New Span, New Steel

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A new steel that doesn't require heat treatment or thermomechanically controlled processing comprises a replacement bridge in suburban Chicago.

LAKE VILLA, ILL. MIGHT NOT BE A PARTICULARLY WELL-KNOWN TOWN, BUT IT IS SIGNIFICANT IN TERMS OF STEEL INNOVATION. The Chicago suburb is home to only the second bridge using a new high-performance ASTM A710 Grade B steel, and the first to use it for main load-carrying members.

The North Milwaukee Avenue bridge carries auto and truck traffic on Illinois Route 83 over the Canadian National Railroad tracks in Lake Villa. The bridge it replaces was originally built in 1930 and was widened in 1964, and again in 1971, to accommodate more traffic; the former structure was removed in stages during construction to permit continued traffic flow.

Completed in October 2006, the new bridge has a continuous span length of 430.6 ft back-to-back of the abutments, where it rests on elastomeric bearings. The span is supported by only two new piers, replacing eight old ones, and there are two new abutments using 12-in.-diameter metal shell piles as foundations. The bridge's overall width between its outer parapet edges is 58 ft. There are two auto lanes, each 15 ft wide, along with a 12-ft central median, and 7-ft-wide sidewalks on both sides of the bridge. The line perpendicular to the center line of the bridge is skewed 70° with respect to the railroad track lines.

Ten plate-girder lines support the 7.5-in.-thick reinforced concrete deck. The plate girders, made composite by use of welded steel studs with the deck, have a nominal depth of 4 ft, with girder center lines spaced 5.75 ft apart. Each girder consists of an ASTM A710 Grade B ½-in.-thick web plate, with 1.125-in. by 16-in. lower flanges, and 0.875-in. by 16-in. upper flanges in the composite areas. In sections over piers, where the girders are non-composite, the upper and lower flanges are 1.875-in. by 16-in. The bearing stiffeners are ¾-in. by 7-in. by 48-in. and milled to bear on the flanges at piers and abutments. The web-to-flange welds are 5⁄16-in. fillets, with ¼-in. fillets on the stiffeners. Since ASTM A710 Grade B high-performance steel is not yet available in rolled shapes, ASTM A588 weathering steel was used as a substitute for the W16×36 diaphragms.

Composing a New Breed of Steel

The girders, made from new weathering ASTM A710 Grade B copper alloy precipitation-strengthened steel, are in the hot-rolled and air-cooled condition. This new breed of steel was developed and thoroughly investigated at Northwestern University with assistance from S. Bhat, Ph.D., of Inland Steel Company (now Mittal USA). Since no heat treatment after hot-rolling or thermomechanical-controlled processing is required, it can be produced by any steel company in any plate length.

The first use of this new steel, produced by Oregon Steel Mills, was used to seismically retrofit the approaches of the Poplar Street Bridge over the Mississippi River, near St. Louis, Mo., in 2000. The new North Milwaukee Ave. Bridge in Lake Villa is the first bridge to use this steel for main-load-carrying members and only the second use of the steel anywhere.

Breaking it down, the steel has a virtually ferritic microstructure, because the carbon content is very low. Alloying elements, such as chromium and molybdenum, frequently used in martensitic alloy steels, are not added and are limited to residual levels found in steel scrap. A limited amount of nickel (0.9 percent) is added to prevent hot-shortness during hot-rolling. Columbium (0.05 percent) and titanium (0.03 percent) are added to control grain size during hot-rolling and welding. Due to its low carbon content and limits on alloying elements that decrease the weldability of steels, A710 Grade B has the lowest carbon equivalent among high-performance steels. When used for bridge construction, it demonstrated outstanding weldability.

The strength of this high-performance steel is derived from nano-sized copper-alloy precipitates that are formed during air-cooling after hot-rolling (Figure 1). A710 Grade B has a yield strength of 70 ksi or

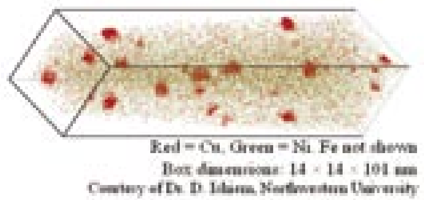

Figure 1. Copper-nickel nano-sized precipitates in A710 Grade B steel.

more for plates up to 2 in. thick (Figure 2). Because of its low carbon, phosphorus, and sulfur contents—and the presence of nano-sized copper precipitates—the steel has remarkably high toughness at low temperatures (Figure 3).

Copper significantly improves the atmospheric corrosion resistance of steel in marine and inland environments. Since A710 Grade B steel contains from 1.3 percent to 1.5 percent copper, it has significantly better weathering and corrosion characteristics than other commercial weathering steels. For example, in the Society of Automotive Engineers J2334 standard accelerated corrosion test performed at the former Bethlehem Steel Corporation (now Mittal Steel USA), A710 Grade B had the lowest penetration losses when compared to other competitive steels. ASTM A36 steel had 133 percent greater penetration; ASTM A588 and ASTM A709 HPS 70W weathering steels had penetration rates 69 percent larger than A710 Grade B (Figure 4). When coated with epoxy-based Carboguard 890 paint, A710 Grade B steel outperformed, by significant margins, other construction steels when exposed to the ASTM D 1654-92 Standard salt-fog test.

The $^{3}/_{8}$-in.- to $1^{7}/_{8}$-in.-thick steel plates for the bridge were produced by International Steel Group (now Mittal Steel USA) in Coatesville, Pa. by hot-rolling and air-cooling. The chemical composition of this steel is provided in the table below. The yield strengths of the plates were in the 72 to 90 ksi range, and the ultimate tensile strengths ranged from 82 to 102 ksi, with elongation to fracture over 25 percent. The Charpy V-notch impact energies for most of the plates were over 100 ft-lb at -10 °F, significantly exceeding the 35 ft-lb required for ASTM A709 HPS 70W steel for Zone 2 for fracture-critical locations (Figure 3).

Welding the Girders

When it comes to welding A710 Grade B steel, submerged-arc welding (SAW) is recommended, since flux-core welding without cover gas might lead to lower toughness of weld deposits. Flux-core-arc welds (FCAW) joining A710 Grade B without argon/CO_2 cover gas and appreciable nickel contents (0.4 percent or more) typically have only about 25 percent of the toughness of A710 Grade B. The lower toughness of FCAW is attributed to the higher hydrogen contents associated with flux-core wire, particularly if self-shielded, as compared to the better shielding characteristics of dry flux with SAW, or the moisture-free cover gases used with gas-metal arc welding (GMAW). All specified SAW and GMAW electrodes should contain at least 0.5 to 0.8 percent nickel in their weld deposit chemistry in order to obtain excellent low-temperature toughness when welding A710 Grade B.

The A710 Grade B girders for the North Milwaukee Ave. bridge were fabricated at Industrial Steel Construction, Gary, Ind. The submerged arc web-to-flange welds used Lincoln LA-75 (AWS ENi1K), $^{3}/_{32}$-in.-diameter electrodes with a neutral Lincolnweld 960 flux. The flanges were shop-spliced with full-penetration butt welds, using Lincoln LA-85 (AWS ENi5), $^{3}/_{32}$-in.-diameter electrodes with MIL 800-HP-Ni flux. This filler metal and flux combination resulted in excellent weld metal toughness. Qualification tests run by Calumet Testing Services for Industrial Steel Construction found that Charpy V-notch impact energy averaged 79 ft-lb (ranging from 52 to 91 ft-lb) at -20 °F. For weld repairs or short-length welds, A710 Grade B can be easily welded with E7018 or E8018 shielded metal-arc welding (SMAW). If A710 Grade B is used as weathering steel, E8018W electrodes are recommended. Toughness values for A710 Grade B welded with E7018 electrodes are typically above 75 ft-lb, even at temperatures of -20 °F. The machining of the A710 Grade B steel is not significantly different from that of other common lower-yield construction steels. Recent milling and grinding tests performed at Machining Research, Inc. have demonstrated that A710 Grade B has equivalent or better machinability than A36 or A709 HPS 70W steels.

An Economical Paint Job

The girders for the bridge were not painted, resulting in a significant cost savings of about $300,000. Unpainted steel

Chemical Composition of the A710 Grade B Steel Used in the North Milwaukee Ave. Bridge (weight percent)												
C	Mn	P	S	Cu	Si	Ni	Cr	Mo	V	Ti	Al	Cb
0.07	0.69	0.008	0.001	1.33	0.41	0.91	0.11	0.07	0.002	0.024	0.044	0.034

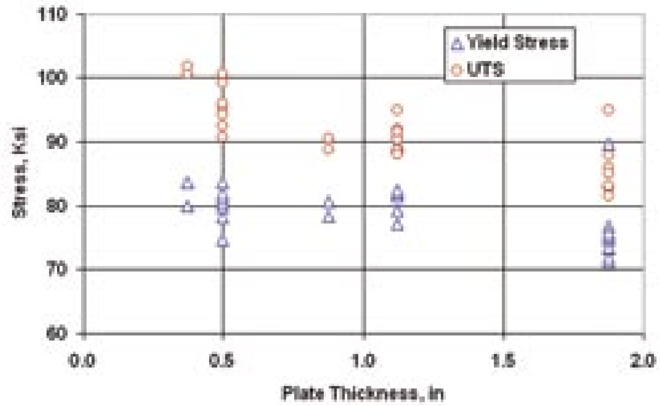

Figure 2. Strength of A710 Grade B steel as a function of plate thickness.

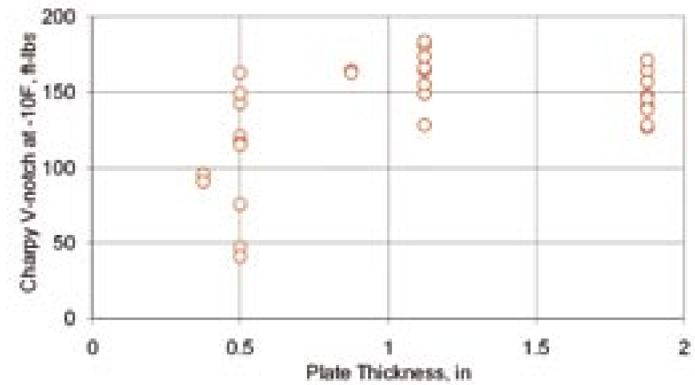

Figure 3. Charpy V-notch impact toughness of A710 Grade B steel at -10 °F as a function of plate thickness.

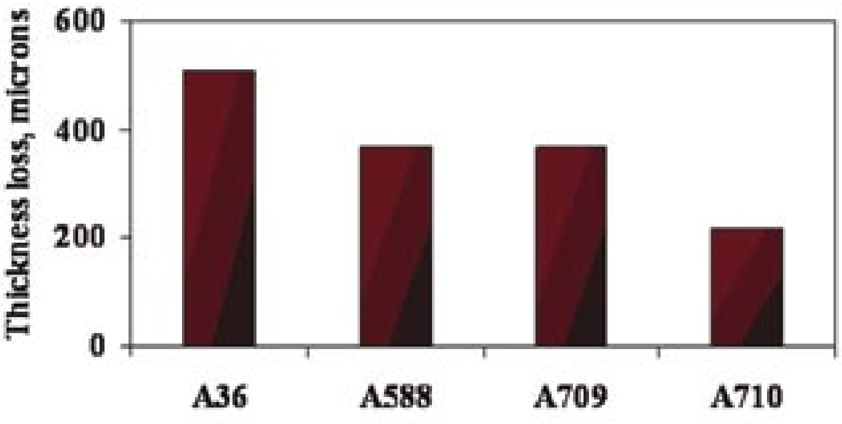

Figure 4. Thickness loss of common structural steels after exposure to Society of Automotive Engineers SAE J2334 accelerated corrosion test, performed by H. Townsend, Ph.D., of the former Bethlehem Steel Co. (now Mittal Steel USA).

girders permit easier handling during assembly, while painted girders require special handling to prevent coating damage. And since repainting will not be required, future maintenance costs will also be reduced.

All the Right Reasons

The construction of the North Milwaukee Ave. bridge clearly demonstrates the advantages of A710 Grade B steel: outstanding mechanical properties, fracture toughness, good weldability, and superior weathering characteristics. It can be produced economically by any steel mill in any plate length, because it does not require heat treatment or controlled hot-rolling and cooling.

Whether they realize it or not, motorists driving over the bridge are relying on a new, yet stable and economical, material to support them on their journey. MSC

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Owner
Illinois Department of Transportation, District 1, Schaumburg, Ill.

Designer
Graef, Anhalt, Schloemer and Associates, Chicago

Steel Producer
Mittal Steel USA, Coatesville, Pa. (AISC member)

Fabricator
Industrial Steel Construction, Gary, Ind. (AISC member)

General Contractor
Dunnet Bay Co., Glendale Heights, Ill.

Photos and Illustrations
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