Example 5.14.1: Determine the effective throat dimension of a $\frac{7}{16}$ in fillet weld made by (a) shielded metal arc welding (SMAW) and (b) submerged arc welding (SAW), in accordance with the AISC specification.

Soln: (a) For shielded metal arc welding (SMAW),

$$t_e = 0.707 a$$

$$= 0.707 \times \left(\frac{7}{16}\right)$$

$$= 0.309 \text{ in}$$

(Ans:)

(b) Since consistent penetration beyond the root of the weld has not been demonstrated by test,

t_e is equal to 0.309 in.

(Ans:)

Example 5.14.2 : Determine the design shear strength ϕR_{nw} of a $\frac{3}{8}$ in. fillet weld produced by (a) shielded metal arc welding, and (b) submerged arc welding. Assume E70 electrodes having minimum tensile strength F_{EXX} of 70 ksi are used, according to the AISC specification.

Soln: (a) SMAW process, $t_e = 0.707\,a$

$\Rightarrow t_e = 0.707 \times \frac{3}{8}$

$\therefore t_e = 0.265$ in

Now, Design shear strength, $\phi R_{nw} = \phi t_e (0.60 F_{EXX})$

$\Rightarrow \phi R_{nw} = 0.75 \times (0.265) \times (0.60 \times 70)$

$\therefore \phi R_{nw} = 8.35$ kips/in (Ans:)

(b) SAW process, same as in part (a)

Example 5.14.3: Determine the design shear strength ϕR_n for a $\frac{3}{4}$ in diam plug weld using E70 electrode material. Use the AISC specification.

Sol^n: Assuming the weld diameter 'D' satisfies the limitations of AISC-J2.3b relating to the dimension of the piece in which the plug weld is made,

Design shear strength, $\phi R_n = 0.75$ (area of faying surface, $\frac{\pi D^2}{4}$) $(0.60 F_{Exx})$

$$= 0.75 \times \frac{\pi}{4} \times \left(\frac{3}{4}\right)^2 \times 0.60 \times 70$$

$$= 13.9 \text{ kips}$$

(Ans:)

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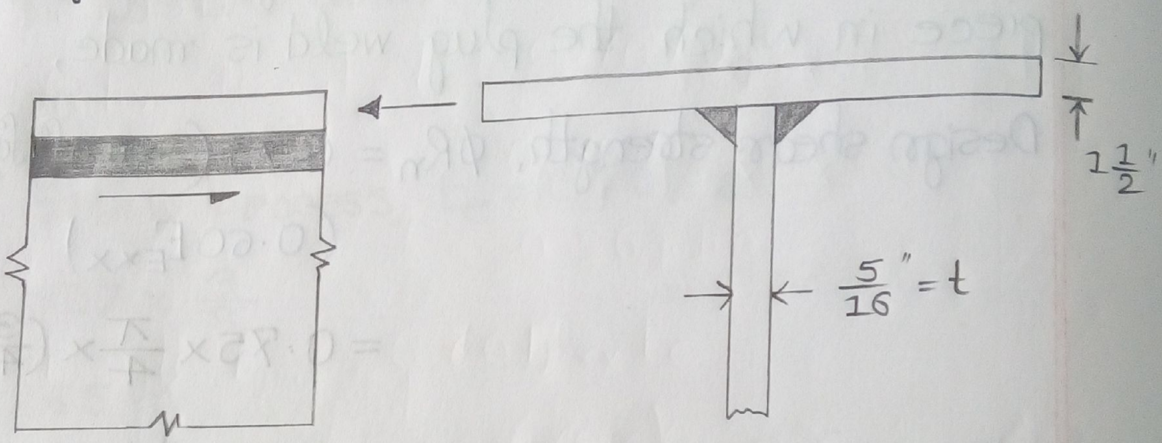
Example 5.14.4: Determine the design shear strength ϕR_{nw} to be used for the flange to web connection in the figure. The plates are A36 steel and electrodes having $F_{EXX} = 70$ ksi are to be used with shielded metal arc welding (SMAW).

Sol^n:



Here, material thickness of thicker part joined is $1\frac{1}{2}$" which is over $\frac{3}{4}$"

So, Minimum size of fillet weld, $a_{min} = \frac{5}{16}$"

Considering base metal (flange) strength governed by rupture,

$$a_{max,eff} = 0.707 \frac{F_u t_1}{F_{EXX}}$$

$$\Rightarrow a_{max,eff} = 0.707 \times \frac{58 \times \left(\frac{5}{16}\right)}{70}$$

$$\therefore a_{max,eff} = 0.183 \text{ in}$$

Now, Design shear strength, $\phi R_{nw} = 0.75\, t_e (0.60\, F_{Exx})$

$$\Rightarrow \phi R_{nw} = 0.75 \times (0.707 \times 0.183) \times 0.60 \times 70$$

$$\therefore \phi R_{nw} = 4.08 \text{ kips/in}$$

or, for two fillets, the design strength is $(2 \times 4.08) = 8.16$ kips/in

(Ans:)

Thus, even though a $\frac{5}{16}$" fillet weld must be placed its strength in design may not be exceeded by the strength assumming $a = 0.183$" ($a_{max,eff}$).

Example 5.15.1 : Determine the allowable shear resistance of a $\frac{3}{8}$ in fillet weld produced by shielded metal arc process. Assume use of E70 electrodes having minimum tensile strength F_{Exx} of 70 ksi, and use AISC ASD method.

Sol^n : Effective throat, $t_e = 0.707a$

$$= 0.707 \times \frac{3}{8}$$

$$= 0.265 \text{ in}$$

Nominal strength, $R_{nw} = 0.60 F_{Exx} t_e$

$$= 0.60 \times 70 \times 0.265$$

$$= 11.1 \text{ kips/in}$$

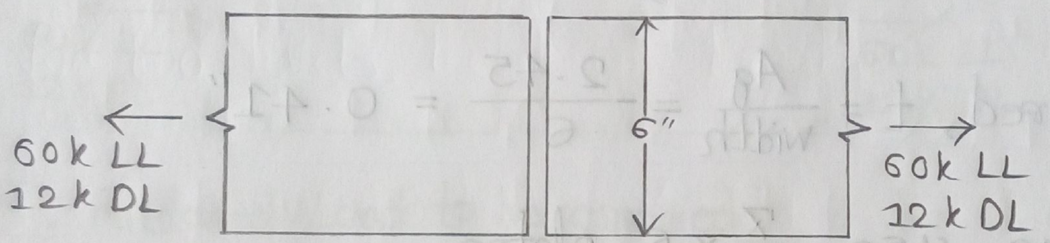
Allowable strength $= \frac{R_{nw}}{\Omega}$

$$= \frac{11.1}{2}$$

$$= 5.55 \text{ kips/in}$$

(Ans:)

Example 5.16.1 : For the plate tension member carrying axial service loads of 60 kips live load and 12 kips dead load, select the required thickness of the plates (A572 Grade 50 steel), the proper electrode material, and specify a proper AWS prequalified groove joint. Use AISC LRFD method.



Sol^n: Factored Load to be carried,

$$T_u = 1.2\,DL + 1.6\,LL$$

$$= 1.2 \times 12 + 1.6 \times 60$$

$$= 110.4\,\text{kips}$$

For computing the thickness required for the plates,

$$\phi T_n = \phi F_y A_g = 0.90(50)\,A_g \quad \text{(yielding limit state)}$$

$$\phi T_n = \phi F_u A_e = 0.75(65)\,A_e \quad \text{(fracture limit state)}$$

Since, there are no holes and no eccentricity of loading the effective net area A_e equals the gross area A_g.

Thus, from the above two equations it is noted that

$0.90(50) < 0.75(65)$;

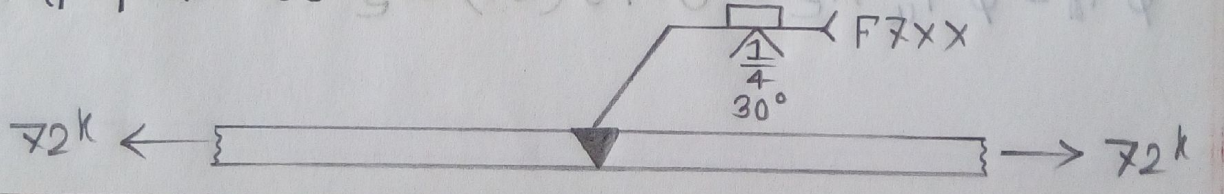
Therefore,

Required, $A_g = \frac{T_u}{0.9(50)} = \frac{110.4}{0.90 \times 50} = 2.45 \text{ in}^2$

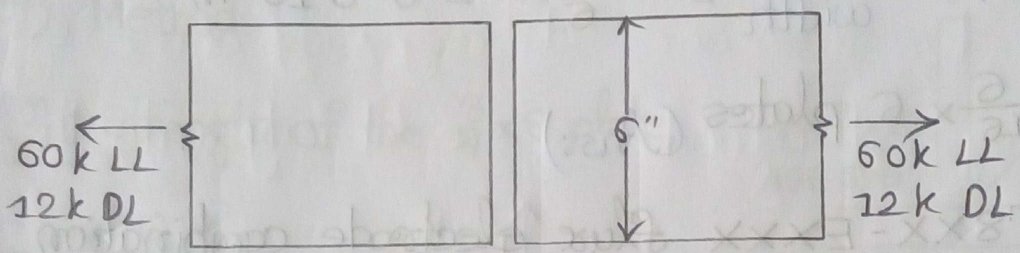
Required, $t = \frac{A_g}{\text{width}} = \frac{2.45}{6} = 0.41''$

Hence, use $\frac{7}{16} \times 6$ plates (Ans:)

Use F7XX, EXXX ($F_{EXX} = 70$ ksi) flux electrode combination. Refering to AISC Manual, select a prequalified single V-groove weld designated "B-L2a-S." The designation B refers to a butt joint, L refers to limited thickness of material for this weld (2" max^m) and S refers to submerged arc welding. This weld requires that a backup plate be used.



Example 5.16.2 : For the plate tension member carrying axial service loads of 60 kips live load and 12 kips dead load, select the required thickness of the plates using A572 Grade 65 plates, a square-groove weld, and submerged arc welding (SAW).



Sol^n: Factored Load to be carried,

$$T_u = 1.2DL + 1.6LL$$
$$= 1.2 \times 12 + 1.6 \times 60$$
$$= 110.4 \text{ kips}$$

For computing the thickness required for the plates,

$$\phi T_n = \phi F_y A_g = 0.9(65) A_g \quad \text{(yielding limit state)}$$

$$\phi T_n = \phi F_u A_e = 0.75(80) A_e \quad \text{(rupture limit state)}$$

Since, there are no holes and no eccentricity of loading the effective net area A_e equals the gross area A_g.

Thus, from the above two equation it is noted that

$0.90(65) < 0.75(80)$;

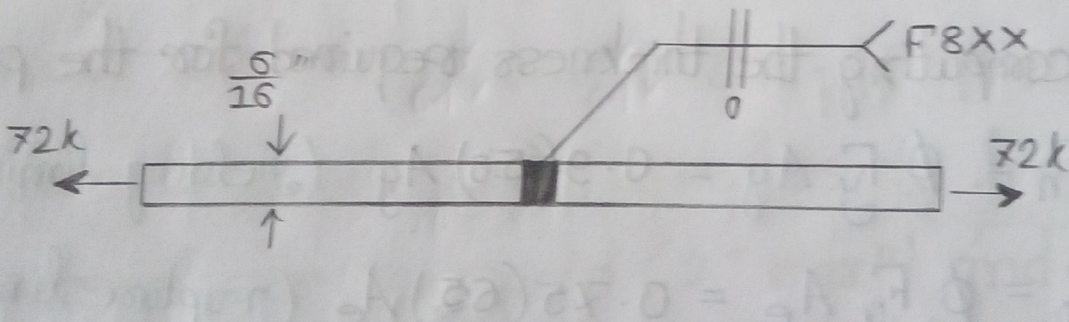
Therefore,

$$\text{Required, } A_g = \frac{T_u}{\phi F_y} = \frac{110.4}{0.90(65)} = 1.89 \text{ in}^2$$

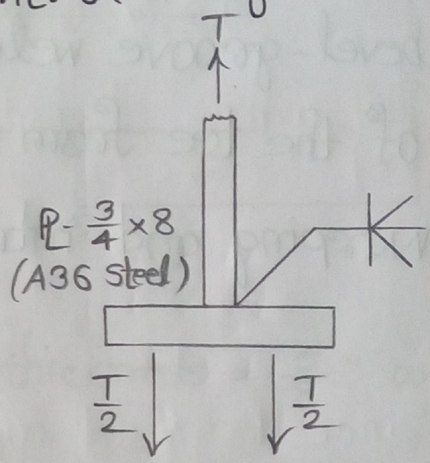
$$\text{Required, } t = \frac{A_g}{\text{width}} = \frac{1.89}{6} = 0.315 \text{ in}$$

Use $\frac{6}{16} \times 6$ plates (Ans:)

Use F8XX-EXXX flux electrode combination. From AISC Manual, select the square-groove weld designated B-L1-S as indicated in the figure. This weld has zero root opening and is prequalified for material no thicker than $\frac{3}{8}$ in.



Example 5.16.3 : Determine the service load capacity, assuming the load is 80% live load, of the tee connection shown in Figure 5.16.3 and detail the proper double-bevel-groove weld for the SMAW process. Assume the flange of the tee does not control design. Use AISC LRFD Method.



Soln: Strength of the $\frac{3}{4}\times 8$ plate,

$$\phi T_n = \phi F_y A_g$$

(yielding governs)

$$= 0.90\times \quad \times\left(\frac{3}{4}\times 8\right)$$

$$= 194.4 \text{ kips}$$

Again, $T_u = 1.2\,DL + 1.6\,LL$

$$= 1.2(0.2T) + 1.6(0.8T)$$

$$= 1.52T$$

Now, $\phi T_n = T_u$

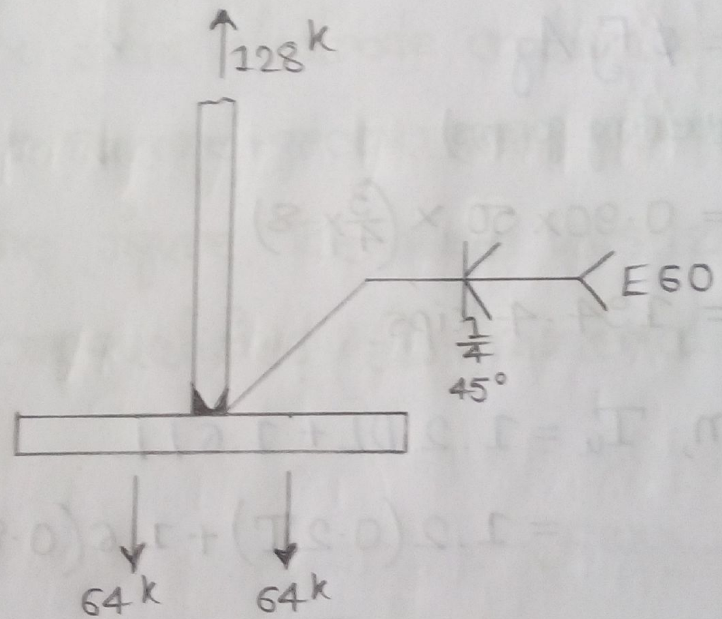
$\Rightarrow 194.4 = 1.52\,T$

$\therefore$ $T = 128$ kips is the service load capacity

(Ans:)

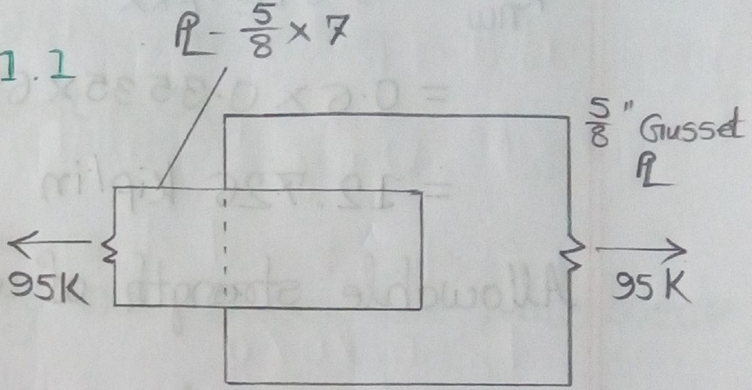
Use E60 electrodes. From the AISC Manual, select the double-bevel-groove joint designated TC-U5a.

Note: On the basis of strength only, a single $\frac{3}{4}$ in bevel (TC-U4b) could have been used instead of the double-bevel-groove weld specified. However, welding the stem of the tee from one side only may cause excessive warping and introduces eccentricity into the connection



Solution

Example 5.16.4 : Determine the size and length of the fillet weld for the lap joint shown in the figure if the plates are A36 steel. Use AISC LRFD and ASD method.



Solⁿ : According to Table 5.11.1

Material thickness of thicker part joined, $t_{max} = \frac{5}{8}$"

So, Minimum size of fillet weld, $S_{min} = \frac{1}{4}$"

Now, as along edges of material thickness $= \frac{5}{8}$" which is $> \frac{1}{4}$",

So, Maximum size of fillet weld,

$S_{max} = \left(\frac{5}{8} - \frac{1}{16}\right) = \frac{9}{16}$"

Use $\frac{1}{2}$" fillet weld, the effective throat dimension te is taken as,

$t_e = 0.707\,a$

$= 0.707 \times \frac{1}{2}$

$= 0.3535$"

Choose E60XX weld, $F_{EXX} = 60$ ksi.

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AISC ASD Method: The nominal strength of $\frac{1}{2}$" fillet weld per inch of length,

$$R_{nw} = 0.6 t_e F_{Exx}$$

$$= 0.6 \times 0.3535 \times 60$$

$$= 12.726 \text{ kip/in}$$

Allowable strength of weld $= \frac{R_{nw}}{\Omega}$

$$= \frac{12.726}{2} \text{ kip/in}$$

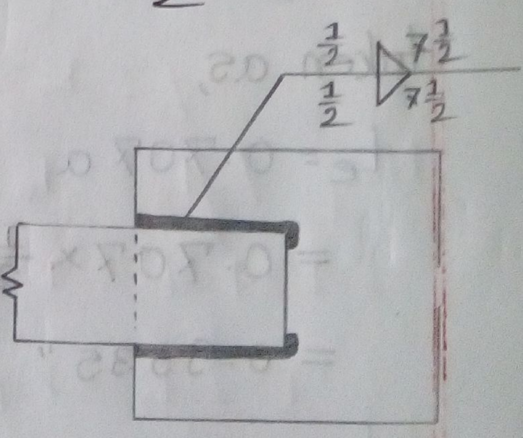
$$= 6.362 \text{ kip/in}$$

Since the weld capacity may not exceed the shear or rupture strength of plate,

Max^m plate shear, $\frac{R_n}{\Omega} = \frac{t(0.60 F_y)}{1.5} = \frac{\frac{5}{8} \times 0.6 \times 36}{1.5} = 9$ kip/in

Max^m plate rupture, $\frac{R_n}{\Omega} = \frac{t(0.60 F_u)}{2} = \frac{\frac{5}{8} \times 0.6 \times 58}{2} = 10.88$ kip/in

∴ Weld strength controls.



Weld length $= \frac{T_n}{\left(\frac{R_n}{\Omega}\right)}$

$$= \frac{95}{6.362}$$

$$= 14.93"$$

Use $7\frac{1}{2}$" on each side.

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AISC LRFD Method : The design strength of $\frac{1}{2}$" fillet weld per inch of length,

$$\phi R_{nw} = \phi t_e (0.60 F_{Exx})$$

$$= 0.75 \times 0.3535 \times (0.60 \times 60)$$

$$= 9.54 \text{ kip/in}$$

Since the weld capacity may not exceed the plate shear or rupture strength,

Max^{m} plate shear, $\phi R_n = \phi t(0.60 F_y) = 1 \times \frac{5}{8} \times (0.6 \times 36) = 13.5$ kip/in

Max^{m} plate rupture, $\phi R_n = \phi t(0.60 F_u) = 0.75 \times \frac{5}{8} \times (0.6 \times 58) = 16.3$ kip/in

∴ Weld strength controls.

Factored tensile load, $T_u = 1.2 DL + 1.6 LL$

$$= 1.2 \times 25 + 1.6 \times 70$$

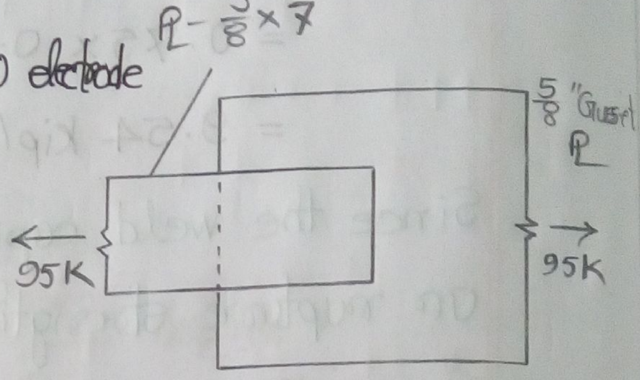
$$= 142 \text{ kips}$$

Total length of fillet weld required,

$$L_w = \frac{T_u}{\phi R_n} = \frac{142}{9.54} = 14.88"$$

Use $7\frac{1}{2}$" weld on each side.

Example 5.16.5: Determine the length of the fillet weld of $\frac{1}{4}$" size for the lap joint shown using SAW process if the plates are A36 steel. Use AISC LRFD method.



Soln: Using $\frac{1}{4}$" fillet weld, E60 electrode

Effective throat dimension,

$$t_e = 0.707\,a$$

$$= (0.707 \times \tfrac{1}{4})$$

$$= 0.177''$$

Design strength of weld, $\phi R_{nw} = \phi t_e (0.60 F_{Exx})$

$$= 0.75 \times 0.177 \times (0.6 \times 60)$$

$$= 4.78 \text{ kips/in}$$

which is well below shear plate strength of 13.5 kips/in.

So, Length of fillet weld required,

$$L_w = \frac{142}{4.78} = 29.71''$$

Use 15" on each side or, 7" transverse weld & $11\frac{1}{2}$" on each side.

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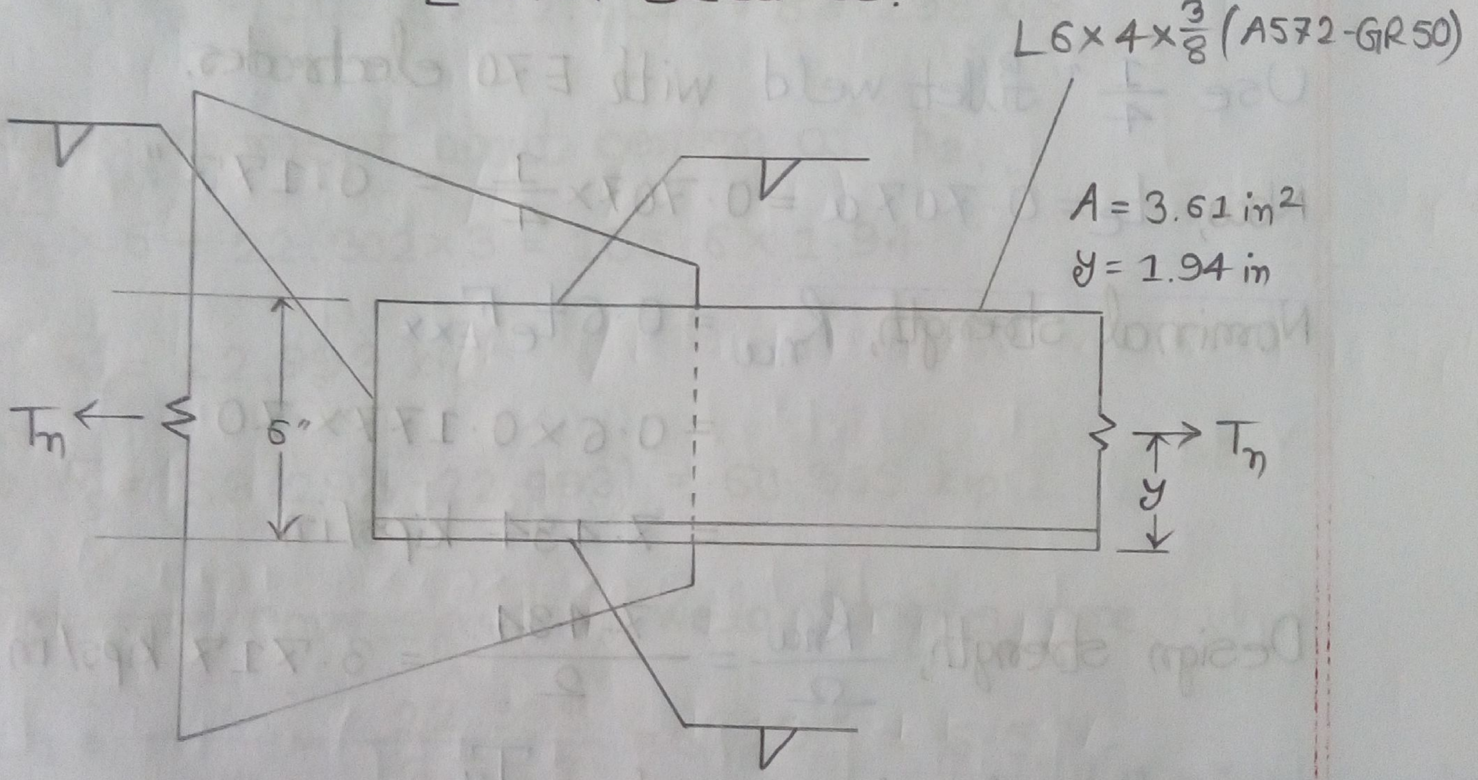
Example 5.16.6: Design the fillet welds to develop the full strength of the angle shown in figure minimizing the effect of eccentricity. Assume the gusset plate does not govern and the SMAW process is used. Use AISC LRFD & ASD method. Material A572-GR50: $F_y = 50$ ksi & $F_u = 65$ Ksi. Use E70XX electrode.



Soln: ASD Method: Determine strength of the angle.

Yield on gross area, $\frac{T_n}{\Omega} = \frac{F_y A_g}{\Omega} = \frac{50 \times 3.61}{1.67} = 108.1$ kip

Rupture on effective area, as weld length yet not known,

Let, $U = 0.90$

$$\frac{T_n}{\Omega} = \frac{F_u A_e}{\Omega} = \frac{F_u U A_g}{\Omega} = \frac{65 \times 0.9 \times 3.61}{2} = 105.6 \text{ kip (controls)}$$

Select weld size,

Minimum size fillet weld $= \frac{3}{16}''$

Maximum size fillet weld $= \left(\frac{3}{8} - \frac{1}{16}\right) = \frac{5}{16}''$

Use $\frac{1}{4}''$ fillet weld with E70 electrodes.

Now, $t_e = 0.707a = 0.707 \times \frac{1}{4} = 0.177''$

Nominal strength, $R_{nw} = 0.6 t_e F_{Exx}$

$$= 0.6 \times 0.177 \times 70$$

$$= 7.434 \text{ kips/in}$$

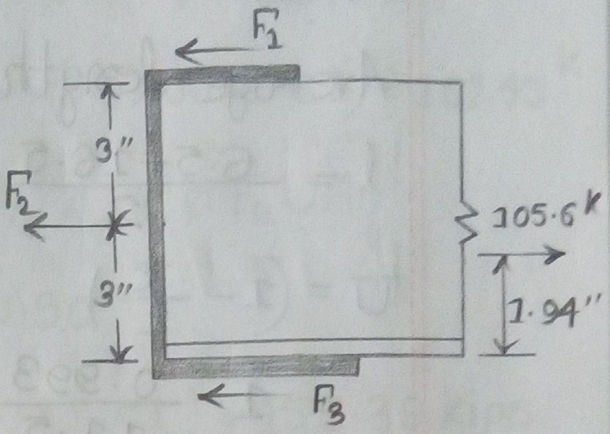
Design strength, $\frac{R_{nw}}{\Omega} = \frac{7.434}{2} = 3.717 \text{ kips/in}$

Total weld length required $= \frac{T_u}{R_{uw}}$

$$= \frac{105.6}{3.717}$$

$$= 28.41''$$

Force carried by the weld at the end of angle,



$F_2 = L_2 R_{uw}$

$= 6" \times 3.717$ kips/in

$= 22.302$ kips

$\therefore F_1 + F_3 = (105.6 - 22.302) = 83.298$ kips

Taking moment about center of F_3,

$F_1 \times 6 + 22.302 \times 3 = 105.6 \times 1.94$

$\therefore F_1 = 22.993$ kip

So, $F_3 = (83.298 - 22.993) = 60.305$ kip

Therefore corresponding weld lengths are,

$L_1 = \frac{F_1}{R_{uw}} = \frac{22.993}{3.717} = 6.19" \approx 6.5"$ (0.5" upper rounding)

$L_3 = \frac{F_3}{R_{uw}} = \frac{60.305}{3.717} = 16.22" \approx 16.5"$

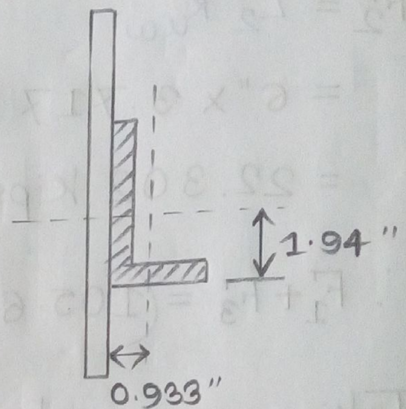
Final allowable weld capacity, $= 3.72 \times (16.5 + 6 + 6.5)$

$= 107.9$ kip

Check U :

Average length of weld in the direction of load

$l = \frac{6.5+16.5}{2} = 11.5''$



$U = \left(1 - \frac{\bar{x}}{l}\right)$

$= 1 - \frac{0.933}{11.5}$

$= 0.92 > 0.90$ (assumed)

So, $\frac{T_n}{\Omega} = \frac{F_u U A_g}{\Omega} = \frac{65 \times 0.92 \times 3.61}{2} = 107.9$ kip (just ok)

Check base material strength :

Yielding : $\frac{T_n}{\Omega} = \frac{0.6 t F_y L}{\Omega} = \frac{0.6 \times \frac{3}{8} \times 50 \times (6.5+6+16.5)}{1.5} = 217.5$ kip

Rupture : $\frac{T_n}{\Omega} = \frac{0.6 t F_u L}{\Omega} = \frac{0.6 \times \frac{3}{8} \times 65 \times (6.5+6+16.5)}{2} = 212.1$ kip

Base material strength (212.1 kip) is higher than the connection strength. (ok)

LRFD Method: Determine strength of the angle:

Yield on gross area: $\phi T_n = \phi F_y A_g = (0.9 \times 50 \times 3.61) = 162.45^k$

Rupture on effective area: $\phi T_n = \phi F_u A_e = \phi F_u U A_g$

As weld length not known, Let $U = 0.90$

So, $\phi T_n = \phi F_u U A_g = (0.75 \times 65 \times 0.90 \times 3.61) = 158.39$ kips (controls)

Select Weld Size:

Minimum size fillet weld $= \frac{3}{16}$"

Maximum size fillet weld $= \left(\frac{3}{8} - \frac{1}{16}\right) = \frac{5}{16}$"

Use $\frac{1}{4}$" fillet weld with E70 electrodes.

$t_e = 0.707a = 0.707 \times \frac{1}{4} = 0.177$"

Nominal Strength of weld, $R_{nw} = t_e(0.60 F_{Exx})$

$= 0.177 \times (0.60 \times 70)$

$= 7.434$ kips/in

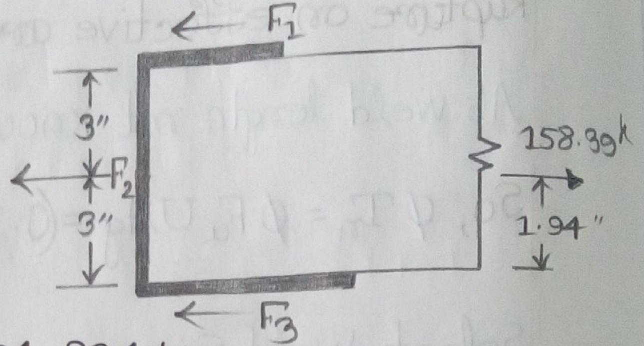
Design strength of weld, $\phi R_{nw} = \phi t_e (0.60 F_{Exx})$

$= 0.75 \times 7.434$

$= 5.576$ kips/in

Total weld length required, $L_w = \frac{\phi T_n}{\phi R_{nw}} = \frac{158.39}{5.576} = 28.41''$

Force carried by the weld at the end of angle,



$F_2 = L_2 \times \phi R_{nw}$

$= 6 \times 5.576$

$= 33.456$ kips

$\therefore F_1 + F_3 = (158.39 - 33.456) = 124.934$ kips

Taking moment about center of F_3 we have,

$F_1 \times 6 + 33.456 \times 3 = 158.39 \times 1.94$

$\therefore F_1 = 34.485$ kips

So, $F_3 = (124.934 - 34.485) = 90.449$ kips

Therefore corresponding weld lengths are,

$L_1 = \frac{F_1}{\phi R_{nw}} = \frac{34.485}{5.576} = 6.18'' \approx 6.5''$

(0.5" upper rounding)

$L_3 = \frac{F_3}{\phi R_{nw}} = \frac{90.449}{5.576} = 16.22'' = 16.5''$

Final allowable weld capacity $= \phi R_{nw} \times L_w$

$= 5.576 \times (6.5 + 6 + 16.5)$

$= 161.704$ kips

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Check U:

Average length of weld in the direction of load

$$l = \frac{6.5+16.5}{2} = 11.5''$$

$$U = \left(1 - \frac{\bar{x}}{l}\right) = \left(1 - \frac{0.933}{11.5}\right) = 0.92 > 0.9 \text{ (ok)}$$

Now, $\phi T_n = \phi F_u U A_g$

$$= 0.75 \times 65 \times 0.92 \times 3.61$$

$$= 161.91 \text{ kip (just ok)}$$

Check Base material strength:

Yielding: $\phi T_n = \phi t (0.6 F_y) L_w$

$$= 1 \times \frac{3}{8} \times (0.6 \times 50) \times (6.5+6+16.5)$$

$$= 326.25^k$$

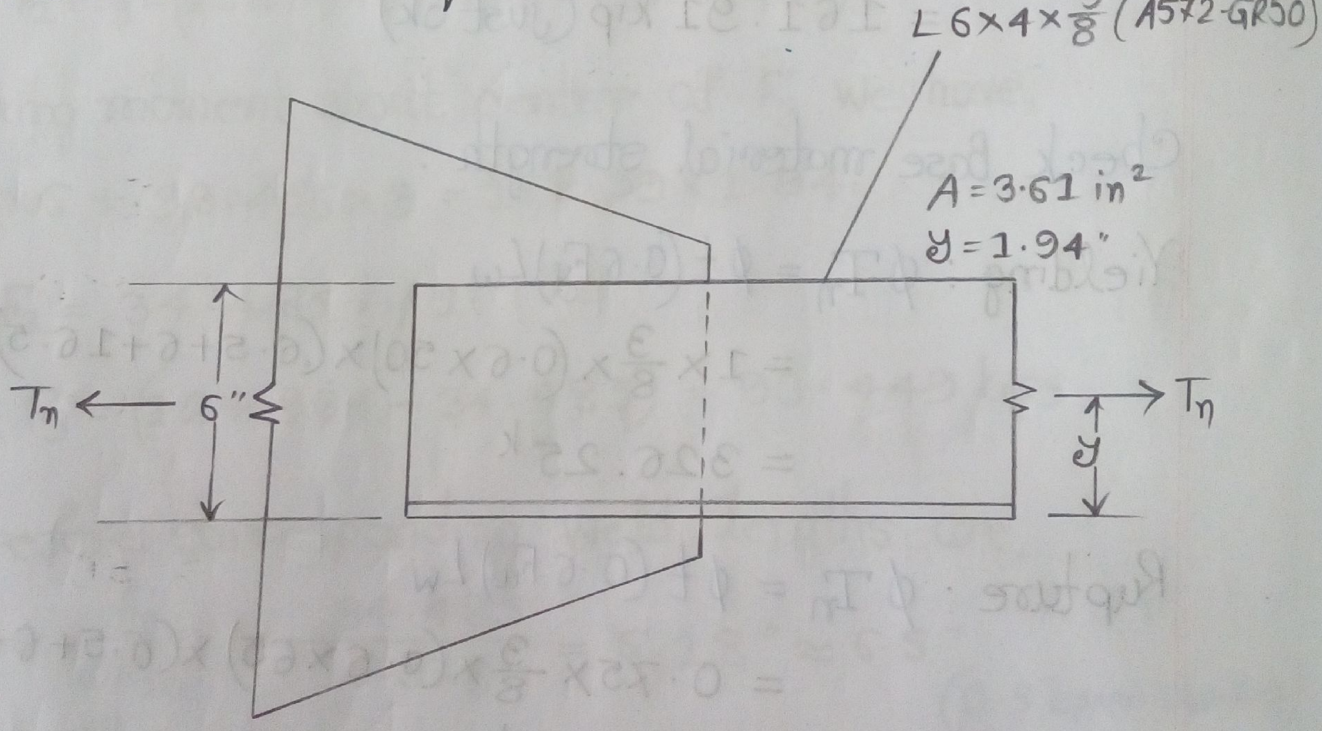
Rupture: $\phi T_n = \phi t (0.6 F_u) L_w$

$$= 0.75 \times \frac{3}{8} \times (0.6 \times 65) \times (6.5+6+16.5)$$

$$= 318.09^k$$

Base material strength (318.09 kip) is higher than the connection strength (OK).

Example 5.16.7 : Design the fillet welds to develop the full strength of the angle shown in the figure if the weld at the end of the angle is omitted and the SAW process is used instead of SMAW. The fillet weld penetration was observed to be consistent beyond the root of the weld, and was found to provide an effective throat equal to the weld size.



Sol^n: ASD Method : Determine strength of the angle,

Yield on gross area : $\frac{T_n}{\Omega} = \frac{F_y A_g}{\Omega} = \frac{50 \times 3.61}{1.67} = 108.08$ kip

Rupture on effective area, as weld length yet not known, Let, $U = 0.90$

$$\frac{T_n}{\Omega} = \frac{F_u U A_g}{\Omega} = \frac{65 \times 0.90 \times 3.61}{2} = 105.6 \text{ kip (controls)}$$

Select Weld Size:

Minimum size fillet weld $= \frac{3}{16}$ "

Maximum size fillet weld $= \left(\frac{3}{8} - \frac{1}{16}\right) = \frac{5}{16}$ "

Use $\frac{5}{16}$ " fillet weld with E70 electrodes as more economical.

t_e = weld size (as per question) $= \frac{5}{16}$ "

Nominal strength of weld, $R_{nw} = t_e (0.6 F_{Exx}) = \left(\frac{5}{16} \times 0.6 \times 70\right)$

$= 13.125$ kip/in

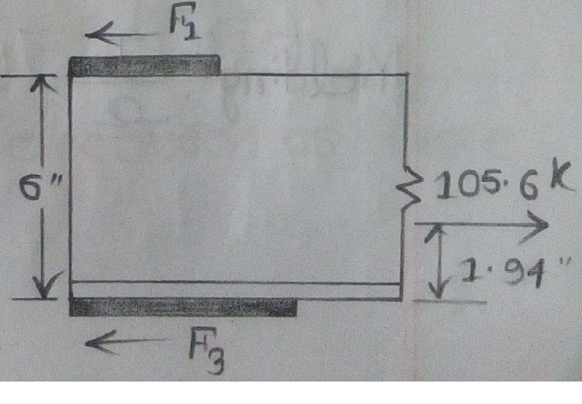
Design strength of weld, $\frac{R_{nw}}{\Omega} = \frac{13.125}{2} = 6.56$ kip/in

Total weld length required, $L_w = \frac{T_u}{R_{uw}} = \frac{105.6}{6.56} = 16.1$ "

Taking moment about center of F_3 we have,

$F_1 \times 6 = 105.6 \times 1.94$

$\therefore F_1 = 34.144$ kip



Now, $F_3 = (105.6 - 34.144)$

$= 71.456$ kip

Therefore, corresponding weld lengths are,

$$L_1 = \frac{F_1}{R_{uw}} = \frac{34.144}{6.56} = 5.2'' \approx 5.5''$$

(0.5" upper rounding)

$$L_3 = \frac{F_3}{R_{uw}} = \frac{71.456}{6.56} = 10.89'' \approx 11''$$

Final allowable weld capacity $= R_{uw} \times L_w$

$$= 6.56 \times (5.5 + 11)$$

$$= 108.24 \text{ kip}$$

Check U :

Average length of weld in the direction of load

$$l = \frac{5.5 + 11}{2} = 8.25''$$

$$U = \left(1 - \frac{x}{l}\right) = \left(1 - \frac{0.933}{8.25}\right) = 0.8869$$

Now, $\frac{T_n}{\Omega} = \frac{F_u U A_g}{\Omega} = \frac{65 \times 0.8869 \times 3.61}{2} = 104.06$ kip (ok)

Check Base material strength :

Yielding : $\frac{T_n}{\Omega} = \frac{t(0.6F_y)L}{\Omega} = \frac{\frac{3}{8} \times 0.6 \times 50 \times (5.5 + 11)}{1.5}$

$= 12$

Rupture: $\frac{T_n}{\Omega} = \frac{t(0.6 F_u)L}{\Omega} = \frac{\frac{3}{8} \times (0.6 \times 65) \times (5.5 + 11)}{2}$

$= 120.66$ kip

Base material strength (120.66 kip) is higher than the connection strength (OK).

<u>LRFD Method</u>: Determine strength of the angle.

Yield on gross area: $\phi T_n = \phi F_y A_g = (0.90 \times 50 \times 3.61)$

$= 162.45^k$

Rupture on effective area, as weld length not yet known,

Let, $U = 0.90$

$\phi T_n = \phi F_u A_e = \phi F_u U A_g = (0.75 \times 65 \times 0.9 \times 3.61)$

$= 158.39^k$ (Controls)

Select Weld Size:

Minimum size fillet weld $= \frac{3}{16}$"

Maximum size fillet weld $= \left(\frac{3}{8} - \frac{1}{16}\right) = \frac{5}{16}$"

Use $\frac{5}{16}$" fillet weld with E70 electrodes as more economical.

t_e = weld size (as per question) = $\frac{5}{16}$"

Design strength of weld, $\phi R_{nw} = \phi t_e (0.6 F_{Exx})$

$= 0.75 \times \frac{5}{16} \times (0.6 \times 70)$

$= 9.84$ kips/in

Total weld length required, $L_w = \frac{\phi T_n}{\phi R_{nw}} = \frac{158.39}{9.84}$

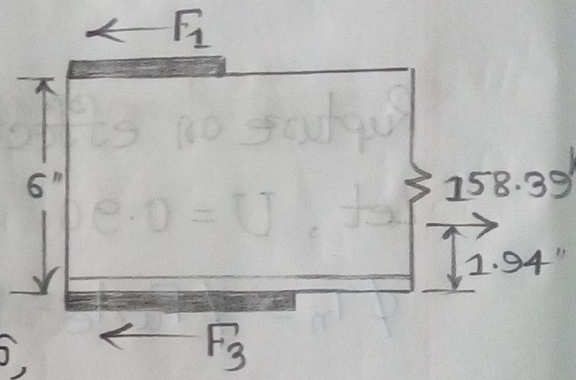
$= 16.1"$

Taking moment about center of F_3,

$F_1 \times 6 = 158.39 \times 1.94$

$\therefore F_1 = 51.21^k$

$F_3 = (158.39 - 51.21) = 107.18^k$



Therefore, corresponding weld lengths,

$L_1 = \frac{F_1}{\phi R_{nw}} = \frac{51.21}{9.84} = 5.2" \approx 5.5"$ (0.5" upper rounding)

$L_3 = \frac{F_3}{\phi R_{nw}} = \frac{107.18}{9.84} = 10.89" \approx 11"$

Final allowable weld capacity = $\phi R_{nw} \times L_w$

$= 9.84 \times (5.5 + 11)$

$= 162.36^k$

Check U:

Average length of weld in the direction of load,

$$l = \left(\frac{5.5+11}{2}\right) = 8.25''$$

$$U = \left(1 - \frac{x}{l}\right) = \left(1 - \frac{0.933}{8.25}\right) = 0.89$$

Now, $\phi T_n = \phi F_u U A_g = (0.75 \times 65 \times 0.89 \times 3.61) = 156.63^k$ (ok)

Check Base material strength:

Yielding: $\phi T_n = \phi t(0.6 F_y) L$

$$= 1.0 \times \frac{3}{8} \times (0.6 \times 50) \times (5.5+11)$$

$$= 185.625^k$$

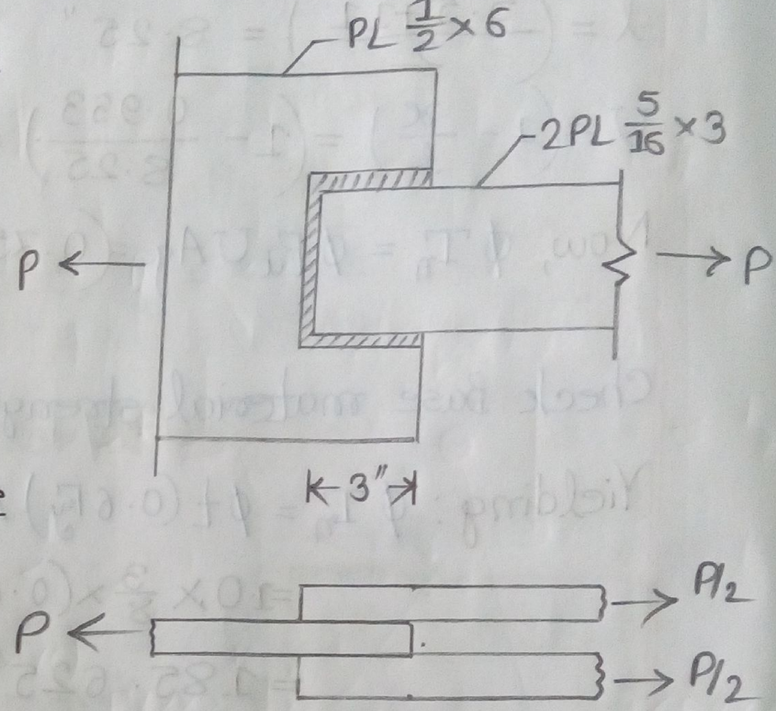
Rupture: $\phi T_n = \phi t(0.6 F_u) L$

$$= 0.75 \times \frac{3}{8} \times (0.6 \times 65) \times (5.5+11)$$

$$= 180.98^k$$

Base material strength (180.98^k) is higher than the connection strength. (OK)

Extra Problem From Handout: A tension member splice is made with $\frac{1}{4}$" E70 fillet welds as shown in figure. Each side of the splice is welded as shown. The inner member is a PL $\frac{1}{2} \times 6$ and each outer member is a PL $\frac{5}{16} \times 3$. All steel is A36. Determine the maximum design capacity ϕP_n based on weld limit states.



Sol^n: Given, all plates A36.

$F_y = 36$ ksi , $F_u = 58$ ksi

Weld strength, $F_{EXX} = 70$ ksi

Weld length on each side $= (3+3+3) = 9$ "

Weld size, $s = \frac{1}{4}$ "

Throat, $t_e = \frac{s}{\sqrt{2}} = \frac{\frac{1}{4}}{\sqrt{2}} = 0.177$ "

Fillet weld capacity : $\phi P_n = \phi R_{nw} L = \phi t_e (0.6 F_{Exx}) L$

$= 0.75 \times 0.177 \times (0.6 \times 70) \times (9+9)$

$= 100.4$ kip

Base metal inner plate :

Yielding : $\phi P_n = \phi R_n L = \phi t (0.6 F_y) L$

$= 1 \times \frac{1}{2} \times (0.6 \times 36) \times 9$

$= 97.2$ kip (governs)

Rupture : $\phi P_n = \phi R_n L = \phi t (0.6 F_u) L$

$= 0.75 \times \frac{1}{2} \times (0.6 \times 58) \times 9$

$= 117.45$ kip

Base metal outer plate :

Yielding : $\phi P_n = \phi R_n L = \phi t (0.6 F_y) L = 1 \times \frac{5}{16} \times (0.6 \times 36) \times (9 \times 2)$

$= 121.5$ kip

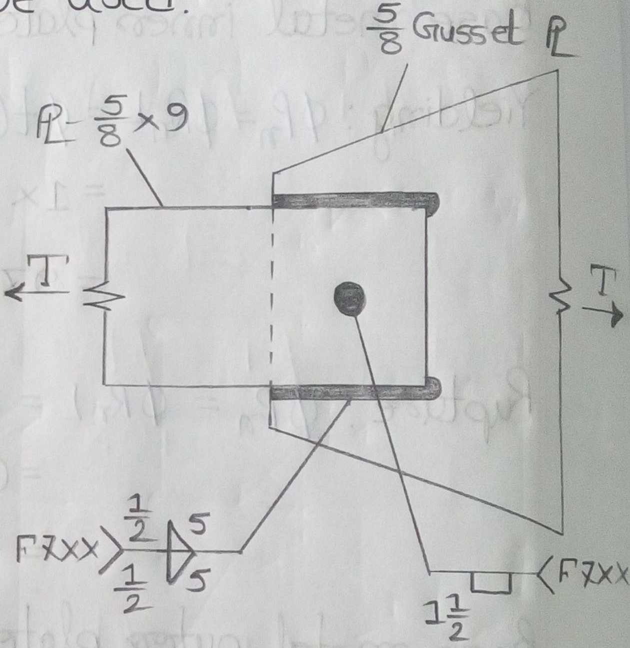
Rupture : $\phi P_n = \phi R_n L = \phi t (0.6 F_u) L = 0.75 \times \frac{5}{16} \times (0.6 \times 58) \times (9 \times 2)$

$= 146.81$ kip

$\therefore$ Base metal (inner plate) yielding governs.

$\therefore \phi P_n = 97.2$ kip (Ans:)

Example 5.16.8 : Determine the service load T permitted on the connection in figure if the load is 80% live load and 20% dead load. The steel is A36 and the AISC LRFD Method is to be used.



Soln: The design strength per inch supplied by the 1/2 inch fillet welds is,

$\phi R_{nw} = \phi t_e (0.60 F_{Exx})$

$= 0.75 \times (0.707 \times \frac{1}{2}) \times (0.6 \times 70)$

$= 11.135$ kip/in

but not to exceed the shear rupture or yield strengths of the plate.

Yielding: $\phi R_n = \phi (0.6 F_y) A_g = 1 \times (0.6 \times 36) \times \frac{5}{8} = 13.5$ kips/in

Rupture: $\phi R_n = \phi (0.6 F_u) A_{nv} = 0.75 \times (0.6 \times 58) \times \frac{5}{8} = 16.3$ kip/in

So, the weld controls.

The strength provided by the fillet welds is,

$T_1 = L_w(\phi R_{nw}) = (2\times5)\times(11.135) = 111.35$ kips

The design strength provided by the $1\frac{1}{2}$" diam plug weld,

$T_2 = \phi R_n = \phi \frac{\pi}{4}(D)^2(0.6 F_{Exx}) = 0.75\times\frac{\pi}{4}(1\frac{1}{2})^2\times 0.6\times 70$

$= 55.665$ kips

The design strength based on the weld is,

$\phi T_n = T_1 + T_2 = (111.35 + 55.665) = 167.015$ kip

Check the tensile capacity of the plate:

Yielding: $\phi T_n = 0.90 F_y A_g = (0.9\times36\times9\times\frac{5}{8}) = 182.25$ kips

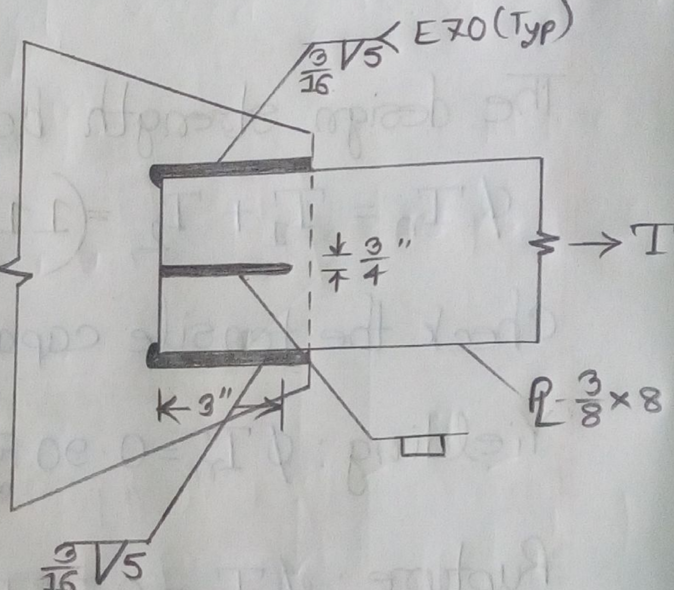
Rupture: $\phi T_n = 0.75 F_u U A_g = (0.75\times58\times1\times9\times\frac{5}{8}) = 244.69$ kips

So, the weld controls. which makes the service load capacity T. $\phi T_n = 1.2(0.2T) + 1.6(0.8T)$

$167.015 = 1.2\times(0.2T) + 1.6(0.8T)$

$\therefore T = 109.88$ kips (Ans:)

Example 5.16.9: Compute the service load capacity of the connection shown in figure when A573 Grade 50 steel and welding by the SMAW process are used. Assume the service load is 83% live load and 17% dead load. Use AISC Load and Resistance Factor Design.



Sol^n: For a $\frac{3}{16}$" fillet weld with E70 electrode,

Design strength of weld,

$$\phi R_{nw} = \phi t_e (0.6 F_{Exx})$$

$$= 0.75 \times \left(0.707 \times \frac{3}{16}\right) \times (0.6 \times 70)$$

$$= 4.18 \text{ kips/in}$$

The resistance provided by the fillet welds is,

$$T_1 = L_w \, \phi R_{nw} = (2 \times 5) \times 4.18 = 41.8 \text{ kips}$$

The resistance provided by the $\frac{3}{4}$" wide slot weld is,

$$\text{Faying area} = \frac{1}{2} \frac{\pi}{4} \left(\frac{3}{4}\right)^2 + 2.25 \times \left(\frac{3}{4}\right)$$

$$= 1.91 \text{ in}^2$$

$T_2 = \phi R_n = \phi A (0.6 F_{Exx}) = 0.75 \times 1.91 \times (0.6 \times 70) = 60.165^k$

The design strength based on the weld is,

$\phi T_n = T_1 + T_2 = (41.8 + 60.165) = 101.965$ kips

Check the tensile capacity of the plate:

Yielding: $\phi T_n = 0.9 F_y A_g = 0.9 \times 50 \times 8 \times \left(\frac{3}{8}\right) = 135^k$

Rupture: $\phi T_n = 0.75 F_u A_e = 0.75 \times 65 \times 8 \times \frac{3}{8} = 146.25^k$

The weld controls.

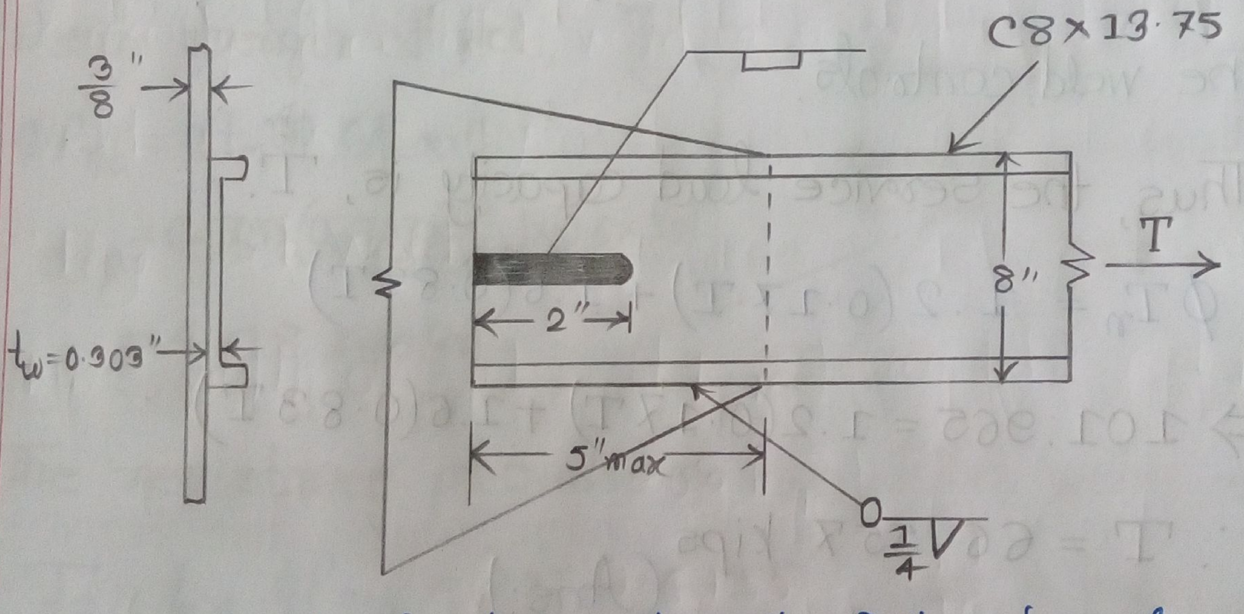
Thus, the service load capacity is, T.

$\phi T_n = 1.2(0.17T) + 1.6(0.83T)$

$\Rightarrow 101.965 = 1.2(0.17T) + 1.6(0.83T)$

$\therefore T = 66.557$ kips (Ans:)

Example 5.16.10: Design an end connection to develop the full tensile strength of a C8×13.75 in a lap length of 5 in as shown in figure. The channel of A572 Grade 50 steel is connected to a $\frac{3}{8}$ in gusset plate and the fillet welds are to be made by the SMAW process and may not exceed $\frac{3}{8}$ in. Use Load and Resistance Factor Design.



Sol^n^: Compute the design strength of the channel: The joint length l is taken as 5" which is the maximum overlap between the connected elements.

$$U = 1 - \frac{\bar{x}}{l} = \left(1 - \frac{0.554}{5}\right) = 0.89$$

Yielding: $\phi T_n = 0.9 F_y A_g = (0.90 \times 50 \times 4.04) = 181.8^k$

Rupture: $\phi T_n = 0.75 F_u A_e = 0.75 \times 65 \times (0.89 \times 4.04) = 175.3^k$ (controls)

Select fillet weld size a and compute length required.

Minimum $a = \frac{3}{16}$ "

Maximum $a = 0.303 - \frac{1}{16} = 0.24$ " $\approx \frac{1}{4}$ "

While $\frac{1}{4}$ in weld must be used on one end along the channel web; $\frac{3}{8}$ in weld could be used along the flanges.

It is better not to mix the fillet sizes, so try $\frac{1}{4}$ " all around.

Design strength of weld, $\phi R_{nw} = \phi t_e (0.6 F_{Exx})$

$$= 0.75 \times \left(0.707 \times \frac{1}{4}\right) \times (0.6 \times 70)$$

$$= 5.57 \text{ kips/in}$$

which cannot exceed the shear yield or rupture strength of the base metal.

Base metal strength:

Yielding: $\phi R_n = \phi(0.6 F_y) A_g = (1 \times 0.6 \times 50 \times \frac{3}{8}) = 11.25 \, k/in$

Rupture: $\phi R_n = \phi(0.6 F_u) A_e = (0.75 \times 0.6 \times 65 \times \frac{3}{8}) = 10.97 \, k/in$

∴ The weld controls.

Required weld length, $L_w = \frac{P_u}{\phi R_{nw}} = \frac{175.3}{5.57} = 31.5''$

Since the length all around is only 26" additional capacity from fillet weld in a slot, slot welds or plug welds is necessary.

Try Slot Weld.

Min^m width of slot $= \left(t + \frac{5}{16}\right)$ (rounded to next $\frac{1}{16}$")

$= \left(0.303 + \frac{5}{16}\right)$

$= 0.6155'' \approx \frac{11}{16}''$

Max^m width of slot $= 2\frac{1}{4}$(weld thickness)

$= 2.25 \times 0.303$

$= 0.68''$

Load T_u to be carried by slot weld.

Required $T_u = [175.3 - (26 - 0.68)5.57] = 34.27^k$

Try $\frac{11}{16}$" width of slot and estimate the slot area as "rectangular" even though the end must be rounded.

Length required $= \frac{T_u}{\phi t_e (0.6 F_{Exx})} = \frac{34.27}{0.75 \times \frac{11}{16} \times (0.6 \times 70)} = 1.58$"

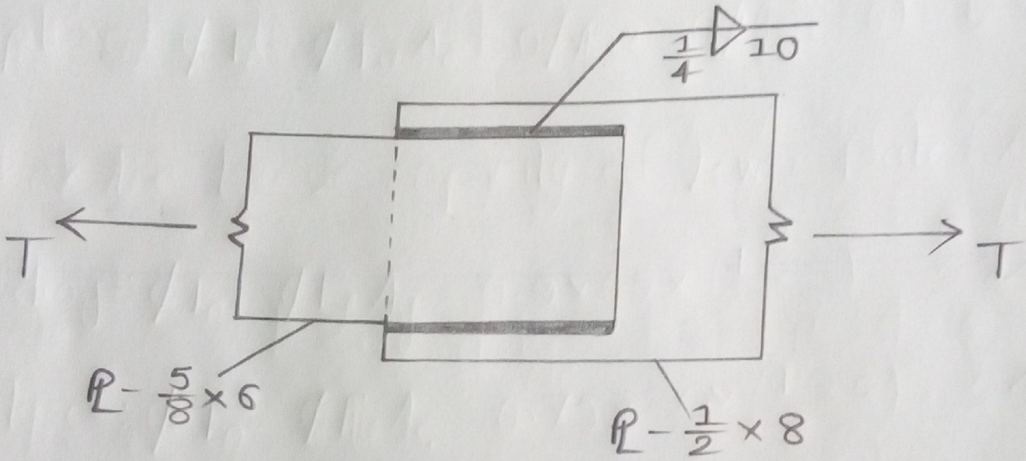
Max^{m} length of slot $= 10$(weld thickness) $= 10 \times 0.303 = 3.03$"

Use a slot weld $\frac{11}{16} \times 2$.

(Ans:)

PROBLEMS

5.3 Determine the service load capacity T of the connection shown when the submerged arc process (SAW) is used. The load is 85% live load and 15% dead load. Use (a) A36 steel and (b) A572 Grade 65 steel. Assume appropriate electrode material is used.



(a) Sol^n: The design strength per inch supplied by the $\frac{1}{4}$" fillet weld is, E 0 electrode is used. (for A36 steel)

$$\phi R_{nw} = \phi t_e (0.60 F_{Exx})$$

$$= 0.75 \times (0.707 \times \tfrac{1}{4}) \times (0.60 \times 60)$$

$$= 4.772 \text{ kips/in}$$

The resistance provided by the fillet welds is,

$$T_u = L_w \phi R_{nw} = (2 \times 10) \times 4.772$$

$$= 95.44 \text{ kips}$$

Check the tensile capacity of Upper Plate : (A36)

Yielding : $\phi T_n = \phi F_y A_g = 0.9 \times 36 \times (\frac{5}{8} \times 6) = 121.5$ kips

Rupture : $\phi T_n = \phi F_u A_e = 0.75 \times 58 \times (\frac{5}{8} \times 6) = 163.125$ kips

Check the tensile capacity of Lower Plate : (A36)

Yielding : $\phi T_n = \phi F_y A_g = 0.9 \times 36 \times (\frac{1}{2} \times 8) = 129.6$ kips

Rupture : $\phi T_n = \phi F_u A_e = 0.75 \times 58 \times (\frac{1}{2} \times 8) = 174$ kips

Thus, weld controls.

So, the service load capacity T,

$$T_u = 1.2(0.15T) + 1.6(0.85T)$$

$$\Rightarrow 95.44 = 1.2(0.15T) + 1.6(0.85T)$$

$$\therefore T = 61.97^k \text{ (Ans.)}$$

(b) The design strength per inch supplied by the $\frac{1}{4}$" fillet weld is, E70 electrode is used (for A572 GR 65 steel)

$$\phi R_{nw} = \phi t_e (0.60 F_{EXX})$$

$$= 0.75 \times (0.707 \times \frac{1}{4}) \times (0.60 \times 70)$$

$$= 5.57 \text{ kips/in}$$

The resistance provided by the fillet weld is,

$T_u = L_W \phi R_{nw} = (2\times10)\times5.57 = 111.4$ kips

Check the tensile capacity of Upper Plate (A572-GR 65)

Yielding : $\phi T_n = \phi F_y A_g = 0.9\times65\times\left(\frac{5}{8}\times6\right) = 219.375^k$

Rupture : $\phi T_n = \phi F_u A_e = 0.75\times80\times\left(\frac{5}{8}\times6\right) = 225^k$

Check the tensile capacity of Lower Plate (A572-GR 65)

Yielding : $\phi T_n = \phi F_y A_g = 0.9\times65\times\left(\frac{1}{2}\times8\right) = 234$ kips

Rupture : $\phi T_n = \phi F_u A_e = 0.75\times80\times\left(\frac{1}{2}\times8\right) = 240$ kips

$\therefore$ The weld controls.

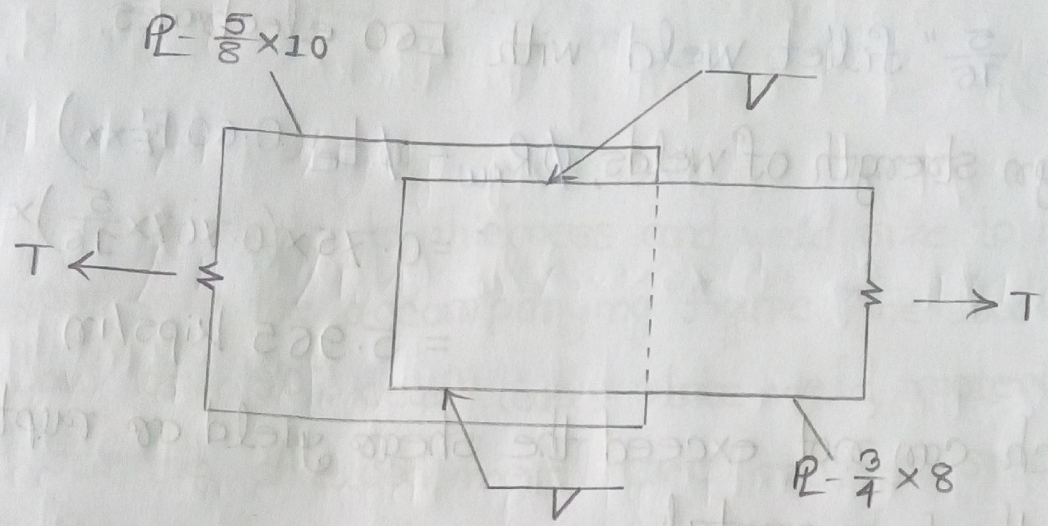
Thus, the service load capacity T is,

$T_u = 1.2(0.15T) + 1.6(0.85T)$

$\Rightarrow 111.4 = 1.2(0.15T) + 1.6(0.85T)$

$\therefore T = 72.338$ kips (Ans:)

5.4 Specify the fillet welds required to develop the strength of the connection shown. State the maximum service load T permitted to be carried. The load is 90% live load and 10% dead load.



Sol^n: Compute the design strength of the connection:

Upper Plate: Assume A36 steel.

Yielding: $\phi T_n = 0.9 F_y A_g = 0.9 \times 36 \times (\frac{3}{4} \times 8) = 194.4$ kips (governs)

Rupture: $\phi T_n = 0.75 F_u A = 0.75 \times 58 \times (\frac{3}{4} \times 8) = 261$ kips

Lower Plate: Assume A36 steel.

Yielding: $\phi T_n = 0.9 F_y A_g = 0.9 \times 36 \times (\frac{5}{8} \times 10) = 202.5$ kips

Rupture: $\phi T_n = 0.75 F_u A_e = 0.75 \times 58 \times (\frac{5}{8} \times 10) = 271.9$ kips

Select fillet weld size 'a' and compute weld length

$Min^m \ a = \frac{1}{4}$"

$Max^m \ a = \left(\frac{3}{4} - \frac{1}{16}\right) = \frac{11}{16}$"

Use $\frac{5}{16}$" fillet weld with E60 electrodes.

Design strength of welds, $\phi R_{nw} = \phi t_e (0.60 F_{Exx})$

$= 0.75 \times (0.707 \times \frac{5}{16}) \times (0.6 \times 60)$

$= 5.965$ kips/in

which can not exceed the shear yield or rupture strength of the base metal.

Base Metal Strength (Lower Plate)

Yielding : $\phi R_n = \phi (0.6 F_y) A_g = 1 \times (0.6 \times 36) \times \frac{5}{8} = 13.5$ k/in

Rupture : $\phi R_n = \phi (0.6 F_u) A_e = 0.75 \times (0.6 \times 58) \times \frac{5}{8} = 16.3$ k/in

∴ The weld controls.

Required weld length, $L_W = \frac{P_u}{\phi R_{nw}} = \frac{194.4}{5.965} = 32.6$"

Use 16.5" fillet weld on each side. (Ans:)

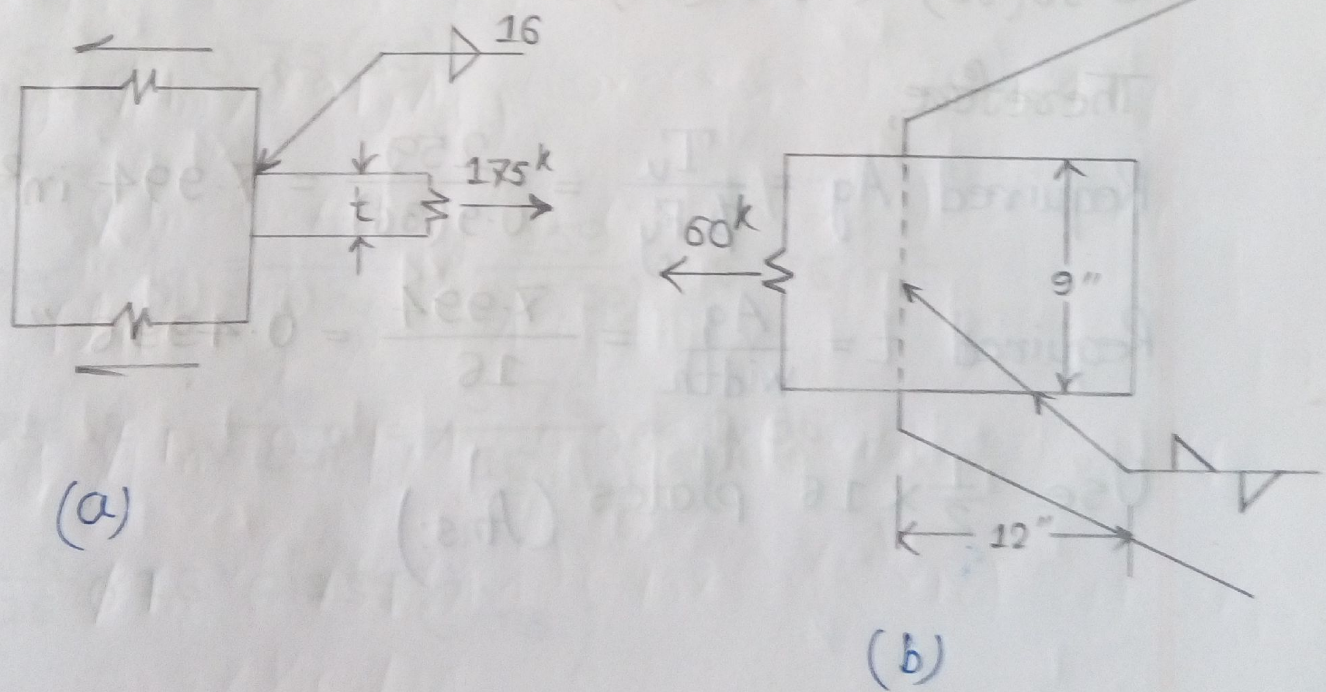
The service load capacity is T,

$$T_u = 1.2(0.10T) + 1.6(0.90T)$$

$$\Rightarrow 194.4 = 1.2(0.10T) + 1.6(0.90T)$$

$$\therefore T = 124.615 \text{ kips}$$ (Ans.)

5.5 Specify the plate thickness and weld size to be used for the joints in the accompanying figure. The loads are 70% live load and 30% dead load. State weld material to be used for the shielded metal arc process (SMAW). Compare A36 and A572 Grade 50 steels for each joint. Indicate the preferred design for each joint.



Sol^n: (a) Factored Load to be carried,

$T_u = 1.2\,DL + 1.6\,LL$

$= 1.2(0.30 \times 175) + 1.6(0.70 \times 175)$

$= 259$ kips

For A36 steel computing the thickness required,

$\phi T_n = \phi F_y A_g = 0.9 \times 36 \times A_g$ (yielding limit state)

$\phi T_n = \phi F_u A_e = 0.75 \times 58 \times A_e$ (fracture limit state)

Since, there are no holes and no eccentricity of loading the effective net area A_e equals the gross area A_g.

Thus, from the above two equations it is noted that

$0.90(36) < 0.75(58)$;

Therefore,

$$\text{Required } A_g = \frac{T_u}{\phi F_y} = \frac{259}{0.9(36)} = 7.994 \text{ in}^2$$

$$\text{Required } t = \frac{A_g}{\text{width}} = \frac{7.994}{16} = 0.4996\ ''$$

Use $\frac{1}{2} \times 16$ plates (Ans:)

Select Weld Size:

Minimum fillet weld size = $\frac{1}{4}$ "

Maximum fillet weld size $= \left(\frac{1}{2} - \frac{1}{16}\right) = \frac{7}{16}$ "

Use $\frac{5}{16}$ " fillet weld with E60 electrodes. (Ans:)

For A572 Grade 50 steels computing the thickness required,

$\phi T_n = \phi F_y A_g = 0.9(50) A_g$ (yielding limit state)

$\phi T_n = \phi F_u A_e = 0.75(65) A_e$ (fracture limit state)

Since, there are no holes and no eccentricity of loading, the effective net area A_e equals the gross area A_g.

Thus, from the above two equation it is noted that,

$0.9(50) < 0.75(65)$;

Therefore,

$$\text{Required } A_g = \frac{T_u}{\phi F_y} = \frac{259}{0.9(50)} = 5.76 \text{ in}^2$$

$$\text{Required } t = \frac{A_g}{\text{width}} = \frac{5.76}{16} = 0.36 \text{ "}$$

Use $\frac{6}{16} \times 16$ plates (Ans:)

Select Weld Size :

Minimum fillet weld size = $\frac{3}{16}$ "

Maximum fillet weld size = $\left(\frac{6}{16} - \frac{1}{16}\right) = \frac{5}{16}$ "

Use $\frac{4}{16}$ " fillet weld with E70 electrodes

(b) Factored Load to be carried,

$T_u = 1.2\,DL + 1.6\,LL$

$= 1.2(0.30 \times 60) + 1.6(0.70 \times 60)$

$= 88.8$ kips

For A36 steel computing the thickness required,

$\phi T_n = \phi F_y A_g = 0.9(36) A_g$ (yielding limit state)

$\phi T_n = \phi F_u A_e = 0.75(58) A_g$ (fracture limit state)

Since, there are no holes and no eccentricity of loading the effective net area A_e equals the gross area A_g.

Thus, from the above two equations it is noted that,

$0.90(36) < 0.75(58)$;

Therefore,

Required $A_g = \frac{T_u}{\phi F_y} = \frac{88.8}{0.90(36)} = 2.74\ in^2$

Required $t = \frac{A_g}{width} = \frac{2.74}{9} = 0.304$ "

Use $\frac{5}{16} \times 9$ plates (Ans.)

Select weld size :

Minimum fillet weld size = $\frac{3}{16}$"

Maximum fillet weld size = $\left(\frac{5}{16} - \frac{1}{16}\right) = \frac{1}{4}$"

Use $\frac{1}{4}$" fillet weld with E60 electrodes.

For A572 Grade 50 steels computing the thickness required,

$\phi T_n = \phi F_y A_g = 0.90(50) A_g$ (yielding limit state)

$\phi T_n = \phi F_u A_e = 0.75(65) A_g$ (fracture limit state)

Since, there are no holes and no eccentricity of loading, the effective net area A_e equals the gross area A_g.

Thus, from the above two equation it is noted that,

$0.90(50) < 0.75(65)$;

There fore,

$$\text{Required } A_g = \frac{T_u}{\phi F_y} = \frac{88.8}{0.90(50)} = 1.973 \text{ in}^2$$

$$\text{Required } t = \frac{A_g}{\text{width}} = \frac{1.973}{9} = 0.219"$$

Use $\frac{1}{4} \times 9$ plates (Ans:)

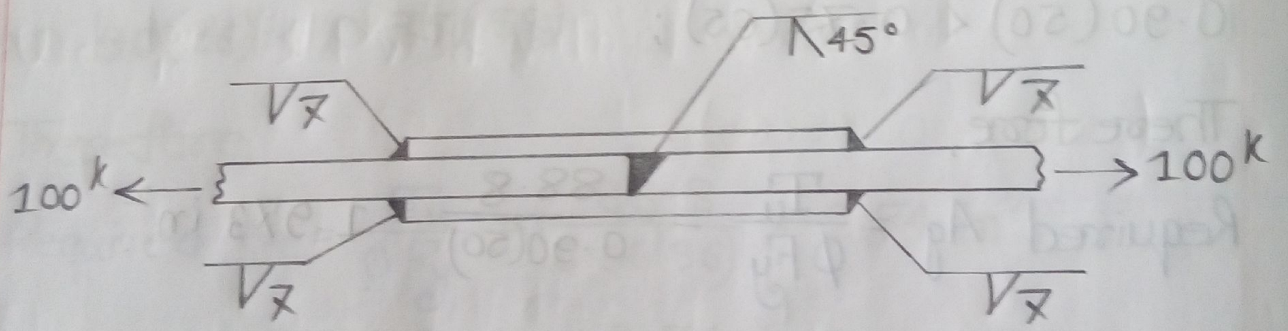
Select weld size:

Minimum fillet weld size = $\frac{1}{8}$"

Maximum fillet weld size = $\left(\frac{1}{4} - \frac{1}{16}\right) = \frac{3}{16}$"

Use $\frac{3}{16}$" fillet weld with E70 electrodes.

5.7 Design the reinforced lap joint shown in the accompanying figure. The plates are 7" wide of A36 steel and the SMAW process is used. Refer to AWS Joint Designation BTC-P4 (LRFD Manual p. 8-150). The given load is 25% dead load and 75% live load.



Soln: For Inner Plate,

Factored Load to be carried, $T_u = 1.2DL + 1.6LL$

$\Rightarrow T_u = 1.2(0.25 \times 100) + 1.6(0.75 \times 100)$

$\therefore T_u = 150^k$

For computing the required thickness of the plate,

$\phi T_n = \phi F_y A_g = 0.9(36) A_g$ (yielding limit state)

$\phi T_n = \phi F_u A_e = 0.75(58) A_e$ (fracture limit state)

Since, there are no holes and no eccentricity of loading, the effective net area A_e equals the gross area A_g.

Thus, from the above two equations it is noted that,

$0.90(36) < 0.75(58)$;

Therefore,

$$\text{Required } A_g = \frac{T_u}{\phi F_y} = \frac{150}{0.9(36)} = 4.63 \text{ in}^2$$

$$\text{Required } t = \frac{A_g}{\text{width}} = \frac{4.63}{7} = 0.661''$$

Use $\frac{11}{16} \times 7$ plates. (Ans:)

For Outer Plates:

Factored Load to be carried, $T_u = \frac{150}{2} = 75^k$

For computing the required thickness of the plate,

$\phi T_n = \phi F_y A_g = 0.90(36) A_g$ (yielding limit state)

$\phi T_n = \phi F_u A_e = 0.75(58) A_e$ (fracture limit state)

Since, there are no holes and no eccentricity of loading the effective net area A_e equals the gross area A_g.

Therefore,

$$\text{Required } A_g = \frac{T_u}{\phi F_y} = \frac{75}{0.9(36)} = 2.315 \text{ in}^2$$

$$\text{Required } t = \frac{A_g}{\text{width}} = \frac{2.315}{7} = 0.331''$$

Use $\frac{6}{16} \times 7$ plates. (Ans:)

Select weld size :

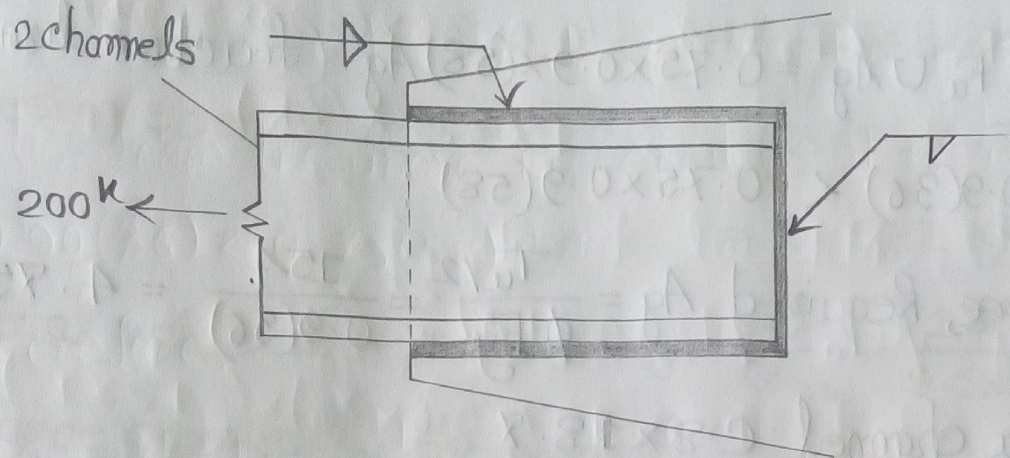
Minimum fillet weld size = $\frac{1}{4}''$

Maximum fillet weld size = $\left(\frac{\text{[illegible]}}{16} - \frac{1}{16}\right) = \frac{5}{16}''$

Use $\frac{5}{16}''$ fillet weld with E60 electrodes.

(Ans:)

5.8 Select a pair of channels and design the fillet welds using the SMAW process. The loading is 85% live load and 15% dead load. Compare for (a) A36 steel and (b) A572 Grade 60 steel.



(a) Sol^n: Select a pair of channels of A36 steel which can carry the design load.

Factored Load to be carried,

$T_u = 1.2DL + 1.6LL$

$= 1.2(0.15 \times 200) + 1.6(0.85 \times 200)$

$= 308$ kips

Load carried by one channel $= \frac{T_u}{2} = \frac{308}{2} = 154$ kip

Design strength of the channel,

$\phi T_n = \phi F_y A_g = 0.9 \times (36) A_g$ (yielding limit state)

Let, $U = 0.9$

$\phi T_n = \phi F_u U A_g = 0.75 \times 0.9 \times (58) A_g$ (fracture limit state)

Here, $0.9(36) < 0.75 \times 0.9(58)$;

Therefore, Required $A_g = \frac{T_u/2}{\phi F_y} = \frac{154}{0.9(36)} = 4.75 \text{ in}^2$

Select a channel C 8×18.7

with, Area, $A = 5.51 \text{ in}^2$

Web thickness, $t_w = 0.487"$

$\bar{x} = 0.565"$

Select weld size : Based on channel dimensions

Minimum size fillet weld $= \frac{3}{16}"$

Maximum size fillet weld $= \left(0.487 - \frac{1}{16}\right)$

$= 0.4245"$

$\approx \frac{7}{16}"$

Use $\frac{5}{16}$" fillet weld with E ∪ electrodes.

$t_e = 0.707a = \left(0.707 \times \frac{5}{16}\right) = 0.221$"

Nominal strength of weld, $R_{nw} = t_e(0.60 F_{Exx})$

$= 0.221(0.6\times\ 0)$

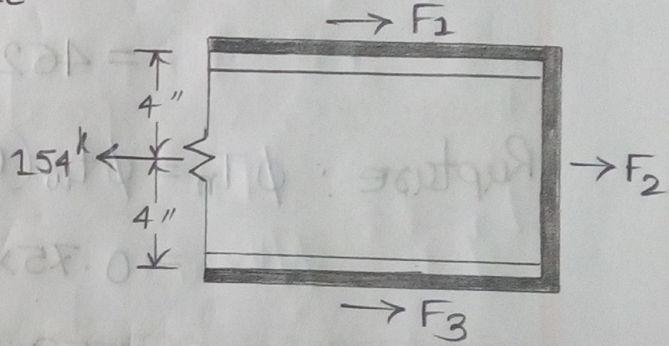
$= 4.774$ kips/in

Design strength of weld, $\phi R_{nw} = (0.75 \times 4.774)$

$= 3.581$ kips/in

Total weld length required, $L_w = \frac{\phi T_n}{\phi R_{nw}} = \frac{154}{3.581} = 43.005$"

Force carried by the weld at the end of channel,



$F_2 = L_2 \times \phi R_{nw}$

$= (8 \times 3.581) = 28.648^k$

$\therefore F_1 = F_3 = \left(\frac{154 - 28.648}{2}\right) = 62.676^k$

Therefore, corresponding weld length,

$L_1 = L_3 = \frac{F_1}{\phi R_{nw}} = \frac{62.676}{3.581} = 17.502" \approx 18"$

Final allowable weld capacity $= \phi R_{nw} \times L_w$

$= 3.581 \times (8 + 18 \times 2)$

$= 157.564^k$ (OK)

Check U :

Average length of weld in the direction of load,

$l = \left(\frac{18+18}{2}\right) = 18''$

$U = \left(1 - \frac{\bar{x}}{l}\right) = \left(1 - \frac{0.565}{18}\right) = 0.97 > 0.9$ (OK)

Now, $\phi T_n = \phi F_y U A_g = (0.9 \times 36 \times 0.97 \times 5.51)$

$= 173.2^k$ (OK)

Check Base Material Strength :

Yielding : $\phi T_n = \phi t_w (0.6 F_y) L_w$

$= 1 \times 0.487 \times (0.6 \times 36) \times (8 + 2 \times 18)$

$= 462.845^k$

Rupture : $\phi T_n = \phi t_w (0.6 F_u) L_w$

$= 0.75 \times 0.487 \times (0.6 \times 58) \times (8 + 2 \times 18)$

$= 559.271^k$

Base material strength (462.845 kip) is higher than the connection strength. (OK)

(b) Select a pair of channel of A572 Grade 60 steel

Design strength of the channel,

$\phi T_n = \phi F_y A_g = 0.9(60) A_g$ (yielding limit state)

Let, $U = 0.9$

$\phi T_n = \phi F_u U A_g = (0.75 \times 75 \times 0.9) A_g$ (fracture limit state)

Here, $(0.75 \times 75 \times 0.9) < 0.9(60)$; rupture controls

Therefore, Required $A_g = \dfrac{T_u/2}{\phi F_u U} = \dfrac{154}{0.75 \times 75 \times 0.9} = 3.042 \text{ in}^2$

Select a channel C 8×11.5 with

Area, $A = 3.37 \text{ in}^2$

Web thickness, $t_w = 0.220$

$\bar{x} = 0.572''$

Select weld size : Based on channel dimensions

Minimum size fillet weld = $\frac{1}{8}''$

Maximum size fillet weld = $0.22'' \approx \frac{1}{4}''$

Use $\frac{1}{4}''$ fillet weld with E70 electrodes.

$t_e = 0.707a = \left(0.707 \times \frac{1}{4}\right) = 0.177$ in

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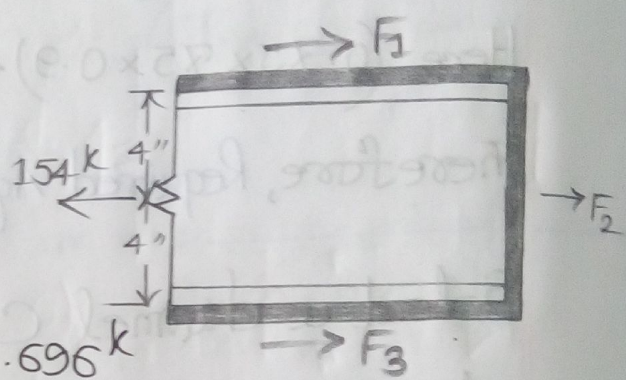
Design strength of weld, $\phi R_{nw} = \phi t_e (0.6 F_{Exx})$

$= 0.75 \times 0.177 \times (0.6 \times 70)$

$= 5.576$ kips/in

Total weld length required, $L_w = \frac{\phi T_n}{\phi R_{nw}} = \frac{154}{5.576} = 27.62''$

Force carried by the weld at the end of channel,



$F_2 = L_2 \times \phi R_{nw}$

$= (8 \times 5.576) = 44.608$ kips

$\therefore F_1 = F_3 = \left(\frac{154 - 44.608}{2}\right) = 54.696^k$

Therefore, corresponding weld lengths,

$L_1 = L_3 = \frac{F_1}{\phi R_{nw}} = \frac{54.696}{5.576} = 9.81'' \approx 10''$

Final allowable weld capacity $= \phi R_{nw} \times L_w$

$= 5.576 \times (8 + 2 \times 10)$

$= 156.128$ kips

Check U :

Average length of weld in the direction of weld,

$$l = \frac{10+10}{2} = 10''$$

$$U = \left(1 - \frac{\bar{x}}{l}\right) = \left(1 - \frac{0.572}{10}\right) = 0.94 > 0.90 \text{ (ok)}$$

Now, $\phi T_n = \phi F_u U A_g = (0.75 \times 75 \times 0.94 \times 3.37) = 178.189$ kips (ok)

Check Base Material Strength :

Yielding : $\phi_n = \phi t_w (0.6 F_y) L_w$

$$= 1 \times 0.22 \times (0.6 \times 60) \times (8 + 10 \times 2)$$

$$= 221.76 \text{ kips}$$

Rupture : $\phi T_n = \phi t_w (0.6 F_u) L_w$

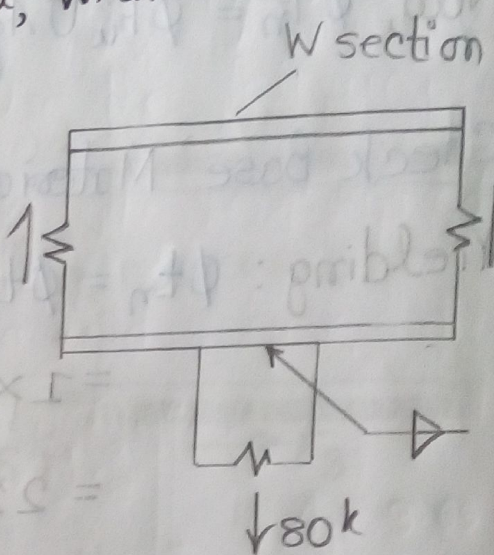
$$= 0.75 \times 0.22 \times (0.6 \times 75) \times (8 + 10 \times 2)$$

$$= 207.9 \text{ kips}$$

Base material strength (207.9 kips) is higher than the connection strength. (OK).

5.9 Design the tension plate attached to the wide-flange (W) section as well as the welds, assuming the SMAW process is used. The load is 70% live load and 30% dead load.

c. Use A572 Grade 42 steel, with fillet welds instead of groove weld.



Solⁿ: Factored load to be carried,

$T_u = 1.2\,DL + 1.6\,LL$

$= 1.2(0.30 \times 80) + 1.6(0.70 \times 80)$

$= 118.4$ kip

Design strength of the plate,

$\phi T_n = \phi F_y A_g = 0.9(42) A_g$ (yielding limit state)

$\phi T_n = \phi F_u A_e = 0.75(60) A_g$ (fracture limit state)

Here, $0.9(42) < 0.75(60)$; yielding governs.

Therefore, Required $A_g = \dfrac{T_u}{\phi F_y} = \dfrac{118.4}{0.9(42)} = 3.132 \text{ in}^2$

Use $\frac{6}{16} \times 10$ plates with $A_g = 3.75 \text{ in}^2$

Select weld size:

Minimum size fillet weld = $\frac{3}{16}$ "

Maximum size fillet weld = $\left(\frac{6}{16} - \frac{1}{16}\right) = \frac{5}{16}$ "

Use $\frac{4}{16}$ " fillet weld with E70 electrodes

$t_e = 0.707a = \left(0.707 \times \frac{4}{16}\right) = 0.177$ "

Design strength of weld, $\phi R_{nw} = \phi t_e (0.6 F_{Exx})$

$= 0.75 \times 0.177 \times (0.6 \times 70)$

$= 5.576$ kips/in

Total weld length required, $L_w = \frac{\phi T_n}{\phi R_{nw}} = \frac{118.4}{5.576} = 21.23$ "

≈ 22 "

Use 11" fillet weld on each side.

Check Base Material Strength:

Yielding: $\phi T_n = \phi t (0.6 F_y) L = 1 \times \frac{6}{16} \times (0.6 \times 42) \times 22$

$= 207.9$ kips

Rupture: $\phi T_n = \phi t (0.6 F_u) L = 0.75 \times \frac{6}{16} \times (0.6 \times 60) \times 22$

$= 222.75$ kips

Base Material strength (207.9 kips) is higher than the connection strength. (OK)

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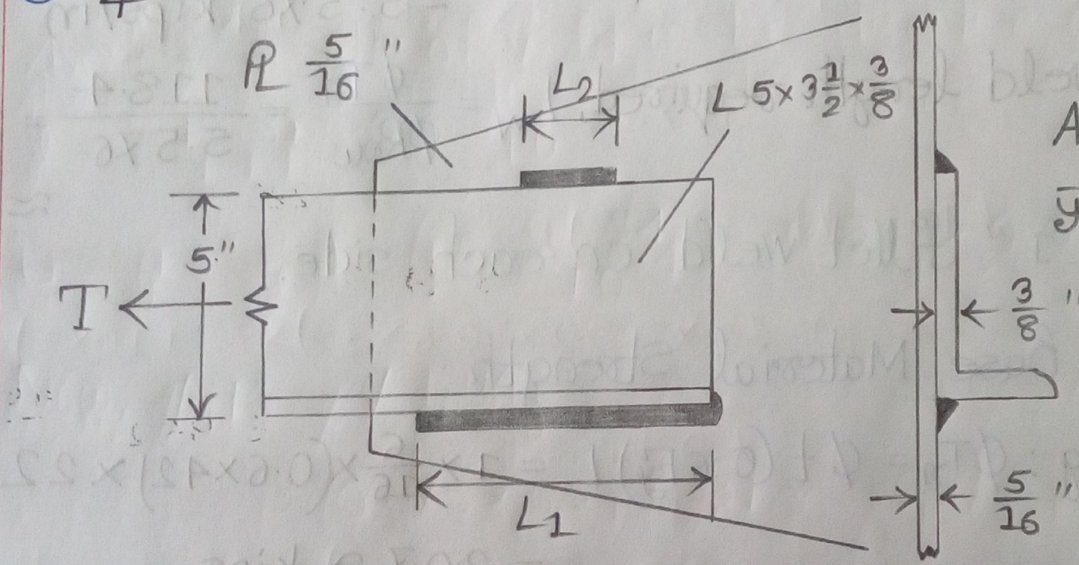
5.10 A $5 \times 3\frac{1}{2} \times \frac{3}{8}$ angle of A572 Grade 50 steel is connected by its long leg to a $\frac{5}{16}$ in gusset plate. Develop the maximum service load capacity (25% dead load; 75% live load) of the angle and use a balanced fillet welded connection with the SMAW process. State the service load capacity. Use the following arrangements

(a) $\frac{5}{16}$ in weld on toe and back, with none on end

(b) $\frac{1}{4}$ in weld on toe and $\frac{3}{8}$ in weld on back, and none on end



$A_g = 3.05 \text{ in}^2$

$\bar{y} = 1.60$ in

$\bar{x} = 0.854$ in

Sol^n: (a) Determine strength of the angle

Yield on gross area: $\phi T_n = \phi F_y A_g = (0.9 \times 50 \times 3.05)$

$= 137.25$ kip

Rupture on effective area: Let, $U = 0.9$ as weld length yet not known.

$\phi T_n = \phi F_u U A_g = (0.75 \times 65 \times 0.9 \times 3.05) = 133.819$ kip (Controls)

Select Weld Size:

Minimum size fillet weld $= 3/16''$

Maximum size fillet weld $= \left(\frac{3}{8} - \frac{1}{16}\right) = \frac{5}{16}''$

Use $\frac{5}{16}''$ fillet weld with E70 electrodes.

$t_e = 0.707a = \left(0.707 \times \frac{5}{16}\right) = 0.221''$

Design strength of weld, $\phi R_{nw} = \phi t_e (0.6 F_{Exx})$

$= 0.75 \times 0.221 \times (0.6 \times 70)$

$= 6.962$ kip/in

Total weld length required, $L_w = \frac{\phi T_n}{\phi R_{nw}} = \frac{133.819}{6.962} = 19.2''$

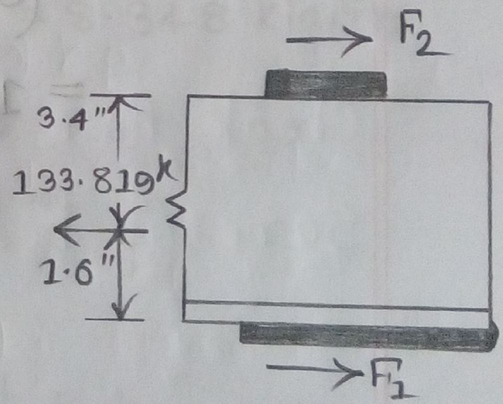
Taking moment about center of F_2,

$F_1 \times 5 = 133.819 \times 3.4$

$\therefore F_1 = 90.997^k$

$F_2 = (133.819 - 90.997)$

$= 42.822^k$



Therefore, corresponding weld lengths are,

$$L_1 = \frac{F_1}{\phi R_{nw}} = \frac{90.997}{6.962} = 13.07'' \approx 13.5''$$

$$L_2 = \frac{F_2}{\phi R_{nw}} = \frac{42.822}{6.962} = 6.15'' \approx 6.5''$$

Final allowable weld capacity $= L_w \times \phi R_{nw}$

$$= (13.5 + 6.5) \times 6.962$$

$$= 139.24 \text{ kip}$$

Check U :

Average length of weld in the direction of load,

$$l = \left(\frac{13.5 + 6.5}{2}\right) = 10''$$

$$U = \left(1 - \frac{\bar{x}}{l}\right) = \left(1 - \frac{0.854}{10}\right) = 0.91 > 0.90 \text{ (OK)}$$

Now, $\phi T_n = \phi F_u U A_g$

$$= (0.75 \times 65 \times 0.91 \times 3.05)$$

$$= 135.31 \text{ kip (ok)}$$

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Check Base Material Strength :

Yielding : $\phi T_n = \phi t(0.6F_y)L = 1 \times \frac{5}{16} \times (0.6 \times 50) \times 20$

$= 187.5$ kip

Rupture : $\phi T_n = \phi t(0.6F_u)L = 0.75 \times \frac{5}{16} \times (0.6 \times 65) \times 20$

$= 182.813$ kip

Base material strength (182.813 kip) is higher than the connection strength. (OK)

ⓑ Use $\frac{1}{4}$" weld on toe & $\frac{3}{8}$" weld on back

$t_e = 0.707a$

$= 0.707 \times \frac{1}{4}$

$= 0.177$"

$\phi R_{nw(toe)} = \phi t_e(0.6F_{Exx})$

$= 0.75 \times 0.177 \times (0.6 \times 70)$

$= 5.576$ kip/in

$t_e = 0.707a$

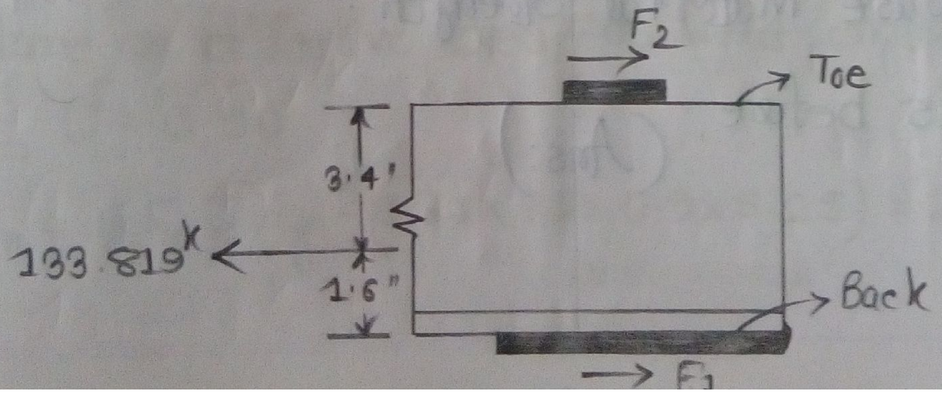
$= 0.707 \times \frac{3}{8}$

$= 0.265$"

$\phi R_{nw(back)} = \phi t_e(0.6F_{Exx})$

$= 0.75 \times 0.265 \times (0.6 \times 70)$

$= 8.348$ kip/in



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Weld length at Toe, $L_{toe} = \frac{F_2}{\phi R_{nw(toe)}} = \frac{42.822}{5.576} = 7.68''$
$\approx 8.0''$

Weld length at Back, $L_{Back} = \frac{F_1}{\phi R_{nw(Back)}} = \frac{90.997}{8.348} = 10.9''$
$\cong 11.0''$

Final allowable weld capacity $= \phi R_{nw(toe)} \times L_{toe} + \phi R_{nw(back)} \times L_{back}$

$= (5.576 \times 8) + (8.348 \times 11)$

$= 136.436$ kip

Check U :

Average weld length in the direction of load,

$l = \frac{8+11}{2} = 9.5''$

$U = \left(1 - \frac{\bar{x}}{l}\right) = \left(1 - \frac{0.854}{9.5}\right) = 0.91 > 0.90$ (ok)

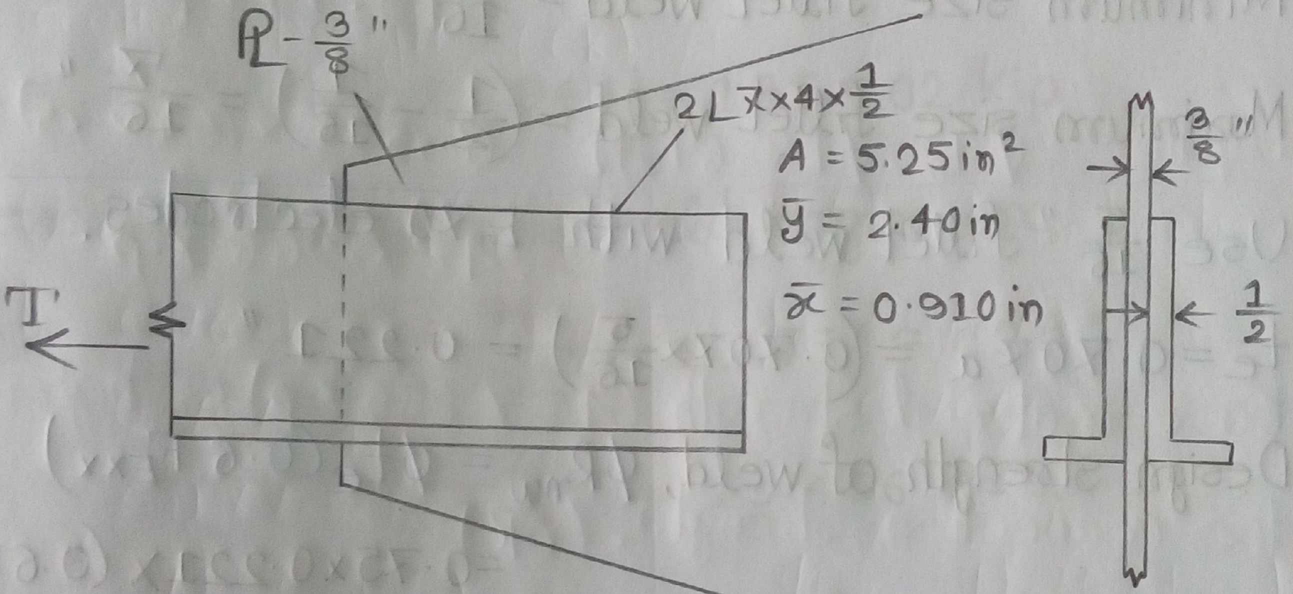
Now, $\phi T_n = \phi F_u U A_g = (0.75 \times 65 \times 0.91 \times 3.05)$

$= 135.306$ kip (OK)

Check Base Material Strength :

Same as before. (Ans:)

5.11 Design a balanced connection for two $7 \times 4 \times \frac{1}{2}$ angle connected by their long legs to a $\frac{3}{8}$" gusset plate. Develop the maximum service load capacity (20% dead load; 80% live load) and state its value. Use A572 grade 60 steel and the SMAW process. Detail the joint to balance the loads using the shortest possible overlap.



Soln: Determine strength of angle: (For each angle)

Yielding on gross area: $\phi T_n = \phi F_y A_g = (0.9 \times 60 \times 5.25)$

$= 283.5$ kip

Rupture on effective area: as weld length is yet not know

Let, $U = 0.90$

$\phi T_n = \phi F_u U A_g = (0.75 \times 75 \times 0.9 \times 5.25) = 265.781$ kip

(Controls)

The service load capacity is T. (considering two angles)

$$2 \times \phi T_n = 1.2(0.20T) + 1.6(0.80T)$$

$$265.781 = 1.2(0.20T) + 1.6(0.80T)$$

$\therefore T =$ kip is the maximum service load capacity

Select Weld Size :

Minimum size fillet weld $= \frac{3}{16}''$

Maximum size fillet weld $= \left(\frac{1}{2} - \frac{1}{16}\right) = \frac{7}{16}''$

Use $\frac{5}{16}''$ fillet weld with E70 electrodes.

$t_e = 0.707a = \left(0.707 \times \frac{5}{16}\right) = 0.221''$

Design strength of weld, $\phi R_{nw} = \phi t_e (0.6 F_{Exx})$

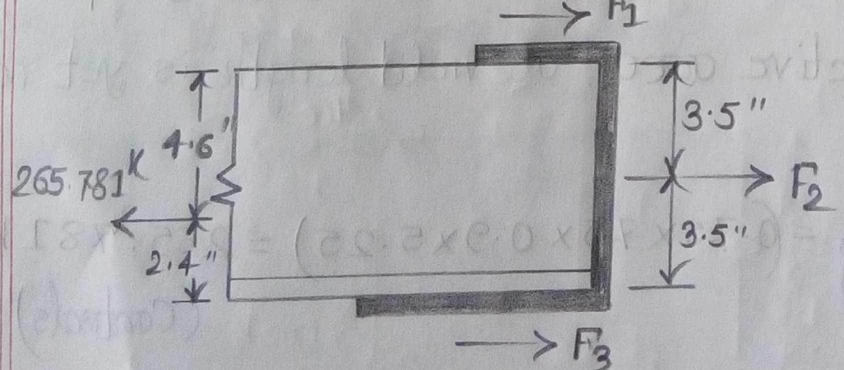
$$= 0.75 \times 0.221 \times (0.6 \times 70)$$

$$= 6.962 \text{ kip/in}$$

Total weld length required, $L_W = \frac{\phi T_n}{\phi R_{nw}} = \frac{265.781}{6.962}$

$$= 38.176''$$

$$\approx 38.5''$$



Force carried by the welds at the end of angle,

$F_2 = L_2 \times \phi R_{nw} = (7 \times 6.962) = 48.734$ kip

$F_1 + F_3 = (265.781 - 48.734) = 217.047$ kip

Taking moment about center of F_3 we have,

$F_1 \times 6 + 48.734 \times 3 = 265.781 \times 2.4$

$\therefore F_1 = 81.945$ kip

$F_3 = (217.047 - 81.945) = 135.102$ kip

Therefore, corresponding weld lengths are,

$$L_1 = \frac{F_1}{\phi R_{nw}} = \frac{81.945}{6.962} = 11.77'' \approx 12.0''$$

$$L_n = \frac{F}{\phi R_{nw}} = \frac{135.102}{6.962} = 19.406'' \approx 19.5''$$

Final allowable weld capacity $= \phi R_{nw} \times L_w$

$= 6.962 \times (7 + 12 + 19.5)$

$= 268.037$ kip

Check U:

Average weld length in the direction of load.

$$l = \left(\frac{12 + 19.5}{2}\right) = 15.75''$$

$U = \left(1 - \frac{\bar{x}}{l}\right) = \left(1 - \frac{0.910}{15.75}\right) = 0.94$

Now, $\phi T_n = \phi F_u U A_g = (0.75 \times 75 \times 0.94 \times 5.25)$

$= 277.594$ kip (OK)

Check Base Material Strength:

Yielding : $\phi T_n = \phi t (0.6 F_y) L = 1.0 \times \frac{3}{8} \times (0.6 \times 60) \times 38.5$

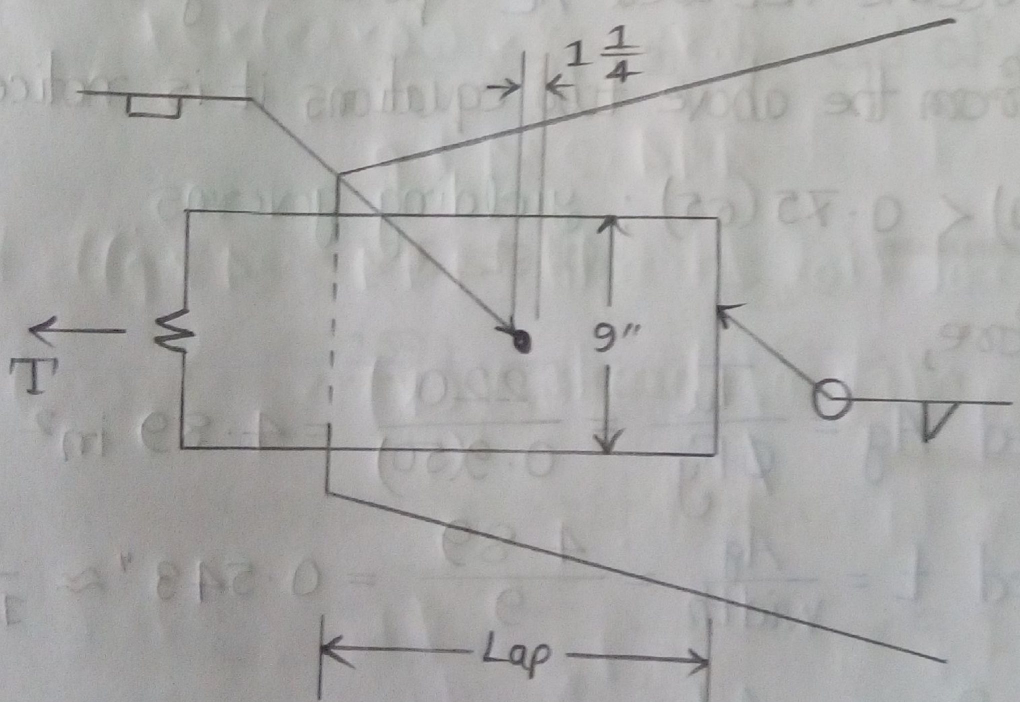
$= 519.75$ kip

Rupture : $\phi T_n = \phi t (0.6 F_u) L = 0.75 \times \frac{3}{8} \times (0.6 \times 75) \times 38.5$

$= 487.266$ kip

Base material strength (487.266 kip) is higher than the connection strength. (OK).

5.13 Assume a 9 in wide plate used in a lap joint must carry 30 kips dead load and 115 kips live load and a possibility exists of some accidental eccentricity that cannot be computed. To insure a tighter joint, a $1\frac{1}{4}$" diam plug weld is to be used. Determine the thickness of the plate, the amount of lap, and the weld size for the best joint. Assume the gusset plate to which the 9 in plate is welded does not c any of the design. Use A572 Grade 50 steel and the SMAW process.



Sol^n: Factored load to be carried,

$$T_u = 1.2DL + 1.6LL$$

$$= 1.2 \times 30 + 1.6 \times 115$$

$$= 220 \text{ kips}$$

For A572 Grade 50 steel computing the thickness required,

$\phi T_n = \phi F_y A_g = (0.9 \times 50) A_g$ (yielding limit state)

$\phi T_n = \phi F_u A_e = (0.75 \times 65) A_g$ (fracture limit state)

Since, there are no holes and no eccentricity of loading, the effective net area A_e equals the gross area A_g.

Thus, from the above two equations it is noticed that,

$0.9(50) < 0.75(65)$; yielding governs.

Therefore,

$$\text{Required } A_g = \frac{T_u}{\phi F_y} = \frac{220}{0.9(50)} = 4.89 \text{ in}^2$$

$$\text{Required } t = \frac{A_g}{\text{width}} = \frac{4.89}{9} = 0.543'' \approx \frac{9}{16}''$$

(Ans.)

Use $\frac{9}{16} \times 9$ plates.

Select Weld Size:

Minimum size fillet weld = $\frac{1}{4}$ "

Maximum size fillet weld = $\left(\frac{9}{16} - \frac{1}{16}\right) = \frac{1}{2}$ "

Use $\frac{6}{16}$ " fillet weld with E70 electrodes.

Design strength of weld, $\phi R_{nw} = \phi t_e (0.6 F_{Exx})$

$$= 0.75 \times \left(0.707 \times \frac{6}{16}\right) \times (0.6 \times 70)$$

$$= 8.351 \text{ kip/in}$$

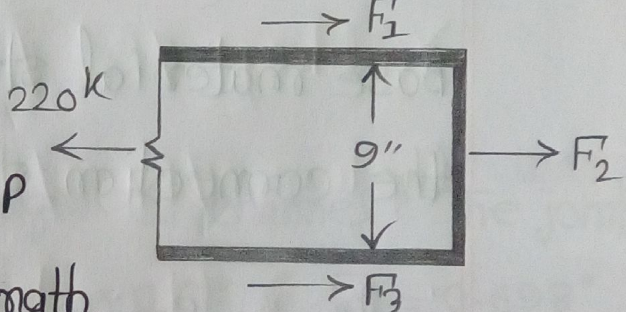
Total weld length required, $L_w = \frac{T_u}{\phi R_{nw}} = \frac{220}{8.351} = 26.34''$

Force carried by the welds at the end of plate

$F_2 = L_2 \times \phi R_{nw}$

$= (9 \times 8.351) = 75.159$ kip

$F_1 = F_3 = \left(\frac{220 - 75.159}{2}\right) = 72.421$ kip



Therefore, corresponding weld length,

$L_1 = L_3 = \frac{F_1}{\phi R_{nw}} = \frac{72.421}{8.351} = 8.67'' \approx 9.0''$

So, Lap length = 9.0" (Ans:)

Final allowable weld capacity $= \phi R_{nw} \times L_w$

$= 8.351 \times (9+2\times 9)$

$= 225.477$ kip.

Check Base Material strength:

Yielding: $\phi T_n = \phi t (0.6 F_y) L$

$= 1 \times \frac{9}{16} \times (0.6 \times 50) \times 27$

$= 455.625$ kip

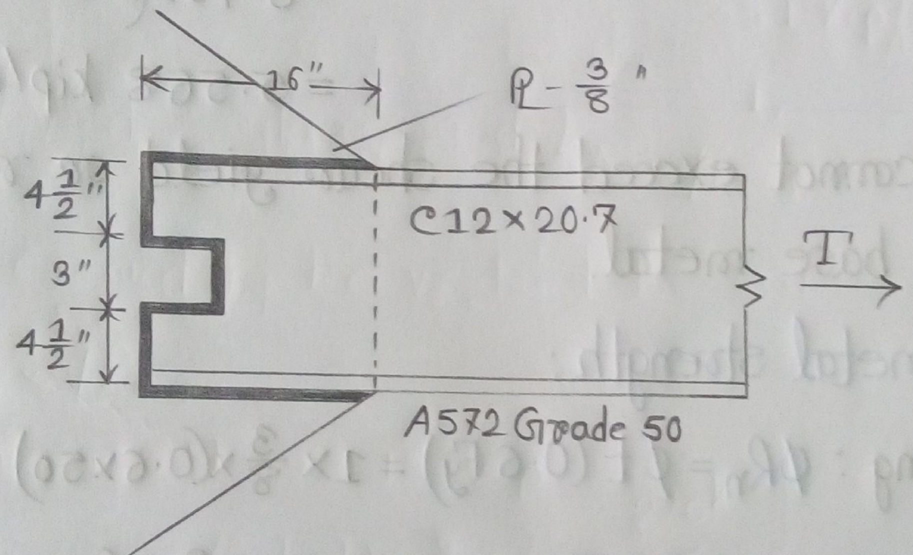
Rupture: $\phi T_n = \phi t (0.6 F_u) L$

$= 0.75 \times \frac{9}{16} \times (0.6 \times 65) \times 27$

$= 444.234$ kip

Base material strength (444.234 kip) is higher than the connection strength. (OK)

5.14 Determine the minimum length of slot in order to develop the full strength of a C 12×20.7 welded to a $\frac{3}{8}$ in plate. Use the same size fillet weld over the entire length, and assume it to be placed by the SMAW process. Assume service load is 35% dead load and 65% live load.



Sol^n: Compute the design strength of channel: The joint length in the direction of load, $l = 16"$ & $\bar{x} = 0.698"$

$$U = \left(1 - \frac{\bar{x}}{l}\right) = \left(1 - \frac{0.698}{16}\right) = 0.96$$

$A_g = 6.08 \text{ in}^2$

$t_w = 0.282"$

Yielding : $\phi T_n = 0.9 F_y A_g = 0.9(50) \quad = 273.6^k$ (controls)

Rupture : $\phi T_n = 0.75 F_u U A_g = 0.75 \times 65 \times 0.96 \times 6.08 = 284.544^k$

Select fillet weld size 'a' and compute length required

Minimum size fillet weld = $\frac{3}{16}$"

Maximum size fillet weld = $\left(0.282 - \frac{1}{16}\right) = 0.2195$"

$\approx \frac{1}{4}$"

Use $\frac{1}{4}$" fillet weld with E70 electrodes.

Design strength of weld $\phi R_{nw} = \phi\, t_e (0.6 F_{Exx})$

$= 0.75 \times \left(0.707 \times \frac{1}{4}\right) \times (0.6 \times 70)$

$= 5.568$ kip/in

which cannot exceed the shear yield or rupture strength of the base metal.

Base metal strength:

Yielding : $\phi R_n = \phi\, t\,(0.6 F_y) = 1 \times \frac{3}{8} \times (0.6 \times 50) = 11.25$ k/in

Rupture : $\phi R_n = \phi\, t\,(0.6 F_u) = 0.75 \times \frac{3}{8} \times (0.6 \times 65) = 10.97$ k/in

∴ The weld controls.

Required weld length, $L_W = \frac{\phi T_n}{\phi R_{nw}} = \frac{273.6}{5.568} = 49.14$'

Available weld length $= [2 \times 16 + 4.5 + (3 \times 3) + 4.5]$

$= 50$"

So, no Slot weld is required.