Cleveland Innerbelt

Green Bulkhead Wall

RFI 0094

WT Substitution

Submitted by:

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WT Section

Size web thickness and member length to meet the requirements of AASHTO 6.8.7.2. & 6.8.7.3.

Bearing: (AASHTO 6.8.7.2)

$\phi P_n = \phi_b A_b F_y = P_u$

$\phi_b = 1.0$

$A_b = t_p \times d_{pin}$

$= 2 t_p$

$135^K = (1.0)(2 \cdot t_p)(50)$

$t_p = 1.35$ in $\rightarrow$ say 1.35"

$\phi P_n = (1)(2 \times 1.35)(50)$

$= 135$ k

$\therefore$ min. rqd. web thickness = 1.35"

Tension: (AASHTO 6.8.2.1)

Check tension on gross section and fracture on net section.

$d_h = 2.125"$

$A_g = l \times t$

$A_n = l \times t - 2.125 t$

$= (l - 2.125) t$

$\phi P_n = \phi_y F_y A_g$

$\phi P_n = \phi_u F_u R_p U$

$\phi_y = 0.95$

$\phi_u = 0.80$

$R_p = 0.90$ (conservative)

$U = 1.0$

$\phi F_y = 0.95(50) = 47.5$ ksi

$\phi F_u R_p U = (0.8)(65)(0.9)(1.0) = 46.8$ ksi

Fracture controls . . .

$A_{n_{rqd}} = \dfrac{P_u}{\phi F_u R_p U}$

$= \dfrac{135}{46.8} = 2.88$

for $t_{min} = 1.35"$

$A_{n_{rqd}} = (l - 2.125)(1.35) = 2.88$

$l = 4.25$

Use $l = 6"$ $\Rightarrow A_n = 5.2$ in^2

Bearing Resistance @ Bolt Holes:

Though not a bolt hole, check provisions of AASHTO 6.13.2.9.

Use distance bt. ℄ Pin and plate edge of 3.25" < 2d

$l_c = 3.25 - \frac{1}{2}(2.125)$

$= 2.1875$ in

$\phi R_n = \phi_{bb}\, 1.2 L_c t F_u$

$= 0.80 (1.2)(2.1875)(\overset{1.35}{\boxed{1.2}})(65)$

$= \underset{184}{\boxed{164}}^K > P_u = 135$ OK

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Proportions (AASHTO 6.8.7.3)

Net area of clevis:

$A_n = 2[8 - 2.125](1.5")$
$= 17.6\ in^2$

The net area of the clevis is more than 2x larger than the required min. gross area of the WT web. The 1st 2 provisions of the section are ∴ met by inspection.

t_{com} = combined thickness of clevis and WT web
$= 2(1.5) + 1.2$
$= 4.2$ in (min)

$t_{com} \geq 0.12 \times \ell_c$

$0.12 \times (2.125) = 0.255"$ } $< t_{com}$
$0.12 \times (4) = 0.480"$ } ok

$t_w \geq 0.12\ \ell_{rqd}$

using $\ell_{rqd} = 6"$

$t_{w_r} = 0.12(6) = 0.72" < 1.2$ ok

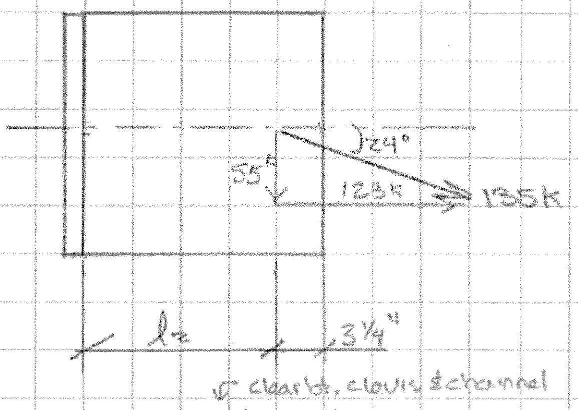
In order to weld the flanges of the WT to the whaler, the required flange width is...

$b_{f_r} = 4 + 2(3.95) + 2" \doteq 14"$

A WT20x251.5 meets the flange and web criteria above.

Combined Bending & Ax. on Web

Check the gross web section for combined bending and flexure for anchor force at 24° to long. axis of WT.



$\ell_{z\,min} = 10" + ½" + 4"$
↖ channel width
$= 14.5$

~~d_{min} = 14.5 + 3.00"(min) ≈ 17.50~~ ~~+3.25~~ ~~20.75~~

For a WT20x251.5 : $t_w = 1.54$

$\ell_z = 21.025 - 2.76 - 3.25$
$= 15.0"$ ok

$M_u = 55^k(15) = 825^{k \cdot in}$
$T_u = 123^k$

Tension Capacity:

$\phi P_n = \phi_y F_y A_g$
$= (0.95)(50)(\boxed{6})(\boxed{1.54}\ in^2)$ 8" 1.34"
$= 439\ k$ → 509 k

WT 20 x 215.5

b_f = 16.~~22~~" >14" ok
t_f = ~~2.24~~" 2.36
d = 20.63" → ℓ_e = ~~14.63~~ 15.02" >14.5" ok
t_w = 1.34" < 1.35" *

* Say ok → Design load of 135k rounded up from 130k.

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Flexural Capacity:

$\phi M_n = \phi_f F_y Z$

$\phi_f = 1.0$

$Z = \frac{1}{4} l^2 t$

$= (1/4)(6^2)(1.54")$

$= 13.86 \text{ in}^3$

$\phi M_n = (1)(50)(13.86)$

$= 693 \text{ k·in} < M_u = 825 \text{ k·in}$

∴ Section must be made longer.

$Z_r = \frac{M_u}{\phi_f F_y}$

$= \frac{825 \text{ k·in}}{50 \text{ ksi}}$

$= 16.5 \text{ in}^3$

$l_r = \sqrt{\frac{4Z}{t}} = \sqrt{\frac{4(16.5)}{1.54}}$

$= 6.55 \text{ in}$

Try 8" long WT.

$Z = \frac{1}{4}(8)^2(1.54)$

$= 24.64 \text{ in}^3$

$\phi M_n = (1)(50)(24.64)$

$= 1232 \text{ k·in} > M_u$ ok.

WT20x215.5

$Z = \frac{1}{4}(8^2)(1.34)$

$= 21.44 \text{ in}^3$

$\phi M_n = 50(21.44)$

$= 1072 \text{ k·in} > M_u = 825 \text{ k·in}$

OK

Interaction: (AASHTO 6.8.2.3)

$\frac{P_u}{\phi P_n} = \frac{123k}{439k} = 0.28 > 0.2$

(509)

$\therefore R = \frac{P_u}{\phi P_n} + \frac{8}{9}\left(\frac{M_u}{\phi M_n}\right)$

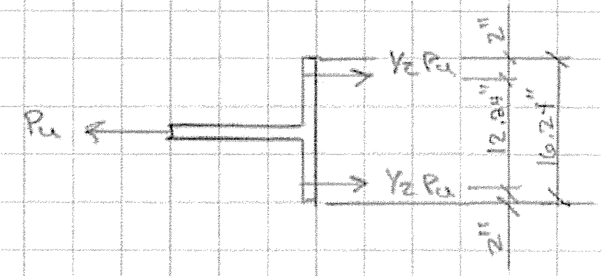
$= 0.28 + \frac{8}{9}\left(\frac{825}{1232}\right)$

$= 0.88 < 1.0$ OK

0.92 w/ WT 20x215.5

Flange Bending

Check bend in flange due to design loading. Worst case will be bolted condition at dead man cap beam. Assume 2" from edge of flange to bolt.



Assume simple span behavior between bolts.

$M_u = \frac{P_u l}{4} = \frac{135^k (12.24)}{4}$

$= 413 \text{ k·in}$

$Z = \frac{1}{4} l t^2$

$= 1/4 (8)(2.76)^2 = 15.2 \text{ in}^3$

WT20x215.5;

$Z = \frac{1}{4}(8)(2.36)^2$

$= 11.14 \text{ in}^3$

$\phi M_n = 557 \text{ k·in}$, ok

$557 \text{ k·in} > M_u$ ok

$\phi M_n = (1)(50)(15.2) = 760 \text{ k·in} > M_u$

$\boxed{\text{WT 20 x 215.5 OK also}}$

∴ Use WT20x251.5 x 8 Long

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Anchor Connections @ Mod. Location

A splayed anchor rod layout is required for a portion of the east bulkhead wall in order to keep the dead man within the ROW limits. To accomodate anchors splayed at a variable skew to both the whaler and dead man cap beam, a pivot type joint incorporating clevises will be used. See the attached sketch for a conceptual detail.

Design Loading

$F_a = 25\ ^{k}/_{ft}$

The anchor rod spacing is reduced to 4'-9" within this segment of the wall. This was done to for the following reasons:

1. to accomodate the axial load in the whaler by reducing the moment demand
2. the capacity of the largest std. clevis will not accomodate the 9.5' spacing.

Calculate anchor rod force:

Conservatively use the value based on skew rod @ 24° to wall

Element Design Approach

1. Select clevis & size grip
2. Design pin size
3. Check WT Section for pin loading:
   - (a) bearing / tear-out
   - (b) tension on gross section
4. Welded connection (WT to whaler)
5. Bolted connection (WT to dead man)
6. Bending on WT flange

Clevis

Per AISC Manual, the factored resistance of a #8 clevis is:

$\phi R_n = 203^{k}$ (w/ $\phi = 0.3$)

$> P_u$ ok

Grip = plate t + 1/4"

$t_p = 1.54''$ see subsequent calcs

Grip = 1.54 + 1/4
$= \underline{1.79''}$

* $P_u = \left(\frac{1}{\cos 24}\right)(25\ ^{k}/_{ft})(4.75) = 130\ ^{k}/_{ft} \Rightarrow$ Use $P_u = 135^{k}$ for design.