

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: ☐ 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:

☒ 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	\$23,349.48	35%

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) plate is welded or bolted to conventional steel bridge girder components. In this case, the 50CR could be placed in a more corrosive environment, such as under a deck joint, and the conventional steel bridge material 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.):

Task 1 – Literature Review

No work was done on this task. 100% completed.

Task 2 – Connection Testing & Verifying Design/Fabrication Details

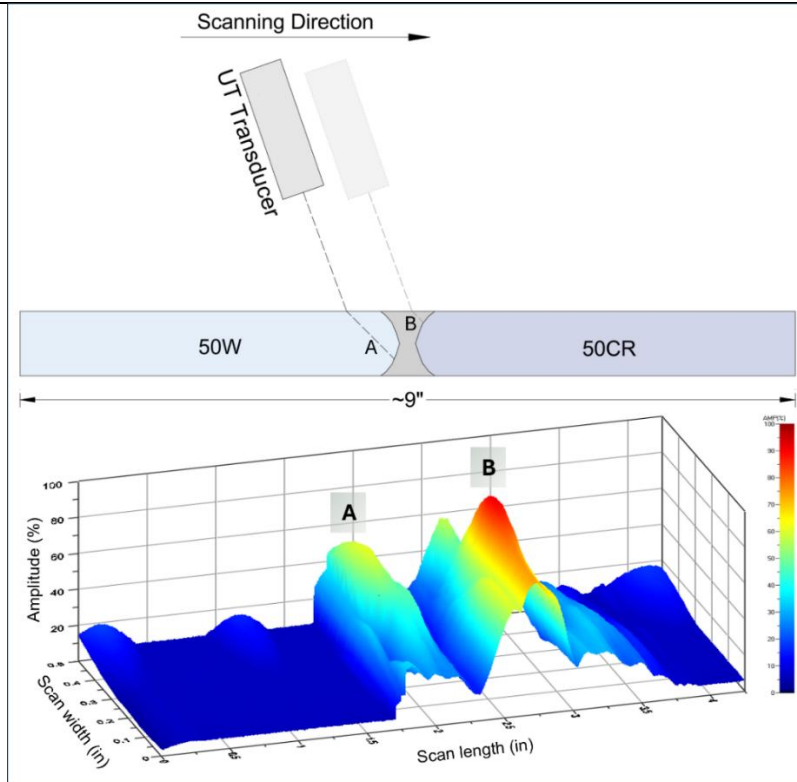
Task 2A – Welded Dual Grade Connections

All dissimilar metal welded plates have been welded by the fabricator and received by VTRC. Specimen G8 failed two rounds of RT by the fabricator and was thus accepted as-is. The specimen had a crack-like indication along its entire length.

Mechanical, corrosion, and NDE specimens have been cut out of all the welded plates recently received from the fabricator (G6 through G14). The CVN and all-weld-metal tension specimens have been prepared to be shipped to an external machining and testing facility. Results are expected to be received within 2 months. The other samples have been prepared to be shipped to either Utah State University or University of Missouri for testing. Shipment is going through the procurement process and is expected to occur by mid October. Since Specimen G8 could not pass RT, it will be shipped directly to University of Missouri for further NDE analysis.

Utah State University has purchased a Digital Image Correlation (DIC) system to perform the reduced section tension tests and is awaiting the equipment arrival to perform those tests. They have machined the macroetch coupons and are preparing to polish and etch them. Utilities are being hooked up for our accelerated corrosion equipment, and they hope to have that equipment operational soon.

University of Missouri has performed UT on the machined dissimilar metal weld specimens (G1–G5) to examine wave propagation behavior and assess how the weld interface affects signal amplitudes at different testing frequencies. These tests were conducted prior to drilling the side-drilled holes (SDH) to characterize background reflections from the weld region that may influence defect detection. The objective was to understand how these background signals may affect defect detection once the SDHs are introduced. A scan length of 4.25 in. was selected along the 9 in. specimen to cover the entire weld region, with a 0.5 in. scanning width. A representative 3D C-scan result obtained using a 1.25 MHz angled transducer (producing 45° shear waves) showed two distinct reflections from the weld fusion boundaries between the 50W and 50CR materials. The intensity of these reflections varied among specimens and across the scan width due to the irregular weld geometry.



Task is 35% completed.

Task 2B – Bolted Dual Grade Connections

VTRC has completed all the torqued tensioning tests of the stainless steel bolting assemblies according to the test procedure in the upcoming AISC/RCSC Stainless Steel Bolting Design Guide (of which PI Provines was an author). Pretension values and nut rotation values have been developed and will be used to tighten the bolts on the corrosion test specimens conducted by Utah State University.

Task is 40% 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

The VTRC research project on dissimilar metal welds made between 50CR and other bridge steels is nearly complete. A draft final report has been prepared and has been circulated to the VDOT technical review panel. Some comments have been received and have been incorporated into the final version of the report.

The weldability evaluation showed that DMWs made between 50CR/412 steel and A36/50W steel are susceptible to solidification cracking and cold cracking. Both types of cracking can be eliminated using lower heat input and a single-V with backgouge weld joint. Crack-free DMWs were found to meet the mechanical property requirements of the AASHTO/AWS D1.5 Bridge Welding Code.

DMWs experienced uniform, pitting, galvanic, and intergranular corrosion. Galvanic corrosion was present in the heat affected zones (HAZs) on both sides of the stainless steel weld interface. The A36/50W steel HAZs experienced accelerated uniform corrosion as compared to A36/50W steel base metal. The 50CR steel experienced accelerated pitting and intergranular corrosion as compared to 50CR steel base metal.

The nondestructive evaluation results showed challenges with radiographic testing, ultrasonic testing (UT), and phased array ultrasonic testing (PAUT) of the DMWs. Some radiographic testing conducted at the fabricator displayed artifacts that could mask potential defects in the welds. DMWs also exhibited ultrasonic anisotropic behavior and ultrasonic wave refraction, causing typical ultrasonic and phased array ultrasonic testing procedures to mislocate or completely miss defects in DMWs.

Based on the results, the Virginia Transportation Research Council recommends that VDOT not pursue using 50CR/412 steel in dissimilar metal welds due to remaining challenges with their corrosion performance and nondestructive evaluation. The Virginia Transportation Research Council also recommends that VDOT continue to exercise caution with specifying 50CR steel due to recent poor quality and long lead times. Both recommendations allow VDOT to proactively manage risk on future projects and help to ensure structural integrity and on time and on budget project delivery.

This project will end in October 2025.

Anticipated work next quarter:

Task 1 – Literature Review

This task has been completed. No additional work planned.

Task 2 – Connection Testing & Verifying Design/Fabrication Details

Task 2A – Welded Dual Grade Connections

All samples will be shipped out to their respective testing agencies.

VTRC will complete analysis on the side bend and fillet weld break tests. Stress corrosion cracking tests will begin.

Utah State University expects to begin analysis of the macroetch samples and begin corrosion testing of the welded and bolted samples. They also hope to receive the new DIC system for mechanical testing this quarter.

University of Missouri will test specimens with SDHs to evaluate the influence of weld-related reflections on defect signal detection at different frequencies and refraction angles. They will also machine the rest of the specimens for UT testing, both with and without SDHs.

Task 2B – Bolted Dual Grade Connections

VTRC will provide stainless steel bolt tension and installation data to Utah State University for use in the corrosion testing of bolted connections.

Task 3 – Final Report & Guidelines

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

VTRC/UVA Dissimilar Metal Welding Research Project

Final revisions will be made on the VTRC dissimilar metal welding report. Then the report will be sent to an editor prior to publication.

Significant Results:

Due to the early stages of this project, no significant results have been found yet.

VTRC/UVA Dissimilar Metal Welding Research Project

- Dissimilar metal welds made between 50CR/412 steel and 50W/A36 steel can meet the mechanical property requirements of the AASTHO/AWS D1.5 Bridge Welding Code. This requires using different welding parameters than those typically used for other steel bridge welds.
- Dissimilar metal welds made with 50CR/412 steel and A36/50W steel experience a significant reduction in corrosion resistance compared to non-dissimilar 50CR steel welds and the base metals in these welds. The heat affected zones of the weld and the base metals experience multiple forms of detrimental corrosion including uniform, pitting, galvanic, and intergranular corrosion. The corrosion resistance of the heat affected zones in these dissimilar metal welds is as follows, from greatest corrosion resistance to least: 50CR steel/309L weld metal >> 50W steel/309L weld metal > A36 steel/309L weld metal.
- Significant challenges remain with the nondestructive evaluation of dissimilar metal welds made with 50CR/412 steel and A36/50W steel. Radiographic testing using parameters typically used for other bridge welds has the potential to mask potential defects in these dissimilar metal welds. Due to the ultrasonic anisotropy of dissimilar metal welds, defects in the welds can be missed or mislocated using traditional ultrasonic testing calibration processes. Further, ultrasonic wave refraction can lead to missing or mislocating defects in these welds when inspecting them using traditional ultrasonic testing or phased array ultrasonic testing.
- 412 steel is a potential alternative to 50CR steel. 412 steel has a similar chemistry to 50CR steel, which gives it a similar corrosion resistance, has similar mechanical properties to 50CR steel, and is regularly produced by a domestic steel supplier. However, it does not meet the current heat treatment requirements for Grade 50CR steel as specified in ASTM A709.

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 AWS 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 balloted and adopted.

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