TECHNICAL REPORT

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FROM

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Bridge Code PQR Testing HPS 100W Steel using MIL800-HPNi & MIL800-H Fluxes with LA-100 Electrode

ABSTRACT

HPS 100W is a new high strength steel designed for bridge applications. HPS 70W and HPS 50W were introduced prior to HPS 100W. No special submerged arc consumables were required for HPS 50W but consumables had to be developed for HPS 70W. The purpose of this testing is to report on results using existing consumables to join HPS 100W. These results are to be used as a guide for determining their application in either matching or under matching strength applications. LA-100 with MIL800-HPNi flux was chosen to standardize on one flux (MIL800-HPNi) for hybrid bridge girder designs that include both HPS 70W and HPS 100W. The results of the testing show that LA-100/MIL800-HPNi is an excellent choice for matching applications. LA-100/MIL800-H is a good choice for under matching strength applications.

KEYWORDS

High Performance Steel, MIL800-H, LA-100, MIL800-HPNi, Copper-nickel alloy, 100 ksi yield, low hydrogen, H2

BACKGROUND

HPS 100W is a new copper nickel based low alloy steel specifically designed for bridge applications where the use of high strength steel will be a benefit. This report covers testing done to determine if two existing wire and flux combinations are capable of joining HPS 100W successfully. The combination LA-85/MIL800-HPNi was developed for matching strength applications on HPS 70W steel. Customers prefer standardizing on consumables when possible. This analysis started because a request was made by a customer to determine the feasibility of using LA-100 with MIL800-HPNi flux to join HPS 100W in matching strength applications. A previous round of testing was done to determine all weld metal properties of LA-100/MIL800-HPNi in a joint made of HPS 100W. This round of testing is intended to duplicate the prior tests with the addition of duplicate test plates to be welded with LA-100/MIL800-H for comparison purposes. All side bends and reduced section tensile specimens required by the D1.5 Bridge Code are to be part of the analysis. The comparison with LA-100/MIL800-H was requested because of the successful history associated with this combination.

EXPERIMENTAL PROCEDURES

The base metal was provided by Lehigh University. The thickness of the plate being tested is 1.0”. Four test plate assemblies were fit and tacked per the AWS D1.5 Bridge Code (See Figure 1). The four assemblies are required to perform high and low heat input tests with two different consumable combinations. The welding procedures are the same as those used to evaluate LA-85/MIL800-HPNi on HPS 70W steel (See Table 1). The HPS 70W testing was performed without preheat. The HPS 100W testing was performed with a minimum preheat of 200° F. The Interpass temperature for the low heat input test plates was maintained at 250° F. The Interpass temperature for the high heat input test plates was maintained at 450° F. The weld passes were located in the joint using a two pass per layer technique. The test plates were held in restraint during welding. They remained in restraint for five days after welding was completed.

Heat Input	Wire Feed Speed	CTWD	Current	Arc Voltage	Travel Speed
kJ/in	ipm	in.	amperes	Volts, DC+	ipm
90	87	1.25	600	30	12
40.5	63	1.25	450	24	16

Table 1: Welding Procedure.

Electrode Type	Electrode Diameter	Flux Type	AWS Classification
LA-100	1/8”	MIL800-HPNi	F11A4-EM2-G-H2
LA-100	1/8”	MIL800-H	F10A6-EM2-M2-H2

Table 2: Welding Consumables.

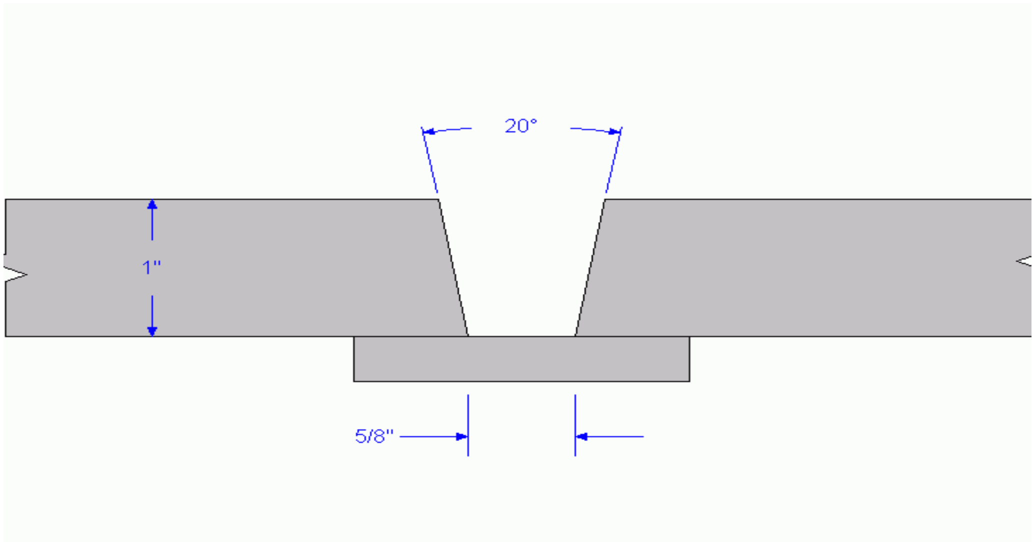

Figure 1: Bridge PQR Joint Dimensions.

RESULTS AND DISCUSSIONS

The joint in the high heat input test plate was filled using 13 passes (6 layers). The joint in the low heat input test plate required 19 passes (9 layers) to complete. The finished welds were removed from restraint and prepared for RT inspection (remove backing bar and mill off weld reinforcement). The RT inspection results all met the requirements of AWS D1.5. Four side bends were extracted from each test plate. A 2.5" dia. plunger was used to bend the samples. The side bends were done in the "as welded" condition (no aging). The side bend test results were all (16) in conformance with AWS D1.5.

	MIL800-HPNi		**MIL800-H**	
	90 kJ/in	40.5 kJ/in	90 kJ/in	40.5 kJ/in
Tensile (psi)	121,000	124,300	109,400	113,000
0.2% Offset Yield (psi)	100,200	115,100	94,300	104,000
Elongation (%)	23	22	25	24
Charpy Impacts @ - 40° F (ft-lbs)	59 53 66 67 72	93 86 82 79 85	101 102 84 63 66	94 91 60 100 102

Table 3: All Weld Metal Tensile & Charpy Results.

Flux	Heat Input	Width (in.)	Thickness (in.)	Tensile Strength (ksi)	Fracture Location
MIL800-HPNi	Low	1.0060	0.8900	121,000	Base
MIL800-HPNi	Low	1.0060	0.9050	119,000	Weld
MIL800-HPNi	High	1.0060	0.9500	117,000	Weld
MIL800-HPNi	High	1.0080	0.9470	116,000	Weld
MIL800-H	Low	1.0030	0.9570	114,000	Weld
MIL800-H	Low	1.0060	0.9570	117,000	Weld
MIL800-H	High	1.0010	0.9140	109,000	Weld
MIL800-H	High	0.9980	0.9140	109,000	Weld

Table 4: Reduced Section Tensile.

	Electrode	Base Metal	Deposit Chemistry	
	LA-100	**HPS 100W**	**MIL800-HPNi**	**MIL800-H**
Carbon	0.062	0.054	0.065	0.055
Manganese	1.52	0.97	1.73	1.52
Silicon	0.47	0.27	0.48	0.45
Chrome	0.03	0.49	0.14	0.12
Nickel	1.84	0.72	2.00	1.65
Molybdenum	0.39	0.49	0.41	0.40
Copper	0.012	0.941	0.330	0.268
Niobium	0.003	0.021	0.008	0.006
Titanium	0.034	0.002	0.011	0.012
Vanadium	0.004	0.060	0.042	0.014
Sulfur	0.007	<0.003	0.004	0.003
Phosphorus	0.006	0.008	0.009	0.008

Table 5: High Heat Input Test Chemistry.

	Electrode	Base Metal	Deposit Chemistry	
	LA-100	HPS 100W	MIL800-HPNi	MIL800-H
Carbon	0.062	0.054	0.078	0.068
Manganese	1.52	0.97	1.78	1.52
Silicon	0.47	0.27	0.49	0.45
Chrome	0.03	0.49	0.06	0.07
Nickel	1.84	0.72	2.22	1.76
Molybdenum	0.39	0.49	0.40	0.40
Copper	0.012	0.941	0.157	0.179
Niobium	0.003	0.021	0.005	0.004
Titanium	0.034	0.002	0.012	0.010
Vanadium	0.004	0.060	0.034	0.008
Sulfur	0.007	<0.003	0.004	0.004
Phosphorus	0.006	0.008	0.009	0.008

Table 6: Low Heat Input Test Chemistry.

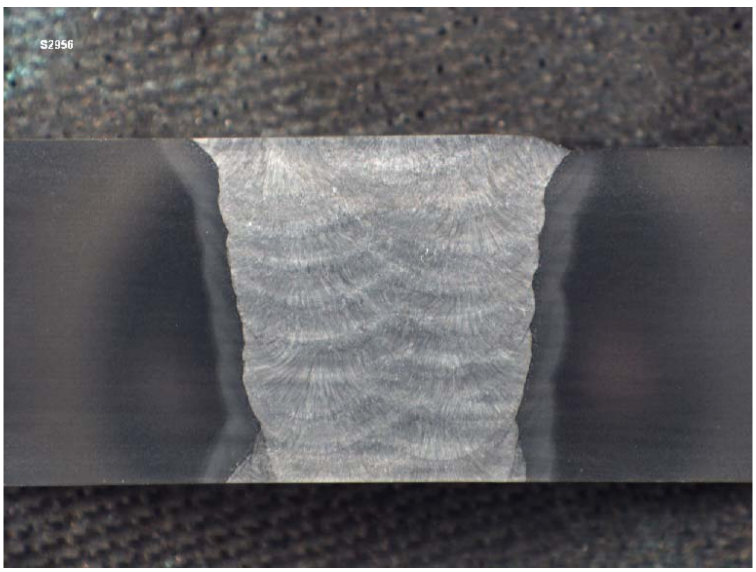

Figure 2: Low Heat Input, MIL800-HPNi.

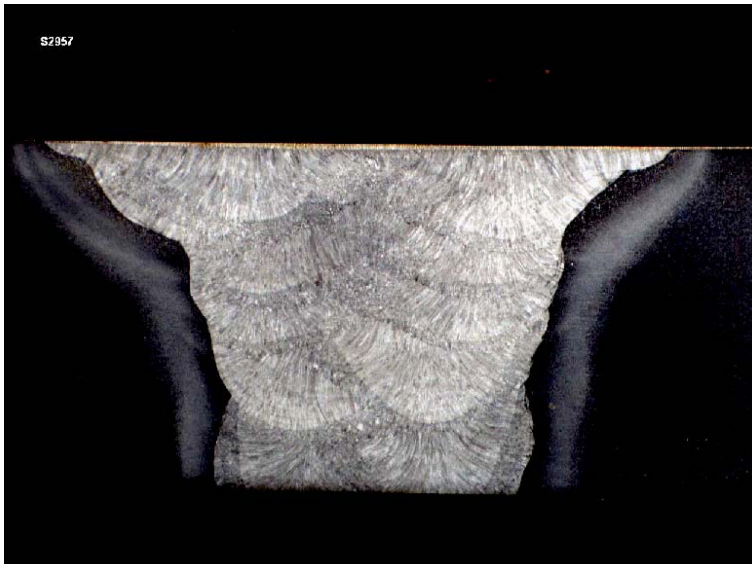

Figure 3: High Heat Input, MIL800-HPNi.

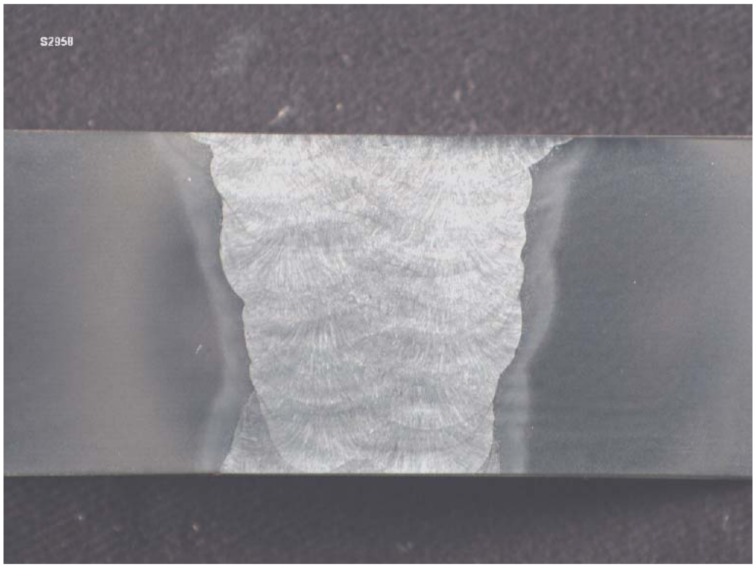

Figure 4: Low Heat Input, MIL800-H.

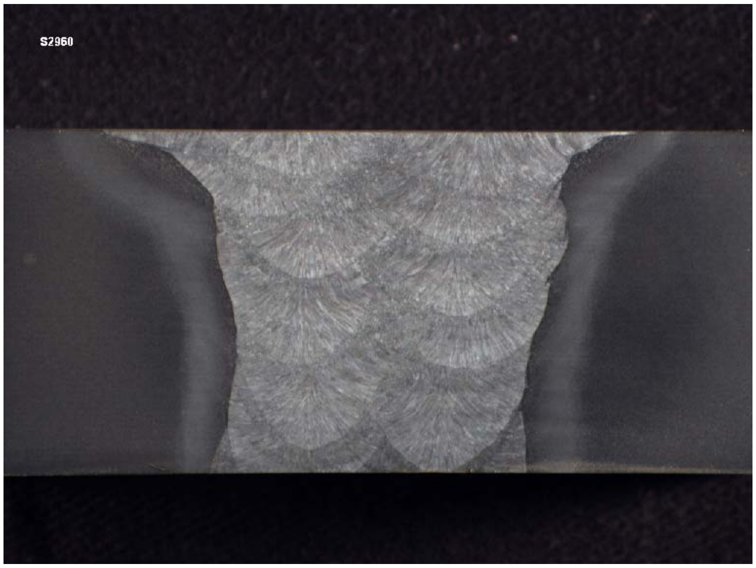

Figure 5: High Heat Input, MIL800-H.

MECHANICAL PROPERTY COMPARISON

	90 kJ/in		40.5 kJ/in	
Report Date	6/27/03	10/27/05	6/27/03	10/27/05
Tensile (psi)	122,600	121,000	125,300	124,300
0.2% Offset Yield (psi)	99,600	100,200	120,700	115,100
Elongation (%)	23	23	21	22
Charpy Impacts @ - 40° F (ft-lbs)	64 69 60 76 69	59 53 66 67 72	70 78 81 77 83	93 86 82 79 85

Table 7: LA-100/MIL800-HPNi Mechanical Property Comparison.

CONCLUSIONS

1. The combination of LA-100 electrode with MIL800-HPNi flux is a good choice for HPS 100W matching strength applications at heat inputs equal to or less than 80 kJ/in.

2. The combination of LA-100 electrode with MIL800-H flux does not develop enough strength for matching strength applications but may be used for under matching applications using HPS 100W steel.

3. There is repeatability in the LA-100/MIL800-HPNi mechanical property test results, as shown by the data in Table 7.

4. The combination of LA-85 electrode with MIL800-HPNi flux is a good choice for HPS 100W under matching applications.