

# DESIGN-BUILD DATELINE

January  
2005

**HIGH-PERFORMANCE CONSTRUCTION MATERIALS —  
WHAT ARE THE OPPORTUNITIES FOR DESIGN-BUILDERS?**

**Reprinted with permission of  
The Design-Build Institute  
of America (DBIA)**

# HIGH-PERFORMANCE STEELS PROVIDE WEIGHT AND COST SAVINGS FOR DESIGN-BUILD PROJECTS

By Delbert F. Boring, P.E.

According to the U.S. Federal Highway Administration, there are currently 591,000 bridges in the country. Of these, 163,000 — approximately 28 percent — are structurally deficient or functionally obsolete. To federal and state transportation officials, such figures can cause headaches. To design-build professionals, and to the North American steel industry that helped develop a new class of high-performance steels for bridges, they spell opportunity.

## WHAT ARE HIGH-PERFORMANCE STEELS?

High-performance steels (HPS) have been in existence for only a decade. In 1992, the U.S. Navy partnered with the American Iron and Steel Institute (AISI) and the Federal Highway Administration (FHWA) to develop new and improved steels for high-challenge applications. The driving force for this project was the need to develop higher-strength steels with improved weldability and characteristics to enhance the overall quality, fabrication, and performance of steels used in bridges in the United States. At the outset, it was determined that these steels should be “weathering” steels, which do not require painting for normal atmospheric exposure conditions.

A steering committee that included representatives from AISI, the U.S. Navy, and FHWA, as well as fabricators, welding consumable suppliers, design engineers, and academia was appointed to guide the project. The steering committee identified goals of the research program, which were to develop 50, 70, and 100 ksi (345, 485, 690 Mpa) minimum yield strength, weathering grade steels, with adequate toughness to meet stringent Zone 3 requirements and significantly improved weldability characteristics.

Since the earliest demonstration projects came online in 1997 and 1998, HPS has been used in over 200 bridges (either in design, fabrication, or open to service) in 42 states in the U.S. In June 2004, representatives from AISI, as well as officials from AASHTO (American Association of Highway and Transportation Officials) and the Federal Highway Administration, gathered to present an award to the Massachusetts Highway Department recognizing the opening to traffic of the United States’ 100<sup>th</sup> HPS bridge, which is the Route 4 bridge northbound and southbound over Route 3.



*The Route 3 Northbound Bridge over the Concord River in Billerica, Massachusetts is a 220-foot long single span bridge with 8-foot deep hybrid plate girders. Grade 70 High-Performance Steel was used on both the top and bottom flanges in the center 118-foot sections.*

## WHY SHOULD DESIGN-BUILD PROFESSIONALS CONSIDER USING HPS?

For bridge owners, designers, and fabricators, using HPS for design-build projects translates into overall weight and cost savings through an optimized balance of strength, weldability, toughness, ductility, and corrosion resistance, providing superior performance and longer life for bridge structures.

Take, for example, HPS 70W (70 ksi). Lon Yost and Scott Funderburk of the Lincoln Electric Company in

Cleveland<sup>1</sup> cite its high strength, high corrosion resistance, low carbon equivalent number, and excellent toughness advantages when compared with conventional steels:

- *HPS 70W has a yield strength of 70 ksi (485 Mpa).* With this high yield strength, bridge decks that would require five girders of a conventional 50 ksi (345 Mpa) steel might need only three to four girders. Because there are fewer girders, construction is quicker and costs less. This also applies to bridge piers, which can be spaced further apart because of the higher strength of the new alloy.
- *HPS 70W has high corrosion resistance.* As a weathering steel, HPS 70W has “controlled rusting” characteristics that allow it to corrode to a certain point, causing a rust barrier to form. Painting is not required, so there is less maintenance for highway crews.
- *HPS 70W has a low carbon equivalent.* It is resistant to cracking and hardening in the heat-affected zone after welding, so the integrity of the bridge is maintained. The material also requires a lower preheat temperature, resulting in cost and time savings and less energy consumed in the preheating process.
- *HPS 70W has high toughness.* The fracture toughness of HPS 70W is higher than that of conventional bridge steels. This improved toughness makes the steel more tolerant to discontinuities in welds, such as weld cracks, porosity, undercuts, or poor bead shape.
- *HPS 70W has useful length.* HPS 70W is produced by quenching

## HIGH-PERFORMANCE STEELS PROVIDE WEIGHT AND COST SAVINGS FOR DESIGN-BUILD PROJECTS

and tempering or by thermo-mechanically controlled processing. Practices have been developed to produce HPS 70W with thickness up to 2 inches (50 mm) and length up to 125 feet (38 m).

Additional advantages to HPS occur in proven cost and weight savings. Michael Barker, P.E., a civil and architectural engineering professor at the University of Wyoming who specializes in bridge design, performed HPS testing and performance evaluation for the Missouri Department of Transportation. In his analysis of the Missouri Department of Transportation's first use of HPS in the highly stressed regions of a 276-foot, two-span, five-girder bridge using hybrid design, he showed that using HPS only in the highly stressed regions (hybrid design) led to a superstructure steel weight savings of nearly 17 percent and a cost savings of approximately 11 percent compared to a conventional 50W bridge.<sup>2</sup> Hybrid design, which utilizes a combination of both conventional steels and HPS, is increasingly being used in bridge design.



Missouri's first completed High-Performance Steel (HPS 70W) bridge, a two-span, five-girder structure located at Route 224 over future Route 13 in Lexington.

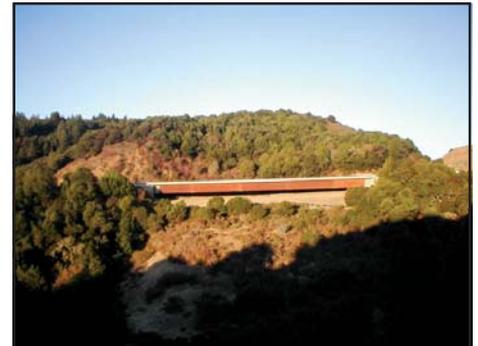
Project managers for the Whites Hill Sidehill Viaduct Bridge in California realized significant cost savings as they tackled the challenge of constructing a 380-foot single-span bridge. They considered truss, arch,

and cable-supported structures but, because of the surrounding hilly terrain and environmental constraints, HPS hybrid girders were selected. The use of the HPS hybrid girders resulted in a 16 percent reduction in steel when compared with an equivalent Grade 50 girder design. (The Grade 50 girder bridge would have required 2.1 million pounds of steel, while the HPS hybrid girder required only 1.75 million pounds.) For this project, HPS steel represented 36 percent of the total steel used. This resulted in an estimated 10 percent savings in fabrication and shipping costs, with additional cost savings realized for erection.<sup>3</sup>



The Whites Hill Sidehill Viaduct, Marin County, CA. A 380-foot-long, 43-foot-wide, 14-foot seven-inch deep, three-girder, single span bridge.

Bridge designers receive significant benefits when taking advantage of HPS's higher yield strength, which provides flexibility in designing longer, shallower spans when strength is the controlling limit state. New York State Thruway Authority designers found this advantage useful when replacing simple-span structures with continuous-span structures. The Thruway engineers found that shoulder piers could be eliminated without increasing the depth of the girders, and that vertical clearance could be increased with little or no modification required for



The Whites Hill Sidehill Viaduct, Marin County, CA. Girders are hybrid, flange — A 709 HPS Grade 702 and web — A 709 Grade 50W. Cost \$4,500,000. Project completed April 2003.

bridge approaches, translating into direct cost savings.<sup>4</sup>

High-Performance Steels are also advantageous for fabricators. *AASHTO's Guide for Highway Bridge Fabrication with HPS 70W Steel* notes that the enhanced toughness of HPS allows structures to absorb and redistribute fatigue loads more effectively. Brad Murphy, sales manager with Universal Structural, Inc., a leading fabricator of structural steel in Vancouver, WA, says: "As long as the design is within the capabilities of the HPS performance standards and the fabricator is AISC-certified, achieving quality workmanship is not a problem."

The steering committee recommends that HPS be fabricated following the provisions of the *Guide Specifications for Highway Bridge Fabrication with HPS 70W Steel*, published by AASHTO.

### HIGH-PERFORMANCE STEEL IN A DESIGN-BUILD PROJECT

The Massachusetts Highway Department recently selected HPS — specifically, Grade 485W (70 ksi) HPS — for a major design-build project. The Route 3 North Transportation Improvements Project consisted of widening 21 miles of limited access highway from two to

## HIGH-PERFORMANCE STEELS PROVIDE WEIGHT AND COST SAVINGS FOR DESIGN-BUILD PROJECTS

three lanes, adding a shoulder, and replacing 45 bridges. Each of the 13 interchanges along the corridor was reconstructed. Located in Middlesex County, MA, the roadway is a link between New Hampshire and Interstate 95. The project was awarded to the Modern Continental Team (consisting of Modern Continental Construction Company and URS Corporation as the design engineer).



*Typical intermediate cross frames consisted of K-frames with a bottom chord. High-performance steel and weathering steel was used throughout the structure.*

MassHighway utilized a design-build contract so that design and construction could be fast-tracked on this heavily traveled highway. Project specifications required that the bridges be designed to support MS 22.5 (HS25) loading modified for military loading and a 75-year design life. The design life provision required the project team to consider high-performance materials in order to provide an edge in durability and reduced maintenance costs.

The design team considered pre-cast concrete and steel plate girder alternatives for the bridge superstructure. Comparative designs were developed based on all Grade 345W steel and a mixed/hybrid girder design that utilized Grade 485W for the bottom flanges in positive moment regions for both simple and continuous spans and Grade 485W for top and bottom flanges over piers. HPS provided the biggest

savings over the bridge piers, since deflection was not a controlling issue.

The team concluded that HPS provided overall cost savings in comparison with conventional steel and provided weight, superstructure depth, and cost advantages over the pre-cast concrete alternative.<sup>5</sup>

### CHALLENGES FOR HIGH-PERFORMANCE STEELS

As a relatively new material, HPS faces the same challenges that any new material encounters.

- **Initial cost.** HPS is currently more expensive than traditional steels, but can produce first-cost savings by requiring less material, which can also reduce fabrication and erection costs.
- **Lead times.** In the past year, lead times for steel mill orders have been extended for all grades of steel used by the bridge industry. If required, quenching and tempering may add two weeks to an order.
- **Development of additional technologies.** While HPS 70W has been successfully used in many applications, there are challenges for other grades of HPS. An example includes the need to develop practical welding techniques for HPS 100W used for



*Central Viaduct, San Francisco, CA. A 10-span, 1,422-foot-long, continuous girder structure with integral concrete bent caps. It replaces a segment of an existing viaduct, and is being constructed while remaining open to the street traffic underneath.*

civilian applications.<sup>6</sup> The development of new steels and practices is contingent in part upon U.S. government funding, which is currently restricted pending reauthorization of TEA-21 (the Transportation Equity Act for the 21<sup>st</sup> Century).



*Central Viaduct, San Francisco, CA. Girders are hybrid, flange — A 709 HPS Grade 70W and web — A 709 Grade 502. Bridge is currently under construction and is expected to be completed by May 2005.*

### THE FUTURE IS BRIGHT FOR HPS IN BRIDGE DESIGN AND FABRICATION

State departments of transportation that have utilized HPS over the past few years continue to prefer its superior characteristics. A case in point is the California Department of Transportation (Caltrans), whose policy is to design bridges with HPS whenever possible. Caltrans' experience with HPS has validated the improved fatigue and corrosion-resistance properties of this new class of steels. According to Lian Duan, Caltrans' steel committee chairman, its use saves money and manhours.<sup>7</sup>

Missouri's Michael Barker notes that the use of HPS lowered bridge costs while improving the fabrication process, fatigue resistance, and long-term durability of bridge structures. Mr. Barker suggests that states could realize further savings for both HPS and conventional steel bridges by considering cost-effective splice designs, integral abutments, elimination of bearings, and wider girder spacings.

HPS is also gaining acceptance by fabricators as they become more

## HIGH-PERFORMANCE STEELS PROVIDE WEIGHT AND COST SAVINGS FOR DESIGN-BUILD PROJECTS

experienced with methods for preheating and maintaining interpass temperatures, improved flux handling procedures, and implementing alternate welding processes. High technology fabrication equipment (such as robotics) is being considered for the fabrication of non-conventional and innovative bridges.<sup>8</sup>

And HPS 70W is being transferred to other applications such as railroad bridges, buildings, and pedestrian walkways.<sup>9</sup>

With 28 percent of America's bridges being structurally deficient or functionally obsolete, HPS provides a cost-effective way for design-build professionals to satisfy demanding requirements. ♦

**Note:** For more information about HPS for bridges, or for information on the case studies provided in this article, please visit AISI's Web site at [www.steel.org](http://www.steel.org) or contact Dan Snyder at [Dsnyder@steel.org](mailto:Dsnyder@steel.org).

*The American Iron and Steel Institute (AISI) is a non-profit association of North American companies engaged in the iron and steel industry. The Institute serves as a voice of the North American steel industry, speaking out on behalf of its members in the public policy arena and advancing the case for steel in the marketplace as the preferred material of choice. AISI also plays a lead role in the development and application of new steels and steelmaking technology. AISI is comprised of 32 member companies, including integrated and electric furnace steelmakers, and 118 associate and affiliate members who are suppliers to or customers of the steel industry. For more news about steel and its applications, view AISI's website at [www.steel.org](http://www.steel.org).*

### NOTES:

- <sup>1</sup> Lon Yost and Scott Funderburk, "Welding High-Performance Steel Bridges," *Advanced Materials & Processes*, November 2002.
- <sup>2</sup> Michael G. Barker, P.E., "Missouri Builds First HPS Bridge."
- <sup>3</sup> Jeff W. Olson, P.E., "Whites Hill Sidehill Viaduct Bridge in California."
- <sup>4</sup> "Early Experiences of the New York State Thruway Authority," U.S. Department of Transportation Federal Highway Administration, June 2001.
- <sup>5</sup> William R. Egan, P.E., URS Corporation, "High-Performance Steel Scores Big with Massachusetts Highway Department's Route 3 North-Design/Build Project."
- <sup>6</sup> Yost and Funderburk.
- <sup>7</sup> Michael Barker, P.E. and Linda Mastaglio, "Steel Structure Stats", *Texas Contractor*, September 6, 2004.
- <sup>8</sup> Yost and Funderburk.
- <sup>9</sup> Yost and Funderburk.

*Delbert F. Boring, P.E. serves as vice president of construction market development for the American Iron and Steel Institute. Previously, Mr. Boring was senior director of construction. He has provided professional direction and leadership to AISI's construction market program for 28 years.*

*During Mr. Boring's tenure with AISI, he has managed steel industry participation in the development of U.S. and Canadian building codes and has participated in the activities of model building code organizations. He has also served as the leading steel industry authority on structural fire protection. He currently directs the activities of AISI's Construction Market program, which encompasses 11 markets in transportation/infrastructure and commercial and residential buildings.*