Investigation of Dual Grade/Hybrid Steel Plate Girders Utilizing Stainless Steel
TPF-5(493)

Study Description:

The corrosion of steel bridges is an ongoing concern for bridge owners due to maintenance and replacement costs. Recently, there have been successful corrosion resistance tests performed on ASTM A709 Grade 50CR (stainless) steel in plate girder bridges. Before stainless steel's adoption into ASTM A709, the steel was marketed under ASTM A1010 and has currently been used in 5 states (OR, CA, IA, PA, VA) and Canada.

Utilizing stainless steel (Grade 50CR) for the portion of the steel girder near bridge deck joints and Grade 50, 50W, etc. for the remainder of the girder provides a means to mitigate deterioration in areas exposed to run-off from failed deck joints. Targeting the use of Grade 50CR to specific areas of the bridge requires bolting or welding stainless steel to conventional steel. The dual grade plate girder provides a reduction in the life cycle maintenance costs and increases the service life of the bridge. However, dual grade connections may be prone to galvanic corrosion or require fabrication processes that differ from conventional plate girder fabrication processes. To take advantage of the corrosion resistant cost savings of a dual grade girder, research is needed to address the galvanic corrosion and fabrication of the dual grade connections.

Objectives:

The objective of this research is to examine the feasibility of connecting bridge-construction approved ASTM stainless steel (currently only Grade 50CR is approved) to conventional steel (Grade 36, 50, 50W, etc.) through welding or bolting and to develop guidelines to assist designers and fabricators when connecting stainless steel plates to conventional steel plates in the superstructure of highway bridges. The guidelines would be considered supplemental to the AASHTO *LRFD Bridge Design Specifications* and the AASHTO *LRFD Bridge Construction Specifications.*

The research would, at a minimum, consider the following:

- Welded connections (both groove and fillet weld) and bolted connection feasibility.
- Welded connection requirements that can be included in AASHTO/AWS D1.5 "Bridge Welding Code".
- Bolted connections that meet the slip-critical assumptions in the AASHTO *LRFD Bridge Design Specifications.*
- Assessing the vulnerability of galvanic corrosion between Grade 50CR and conventional grade steel, and measures to prevent it if it occurs.
- Design aspects that may change when transitioning to stainless alloys.
- Documented guidelines covering:
    - Design details
    - Fracture toughness or impact energy
    - Fatigue resistance
    - Installation/fabrication practices that meet performance criteria

The research results should answer key questions regarding mechanical properties of dual grade girder connections and any concerns with galvanic corrosion. The research must demonstrate that consumables (bolts/nuts/washers or welding wire) can be procured domestically to meet Buy America requirements.

Research Tasks:
The proposed project is focused on the design details, fabrication, and performance of dual grade steel girders. The project work plan is divided into three main research tasks.

Task 1 – Literature Review
3 Months ($50,000)

Conduct a current literature review of sources that have published mechanical and corrosion properties of stainless-steel plates connected to conventional steel plates with emphasis on ASTM A1010 and ASTM A709 Grade 50CR stainless steels. The Research Team will provide a literature review report and present findings to the Technical Advisory Committee (TAC). Results of the literature review will guide discussions between the Research Team and TAC to identify gaps in research and direct research effort for Task 2 of welded and bolted dual grade connections.

Task 2 – Connection Testing & Verifying Design/Fabrication Details
24 Months

The Research Team proposes to the TAC a work plan for research to fill the gaps identified in Task 1. This will lead to mechanical property evaluation of complete joint penetration and fillet welds, along with bolted connections. Pending the findings from Task 1, the second task will include:

Task 2A ($250,000):

- Development of AASHTO/AWS D1.5 Bridge Welding Code Welding Procedure Specification(s) proven through a Procedure Qualification Record (PQR).
- Development of refined nondestructive evaluation procedures for dual grade welded connections.
- Assessment of dual grade welded connections to stress corrosion and galvanic corrosion.

Task 2B (Optional, not to exceed $50,000):

- Determining the appropriate grades of bolts to use in a dual grade connection to minimize or eliminate the effects of galvanic and pitting corrosion.
- Determining the appropriate grades of stainless bolts to use in dual grade connections that could achieve minimum installation pretension and the procedure to attain the minimum installation pretension.
- Determine if a dual grade bolted connection can attain slip-critical design loading.

Task 3 – Final Report & Guidelines
6 Months ($50,000)

Provide a final report that, at a minimum, provides:

- A summary of the literature review.
- Documented tests, test results, summaries, and conclusions from Task 2 activities including, but not limited to:
    - All Welding Procedure Specifications (WPS) used in the research and their associated Procedure Qualification Records (PQRs)
    - Nondestructive evaluation (NDE) procedures
- A cost analysis with recommendations to reduce dual grade girder connection costs.
- A cost analysis procedure tool for bridge designers.
- Propose draft language for AASHTO/AWS D1.5 ballot for welding Grade 50CR to conventional grade steel.
- Guidelines covering the design details, fabrication, and installation of dual grade plate girders in two-column format similar to other AASHTO *LRFD Bride Design Specifications* and AASHTO *LRFD Bridge Construction Specifications*.

A draft of the final report will be provided to the Technical Advisory Committee (TAC) for review and comment prior to submission of the final report.

The Research Team will also develop an educational program to instruct steel bridge fabricators on the proper procedures to weld conventional grade steel to Grade 50CR stainless steels and qualified NDT procedures meeting AASHTO/AWS D1.5 *Bridge Welding Code* requirements.

Quarterly Progress Reports:
The Research Team is responsible for providing quarterly progress reports (QPRs). QPRs must be in sufficient detail to communicate achievements to date and future work, including potential problems. The QPR must include an exhibit showing the progress on the project tasks and the budget status.

Research Team Minimum Qualifications:
For consideration by the TAC the Research Team shall document and demonstrate in the research proposal the following minimum level of experience:
Task 2A

- 5 years of welding research experience.
- 5 years of experience on how to weld dissimilar metals.
- Experience with developing weld procedure qualifications records and weld procedure specifications.
- 5 years of experience with nondestructive evaluations of weldments employing dissimilar metals.
- Experience with developing and qualifying nondestructive evaluation procedures.

- Experience in welding inspection and bridge fabrication inspection with the following certifications:
    - Personnel performing nondestructive testing shall be certified as NDT Level II in conformance with the latest edition of the American Society for Nondestructive Testing's (ASNT) recommended practice number (SNT-TC-1A) in the test method they are performing / witnessing including UT, VT, RT, PT and MT. ASNT NDT Level III certification is preferred.
    - Personnel performing welding inspection shall be American Welding Society (AWS) Certified Welding Inspectors (CWI) and qualified in accordance with AASHTO/AWS D1.5 *Bridge Welding Code* Inspection Personnel Qualification requirements.

Task 2B

- Experience with testing bolted connections.
- Experience in performing bolted connection slip-testing per the Research Council of Structural Connections "Specification for Structural Joints Using High-Strength Bolts" Appendix A entitled "Testing Method to Determine the Slip Coefficient for Coatings Used in Bolted Connections." Equivalent experience with similar testing specifications will be considered.
- Experience in developing tension-torque-rotation curves of bolt assemblies to determine minimum pretension and installation criteria.

Proposers should be aware of the following references when developing their proposal:

Daghash, S.M., Huang, Q., and Ozbulut, O.E. (2019). Tensile Behavior and Cost-Efficiency Evaluation of ASTM A1010 Steel for Bridge Construction. Journal of Bridge Engineering 24(8). American Society of Civil Engineers. Reston, VA.

Ebrahimi, N., Zhang, J., Baldock, B., and Lai, D. (2018). Galvanic Corrosion Risk Assessment of Bolt Materials in Contact With ASTM A1010 Steel Bridges. NACE CORROSION 2018. NACE International. Houston, TX.

Fitz-Gerald, J.M., Agnew, S.R., and Xia, X. (2020). Welding of ASTM A709 50CR Using Austenitic Filler Wires With Varying Heat Inputs and Maximum Interpass Temperatures. VTRC 20-R24. Virginia Transportation Research Council, Charlottesville, VA.

Groshek, I. G. (2017). Corrosion Behavior of ASTM A1010 Stainless Steel for Applications in Bridge Components. Virginia Tech.

Hebdon, M.H., and Provines, J.T. (2020). The Use of ASTM A1010 (A709 GR50CR) Stainless Steel for Bridges in the United States. Journal of Performance of Constructed Facilities 34(6). American Society of Civil Engineers. Reston, VA.

Phares, B., Shafei, B., and Shi, W. (2020). Evaluation of the Performance of A1010 Bridge Steel. InTrans Project 16-562. Iowa Department of Transportation. Ames, IA.

Provines, J.T., Moruza, A.K., and Sharp, S.R. (2021). Corrosion-Resistant Steel Fastener Assemblies for ASTM A709 Grade 50CR Steel Bridges. FHWA/VTRC 21-R13. Virginia Transportation Research Council, Charlottesville, VA.

Sharp, S.R., Provines, J.T., Moruza, A.K., Via, W.F., and Harrop, K.N. (2019). Virginia's First Corrosion Resistant ASTM A1010 Steel Plate Girder Bridge. FHWA/VTRC 20-R10. Virginia Transportation Research Council, Charlottesville, VA.

Russian, O., and Ocel, J. (2020). Mechanical Performance of Welds Using ASTM A709 Grade 50CR Steel as Base Metal. Journal of Constructional Steel Research 170. https://doi.org/10.1016/j.jcsr.2020.106121.