CIVE 3205
Example T-5

Revisions

- 2020-02-21:
  - corrected heading, p5
  - new page 5.1 – more block shear patterns
  - corrected A_{ne} calc for HSS – p6 & new page 6.1
- 2012 – Original posting

Example T-5:

Compute the factored tension capacity, T_r, of a tension member similar to that used extensively in the new construction at the corner of Bank St. & Sunnyside Ave, Ottawa, Fall 2010. In that construction, these tension members are bracing to resist lateral loads due to wind and earthquake.

The tension members are square HSS with plates welded to the ends for the connections.

See the photos on the next 2 pages.

The problem starts on page 4, where the particulars are given:

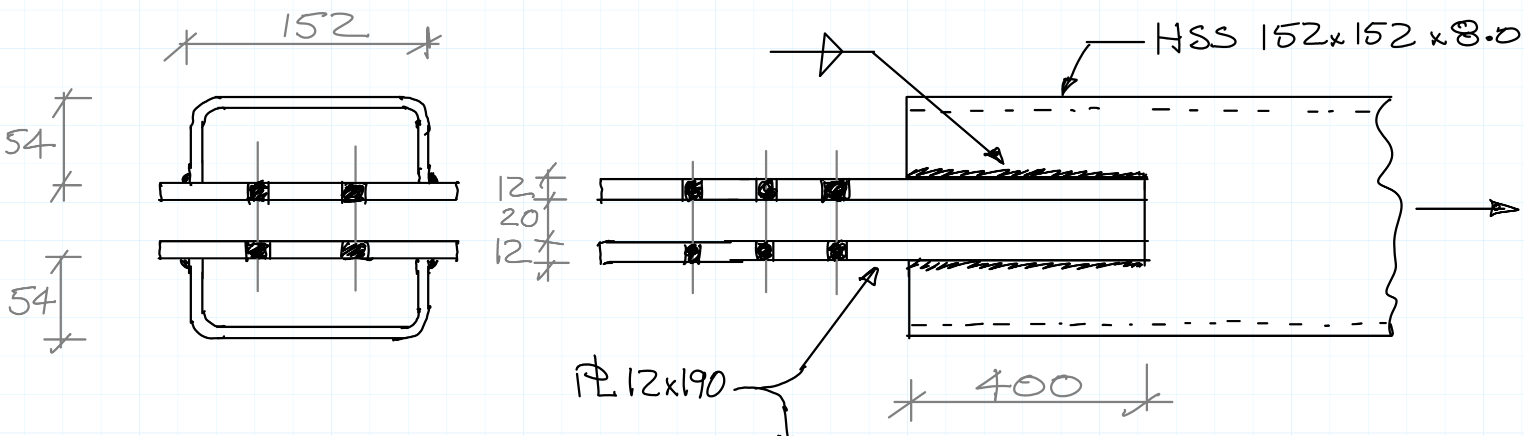
Assume: G40.21 350 W Steel
M20 bolts
punched holes

Do not calculate the strength of the fasteners (the bolts and welds).


2/6
HSS Tension
Members

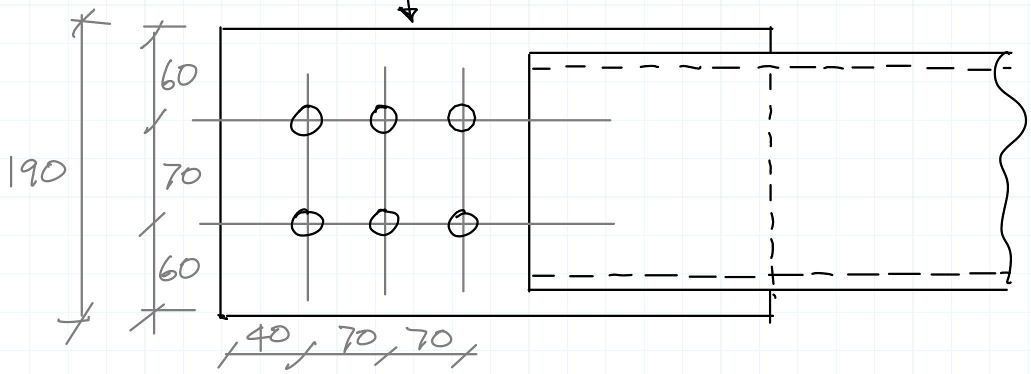

3/6
HSS
Tension Member

Compute T_r



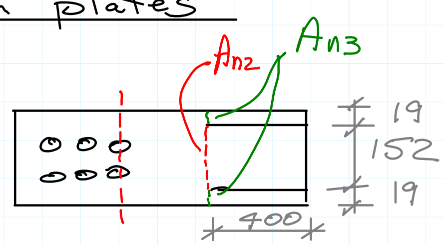
152
$-(12+20+12) = 108$

$\frac{108}{2} = 54$



N.T.S. (Not to scale)

12 mm plates



$A_g = 12\,mm \times 190\,mm \times 2 = 4560\ mm^2$

holes: $A_n = 4560 - 2 \times 24 \times 12 \times 2 = 3408\ mm^2$

no reduction for shear lag

welds / shear lag

A_{n2}: $L = 400$ $\quad w = 152$

$L > 2w$

$\therefore A_{n2} = 152 \times 12 \times 2 = 3648\ mm^2$

A_{n3}: $L = 400$ $\quad w = 19$ $\quad \bar{x} = 9.5$

$L > w$

$\therefore A_{n3} = \left(1 - \frac{9.5}{400}\right) \times 19 \times 12 \times 2 \times 2 = 890\ mm^2$

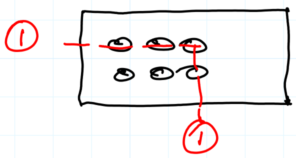
$A_{ne} = 3648 + 890 = 4538\ mm^2$

$\therefore A_n$ governs $\quad A_n = 3408\ mm^2$

gross yield: $T_r = \phi A_g F_y$
$= 0.9 \times 4560\ mm^2 \times 350 \times 10^{-3} \frac{kN}{mm^2}$
$= 1436\ kN$

net fracture: $T_r = \phi_u A_n F_u$
$= 0.75 \times 3408\ mm^2 \times 450 \times 10^{-3}\ kN/mm^2$
$= 1150\ kN$

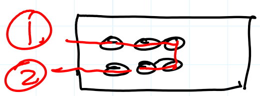
Block Shear



Path ①-①

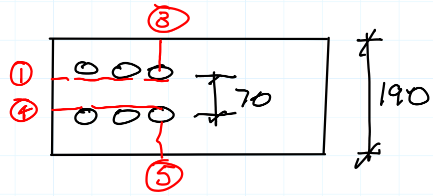
$A_n = (130 - 1.5 \times 24) \times 12 \times 2 = 2256\ mm^2$
$A_{gv} = (40 + 70 + 70) \times 12 \times 2 = 4320\ mm^2$

$T_r = \phi_u \left[U_t A_n F_u + 0.6 A_{gv} \frac{F_y + F_u}{2} \right]$ $\quad U_t = 0.9$
$= 0.75 \left[0.9 \times 2256 \times .450 + 0.6 \times 4320 \times \frac{.35 + .45}{2} \right]$
$= 1463\ kN$



Path ①-②
$A_n = (70 - 24) \times 12 \times 2 = 1104\ mm^2$
$A_{gv} = 4320 \times 2 = 8640\ mm^2$
$U_t = 1.0$
will not govern

Block Shear



$A_{gv} = 8640 \text{ mm}^2$ (as above)

$A_{nt} = \left(190 - 70 - \frac{24}{2} \times 2\right) \times 12 \times 2$

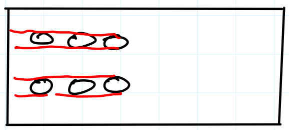
$= 2304 \text{ mm}^2$

$U_t = 0.6$

$T_r = 0.75\left(0.6 \times 2304 \times 0.45 + 0.6 \times 8640 \times 0.40\right)$

$T_r = 2022 \text{ kN}$

Tearout



$A_{nt} = 0$

$A_{gv} = 4 \times 4320$

$= 17280 \text{ mm}^2$

$T_r = 0.75 \times 0.6 \times 17280 \times 0.4$

$\underline{T_r = 3110 \text{ kN}}$

$\therefore$ For plates, $T_r = 1150 \text{ kN}$

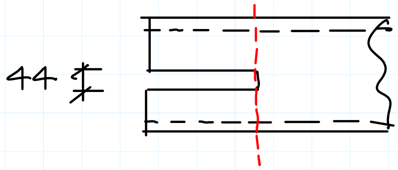
Governed by net section fracture, welded end.

HSS 152 x 152 x 8.0

$A_g = 4430\ mm^2$

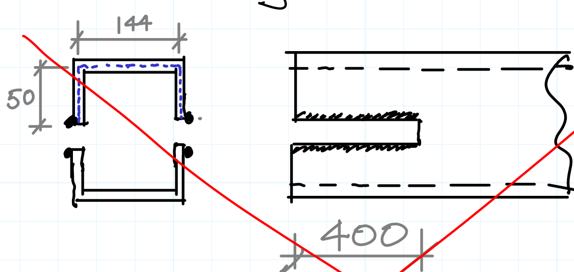
$t = 7.95\ mm$

Net area @ end of slot cut for plates -



$A_n = 4430 - 44 \times 7.95 \times 2 = 3730\ mm^2$

Shear lag - for load xfered by weld into the HSS



Note - this method of Ane calc. corresponds to S16-09.
See p 6.1 for S16-14.

~~L - Length of weld~~

~~L = 400 mm~~

~~w - width of plate = circumferential dist. between welds~~

~~w = 50 + 144 + 50 = 244 mm.~~

$\cancel{2w > L > w}$

$\cancel{\therefore A_{n2} = (0.5 \times 244 \times 7.95 + 0.25 \times 400 \times 7.95) \times 2 = 3530\ mm^2}$

$\cancel{\therefore A_{ne} = 3530\ mm^2}$

gross yield $\quad T_r = \phi A_g F_y = 0.9 \times 4430 \times .350 = 1395\ kN$

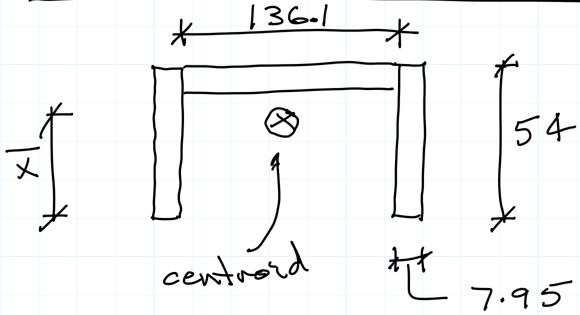
net fracture $\quad T_r = \phi_u A_{ne} F_u = 0.75 \times 3730 \times 0.45 = 1259\ kN$

∴ Plates Govern

$\underline{T_r = 1150\ kN}$ ←

this does not account for fastener (bolts, welds) strength.

A_{ne} - slotted HSS



Compute centroid distance $\bar{x}$

Part	w	h	x_c	A	$A x_c$
1	7.95	54	27	429.3	11591
2	7.95	54	27	429.3	11591
3	136.1	7.95	50.02	1082.0	54122
				1940.6	77304

$$\bar{x}' = \frac{77304}{1940.6} = 39.84\,mm$$

S16 12.3.3.4

$$\frac{\bar{x}'}{L_w} = \frac{39.84}{400} = 0.10$$

$$\therefore \quad A_{ne} = A_n \quad \text{as} \quad \frac{\bar{x}'}{L_w} \leq 0.10$$

$$\underline{A_{ne} = 3730\ mm^2}$$