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TECHNICAL MEMORANDUM

Contract No.: **T4541-AO**
Report No.: **405160-16 (revised 2010-10-26)**
Project Name: **US 11 Lake Pontchartrain Bridge Rail Replacement**
Sponsor: **Pooled Fund**

DATE: **October 26, 2010**

TO: **David Olson**
Chair, Pooled Fund

COPY TO: **Paul Fossier**, Louisiana Department of Transportation & Development
Rhonda Brooks, Washington State DOT
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FROM: **William F. Williams**, P.E., Assistant Research Engineer, Texas Transportation Institute, Roadway Safety & Physical Security Division

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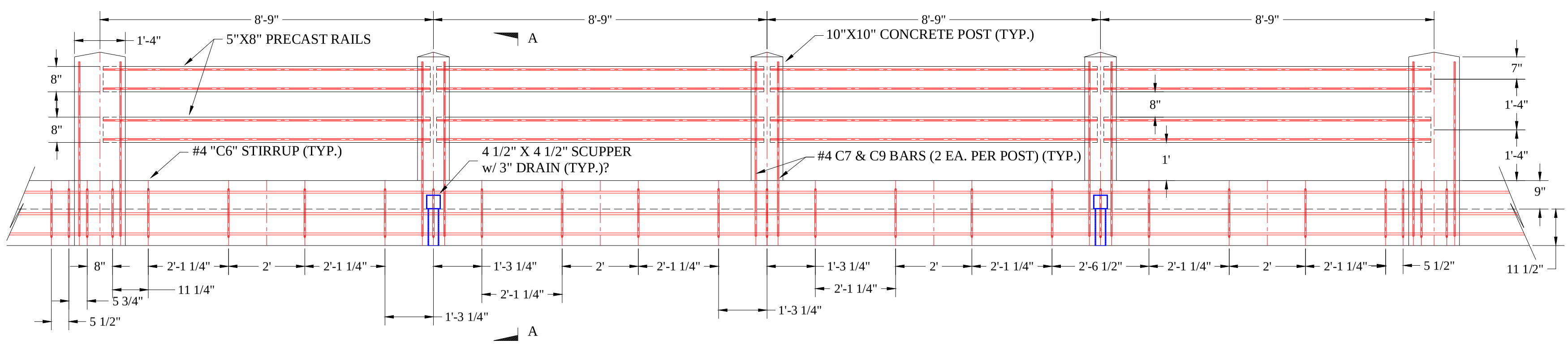
SUMMARY REPORT:

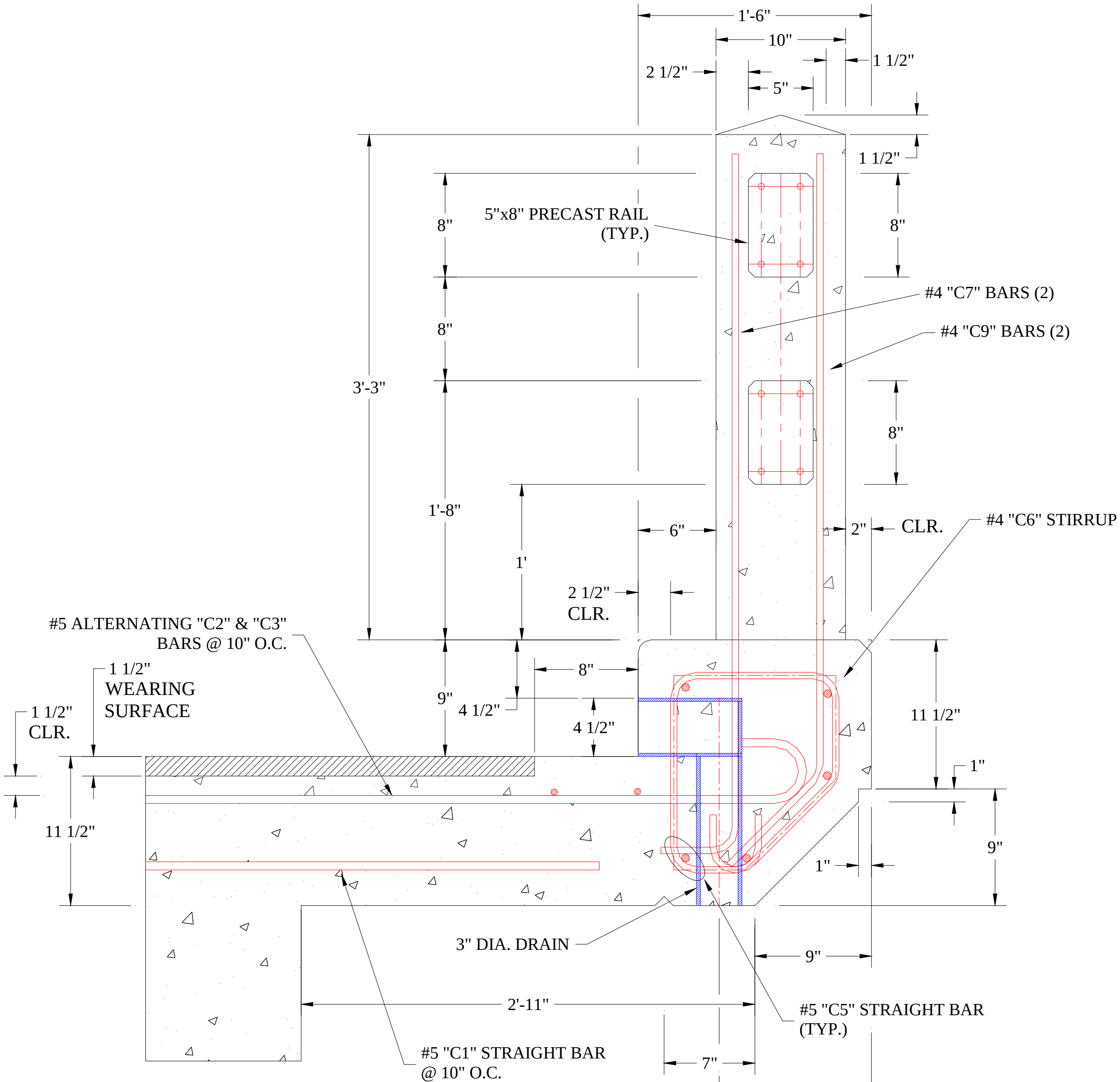
INTRODUCTION

The US 11 Lake Pontchartrain Bridge crosses over Lake Pontchartrain just northeast of New Orleans in Orleans Parish, Louisiana. This bridge is approximately 4.72 miles in length and was constructed in the late 1920s. Texas Transportation Institute (TTI) received several drawings of the bridge structure entitled “State Project No. 18-02-22 Lake Pontchartrain Bridge,” and dated April 29, 1926. The Lake Pontchartrain Bridge supports two 12-ft roadway lanes with 3 ft shoulders. The total roadway width is 30 ft. The existing bridge rail consists of two 5-inch by 8-inch precast concrete rail members supported by cast-in-place 10-inch by 10-inch concrete posts. The concrete posts are spaced 8-ft-9-inches on centers. The posts are cast on top of a 9-inch high by 18-inch wide concrete curb. Details of the existing bridge rail are shown in Figure 1.



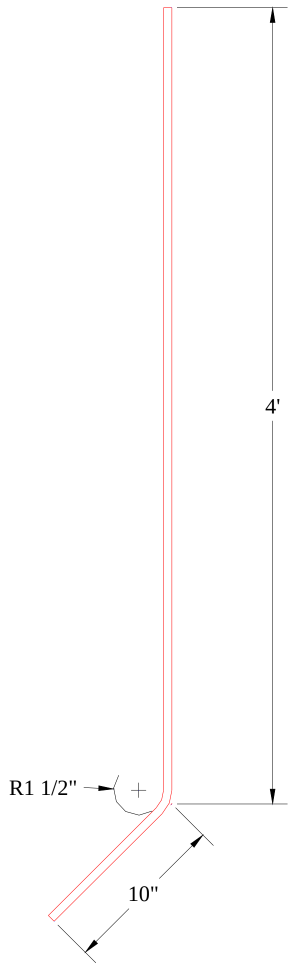
RAIL ELEVATION VIEW (FIELD SIDE VIEW)

Figure 1 – Details of US 11 Bridge over Lake Pontchartrain Bridge Rail.

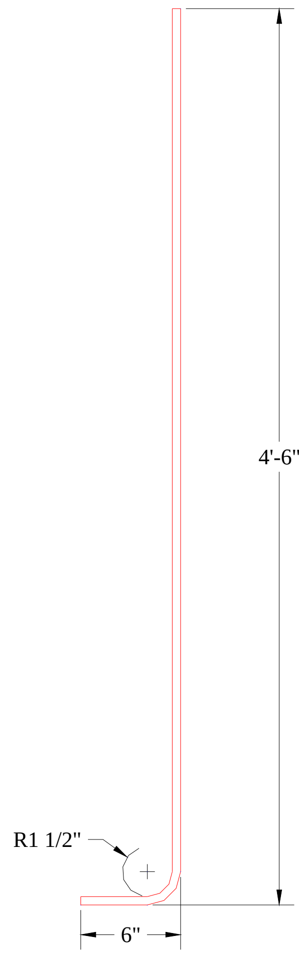


SECTION A-A

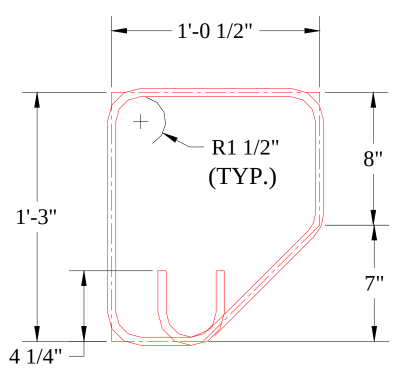
Figure 1 – Details of US 11 Bridge over Lake Pontchartrain Bridge Rail (continued).



#4 "C9" POST BARS



#4 "C7" POST BARS



#4 "C6" STIRRUP

Figure 1 – Details of US 11 Bridge over Lake Pontchartrain Bridge Rail (continued).

TTI visited the bridge site on September 24, 2008, to review the condition of the bridge and to gather structural design information and other details. Photos of the existing bridge rail are shown in Figures 2 and 3. The existing bridge railings were severely damaged during hurricanes Katrina & Rita in 2005. Repair of the existing bridge railings is not feasible since the original rail design has deteriorated and is deficient with respect to the current American Association of State Highway and Transportation Officials (AASHTO) *LRFD*[(1)] strength requirements, as well as the impact performance requirements of National Cooperative Highway Research Program (NCHRP) *Report 350*[(2)] for Test Level 3 (TL-3). A new retrofit bridge rail design that the current AASHTO *LRFD* TL-3 strength requirements as well as meets the performance requirements of *NCHRP Report 350* TL-3 is needed.

Figure 2 – Existing US 11 Lake Pontchartrain Bridge Rail Traffic Side View.

Figure 3 – Existing US 11 Lake Pontchartrain Bridge Rail Lake Side View

OBJECTIVE

Several bridge rail retrofit designs have been developed at TTI for a host of different states, as well as for the FHWA. In addition, hundreds of crash tests have been performed at TTI on various TL-3 bridge rail designs. For this project, TTI reviewed several different TL-3 bridge rail designs that meet the performance requirements of *NCHRP Report 350*.

The objective of this project is to develop a new retrofit bridge rail design to be used for the US 11 Lake Pontchartrain Bridge that meets the current AASHTO *LRFD* strength and *NCHRP Report 350* performance requirements. Some of the existing reinforcement in the existing bridge rail has deteriorated due to weathering in a marine environment. In addition, the bridge railing was damaged from the high water surge forces from hurricanes Katrina and Rita. Figure 4 shows some of the damaged bridge railing and deterioration in the reinforcing steel in the bridge rail.

Figure 4 – Existing U.S. 11 Lake Pontchartrain Bridge Rail Damage

RESEARCH METHODOLOGY

The objective of this project is to design a retrofit bridge rail that meets the performance requirements of *NCHRP Report 350* TL-3 and can be constructed on top of the existing curb of the US 11 Lake Pontchartrain Bridge. Several bridge rail design options meeting the crash requirements of *NCHRP Report 350* performance requirements were evaluated as part of this project. These options were submitted to the state technical representative for review and approval. One option was selected for engineering strength analysis per AASHTO *LRFD* strength requirements.

The retrofit bridge rail selected for this project was the Illinois 2399-1 Curb Mount Bridge Rail. The Illinois 2399-1 bridge rail was modified from the previous Illinois 2399 design. The original 2399 railing design consisted of W6x25 posts spaced at 6 ft-3 inches on centers with a TS4x3x5/16 top rail element and a TS8x3x1/4 bottom rail element. The height of the metal railing above the top of the curb was 23 inches, with a total height from the pavement surface of 30 inches.

The modified Illinois 2399-1 bridge rail is similar to the original design except it utilizes a TS8x5x5/16 top rail element and a TS4x4x1/4 lower rail element. TTI performed engineering analyses and full-scale crash testing on the Illinois 2399-1 Bridge Railing design in September, 1993.[3] Based on engineering strength calculations, the Illinois 2399-1 bridge rail design will resist 93.5 kips at 23 inches above the surface of the deck, or 83.6 kips at 28 inches. At the time the railing was designed, the proposed strength test conditions for Performance Level Two (PL-2) was a 5400 lb pickup truck traveling 65 miles per hour with an impact angle of 20 degrees. For Performance Level Three (PL-3), it was a 40,000 lb single unit truck traveling 60 miles per hour with an impact angle of 15 degrees. Details of the Illinois 2399-1 Bridge Rail are presented in Figure 5.

The strength test for PL-2 given in the 1989 *Guide Specifications for Bridge Railings*[4], is 18,000 lb single unit truck traveling at a speed of 50 miles per hour with and impact angle of 15 degrees. The design force for this condition is a line force of 56 kips uniformly distributed over a longitudinal distance of 42 inches at 28 inches above the deck surface. The Illinois 2399-1 design met this requirement as per the engineering analyses performed for this project.

Full scale crash testing was performed on the Illinois 2399-1 bridge rail. The Illinois 2399-1 bridge rail was tested to PL-2 requirements of the 1989 *Guide Specifications for Bridge Railings*. The following test conditions were performed on the Illinois 2399-1 bridge rail:

1.) 1800-lb passenger car at 60 miles per hour with an impact angle of 20 degrees
2.) 5400-lb pickup truck at 65 miles per hour with an impact angle of 20 degrees
3.) 18,000-lb single-unit truck at 50 miles per hour with an impact angle of 15 degrees

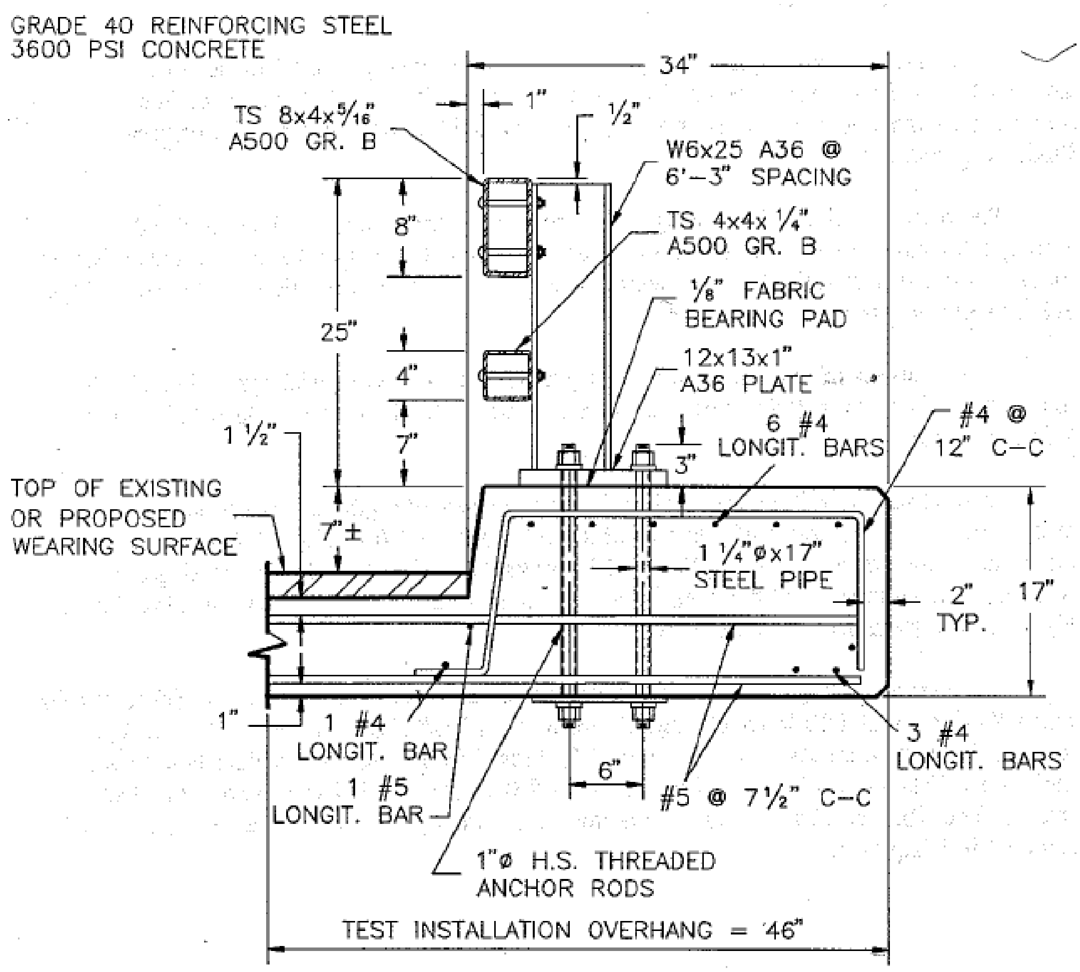


Figure 5 – Cross Section of Illinois 2399-1 Bridge Railing

A full-scale crash was performed on the Illinois 2399-1 bridge railing using the 1800-lb passenger car. This test was performed in accordance with the 1989 *Guide Specifications for Bridge Railings*. The Illinois 2399-1 bridge railing contained and smoothly redirected the vehicle with no lateral movement of the bridge railing. There was no debris or detached elements. There was minimal intrusion into the occupant compartment. The vehicle trajectory at loss of contact indicated minimum intrusion into adjacent lanes. The vehicle remained upright and stable during the entire test period.

According to the evaluation criteria recommended by FHWA and *NCHRP Report 230*[(5)] specifications, this test meets the requirements for structural adequacy, vehicle trajectory, and occupant risk factors. Performance of the railing was considered marginally acceptable with respect to the occupant risk values as stated in *NCHRP Report 230*, Test S13.

A second full-scale crash was performed on the Illinois 2399-1 bridge railing using the 5400-lb pickup truck. This test was performed in accordance with the 1989 *Guide Specifications for Bridge Railings*. The Illinois 2399-1 bridge railing contained and smoothly redirected the vehicle with minimal lateral movement of the bridge railing. There was no debris or detached elements. There was no intrusion into the occupant compartment. The vehicle trajectory at loss of contact indicated minimum intrusion into adjacent lanes. The vehicle remained upright and stable during the entire test period.

According to the criteria recommended by FHWA, this test met the requirements for structural adequacy, vehicle trajectory, and occupant risk factors. This test was considered acceptable with respect to 1989 *Guide Specifications for Bridge Railings*.

A third full-scale crash was performed on the Illinois 2399-1 bridge railing using the 18,000-lb single-unit truck. This test was performed in accordance with the 1989 *Guide Specifications for Bridge Railings*. The Illinois 2399-1 bridge railing contained and smoothly redirected the vehicle with minimal lateral movement of the bridge railing. There was no intrusion into the occupant compartment and very little deformation of the compartment. The vehicle trajectory at loss of contact indicated minimum intrusion into adjacent lanes. The vehicle remained upright and stable during the entire test period.

According to the criteria recommended by FHWA, this test met the requirements for structural adequacy, vehicle trajectory, and occupant risk factors. This test was considered acceptable with respect to 1989 *Guide Specifications for Bridge Railings*.

The crash tests for the Illinois 2399-1 Curb Mounted Bridge Rail were evaluated according the *NCHRP Report 230* specifications with test conditions as per the 1989 *Guide Specifications for Bridge Railings* (i.e., vehicles, impact speed, impact angle). The Illinois 2399-1 Curb Mounted Bridge Rail was crash tested before *NCHRP Report 350* was established, and therefore was not tested under the *NCHRP Report 350* criteria. However, FHWA later concluded that the Illinois 2399-1 Curb Mounted Bridge Rail Design meets the requirements of *NCHRP Report 350* TL-4 specifications without further testing.[(6)]

US 11 LAKE PONTCHARTRAIN RETROFIT BRIDGE RAIL ENGINEERING STRENGTH ANALYSES & DESIGN

A new retrofit bridge rail has been designed for the US 11 Lake Pontchartrain Bridge. Prior to constructing the new retrofit bridge rail, the existing posts and bridge rail elements should be demolished to the top of the concrete curb. The existing concrete curb will be used to anchor the new retrofit bridge rail. Two concrete cores were taken from the existing concrete deck in August 2009. One core (H-1) was taken on the Slidell end (north end) of the bridge approximately 33 ft from the end of the bridge in the north bound lane. The other core (H-2) was taken on the Irish Bayou end (south end) of the bridge approximately 41 ft and-6 inches from the end of the bridge in the south bound lane. The compressive strength of core H-1 and H-2 measured 7087 psi and 6005 psi, respectively.

Engineering strength analyses were performed using the Illinois 2399-1 bridge rail design anchored to the existing 9-inch high by 18-inch wide concrete curb for the US 11 Lake Pontchartrain Bridge. The proposed retrofit design consists of W6x25 steel posts spaced on 6 -3 inches on centers supporting two steel tubular rail elements. The top rail element is an

HSS8x4x5/16 steel tube located 30 inches from the roadway surface. The lower rail element is an HSS4x4x1/4 steel tube located 18 inches from the roadway surface. The bridge rail elements are attached to each post using two ¾-inch diameter by 6 inch long, A307 galvanized button-head bolts with nuts and washer. Each post shall be anchored to the concrete curb using four Hilti 7/8-inch diameter by 13 inches long, A193 B7 threaded rods anchored 10 inches into the concrete curb using Hilti RE500 Epoxy Anchoring System. The adhesive anchors should be installed in accordance with Hilti RE500 Epoxy Anchoring System specifications. All steel tubes shall conform to the requirements of ASTM Designation A500 Grade B Material. All other steel shapes and plate shall conform to AASHTO M 270 Grade 3 Material. The calculated strength of the retrofit bridge rail design using the Illinois 2399-1 steel bridge rail is approximately 55.4 kips. This calculated strength exceeds the design force listed for TL-3 traffic railing in Section 13 of AASHTO LRFD. Please refer to Figure 6 for additional information. The strength calculations are included in Attachment A. For additional information please refer to the FHWA Bridge Rail Guide which can be found online at www.fhwa.dot.gov/bridge/bridgerail. Details for the Illinois 2399-1 Curb Mounted Bridge Rail can be found on this website.

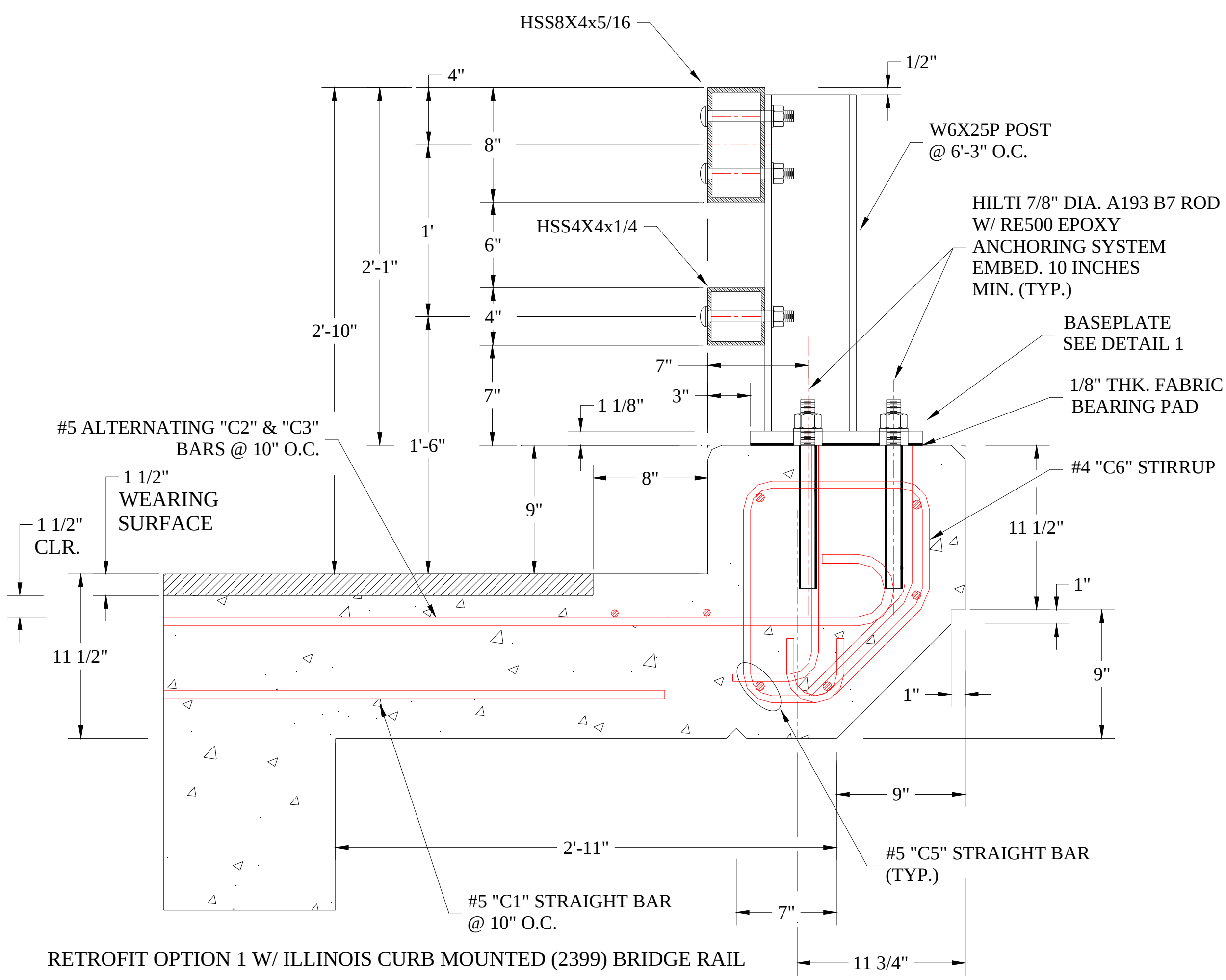


Figure 6 – Cross Section of Illinois 2399-1 Bridge Railing Retrofit Design

SUMMARY AND CONCLUSIONS

The new retrofit bridge rail design presented in this report incorporates the Illinois 2399-1 Curb Mounted Bridge Rail anchored to the top of the existing 9-inch high by 18-inch wide concrete curb. The existing concrete posts and rails on the US 11 Lake Pontchartrain Bridge should be demolished. The posts should be removed using saw cutting or other means that would provide a flat surface without damaging the existing concrete curb. Based on engineering analyses, it is recommended that the bridge rail posts be anchored to the top of the concrete curb using Hilti 7/8-inch diameter A193 B7 threaded rods with Hilti RE500 Adhesive Epoxy Anchoring System (4 anchors per post). The threaded rods should be embedded a minimum depth of 10 inches and installed in accordance with the manufacturer's recommendations. The recommended post spacing is 7 ft as shown in Sheet 1 of Attachment A. For additional information, please refer to the FHWA Bridge Rail Guide which can be found online at www.fhwa.dot.gov/bridge/bridgerail. Details for the Illinois 2399-1 Curb Mounted Bridge Rail can also be found on this website.

REFERENCES

1. *Load and Resistance Factor Design*, American Institute of Steel Construction, 1994.
2. H.E. Ross, Jr., D.L. Sicking, R.A. Zimmer and J.D. Michie, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, National Cooperative Highway Research Program Report 350, Transportation Research Board, National Research Council, Washington, D.C., 1993.
3. C.E. Buth, T.J. Hirsch, and W.L. Menges, *Testing of New Bridge Rail and Transition Designs, Volume Iv: Illinois 2399-1 Bridge Railing, Appendix C*, Contract DTFH61-86-C-00071, Federal Highway Administration, Washington, DC, 1993.
4. *Guide Specifications for Bridge Railings*, American Association of State Highway and Transportation Officials (AASHTO), Washington, DC, 1989.
5. J.D. Michie, *Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances*, National Cooperative Highway Research Program Report 230, Transportation Research Board, National Research Council, Washington, D.C., March 1981.
6. Memo from FHWA Chief, Federal-Aid and Design Division, "Subject: ACTION: Crash Testing of Bridge Railings," Federal Highway Administration, Washington, DC, May 30, 1997.

ATTACHMENT A: LRFD STRENGTH CALCULATIONS & DETAILS

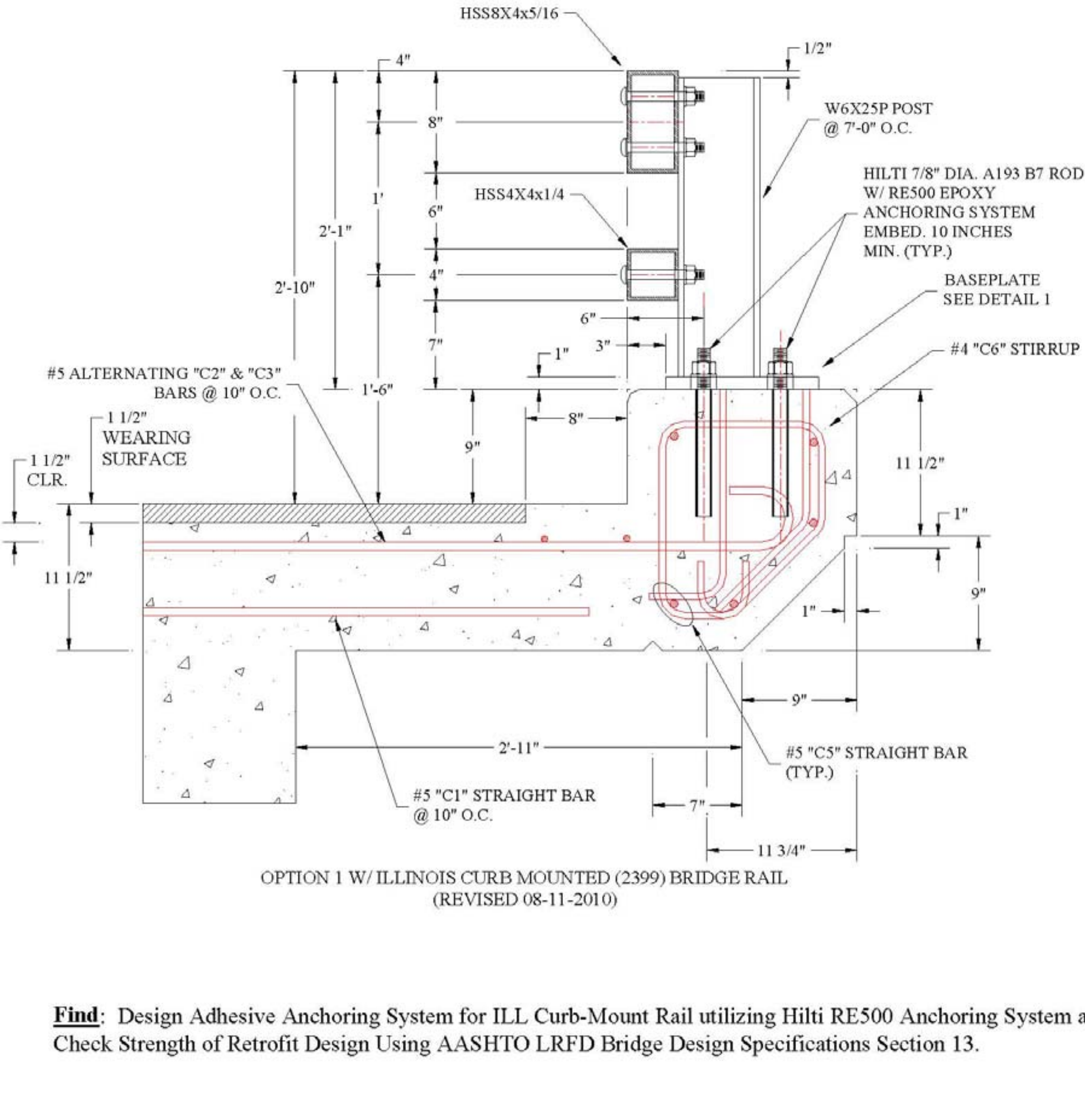
Texas Transportation Institute

Project #: **405160-16**

Subject: **U.S. Route 11 Bridge over Lake Pontchartrain Retrofit Bridge Rail Design**

Sponsor: **WADOT Pooled Fund /LADOT**

Consider the following Cross-Section Using Illinois Curb-Mount 2399 2-Tube Bridge Rail:



OPTION 1 W/ ILLINOIS CURB MOUNTED (2399) BRIDGE RAIL
(REVISED 08-11-2010)

Find: Design Adhesive Anchoring System for ILL Curb-Mount Rail utilizing Hilti RE500 Anchoring System an
Check Strength of Retrofit Design Using AASHTO LRFD Bridge Design Specifications Section 13.

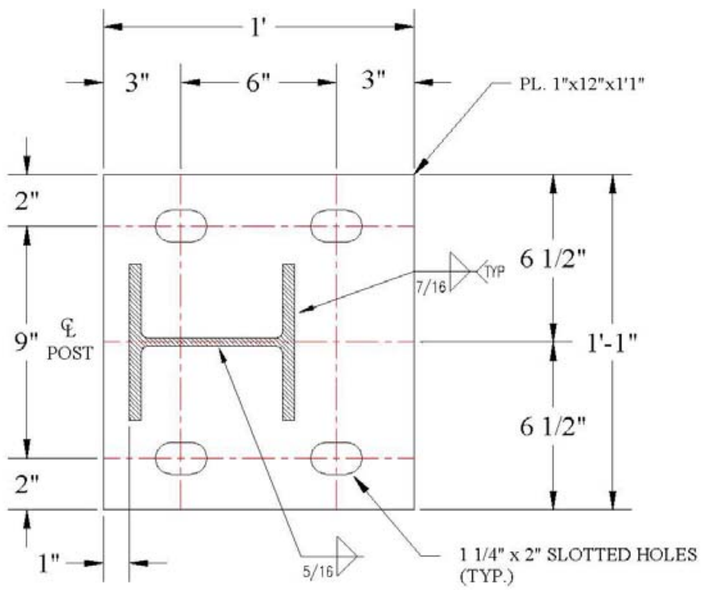
405160-16RailDesignWFWrev10-25- William Williams, P.E 1

Project #: **405160-16**

Subject: **U.S. Route 11 Bridge over Lake Pontchartrain Retrofit Bridge Rail Design**

Sponsor: **WADOT Pooled Fund /LADOT**

Revised Post Base Details (08-10-2010):



DETAIL 1 - BASE PLATE DETAIL
(Revised 08-11-2010)

Texas Transportation Institute

Project #: **405160-16**

Subject: **U.S. Route 11 Bridge over Lake Pontchartrain Retrofit Bridge Rail Design**

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1.) Given the Bridge Rail Information & Infor. from AASHTO Section 13, A13.3.2

$L := 7ft$ Post Spacing

$L_t := 4.0ft$ Length of Loading Distrubution

$Curb_{ht} := 9in$ Height of Curb

$F_t := 54kips$ Magnitude of Distributed Load (kips)

$H_e := 27in$ Height of Load for TL-3

2.) Given the Following Global Units:

$kips \equiv kip \qquad psi \equiv \frac{lbf}{in^2}$

3a) Input for HSS8x4x5/16 Top Rail Properties (ASTM A500 Grade B):

$Z_{top} := 9.91in^3$ Plastic Section Modulus of Top Rail

$Y_1 := 2ft + 6in$ height to the Center of the top Rail

$F_{ytop} := 42ksi$ yield of Top Rail Material, (ksi)

3b) Input for HSS4x4x1/4 Bottom Rail Properties (ASTM A500 Grade B):

$Z_{bott} := 4.69in^3$ Plastic Section Modulus of Bottom Rail

$Y_2 := 1ft + 6in$ height to the Center of the Bottom Rail

$F_{ybott} := 42ksi$ yield of Top Rail Material, (ksi)

4a.) Input for W6x25 Post properties (Grade 36):

$Z_{post} := 19.0in^3$ Plastic Modulus of W6x25 Post $\quad t_f := 0.455in \quad d := 6.38in$

$F_{ypost} := 36ksi$ Yield of post material. $\quad t_w := 0.32in \quad b_f := 6.08in$

4b.) Post Baseplate Infomation & properties:

$F_{yBP} := 36ksi$ Yield of Base Plate Material (ksi)

$BP_{thk} := 1in$ Thickness of Base Plate

5.) Anchor Bolt Properties:

$F_{ubolts} := 125ksi$ High Strength Super HAS Rod Material, ASTM A193, Grade B7 Material (ksi)

$Dia_{bolt} := \frac{7}{8}in$ Dia. of anchor bolts (in.) $Area_{bolt} := \pi\,Dia_{bolt}^{2} \cdot 0.25$ $Area_{bolt} = 0.601 \cdot in^{2}$

$\phi_{bolt} := 1.0$ Strength Reduction Factor For Bolts

6.) Concrete Deck & Curb Properties:

$$\left(f_c\right) \equiv 4000\frac{lbf}{in^2}$$

7.) Calculate the Total Rail Resitance of both Rails

$$M_{ptop} := Z_{top} \cdot F_{ytop}$$

$$M_{ptop} = 34.685 \cdot kip \cdot ft$$

$$M_{pbott} := Z_{bott} \cdot F_{ybott}$$

$$M_{pbott} = 16.415 \cdot kip \cdot ft$$

$$M_p := M_{ptop} + M_{pbott}$$

$M_p = 51.1 \cdot kip \cdot ft$ Total Resistance of the Rails

8.) Calculate the Average Height of Combined Rail Resistances Y_{bar} (ft.)

$$Y_{bar} := \frac{\left[\left(M_{ptop} \cdot Y_1\right) + \left(M_{pbott} \cdot Y_2\right)\right]}{M_p}$$

$Y_{bar} = 2.179 \cdot ft$ Average Height of Combined Rail Resistances from pavement surface

9a.) Calculate the Ultimate transverse Load Resistance of a Single Post located @ Y_{bar} above the deck based on Plastic Strength of Post (P_{p1}):

$$P_{p1} := \frac{Z_{post} \cdot F_{ypost}}{Y_{bar} - Curb_{ht}}$$

$P_{p1} = 39.895 \cdot kips$ Strength based on post strength alone

9b.) Check Post Strength Based on Strength of Welds (P_{p2}):

Calculate fillet weld strength on Web: $F_{EXX} := 70ksi$ $\Phi := 1.0$

$t_{weld5} := \frac{5}{16} in$ Weld size (in.)

$t_{e5} := 0.707 \cdot t_{weld5}$ $t_{e5} = 0.221 \cdot in$ throat size $L_{fillet5} := (d - 2 \cdot t_f) \cdot 2$

$$\Phi R_{filletweld5} := \Phi \cdot t_{e5} \cdot (0.60 \cdot F_{EXX}) \cdot L_{fillet5}$$

$$\Phi R_{filletweld5} = 101.516 \cdot kips$$

Calculate 7/16 inch fillet strength on flanges:

$t_{weld7} := \frac{7}{16} in$ $t_{e7} := 0.707 \cdot t_{weld7}$

$L_{fillet7} := b_f \cdot 2$

$$\Phi R_{filletweld7} := \Phi \cdot t_{e7} \cdot (0.60 \cdot F_{EXX}) \cdot L_{fillet7}$$

$$\Phi R_{filletweld7} = 157.972 \cdot kips$$

Sum Moments about field side flange:

$$M_{welds} := \left[\left(\frac{d}{2} - \frac{t_f}{2}\right) \cdot (\Phi R_{filletweld5}) + \left[(d - t_f)(\Phi R_{filletweld7})\right]\right]$$

$$M_{welds} = 103.061 \cdot kip \cdot ft$$

$$P_{p2} := \frac{M_{welds}}{Y_{bar} - Curb_{ht}}$$

$P_{p2} = 72.133 \cdot kips$ Post strength based on summing moments about center of field side flange

Subject: **U.S. Route 11 Bridge over Lake Pontchartrain Retrofit Bridge Rail Design**

Sponsor: **WADOT Pooled Fund /LADOT**

Calculate Weld Strength based on Properties of Weld Treated as a Line
See "Design of Welded Structures", Blodgett, Table 5 - page 7.4-7,

Properties of W6x25:

$d = 6.38 \cdot in$ depth of Section (in.)

$t_w = 0.32 \cdot in$ Thickness of Web (in.)

$b_f = 6.08 \cdot in$ Flange Width (in.)

$t_f = 0.455 \cdot in$ Flange thickness (in.)

**** Weld on Web ****

$d_w := d - 2 \cdot t_f$ $d_w = 5.47 \cdot in$ weld length along web

$S_w := \frac{{d_w}^2}{3}$ $S_w = 9.974 \cdot in^2$ Section Modulus of Line Welds on web

**** Weld on Exterior Flange *****

$d_{f1} := d + \frac{7}{16} in$ Distance to center-to-center of exterior welds on flange

$S_{f1} := b_f \cdot d_{f1}$ Section Modulus of exterior line welds on Flange

**** Weld on Interior Flange ****

$d_{f2} := d - \left(\frac{7}{16} in - t_f \cdot 2 \right)$ Distance to center-to-center of interior welds on flange

$S_{f2} := d_{f2} \cdot b_f$ Section Modulus of Interior line welds on Flange

$$M_{weld} := S_w \cdot \left[\Phi \cdot t_{e5} \cdot \left(0.60 \cdot F_{EXX} \right) \right] + S_{f1} \cdot \left[\Phi \cdot t_{e7} \cdot \left(0.60 \cdot F_{EXX} \right) \right] + S_{f2} \cdot \left[\Phi \cdot t_{e7} \cdot \left(0.60 \cdot F_{EXX} \right) \right]$$

$M_{weld} = 97.691 \cdot kip \cdot ft$ $Y_{bar} = 26.145 \cdot in$

$Curb_{ht} = 9 \cdot in$

$$P_{p2a} := \frac{M_{weld}}{Y_{bar} - Curb_{ht} - BP_{thk}}$$

$P_{p2a} = 72.609 \cdot kips$ Post Strength based on Line Method

Subject: **U.S. Route 11 Bridge over Lake Pontchartrain Retrofit Bridge Rail Design**

Sponsor: **WADOT Pooled Fund /LADOT**

9c.) Calculate the Ultimate transverse Load Resistance of a Single Post located @ Y_{bar} above the deck based on The Bond Strength of The HILTI RE500 Adhesive Strength (P_{p3}):

As per page 163, 2006 Hilti Product Technical Guide,
HIT RE 500 Epoxy System, Average values for 4000 psi concrete:

$$Tension := \begin{pmatrix} 22670 \\ 63495 \\ 64730 \end{pmatrix} lbf \qquad Shear := \begin{pmatrix} 33050 \\ 72860 \\ 112160 \end{pmatrix} lbf$$

This information from the Ultimate Bond/Concrete Capacity for Hilti HIT RE 500 with concrete strength = to 4000 psi

Actual Embedment Depth (inches), see Hilti guide

$$Depth_{embed} := \begin{pmatrix} 4 \\ 7.875 \\ 10.5 \end{pmatrix} in \qquad h_{ef} := 10in$$

Actual Embedment Depth of Anchors used in the Design

Use Hilti Hight Strength Super HAS A193 Galvanized , 7/8" Dia. Rods:

$$HIT_{ultimatetensile} := linterp(Depth_{embed}, Tension, h_{ef})$$ Interpolate for Embedment Depth, h_{ef}

$$HIT_{ultimateshear} := linterp(Depth_{embed}, Shear, h_{ef})$$

$$HIT_{ultimatetensile} = 64.495 \cdot kips$$ Ultimate tension bond Strength based on actual anchor embedment

$$HIT_{ultimateshear} = 104.674 \cdot kips$$ Ulitmate shear strength of anchor based on actual anchor embedment

MCAD Calcs. Hilti

Subject: Lake Pontchartrain Bridge Rail (Route 11) Retrofit Design OPTION 1

Sponsor: WADOT Pooled Fund /LADOT

$Temperature := 130\,°F$ Max Temperature for Temperature Reduction used in Design

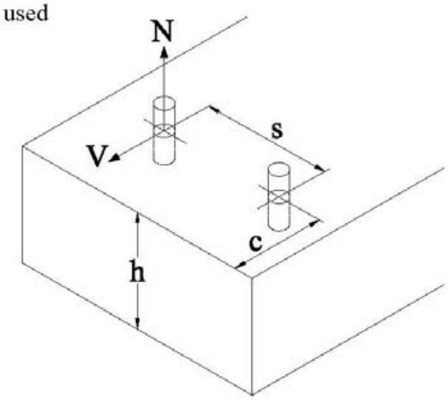
Check Load Adjustment Factors for Anchor Spacings & Clearance:

From page 168, Hilti 2006 Technical Guide

$S_{act} := 9.0in$ Actual anchor spacing (inches)

$C_{act} := 6in$ edge distance (inches) from concrete edge to Centerline of tension bolts

$h_{nom} := 7.875in$ Standard embedment depth (inches), see page 161 Table 4.2.6.3 for 7/8-inch Dia. Anchor



ANCHOR DETAILS

$h_{ef} = 10\cdot in$ Actual embedment depth (in.)

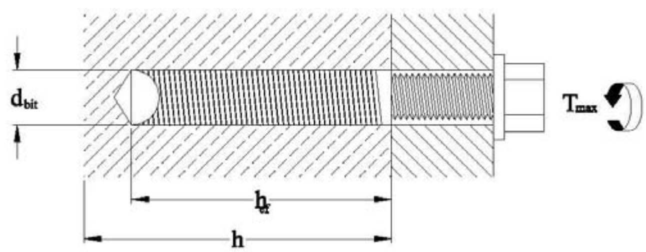
See Design Information Page 168 Tech Guide 2006

$S_{min} := 0.5\cdot h_{ef}$ $S_{min} = 5\cdot in$

$S_{cr} := 1.5\cdot h_{ef}$ $S_{cr} = 15\cdot in$

$C_{min} := 0.5\cdot h_{ef}$ $C_{min} = 5\cdot in$

$C_{cr} := 1.5\cdot h_{ef}$ $C_{cr} = 15\cdot in$



ANCHOR GEOMETRY

**** Calculate Hilti Reduction Factors for Spacing Tension & Shear ******

$$f_A := \begin{cases} f_A \leftarrow 0.3 \cdot \left(\dfrac{S_{act}}{h_{ef}}\right) + 0.55 & \text{if } S_{cr} \geq S_{act} \geq S_{min} \\ f_A \leftarrow 1.0 & \text{if } S_{act} \geq S_{cr} \\ f_A \leftarrow 0 & \text{if } S_{act} < S_{min} \end{cases}$$

$$f_A = 0.82$$

***** Calculate Reduction Factors for Edge Distance Tension, "f_{RN}" *******

$$f_{RN} := \begin{cases} f_{RN} \leftarrow 0.3 \cdot \left(\dfrac{C_{act}}{h_{ef}}\right) + 0.55 & \text{if } C_{cr} \geq C_{act} \geq C_{min} \\ f_{RN} \leftarrow 1.0 & \text{if } C_{act} \geq C_{cr} \\ f_{RN} \leftarrow 0 & \text{if } C_{act} < C_{min} \end{cases}$$

$$f_{RN} = 0.73$$

Calculate Reduction Factors for Edge Distance Shear, "f_{RVperp}"

$$f_{RVperp} := \begin{cases} f_{RVperp} \leftarrow 0.54 \cdot \left(\dfrac{C_{act}}{h_{ef}}\right) - 0.09 & \text{if } C_{cr} \geq C_{act} \geq C_{min} \\ f_{RVperp} \leftarrow 1.0 & \text{if } C_{act} \geq C_{cr} \\ f_{RVperp} \leftarrow 0 & \text{if } C_{act} < C_{min} \end{cases}$$

$$f_{RVperp} = 0.234$$

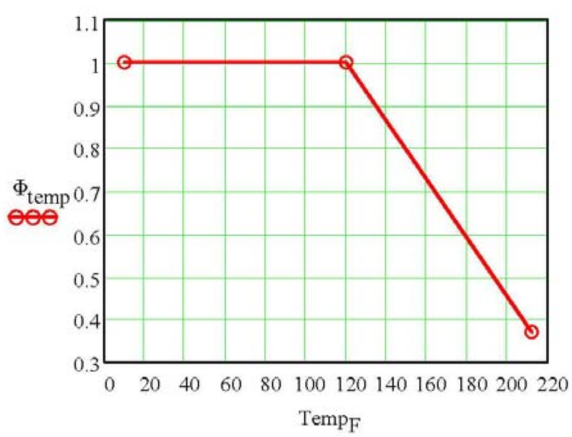
Calculate total combined Reduction Factors for tension & shear:

$f_{RVperp} = 0.234 \qquad f_A = 0.82 \qquad f_{RN} = 0.73$

$$\Phi_{temp} := \begin{pmatrix} 1.0 \\ 1.0 \\ 0.37 \end{pmatrix} \qquad Temp := \begin{pmatrix} 10 \\ 120 \\ 212 \end{pmatrix} {}^\circ F$$

$$Temp = \begin{pmatrix} 260.928 \\ 322.039 \\ 373.15 \end{pmatrix} K \qquad Temp = \begin{pmatrix} 260.928 \\ 322.039 \\ 373.15 \end{pmatrix} K$$

$$Temp_F := \frac{\left[(Temp - 273.15K)\cdot\frac{9}{5}\right] + 32K}{K}$$ Temperature conversion



$$\Phi_{tempreduce} := \text{linterp}\left(Temp, \Phi_{temp}, Temperature\right)$$

$$\Phi_{tempreduce} = 0.932$$

Subject: **Lake Pontchartrain Bridge Rail (Route 11) Retrofit Design OPTION 1**

Sponsor: **WADOT Pooled Fund /LADOT**

Calculate total Reduction for Anchor bond strength considering the previous factors:

$$\Phi_{tension} := \overrightarrow{\left(f_A \cdot f_{RN} \cdot \Phi_{tempreduce}\right)} \qquad \Phi_{shear} := \overrightarrow{\left(f_A \cdot f_{RVperp}\right)}$$

$$\Phi_{tension} = 0.558 \qquad \Phi_{shear} = 0.192$$

$$\Phi R_{tension} := \Phi_{tension} \cdot HIT_{ultimatetensile} \quad \Phi R_{shear} := \Phi_{shear} \cdot HIT_{ultimateshear}$$

MCAD Calcs. Hilti

$\Phi R_{tension} = 35.963 \cdot kips$ $\Phi R_{shear} = 20.085 \cdot kips$ Hilti Factored Anchor Strengths for 7/8-inch Dia Anchors with

$h_{ef} = 10.00 \cdot in$ Embedment depth min.

9d.) Calculate Y_{bar} for the Post:

$Y_{barpost} := Y_{bar} - Curb_{ht}$

$Y_{barpost} = 17.145 \cdot in$ Use the height for determining the moment applied to the post for anchor bolt calculatior

$Y_{barpost} = 1.429 \cdot ft$

$P_{p3} := 24kips$ $M_{post} := P_{p3} \cdot Y_{barpost}$ $M_{post} = 34.29 \cdot kip \cdot ft$

Use this moment and Pp3 shear in RISA Base plate analyses as shown below
Use base plate analysis to obtain forces on adhesive anchors.

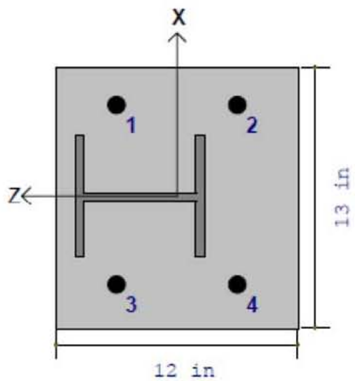
Subject: **U.S. Route 11 Bridge over Lake Pontchartrain Retrofit Bridge Rail Design**

Sponsor: **WADOT Pooled Fund /LADOT**

9e.) Check Baseplate & Anchor Forces using RISABase:

Considering Ybarpost & Mpost above .... calculate anchor bolt forces using RISA program:

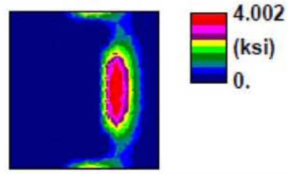
ILL2399 Base Plate



Bearing Pressure

Maximum Bearing 4.002 ksi

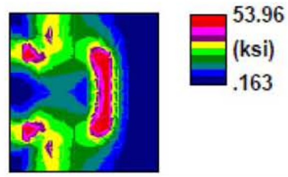
Max/Allowable Ratio .981 IMPACT LOADING (ABIF = 1.000)



Base Plate Stress

Maximum Stress 53.96 ksi

Max/Allowable Ratio 1.665 IMPACT LOADING (ASIF = 1.000)



Plain Base Plate Connection

Base Plate Thickness	: 1. in
Base Plate Fy	: 36. ksi
Bearing Surface Fp	: 4.08 ksi
Anchor Bolt Diameter	: .875 in
Anchor Bolt Material	: A325-120
Anchor Bolt Fu	: 120. ksi
Column Shape	: W6X25
Design Code	: AISC LRFD 2nd

Anchor Bolts

Bolt	X (in)	Z (in)	Tens.(k)	Vx (k)	Vz (k)	Ft (ksi)	Fv (ksi)	Unity	Combination
1	4.5	3.	35.49	0.	6.	67.5	36.	.874	IMPACT LOADING
2	4.5	-3.	0.	0.	6.	67.5	36.	.277	IMPACT LOADING
3	-4.5	3.	35.49	0.	6.	67.5	36.	.874	IMPACT LOADING
4	-4.5	-3.	0.	0.	6.	67.5	36.	.277	IMPACT LOADING

Loads

	P (k)	Vx (k)	Vz (k)	Mx (k-ft)	Mz (k-ft)	Reverse
DL	.1					No
LL			-24.	34.27		No

10.) Check Tensile Strength of Anchor Rods:

$Dia_{bolt} = 0.875 \cdot in$ Diameter of bolt (in)

$F_{ubolts} = 125 \cdot ksi$ Tensile Strength of Bolt (ksi)

$Area_{bolt} = 0.601 \cdot in^2$ Area of Bolt (in)

$\Phi_t := 0.75$

$$\Phi R_{ntension} := \Phi_t \cdot Area_{bolt} \cdot (0.75 \cdot F_{ubolts})$$

$\Phi R_{ntension} = 42.28 \cdot kips$ ..... Tensile strength of single bolt ....o.k.> 37 kips above

Project #: **405160-16**

Subject: **U.S. Route 11 Bridge over Lake Pontchartrain Retrofit Bridge Rail Design**

Sponsor: **WADOT Pooled Fund /LADOT**

11.) Summarize Post Strengths:

$P_{p1} = 39.895 \cdot kips$ Post Strength based on Plastic Stength of Post Section

$P_{p2} = 72.133 \cdot kips$ Post Strength Based on Post Weld (sum moments capacity about field side flange center)

$P_{p2a} = 72.609 \cdot kips$ Post Strength Based on Post Weld section moduli of welds treated as lines

$P_{p3} = 24 \cdot kips$ Post Strength based on Bond strength of RE 500 Adhesive in 4000 psi concrete @ 130 degrees, with A193 B7 Threaded Rods embedded 10 inches

In Summary Limitng post strength based on bond strength of anchors.

Therefore: $P_p := P_{p3}$

$P_p = 24 \cdot kips$ Use this Post Capacity in LRFD Strength Calculations for Bridge Rail

11.) Calculate the Rail Strength for Multiple Spans @ H_e height:

$H_e = 27 \cdot in$

**** 1 Span Case ****

$Y_{bar} = 26.145 \cdot in$

$N_1 := 1$ 1 Span Case

$M_p = 51.1 \cdot kip \cdot ft$ $P_p = 24 \cdot kips$ $L = 7 \cdot ft$ $L_t = 4 \cdot ft$

$$R_1 := \frac{16 \cdot M_p + (N_1 - 1) \cdot (N_1 + 1) \cdot P_p \cdot L}{2 \cdot N_1 \cdot L - L_t} \cdot \left(\frac{Y_{bar}}{H_e}\right)$$

$\boxed{R_1 = 79.172 \cdot kips}$ Resistance for 1 Span.... ok > 54 kips

**** 2 Span Case ****

$N_2 := 2$ 2 Span Case $Y_{bar} = 26.145 \cdot in$

$M_p = 51.1 \cdot kip \cdot ft$ $P_p = 24 \cdot kips$ $L = 7 \cdot ft$ $L_t = 4 \cdot ft$

$$R_2 := \frac{16 \cdot M_p + N_2^{\,2} \cdot P_p \cdot L}{2 \cdot N_2 \cdot L - L_t} \cdot \left(\frac{Y_{bar}}{H_e}\right)$$

$\boxed{R_2 = 60.102 \cdot kips}$ Resistance for 2 Spans... ok > 54 kips

**** 3 Span Case ***** $H_e = 27 \cdot in$

$N_3 := 3$ 3 Span Case $Y_{bar} = 26.145 \cdot in$

$M_p = 51.1 \cdot kip \cdot ft$ $P_p = 24 \cdot kips$ $L = 7 \cdot ft$ $L_t = 4 \cdot ft$

$$R_3 := \frac{16 \cdot M_p + (N_3 - 1) \cdot (N_3 + 1) \cdot P_p \cdot L}{2 \cdot N_3 \cdot L - L_t} \cdot \left(\frac{Y_{bar}}{H_e}\right)$$

$\boxed{R_3 = 55.083 \cdot kips}$ Resistance for 3 Spans... ok > 54 kips

**** 4 Span Case ****

$N_4 := 4$ 4 Span Case $Y_{bar} = 26.145 \cdot in$ $H_e = 27 \cdot in$

$M_p = 51.1 \cdot kip \cdot ft$ $P_p = 24 \cdot kips$ $L = 2.134 m$

$$R_4 := \frac{16 \cdot M_p + N_4^{\,2} \cdot P_p \cdot L}{2 \cdot N_4 \cdot L - L_t} \cdot \left(\frac{Y_{bar}}{H_e}\right)$$

$\boxed{R_4 = 65.281 \cdot kips}$ Resistance for 4 Spans.... ok > 54 kips

Texas Transportation Institute

Project #: **405160-16**

Subject: **U.S. Route 11 Bridge over Lake Pontchartrain Retrofit Bridge Rail Design**

Sponsor: **WADOT Pooled Fund /LADOT**

12.) **Design Summary:**

1.) Use ILLinois 2-Tube Curb Mounted 2399 Bridge Rail
2.) Use Hilti RE 500 Adhesive Anchor System to anchor 7/8-inch Dia A193 B7 Threaded Rods
3.) Minimum Embedment of 7/8-inch Dia. Anchors is 10 inches.
4.) Post Spacing 7'-0"
5.) Install bridge rail in accordance with the details shown on Page one of these calculations.
6.) Install anchors in accordance with manufacture's specifications.
7.) All bridge railing tubular sections shall conform to ASTM A500 Grade B Material
8.) All W6x25 Posts Shall be Grade 36 Material
9.) All base plate material shall be Grade 36 Material.
10.) All bridge railing material (posts & rail elements) including anchor bolts shall be galvanized.
11.) Calculated strength of the retrofit rail design = 55 kips based on AASHTO LRFD Specifications