

The World Steel Association (worldsteel) case studies use a life cycle assessment (LCA) approach to measure the potential greenhouse gas impacts from all stages of manufacture, product use and end-of-life. worldsteel has developed this series of case studies to demonstrate the reduction of CO₂ emissions through the use of high-performance steels.

High-performance steels build longer and stronger bridges

Cantilever or cable-stay bridges are large, long-lasting structures made of high-performance steels. The strength of the steel enables these bridges to meet safety standards and to withstand natural disasters such as hurricanes and earthquakes.

Bridges shorten travel times and distances. The Arthur Ravenel, Jr. Bridge, commonly known as the Cooper River Bridge, reduces the commuting distance between Mt Pleasant and the Charleston Peninsula, South Carolina, USA, saving 167,000 tonnes of CO₂ equivalents a year from vehicles' exhaust pipes.¹ This has a lifetime implication of 16.7 million tonnes of savings in CO₂ equivalents (based on average petrol consumption and current automotive design).

The Cooper River Bridge replaces two obsolete bridges.² Due to advances in steel production technology, a similar amount of steel was used in the construction of the new eight-lane bridge as was used in the bridges it replaced. Recycling the old bridges saved 33,460 tonnes of CO₂ that would have been required for producing virgin steel.

Better steels in construction

The construction sector is the largest consumer of today's steels. Around 50% of world steel production is directed towards this market segment, and bridges have a significant share.

For more than 150 years, steel has been the cornerstone in bridge construction. Steel is used in plates, sections and reinforcing bar. New types of bridges have continued to appear in recent decades, a result of the development of functional requirements, new steels and construction technologies.

This case study analyses the greenhouse gas impact of one particular replacement project: the Cooper River Bridge.

Background to the Cooper River Bridge

The first bridge to cross the lower Cooper River near Charleston opened in 1929. The main span (the section of the bridge between the two main supports) of the double cantilever truss bridge was the fifth longest in the world at 320 m and soared 46 m above the river. Its main span was the twelfth-longest in the world. The total length of the structure was about 4.3 km. Following a 17-month construction period at a cost of US\$6 million, and using 41,000 tonnes of steel, it opened on 8 August 1929.



The Arthur Ravenel, Jr. Bridge (Picture: Liz Clayton)

This bridge was originally designed to last 50 years and should have become functionally obsolete by 1979. However, because of steel's strength and durability, it was not until 1995 that the bridge received an "F" (Failure) safety rating. Construction of an eight-lane replacement began in 2001 and the new bridge opened for business on 16 July 2005.

Design and construction

The new Cooper River Bridge is the longest steel cable-stay bridge in North America. The main span is 471 m long. The diamond towers extend 175 m in the air, making them the tallest concrete structures in South Carolina. Each tower was built using 3,357 tonnes of reinforcing steel. The steel girders, the cable tower anchorage steel boxes, steel deck pans, etc. use approximately 45,000 tonnes of steel.

For cost, structural and durability reasons, cable-stay bridges are steel intensive. The new eight-lane bridge contains a similar amount of steel as the bridges it replaced. Just as importantly, the bridge is in a hurricane zone and the area sees some of the highest seismic activity in North America. The strength of steel meets the extreme requirements of this site.

Environmental benefits

One of the main purposes of a bridge is to shorten the distance between two points. In the case of the Cooper River Bridge, driving from Mt Pleasant to Charleston covers 11.6 km, a journey that can be accomplished in 14 minutes. Without the bridge, the commute would be 39 km and take 30 minutes.



The Arthur Ravenel, Jr. Bridge (source: Wikipedia)

The average annual daily use of the bridge is 69,200 vehicles. Assuming that the average vehicle meets the US Environmental Protection Agency standard of 11.7 km a litre, total petrol savings on an annual basis is greater than 59 million litres. This bridge allows commuters to save petrol, and results in lifetime savings of approximately 16.7 million tonnes of CO₂ equivalents.

The original bridge was designed to last 50 years, but because of steel's strength and durability it lasted 75 years. As a result of this extended life, significant savings of CO₂ were realised as a replacement bridge was not required.

In the early 1980s, steelmaking processes in the US consumed 37.8 GJ of energy per tonne of steel produced. By 2005, the US steel industry had lowered the average energy consumption per tonne of steel produced to 11.5 GJ, through increased use of scrap and technology improvements. The resulting reduction of CO₂ equivalents from this dramatic improvement in energy efficiency was 230,000 tonnes. Using 21st century bridge-building technology and high-performance steels, this new bridge is designed to last at least 100 years; a 33% improvement over its predecessor.

The demolition of the Grace Bridge began in August 2005. It took approximately two years and required closing the shipping lane for half a day so that the main span could be cut from the cantilever sections, lowered on to a barge below and shipped to a steel mill as raw material. Of the steel used in the bridge, 18,970 tonnes was recycled resulting in a saving of 33,460 tonnes of CO₂ that would have resulted from producing new steel from iron ore.

Most of the rest of the steel (approximately 20,000 tonnes) was taken out to sea to form an artificial reef for marine life and to protect the shoreline at the mouth of the Cooper River.

Did you know?

- The longest cable-stay bridge in the world is the Sutong Bridge in China, which is 8.2 km long. It has a main span of 1.1 km.
- The Millau Viaduct in France (pictured below), also a cable-stay bridge, is the world's tallest road bridge, reaching 343 m high. It uses 65,000 tonnes of steel.



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Footnotes

1. An LCA-GHG Parametric Model, Dr Roland Geyer, Dr Donald Bren School of Environmental Science and Management, University of California Santa Barbara, 2006
2. The South Carolina Department of Transportation, Community Bridge Office (www.cooperriverbridge.org), the Corrugated Steel Pipe Institute (www.cspi.ca), Wade Watson of Tidewater Skanska, Inc. and Bernd Laudorn of High Steel Structures, Inc. provided information for this case study.