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 #	**Transportation Pooled Fund Program - Report Period:**
TPF-5(493)	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	$40,170.06	60%

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.):

<u>Task 1 – Literature Review</u>

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

<u>Task 2 – Connection Testing & Verifying Design/Fabrication Details</u>

Task 2A – Welded Dual Grade Connections

At VTRC, all samples have been machined for the stress corrosion cracking specimens. The digital image correlation (DIC) stress measurement approach is currently being developed. Once complete, specimens will be stressed to their appropriate levels, and accelerated corrosion testing of stress corrosion cracking will begin. These specimens will be tested for 3 months.

Utah State has completed the macroetch testing and yielded the following results. The selected WPS welding parameters were demonstrated to be effective in achieving acceptable weld quality based on the macroetching test in accordance with AASHTO/AWS D1.5 (2025), with compliant weld profiles and discontinuity limits observed in most specimens. The fusion zone geometry and heat-affected zone (HAZ) characteristics were found to be strongly correlated with heat input. Higher heat input resulted in greater fusion depth and dilution. At the same time, the HAZ width remained relatively consistent across specimens, with slightly larger or comparable values on the stainless-steel side than on the ASTM A709 50W side. Segregation (carbon), widely observed at the macro- and micro-scale, is attributed to solidification-induced solute redistribution and is further influenced by etching-induced morphology; however, they represent a common metallurgical phenomenon and is not expected to compromise the structural integrity of the welded components.

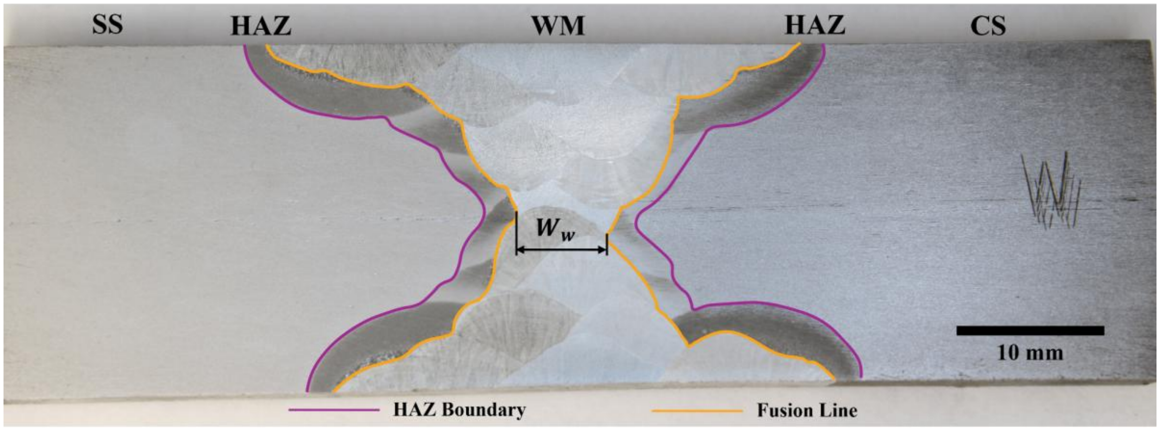
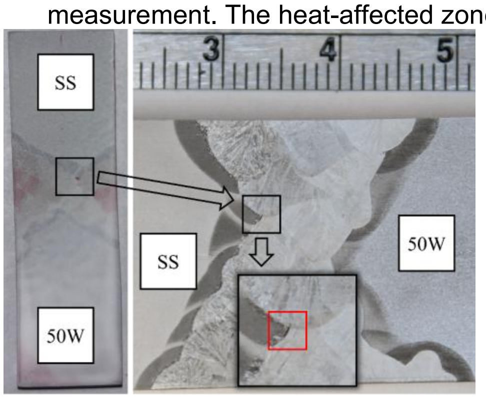
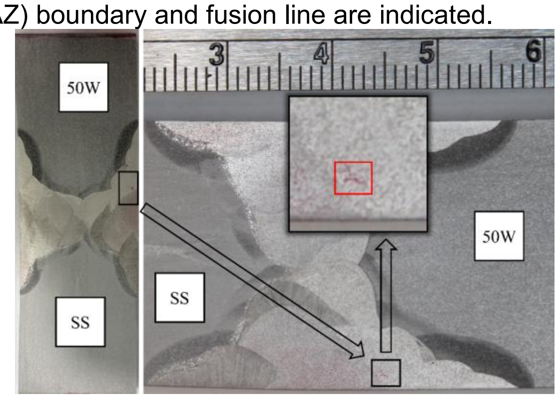


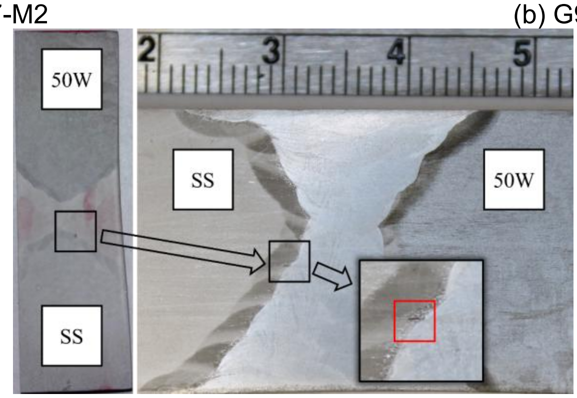
Figure 1. Representative macroetch cross-section of a dissimilar weld, showing the identification of stainless steel (SS), weld metal (WM), and carbon steel (CS), and weld neck width (W_w) measurement. The heat-affected zone (HAZ) boundary and fusion line are indicated.



(a) G7-M2

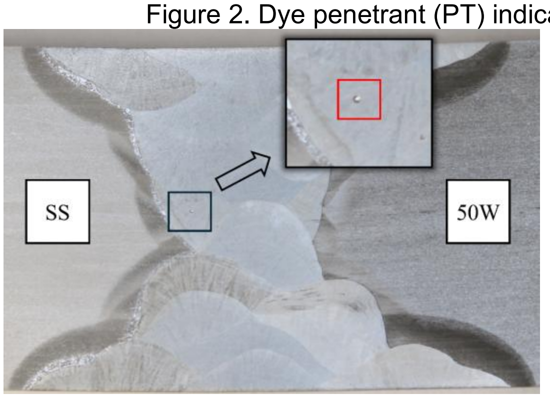


(b) G9A-M1

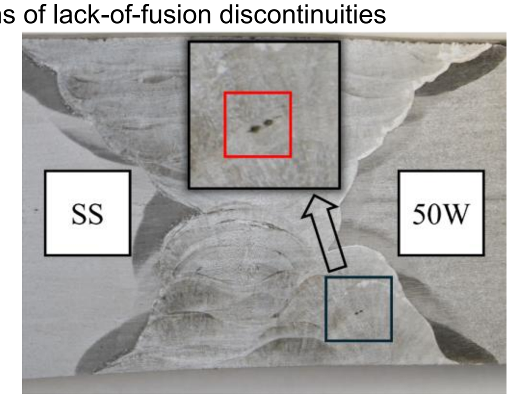


(C) G14-M2

Figure 2. Dye penetrant (PT) indications of lack-of-fusion discontinuities



(a) Porosity in G9A-M2



(b) Slag Inclusion in G4-M3

Figure 3. Representative discontinuities observed in welded plate specimens: (a) porosity in G9A-M2 and (b) slag inclusion in G4-M3

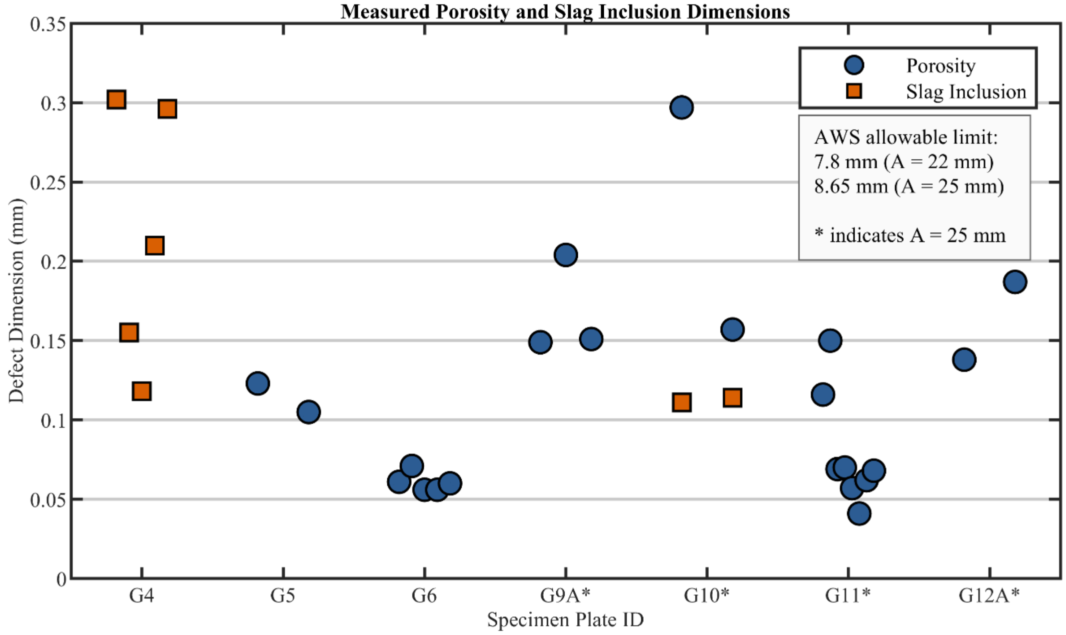


Figure 4 Measured porosity and slag inclusion dimensions

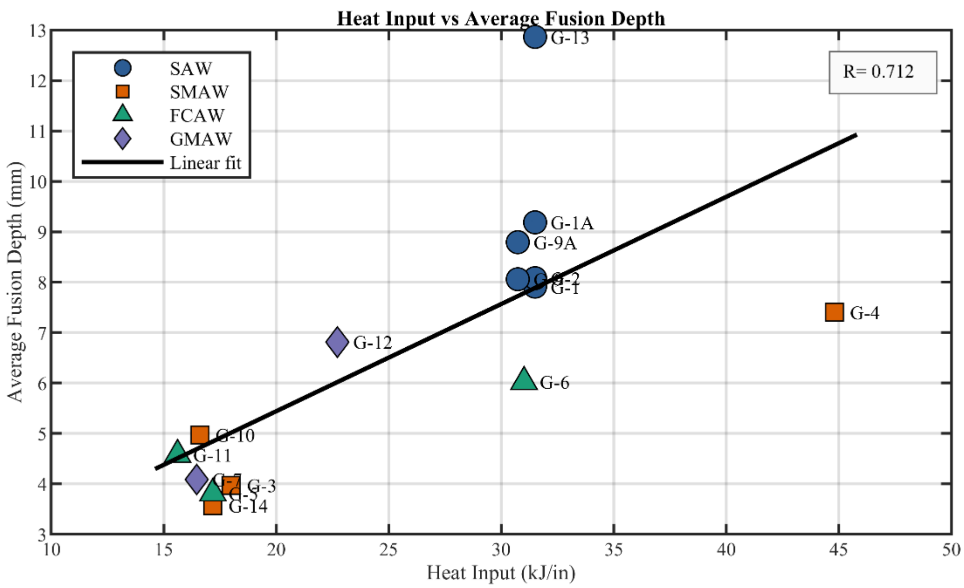


Figure 5 Heat Input VS Fusion Depth

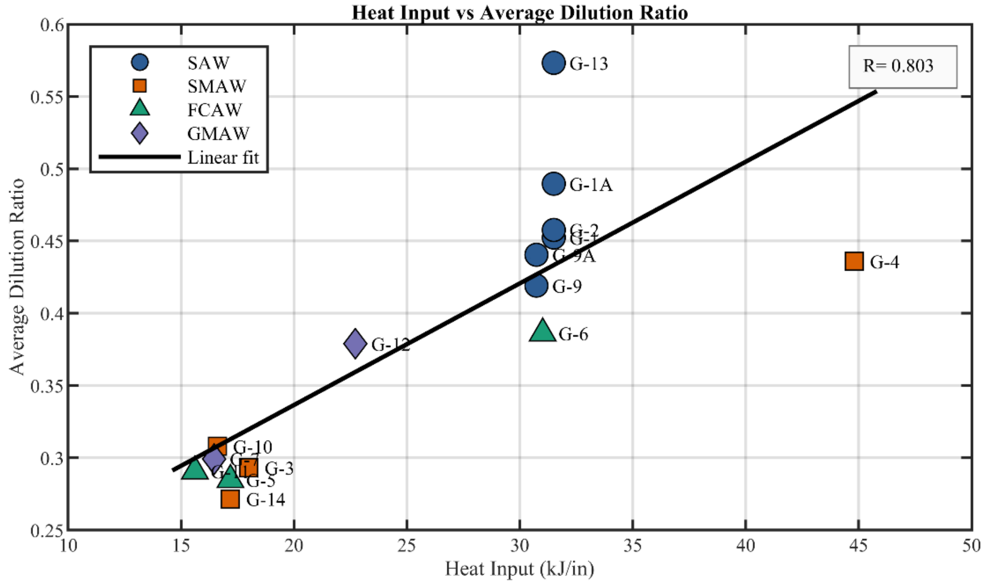


Figure 6 Heat Input VS Dilution Ratio

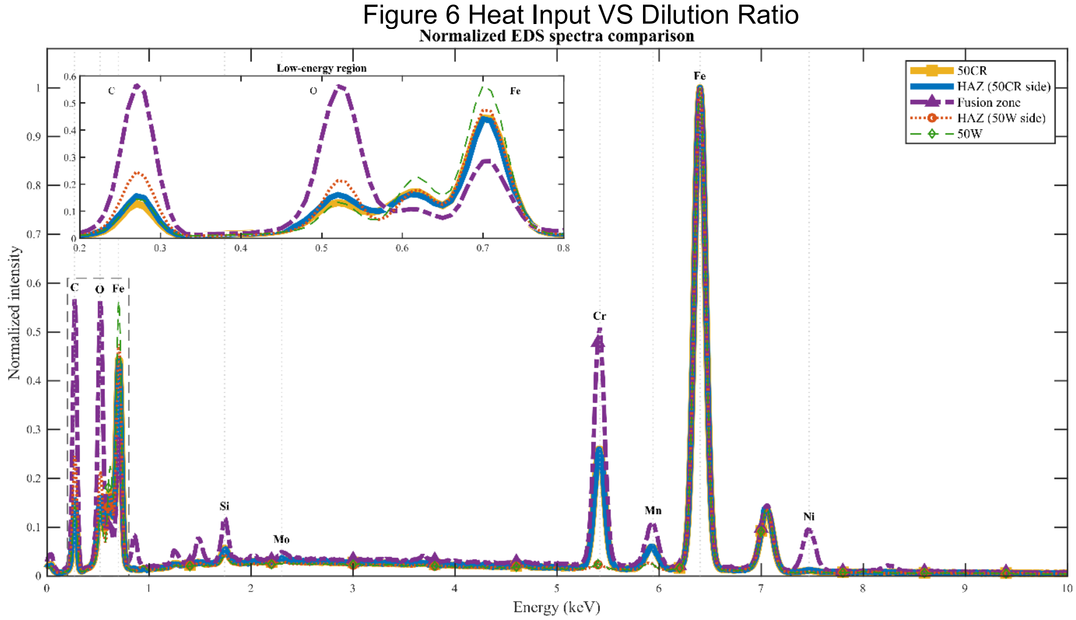


Figure 75 Normalized EDS spectra obtained from five different regions across the dissimilar weld, including 50CR base metal, heat-affected zone (HAZ) on the 50CR side, fusion zone, HAZ on the 50W side, and 50W base metal, with an enlarged view of the low-energy region.

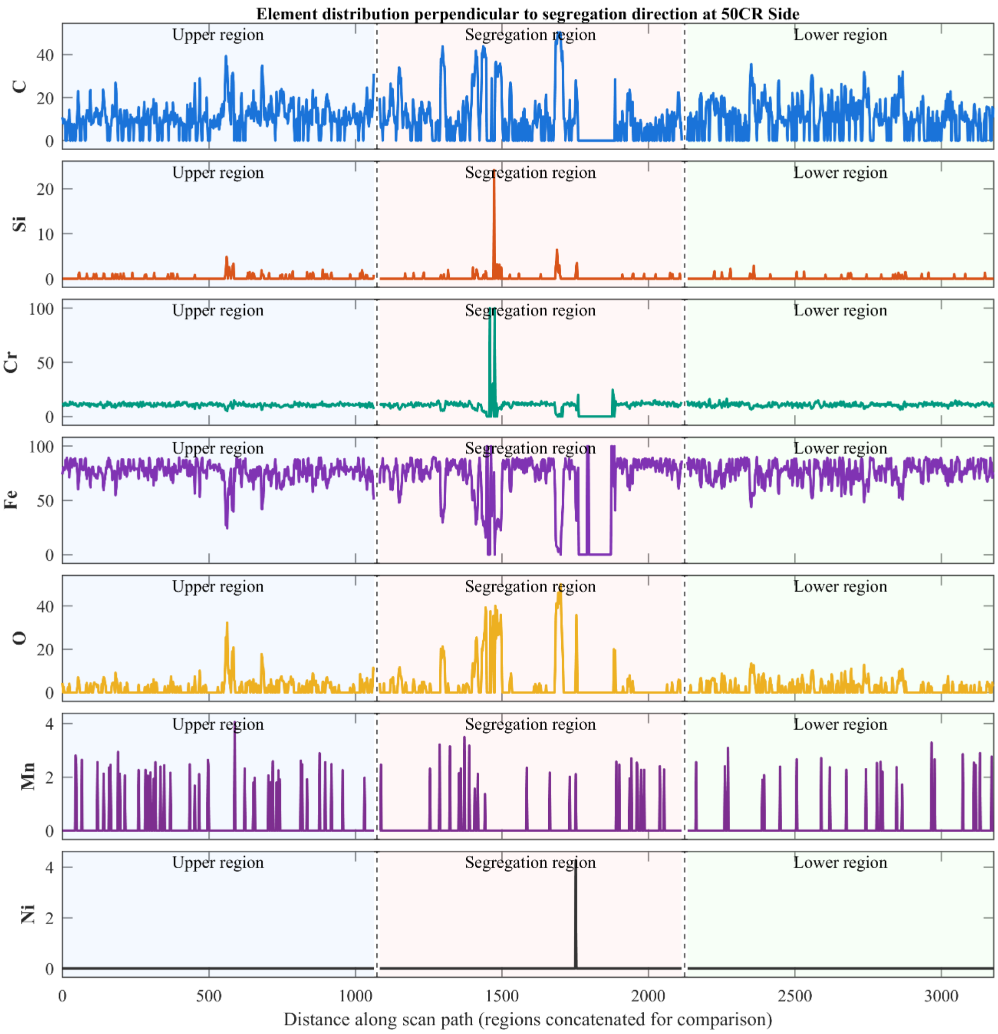


Figure 8 Element distributions from three independent EDS line scans (upper region, segregation zone, and lower region). The horizontal axis represents the relative scan position, and the three regions are concatenated for comparison only, not as a continuous spatial scale.

Other Utah State work includes the DIC system has been delivered, and training has been completed. Supporting equipment for the universal testing machine (UTM) has been procured, and setup is currently underway. Laboratory preparation for accelerated corrosion testing was completed, with the corrosion chamber installation in its final stage.

Missouri University continues to progress on the ultrasonic testing of dissimilar metal welds. UT was expanded to evaluate the influence of wave mode, refracted angle, and frequency on defect detectability. The specimens contain side-drilled holes (SDHs) located in the base metals and at each fusion boundary (i.e., weld metal–base metal interface) to simulate defects at critical regions. Scanning was performed over a 0.25 in. width and along the specimen length to capture all reflectors. Representative results obtained using a 2.25 MHz, 45° angle-beam shear wave are shown in Figure , where reflected signal amplitudes are presented as a C-scan intensity map. The results indicate clear detection of SDHs in the base metal and at the near-side fusion boundary; however, detectability of the far-side fusion boundary SDH was significantly reduced after wave propagation through the weld, primarily due to scattering and structural heterogeneity within the weld region.

Preliminary comparisons with longitudinal-wave inspections indicate improved transmission through the weld and enhanced detectability of fusion-boundary defects relative to shear waves, suggesting reduced sensitivity to weld-induced scattering effects. Ongoing work is focused on systematically evaluating longitudinal waves at multiple frequencies (1, 2.25, and 5 MHz) and refracted angles to identify optimal inspection parameters. Detection performance will be quantified by comparing signal attenuation from fusion-boundary SDHs relative to base-metal reference reflectors.

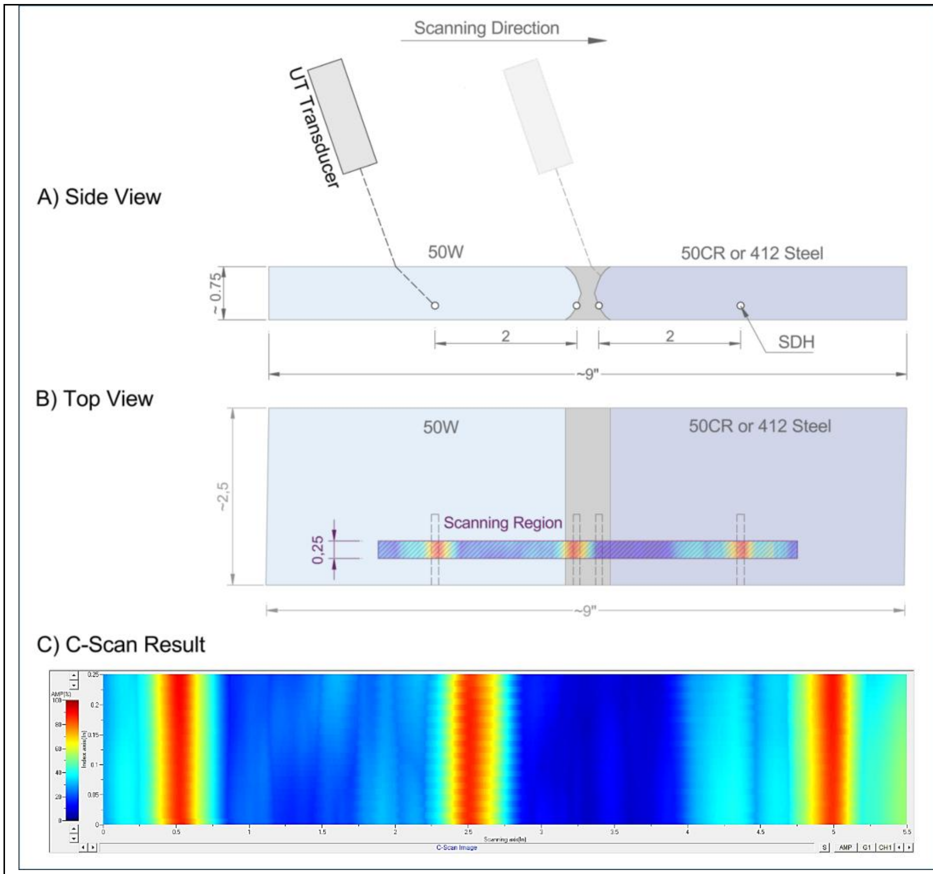


Figure 9: Ultrasonic testing scheme and sample C-scan result using 45-degree shear waves.

Task is 65% completed.

Task 2B – Bolted Dual Grade Connections

VTRC continues work on the bolted dissimilar metal connections. Plates for the dissimilar metal bolted corrosion tests have been procured and are located at VTRC. Carbon steel and stainless steel bolts have been order for these specimens. There is a delay on receiving the stainless steel bolts due to the supplier, but VTRC still anticipates receiving the bolts to finish the accelerated corrosion testing of bolted connections on time.

Task is 65% 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/UVA research project on dissimilar metal welds is complete. Findings from that study were shared in the last progress report. The final VTRC report will be shared with the TAC once it has been approved by VDOT.

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

VTRC will finalize the DIC stress measurement approach for the stress corrosion cracking tests, and testing will begin.

The Reduced Section Tensile (RST) testing program will be conducted by Utah State using the newly installed DIC system to capture full-field strain measurements. The accelerated corrosion testing program will be initiated once the corrosion chamber setup and calibration are finalized.

Missouri University will continue to work on the UT and evaluation of the dissimilar metal welds.

Task 2B – Bolted Dual Grade Connections

VTRC will continue to receive materials for these tests and will begin testing once all materials are received.

Task 3 – Final Report & Guidelines

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

VTRC/UVA Dissimilar Metal Welding Research Project

No additional work. This project has officially completed.

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.