TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): North Carolina DOT

INSTRUCTIONS:
Lead Agency contacts should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *TPF-5(493)*	**Transportation Pooled Fund Program - Report Period:** X Quarter 1 (January 1 – March 31) ☐ Quarter 2 (April 1 – June 30) ☐ Quarter 3 (July 1 – September 30) ☐ Quarter 4 (October 1 – December 31)
TPF Study Number and Title: TPF-5(493) – Investigation of Dual Grade/Hybrid Steel Plate Girders Utilizing Stainless Steels	

Lead Agency Contact: Jason Provines	**Lead Agency Phone Number:** (434) 293-1917	**Lead Agency E-Mail:** Jason.provines@vdot.virginia.gov
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:** 2/13/24
Original Project Start Date: 2/13/24	**Original Project End Date:** 11/13/26	**If Extension has been requested, updated project End Date:** N/A

Project schedule status:

X On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Funds Expended This Quarter	Percentage of Work Completed to Date
$400,000	Approx. $2,000	2%

Project Description:

Corrosion is a major concern for steel bridges, and if not properly designed for or mitigated, can lead to costly maintenance or service failures. One such option for making steel bridges more corrosion resistant is by using a dual grade girder, in which ASTM A709 Grade 50CR (50CR) is welded or bolted to a conventional steel bridge corrosion protection system. In this case, the 50CR could be placed in a more corrosive environment, such as under a deck joint, and the conventional steel bridge corrosion protection system would be placed in other areas to allow for cost savings. However, there are still several unknowns related to welded and bolted dual grade connections.

This project will address those unknowns through experimental testing and analysis. Dual grade welds will be fabricated with different welding parameters, and PQR tests will be conducted to evaluate the welds for their structural performance. NDE research will be conducted to determine the suitability of eddy current to be used for weld inspection and to refine UT techniques to account for the high attenuation of austenitic weld metals and the different ultrasonic velocity and high anisotropic ratio of 50CR. Corrosion research will be conducted to assess the galvanic, stress, pitting, and crevice corrosion performance of dual grade connections. Results from that corrosion research will then be used to determine appropriate bolt types to be used in bolted dual grade connections. Additionally, torqued tension testing of stainless steel bolts will be conducted to determine tabulated values for installation pretension and installation criteria (such as rotation requirements for turn-of-nut installation).

After the experimental testing and analysis are complete, a final report will be developed. It will include recommendations for additions or revisions to be made in the AASHTO LRFD Bridge Design Specifications, AASHTO Bridge Construction Specifications, and AASHTO/AWS D1.5 that will allow welded and bolted dual grade connections to be designed, fabricated, and constructed successfully.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

The project officially started on 2/13/24. A kickoff meeting between the research team and TAC was held on 3/14/24.

Task 1 – Literature Review

The research team is currently developing the literature review based on reviewing of relevant research reports, journal publications, specifications, and product datasheets. The literature review is being written narrative form, not as an annotative bibliography, as approved by the TAC. 20% completed.

Task 2 – Connection Testing & Verifying Design/Fabrication Details

Task 2A – Welded Dual Grade Connections

No work was done on this task in this report period. 0% completed.

Task 2B – Bolted Dual Grade Connections

No work was done on this task in this report period. 0% completed.

Task 3 – Final Report & Guidelines

No work was done on this task in this report period. 0% completed.

Virginia Transportation Research Council (VTRC)/University of Virginia (UVA) Dissimilar Metal Welding Research Project

As stated in the project proposal, updates from the VTRC/UVA dissimilar metal welding research project will be provided in these quarterly reports. This will be a concise summary of the project to date, but a more complete summary will be submitted in the literature review. Most of the welds in this project have been made with 50CR connected to either A36 or 50W using the submerged arc welding (SAW), shielded metal arc welding (SMAW), and flux cored arc welding (FCAW) processes. Originally, welds were made using a single vee joint with a carbon steel backing plate. Electrodes used include 309L, 312, and 309L cored wire for SAW.

Procedure qualification record (PQR) testing revealed cracks in all the SAW specimens welded with “medium” or “high” heat input. Some SMAW and FCAW samples passed PQR tests, but those made with the 312 electrodes failed. Metallurgical analysis identified two causes of cracking in SAW samples. Solidification cracking, also called hot cracking, was observed in the diluted regions of the austenitic weld metal adjacent to the carbon steel. This was due to local segregations of low-melting point elements that remain in liquid form as the rest of the weld solidifies and

contracts. Cold cracking was observed in the root pass of the weld. This was caused by brittle carbide formed by dilution from the carbon steel backing plate and a faster cooling rate than other portions of the weld. Differences in the thermal properties of the weld and base metals contributed to high residual stresses in the same locations as the brittle carbides, which lead to cracking.

To attempt to alleviate these cracking mechanisms, four specimens were fabricated using a single vee backgouged joint with SAW at "low" heat input. The backgouged joint allowed for the carbon steel backing plate to be eliminated, which reduced dilution, and also balanced the number of weld passes on either side of the weld, which reduced residual stresses. The low heat input further reduced dilution, which helped both the hot and cold cracking. PQR tests were conducted on these four specimens, and all had passing results, showing that the welding modifications were able to alleviate both the hot and cold cracking.

An alternative alloy to 50CR, ATI 412™ made by ATI , was identified to potentially solve the availability challenges with 50CR. ATI 412 has similar chemical and mechanical properties to 50CR. ATI 412 was ordered with an approximate 12 week lead time, compared to the 11 month lead time for 50CR. Dissimilar metal welded samples between ATI 412 and either A36 or 50W are currently being welded to determine if ATI 412 can be used for these types of welds.

Anticipated work next quarter:

Task 1 – Literature Review

The literature review and an updated proposed workplan will be submitted to the TAC by 5/13/24. Another meeting will be scheduled between June 10-21, after the submittal, to get feedback from the TAC on the literature review and proposed workplan.

Task 2 – Connection Testing & Verifying Design/Fabrication Details

Task 2A – Welded Dual Grade Connections

Once the workplan has been approved by the TAC, fabrication of welded specimens will begin. During this time, the research team will have continued discussions with the High Steel welding team to learn from their observations during welding.

Task 2B – Bolted Dual Grade Connections

After workplan approval, the research team will begin assembling the required equipment and samples needed for conducting the tests on bolted dual grade connections. This will focus on the bolted corrosion tests first since these tests will be conducted prior to the testing required to develop pretension values and installation criteria for stainless steel bolts.

Task 3 – Final Report & Guidelines

No work is planned on this task in the next report period.

VTRC/UVA Dissimilar Metal Welding Research Project

Now that the cracking issues have been alleviated, corrosion testing of dissimilar metal welds will begin. Four welding parameter combinations will be partially submerged in a saltwater bath and galvanic corrosion performance will be monitored. Other planned corrosion tests include saltwater droplet testing and stress corrosion cracking testing. It is anticipated that the dissimilar metal welded samples made with ATI 412 will be completed and PQR testing can begin.

Significant Results:

Due to the project just beginning this quarter, no significant results have been found yet.

VTRC/UVA Dissimilar Metal Welding Research Project

- According to welder observations, it is much easier to make good, quality welds using FCAW compared to SMAW.
- FCAW and SMAW welds made using a 309L consumable can pass PQR tests using typical welding parameters.
- Solidification and cold cracking can be alleviated in the SAW welds by using a single vee with backgouged joint at a low heat input.
- ATI 412 may be a potential alternative to 50CR. It has similar properties and much shorter lead times. PQR test results may confirm this when completed.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.

Potential Implementation:

The primary research product will be the final report as developed in Task 3. Recommended changes to the AASHTO LRFD BDS/BCS and D1.5 will be included in appendices within the report and will be based on the combined results from this research and the VTRC/UVA research dual grade welding research. Recommended changes will be written in a similar format to the specifications for which they are intended (i.e., recommendations for AASHTO specifications will follow a two-column specification/commentary format, and recommendations for D1.5 will follow a two-chapter specification/commentary format.). Using a similar format to existing specifications will allow these revisions to be more easily implemented.

The research team will present at conferences, meetings, and the AASHTO/NSBA Collaboration as well as develop journal publications to disseminate research findings into the steel bridge community. The research team will also present recommendations to the AASHTO COBS Technical Committee T-14 Structural Steel Design committee for review/adoption into the AASHTO LRFD BDS/BCS and to the Joint AASHTO/AWS Bridge Welding Subcommittee for review/adoption into D1.5.