

CVG3547 Solution for Assignment on Tension Member Design

Slenderness:	$l / r_{\min} \leq 300$
Yield Limit State	$T_r = \phi A_g F_y$
Fracture Limit State	$T_r = \phi_u A_n F_u$

$$l = 4,000 \text{ mm}$$

$$F_y = 300 \text{ MPa}$$

$$F_u = 450 \text{ MPa}$$

Since there are no holes for welded connections, we have $A_n = A_g$

$$\text{Slenderness requirement: } 4000/r_{\min} \leq 300 \Rightarrow \boxed{r_{\min} \geq 13.3\text{mm}}$$

Yield limit state:

$$T_{r1} (kN) = 0.9 \times A_g (mm^2) \times 300 (N / mm^2) \times 10^{-3} (kN / N) = 0.270 A_g (mm^2)$$

Fracture limit state:

$$T_{r2} (kN) = 0.75 \times A_g (mm^2) \times 450 (N / mm^2) \times 10^{-3} (kN / N) = 0.3375 A_g (mm^2)$$

$$T_r (kN) = \min(T_{r1}, T_{r2}) = 0.270 A_g (mm^2)$$

Thus, yield limit state is more critical than fracture and the required area is given by:

$$\boxed{A_{g-req} = T_r (kN) / 0.270 (mm^2)}$$

80 kN Load:

Required gross area $A_{g-req} \geq 80 / 0.270 = 296 \text{mm}^2$

i) Single Angle: Use L76x64x4.8

$$A = 643 \text{mm}^2$$

$$r_x = 24.2 \text{mm}, r_y = 19.3 \text{mm}, r_x' = 27.9, r_y' = 13.5 \text{mm} \Rightarrow r_{\min} = 13.5 \text{mm}$$

Maximum slenderness ratio:

$$L / r_{\min} = 4000 / 13.5 = 297 < 300$$

Resistance based on yield strength:

$$T_{r1} = \phi A_g F_y = 0.9 \times 643 \times 300 \times 10^{-3} = 173 \text{kN} \gg 80 \text{kN}$$

Resistance based on fracture:

$$T_{r1} = \phi_u A_n F_u = 0.75 \times 643 \times 450 \times 10^{-3} = 217 \text{kN} \gg 80 \text{kN}$$

Slenderness requirement governs the design

ii) Wide Flange Use W150x13

$$A = 1630 \text{mm}^2$$

$$r_x = 61.7 \text{mm}, r_y = 22.5 \text{mm}$$

Maximum slenderness ratio:

$$L / r_{\min} = 4000 / 22.5 = 178 \ll 300$$

Resistance based on yield strength:

$$T_{r1} = \phi A_g F_y = 0.9 \times 1630 \times 300 \times 10^{-3} = 440 \text{kN} \gg 80 \text{kN}$$

Resistance based on fracture:

$$T_{r1} = \phi_u A_n F_u = 0.75 \times 1630 \times 450 \times 10^{-3} = 550 \text{kN} \gg 80 \text{kN}$$

All W-sections satisfy the slenderness and the area required. Thus, the lightest W section is selected.

iii) **HSS:** Use HSS 38x38x3.2

$$A = 382\text{mm}^2$$

$$r = 14.2\text{mm}$$

Maximum Slenderness ratio:

$$L / r_{\min} = 4000 / 14.2 = 282 < 300$$

Resistance based on Yield strength:

$$T_{r1} = \phi A_g F_y = 0.9 \times 382 \times 300 \times 10^{-3} = 103\text{kN} > 80\text{kN}$$

Resistance based on Fracture:

$$T_{r1} = \phi_u A_n F_u = 0.75 \times 382 \times 450 \times 10^{-3} = 128\text{kN} > 80\text{kN}$$

All of the HSS-sections satisfy the slenderness and the area required. Thus, the lightest HSS section is selected.

630 kN Load

$$A_{g\text{-req}} \geq 630^3 / 0.270 = 2,333\text{mm}^2$$

i) **Single Angle** Use L127x127x9.5

$$A = 2,330\text{mm}^2 \quad r_x = 39.5\text{mm}, \quad r_y = 39.5\text{mm}, \quad r_x' = 49.9, \quad r_y' = 25.1\text{mm} \Rightarrow r_{\min} = 25.1\text{mm}$$

Maximum Slenderness ratio:

$$L / r_{\min} = 4000 / 25.1 = 160 \ll 300$$

Resistance based on Yield strength:

$$T_{r1} = \phi A_g F_y = 0.9 \times 2330 \times 300 \times 10^{-3} = 629\text{kN} \approx 630\text{kN}$$

The section marginally attains the required yield strength.

Resistance based on Fracture:

$$T_{r1} = \phi_u A_n F_u = 0.75 \times 2330 \times 450 \times 10^{-3} = 786\text{kN} > 630\text{kN}$$

Minimum area governs the design

ii) Wide Flange Use W100x19

$$A = 2470 \text{ mm}^2$$

$$r_x = 43.9 \text{ mm}, r_y = 25.5 \text{ mm}$$

Maximum Slenderness ratio:

$$L / r_{\min} = 4000 / 25.5 = 157 \ll 300$$

Resistance based on Yield strength:

$$T_{r1} = \phi A_g F_y = 0.9 \times 2470 \times 300 \times 10^{-3} = 666 \text{ kN} > 630 \text{ kN}$$

Resistance based on Fracture:

$$T_{r1} = \phi_u A_n F_u = 0.75 \times 2470 \times 450 \times 10^{-3} = 833 \text{ kN} > 630 \text{ kN}$$

Minimum area governs the design.

iii) HSS: Use HSS 152x76x6.4

$$A = 2400 \text{ mm}^2$$

$$r_x = 53.6 \text{ mm}, r_y = 31 \text{ mm}$$

Maximum Slenderness ratio:

$$L / r_{\min} = 4000 / 31 = 129 \ll 300$$

Resistance based on Yield strength:

$$T_{r1} = \phi A_g F_y = 0.9 \times 2400 \times 300 \times 10^{-3} = 648 \text{ kN} > 630 \text{ kN}$$

Resistance based on Fracture:

$$T_{r1} = \phi_u A_n F_u = 0.75 \times 2400 \times 450 \times 10^{-3} = 810 \text{ kN} > 630 \text{ kN}$$

Minimum area governs the design.

1000 kN Load

$$A_{g-req} \geq 1000 / 0.270 = 3704 \text{ mm}^2$$

i) Single Angle: Use L152x152x13

$$A = 3710 \text{ mm}^2$$

$$r_x = 47.1 \text{ mm}, r_y = 47.1 \text{ mm}, r_x' = 59.5 \text{ mm}, r_y' = 30 \text{ mm} \Rightarrow r_{\min} = 30 \text{ mm}$$

Maximum Slenderness ratio:

$$L / r_{\min} = 4000 / 30 = 133 \ll 300$$

Resistance based on Yield strength:

$$T_{r1} = \phi A_g F_y = 0.9 \times 3710 \times 300 \times 10^{-3} = 1001 \text{ kN} > 1000 \text{ kN}$$

Resistance based on Fracture:

$$T_{r1} = \phi_u A_n F_u = 0.75 \times 3710 \times 450 \times 10^{-3} = 1252 \text{ kN} > 1000 \text{ kN}$$

Minimum area governs the design

ii) Wide Flange: Use W150x30

$$A = 3790 \text{ mm}^2$$

$$r_x = 67.3 \text{ mm}, r_y = 38.3 \text{ mm}$$

Maximum Slenderness ratio:

$$L / r_{\min} = 4000 / 38.3 = 105 \ll 300$$

Resistance based on Yield strength:

$$T_{r1} = \phi A_g F_y = 0.9 \times 3790 \times 300 \times 10^{-3} = 1023 \text{ kN} > 1000 \text{ kN}$$

Resistance based on Fracture:

$$T_{r1} = \phi_u A_n F_u = 0.75 \times 3790 \times 450 \times 10^{-3} = 1279 \text{ kN} > 1000 \text{ kN}$$

Minimum area governs the design.

iii) HSS: Use HSS 102x102x13

$$A = 3790 \text{ mm}^2$$

$$r = 35.9 \text{ mm}$$

Maximum Slenderness ratio:

$$L / r_{\min} = 4000 / 35.9 = 112 \ll 300$$

Resistance based on Yield strength:

$$T_{r1} = \phi A_g F_y = 0.9 \times 3790 \times 300 \times 10^{-3} = 1023 \text{ kN} > 1000 \text{ kN}$$

Resistance based on Fracture:

$$T_{r1} = \phi_u A_n F_u = 0.75 \times 3790 \times 450 \times 10^{-3} = 1279 \text{ kN} > 1000 \text{ kN}$$

Minimum area governs the design.

Factored Tensile force (kN)	Section Designation	Gross Area (mm^2)	Maximum slenderness (S)	Yield strength (Y) (kN)	Fracture capacity (F) (kN)	Governing mode of failure	Is chosen section <u>type</u> economic?
80	L76x64x4.8	643	297	173	217	S	Yes
80	W150x13	1630	178	440	550	none	No
80	HSS 38x38x3.2	382	282	103	128	S	Yes
630	L127x127x9.5	2330	160	629	786	Y	Yes
630	W100x19	2470	157	666	833	Y	Yes
630	HSS 152x76x6.4	2400	129	648	810	Y	Yes
1000	L152x152x13	3710	133	1001	1252	Y	Yes
1000	W150x30	3790	105	1023	1279	Y	Yes
1000	HSS 102x102x13	3790	112	1023	1279	Y	Yes