OREGON'S SECOND ASTM A1010 BRIDGE

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BIOGRAPHY

Hormoz Seradj is a Steel Bridge Standards Engineer with the Bridge Engineering Section of the Oregon Department of Transportation. He has twenty years with the Bridge Engineering Section and more than eleven years overseas experience in structural design and construction. He has a MS in civil engineering from the University of Oklahoma in Norman, Oklahoma and BS in civil engineering from the University of Science and Technology in Tehran, Iran. Hormoz holds professional engineering licenses in Oregon and Oklahoma. He designed the first high performance steel tub girder bridge in the United States. Hormoz is a member of two AASHTO's Technical Sub-committees for Structural Steel Design (T-14) and Bearings and Expansion Devices (T-2) of the AASHTO Subcommittee on Bridges and Structures. He also is a panel member of many NCHRP projects.

SUMMARY

The composition of ASTM A1010 Steel includes over 10.5 percent chromium, which gives superior corrosion resistant to corrosion than weathering and Grade HPS 70W or 100W. Grade 50 of A1010 has superior toughness compared to grade HPS 50W. The Oregon Department of Transportation became interested in ASTM A1010 for possible use in the construction of steel girder bridges. Furthermore, the State of Washington expressed an interest using this steel when constructing bridges that are known to have a high risk for corrosion.

The Oregon Department of Transportation considered a broader use for ASTM A1010 (Duracorr) as they are interested to utilizing in bridges spanning more the 100 feet.

This paper explains how the State of Oregon successfully utilized ASTM A1010 as a structural steel in steel bridge construction. Now there are two ASTM A1010 steel bridges in the State of Oregon in service.

OREGON'S ASTM A1010 BRIDGES

Corrosion of steel bridges is an ongoing problem that requires significant expenses for upkeep and replacement. This problem is more pronounced in areas with coastal weather conditions such as in the State of Oregon.

This paper explains how the State of Oregon, fabricators and a steel mill worked together to make a success story in utilizing ASTM A1010 as a structural steel in steel bridge construction. Now there are two ASTM A1010 steel bridges in service in the State of Oregon.

Key words: girder, steel, corrosion, life-cycle cost, coastal, A1010

Background

For some number of years the Oregon Department of Transportation did not take much advantage of the strength, ductility and efficiency of steel in new or replacement bridges because of the perceived high life-cycle cost of existing steel structures. Recently, in many cases construction of longer span steel bridges reduces cost while being environmentally friendly which motivates engineers considering steel girders option. Weathering steel performs well in those parts of Oregon that do not have persistent fog and where conditions meet the Federal Highway Administration recommendation (4) that weathering steel be used with caution for low water crossing with ten feet or less over stagnant sheltered water and eight feet or less over moving water. The question was: if not weathering steel, what type of steel could reduce the life cycle cost of steel bridges in the coastal portion of the State of Oregon?

High performance steel (HPS) is an important development for bridge construction because it increases toughness of the steel, has excellent weldability, and HPS has a slightly higher corrosion index compared to conventional weathering steel. However HPS is also vulnerable to persistent fog, high humidity environment, and high-chloride-containing coastal climate. Because A1010 steel contains more than 10.5 percent chromium, this steel is much more resistant to corrosion than weathering and HPS grades (2, 3). The Oregon Department of Transportation became interested in ASTM A1010 for use in steel girder bridges even though there were previously no plate girder bridges made with this steel. So before moving ahead with a bridge project using A1010, the Oregon Department of Transportation required an independent assessment of A1010's resistivity to corrosion, weldability and machinability (2). The State of Washington expressed an interest in using this steel when constructing bridges that are known to have a high rate of corrosion so Washington agreed to share a portion of the weldability study.

Until 2013, ASTM limited the maximum plate thickness of A1010 steel to one inch (the 2013 revision of ASTM A1010 increased this to two inches). Conventional steel plate and tub girders require plate thickness more than one inch. So the question was, is it possible to have A1010 steel plate thicker than one inch that meets all A709 steel properties for bridge design and fabrication?

Weldability Study

A literature review revealed that there was no welding procedure for the material except the recommendations of ArcelorMittal, the steel producer of Duracorr®, the trade name they use for ASTM A1010. ArcelorMittal had investigated the weldability and the welding procedures for one-inch thick plate of A1010 steel. One recommendation was to limit the interpass temperature within 210-225 degrees Fahrenheit. This restrictive recommendation might work for a very small project but Oregon's fabricators were concerned about the fabrication cost since the low interpass temperature was big hurdle to production.

Many different interpass temperatures ranging from 225 °F to the maximum production interpass temperature of 450°F were investigated. The heat input for the submerged arc welding process was set at 55kJ/inch. Average Charpy V-notch impact results from the heat affected zones for test samples with different interpass temperatures from 225 °F to 450 °F exceeded the minimum AASHTO LRFD Bridge Design Specification requirements for base materials. Side bend tests were performed according to AWS D1.5 requirements and no cracks were observed. Macro and Micro metallurgical samples indicated good fusion and grain structures. It was concluded that the interpass temperature could be increased to levels consistent with high production rates (3).

Accelerated Corrosion Test

The Research Section of the Oregon Department of Transportation conducted accelerated corrosion tests simulating non-aggressive conditions to coastal service conditions. Check samples for study were 1”x1.5”x2.5” plates from A1010, A588 and A709 HPS70W. The other steels were selected to have a basis of comparison for these different bridge steels (3).

Test samples were exposed to three different environments, fresh water plus drying, fresh water and salt water plus drying, and an aggressive condition of salt water and high humidity. All A1010 samples performed very well and showed superior performance compared to A588 and HPS70W samples in all environments (3).

Machinability of ASTM A1010

A Cincinnati Bickford drill machine was used to drill holes in 1-inch thick ASTM A1010 and A572 Grade 50 steel. The fabricator drilled three holes with the same feed and speed on each sample plate and reported no abnormal wear on the drill bit or on the quality of the holes.

A Do-All commercial band saw was used to cut samples of 1-inch thick ASTM A1010 and ASTM A572 Grade 50 steel. The fabricator reported ASTM A1010 is tougher than A572 Grade 50, but without any abnormal wear of the saw blade.

Dodge Creek Bridge

The encouraging test results convinced the Oregon Department Transportation to go ahead with a trial project including design and fabrication of the first public A1010 steel plate girder bridge. FHWA supported Oregon Department of Transportation’s proposal by awarding an IBRD grant to cover the extra cost for design and fabrication of the high corrosion resistant steel plate girders. The Dodge Creek Bridge is the world’s first steel girder bridge utilizing ASTM A1010 steel. Web plate thicknesses were ½” and 5/8”, top flange plate thickness 1”, and bottom flange plate thicknesses of 1”, 1½” and 1¾”. The superstructure consists of four girder lines spaced at 12’-0”, as shown in Figure 1.

Figure 1 - Grade 50W K-frame connected to ASTM A1010 connection plate with type 3 bolts.

Design Parameters

The replacement bridge with the new structure on a new roadway alignment is located on Highway 138 at MP 21.15. The bridge is located within a 4 degree horizontal curve with 400 ft. of approach and departure spirals and a 5% super elevation rate as shown in Figure 2.

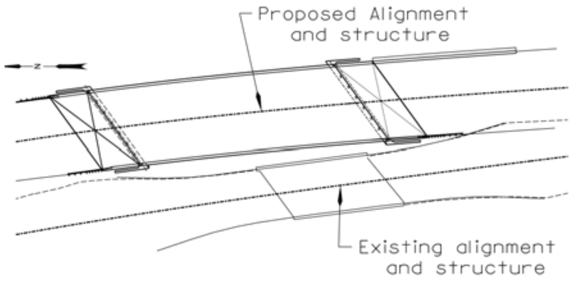

Figure 2 - Existing alignment and proposed new alignment.

The bridge falls within the 600 ft. sag curve of the vertical alignment on an increasing grade to the West. The Dodge Creek Bridge was designed in accordance with the 2007 edition of the AASHTO LRFD Bridge Design Specifications (including 2007 thru 2008 interim revisions) and the Oregon Bridge Design and Drafting Manual with an allowance for 25 psf for future wearing surface and HL-93 design truck or tandems and design lane load. Also the bridge was designed for strength II limit state for ODOT Type STP-5BW and ODOT Type STP-4E permit trucks. See Figure 3.

The structural steel was required to conform to the mechanical property requirements of HPS50W including 50 ksi minimum yield strength, 70 ksi minimum tensile strength, 18 % minimum tensile elongation. Charpy V-notch impact test minimum absorbed energy requirement was set at the value for HPS50W fracture critical members: 30 ft-lbs at +10 °F. The modulus of elasticity and the thermal coefficient of expansion were assumed to be 29000 ksi and 6.5×10^{-6} in./in./°F, respectively.

This was a new territory for the steel mill since ASTM limits the A1010 plate thickness to one inch and the mill was producing thin A1010 plates for industrial use. ArcelorMittal was the only producer that agreed to support the project needs.

Because A1010 was a new material, the Contract Fabrication Specifications established by the Oregon Department of Transportation required extra testing to ensure the material met the requirements of ASTM A709 Grade HPS50W properties. The extra testing requirements were not limited to heat affected zones and were as follows, see Figure 4:

- Check samples from both ends of each plate are required and each check sample shall meet the following:
  - Charpy V-notch fracture toughness for zone 2 of base material and heat affected zone.
  - Yield and tensile strength of A709 Grade HPS 50W.
  - Young's Modulus of 2900 ksi.
  - The Oregon Department of Transportation's weldability study was limited to 1-inch-thick plate but the Project Special Provisions required weld procedure prequalification of full penetration weld for ½" and 1¾" plate thicknesses. This requirement covers a broad base for examination of the base weld procedure prequalification of full penetration weld for ½" and 1¾" plate thicknesses. This requirement covers a broad base for examination of the base metal for full penetration weld procedure and quality.

Fabrication

All check samples of thin plates met the contract specification requirements but a few check samples of 1½" and 1¾" thick plates did not meet the specification requirements, see Figure 5.

ASTM A1010 steel is a stainless steel with minimum of 10.5 percent of chromium and therefore it has to be plasma cut rather than oxyfuel cut. There were a limited number of fabrication shops in Oregon with fully equipped plasma cutting plasma cutters with water tables. The water table absorbs the smoke generated from plasma cutting and reduces any health concerns.

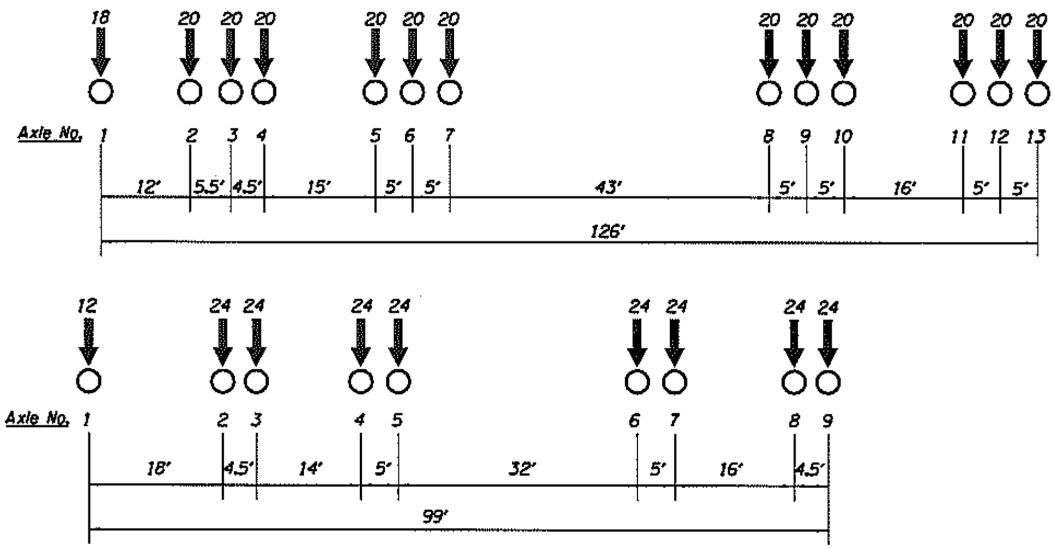

Figure 3 - Oregon's Single Trip Permit Trucks, top 13 axle vehicle with gross weight of 258 kips STP-5BW and lower STP-4E a nine axle with a gross weight 204 kips.

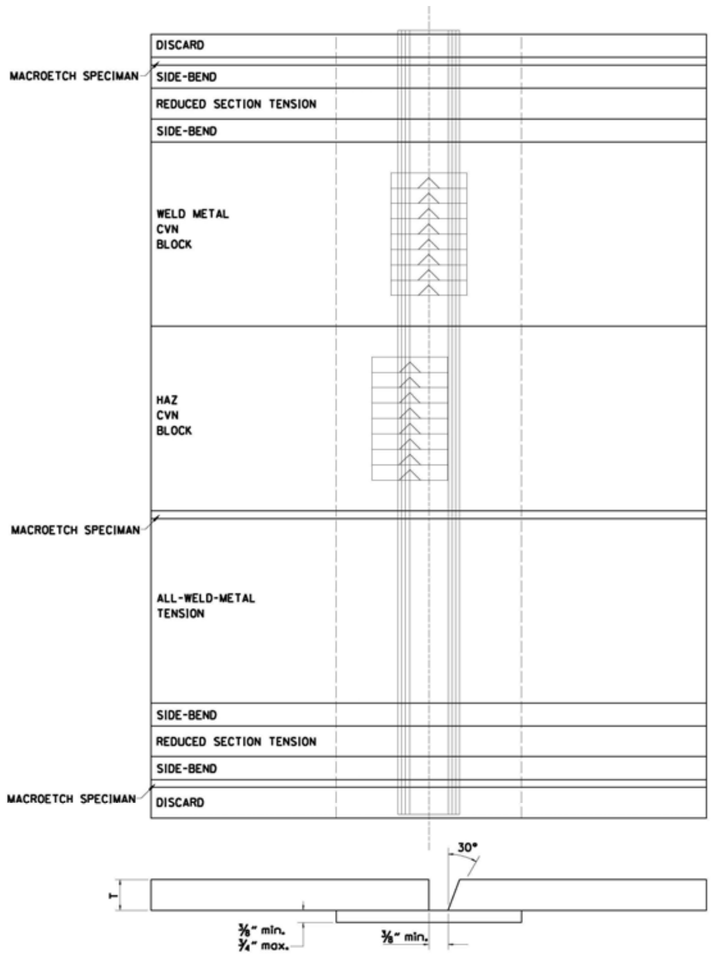

Figure 4 - Check sample and related test requirements meeting contract requirements.

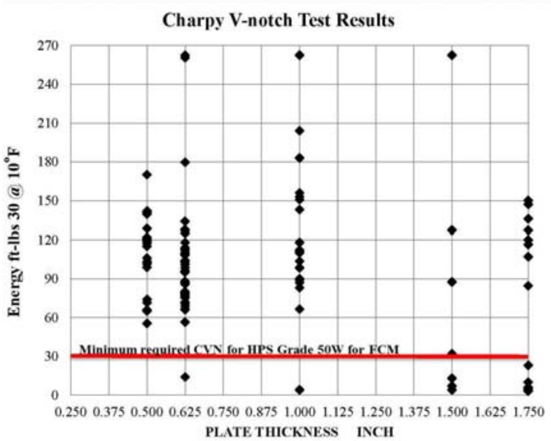

Figure 5 - Charpy CVN of first set of delivered plates to fabrication shop

The Fabricator subcontracted 1½“ and 1¾“ thick plates to two different steel shops with plasma cutting capability to strip bottom flange plates. The Fabricator observed cracks in stripped plates from one of the 1¾-inch thick rolled plates. The Oregon Department of Transportation, the fabricator and the steel mill’s representative met to discuss the material properties of the steel plates and find a resolution to the unexpected failing test results and cracking on some plasma cut edges. The Oregon Department of Transportation decided to add a metallurgist to the team to study the cause of observed cracks in one of the rolled 1¾ inch thick plates.

The metallurgist reported the followings:

- No defects in material or processing other than the plasma edge cracks were revealed by the analysis.
- The generally high impact toughness values suggest that cracking was not the result of metallurgical embrittlement.
- The Charpy V-notch tests suggest that impact loading and temperatures as low as 10°F are not sufficient to promote brittle overload.
- The absence of defects or metallurgical embrittlement and the high toughness suggest that fracture occurred during a transient or abnormal condition that promoted cracking on the plasma cut edge.
- One transient condition may be the cold leveling process employed at the mill.
- Cracking during cold leveling is consistent with several of the observations noted above, including the absence of elevated temperature oxides on the fracture surface, deformation of the fracture surface, and the presence of plasma cutting spatter on the fracture surface.

It was decided to replace all bottom flange plates with new rolled plate using an improved process developed and tested by the Mill. The steel mill determined contributing factors that could lead to cracking 1¾- inch-thick plate on plasma cut edges. The mill rolled new A1010 plates and reported very good test results from the new processing limitations. All replacement plates were successfully stripped by plasma cutting with no edge cracking. The Oregon Department of Transpiration conducted independent tests on check samples of replaced plates. Test results from check samples all exceeded specification requirements, see Figure 6.

The fabricator's weld procedure was similar to the weldability study performed by the Oregon Department of Transportation and met The Specification requirements. The Dodge Creek bridge was placed in service in 2012.

Mill Creek Bridge

The Mill Creek Bridge is the second Oregon’s steel plate girder bridge utilizing ASTM A 1010. The Bridge is located approximately 5 miles east of Astoria on Lower Columbia River Highway (US 30), at MP 94.57. It is in a tidal area of the Pacific Coast, and has to resist very aggressive and corrosive environment because the highway is a designated freight route, see Figure 7. The bridge span length is 120-feet with tall integral abutments. The Mill Creek Bridge was designed in accordance with the 2010 edition of the AASHTO LRFD Bridge Design Specifications (including 2010 interim revisions) with an allowance for 25 psf for future wearing surface and HL-93 design truck or tandems and design lane load. Also the bridge was designed for strength II limit state for ODOT Type STP-5BW and ODOT Type STP-4E permit trucks.

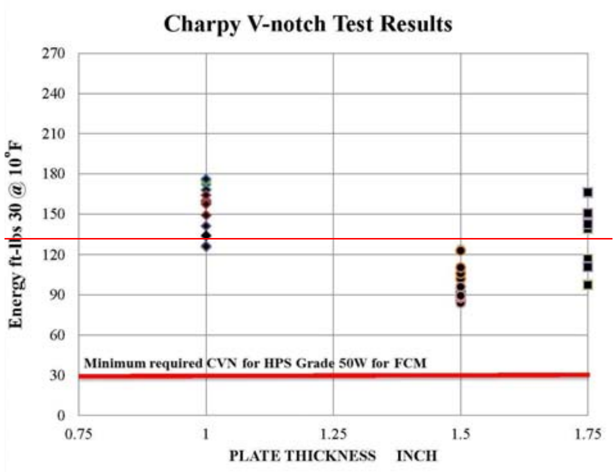

Figure 6 - Charpy CVN of replacement plates.

As in the case of the Dodge Creek bridge, the Contract Fabrication Specifications established by the Oregon Department of Transportation for the Mill Creek Bridge required extra testing requirements to ensure the A1010 material met the requirements of ASTM A709 Grade HPS 50W properties. The extra testing requirements were as described above. All the mill certified properties were confirmed.

The contract specification required the fabricator of the Mill Creek bridge to develop a weld prequalification procedure. The fabricator provided test results similar to Figure 5.1 of AWS D1.5 with an extra requirement test from the weld heat affected zone.

Unlike the case of the Dodge Creek bridge, the fabricator of the Mill Creek Bridge had the capability to plasma cut the A1010 plates into the web and flange pieces. All plasma cut edges from this fabricator were crack-free and satisfactory quality. The girders were all fabricated by welding in accordance with the PQR they established.

The fabricator of Oregon's second A1010 Bridge, the Mill Creek Bridge, did not have any issues with the steel plates and weld procedure. All Charpy V-notch test results exceeded minimum project specifications requirements, as shown in Figure 8. Fabrication of the second A1010 bridge was completed as scheduled.

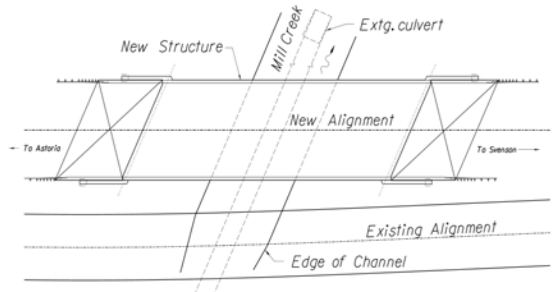

Figure 7 - Existing alignment and new alignment of US 30 at Mill Creek Bridge location (MP 94.57).

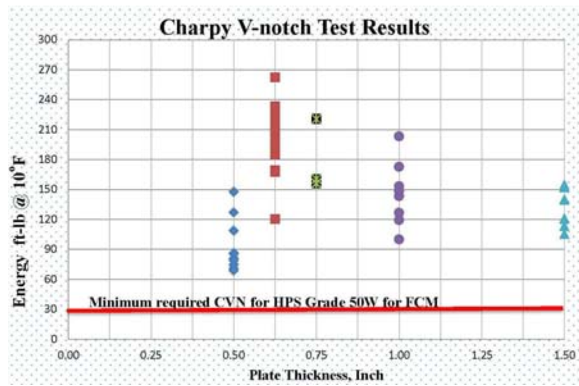

Figure 8 - Charpy V-Notch absorbed energy results on ASTM A1010 plates used for the Mill Creek Bridge.

Conclusion

The willingness of fabricator and the steel mill to work together as a team, and having the Oregon Department of Transportation leadership in completing the world's first high corrosion resistant steel plate girder bridge, paid off. The Dodge Creek Bridge is in service, see Figure 9. The Oregon Department of Transportation did not make any compromises in relaxing the fabrication specification requirements and held the steel mill and fabricator to the contract document.

Figure 9 - Dodge Creek Bridge in service.

The Oregon Department of Transportation constructed a second ASTM A1010 steel bridge in a tidal area. This Mill Creek Bridge is located in a very aggressive corrosive environment. The expectation is the bridge will remain maintenance free for the design life of the structure. This expectation is supported by FHWA Publication "FHWA-HRT-11-061, July 2011" ASTM A1010 will last in coastal environment up to 125 years without requiring corrosion protection. The Mill Creek Bridge, Figure 10, is the first of Oregon's unpainted steel girder bridges in a coastal environment.

Figure 10 - Mill Creek Bridge construction in a tidal area of the Pacific Ocean.

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