Welding Advantages with High Performance Steel

By Louis N. Triandafilou, P.E. and William Wright, Ph.D., P.E.

During the early to mid-1990s, the research, development, demonstration and project implementation of high performance steel (HPS) achieved remarkable and rapid success as a viable bridge material. A cooperative research program between the Federal Highway Administration (FHWA), the U.S. Navy, and the American Iron and Steel Institute (AISI) has been guided by a steering committee of experts from Federal and State transportation agencies, the steel and welding industries and academia. This group has branched off into advisory groups that address steel, welding, design and corrosion issues.

Over 200 HPS bridges have been constructed and put into service over the past 12 years, and another 200 are in the design and planning stages. More than 40 States have been taking advantage of the properties of HPS that are superior to conventional structural steels – higher strength, improved weldability, excellent toughness, and corrosion resistance (*Figure 1*).

This article focuses on the weldability advantages of HPS, along with research undertaken and currently underway to resolve issues that have arisen during the implementation of HPS.

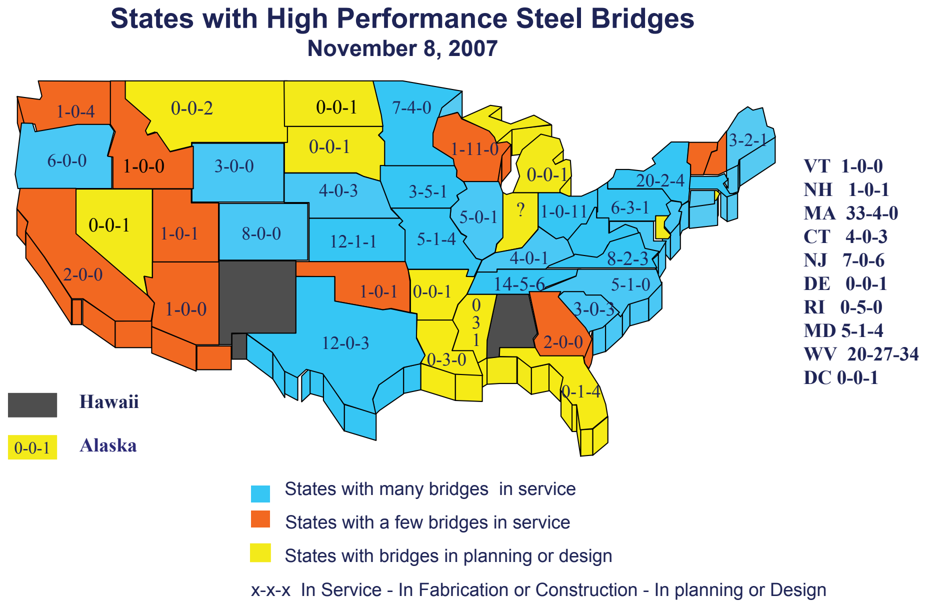

Figure 1: Roy Teal Memorial HPS Scoreboard.

Weldability Advantages

HPS was developed to maintain a high level of safety in steel bridges, along with reducing first costs and life-cycle costs. In the area of welding, costs were reduced by streamlining the initial welding process (reduced or eliminated preheating, reduced weld defects, tolerance of variations in conditions), and lowering long-term costs by allowing field weld repairs.

The benefits of the very low carbon/carbon equivalent composition of HPS are evident in the plotting of the graphs in the Graville Diagram (*Figure 2*). This diagram is a common way to assess the susceptibility of a steel composition to heat-affected zone cracking. Conventional high strength steels fall in zones II and III, indicating that cracking is possible if conditions are not right. This is the basis for preheats, etc. in the American Welding Society (AWS) welding code. HPS steels are entering zone I, indicating that the probability of cracking is low under most conditions. This opens the door for lower preheat and easier welding of HPS than grade 50 steels.

Research undertaken at LeTourneau University noted that HPS steels needed to be preheated to temperatures that were 100-175 degrees F lower than specified for conventional steels, in order to avoid heat affected zone (HAZ) cracking in plates up to 2-inch thickness. It was shown that hydrogen-induced cracking susceptibility of the HAZ was lower than in the weld fusion zone for the same deposit strength and diffusible hydrogen level. This indicates that the cracking resistance of the weld metal, not the base plate, is the weakest link in the process. Therefore, low hydrogen welding consumables are preferred to maximize the weldability potential of HPS.

Based on research and development leading to field trials, and projects demonstrating an improved narrow gap process, FHWA has been able to re-introduce and recommend electroslag welding (NGI-ESW) on steel bridge tension members. The new process increases productivity, improves fracture toughness in welds and heat-affected zones, and provides a much higher degree of freedom from fusion weld defects and cracking. It has excellent application on HPS bridges.

A document key to the successful implementation of HPS was the *Guide for Highway Bridge Fabrication with HPS-70W Steel*. The Guide describes 2 types of weld metal strength – matching and optimized (undermatching). Matching strength refers to the traditional method of designing welded joints where the weld metal strength exceeds that of the base metal. Since the hydrogen cracking susceptibility of weld metal varies inversely to its strength, minimizing weld metal strength will increase cracking resistance. This is particularly important for welding HPS-100W since available matching strength weld metals are subject to hydrogen-assisted cracking.

Optimized (undermatching) strength refers to welds that have yield and tensile strengths less than that of the surrounding metal. Because they are less sensitive and have reduced residual stresses, optimized (undermatched) welds are recommended for all fillet welding used in HPS-70W fabrication to reduce hydrogen cracking. It is still very important to handle welding consumables as specified in the AWS D1.5 Bridge Welding Code, particularly for fracture critical members.

Research carried out at Lehigh University for the Pennsylvania Department of Transportation showed that optimized (undermatched) butt welds tested to yield and tensile strengths equal to the 1.5-inch base steel plates that they joined, and with adequate ductility. These results were reached as long as the plates had a width to thickness ratio of at least 7, and the tensile strength of the weld was at least 90% of the base metal strength.

HPS-related Welding Activities

The HPS welding advisory group continues to identify and prioritize research needs, review and comment on ongoing research, review other funded research for adaptability to steel bridge welding and fabrication, and recommend specification upgrades for presentation to AASHTO Technical Committee T-14 on steel bridges.

Current and anticipated HPS-related welding activities include: updating AWS D1.1 Structural Welding Code provisions and including the HPS fabrication guide in the appendix of D1.5; research on optimized weldments of HPS 70W and HPS 100W; guidelines for HPS consumables; HPS 100W welding guidelines; HPS 50W guidelines and flux-cored and gas metal arc welding issues; demonstrations on the NGI-ESW process described above; developing robotic and laser welding technology.

In conclusion, the swift development from research to project implementation has allowed State DOTs to gain many benefits from using HPS, including improved welding properties. Compared to conventional high strength steels (70 and 100 grade) that were difficult to weld, fabricators are reporting almost no problems with the new generation of HPS steels. These advantages should carry over to the new HPS grades currently under development, including ASTM A1010 and ASTM A710 Grade B steels designed for enhanced corrosion resistance. Ultimately the goal is to provide longer lasting, more cost-effective structures which are consistent with FHWA's concept of the 'Bridge of the Future.'▪

*Louis N. Triandafilou, P.E. is a senior structural engineer for the FHWA Resource Center's Structures Technical Service Team in Baltimore, MD. He has over 33 years experience in all aspects of the bridge program and is a licensed P.E. in Ohio. Louis may be reached via email at **lou.triandafilou@dot.gov**.*

*William Wright, Ph.D., P.E. is the Team Leader for Bridge Design and Construction Research at the FHWA's Turner-Fairbank Highway Research Center in McLean, VA. Dr. Wright has 21 years of steel bridge research experience and has worked on many failure investigations involving bridge collapse. Dr. Wright is a licensed professional engineer in Maryland and may be reached via email at **bill.wright@dot.gov**.*

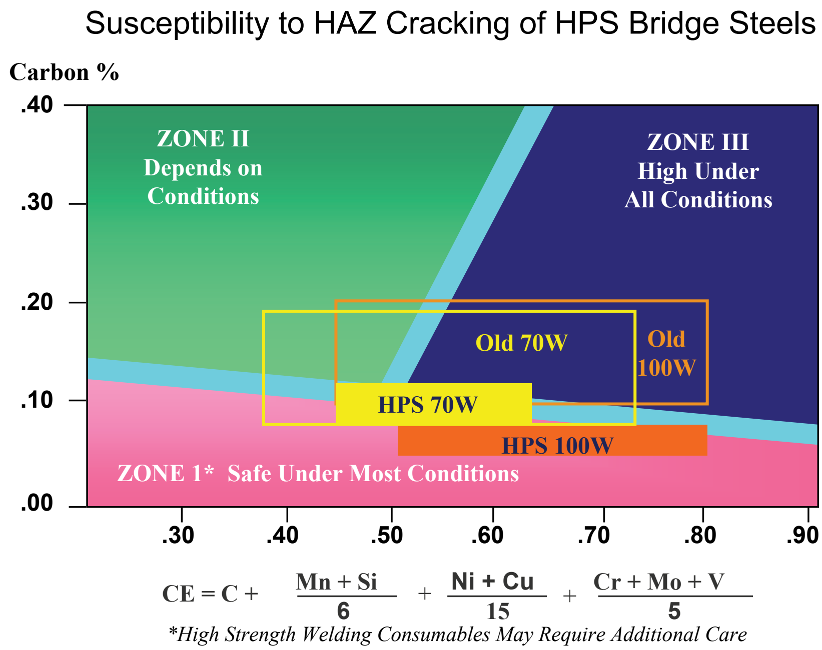

Figure 2: The Graville Weldability Diagram.

References

1. Adonyi, A., "Weldability of High Performance Steels," Proceedings of Conference on Steel Bridge Design and Construction for the New Millennium with emphasis on High Performance Steel, December 2000, pp. 81-95.
2. FHWA-SA-95-039, Narrow-Gap Improved Electroslag Welding for Bridges
3. Lwin, M., "High Performance Steel Designers' Guide," First Edition, April 2001.
4. Repetto, N. and Pense, A., "Optimized Welds in High Performance Steel," Proceedings of the 2004 FHWA Steel Bridge Conference, Steel Bridges: Emerging Technologies with Emphasis on High Performance Steel & Accelerated Bridge Construction, December 2004, pp. 89-97.
5. Yost, L., and Miller, D., "Welding HPS with Confidence," Proceedings of Conference on 2002 FHWA Steel Bridge Conference for the Western United States, December 2002, pp. 27-35.