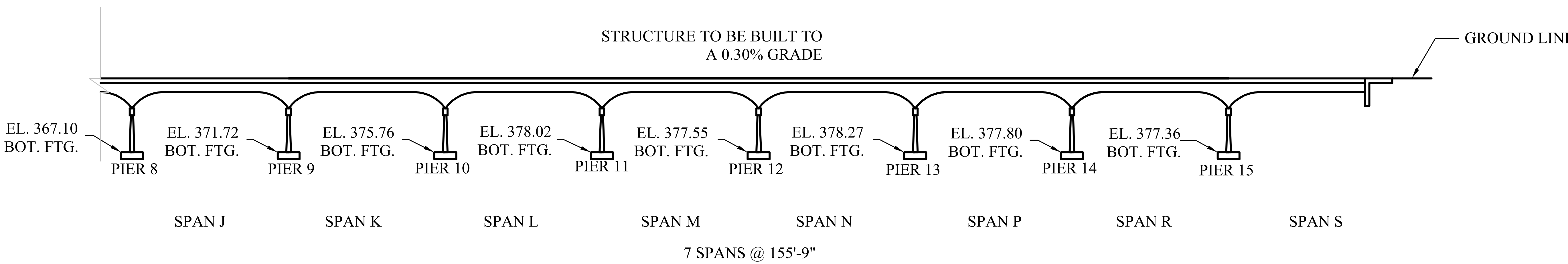
APPENDIX A – INSTRUMENTATION PLANS



BOWEN LABORATORY
PURDUE UNIVERSITY

1040 SOUTH RIVER ROAD
WEST LAFAYETTE, IN 47906
P: 765-494-2227 F: 765-494-9886

PROJECT:

US-41 OVER WHITE RIVER

SHEET NOTES:
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REVISIONS:

NO.	DATE	BY
DESCRIPTION		

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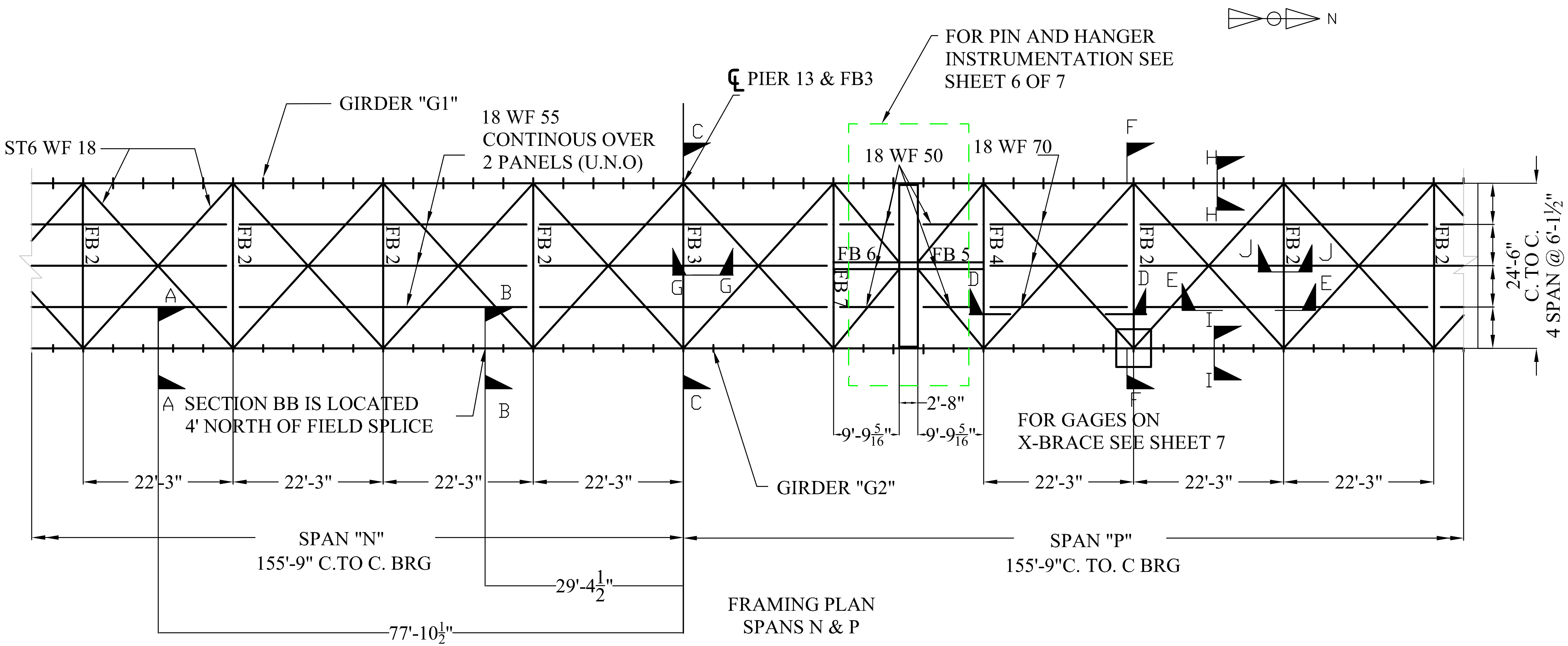
DRAWN BY:
CHECKED BY:
DATE:
PROJECT NO.:
SHEET TITLE:

HANGERS



FRAMING PLAN
SPANS N & P

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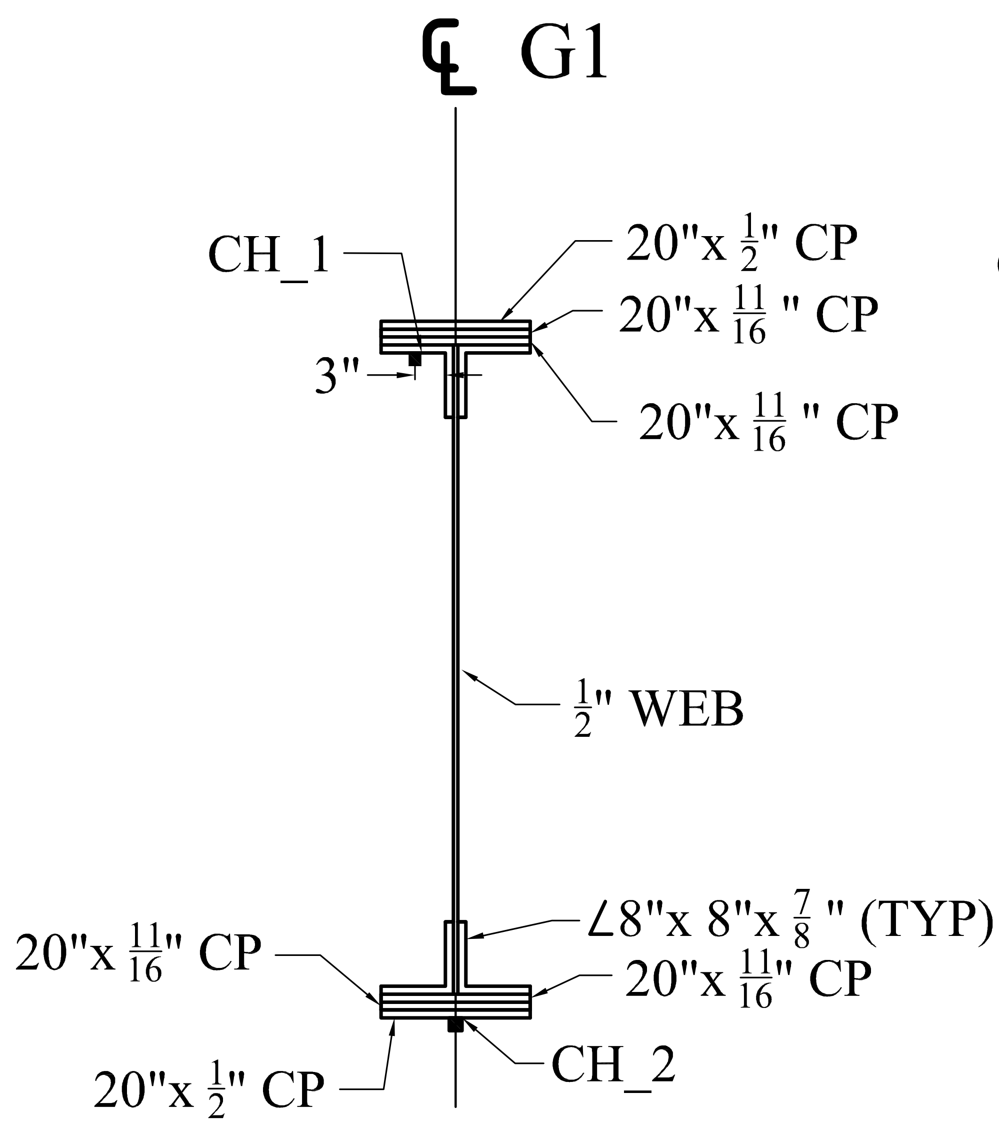
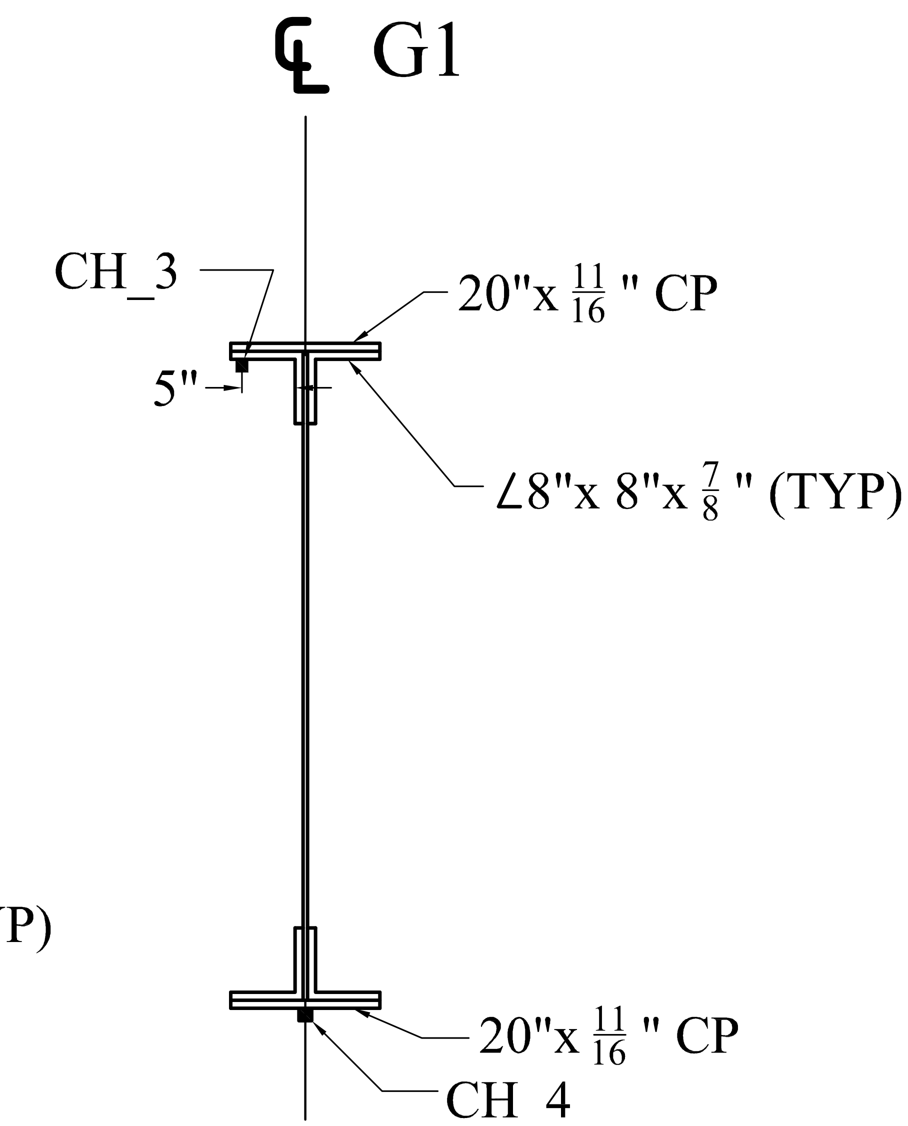
PROJECT NO.:
SHEET TITLE:
PLAN VIEW

SHEET NO.:
1 of 7



SECTION A-A

CENTER OF SHOP SPLICE
(FACING NORTH)



SECTION B-B

4' NORTH OF FIELD SPLICE
(FACING NORTH)

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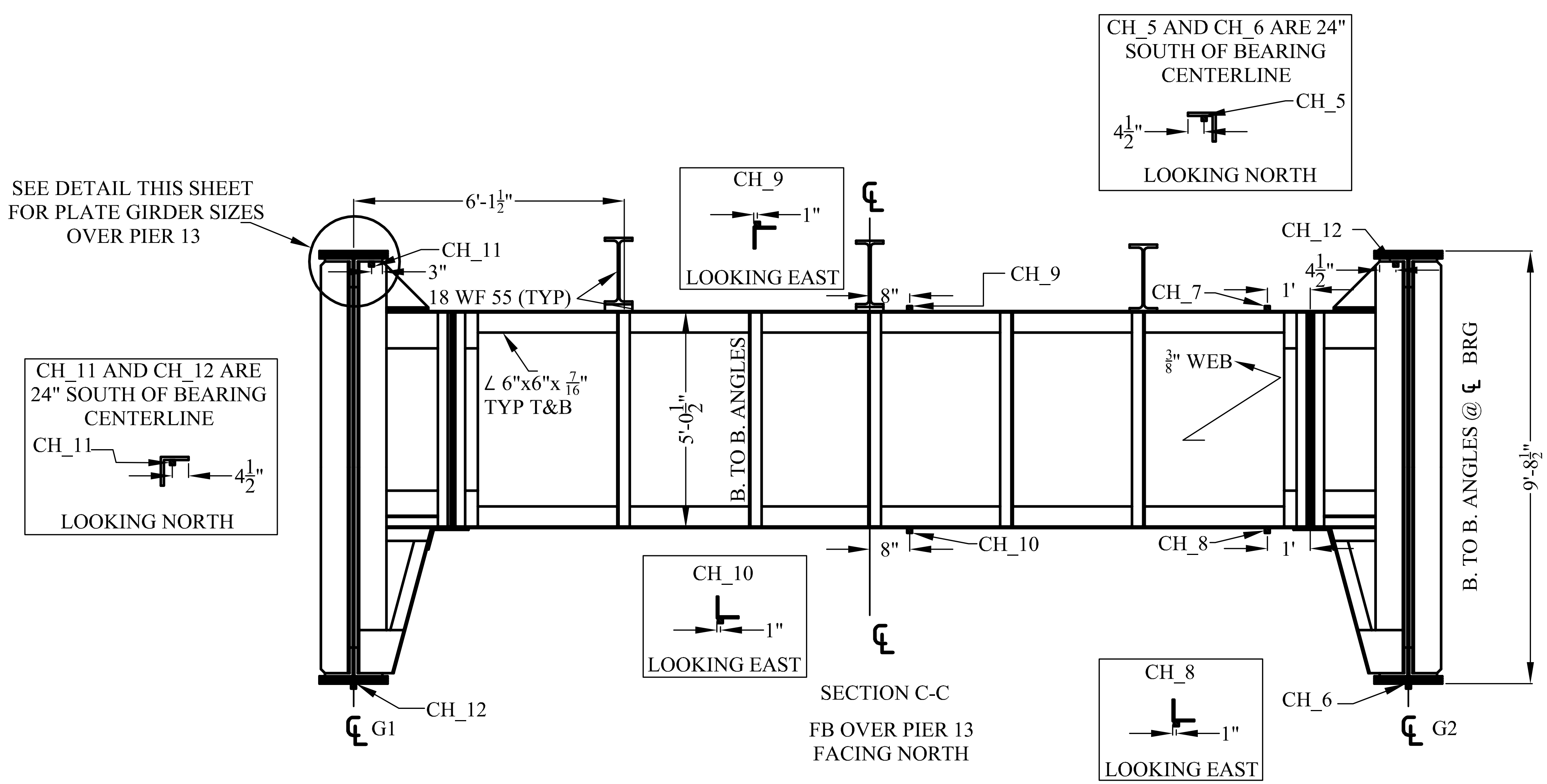
DATE:
PROJECT NO.:
SHEET TITLE:
A-A AND B-B

SHEET NO.:



SECTION C-C

FB OVER PIER 13
FACING NORTH

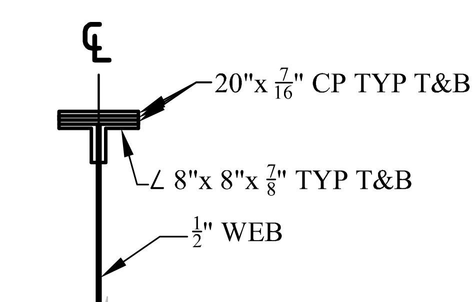
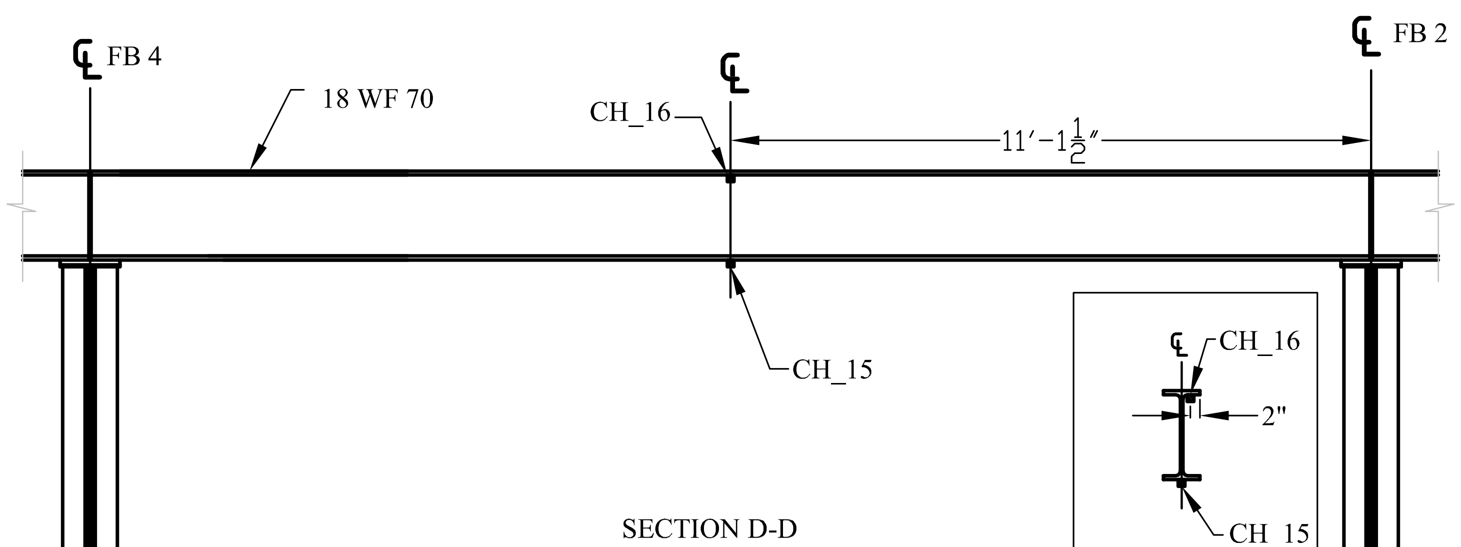


PLATE SIZES
OVER PIER13



SECTION D-D

EAST STRINGER N. OF PIER
13 SIMPLE PLAN

N

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WHITE RIVER

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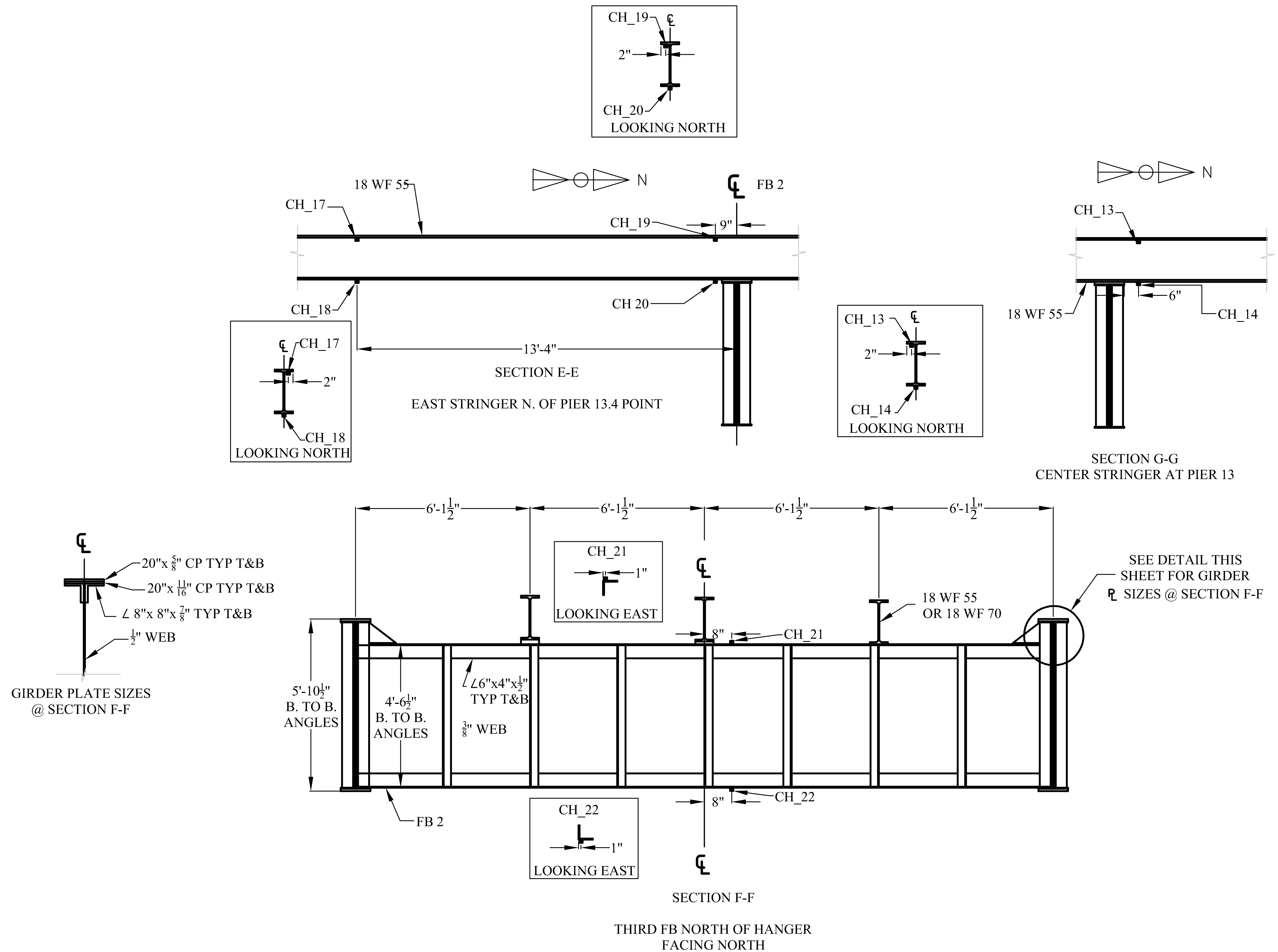
PROJECT NO.:
SHEET TITLE:
C-C AND D-D

SHEET NO.:



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DESCRIPTION		

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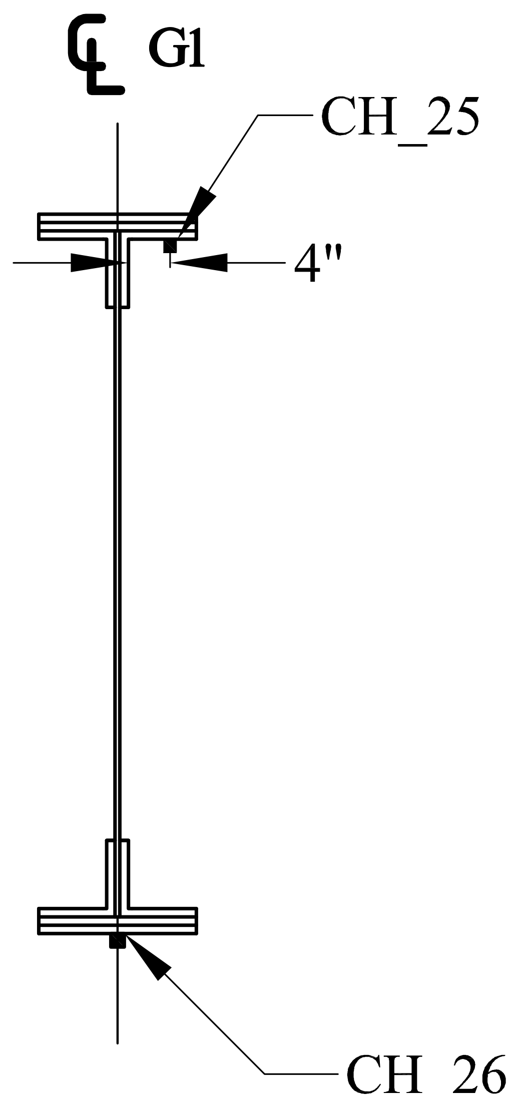
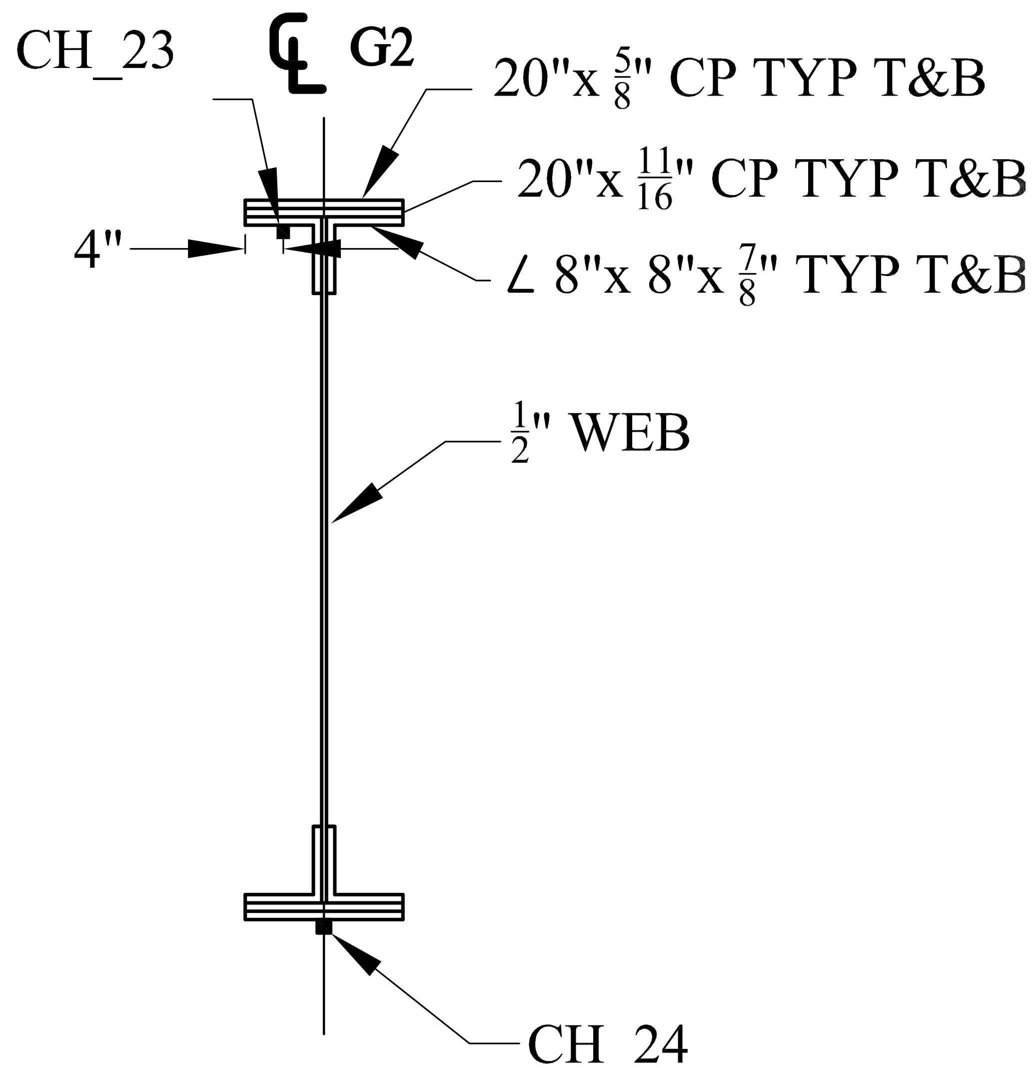
PROJECT NO.:
SHEET TITLE:
E-E, F-F AND G-G



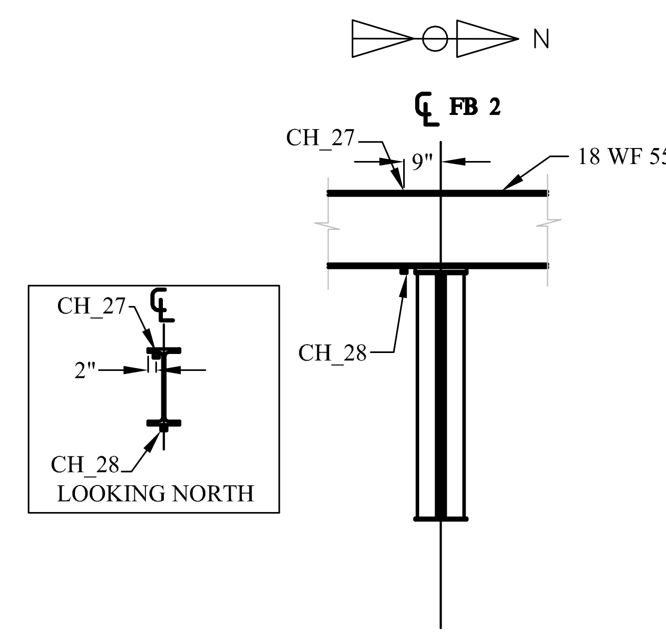
SECTION H-H

CENTER OF SHOP SPLICE
(FACING NORTH)



SECTION I-I

CENTER OF SHOP SPLICE
(FACING NORTH)



SECTION J-J
CENTER STRINGER N. OF 4TH FB FROM HANGER

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US-41 OVER WHITE RIVER

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REVISIONS:

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DESCRIPTION

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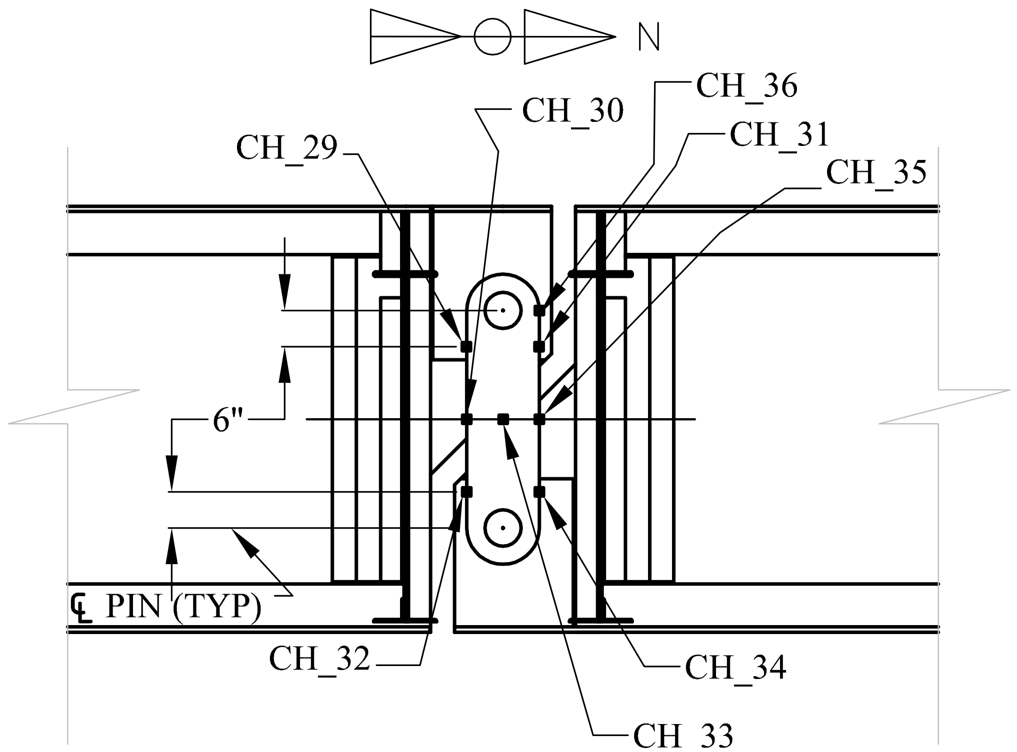
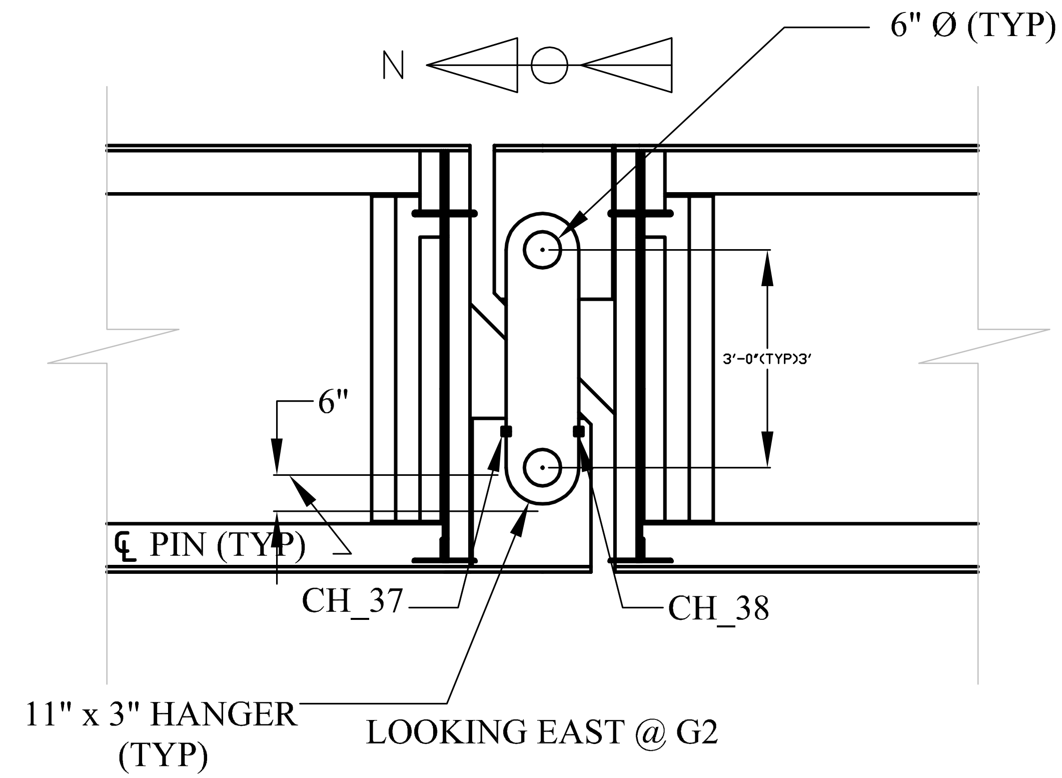
CHECKED BY:
DATE:
PROJECT NO.:
SHEET TITLE:
H-H, I-I, AND J-J

SHEET NO.:

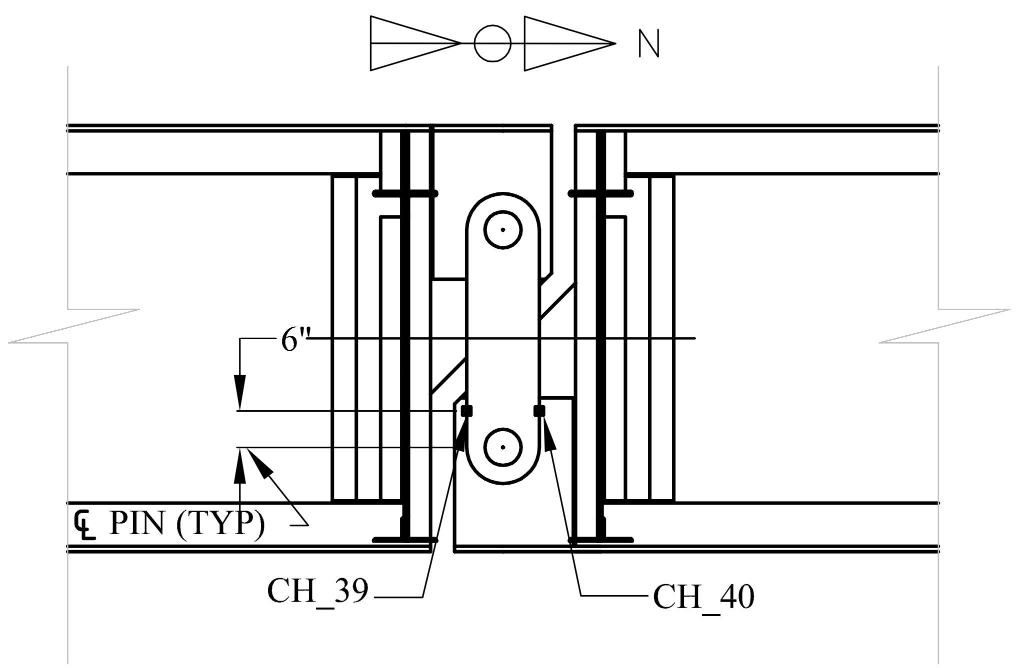


LOOKING WEST @ G2

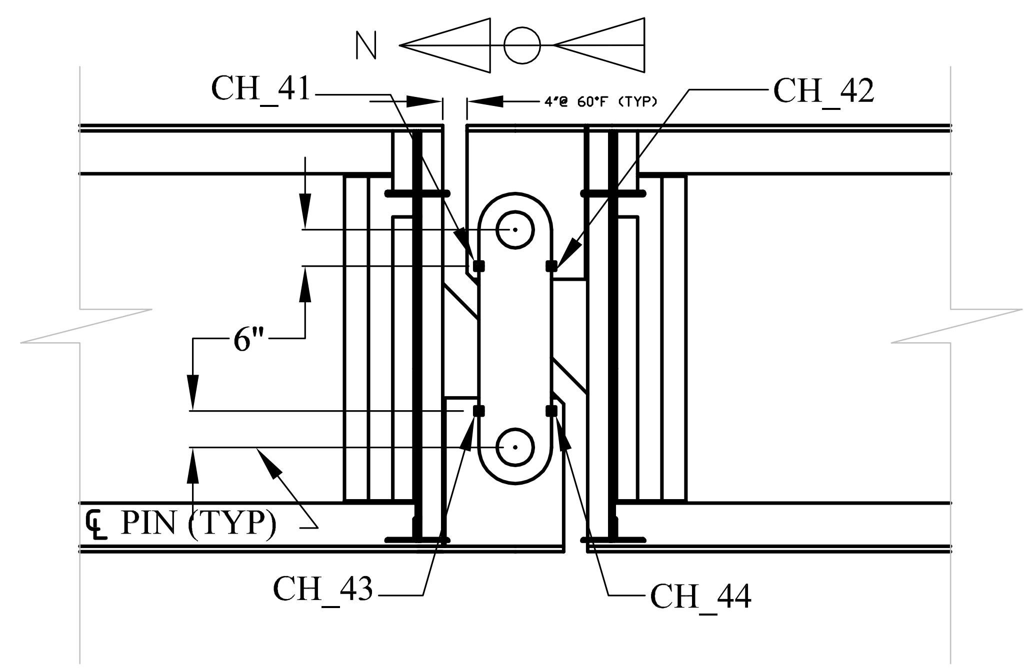


LOOKING EAST @ G2

℄ PIN (TYP)



LOOKING WEST @ G1



LOOKING EAST @ G1

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PROJECT:
US-41 OVER WHITE RIVER

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DESCRIPTION		

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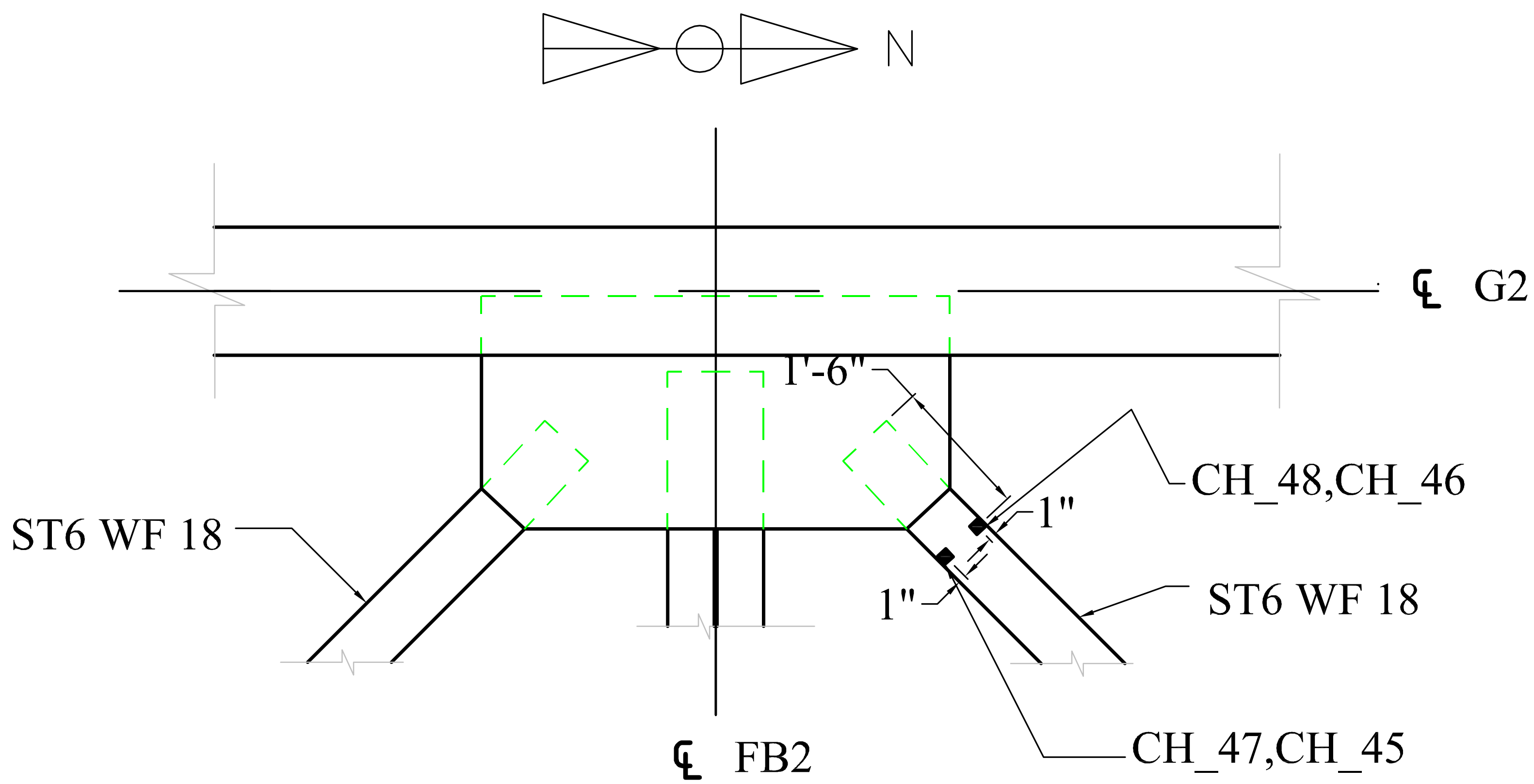
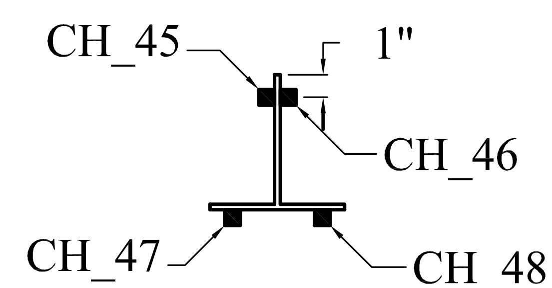
DRAWN BY:
CHECKED BY:
DATE:
PROJECT NO.:
SHEET TITLE:
HANGERS

SHEET NO.:





LOOKING SOUTHWEST

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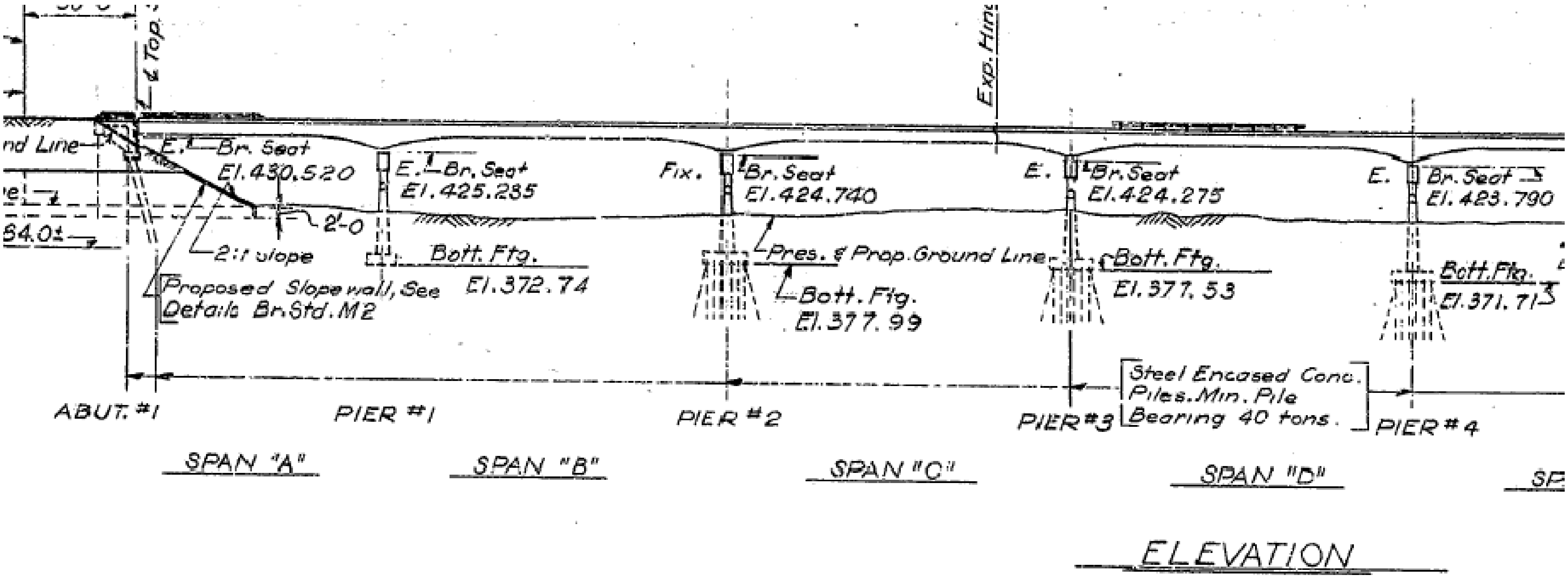
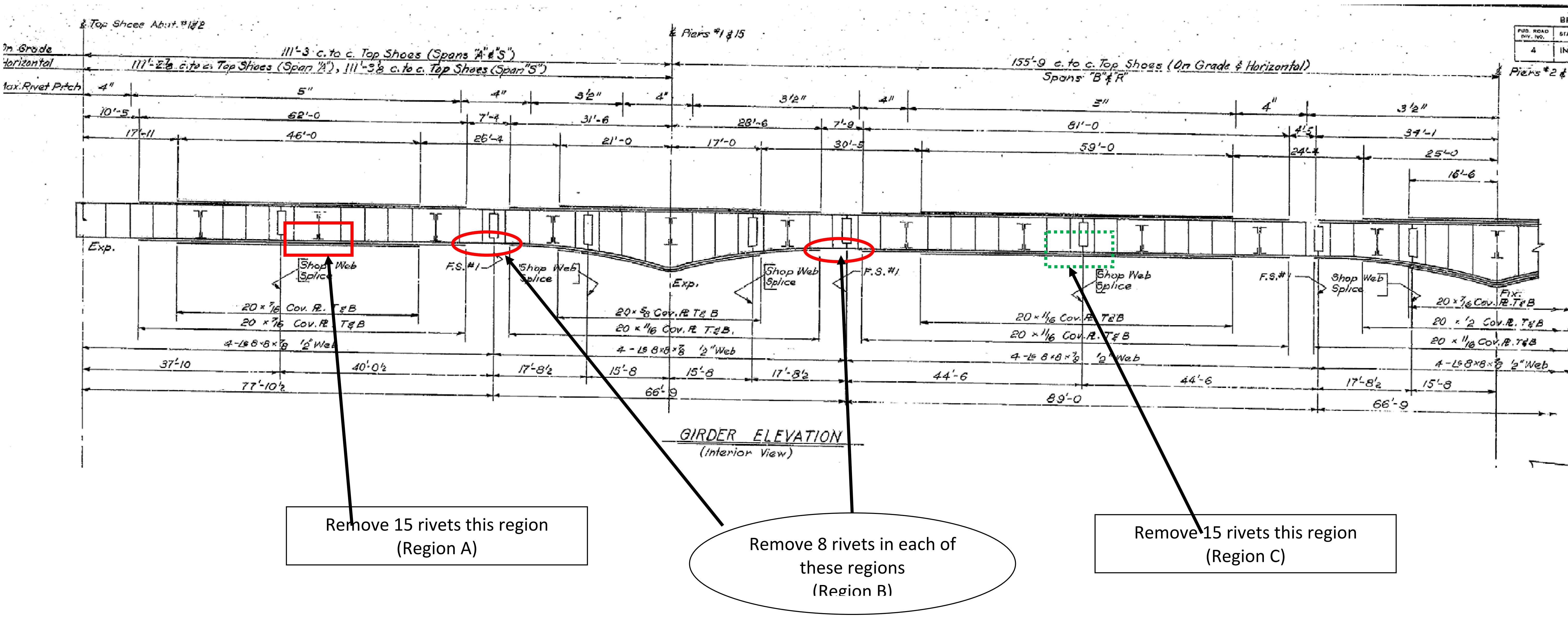
PROJECT NO.:
SHEET TITLE:
CROSS-BRACING

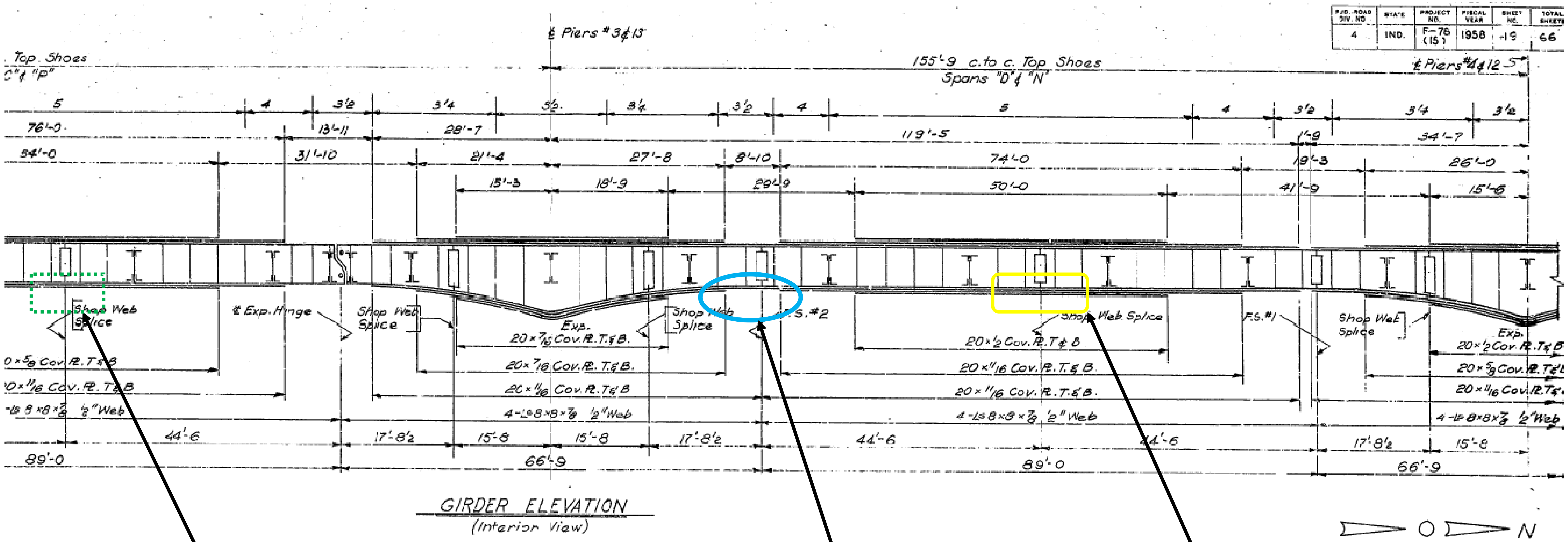
APPENDIX B – RIVET REMOVAL PLAN



CORRESPONDS TO NORTH END OF BRIDGE - LOOKING TOWARD THE EAST

Span name conversion: Span A = Span S
Span B = Span R
Span C = Span P
Span D = Span N

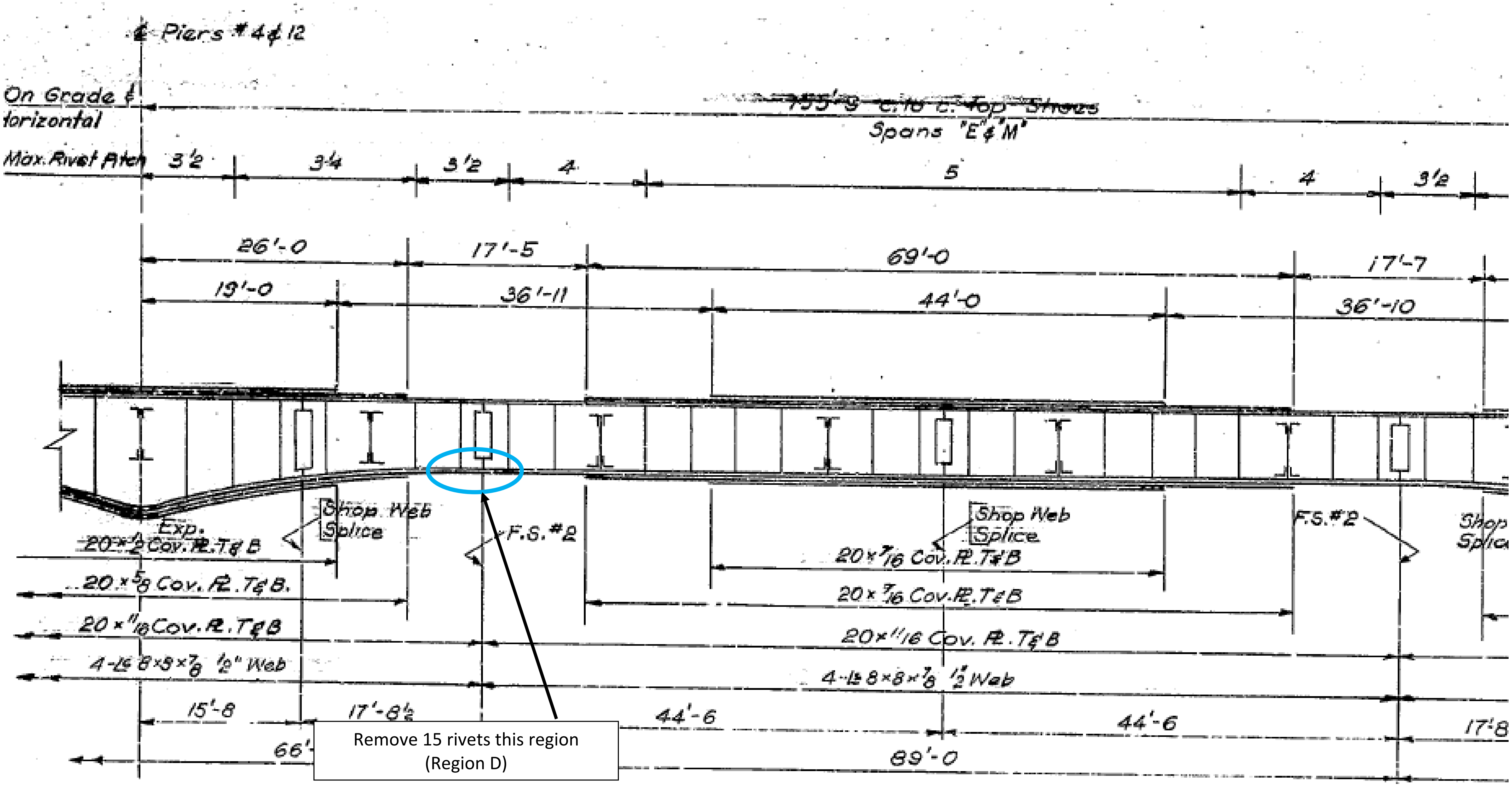

GIRDER ELEVATION
(Interior View)
Piers #1 & 15
Piers #2 & 14
155'-9 c. to c. Top Shoes (On Grade & Horizontal)
Spans "B" & "R"
111'-3 c. to c. Top Shoes (Spans "A" & "S")
Exp.
Fix.
Shop Web Splice
F.S. #1
Remove 15 rivets this region
(Region A)
Remove 8 rivets in each of
these regions
(Region B)
Remove 15 rivets this region
(Region C)



Remove 15 rivets this region
(Region C)

Remove 15 rivets this region
(Region D)

Remove 15 rivets this region
(Region E)



℄ Piers #4 & 12
On Grade & Horizontal
Spans "E & M"
Max. Rivet Pitch
3½
3¼
3½
4
5
4
3½
26'-0
17'-5
69'-0
17'-7
19'-0
36'-11
44'-0
36'-10
Exp.
Shop Web Splice
F.S. #2
20×½ Cov. Pℓ. T & B
20×⅝ Cov. Pℓ. T & B.
20×¹¹⁄₁₆ Cov. Pℓ. T & B
4-Ls 8×8×⅞ ½" Web
20×⁷⁄₁₆ Cov. Pℓ. T & B
20×⁷⁄₁₆ Cov. Pℓ. T & B
20×¹¹⁄₁₆ Cov. Pℓ. T & B
4-Ls 8×8×⅞ ½" Web
15'-8
17'-8½
44'-6
44'-6
17'-8
66'
89'-0
Remove 15 rivets this region (Region D)

<u>**Details – Per Girder**</u>

Region A – This region consists of 8x8x7/8 angles, and two cover plates that are 20x7/16. It is the positive moment region and is located in the end span near 2nd floorbeam from the end floor beam near the north abutment. Remove 15 rivets which connect the angles to the cover plate at this location, distributed over a length of five (5) feet.

Region B – This region consists of 8x8x7/8 angles and a ½ inch web; there are no cover plates. These are located at the inflection point and is located either side of pier 14. Remove 10 rivets in the <u>**web**</u> at this location distributed in the region where only the angles and NO cover plates are present. There are two of these regions, so 16 rivets total.

Region C – This region consists of 8x8x7/8 angles, and two cover plates that are 20x11/16. It is in the positive moment region and is located in the middle of the span near the shop splice. Remove 15 rivets which connect the angles to the cover plate at this location, distributed over a length of five (5) feet. Avoid the area at the splice if there are added plates due to the shop splice. There are two of these regions, so 30 rivets total.

Region D – These regions consists of 8x8x7/8 angles, and one cover plate is 20x11/16. They are located at the inflection point just south of Pier 13 and Pier 12. Remove 15 rivets which connect the angles to the cover plate in the flange angles at this location, distributed over the region <u>where only one cover plate exists</u>. Avoid the area at the splice if there are added plates due to the shop splice. _There are two of these regions, so 30 rivets total.

Region E– This region consists of 8x8x7/8 angles, and two cover plates that are 20x11/16 and one that is 20x1/2. It is the positive moment region and is located in the middle of the span near the shop splice. Remove 15 rivets which connect the angles to the cover plate at this location, distributed over a length of five (5) feet. Avoid the area at the splice if there are added plates due to the shop splice.

General Notes

1. The work involves the removal of 106 rivets per girder for a total of 212 rivets.
2. It is noted that the sketches provided above are from the original design drawings and plate thickness has not been verified. They are oriented looking west at the south end of the bridge in the original plan set. The bridge is symmetric about pier 8. Hence, for the drawings to apply, they should be viewed looking east at the north end of bridge.
3. The rivets are to be removed on the exterior girders (i.e., west girder of southbound spans and east girder of northbound spans at the north end of the bridge)
4. Remove no more than five (5) rivets at a time. Ensure there are a minimum of two (2) rivets that remain in place between any two (2) rivets that are removed.
5. Inspect the edges of the holes on the top and bottom surfaces of the plate (or on either side of the web). An appropriate NDT technique, such as magnetic particle testing is required to test for the presence of cracks.
6. Document all defects, cracks or other notable information. All cracks must be measured and photographed. If any cracks are found that are greater than ½ inch, notify INDOT immediately. If no cracks are found, simply report "no crack found".
7. As much as possible, using sufficient lighting, attempt to examine the inside of the hole where multiple cover plates to determine if any of the internal plates have cracks.
8. Replace all removed rivets with a fully-pretensioned 7/8 inch diameter A325 Bolt.
9. Apply an acceptable primer coat of paint to minimize future corrosion.
10. Strain gages and wire are located at some of the locations were rivets are to be removed. Use extreme caution in these regions to avoid damage to the instrumentation. Notify Purdue University if a gage or wire gets damaged.

APPENDIX C – API 579-1 EQUATION C.108

API 579-1 Fitness for Service Manual EQN C.120 on page C-19

Given

$a := \frac{3}{8} in$

$c := \frac{3}{8} in$

$t := \frac{7}{8} in$

$W := 2in$

$\phi := \frac{\pi}{2}$

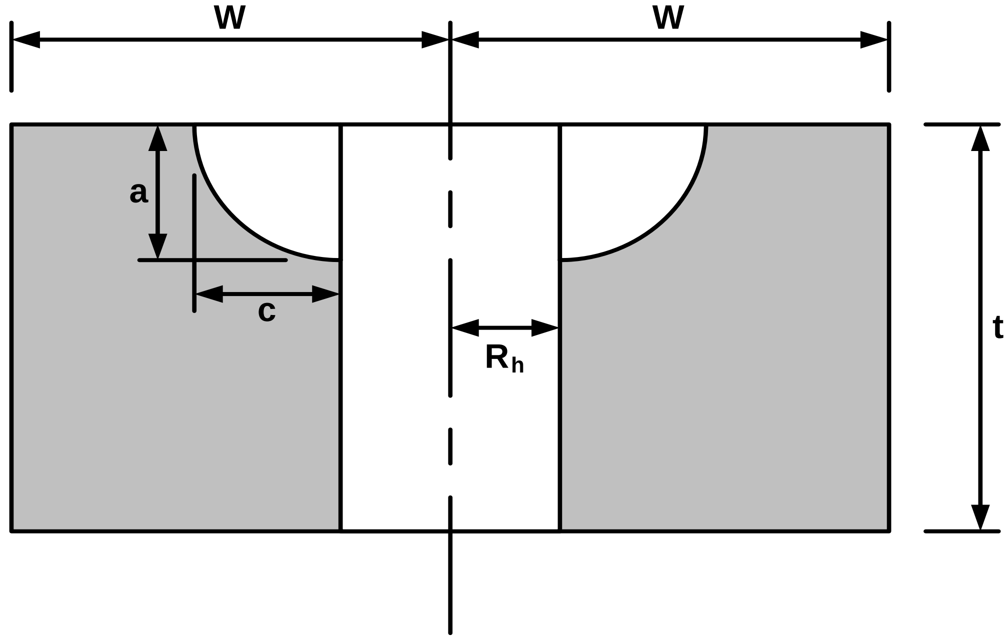
$R_h := \frac{15}{32} in$

$n := 1$

$p_c := 0$

$\sigma := 18ksi$

$\mu := 0.85$



Crack and Geometry Dimensional Limits

$0 < \frac{a}{t} < 1.0 = 1$

$0.2 \le \frac{a}{c} \le 2.0 = 1$

$0.5 \le \frac{R_h}{t} \le 2.0 = 1$

$\frac{(R_h + c)}{W} < 0.5 = 1$

$0 \le \phi \le \frac{\pi}{2} = 1$

Calculate Stresses

$\sigma_m := \frac{1}{t}\left(\int_0^t \sigma \, dx\right)$ $\sigma_m = 18 \cdot ksi$

$\sigma_b := \frac{6}{t^2}\left[\int_0^t \sigma \cdot \left(\frac{t}{2} - x\right) dx\right]$ $\sigma_b = 0 \cdot ksi$

Membrane Correction Factor

$$f_w := \sqrt{\sec\left(\frac{\pi \cdot R_h}{2 \cdot W}\right) \sec\left[\pi \frac{(2 \cdot R_h + n \cdot c)}{4(W - c) + 2n \cdot c} \cdot \sqrt{\frac{a}{t}}\right]} \qquad f_w = 1.07$$

$$\zeta := \frac{1.0}{1.0 + \left(\frac{c}{R_h}\right) \cdot \cos(\mu \cdot \phi)} \qquad \zeta = 0.84$$

$$M_1 := \begin{cases} 1.13 - 0.09\left(\frac{a}{c}\right) & \text{if } \frac{a}{c} \le 1.0 \\ \sqrt{\frac{c}{a}} \cdot \left[1 + 0.04\left(\frac{c}{a}\right)\right] & \text{if } \frac{a}{c} > 1.0 \end{cases} \qquad M_1 = 1.04$$

$$M_2 := \begin{cases} \left(\frac{0.89}{0.2 + \frac{a}{c}} - 0.54\right) & \text{if } \frac{a}{c} \le 1.0 \\ 0.2\left(\frac{c}{a}\right)^4 & \text{if } \frac{a}{c} > 1.0 \end{cases} \qquad M_2 = 0.2$$

$$M_3 := \begin{cases} 0.5 - \frac{1}{0.65 + \frac{a}{c}} + 14 \cdot \left(1 - \frac{a}{c}\right)^{24} & \text{if } \frac{a}{c} \le 1.0 \\ -0.11 \cdot \left(\frac{c}{a}\right)^4 & \text{if } \frac{a}{c} > 1.0 \end{cases} \qquad M_3 = -0.11$$

$$g_1 := \begin{cases} 1 + \left[0.1 + 0.35\left(\frac{a}{t}\right)^2\right] \cdot (1 - \sin(\phi))^2 & \text{if } \frac{a}{c} \le 1.0 \\ 1 + \left[0.1 + 0.35\left(\frac{c}{a}\right) \cdot \left(\frac{a}{t}\right)^2\right] \cdot (1 - \sin(\phi))^2 & \text{if } \frac{a}{c} > 1.0 \end{cases} \qquad g_1 = 1$$

$$g_2 := \frac{1.0 + 0.358\zeta + 1.425\zeta^2 - 1.578\zeta^3 + 2.156\zeta^4}{1.0 + 0.13\zeta^2} \qquad g_2 = 2.25$$

$$g_3 := \begin{cases} \left[1 + 0.04 \cdot \left(\frac{a}{c}\right)\right] \cdot \left[1 + 0.1 \cdot (1 - \cos(\phi))^2\right] \cdot \left[0.85 + 0.15 \cdot \left(\frac{a}{t}\right)^{0.25}\right] & \text{if } \frac{a}{c} \le 1.0 \\ \left[1.13 - 0.09 \cdot \left(\frac{c}{a}\right)\right] \cdot \left[1 + 0.1 \cdot (1 - \cos(\phi))^2\right] \cdot \left[0.85 + 0.15 \cdot \left(\frac{a}{t}\right)^{0.25}\right] & \text{if } \frac{a}{c} > 1.0 \end{cases} \qquad g_3 = 1.11$$

$$g_4 := \begin{cases} 1 - 0.7\left(1 - \frac{a}{t}\right) \cdot \left(\frac{a}{c} - 0.2\right) \cdot \left(1 - \frac{a}{c}\right) & \text{if } \frac{a}{c} \le 1.0 \\ 1.0 & \text{if } \frac{a}{c} > 1.0 \end{cases} \qquad g_4 = 1$$

$$f_\phi := \begin{cases} \left[\left(\frac{a}{c}\right)^2 \cdot \cos(\phi)^2 + \sin(\phi)^2\right]^{0.25} & \text{if } \frac{a}{c} \le 1.0 \\ \left[\left(\frac{c}{a}\right)^2 \cdot \sin(\phi)^2 + \cos(\phi)^2\right]^{0.25} & \text{if } \frac{a}{c} > 1.0 \end{cases}$$ $f_\phi = 1$

$$M_m := \left[M_1 + M_2 \cdot \left(\frac{a}{t}\right)^2 + M_3 \cdot \left(\frac{a}{t}\right)^4\right] \cdot g_1 \cdot g_2 \cdot g_3 \cdot g_4 \cdot f_w \cdot f_\phi$$ $M_m = 2.88$

Bending Correction Factor

$$\mu\_Mb := 0.85 - 0.25\left(\frac{a}{t}\right)^{0.25}$$ $\mu\_Mb = 0.65$

$$\zeta\_Mb := \frac{1.0}{1.0 + \left(\frac{c}{R_h}\right) \cdot \cos(\mu\_Mb \cdot \phi)}$$ $\zeta\_Mb = 0.7$

$$g_{2\_Mb} := \frac{1.0 + 0.358\zeta\_Mb + 1.425\zeta\_Mb^2 - 1.578\zeta\_Mb^3 + 2.156\zeta\_Mb^4}{1.0 + 0.13\zeta\_Mb^2}$$ $g_2 = 2.25$

$$M_{m\_Mb} := \left[M_1 + M_2 \cdot \left(\frac{a}{t}\right)^2 + M_3 \cdot \left(\frac{a}{t}\right)^4\right] \cdot g_1 \cdot g_{2\_Mb} \cdot g_3 \cdot g_4 \cdot f_w \cdot f_\phi$$ $M_{m\_Mb} = 2.33$

$$q := \begin{cases} 0.2 + \frac{a}{c} + 0.6\frac{a}{t} & \text{if } \frac{a}{c} \le 1.0 \\ 0.2 + \frac{c}{a} + 0.6\frac{a}{t} & \text{if } \frac{a}{c} > 1.0 \end{cases}$$ $q = 1.46$

$$G_{11} := \begin{cases} -0.43 - 0.74\frac{a}{c} - 0.84\left(\frac{a}{c}\right) & \text{if } \frac{a}{c} \le 1.0 \\ -2.07 + 0.06\frac{c}{a} & \text{if } \frac{a}{c} > 1.0 \end{cases}$$ $G_{11} = -2.01$

$$G_{12} := \begin{cases} 1.25 - 1.19\frac{a}{c} + 4.39\left(\frac{a}{c}\right)^2 & \text{if } \frac{a}{c} \le 1.0 \\ 4.35 + 0.16\frac{c}{a} & \text{if } \frac{a}{c} > 1.0 \end{cases}$$ $G_{12} = 4.45$

$$G_{13} := \begin{cases} -1.94 + 4.22\frac{a}{c} - 5.51\left(\frac{a}{c}\right)^2 & \text{if } \frac{a}{c} \le 1.0 \\ -2.93 - 0.3\frac{c}{a} & \text{if } \frac{a}{c} > 1.0 \end{cases}$$ $G_{13} = -3.23$

$$G_{21} := \begin{cases} -1.5 - 0.04\frac{a}{c} - 1.73\left(\frac{a}{c}\right)^2 & \text{if } \frac{a}{c} \le 1.0 \\ -3.64 + 0.37\frac{c}{a} & \text{if } \frac{a}{c} > 1.0 \end{cases}$$ $G_{21} = -3.27$

$$G_{22} := \begin{cases} 1.71 - 3.17\frac{a}{c} + 6.84\left(\frac{a}{c}\right)^2 & \text{if } \frac{a}{c} \le 1.0 \\ 5.87 - 0.49\frac{c}{a} & \text{if } \frac{a}{c} > 1.0 \end{cases}$$ $G_{22} = 5.38$

$$G_{23} := \begin{cases} -1.28 + 2.71\frac{a}{c} - 5.22\left(\frac{a}{c}\right)^2 & \text{if } \frac{a}{c} \le 1.0 \\ -4.32 + 0.53\frac{c}{a} & \text{if } \frac{a}{c} > 1.0 \end{cases}$$ $G_{23} = -3.79$

$$H_1 := 1 + G_{11}\cdot\left(\frac{a}{t}\right) + G_{12}\cdot\left(\frac{a}{t}\right)^2 + G_{13}\cdot\left(\frac{a}{t}\right)^3$$ $H_1 = 0.7$

$$H_2 := 1 + G_{21}\cdot\left(\frac{a}{t}\right) + G_{22}\cdot\left(\frac{a}{t}\right)^2 + G_{23}\cdot\left(\frac{a}{t}\right)^3$$ $H_2 = 0.29$

$$H := H_1 + \left(H_2 - H_1\right)\sin(\phi)^q$$ $H = 0.29$

$$M_b := M_{m\_Mb}\cdot H$$ $M_b = 0.67$

Stress Intensity Factor

$$Q := \begin{cases} 1.0 + \left[1.464\left(\frac{a}{c}\right)^{1.65}\right] & \text{if } \frac{a}{c} \le 1.0 \\ 1.0 + \left[1.464\left(\frac{c}{a}\right)^{1.65}\right] & \text{if } \frac{a}{c} > 1.0 \end{cases}$$ $Q = 2.46$

$$K_{2\_crack} := \left[M_m\cdot\left(\sigma_m + p_c\right) + M_b\cdot\sigma_b\right]\cdot\sqrt{\frac{\pi\cdot a}{Q}}$$ $K_{2\_crack} = 35.8\cdot ksi\cdot\sqrt{in}$

$$K_{1\_crack} := \sqrt{\frac{\frac{4}{\pi} + \frac{a\cdot c}{2\cdot t\cdot R_h}}{\frac{4}{\pi} + \frac{a\cdot c}{t\cdot R_h}}}\cdot K_{2\_crack}$$ $K_{1\_crack} = 33.9\cdot ksi\cdot\sqrt{in}$