worldsteel ASSOCIATION

STEEL ADVANTAGE

Bridges

Steel is an indispensable part of our everyday lives. It is a critical component in transport, homes and workplaces. It is essential to ensure the safety of water and food supply. It is basic to energy generation. No other material offers the combination of strength, formability and versatility. The worldsteel Steel Advantage series of publications presents the unique capabilities of steel across a range of applications.

Steel bridges: strength, economy and innovation

Steel is an essential part of modern bridges because it is strong, can flex without fracturing and has a long life, even in the harshest conditions. New grades of steel increase the economic advantages of steel, while ensuring that it meets the increasing demands for high performance.

Early bridges were made of stone, wood and concrete. The arrival of the steam train in the mid-18th century ushered in a new era in bridge design. A stronger material was needed as bridges were required to carry heavier loads over longer spans. Iron was first used to bridge the Tees River in England in 1741. By the 1880s, steel had become a material of choice.[1]

Bridges with built-in durability and cost efficiency

Steel can be used to build bridges of any length because of its durability and ease of manufacture and maintenance. Bridge engineers also choose weathering steel for its economic and environmental benefits. Weathering steels contain elements that allow them to form a protective coating when properly exposed to the atmosphere. The first bridge to use this material was built in New Jersey in the US in 1964.

The use of uncoated weathering steel typically provides initial cost savings of 10% or more, and life cycle cost savings of at least 30% over the life of the structure. Initial cost savings are realised because weathering steels do not need to be painted. Life cycle cost savings come from the material's durability. Inspections of bridges of between 18 and 30 years old show that weathering steel performs well in most environments.[2]

Weathering steels provide environmental benefits as well. They do not require initial painting, thereby reducing emissions of volatile organic compounds (VOC) from oil-based coatings. They do not require coating removal or disposal of contaminated blast debris over the life span of the structure, another significant environmental benefit.

A weathered steel bridge in Höxter, Germany

Emerging technologies: high performance steel

As the number of aging and deteriorated bridges in many places around the world has grown, so has interest in improved materials for construction, repair and rehabilitation projects.

Bridge designers and builders increasingly seek materials that are stronger, more durable and less subject to corrosion or other distress than conventional steel and reinforced concrete.

High-strength steel can be used to produce bridges that are more cost-effective, stronger, lighter and even more resistant to weather conditions than conventional steel. These bridges also have improved fatigue and corrosion resistance. In a study by the US Federal Highway Association, high-strength steel was found to provide lifetime cost savings of up to 18% and weigh 28% less than traditional steel bridge design materials.[3]

Designers and engineers can now specify new high-performance steels that have yield strengths of 70 ksi and 100 ksi. They have superior toughness and can be welded with little or no pre-heat. Alternative bridge form designs are also in development and promise even greater design flexibility and cost efficiencies.

CASE STUDY: THE MILLAU VIADUCT

Even before construction was completed in 2004, the Millau Viaduct was hailed as an engineering marvel. This cable-stay bridge reaches a summit of 343 m, making it the tallest vehicular bridge in the world. The bridge is also the longest of its type, with a roadway that runs a continuous length of 2,460 m, providing a direct route between Paris and Barcelona by spanning the River Tarn that flows through a spectacular gorge in southern France.

The dramatic setting of the bridge and the delicacy of its design placed extreme demands on the materials used for its construction. Engineers had to factor in seismic and meteorological conditions in a location where the bridge would be exposed to winds of up to 151 km/h. In addition, the design was required to guarantee faultless operation for a minimum of 120 years.

Several materials were considered, and steel was chosen because it could meet the rigorous performance requirements. The 36,000 tonne deck is supported by 154 stay cables made from 5,000 tonnes of steel. Architectural concrete used for the single-shafted piers require a steel formwork to meet the stringent structural demands.

Unusually, the deck is made of high-strength steel because it offers a firm road base over the span between the eight piers – a distance that ranges up to 304 m. The combination of material strength and ability to flex without breaking also enables steel to safely withstand the torsional forces imposed on the structure.

These high performance characteristics also played an important part in the aesthetics of the bridge. Its slim profile is made possible by the high-strength steel.

CASE STUDY: 1994 NORTHRIDGE EARTHQUAKE

The strength and ductility of steel make it highly resistant to extreme natural disasters such as earthquakes. This fact has been demonstrated over thousands of seismic events around the world, including the 1994 Northridge earthquake in California.

Although the quake destroyed the surrounding transport infrastructure, 96% of all the existing steel bridges were completely undamaged, even though they were designed using 1940s technology.[4] For example, steel preserved the structural integrity of the bridge supports under the Santa Monica Freeway in Los Angeles (see picture above).

Steel was also an important factor in the performance of bridge structures that had been retrofitted to increase strength and prevent collapse. Concrete columns that had been fitted with steel jackets survived with no apparent damage.

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Footnotes

1. "The Manual of Bridge Engineering," M. J. Ryall, G. A. R. Parke, J. E. Harding, 2003
2. "Cost Effective Design and Detailing of Steel Bridges," University of West Virginia, 2002
3. "High Performance Steel Designers' Guide," second edition, 2002, US Federal Highway Safety Administration
4. "Seismic Performance of Steel Bridges During the 1994 Northridge Earthquake," Department of Civil Engineering at the University of California,Berkeley, 1994