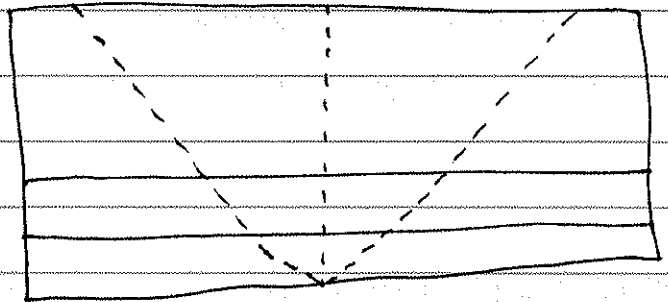
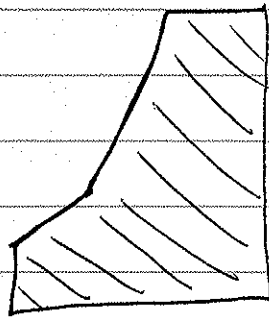


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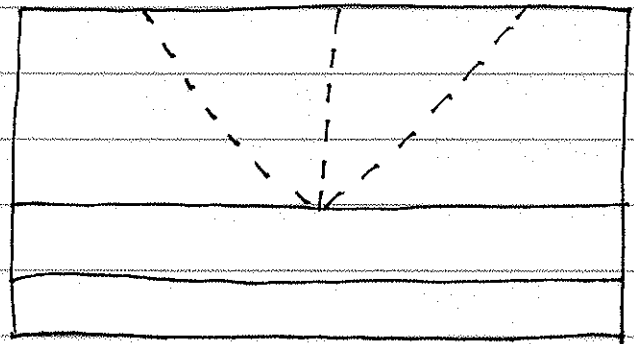
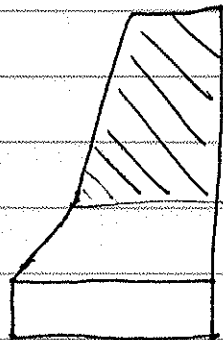
YIELD LINE ANALYSIS OF MN DOT BRIDGE RAIL - FIG. 5-397.117.

* 2 POSSIBLE FRACTURE PATTERNS DUE TO
GEOMETRY OF BARRIER (SAFETY SHAPE).

① - FULL SECTION BENDING/YIELDING/FAILURE.



② TOP SECTION YIELDING/FAILURE



- SOLVE YIELD LINE FOR BOTH FAILURES.

$M_c \rightarrow$ OVERTURNING MOMENT RESISTANCE

1- FULL SECTION

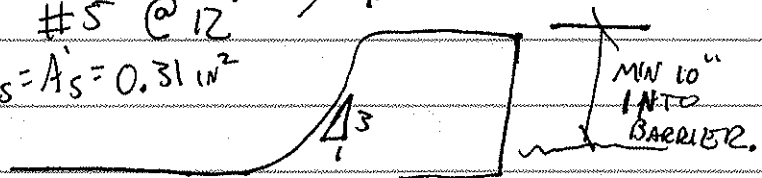
BASE WIDTH = 18"

CLEAR COVER (BACK) = $2\frac{1}{4}$ "

$d = 18 - 2\frac{1}{4} - \frac{(5/8)/2}{2} = 15\frac{3}{8}$ "

STIRRUP \rightarrow #5 @ 12"

$A_s = A'_s = 0.31 \text{ in}^2$



WIDTH OF STIRRUP AT DECK/BARRIER INTERFACE.

$= 9" + 10"/(3/1) \approx 12\frac{3}{8}"$

$d' = d - 12\frac{3}{8}" = 3"$

$f_y = 60 \text{ ksi}$

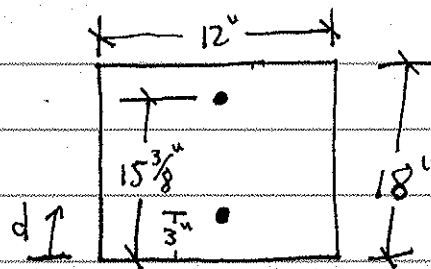
$f'_c = 4 \text{ ksi}$

$A_s = 0.31 \text{ in}^2$

$d = 15\frac{3}{8}"$

$d' = 3"$

IDEALIZED SHAPE \rightarrow



$M_c = 325 \text{ k-in}$

$M_c = 27.1 \text{ k-ft/ft}$

2- TOP SECTION

BASE WIDTH = $10\frac{1}{2} + 2\frac{1}{2} = 13"$

CLEAR COVER = $2\frac{1}{4}"$

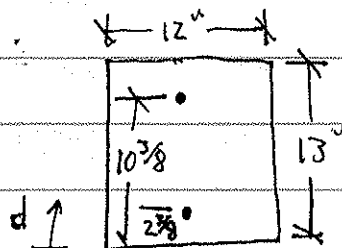
$d = 13 - 2\frac{1}{4} - \frac{(5/8)/2}{2} = 10\frac{3}{8}"$

FRONT COVER = 2"

$d' = 2\frac{3}{8}"$

$A_s = A'_s = 0.31 \text{ in}^2$

SIMPLIFIED X-SECTION



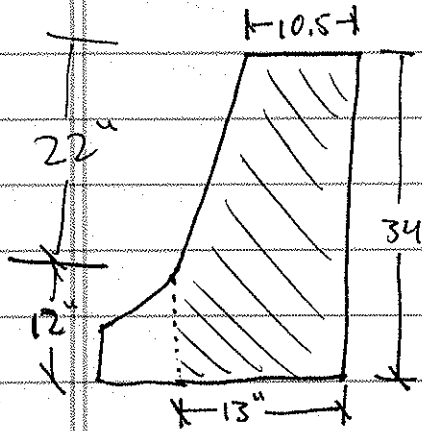
$M_c = 220 \text{ k-in}$

$M_c = 18.3 \text{ k-ft/ft}$

$M_W \rightarrow$ WALL MOMENT RESISTANCE.

1 FULL SECTION

- IGNORE TOE OF BARRIER (NO STEEL ANYWAY).

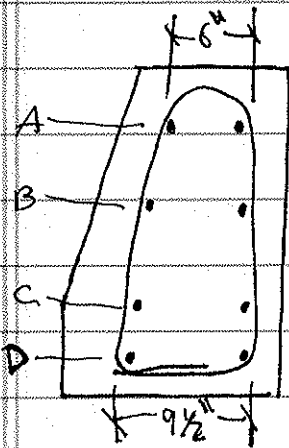


AVE WIDTH (TOP) = $(10.5 + 13) / 2 = 11\frac{3}{4}$ "

AVE WIDTH = $[(11\frac{3}{4} \times 22) + (13 \times 12)] / 34 = 12\frac{1}{8}$ "

LONG. STEEL = #4 BARS

BACK ROW OF STEEL \rightarrow ~~XXXXXXXXXX~~ $d = 2\frac{1}{4} + \frac{5}{8} + (\frac{1}{2})/2$
 $d = 3\frac{1}{8}$ "

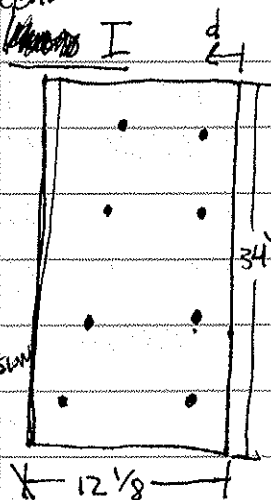


$d_A = 3\frac{1}{8} + (6 - \frac{5}{8} - \frac{1}{2}) = 8$ "

ASSUME EVEN VERT DISTRIBUTION $\left\{ \begin{array}{l} d_B = 9\frac{1}{8}" \\ d_C = 10\frac{3}{8}" \end{array} \right.$

$d_D = 3\frac{1}{8} + (9\frac{1}{2} - \frac{5}{8} - \frac{1}{2}) = 11\frac{1}{2}$ "

RESISTANCE



$A_s = 0.20 \text{ IN}^2/\text{BAR}$

$d' = 3\frac{1}{8}" (4)$

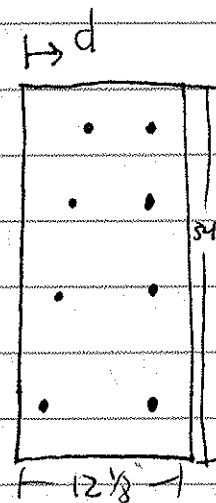
$d_A = 8" (1)$

$d_B = 9\frac{1}{8}" (1)$

$d_C = 10\frac{3}{8}" (1)$

$d_D = 11\frac{1}{2}" (1)$

RESISTANCE



$A_s = 0.20 \text{ IN}^2/\text{BAR}$

$d = 9" (4)$

$d'_A = 4\frac{1}{8}" (1)$

$d'_B = 3" (1)$

$d'_C = 1\frac{3}{4}" (1)$

$d'_D = 5\frac{1}{8}" (1)$

AVERAGE

$M_W = 578 \text{ k-IN}$

$M_W = 17 \text{ k-ft/ft}$

$M_W = 544 \text{ k-IN}$

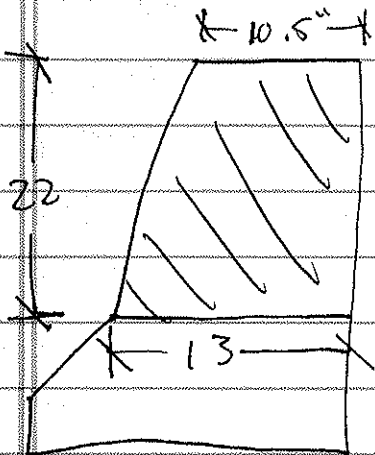
$M_W = 16 \text{ k-ft/ft}$

$M_W = 510 \text{ k-IN}$

$M_W = 15 \text{ k-ft/ft}$

M_w - CONTINUED.

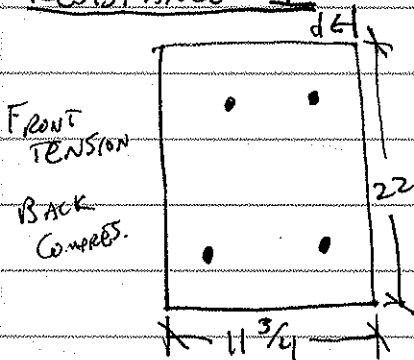
TOP SECTION



$$\text{AVE WIDTH} = (10.5 + 13) / 2 = 11 \frac{3}{4} \text{ inches}$$

★ ONLY TOP 2 ROWS OF STEEL IN TOP PORTION. - SAME (d)'S AS PREVIOUSLY CALCULATED.

RESISTANCE I



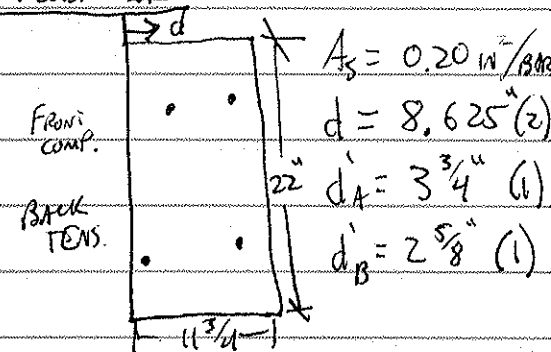
$$A_s = 0.20 \text{ in}^2/\text{BAR}$$

$$d' = 3 \frac{1}{8} \text{ inches (2)}$$

$$d_A = 8 \text{ inches (1)}$$

$$d_B = 9 \frac{1}{8} \text{ inches (1)}$$

RESIST II



$$A_s = 0.20 \text{ in}^2/\text{BAR}$$

$$d = 8.625 \text{ inches (2)}$$

$$d'_A = 3 \frac{3}{4} \text{ inches (1)}$$

$$d'_B = 2 \frac{5}{8} \text{ inches (1)}$$

Ave.

$$M_w = 265 \text{ k-in}$$

$$M_w = 12.05 \text{ k-ft/ft}$$

$$M_w = 266.5 \text{ k-in}$$

$$M_w = 12.1 \text{ k-ft/ft}$$

$$M_w = 268 \text{ k-in}$$

$$M_w = 12.18 \text{ k-ft/ft}$$

INTERIOR SECTION YIELD LINE CALCULATIONS

$$L_{CR} = \frac{l}{2} + \sqrt{\left(\frac{l}{2}\right)^2 + 8H \frac{(M_B + M_w H)}{M_c}}$$

$$R_w = \frac{8M_B}{L_{CR} - \frac{l}{2}} + \frac{8M_w H}{L_{CR} - \frac{l}{2}} + \frac{M_c L_{CR}^2}{H(L_{CR} - \frac{l}{2})}$$

LOAD LENGTH l	TEST LEVEL
4 ft	TL-3
3.5 ft	TL-4
8 ft	TL-5

1 Full SECTION

$$M_B = \emptyset$$

$$M_c = 27.1 \text{ k-ft/ft}$$

$$M_w = 16.0 \text{ k-ft/ft}$$

$$H = 34" = 2.83 \text{ ft}$$

$$l = 3.5 \text{ ft}$$

$$L_{CR} = 8.15 \text{ ft}$$

$$R_w = 155.9 \text{ kips}$$

$$\emptyset R_w = 140 \text{ kips}$$

2 TOP SECTION

$$M_B = \emptyset$$

$$M_c = 18.3 \text{ k-ft/ft}$$

$$M_w = 12.1 \text{ k-ft/ft}$$

$$H = 22" = 1.83 \text{ ft}$$

$$l = 3.5 \text{ ft}$$

$$L_{CR} = 6.31 \text{ ft}$$

$$R_w = 126.3 \text{ kips}$$

$$\emptyset R_w = \underline{\underline{114 \text{ kips}}}$$

INTERIOR WALL STRENGTH = 114 kips

114 > 100 kips → MEETS MASH TL-4 STRENGTH

END SECTION

YIELD LINE CALCS.

M_c VALUES: THE END SECTION (x4 ft) HAS SAME STIRRUPS, BUT AT CONDENSED SPACING. AVE SPACING $\approx 6''$ OR $\frac{1}{2}$ OF PREVIOUS INT. SPACING. • THUS, FOR SIMPLICITY, JUST MULTIPLY INT. M_c VALUES BY 2.

M_w VALUES: ~~XXXXXXXXXX~~ • SINCE END SECTION BENDING ONLY HAS THE SINGLE YIELD LINE, MUST USE RESISTANCE I STRENGTHS.

~~XXXXXXXXXX~~

1

$$M_c = 27.1 \times 2 \\ = 54.2 \text{ k-ft/ft}$$

$$M_{wE} = 17 \text{ k-ft/ft}$$

2

$$M_c = 18.3 \times 2 \\ = 36.6 \text{ k-ft/ft}$$

$$M_{wE} = 12.1 \text{ k-ft/ft}$$

• ALL H, l VALUES ARE THE SAME.

★ END SECTION YIELD LINE EQUATIONS. ★

$$L_{CR} = \frac{l}{2} + \sqrt{\left(\frac{l}{2}\right)^2 + H(M_B + M_w H)/M_c}$$

$$R_w = \frac{M_B}{L_{CR} - \frac{l}{2}} + \frac{M_w H}{L_{CR} - \frac{l}{2}} + \frac{M_c L_{CR}^2}{H(L_{CR} - \frac{l}{2})}$$

RESULTS

1 FULL SECTION

$$L_{CR} = 4.1 \text{ ft}$$

$$R_w = 156 \text{ KIPS}$$

$$\phi R_w = 140 \text{ KIPS}$$

2 TOP SECTION.

$$L_{CR} = 3.8 \text{ ft}$$

$$R_w = 152 \text{ KIPS}$$

$$\phi R_w = 136 \text{ KIPS}$$

END SECTION STRENGTH = 136 KIPS

COMMENTS.

★ THIS BARRIER HAS ENOUGH CAPACITY FOR TL-4 OF MASH.

~~2~~

- STIRRUP SPACING IN THE END SECTIONS IS VERY UNEVEN. I WOULD AIM FOR A CONSISTENT 6" SPACING. MAY HAVE TO CHANGE A FEW LOCATIONS TO AVOID GAUDDRAIL CONNECTION BOLTS.
- TO ENSURE END SECTION STRENGTH, I WOULD USE 6" STIRRUP SPACING ^{WITHIN} ~~5~~ 5 FT FROM END.

★ END SECTION REINFORCEMENT/STIRRUPS SHOULD BE USED AT ALL EXPANSION JOINTS, OR ANY OTHER DISCONTINUITY. CURRENT CONFIGURATION ONLY WITHIN 1 FT OF JOINT.

- BARRIER WIDTH: REINFORCEMENT COULD BE OPTIMIZED TO REDUCE MATERIALS AND STILL OBTAIN $\phi R_w \geq 100 \text{ kIP}$.
- REMOVE DEFLECTION JOINT FROM STANDARD DRAWINGS.
 - NOT GOOD FOR STRENGTH.