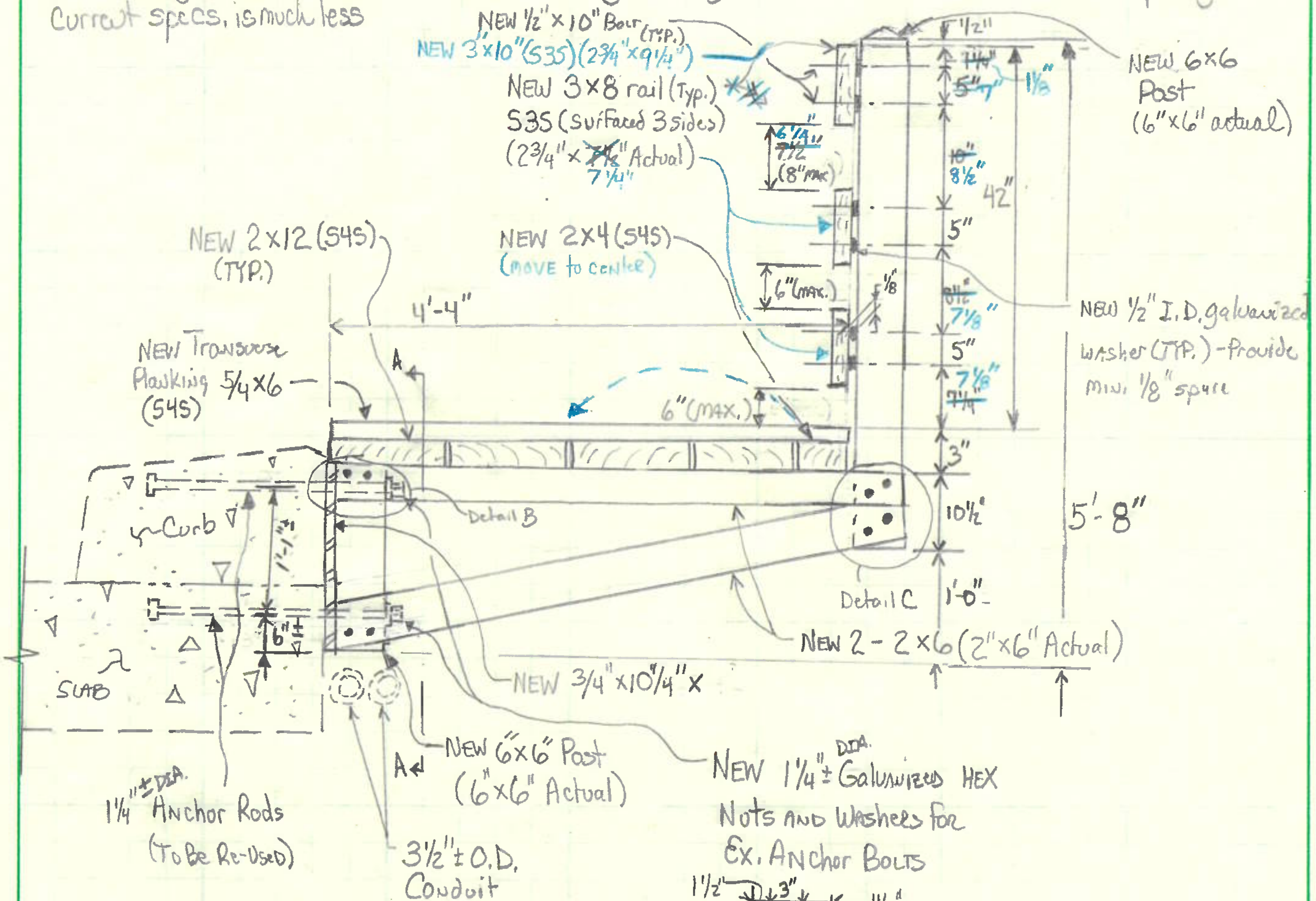
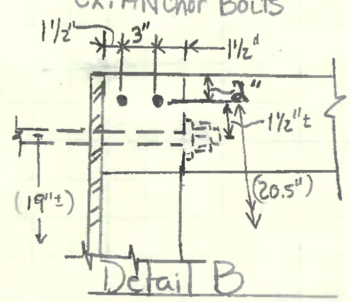
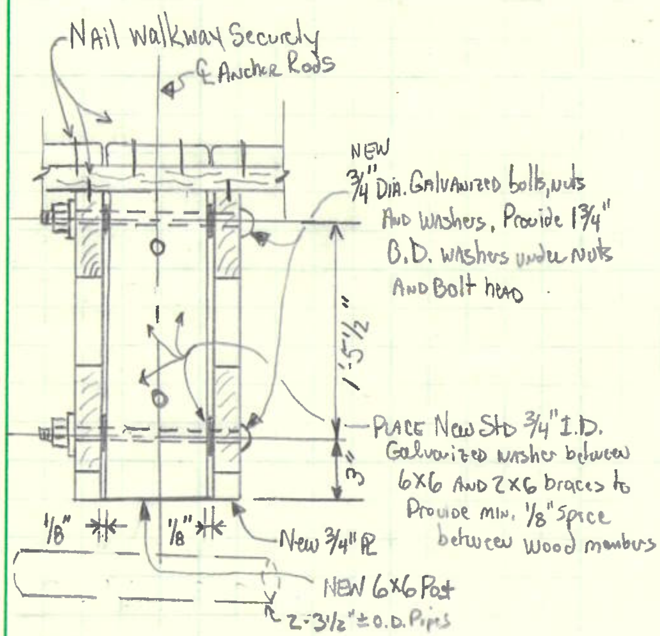
Proposed Sidewalk Section - This varies slightly from the original plan in that it is 4" wider than original to provide a full 4'-0"(min.) of usable surface; and the pedestrian rail is taller to comply with current pedestrian railing requirements (42" above rail vs 36" Existing) Also, adding transverse planking for ADA to walking. Railing must include more rails as max. opening in current specs. is much less

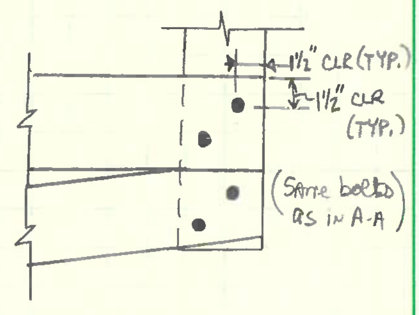



Detail B



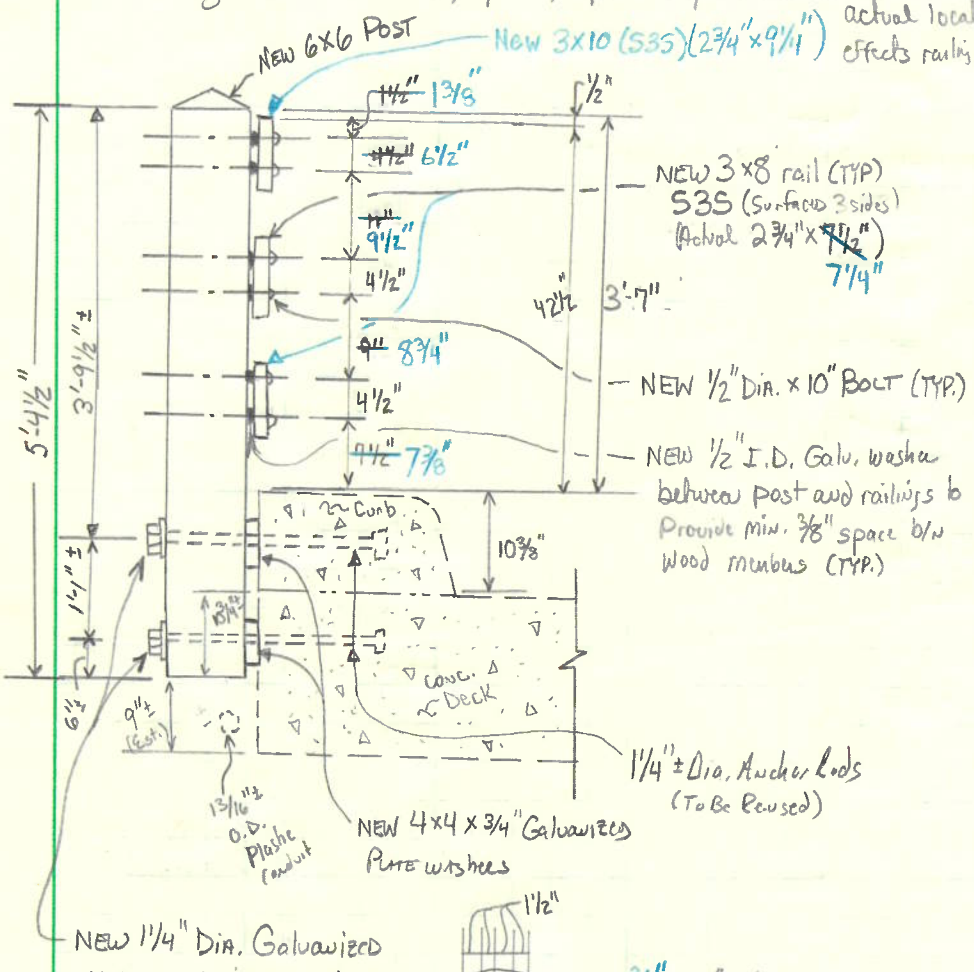

Section A-A

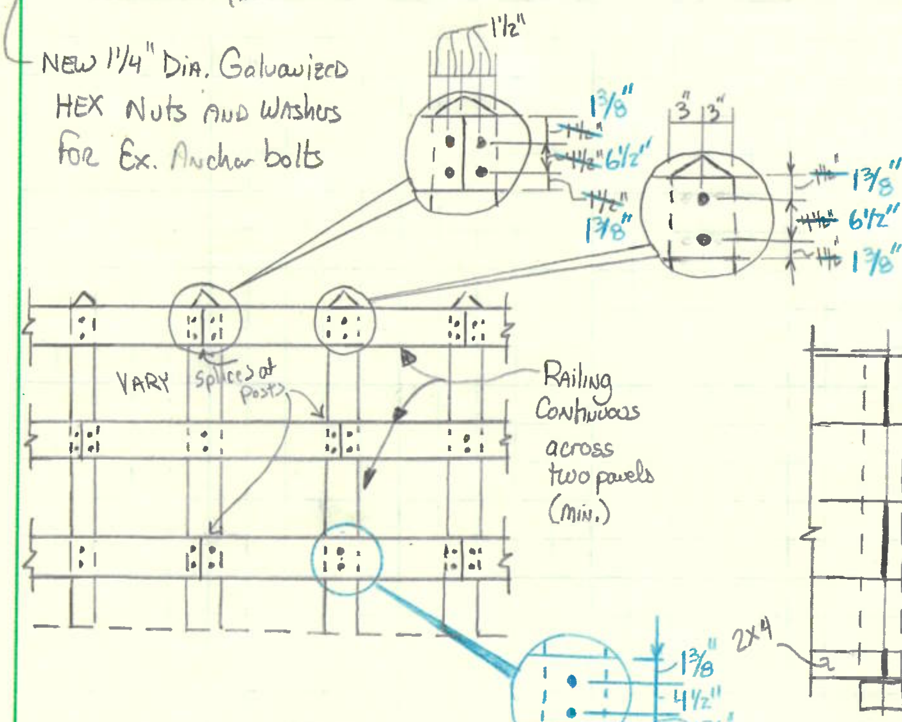



Detail C

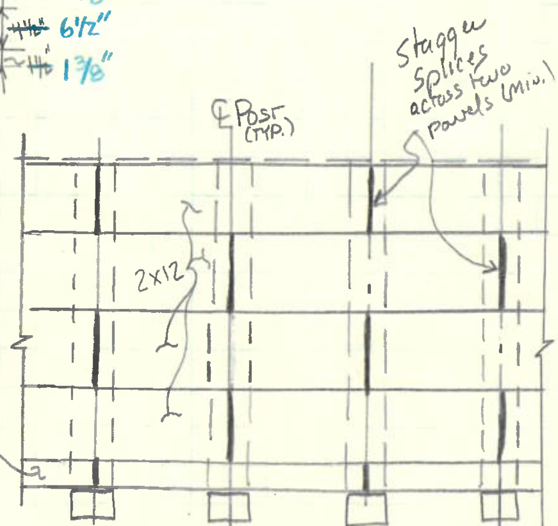
## Proposed Upstream Railing

What is out there now is about 36"-38"± above curb. This railing was never designed to stop an AASHTO Vehicular load. Design new rail for pedestrian load with 42" (min.) tall config. only. The curb is what prevents low-speed vehicles & bicycles from engaging rail. Again, current railing spacing specs require an additional rail. Provide 42½" tall rail as actual location of Anchor bolts is assumed & effects railing height




Proposed Railing Splice Details




Proposed Floor Planking Splice Details

## Specifications

WOOD - RED OAK - #2 or Better (unfactored allowable Bending Stress $F_b = 800$ psi)

HARDWARE - Connections ASTM A307 GRADE: A BOLTS - Galvanized

ASTM A563A HEX NUTS, Galvanized

ASTM F844 Washers, Galvanized

STEEL PLATES - ASTM A709 GR 36 or GR 50 - Galvanized

WOOD TREATMENT - ACQ-TYPE D Retention 2.4 $kg/m^3$ (MIN.)

## SIDEWALK / RAILING DESIGN CALCS.

5/4 x 6 PLANKING - Fully Supported - No Design  use RED OAK

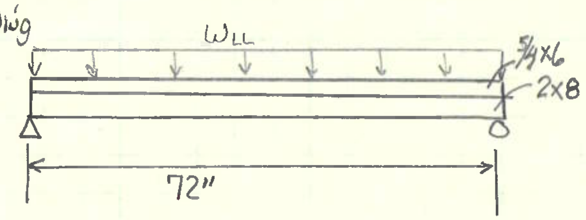
2x12 PLANKS  - S4S - Actual Dim. ~~$7\frac{1}{2}$~~ $11\frac{1}{4}$" x $1\frac{1}{2}$"  use RED OAK  $F_b = 800$ psi (Bending) (No. 2 or better)

WOOD Factors

- $C_m$ (moisture Content - See AASHTO = 0.85 (>19%) for $F_b$ (bending) [could use $C_m = 1.0$ for $F_b \cdot C_F < 1150$ psi]
- $C_d$ (duration factor) = 1.15 (or higher) - Snow & ice
- $C_t$ (temperature factor) = 1.0
- $C_F$ (Size factor - bending) = 1.3 for OAK 2x6 - allowed increase for thin wood laid flat
- $C_f$ (form factor) = 1.0 for Rectangular/Square members
- $C_L$ (lateral Stability factor) = 1.0 (fully braced)
- $C_R$ (Fire retardant) = 1.0 (seldom used on bridges)
- $C_C$ = Curvature = 1.0 (N/A)
- $C_{FU}$ - Flat use = 1.15 for 2" thick x 8"
- $C_r$ = repetitive member factor for Sawn Lumber = 1.15 (see footnote 5 - AASHTO TABLE 13.5.1.A)

Worst case - Plank is simply supported b/w two supports (should be continuous)

Bending




LOADS:

DL: $(1" + 1\frac{1}{2}")/12 \times 1' \times 50\ lb/ft^3 = 10.4\ lb/ft$

LL: $85\ lb/ft^2 \times 1' = 85\ lb/ft$

(No impact for Timber)

$$M_{max} = \frac{wl^2}{8} = \frac{(10.4\ lb/ft + 85\ lb/ft)(6\ ft)^2}{8} = 429.3\ lb\cdot ft$$

$$S_x = \frac{bh^2}{6} = \frac{(\cancel{11.5}\ 11\tfrac{1}{4})(1.5)^2}{6} = \cancel{4.31}\ 4.22\ in^3$$

max bending stress $f_b = M/S = \frac{429.3\ lb\cdot ft \times 12\ in/ft}{\cancel{4.31}\ 4.22\ in^3} = \cancel{1195}\ 1221$ psi < 1344 psi OK

Allowable bending stress $F_b' = F_b \cdot C_m \cdot C_d \cdot C_F \cdot C_{fu} \cdot C_r = 800\ lb/in^2 \times 0.85 \times 1.15 \times 1.3 \times 1.15 \times 1.15$ = 1344 psi

WORST CASE - RED OAK, #2 or Better - $F_b = 800\ lb/in^2$

SHEAR (* This is conservative, doesn't factor in shear not taken @ bearing)

$V = (95.4\ lb/ft)(72"/12)/2 = 286$ lbs  $f_v = \frac{3V}{2b \cdot d} = \frac{3 \times 286\ lbs}{2 \times \cancel{11.5}\ 11.25" \times 1.5"} = \cancel{24.9}\ 25.4$ psi << 85 psi OK

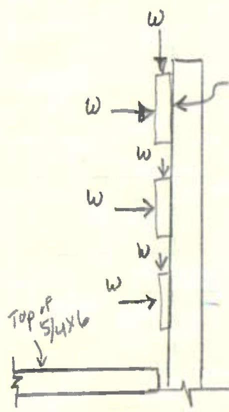
Unfactored $F_v$

(Not going to take time to Factor This)

## Sidewalk Railing Design

Loads Per AASHTO

* (Revising to 7 1/4" x 2 3/4" does not warrant new calcs based on Demand/Capacity)




where $\omega = 50\ \text{lb/ft}$

$\omega_{DL} = (2.75'' \times 7\tfrac{1}{2}'')/144 \times 50\ \text{lb/ft}^3 = 7.2\ \text{lb/ft}$

$S_x = \dfrac{bh^2}{6} = \dfrac{(2.5)(7.5^2)}{6} = 23.4\ \text{in}^3$ $\quad S_y = \dfrac{h \cdot b^2}{6} = \dfrac{(7.5)(2.5)^2}{6} = 7.81\ \text{in}^3$

$M_x = \dfrac{wl^2}{8} = \dfrac{(50\ \text{lb/ft} + 7.2\ \text{lb/ft})(6\text{ft})^2}{8} = 257.4\ \text{lb·ft}$ $\quad M_y = \dfrac{(50\ \text{lb/ft})(6\text{ft})^2}{8} = 225\ \text{lb·ft}$

$f_{bx} = \dfrac{M_x}{S_x} = \dfrac{(257.4\ \text{lb·ft})(12\ \text{in/ft})}{23.4\ \text{in}^3} = 132\ \text{psi}$ $\quad f_{by} = \dfrac{M_y}{S_y} = \dfrac{225 \times 12}{7.81} = 345\ \text{psi}$

Allowable stress - Use Red Oak #2 or better $\quad F_b = 800\text{psi}$

Factors: $C_m = 0.85$ (could use 1.0)

$C_d = 1.25$ (snow & ice?) $\quad F_b' = F_b \cdot C_m \cdot C_d \cdot C_F = \underline{1020\text{psi}}$

$C_F = 1.2$ (size factor) - 8" wide

$C_{FL} = 1.0$ (Flat use - could use 1.15 for horiz loads)

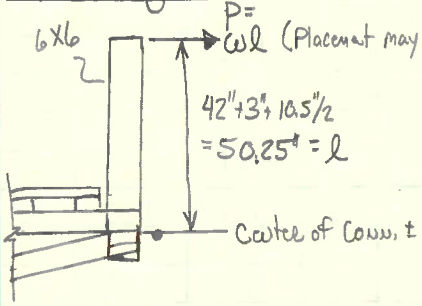
$C_r = 1.0$

Total Combined Bending Stress (interaction formula) $\sqrt{\left(\dfrac{f_{bx}}{F_b'}\right)^2 + \left(\dfrac{f_{by}}{F_b'}\right)^2} = \sqrt{\left(\dfrac{132}{1020}\right)^2 + \left(\dfrac{345}{1020}\right)^2} = 0.36 < 1.0$ **OK**

Quick, conservative shear check: $V_x \approx V_y \approx (57.2\ \text{lb/ft} \times 6\text{ft})/2 = 172\ \text{lbs}$ $\quad f_{vx} = f_{vy} = \tfrac{3}{2}\left(\dfrac{V}{bd}\right) = \dfrac{1.5(172\ \text{lb})}{(7\tfrac{1}{2} \times 2\tfrac{3}{4})} = 12.5\text{psi}$

Total shear $\approx \sqrt{\left(\dfrac{12.5}{85}\right)^2 + \left(\dfrac{12.5}{85}\right)^2} = 0.21 < 1.0$ **OK** (Red Oak unfactored shear ≈ 85 psi)

## Post Design




$P = 50\ \text{lb/ft} \times 6' = 300\ \text{lbs}$ $\quad M_{LL} = P \cdot l = 300\ \text{lb} \times \dfrac{50.25''}{12} = 1256\ \text{lb·ft}$

$S_x = \dfrac{bh^2}{6} = \dfrac{(6'')(6'')^2}{6} = 36\ \text{in}^3$ $\quad$ (DL is negligible)

$f_b = \dfrac{M_{LL}}{S_x} = \dfrac{(1256\ \text{lb·ft})(12\ \text{in/ft})}{36\ \text{in}^3} = 419\text{psi} < 920\text{psi}$ **OK**

Use Red Oak, #2 or Better $F_b = 800$ psi $\quad F_b' = F_b \times C_d = 800 \times 1.15 = 920\ \text{lbs/in}^2$

Factors: $C_m = 1.0$ (5"x5" or larger)

$C_d = 1.15$ (Snow & ice)

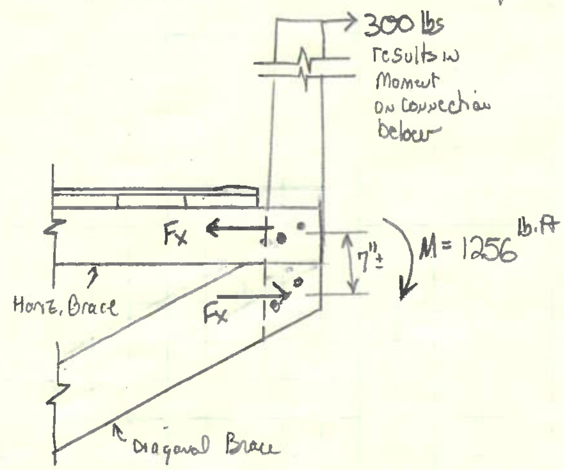
$C_F = 1.0$ (> 4" width)

$C_{FL} = 1.0$ (N/A - flat use)

$C_r = 1.0$ (repetitive)

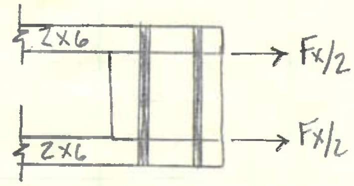
## SIDEWALK Post Design (CONT.)

Estimate shear load to bolts in top horiz 2x6




$M = F_x \cdot d$

$F_x = M/d = \frac{1256^{lb.ft} \times 12}{7''\pm} = 2153^{lbs}$




PLAN View
two bolts in double shear

$V_{bolt} = \frac{F_x}{4} = \frac{2153^{lbs}}{4}$

$= 538^{lbs}$/bolt/shear plane

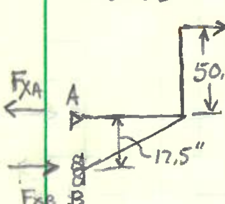
A307 bolts typ. used for timber (A325 would likely be too strong for wood)

Allowable stress (tension) 20,000 psi
" " (shear) 10,000 psi
60,000 psi yield

Stress on bolt: $f_V = \frac{V_{bolt}}{A} = \frac{538^{lbs}}{0.44_{in^2}} = 1{,}223$ psi
3/4" Dia
$< 20{,}000$ psi

Conn. Bolts **OK**

Loads to Horizontal & Diagonal Supports




Determine Loads $\circlearrowleft^{+} \Sigma M_B = 0$: $-300^{lbs}(50.25''+17.5'') + F_{xA}(17.5'') = 0$

$F_{xa} = 20{,}325^{lb \cdot in}/17.5'' = \underline{1161.4^{lbs}}$

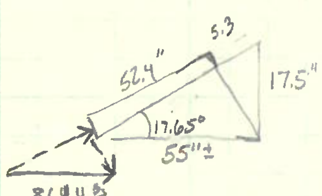
$\Sigma F_x = 0$: $300^{lbs} + F_{xa} + F_{xB} = 0$ $\quad F_{xB} = -300 - (-1164.4^{lbs}) = \underline{864.4^{lbs}}$
$\xrightarrow{+}$

Check Tension in horiz. Braces (2-2x6 full section): $f_t = \frac{F_{xA}}{A_{Net}} = \frac{1161.4^{lbs}}{(2)(2''\times6''-0.875''\times2'')} = 56.5$ psi $< .475$ psi ± $F_B'$

By inspection, factored tension is well above load

For Red Oak #2 or Better $F_B$ = 475 psi (min) unfactored
Tension parallel to grain

Check Compression/Bending in Diagonal




Red Oak #2 or Better $\quad C_m \quad C_D$
$F_B$ = 800 psi (Bending) $\times 1.0 \times 1.65 = 1320$ psi

$F_c$ = 625 psi (Comp. ∥ to Grain) $\times 1.0 \times 1.65 = 1031$ psi
consider part of railing -5 min load

Column type: Slenderness $= \frac{l_e}{d} = \frac{57.7''}{6''} = 9.6 < 11$
where pinned ends
$l_e = K_e \cdot l = 1.0(9.62)$
This is a "short" column

See Next Sheet

$P_a = 861.4^{lbs} \times \cos 17.65° = 820.9^{lbs}$

$M_x = (861.4^{lbs} \times \sin 17.65° \times 52.4'') = 13{,}685.7^{lb.in}$

Railing Support Diagonal Design (Cont.)

Determine $C_p$, Column Stability Factor per AASHTO 13.7.3.3.5

$$C_p = \frac{1+F_{CE}/F_c^*}{2c} - \sqrt{\frac{(1+F_{CE}/F_c^*)^2}{(2c)^2} - \frac{F_{CE}/F_c^*}{c}} = \frac{\left(1+\frac{24{,}957}{1031}\right)}{2(0.8)} - \sqrt{\frac{(1+24.2)^2}{(2\times0.8)^2} - \frac{24.2}{0.8}}$$

where $F_{CE} = \frac{K_{CE}E'}{(\ell_e/d)^2} = \frac{(0.3)(1.2\times10^6)}{(57.7''/4'')^2} = 24{,}957$ (2-2" Members)

$= 15.75 - \sqrt{217.8}$

$= \underline{0.992}$

where $E' = E \cdot C_m$
$= 1{,}200{,}000\text{psi}$

$C = 0.8$ (sawn lumber)

$F_c^* = 1031$ psi

so: $F_c' = F_c \cdot C_m \cdot C_D \cdot C_F \cdot C_p = 625\text{psi} \times 1.0 \times 1.65 \times 1.0 \times 0.992 = 1023\text{psi}$
Allowable Compressive Stress

Combined Bending & Compression must satisfy

$$\frac{f_c}{F_c'} + \frac{f_b}{F_b'} \le 1.0$$

where $f_c = P/A = 820.9^{\text{lbs}}/(2\times2''\times6'') = 34.2\text{psi}$
(column failure not @ net section)

$f_b = \frac{M_x}{bh^2/6} = \frac{13{,}685.7^{\text{lb-in}}}{\left(\frac{2\times2''\times6''^2}{6}\right)} = 570.2\text{psi}$

Column is short (Neglect P-delta)

$$\frac{34.2\text{psi}}{1023\text{psi}} + \frac{570\text{psi}}{1320\text{psi}} = 0.465 < 1.0 \ \underline{\underline{OK}}$$

(This "bending" is probably very conservative)

Loads to Ex. Anchor Rods embeded in Slab

Tension in these rods (1¼"Ø) No more than $2153^{\text{lbs}}$ - by inspection OK

## Upstream Railing Design

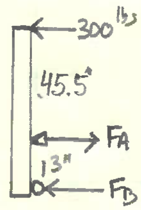
Railing - Same 3x8 as Sidewalk side with same spans b/w posts - OK

Post Design - Distance to Center of Anchor Rod Connection $d = 45.5'' + 13/2 = 52'' > 50.25''$

$M_{LL} = P \times l = 300^{lbs} \times 52''/12 = 1300^{lb \cdot ft}$ (DL is negligible)

$f_b = \frac{M_{LL}}{S_x} = \frac{1300^{lb \cdot ft} \times 12}{(6'' \times 6'')^2/6)} = 433 \text{ psi} < 920 \text{ psi}$

Ex. Anchor Rod Loads




$\circlearrowleft + \Sigma M_A = 0 : 300^{lb}(45.5'') - F_B(13'') = 0$

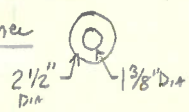
$F_B = 1050^{lbs}$

$F_A = 1350^{lbs}$

Stress in Rod $= \frac{1350^{lbs}}{(\pi \times 1.25^2/4)} = 1100 \text{psi}$

By inspection << 20 ksi OK

Bearing Pressure on Washer




$A = \pi(1.25^2 - 0.6875^2) = 3.42 \text{in}^2$ $f = \frac{F_A}{A} = \frac{1350^{lbs}}{3.42 \text{in}^2} = 394 \text{psi} < 820 \text{psi} \pm$ OK

For Reference An AASHTO Traffic Rail Load is $10^{Kips}$ applied @ top of Post.

$M_{LL} = 10{,}000^{lbs} \times 52''/12 = 43.3^{K \cdot ft}$ $S_x = \frac{(6'')(6'')^2}{6} = 36 \text{in}^3$

$f_b = M/S = \frac{(43.3^{K \cdot ft} \times 12 \text{in/ft})}{36 \text{in}^3} = \underline{\underline{14{,}444 \text{ psi}}} << 800 \text{psi}$ → You would need something like a 12x12 post to stop a vehicle.

This is not an AASHTO Combo rail, Curb stops the low-speed vehicles