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Design tension member + end connections for $T_f = 800\,kN$.

Angles & plates - 300W $F_y = 300\,MPa$
$F_u = 440\,MPa$

HSS 350W $F_y = 350\,MPa$
$F_u = 450\,MPa$

Bolts A325 $F_u = 825\,MPa$
Welds E49xx $X_u = 490\,MPa$

1. Main Member

Estimate $A_n = 0.9 A_g$
$A_{ne} = 0.85\,A_n$

from net area fracture

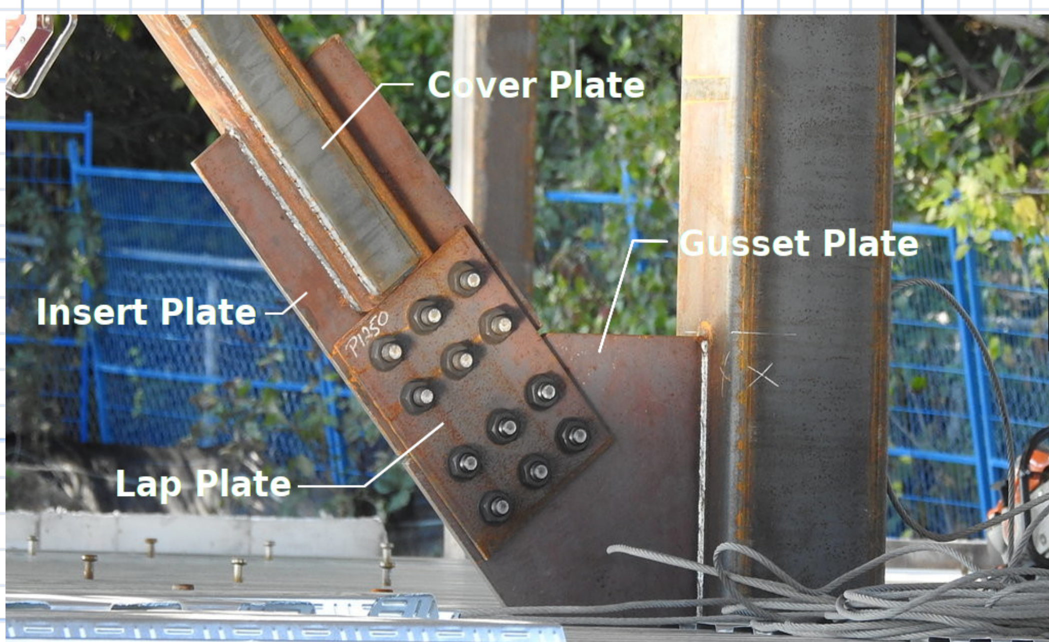
$$T_r = \phi_u A_{ne} F_u$$
$$= \phi_u \times 0.85 \times 0.9 \times A_g \times 0.45 \frac{kN}{mm^2} \geq 800\,kN$$

$$A_g \geq 2582\,mm^2$$

Try HSS 127×127×6.4

$$A = 2960\,mm^2$$

In an arrangement similar to this:



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Bolting details

min spacing = $2.7 \times 19.05 = 51.4$ mm. §22.3.1

min edge = 25 mm (rolled edge) Table 6
32 mm (cut edge)

min end distance = 32 mm (cut end) Table 6

max edge distance = $12t \leq 150$ §22.3.3

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2. Bolting Requirements

$\frac{3}{4}$" A325 bolts in 22mm punched holes

bearing-type connection, threads intercepted

$A_b = \pi \times (\frac{3}{4} \times 25.4)^2 / 4 = 285\ mm^2$ Double Shear

1 bolt: $V_r = 0.6\,\phi_b\, n\, m\, A_b\, F_u \times 0.7$

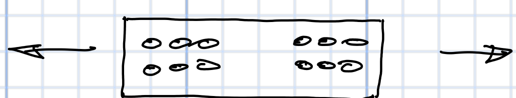
$= 0.6 \times 0.8 \times 1 \times 2 \times 285\ mm^2 \times 0.825 \frac{kN}{mm^2} \times 0.7$

$= 158\ kN$ (or see Table 3-4)

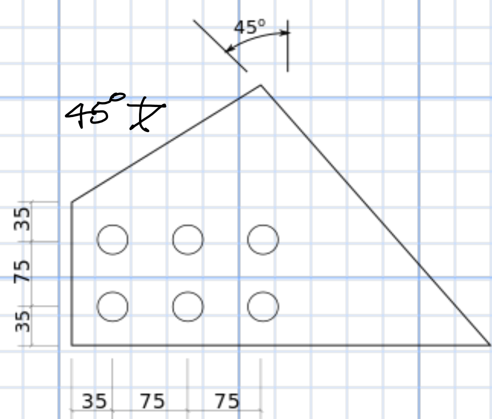
$\#$ of bolts reqd $= \frac{800}{158} = 5.06$

Try 6 bolts in a 2x3 pattern.

(to keep connection narrow)



3. Gusset Plate



Compute capacity of 1mm thick,

then compute reqd thickness.

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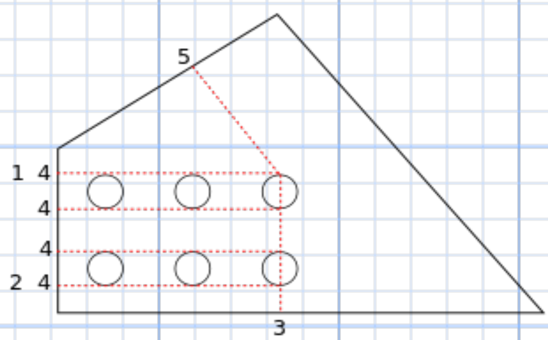

3.1 Block Shear – Path 1–2

$A_n = (75 - \frac{24}{2} \times 2) \times 1 = 51 \ mm^2$

$U_t = 1.0$

$A_{gv} = 2 \times (35 + 75 + 75) \times 1 = 370 \ mm^2$

$v_{r_1} = 0.75 \left[1 \times 51 \times .44 + .6 \times 370 \times \frac{.30 + .44}{2} \right]$

$= 78.44 \ kN / mm$ of thickness

3.2 Block Shear - Path 1-3

$A_n = (35 + 75 - \frac{24}{2} \times 3) \times 1 = 74 \ mm^2$

$U_t = 0.6$ (conservative)

$A_{gv} = 1 \times (35 + 75 + 75) \times 1 = 185 \ mm^2$

$v_{r_2} = 0.75 (0.6 \times 74 \times .44 + .6 \times 185 \times .37)$

$= 45.45 \ kN / mm$ ⟵ governs

3.3 Tearout - Path 4-4-4-4

$A_n = 0$

$A_{gv} = 4 \times 185 = 740 \ mm^2$

$v_{r_3} = .75 \times .6 \times 740 \times .37$

$= 123 \ kN / mm$

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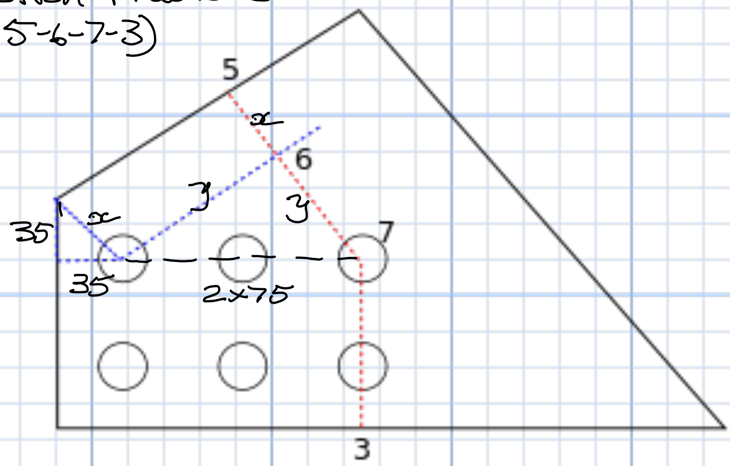
3.4 Net Section Fracture
(Path 5-6-7-3)

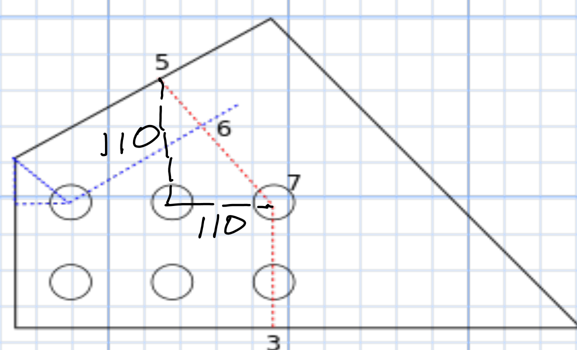


$$\text{dist } 5\text{-}6 = x = \sqrt{35^2 + 35^2} = 49.5 \text{ mm}$$

$$\text{dist } 6\text{-}7 = y = 150/\sqrt{2} = 106.1 \text{ mm}$$

$$\text{dist } 5\text{-}7 = x + y = 155.6 \text{ mm}$$

$$\text{dist } s = g = \frac{155.6}{\sqrt{2}} = 110 \text{ mm}$$



$$A_{ne} = \left(35 + 75 + 155.6 - 2 \times 24 + \frac{110^2}{4 \times 110}\right) \times 1$$

$$= 245.1 \text{ mm}^2$$

$$tr_{+} = 0.75 \times 245.1 \times 0.44$$

$$= 80.87 \text{ kN / mm of thickness}$$

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3.5 Bearing Resistance

$$B_r = 3\phi_{br} \times n \times d \times t \times F_u$$
$$= 3 \times 0.8 \times 6 \times 19.05 \times 1 \times .440$$
$$= 120.7 \text{ kN}$$

Block Shear path 1-3 governs

$$T_r = 45.45 \text{ kN / mm}$$

Req'd thickness

$$\frac{800}{45.45} = 17.6 \text{ mm.}$$

3.7 Try 20 mm Gusset Plate

4. Insert Plate

Plate - slotted into HSS - must be same thickness as gusset

Width required:

4.1 - Gross Area Yield:

$$0.9 \times wt \times 0.30 \geq 800$$
$$w \geq 148 \text{ mm.}$$

4.2 - Net section Fracture

$$0.75(w - 2 \times 24) \times 20 \times 0.44 \geq 800$$
$$w \geq \frac{800}{.75 \times 20 \times .44} + 48$$
$$w \geq 169 \text{ mm.}$$

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this leads to edge dist of $\frac{169-75}{2} = 50$ mm.

Might be better to use 3x2 arrangement

reqid width, net section fracture

$$w \geq \frac{800}{.75 \times 20 \times .44} + 3 \times 24$$

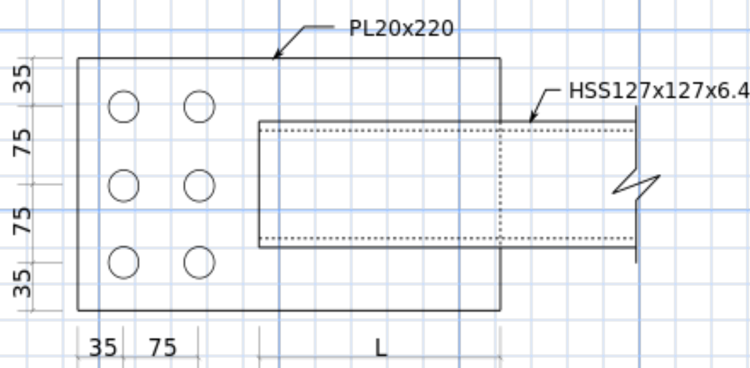
$$w \geq 193.2 \text{ mm.}$$

using min edge distance

$$w = 32 + 75 + 75 + 32 = 214 \text{ mm.}$$

4.3 try 220 mm wide plate

35 mm edge distance
35 mm end distance



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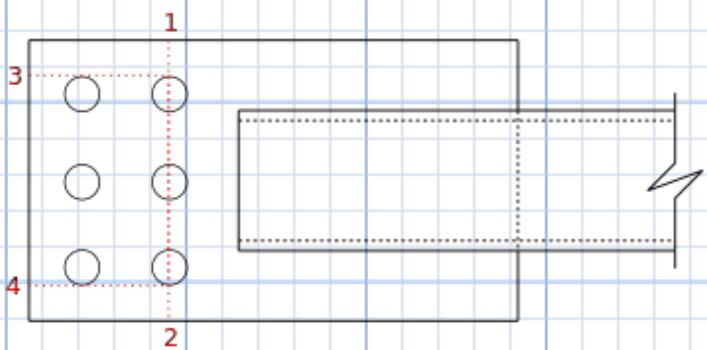
5. Insert Plate - Bolted End



Gross Area Yield OK (from above)

Net Sect Fracture Ok (from above)

5.1 Block Shear - Path 3-2

$A_n = (75+75+35 - 2.5\times24)\times20 = 2500 \text{ mm}^2$

$U_t = 0.6$

$A_{gv} = (35+75)\times20 = 2200 \text{ mm}^2$

$T_r = 0.75\left[0.6\times2500\times.44 + 0.6\times2200\times\frac{.3+.44}{2}\right]$

$= 861 \text{ kN} > 800 \text{ kN}$ OK

5.2 Block Shear - Path 3-4

$A_n = (75+75 - 2\times24)\times20 = 2040 \text{ mm}^2$

$U_t = 1.0$

$A_{gv} = 2\times(35+75)\times20 = 4400 \text{ mm}^2$

$T_r = 0.75[1\times2040\times.44 + .6\times4400\times.37]$

$= 1406 > 800 \text{ kN}$ OK

5.3 Tearout

$A_n = 0$

$A_{gv} = 6(35+75)\times20 = 13200 \text{ mm}^2$

$T_r = 0.75\times0.6\times13200\times.37$

$= 2198 \text{ kN} > 800 \text{ kN}$ OK

5.4 Bearing

OK (from 3.5, above)

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6. Insert Plate – Welded End

6.1 Size, and Length, L, of Weld

Min weld size, $t = 20\,mm$

for $12 \le t \le 20$ $\quad D_{min} = 6$ $\quad$ (p 6-186)

Longer welds are preferable wrt shear lag in the HSS. Therefore use min size weld

$D = 6\,mm.$

1 mm of 6mm fillet weld, $\theta = 0°$

$v_r = 0.67\,\phi_w\,A_w\,X_u$ $\quad$ § 13.13.2.2

$= 0.67 \times 0.67 \times 0.707 \times 6 \times 1 \times 0.49$

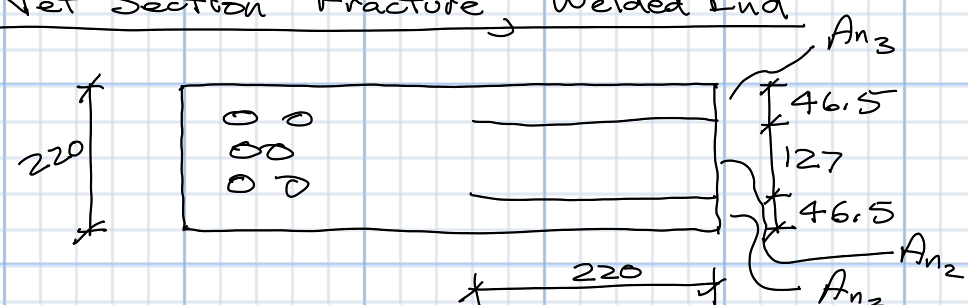
$v_r = 0.933\ kN$ $\quad$ (also see Table 3-24b)

$4L \times 0.933 \geq 800$

$L \geq 214.2\ mm.$

Try 220 mm of weld in 4 locations

6.3 Net Section Fracture, Welded End



A_{n2} $\quad w = 127$
$\quad L = 220$
$\quad t = 20$

$2w \geq L \geq w$

$\therefore A_{n2} = .5wt + .25Lt$ $\quad$ § 12.3.3.3. b) ii)

$= .5 \times 127 \times 20 + .25 \times 220 \times 20$

$= 2370\ mm^2$

A_{n_3}:
$w = 46.5$
$L = 220$
$t = 20$

$\bar{x} = \frac{w}{2} = 23.25$

$A_{n_3} = \left(1 - \frac{23.25}{220}\right) \times 46.5 \times 20$

$A_{n_3} = 831.7 \text{ mm}^2$

$A_{ne} = 2A_{n_3} + A_{n_2}$

$= 2 \times 831.7 + 2370$

$= 4033 \text{ mm}^2$

$T_r = 0.75 A_{ne} F_u$

$= 0.75 \times 4033 \times 0.44$

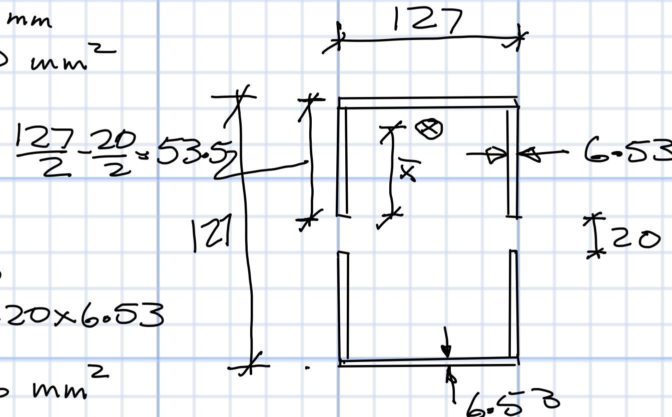
$= 1331 \text{ kN} > 800 \text{ kN}$ OK.

∴ Insert Plate OK

7. HSS Net Section Fracture

HSS $127 \times 127 \times 6.4$

$t = 6.53$ mm
$A_g = 2960 \text{ mm}^2$



$A_n = 2960 - 2 \times 20 \times 6.53$

$= 2706 \text{ mm}^2$

From § 12.3.3.4

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Fig on page 7-88 CISC HB
with $d = 127$
$b = 53.5$
$t = w = 6.35$
$A = dw + 2(b-w)t = 1405$
$\bar{x} = b - x$
$= 53.5 - \frac{1}{2A}\left((d-2t)w^2 + 2tb^2\right)$
$= 38.93\ mm$

$\bar{x}/L = 38.93/220 = 0.177$

$\bar{x}/L > 0.1$

$\therefore A_{ne} = (1.1 - 0.177)A_n$
$= 0.923 \times 2706$
$= 2498\ mm^2 > 0.8A_n$

$T_r = 0.75 \times 2498 \times 0.45$
$\underline{T_r = 843\ kN > 800\ kN}$ OK

$\therefore$ HSS is OK