INDEPENDENT STRUCTURAL ANALYSIS FOR THE CORPUS CHRISTI NEW HARBOR BRIDGE PROJECT

Legacy Contract No. 88-0SDP5002 PS 10781

TECHNICAL MEMORANDUM

DELTA FRAME – TO – BOX GIRDER CONNECTION

DOCUMENT NUMBER: TM1003

08/12/2022

Revision 0

Prepared For: Texas Department of Transportation

TxDOT Bridge Division
118 E. Riverside Drive
Austin, TX 78704
Contact: Jamie Farris, PE

Prepared By: SYSTRA International Bridge Technologies

9325 Sky Park Court Suite 320
San Diego, CA 92123

STATE OF TEXAS
MICHAEL W. SMART
113501
LICENSED
PROFESSIONAL ENGINEER

12 August 2022

INDEPENDENT STRUCTURAL ANALYSIS FOR THE CORPUS CHRISTI NEW HARBOR BRIDGE PROJECT

TECHNICAL MEMORANDUM

DELTA FRAME – TO – BOX GIRDER CONNECTION

DOCUMENT NUMBER: TM1003

ORIGINATOR: Michael W. Smart, PE

Revision History

Revision	Date	Description
0	08/12/2022	Original Issue

Table of Contents

1. Introduction

This technical memorandum discusses previously reported findings of the Independent Structural Analysis (ISA) concerning the delta frame – to – box girder connections of the Corpus Christi New Harbor Bridge, cable-stayed main bridge, where the current design does not meet the project requirements. This and several other findings related to the delta frames have been documented in previous reports (see References 3. and 4. below) and discussed in meetings (see References 6., 7., and 8. below). These findings have yet to be resolved by the Developer, and they have not been addressed by changes in wind input recently observed in the updated (Rev. 2) Wind Report (see Reference 5. below). This technical memorandum focuses solely on the findings related to the delta frame – to – box girder connection design, as shown in Figure 1 below.

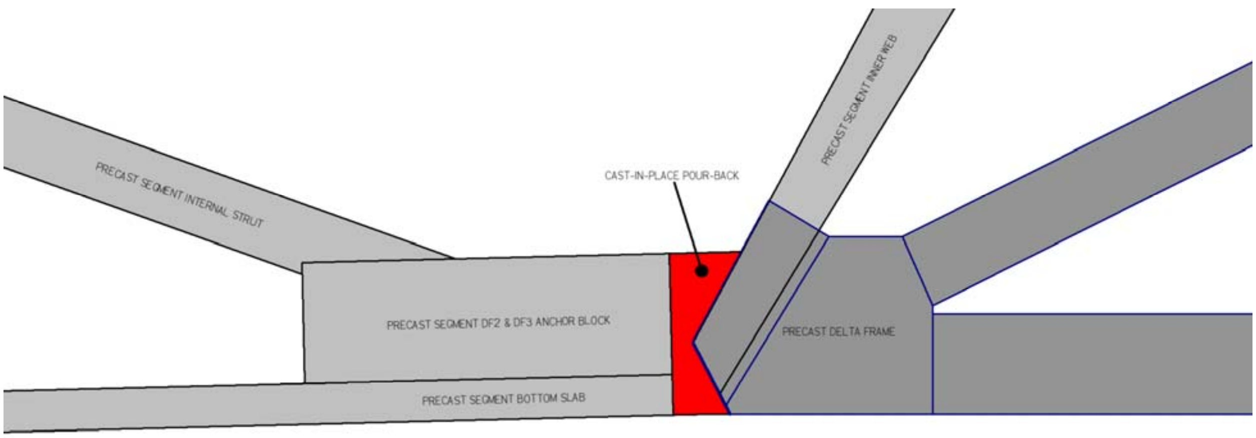


Figure 1: Delta Frame – To- Box Girder Connection (NB Shown, SB Similar)

2. References

The following documents are referenced in this memorandum.

1. American Association of State Highway and Transportation Officials (AASHTO), "LRFD Bridge Design Specifications," 7th Edition, 2014 with 2015 Interim Revisions. [AASHTO LRFD]
2. "277609-NHB-PLN-MSUPER_A-00" and "NDC No. 0512" ["Design Drawings" or "Current Design"]
3. Independent Structural Analysis for the Corpus Christi New Harbor Bridge Project, Document Number: 1010 dated January 8, 2021 ["ISA Phase 1 Report"]
4. Independent Structural Analysis for the Corpus Christi New Harbor Bridge Project, Document Number: 2010 dated April 23, 2022 ["ISA Phase 2 Part 1 Report"]
5. "277609-NHB-REP-MWER-02: US181 Harbor Bridge Replacement Project: Wind Engineering Report," Revision 2, May 4, 2021 (First received by ISA Team June 7, 2022) ["Wind Report"]
6. Meeting Notes of 26 May 2022 meeting in Austin, TX between TxDOT, FDLLC, HNTB, ARUP-CFC, and IBT ["May 2022 Meeting"]
7. Meeting Notes and Presentations of 10 June 2022 meeting in Austin, TX between TxDOT, FDLLC, HNTB, ARUP-CFC, and IBT ["June 2022 Meeting"]

8. Meeting Notes and Presentations of 29 July 2022 meeting in Austin, TX between TxDOT, FDLLC, HNTB, ARUP-CFC, and IBT [“July 2022 Meeting”]
9. “SEL-000772” Letter from FDLLC to TxDOT dated June 24, 2022 [“FDLLC Letter”]

3. Summary of Findings

AASHTO LRFD §5.8.4.1 requires, “The minimum area of interface shear reinforcement specified in Article 5.8.4.4 shall be satisfied.” In the current design as shown in Figure 2 below, there has been no interface reinforcement provided across the interfaces between the cast-in-place pour-back and the bottom precast segment DF2 & DF3 anchor block nor between the pour-back and the precast delta frame. This does not meet the requirements of AASHTO LRFD §5.8.4.1 and §5.8.4.4.

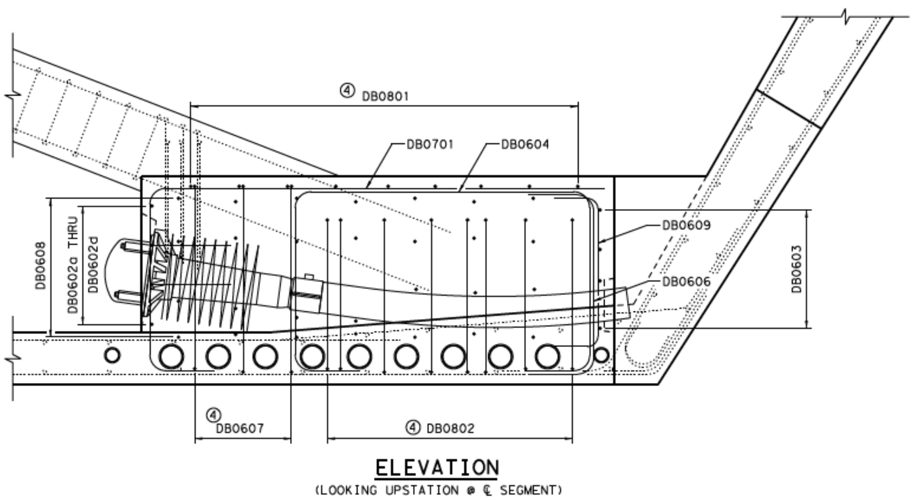


Figure 2: Delta Frame Tendon DT2 & DT3 Anchor Block Details (NB Shown, SB Similar) – Schematics by Others

These unreinforced interfaces, which must be able to transfer axial load, shear, and flexure from the box girders to the delta frames, lack a ductile means to adequately resist flexure and shear at this critical connection. The DF2 and DF3 post-tensioning tendons cross two of these interfaces. However, AASHTO LRFD §5.8.4.1 does not include post-tensioning as an acceptable means to resist interface shear. Further, literature cited in the AASHTO LRFD Commentary and other relevant literature lack experimental research to support the sole use of post-tensioning to provide ductile interface shear resistance without interface reinforcement allowed by AASHTO LRFD §5.8.4.1: single bars, multiple leg stirrups, or welded wire fabric.

Flexural moments under Service (and Strength) limit state loadings cause top fiber tensile stresses across the interface that exceed the no tension allowable limits of AASHTO LRFD §5.9.4.2.2. There is no reinforcement to arrest cracking in the pour-back, and so the current design also does not meet the requirements of AASHTO LRFD §5.7.3.4. As cracks deepen, the ability of the interfaces to resist shear decreases. The shear from each box girder (NB and SB) must transfer through these interfaces to the delta frame on its way to the support at the stays. Well anchored reinforcement must be provided across both interfaces of the pour-back to satisfy the above-referenced requirements. Without this reinforcement, brittle failure of these critical connections cannot be ruled out.

AASHTO LRFD §5.8.4 provides formulas to compute interface shear resistance. However, calculations using these formulas are not valid unless the AASHTO LRFD §5.8.4.1 and §5.8.4.4 minimum interface reinforcement requirements are satisfied. To further demonstrate the severity of the problem, Appendix A presents sample computations of shear demand and interface shear resistance using these formulas considering an assumed crack depth. The 1.97 shear demand-to-capacity ratio computed would decrease significantly, and the AASHTO LRFD requirements discussed could be satisfied, if sufficiently anchored continuous reinforcement were provided across the pour-back interfaces. The demand-to-capacity ratio could also be improved by intentional roughening. However, roughening alone would not address the lack of ductility, and it would not satisfy the AASHTO LRFD §5.8.4.1 and §5.8.4.4 minimum interface reinforcement requirements.

The unreinforced pour-back also does not meet some of the requirements of AASHTO LRFD §5.10 – Details of Reinforcement (e.g., minimum reinforcement spacing requirements, temperature and shrinkage requirements, effects of curved tendons, etc.). Referring to Figure 2 below, the pour-backs must resist radial stresses from the 2 x 31-strand tendons that deviate through this element with a 15' radius. Without reinforcement, the pour-back does not have a means to meet the requirements of AASHTO LRFD §5.10.4.3.

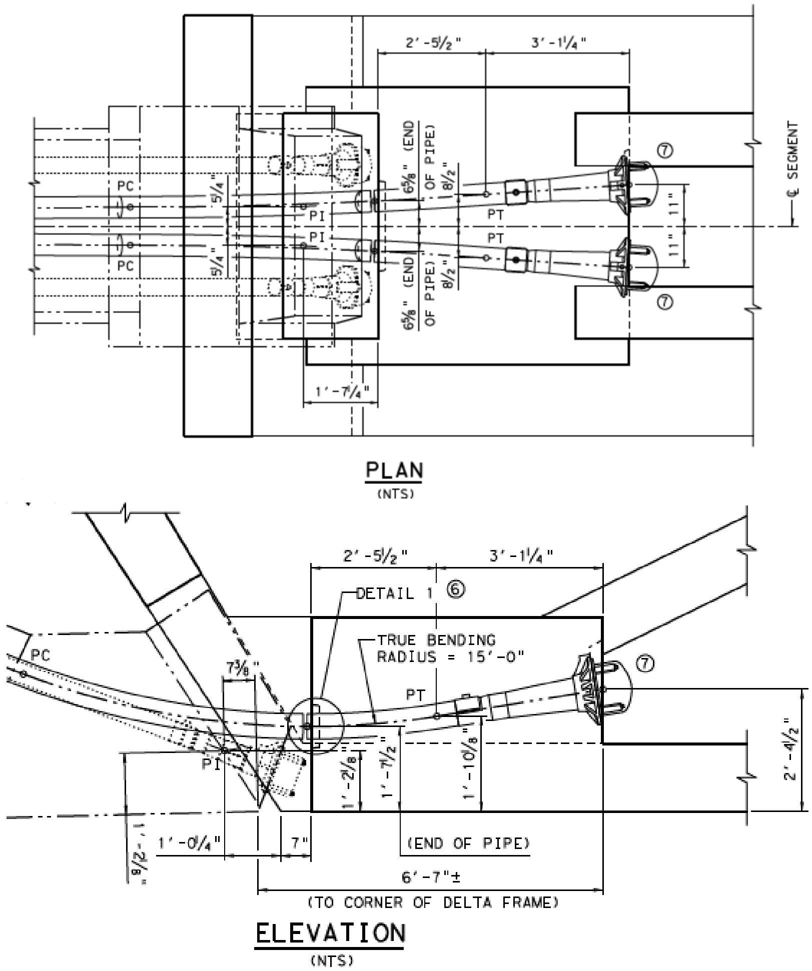


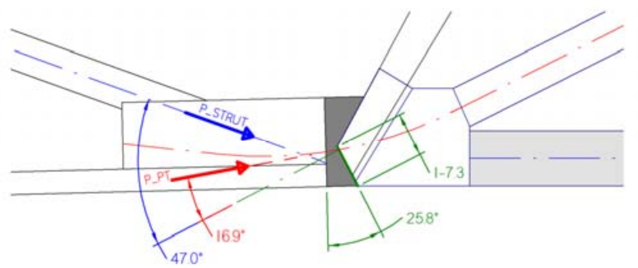
Figure 2: Delta Frame Tendon DT2 & DT3 Anchor Block Details (SB Shown, NB Similar) – Schematics by Others

The characteristics of the cast-in-place pour-back material has not yet been specified in the Current Design; therefore, the it does not meet the requirements of AASHTO LRFD §5.4.1 Also, the above-referenced FDLLC Letter shows that the delta frame surface adjacent to the cast-in-place pour-back has not been intentionally roughened to a minimum amplitude of ¼" to maximize cohesion and friction properties of the interface, as was specified for the bottom precast segment DF2 & DF3 anchor block vertical face adjacent to the cast-in-place pour-back.

4. Conclusion

The ISA has identified several deficiencies in the current Delta Frame – to – Box Girder connection design. The current design does not meet the project requirements, namely AASHTO LRFD §5.4.1; §5.8.4.1 and §5.8.4.4; §5.9.4.2.2; §5.7.3.4; and §5.10. Other findings related to the delta frame also remain unresolved, and these findings have not been addressed by changes in wind input recently observed in the updated (Rev. 2) Wind Report.

Appendix A. Hypothetical Interface Shear Calculation (Valid only if the minimum interface reinforcement requirements of AASHTO LRFD §5.8.4.1 and §5.8.4.4 are satisfied)



NB BOX GIRDER SOCKET

Delta Frame Socket Interface Shear   AASHTO LRFD § 5.8.4

$\alpha = 16.9°$ $P_{u_{STRUT}} = 991\ kip \times 2 = 1982\ kip$ $f'_c = 10{,}000\ psi = 10\ ksi$

$\beta = 47.0°$

$\mu = 0.6$ $\phi = 0.9$ $P_{u_{PT}} = 1855\ kip$ (51% f_{pu}, $2 \times 31\ \phi 0.6''$)

$c = 0.075\ ksi$

$A_{cv} = 6'\text{-}2'' \times 1'\text{-}7'' = 74\ in \times 19\ in = 1406\ in^2$

$V_u = 1855\ kip \cdot \sin 16.9° + 1982\ kip \cdot \sin 47.0°$
$= 539\ kip + 1450\ kip = 1989\ kip$

$N = 1855\ kip \cdot \cos 16.9° + 1982\ kip \cdot \cos 47.0°$
$= 1775\ kip + 1351\ kip = 3127\ kip$

$\phi V_{ni} = \phi(cA_v + \mu N) = 0.9(0.075 \cdot 1406\ in^2 + 0.6 \cdot 3127\ kip)$
$1783\ kip < V_u$ N.G.
$D/C = 1.12$

Check AASHTO LRFD § 5.8.4.1 limits:

Eq. 5.8.4.1-4 : $K1 = 0.2$
    ; -5 $K2 = 0.8\ ksi$

$V_{ni} = K_1 f'_c A_{cv}$ eq. 1-4
$= 0.2\,(10\,ksi)(1406\,in^2)$
$= 2812\,kip$

$V_{ni_{max}} = K_2 A_c$ eq. 1-5
$= 0.8\,ksi \cdot 1406\,in^2$
$= 1125\,kip \Rightarrow \phi V_{ni_{max}} = 1012\,kip$

$D/C = 1.97$