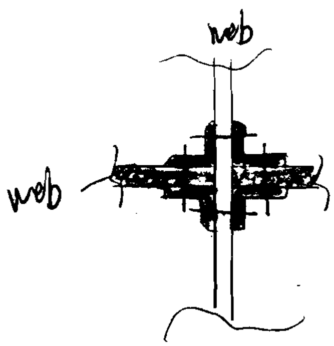
DESIGN CONNECTIONS AT POINT J, K, L, & F

[redacted]

From the ansys results, knowing the worst combination loading condition at point E, F, G, J, K, & L are:

ELEMENT 284–0°	$F_x = 438.89$ lb
ELEMENT 254–0°	$F_y = +234.85$ lb
ELEMENT 263–0°	$F_z = 335.54$ lb
ELEMENT 263–0°	$M_x = 3090.9$ lb-in
ELEMENT 263–0°	$M_y = +34972$ lb-in (DESIGN FOR WELDS)
ELEMENT 254–0°	$M_z = +4891$ lb-in



Thus:

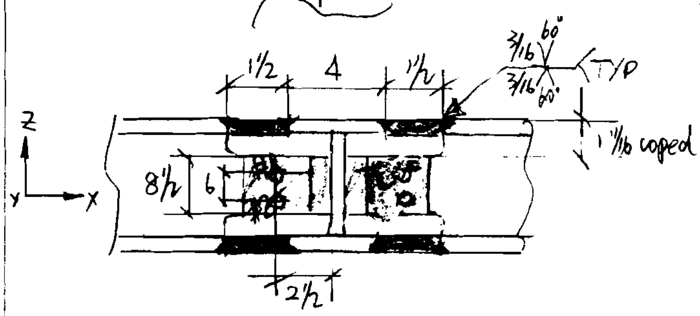
shear in x-direction = 438.89 lb

Tension in Y-direction = 234.85 lb

shear in z-direction = 355.54 lb

Top Bolts Tension caused by M_x

$$\frac{3090.9}{6} = 515.15 \text{ lb}$$



Bottom Bolts compression caused by M_x:

$$\frac{3090.9}{6} = 515.15 \text{ lb}$$

Left side Bolts Tension caused by M_z:

$$\frac{4891}{(2\frac{1}{2} + 0.22 + 2\frac{1}{2})} = 936.9 \text{ lb}$$

Angle: L4×4×3/8"·8½" ×4 (each)

Bolt: A325 – 3/4" – 13/16 dia hole ×4 (each)

plate: 1/4" × 1½" × 4" × 4 (each

Therefore,

- Combined shear in x-z plane:

$$\sqrt{438.89^2 + 355.54^2} = 564.83 \text{ lb}$$

- shear per bolt in x-z plane:

$$\tfrac{1}{2} \times 564.83 = 282 \text{ lb}$$

- Combined Tension / compression on Bolt #1

$$\left(\tfrac{1}{2} \times 234.85\right) + 515.15 + \left(\tfrac{1}{2} \times 936.9\right) = 1101.02 \text{ lb}$$

- Combined Tension / compression on Bolt #2

$$\left(\tfrac{1}{2} \times 234.85\right) - 515.15 + \left(\tfrac{1}{2} \times 936.9\right) = 70.70 \text{ lb}$$

Bolt #1 is critical because it carries the largest tension load.

o FIND THE COMPUTED SHEAR STRESS f_v (ksi)

$$f_v = \frac{P}{A} \quad \text{where } P = 282\ lb$$
$$A = 0.4418\ in^2$$

$$f_v = \frac{282}{0.4418} = 0.638\ ksi$$

o FIND THE ALLOWABLE SHEAR STRESS F_v (ksi)

According to AISC, ASD, Table J3.2, page 5-73, knowing:
when the connection is the bearing type and threads in the shear plane, $F_v = 21\ ksi$ —— governs

According to ANSI-ASME, B30.20-1993, Below the Hook Lifting Devices, knowing:

$$F_v = \frac{1}{3} F_y \quad \text{where } F_y = 92\ ksi \text{ for A325}$$
$$F_v = \frac{1}{3} \times 92 = 30.6\ ksi$$

o FIND THE SAFETY FACTOR ON SHEAR STRESS

$$f_v = 0.638\ ksi$$
$$F_v = 21\ ksi$$
$$SF = \frac{F_v}{f_v} = \frac{21}{0.638} = 32.9$$

○ FIND THE COMPUTED TENSILE STRESS f_t (ksi)

$$f_t = \frac{1101.02}{0.4418} = 2.492 \text{ ksi}.$$

○ FIND THE ALLOWABLE TENSION STRESS F_t (ksi)

From Table J3.3, AISC, ASD. page 5-74

knowing, when the connection is bearing type and threads in the shear plane

$$F_t = \sqrt{(44)^2 - 4.39(f_v)^2}$$

where $f_v = 0.638$ ksi

$$F_t = \sqrt{44^2 - 4.39 \times 0.638^2} = 43.99 \text{ ksi}$$

According to ANSI/ASME B30.20-1985 Below the Hook Lifting Devices, knowing

$F_t = \frac{1}{3} F_y$ where $F_y = 92$ ksi for A325

$F_t = \frac{1}{3} \times 92 = 30.6$ ksi —— governs

○ FIND THE SAFETY FACTOR ON TENSILE STRESS

$f_t = 2.492$ ksi

$F_t = 30.6$ ksi

$$SF = \frac{30.6}{2.492} = 12.3$$

o FIND THE BOLT BEARING STRESS ON CONNECTING MATERIAL F_p (ksi)

Beam web : $t = 0.22in$

From Table I-E, AISC, ASD page 4-6

When $t = 0.2$ in, Bearing allowable load per bolt is

$$52.2 \times 0.22 = 11.484 \text{ Kips}$$

$$F_p = \frac{P/n}{dt}$$ where d — nominal dia. of fasteners
t — the thickness of the connection mater

$$F_p = \frac{11.484}{0.75 \times 0.22} = 69.6 \text{ ksi}$$

Angle : $t = 0.375 \text{ in} \times 2 = 0.75$ in

From Table I-E, AISC, ASD page 4-6

When $t = 0.75$ in, Bearing allowable load per bolt is

$$52.2 \times 0.75 = 39.15 \text{ Kips}$$

$$F_p = \frac{P/n}{dt} = \frac{39.15}{0.75 \times 0.75} = 69.6 \text{ ksi}$$

According to ANSI/ASME B30.20-1985 Below the Hook Lifting Devices

$F_p = \frac{1}{3} F_y$ where $F_y = 36$ ksi for A36

$F_p = \frac{1}{3} \times 36 = 12$ ksi ——— governs

O FIND THE COMPUTED BOLT STRESS ON CONNECTING MATERIAL f_p (ksi)

for beam web:

$$f_p = \frac{P/n}{dt}$$

"STRUCTURAL STEEL DESIGN"
chap. 18, page 396

where P — load
d — nominal fasteners dia.
t — the thickness of the material

knowing: $P = 564.83 \text{ lb}$
$n = 2$
$d = 0.75 \text{ in}$
$t = 0.22 \text{ in}$

$$f_p = \frac{564.83/2}{0.75 \times 0.22} = 1.711 \text{ ksi}$$ — governs

for single angle:

$$f_p = \frac{P/n}{dt}$$

where $P = \frac{1}{2} \times 564.83 = 282.41 \text{ lb}$
$n = 2$
$d = 0.75 \text{ in}$
$t = 0.375 \text{ in}$

$$f_p = \frac{282.41/2}{0.75 \times 0.375} = 0.502 \text{ ksi}$$

o FIND THE SAFETY FACTOR ON BOLT BEARING STRESS

$f_p = 1.711$ ksi

$F_p = 12$ ksi

$SF = \frac{12}{1.711} = 7$

o FIND THE ALLOWABLE SHEAR STRESS ON THE NET AREA OF THE CONNECTION ANGLE R_v (ksi)

According to AISC, ASD J4 page 4-10.

$R_v = 2 \times 0.3\, F_u$ where $F_u = 58$ ksi for A36

$R_v = 2 \times 0.3 \times 58 = 34.8$ ksi

for single angle, $R_v = \frac{1}{2} \times 34.8$ ksi $= 17.4$ ksi

According to ANSI/ASME B30.20-1985 Below the Hook Lifting Devices,

$R_v = \frac{1}{3} F_y$ where $F_y = 36$ ksi for A36

$R_v = \frac{1}{3} \times 36 = 12$ ksi ——— governs

o FIND THE COMPUTED SHEAR STRESS ON THE NET AREA OF THE CONNECTION ANGLE γ_v (ksi)

for single angle,

Shear force $= \frac{1}{2} \times 564.83 = 282.41$ lb net area $= t\,[L - n(d + \frac{1}{16})]$

$= 0.375 \times [8.5 - 2(0.75 + \frac{1}{16})]$

$= 2.578\ in^2$

$\gamma_v = \frac{282.41}{2.578} = 0.110\ ksi$

O FIND THE SAFETY FACTOR ON SHEAR STRESS ON THE NET AREA OF THE CONNECTION ANGLE

$\gamma_v = 0.110\ ksi$

$R_V = 12\ ksi$

$SF = \frac{12}{0.110} = 109$

O FIND THE ALLOWABLE BLOCK SHEAR IN THE BEAM WEB V_{BS} (ksi)

From Table I-G, AISC, ASD, page 4-8

$R_{BS} = (C_1 + C_2)\,F_u t$.

where R_{BS} — Resistance to block shear (kips)

F_u — Tensile strength for A36 (58 ksi)

t — web thickness (in)

C_1 — coefficient

C_2 — coefficient

when $l_v = 1\frac{1}{4}$ $\quad l_h = 2\frac{1}{2} - \frac{1}{2} = 2$

$C_1 = 1.38$

When $n=2$ Bolt dia $= 3/4$

$C_2 = 0.33$

Thus, $R_{BS} = (1.38+0.33)\times 58 \times 0.22$

$= 21.819$ Kips

$A_{net} = t\,[L - n(d+\frac{1}{16})]$

$= 0.22\times[8.5-2(0.75+\frac{1}{16})]$

$= 1.513\ in^2$

$V_{BS} = \frac{R_{BS}}{A_{net}}$

$= \frac{21.819}{1.513} = 14.42$ ksi

According to ANSI/ASME B30.20-1985 Below the Hook Lifting Devices,

$V_{BS} = \frac{1}{3}F_y$ where $F_y = 36$ ksi for A36

$V_{BS} = \frac{1}{3}\times 36 = 12$ ksi — governs

o FIND THE COMPUTED BLOCK SHEAR IN THE BEAM WEB ν_{BS} (ksi)

$\nu_{BS} = \frac{564.83}{1.513} = 0.373$ ksi

o FIND THE SAFETY FACTOR ON BLOCK SHEAR

$\nu_{BS} = 0.373$ ksi

$V_{BS} = 12$ ksi

$SF = \frac{12}{0.373} = 32.2$

O FIND THE ALLOWABLE BENDING STRESS ON THE NET AREA OF THE CONNECTION ANGLE Fb (ksi)

According to ASIC, ASD, page 5-46.

For non-compact section angles,

$F_b = 0.60 F_y$ when $F_y = 36$ ksi for A36

$F_b = 0.60 \times 36 = 21.6$ ksi

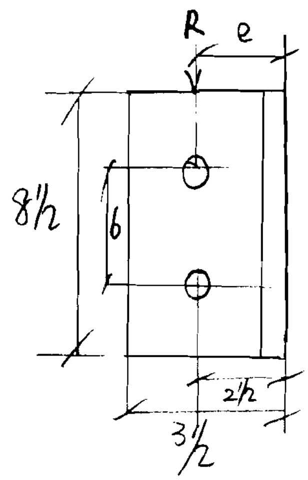
According to ANSI/ASME B30.20-1985 Below the Hook Lifting Devices

$F_b = \frac{1}{3} F_y$ where $F_y = 36$ ksi for A36

$F_b = \frac{1}{3} \times 36 = 12$ ksi —— governs

O FIND THE COMPUTED BENDING STRESS ON THE NET AREA OF THE CONNECTION ANGLE fb (ksi)

For single angles



$M = R \times e$

where $R = 282.41$ lb

$e = 2.5$ in

$M = 282.41 \times 2.5 = 706.03$ lb-in

$S_{net_x} = 3.1259$ in^3

$f_b = \frac{M}{S_{net_x}} = \frac{706.03}{3.1259} = 0.226$ ksi

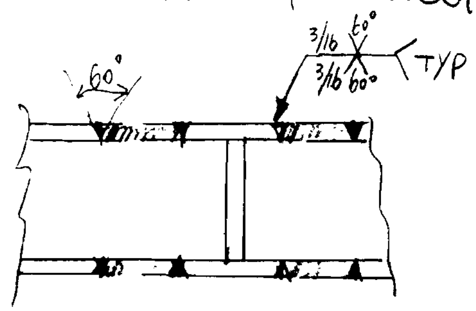
O FIND THE SAFETY FACTOR ON BENDING STRESS ON THE NET AREA OF THE CONNECTION ANGLE

$f_b = 0.226$ ksi

$F_b = 12$ ksi

$$SF = \frac{12}{0.226} = 53.1$$

DESIGN THE MOMENT CONNECTION DUE TO M_y



V-groove welds

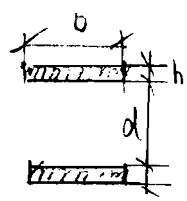
$\alpha = 60°$

Welds: E70XX

Acording to AISC, ASD, page 4-168, knowing. the SingleVgroove welds is acceptable.

Acording to AISC, ASD, Table J2.1 & Table J2.3, page 5-66, knowing, the effective throat thickness is 3/16"

Acording to "Mechanical Engineering Design" Shigley 5th edition, chapter 9. Bending in welded joints, knowing:



$$\sigma = \frac{1.44M}{bdh}$$

Where $M = 34972$ lb-in

$d = 11.99 - 2\times0.1875 = 11.615$ in

$h = 0.1875$ in

Acording to AISC, ASD, TABLE J2.5, page 5-70. knowing for partial penetration Groove welds under compression normal to effective area, the allowable stress on welds is the same as the base metal.

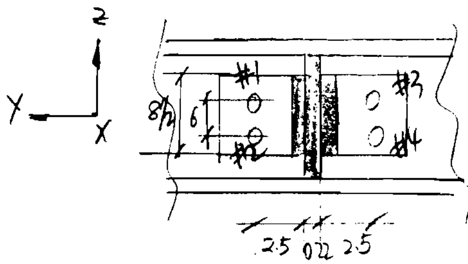
therefore, $\sigma = 12000$ psi

$$b = \frac{1.44M}{\sigma d h} = \frac{1.44\times34972}{12000\times11.615\times0.1875} = 1.9 \text{ in}$$

USE 4 in

$$SF = \frac{4}{1.9} = 2.1$$

[redacted]



Angle: ∟ 4×4× 3/8" × 8½ ×(2)

Bolt: A325 – 3/4" dia – 13/16" in holes

From Ansys results at points E, F, G, J, K & L with the worst combination. Knowing:

$F_x = 438.89$ lb

$F_y = 234.85$ lb

$F_z = 355.54$ lb

$M_x = 3090.9$ lb-in

$M_y = 34972$ lb-in (Design for welds)

$M_z = 4891$ lb-in

Thus,

Tension in x-direction = 438.89 lb

Shear in y-direction = 234.85 lb

Shear in z-direction = 355.54 lb

Shear caused by M_x in z direction

$$\frac{3090.9}{(2.5+0.22+2.5)} = 592.13 \text{ lb}$$

Tension on left side Bolts caused by M_z

$$\frac{4891}{(2.5+0.22+2.5)} = 936.97 \text{ lb}$$

Compression on right side Bolts caused by M_z

$$\frac{4891}{(2.5+0.22+2.5)} = 936.97 \text{ lb}$$

Therefore:

- Combined shear in z-direction:

  $355.54 + 592.13 = 947.67$ lb

- Resultant shear in y-z plane:

  $\sqrt{947.67^2 + 234.85^2} = 976.33$ lb

- Shear on #1 bolt

  $\sqrt{(\frac{1}{4} \times 234.85)^2 + (\frac{1}{2} \times 592.13 + \frac{1}{4} \times 355.54)^2} = 389.4$ lb

- Shear on #2 bolt

  same as #1 Bolt

- Shear on #3 Bolt

  $\sqrt{(\frac{1}{4} \times 234.85)^2 + (\frac{1}{4} \times 355.54 - \frac{1}{2} \times 592.13)^2} = 215.34$ lb

- Shear on #4 Bolt

  Same as #3 Bolt

- Compression / Tension on Bolt #1

  $(\frac{1}{4} \times 438.89) + (\frac{1}{2} \times 936.97) = 578.46$ lb

- Tension / compression on Bolt #2

  $(\frac{1}{4} \times 438.89) + (\frac{1}{2} \times 936.97) = 578.46$ lb

- Tension / compression on Bolt #3

  $(\frac{1}{4} \times 438.89) - (\frac{1}{2} \times 936.97) = -358.76$ lb

- Tension / compression on Bolt #4

  $(\frac{1}{4} \times 438.89) - (\frac{1}{2} \times 936.97) = -358.76$ lb

Bolts #1 & #2 are critical because they carry the largest tension load.

O FIND THE ALLOWABLE SHEAR STRESS ON THE BOLT F_v (ksi)

From Table J3.2 AISC, ASD, page 5-73

When the connection is bearing type and threads in the shear plane,

$F_v = 21$ ksi —— governs

According to ANSI/ASME B30.20-1985 Below the Hook Lifting Devices

$F_v = \frac{1}{3} F_y$ where $F_y = 92$ ksi for A325

$F_v = \frac{1}{3} \times 92 = 30.6$ ksi

O FIND THE COMPUTED SHEAR STRESS f_v (ksi)

From Table I-A AISC, ASD, page 4-3

Knowing: A325 3/4" Bolt → $A = 0.4418\ in^2$

thus, $f_v = \frac{389.4}{0.4418} = 0.881$ ksi

O FIND THE SAFETY FACTOR ON BOLT SHEAR STRESS

$f_v = 0.881$ ksi

$F_v = 21$ ksi

$SF = \frac{21}{0.881} = 23.8$

O FIND THE ALLOWABLE TENSION STRESS ON BOLT F_t (ksi)

From Table J3.3 AISC, ASD, page 5-74,
When, the connection is bearing type and the threads in the shear plane

$$F_t = \sqrt{(44)^2 - 4.39\,(f_v)^2}$$

where $f_v = 0.881$ ksi

$$F_t = \sqrt{44^2 - 4.39 \times 0.881^2} = 43.96 \text{ ksi}$$

According to ANSI/ASME B30.20-1985 Below the Hook Lifting Devices,

$F_t = \frac{1}{3} F_y$ where $F_y = 92$ ksi for A325

$F_t = \frac{1}{3} \times 92 = 30.6$ ksi —— governs

O FIND THE COMPUTED TENSION STRESS ON THE BOLT f_t (ksi)

$$f_t = \frac{578.46}{0.448} = 1.309 \text{ ksi}$$

O FIND THE SAFETY FACTOR ON BOLT TENSION STRESS

$f_t = 1.309$ ksi

$F_t = 30.6$ ksi

$$SF = \frac{30.6}{1.309} = 23.4$$

○ FIND THE ALLOWABLE BOLT BEARING STRESS ON THE CONNECTING MATERIALS. F_p (ksi)

For web, $t = 0.22$ in

From Table I-E, AISC, ASD, page 4-6

When $t = 0.2$ in, Bearing allowable load per bolt is

$52.2 \times 0.22 = 11.484$ kips

$$F = \frac{P}{dt} = \frac{11.484}{0.75 \times 0.2} = 69.6 \text{ ksi}$$

For angles, $t = 0.375 \times 2 = 0.75$ in

From Table I-E, AISC, ASD, page 4-6

When $t = 0.75$ in, Bearing allowable load per bolt is

$52.2 \times 0.75 = 39.15$ kips

$$F = \frac{P}{dt} = \frac{39.15}{0.75 \times 0.75} = 69.6 \text{ ksi}$$

According to ANSI/ASME B30.20-1985 Below the Hook Lifting Devices

$F_p = \frac{1}{3} F_y$ where $F_y = 36$ ksi for A36

$F_p = \frac{1}{3} \times 36 = 12$ ksi —— governs o FIND THE COMPUTED BOLT BEARING STRESS ON CONNECTING MATERIAL f_p (ksi)

For web,

$$f_p = \frac{P/n}{dt}$$ "STRUCTURAL STEEL DESIGN" chap. 18 page 596

where $P = 976.3 lb$

$n = 4$

$d = 0.75$

$t = 0.22$

$$f_p = \frac{9763/4}{0.75 \times 0.22} = 1.479 ksi$$ — governs

For angles,

$$f_p = \frac{P/n}{dt}$$ "STRUCTURAL STEEL DESIGN" chap. 18, page 596

Where $P = \frac{1}{2} \times 976.33 = 488.17 lb$

$n = 2$

$d = 0.75 in$

$t = 0.375 in$

$$f_p = \frac{488.17/2}{0.75 \times 0.375} = 0.868 ksi$$

o FIND THE SAFETY FACTOR ON BOLT BEARING STRESS

$f_p = 1.479 ksi$

$F_p = 12 ksi$

$$SF = \frac{12}{1.479} = 8.1$$

O FIND THE ALLOWABLE SHEAR STRESS ON THE NET AREA OF CONNECTION ANGLE R_V (ksi)

According to AISC, ASD J.4 page 4-10

$R_V = 0.3\,F_u$ for single angle

where $F_u = 58$ ksi for A36

then, $R_V = 0.3 \times 58 = 17.4$ ksi.

According to ANSI/ASME B30.20-1985 Below the Hook Lifting Devices

$R_V = \frac{1}{3} F_y$ where $F_y = 36$ ksi for A36

$R_V = \frac{1}{3} \times 36 = 12$ ksi —— governs

O FIND THE COMPUTED SHEAR STRESS ON THE NET AREA OF CONNECTION ANGLE γ_V (ksi)

For single angle,

shear load $= \frac{1}{2} \times 976.33$ lb $= 488.17$ lb

Net area $= 2.578$ in^2

$$\gamma_V = \frac{488.17}{2.578} = 0.189 \text{ ksi}$$

O FIND THE SAFETY FACTOR ON SHEAR STRESS ON THE NET AREA OF THE CONNECTION ANGLE.

$\gamma_V = 0.189$ ksi

$R_V = 12$ ksi

$$SF = \frac{12}{0.189} = 63.5$$

○ FIND THE ALLOWABLE BENDING STRESS ON THE NET AREA OF THE CONNECTION ANGLE

According to AISC, ASD, page 5-46

For non-compact section angles,

$F_b = 0.60 F_y$ where $F_y = 36$ ksi for A36

$F_b = 0.60 \times 36 = 21.6$ ksi

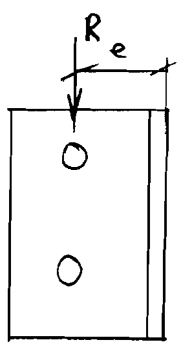
According to ANSI/ASME B30.20-1985 Below the Hook Lifting Devices

$F_b = \frac{1}{3} F_y$ where $F_y = 36$ ksi for A36

$F_b = \frac{1}{3} \times 36 = 12$ ksi ——— governs

○ FIND THE COMPUTED BENDING STRESS ON THE NET AREA OF THE CONNECTION ANGLE.

For single angle,



$M = Re$

where $R = 976.33 \times \frac{1}{2} = 488.17$ lb

$e = 2.5$ in

$M = 488.17 \times 2.5 = 1.220$ kip-in

$S_{net} = 3.1259$ in^3

$$f_b = \frac{M}{S_{x\,net}} = \frac{1.220}{3.1259} = 0.390 \text{ ksi}$$

O FIND THE SAFETY FACTOR ON BENDING STRESS ON THE NET AREA OF THE CONNECTION ANGLE.

$f_b = 0.390$ ksi

$F_b = 12$ ksi

$$SF = \frac{12}{0.390} = 30.8$$

O CHECK THE ASSEMBLING CLEARANCES

— Bolt connected with Horizontal member:

* Bolt: 3/4-10 UNC-2A type 1. (medium carbon steel)
  HEX HEIGHT 1/2"
* NUT: A194 grade 2 for Bolt 3/4" dia (hardened)
  nut HEIGHT 3/4"
* Washer: F436 hardened flat washer for Bolt 3/4" dia.
  Washer height 5/32"

Bolt length = the total thickness of all connected material + Grip + Washer

$= (0.24 + 0.375 \times 2) + (1) + (5/32)$

$= 2.12625"$ ↳ 2½" Long

Bolt: 3/4-10 UNC 2A x 2½" Long x (2) each

– Bolt connected with vertical member :

Bolt length = the ~~treal~~ thickness of all connected material + Grip + washer

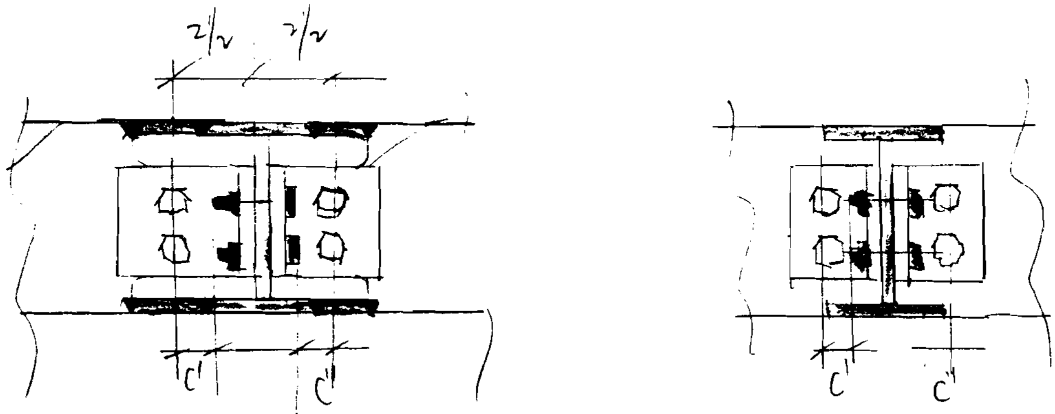
$= (0.22 + 0.375 \times 2) + (1) + (5/32)$

$= 2.126''$

↳ USE $2\frac{1}{4}''$ long Bolt

Bolt : $\frac{3}{4}$ – 10UNC 2A + $2\frac{1}{4}''$ long × 4 (each)

-CHECK THE ASSEMBLING CLEARANCE :



According to AISC, ASD, page 4-137, knowing, for A325 Bolt ¾" dia.

C_1 = tightening clearance = 1¼"

C_2 = entering clearance = ¾"

$C' = 2\frac{1}{2} - (2\frac{1}{4} - 0.22 - 0.375 \times 1)$

$= 0.845'' > C_2$ use open end wrench

$C'' = 2\frac{1}{2} - (0.375 + \frac{1}{2})$

$= 1.625$ in $> C_1$ use socket wrench

In Conclusion, the connection as sketched is adequate.