16	91	114
M20	142	179
M22	176	221
M24	205	257
M27	267	334
M30	326	408
M36	475	595

*Equal to 0.70 times the minimum tensile strength of bolts, rounded off to nearest kN, as specified in ASTM specifications for A325M and A490M bolts with UNC threads.

Instalación de pernos

- Vuelta de tuerca



Instalación de pernos

- Vuelta de tuerca

TABLE 4.5.1. NUT ROTATION* FROM SNUG TIGHT CONDITION (FROM REF. 4.7)

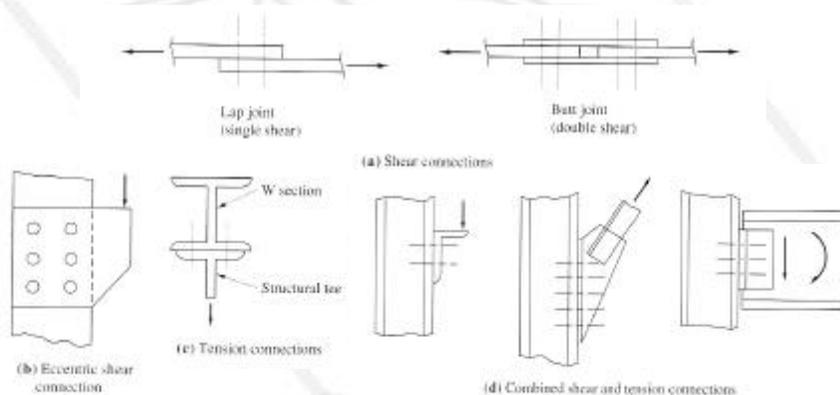
Bolt length (underside of head to end of bolt)	Disposition of outer faces of bolted parts		
	Both faces normal to bolt axis	One face normal to bolt axis and other face sloped not more than 1:20 (beveled washer not used)	Both faces sloped not more than 1:20 from normal to bolt axis (beveled washer not used)
Up to and including 4 diameters	$\frac{1}{2}$ turn	$\frac{1}{2}$ turn	$\frac{3}{4}$ turn
Over 4 diameters but not exceeding 8 diameters	$\frac{1}{2}$ turn	$\frac{4}{5}$ turn	$\frac{1}{2}$ turn
Over 8 diameters but not exceeding 12 diameters	$\frac{1}{2}$ turn	$\frac{4}{5}$ turn	1 turn

* Nut rotation is relative to bolt regardless of the element (nut or bolt) being turned. For bolts installed by $\frac{1}{2}$ turn and less, the tolerance should be plus or minus 30%; for bolts installed by $\frac{1}{2}$ turn and more, the tolerance should be plus or minus 45%.

† No research has been performed by the Council to establish the run-of-the-nut procedure for bolt lengths exceeding 12 diameters. Therefore, the required rotation must be determined by actual test in a suitable tension measuring device which simulates conditions of solidly fitted steel.

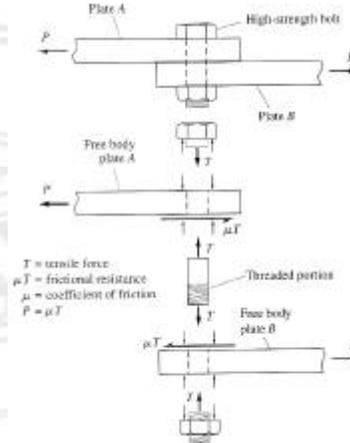
Resistencia individual de pernos

- Pernos pueden estar sujetos a diferentes esfuerzos

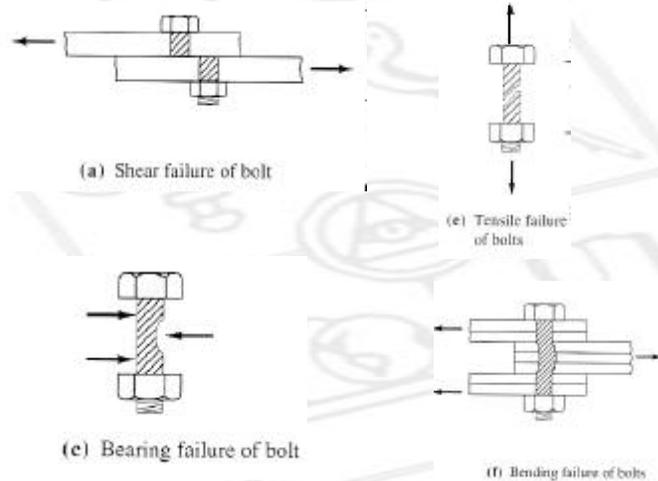


Resistencia individual de pernos

- DCL de una conexión apernada (solo corte)
- Se distinguen 2 tipos
 - Contacto
 - Deslizamiento crítico



Modos de falla (pernos)



AISC Specification for Structural Steel Buildings

- Factores

$$f = 0,75 \quad \Omega = 2,0$$

- Resistencia a la tracción

$$R_n = F_{nt} \cdot A_b$$

$$F_{nt} = 0,75 F_u \text{ (ver Tabla J3.2)}$$

A_b = área bruta del perno

AISC Specification for Structural Steel Buildings

- Resistencia al corte (contacto)

$$R_n = F_{nv} \cdot A_b$$

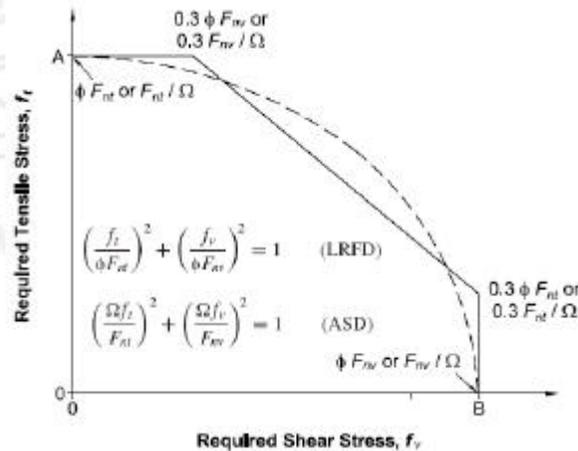
$$F_{nv} = 0,50 F_u \text{ (hilos excluidos)}$$

$$0,40 F_u \text{ (hilos incluidos)}$$

A_b = área bruta del perno

AISC Specification for Structural Steel Buildings

- Interacción corte-tracción:



AISC Specification for Structural Steel Buildings

- Interacción corte-tracción: modificar la tensión nominal de tracción

$$F'_{nt} = \begin{cases} 1,3F_{nt} - \frac{F_{nt}}{F_{nv}} f_v \leq F_{nt} & \text{LRFD} \\ 1,3F_{nt} - \frac{\Omega F_{nt}}{F_{nv}} f_v \leq F_{nt} & \text{ASD} \end{cases}$$

AISC Specification for Structural Steel Buildings

- Resistencia al deslizamiento
 - $f = 1,00$, $\Omega = 1,50$ (nivel de servicio)
 - $f = 0,85$, $\Omega = 1,76$ (nivel de resistencia)

$$R_n = m \cdot D_u h_{sc} T_b N_s$$

μ = coef. de fricción = 0,35 superficie Clase A
= 0,50 superficie Clase B

D_u = sobre-pretensión promedio = 1,13

h_{sc} = factor por perforación = 1,0; 0,85; 0,70

T_b = pretensión mínima

N_s = número de planos de deslizamiento

AISC Specification for Structural Steel Buildings

- Reducción de la resistencia al deslizamiento debido a tracción

$$R'_n = k_s \cdot R_n$$

$$k_s = \begin{cases} 1 - \frac{T_u}{D_u T_b N_b} & \text{LRFD} \\ 1 - \frac{1,5 T_a}{D_u T_b N_b} & \text{ASD} \end{cases}$$

T_a = tracción de servicio

T_u = tracción última

Conexiones excéntricas

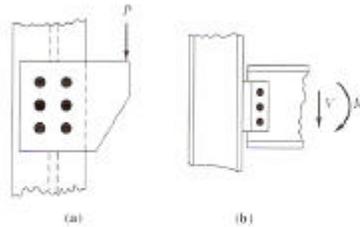


Figure 4.12.1 Typical eccentric shear connections.

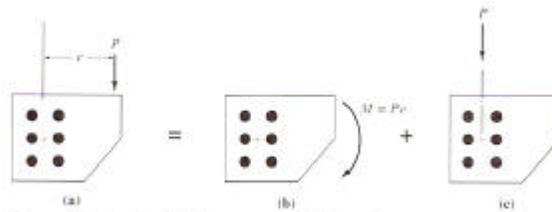
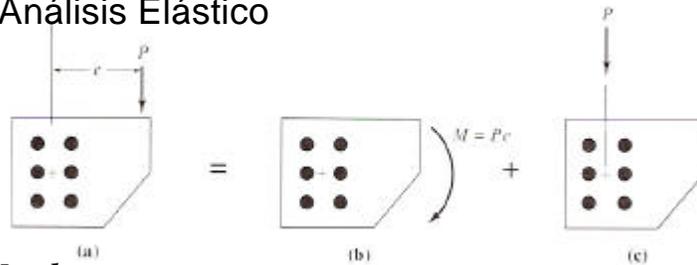


Figure 4.12.2 Combined moment and direct shear.

Conexiones excéntricas

- Hay dos métodos de encontrar los esfuerzos en cada perno:

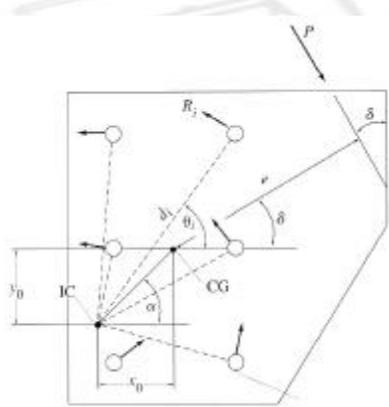
– Análisis Elástico



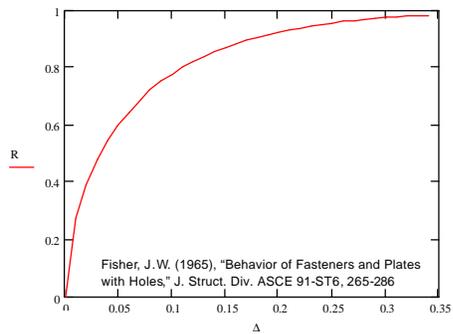
$$R_i = \frac{M \cdot d_i}{\sum_j d_j^2} \quad R_v = \frac{P}{N} \quad R = \sqrt{(R_{iy} + R_v)^2 + R_{ix}^2}$$

Conexiones excéntricas

– Análisis Plástico (centro instantáneo de rotación)



$$R_i = R_{ult} (1 - e^{-10\Delta})^{0,55}$$



Conexiones excéntricas

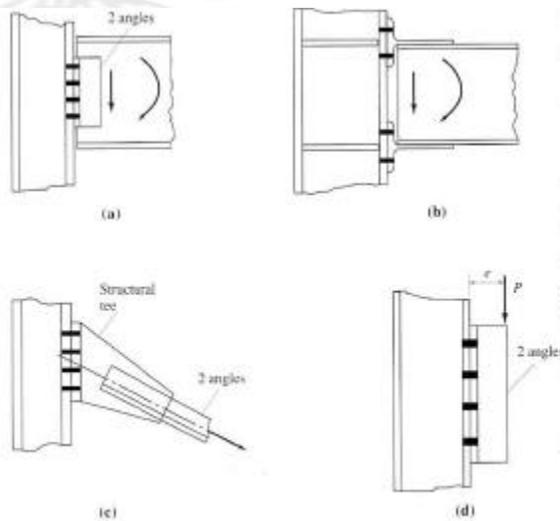
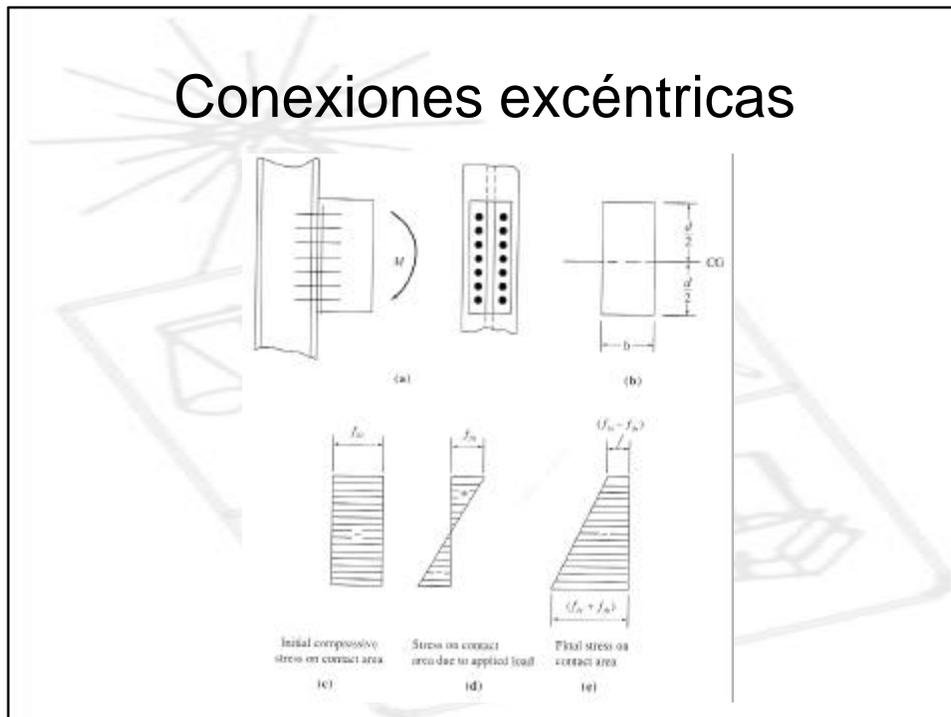


Figure 4.14.1 Typical combined shear and tension connections.

Conexiones excéntricas



Dimensionamiento

- Para el tamaño de perforaciones estándar, sobredimensionadas y ranuradas ver Tabla J3.3
- Espaciamento mín.: $2 \frac{2}{3} d_{\text{perno}}$ ($3 d_{\text{perno}}$)
- Espaciamento máx.:
 - Elementos pintados o no expuestos a corrosión: mín($24t, 12''$)
 - Elementos expuestos a corrosión: mín($14t, 7''$)

Dimensionamiento

- Distancia mín. a borde: ver Tablas J3.4 y J3.5
- Distancia máx. a borde:
 - Elementos pintados o no expuestos a corrosión: mín($12t$, 6")

Capítulo 8: Diseño de Conexiones

8.3. Soldadura

Métodos de Soldadura

- SMAW (Shielded Metal Arc Welding)

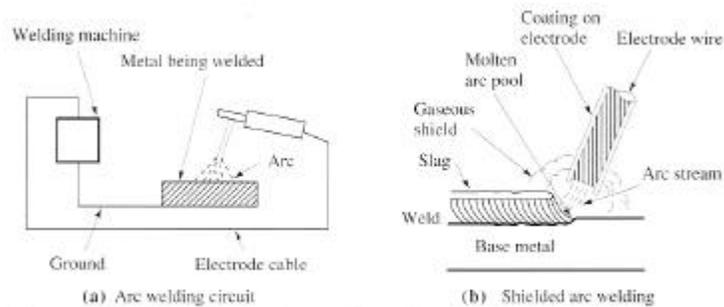


Figure 5.2.1 Shielded metal arc welding (SMAW).

Métodos de Soldadura

- SAW (Submerged Arc Welding)

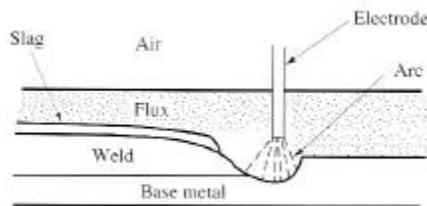


Figure 5.2.2 Submerged arc welding (SAW).

Métodos de Soldadura

- GMAW (Gas Metal Arc Welding)

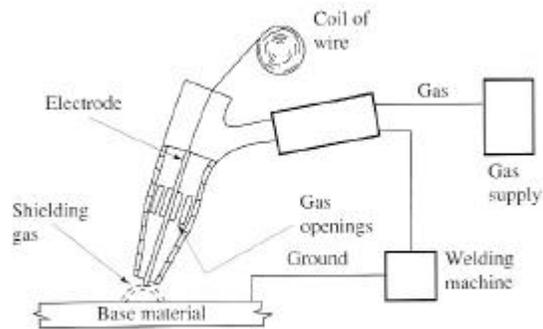


Figure 5.2.3 Gas metal arc welding (GMAW).

Métodos de Soldadura

- FCAW (Flux Cored Arc Welding)
- EGW (Electrogas Welding)
- ESW (Electroslag Welding)

Tipos básicos de junta

- De tope
- Traslapada
- T
- Esquina
- Borde

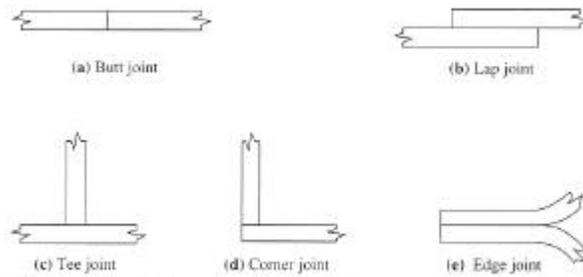


Figure 5.4.1 Basic types of welded joints.

Tipos de soldadura

- Penetración (parcial o completa)
- Filete o cordón
- Ranura o tapón

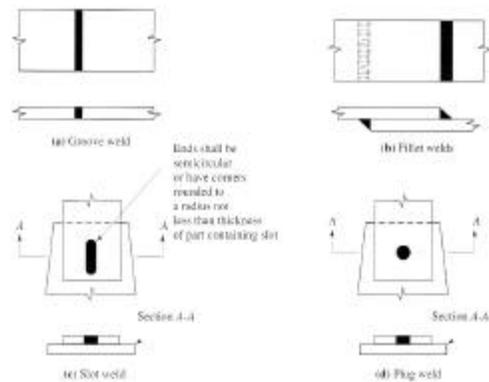
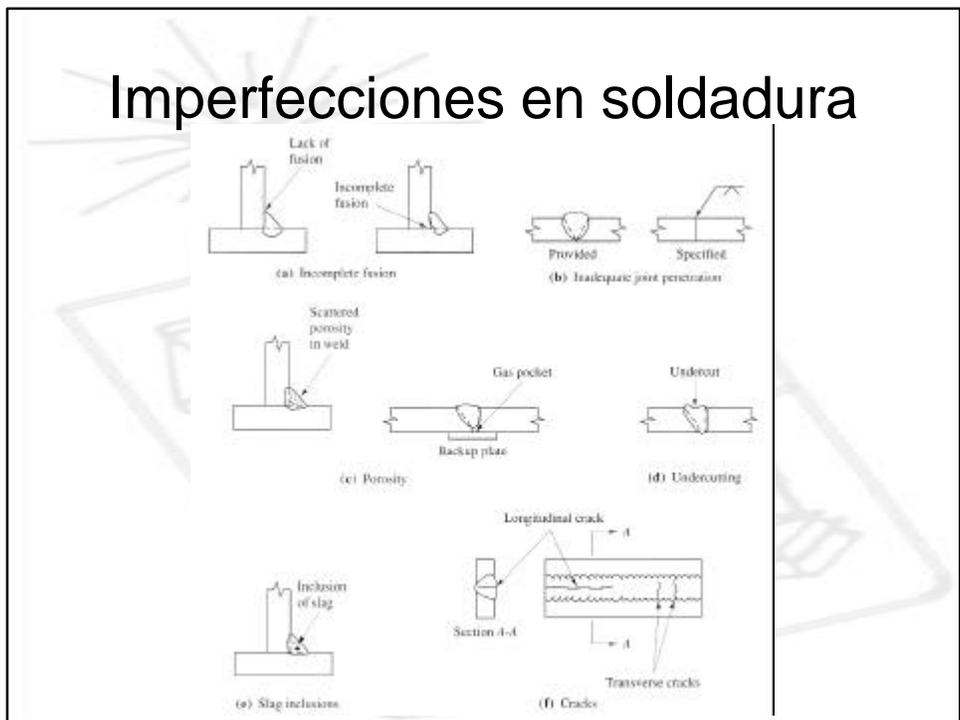


Figure 5.5.1 Types of welds.

Símbolos de soldadura

Basic Weld Symbols									
Back	Fillet	Plug or Slot	Groove or Butt						
			Square	V	Bevel	U	J	Flare V	Flare Bevel
Supplementary Weld Symbols									
Backing	Spacer	Weld All Around	Field Weld	Contour		For other basic and supplementary weld symbols, see AWS A2.4			
				Flush	Convex				

Imperfecciones en soldadura



AISC Specification for Structural Steel Buildings

- Factores f y Ω dependen de la sollicitación y el tipo de soldadura (ver Tabla J2.5)

- Resistencia nominal

– Metal base

$$R_n = F_{BM} \cdot A_{BM}$$

– Soldadura

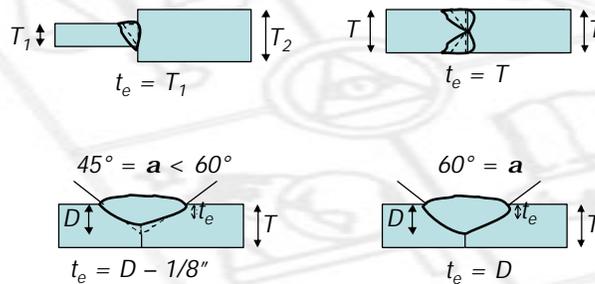
$$R_n = F_w \cdot A_w = F_w \cdot t_e \cdot l_w$$

t_e = garganta efectiva de soldadura

AISC Specification for Structural Steel Buildings

– Area efectiva de soldadura:

- Soldadura de penetración (tamaño mínimo ver Tabla J2.3, sección J2.1b)



GMAW, FCAW posiciones v y o

AISC Specification for Structural Steel Buildings

– Area efectiva de soldadura:

- Soldadura de filete

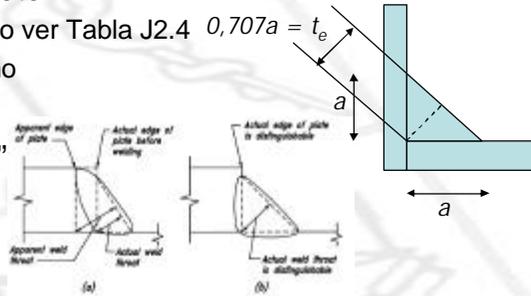
– Tamaño mínimo ver Tabla J2.4 $0,707a = t_e$

– Tamaño máximo

$t = 1/4''$: t

$t > 1/4''$: $t - 1/16''$

– $l_w = 4a$



- Soldadura de tapón: área transversal de la perforación

AISC Specification for Structural Steel Buildings

- Soldaduras de penetración

– Tracción o compresión normal al eje de la soldadura en elementos diseñados para contacto

- Metal base

$$f = 0,9$$

$$W = 1,67$$

$$R_n = F_y \cdot t_e \cdot l_w$$

- Soldadura

$$f = 0,8$$

$$W = 1,88$$

$$R_n = 0,60F_{EXX} \cdot t_e \cdot l_w$$

AISC Specification for Structural Steel Buildings

- Soldaduras de penetración

- Corte

- Metal base: ver sección J4

- Soldadura

$$f = 0,75$$

$$W = 2,00$$

$$R_n = 0,60F_{EXX} \cdot t_e \cdot l_w$$

AISC Specification for Structural Steel Buildings

- Soldaduras de filete

- Corte

- Metal base: ver sección J4

- Soldadura

$$f = 0,75$$

$$W = 2,00$$

$$R_n = 0,60F_{EXX} \cdot t_e \cdot l_w$$

AISC Specification for Structural Steel Buildings

- Soldaduras de tapón
 - Corte
 - Metal base: ver sección J4
 - Soldadura

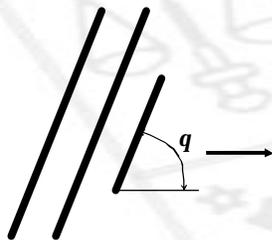
$$f = 0,75$$

$$W = 2,00$$

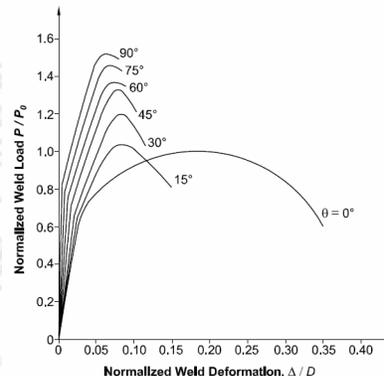
$$R_n = 0,60F_{EXX} \cdot A_{\text{tapon}}$$

AISC Specification for Structural Steel Buildings

- Grupos colineales o paralelos de filetes cargados a través del centro de gravedad

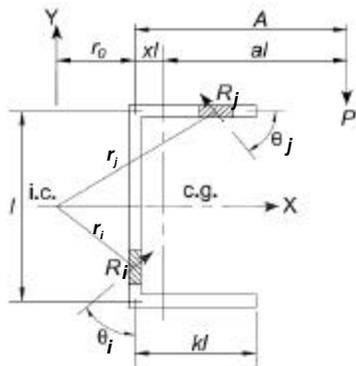


$$F_w = 0,60F_{EXX} \left(1 + 0,5(\sin q)^{1,5}\right)$$



AISC Specification for Structural Steel Buildings

- Grupos de soldaduras de filete (método plástico)



$$F_w = 0,60F_{EXX} (1 + 0,5(\sin q)^{1,5}) f(p)$$

$$f(p) = [p(1,9 - 0,9p)]^{0,3}$$

$$p = \Delta_i / \Delta_m$$

$$\Delta_i = r_i \Delta_u / r_{crit}$$

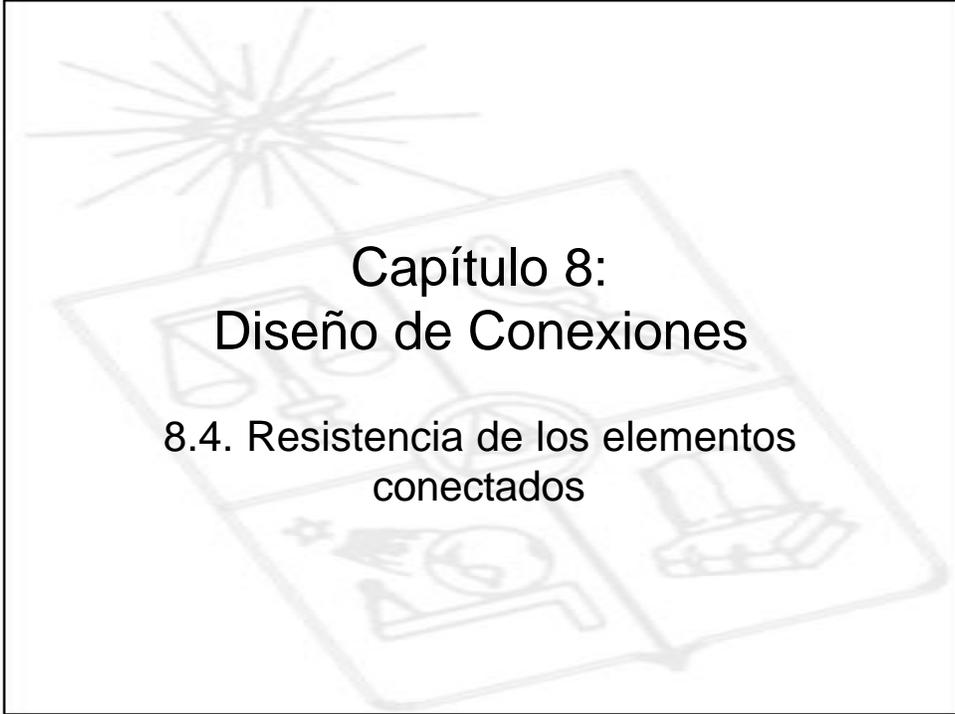
$$\Delta_m = 0,209(q + 2)^{-0,32} w$$

$$\Delta_u = 1,087(q + 6)^{-0,65} w \leq 0,17w$$

AISC Specification for Structural Steel Buildings

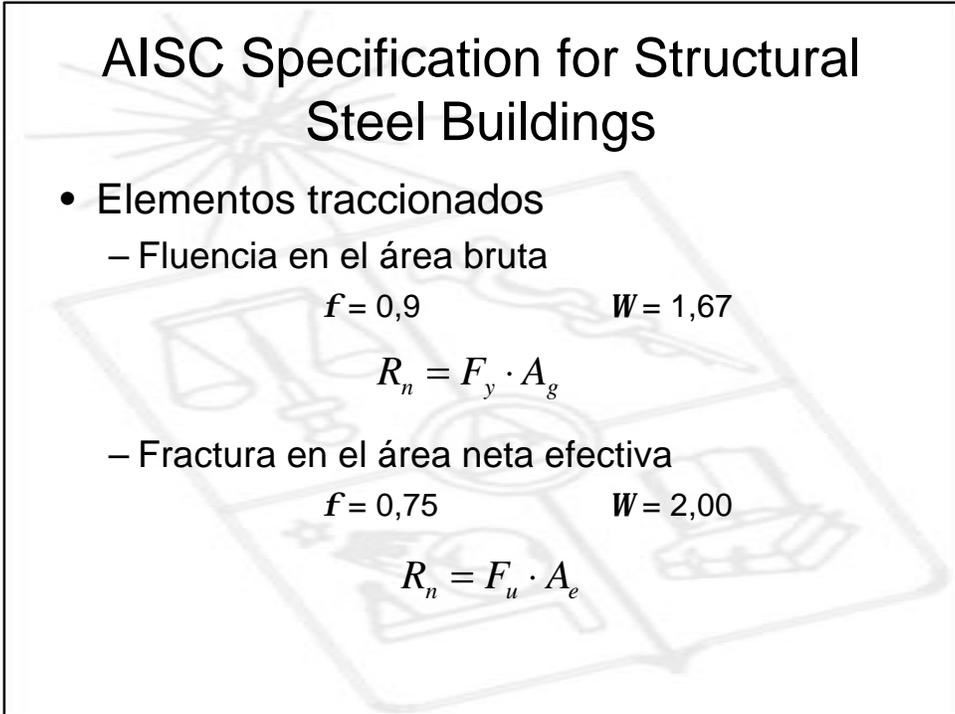
- Grupos de filetes longitudinales y transversales cargados a través del centro de gravedad

$$R_n = \max(R_{wl} + R_{wr}, 0,85R_{wl} + 1,5R_{wr})$$



Capítulo 8: Diseño de Conexiones

8.4. Resistencia de los elementos conectados



AISC Specification for Structural Steel Buildings

- Elementos traccionados

- Fluencia en el área bruta

$$f = 0,9$$

$$W = 1,67$$

$$R_n = F_y \cdot A_g$$

- Fractura en el área neta efectiva

$$f = 0,75$$

$$W = 2,00$$

$$R_n = F_u \cdot A_e$$

AISC Specification for Structural Steel Buildings

- Elementos comprimidos

$$KL/r \leq 25: P_n = F_y \cdot A_g$$

$$f = 0,9 \quad W = 1,67$$

$$KL/r > 25: \text{Capitulo E}$$

AISC Specification for Structural Steel Buildings

- Elementos en corte
 - Fluencia en el área bruta

$$f = 1,0 \quad W = 1,5$$

$$R_n = 0,6F_y \cdot A_{gv}$$

- Fractura en el área neta efectiva

$$f = 0,75 \quad W = 2,00$$

$$R_n = 0,6F_u \cdot A_{nv}$$

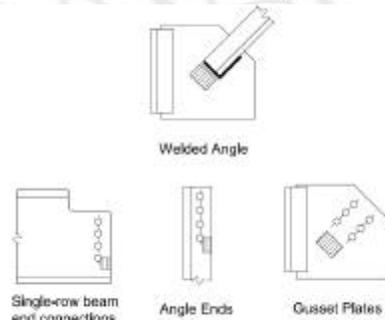
AISC Specification for Structural Steel Buildings

- Falla por bloque de corte

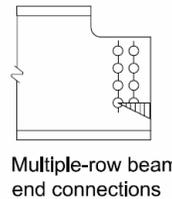
$$f = 0,75$$

$$W = 2,00$$

$$R_n = 0,6F_u \cdot A_{nv} + U_{bs}F_u \cdot A_{nt} \leq 0,6F_y \cdot A_{gv} + U_{bs}F_u \cdot A_{nt}$$



(a) Cases for which $U_{bs} = 1,0$



(b) Case for which $U_{bs} = 0,5$

AISC Specification for Structural Steel Buildings

- Aplastamiento de la perforación para pernos

$$f = 0,75$$

$$W = 2,0$$

- Perforaciones estándar, sobredimensionadas, ranuras cortas cualquiera y ranuras largas paralelas a la dirección de carga

- No deformación de perforación a nivel de servicio

$$R_n = 1,2L_c t F_u \leq 2,4dt F_u$$

- Deformación de perforación no es consideración

$$R_n = 1,5L_c t F_u \leq 3,0dt F_u$$

AISC Specification for Structural Steel Buildings

- Aplastamiento de la perforación para pernos

$$f = 0,75 \quad W = 2,0$$

- Ranura larga perpendicular a la dirección de carga

$$R_n = 1,0L_c t F_u \leq 2,0dt F_u$$

AISC Specification for Structural Steel Buildings

- Aplastamiento (otras perforaciones)

$$f = 0,75 \quad W = 2,0$$

$$R_n = 1,8F_y A_{pb}$$

donde A_{pb} : área proyectada de aplastamiento