FABRICATION WITH
HIGH PERFORMANCE STEEL GRADE HPS70W

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Abstract

High Performance Steel Grade HPS70W has entered the bridge industry like a whirlwind. The first HPS70W bridge was placed in service in December 1997, only three years after the onset of a research effort sponsored by the Federal Highway Administration, the American Iron and Steel Institute, and the US Navy. The effort included participation of all disciplines in the bridge industry, including academia, industry, and government. Today, at least 17 bridges are in service nationally, at least 9 more are in fabrication or construction, 23 are being designed using HPS70W steel, and another 15 HPS70W structures are in the pre-design stage. This paper provides a brief description of experiences gained during both the development stages and ongoing fabrication of bridge girders using high performance steel.

Introduction

High Performance Steel Grade HPS70W is a quenched and tempered plate product available in thicknesses to 4 inches for use in bridges, conforming to ASTM A709/A709M-00, Grade HPS70W specification requirements. It is also a Thermo-Mechanical-Controlled-Processed (TMCP) product (Non-Q&T) which has been developed by manufacturers and is available in thicknesses to 2 inches for use in bridges. HPS70W (TMCP) is currently being balloted by ASTM for inclusion in the A709/A709M specification.

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The typical properties of both the A709 Grade HPS70W Q&T product and the HPS70W TMCP product, when compared to the former A709 Grade 70W steel, have been significantly enhanced, including:

a) More controlled ranges of elements, including lower carbon, sulfur and phosphorus to improve weldability, fracture toughness, and crack resistance.
b) CVN toughness properties that exceed Zone 3 FCM requirements for all zones and all thicknesses.
c) The minimum requirement for atmospheric corrosion resistance (CI), as measured in accordance with ASTM G101, is increased from 6.0 for Grade 70W steel to 6.5 for Grade HPS70W steel.

Learning to Use HPS70W

Like all new products, owners, contractors and fabricators should expect a learning curve when fabricating with HPS70W steel. This includes cleaning, drilling and cutting, welding, handling, and repairs to the steel. AASHTO has recently published the *Guide Specification for Highway Bridge Fabrication with HPS70W Steel,* an Addendum to the ANSI/AASHTO/AWS D1.5 Bridge Welding Code, which was developed by the HPS Steering Committee, including the HPS Welding Advisory Group and the HPS Design Advisory Group, under sponsorship of the Federal Highway Administration, the U.S. Navy, Carderock Division, Naval Surface Warfare Center, and the American Iron and Steel Institute. This document reports the results of the joint research effort between government, industry, academia and owners during the development and initial use of HPS70W steel, and provides recommendations for fabrication, welding and handling of HPS70W steel.

Although entitled a *Guide Specification* and an *Addendum* to AWS D1.5, owners who choose to use all or part of this document must specifically include the *Guide* as part of their contract documents, since it is not included as an automatic part of AWS D1.5 specifications.

Fabrication Experiences

As-Delivered Base Metal

Owners and fabricators must be aware that the length of HPS70W Quenched and Tempered (Q&T) steel plates are limited to 50 feet maximum as a result of the heat-treating process, regardless of the manufacturer. Use of the Q&T material may result in the introduction of additional weld splices in girder webs and flanges. Currently, HPS70W Thermo-Mechanical-Controlled-Processing (TMCP) plates are available in thicknesses to 2 inches, with widths and lengths similar to that of Grade 50W steel plates. HPS70W TMCP is not currently included in ASTM A709-00 specifications. However, it is being balloted by ASTM for inclusion in the next issue of A709. Until then, it is recommended that owners specifically allow TMCP as a direct substitute for Q&T in their contract documents.

In general, HPS70W steel has been delivered from the manufacturer to the fabricator in approximately six to eight weeks after placement of the order. The plates have generally been free of unacceptable base metal discontinuities when compared to the provisions of ASTM A6 *Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes and Sheet Piling*.

Drilling and Cutting

Fabricators have reported varied experiences when drilling HPS70W Q&T steel. These experiences have ranged from "no different than Grade 50W steel", to "drills and reamers dull quickly." If problems are experienced when drilling or reaming Q&T steels, the HPS Steering Committee recommends that drilled or reamed holes be flooded with lubricant during the work to achieve what is considered normal drilling or reaming operations.

Fabricators report no difference in flame cutting procedures when compared to other steels, such as Grades 36, 50 or 50W.

Mill Scale Removal

Mill scale removal from HPS70W steel by abrasive blasting basically requires the same work effort as Grade 50W. However, mill scale removal by descaler or grinder has been reported to be extremely difficult for the quenched and tempered steel. There have been no reports of difficult mill scale removal for the TMCP product.

Pre-Cut Camber

Fabricators should be aware that prediction of pre-cut camber gain or loss may require experimentation. The quenched and tempered product has reportedly not necessarily responded similar to Grade 50W steel.

Welding

Welding of HPS70W steel is currently restricted to the submerged arc and shielded metal arc welding processes for both Q&T and TMCP products. However, research is being conducted to investigate the use of the gas metal arc welding process as well, but this work is in the preliminary stages.

Submerged arc consumables should be handled such that the diffusible hydrogen is controlled to a level of H4 maximum. SMAW consumables can meet a level of either H4 or H8, except that preheat and interpass temperature requirements of AWS D1.5, Bridge Welding Code, must be applied to H8 conditions.

The *Guide Specification for Highway Bridge Fabrication with HPS70W Steel* recommends that matching filler metals be used for all complete penetration groove welds

connecting Grade HPS70W/HPS485W plates, and further recommends the use of the consumable combination of Lincoln LA85 electrode and MIL800HPNi flux. Many fabricators have successfully used this SAW combination to consistently produce acceptable quality weld metal. Comparison tests were done as part of a HPS Steering Committee demonstration project to compare the mechanical, chemical and toughness properties of the above consumables using both Q&T and TMCP base metal. Test parameters, along with test results shown in Tables 1 and 2 respectively, suggest that both the Q&T product and the TMCP product are equally weldable with the recommended consumables.

The Contractor may request approval of alternate consumables in lieu of the above filler metals for SAW, based on successful completion of welding procedure qualification tests and diffusible hydrogen tests. The matching submerged arc welding consumables ESAB ENi4 electrode in combination with Lincoln Mil800H, recommended in Appendix A of the *Guide*, has produced weldments containing unacceptable discontinuities in a substantial number of complete penetration groove welds. In September 2000, the HPS Steering Committee rescinded its recommendation of this combination of welding consumables.

Filler metals used for all complete penetration groove welds connecting Grade HPS70W plate to ASTM A709, Grade 50W plate, filler metals used to make single pass fillet welds up to 5/16" leg size, and all complete penetration groove welds where the stress in the weld is in tension or compression parallel to the longitudinal weld axis are recommended to be in conformance with AWS D1.5, Table 4.1 for ASTM A709 Grade 50W base metal. For all these applications, shear on the effective weld area must meet design requirements. Filler metals for single pass fillet welds need not meet the requirements for exposed bare applications. For interest, Tables 1 and 2 report the test parameters and test results for a typical combination of SAW consumables that could be selected for single pass fillet welds.

Handling

During fabrication and erection of girders using HPS70W steel, reports suggested that there was no basic difference in handling procedures when compared to girders fabricated using Grade 50W steel of equal size.

Heating

The *Guide* recommends that short term applications of heat for purposes of heat curving, heat straightening, camber and sweep adjustment, or other reasons, be limited to 1100º F/590° C maximum. This recommendation is based on research work done as part of HPS Steering Committee demonstration projects, and by tests performed by steel manufactures, and applies to both the Q&T and TMCP products.

Repairs

In general, repairs to weld and base metal should conform to the requirements of AWS D1.5, Section 3.7, providing preheat and interpass temperature for repair welds does not exceed 450° F and short term applications of heat for any reason do not exceed 1100° F. In addition, magnetic particle inspection should be restricted to the yoke technique. The prod technique should not be allowed.

Cost Effective Designs

The use of hybrid girders, that is, girders using different grades of steel in the same cross section, as required to achieve design strength, appears to offer the most economical use of high performance steel. A typical example of a hybrid girder would use HPS70W flanges and Grade 50W web, with Grade 50W welded attachments, i.e., bearing stiffeners, connection plates, web stiffeners, etc. Generally, the cost of HPS base metal, whether Q&T or TMCP, is inherently more than Grade 50W as a result of the heat-treating processes. A hybrid girder provides for the additional strength and/or toughness where required or desired by design, and uses the lesser strength materials at other locations consistent with design requirements.

The use of mixed girders, that is, girders using HPS70W steel in the negative moment areas and Grade 50W steel in the positive moment areas, consistent with design requirements, also provides for a more economical girder when compared to girders fabricated entirely with HPS70W steel. Mixed girders would generally use Grade 50W welded attachments, i.e., bearing stiffeners, connection plates, web stiffeners, etc.

Since the length of quenched and tempered plates is restricted to 50 feet by the heat-treating process, designers should select plate lengths and field splice locations that will minimize the number of butt splices, consistent with design requirements. Further, the HPS Steering Committee recommends using the HPS70W TMCP product wherever thickness permits.

Further economy can be realized by limiting fillet welds to single pass, ¼" or 5/16" welds consistent with the AWS D1.5 *Bridge Welding Code,* unless horizontal shear or transverse loads require a larger size, using optimized strength consumables for fillet welds whenever possible, and using non-weathering consumables for all single pass welds.

Summary

High performance steel can provide an economical solution to fabrication of bridge structures. It's additional strength, combined with it's enhanced toughness and enhanced weathering characteristics, provide designers and owners with an option that can realize substantial savings in the overall cost of the structure. Some owners have reported a 10% savings in the cost of the fabricated steel, based on reduced weight of the steel. Other owners have found that the cost of fabricated steel has increased, mostly due the increased cost of the

heat treated base metal, but that substantial cost savings could be realized in the overall cost of the structure resulting from longer span lengths which reduce substructure needs, shallower girders that result in increased vertical clearance with little or no modification of approaches on replacement structures, and the potential for increased service life resulting from enhanced CVN toughness and corrosion resistance.

Based on the combined experience of the HPS Steering Committee as well as owners and fabricators, the single, most effective solution to successfully welding high performance steel is to **control diffusible hydrogen**!!!

As a minimum, all fabrication and welding should be done as described in the *Guide Specification for Highway Bridge Fabrication with HPS70W Steel,* an Addendum to the ANSI/AASHTO/AWS D1.5 Bridge Welding Code. Again, this document reports the results of the joint research effort between government, industry, academia and owners during the development and initial use of HPS70W steel, and provides recommendations for fabrication, welding and handling of HPS70W steel. The *Guide* will be updated by the HPS Steering Committee as research and development of high performance steel progresses and with the continued use of this product. Updates will be made available on the American Iron and Steel Institute website, http://www.steel.org. Currently at least 25 of the 48 continental United States are using, or plan to use high performance steel in their bridge structures.

Table 1 – SAW Procedure Qualification Test Parameters[2]
Comparison of Q&T and TMCP Base Metals

Welding Consumables	AWS Class.	PQR Base Metal	Base Metal Thickness	Amps	Volts	Travel Speed (IPM)	Current & Polarity	Heat Input (Kj/in)
Lincoln 3/32" LA85/Mil800HPNi	F9A4-ENi5-G-H2	HPS70W Q&T	1-1/2"	500	30	15	DCRP	60
Lincoln 3/32" LA85/Mil800HPNi	F9A4-ENi5-G-H2	HPS70W TMCP	1"	500	30	15	DCRP	60
Lincoln 3/32" L61/960 H2-EN	F7A2-EM12K-H8	HPS70W TMCP	1"	500	30	15	DCRP	64

Table 2 – SAW Procedure Qualification Test Results[3]
Comparison of Q&T and TMCP Base Metals

Welding Consumables	PQR Base Metal	Base Metal Thickness	Tensile Strength (ksi)	Yield Strength (ksi)	Elong. In 2" (%)	Reduced Section Tension (ksi)	Weld Metal CVN (ft/lbs@-25^{0}F)	RT, UT, Visual
Lincoln 3/32" LA85/Mil800HPNi	HPS70W Q&T	1-1/2"	T - 107.4 B - 106.4	T - 100.0 B- 97.9	T - 22.5 B - 22.5	100.9 BM 101.2 BM	105	OK
Lincoln 3/32" LA85/Mil800HPNi	HPS70W TMCP	1"	107.0	99.7	22	101.4 BM 99.1 BM	151	OK
Lincoln 3/32" L61/960 H2-EN	HPS70W TMCP	1"	85.0	73.5	27	88.9 WM 88.4 WM	51.5	OK
Specification Requirements		HPS70W Gr 50W	90 - 110 70 - 95	70 min 58 min	19 min 22 min		25	

2 Courtesy of Stupp Bridge, Bowling Green, KY
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