



The footbridge in Kolding, Denmark was the first composite bridge in Europe to be built over a railway. Inset: the new bridge in Kokkedal being assembled.

ENDURANCE FEAT

DESIGN & ENGINEERING

Two decades since completion of the first footbridge in Scandinavia built using advanced composites, the technology continues to win support as its long-term benefits are proven

When Scandinavia's first advanced-composite bridge was built, it was considered innovative and boundary-pushing. Two decades on, it may no longer be regarded as a new material but it continues to push the limits in terms of new ways to build bridges. Public-sector companies are still motivated by the same considerations when choosing a composite bridge; freedom from maintenance and the benefits of light weight, which enables faster erection and requires smaller foundations.

The former was the main reason for the choice of a GFRP bridge deck on a new, almost 40m-long hybrid bridge being built at Kokkedal just north of Copenhagen in Denmark. This bridge, being built by Fiberline Composites, replaces an existing bridge across the railway and is currently under construction. Banedanmark, the company responsible for Danish railway infrastructure, was advised by consultant Cowi to choose this type of deck rather than the steel or concrete options that Banedanmark usually specifies, for reasons of future maintenance.

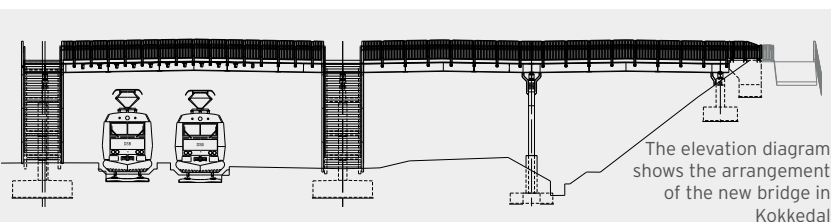
Cowi project manager Finn Jensen explains: "If using GFRP means freedom from painting the bridge deck throughout the life of the bridge, then we have made the right decision for Banedanmark and not least for the passengers using the railway by recommending this future-proof solution."

The Kokkedal bridge spans the railway that connects Copenhagen with the Öresund region, and is one of Denmark's busiest rail lines, carrying 10 million passengers a year. Maintenance work on bridges over railways are frequently responsible for train cancellations and the subsequent disruption to passengers. Using fibreglass, Cowi expects the bridge deck to be maintenance-free throughout the life of the bridge.

As with Scandinavia's first advanced-composite footbridge which was built over a railway line in Kolding, Denmark in June 1997, Fiberline's composite bridges are today still prefabricated and transported either as complete units or as large modules to the erection site where they can be easily lifted into position. This reduces erection time significantly and also minimises disruption to rail services.

Measuring 39.7m long by 2.2m wide, the Kokkedal bridge consists of a high-durability GFRP deck that provides a watertight cap for the steel substructure. The stairs are also made of steel and GFRP. Total bridge erection time, excluding factory assembly of the modules, is estimated to be just one day.

In 1997 the loading limits were calculated very conservatively, and for safety reasons the Kolding footbridge was ultimately over-dimensioned. Nowadays, however, a better understanding of how to use advanced composites enables slimmer and lighter bridge structures to be designed and built. This is achieved by



strengthening the bridge deck itself and by use of carbon-fibre lamellas to reinforce the substructure. This harnesses the greater stiffness of carbon fibre and means that fewer materials can be used to create a more rigid bridge structure and thereby increase the span.

As well as being the first of its kind in Scandinavia, the footbridge in Kolding, Denmark, was the first composite bridge in Europe to be built over a railway. Fiberline Composites founder Henrik Thorning says: "Twenty years ago it was the state-of-the-art in pedestrian bridges. By demonstrating that it was possible to build a bridge entirely of composites we generated tremendous interest, and this has paved the way for many subsequent composite bridges. Today the bridge is continued proof that composite materials not only produce durable bridges but is a competitive alternative to traditional construction materials."

About 3,000 full-composite or hybrid bridges incorporating Fiberline profiles have since been built in Europe. Some, like the Kolding bridge, traverse a railway, a purpose for which glass-fibre reinforced polymer is especially suitable due to its light weight and lack of maintenance requirements.

Thorning says: "The whole idea behind the footbridge was to rethink the way we build bridges and harness the potential offered by a new material. Using GFRP we could create a more durable bridge, which unlike concrete and timber neither weathers nor rots, and which is so light that we can build larger bridges in house, reducing on-site erection time and the size of bridge foundations."

The bridge still fulfills its primary purpose of carrying cyclists and pedestrians across one of Denmark's busiest railways and has so far required only cosmetic maintenance. The only attention received to date is removal of graffiti.

A detailed report on the condition of the bridge, including the durability of the fibreglass, was published four years ago by engineering consultant Ramboll. The report found that after 15 years' service and exposure to sun, frost and salt the characteristics of the fibreglass were unchanged. "We can find no form of significant deviation in the material properties, and it is Ramboll's opinion based on the tests performed that the material properties are unchanged after 15 years of bridge service," said the report.

Fiberline's expectation is that no structural maintenance will be needed in the next 20 years either. This is a notable economic benefit for the Municipality of Kolding as the running costs associated with the bridge will be far lower than for bridges built out of conventional materials, thereby making fibreglass a competitive alternative. According to Ramboll's manager of design section, in the large projects division, Niels Tornsberg, a great deal of curiosity existed about the new material in 1997, as the Danish industry was very conservative.

"At that time, however, it was not possible to document whether fibreglass could compete on cost of construction with conventional materials like steel, concrete and aluminium," he recalls. "Considerable advances have been made since then, not least at assembly level, and if we also look at the long-term maintenance costs then fibreglass becomes more competitive in price terms."

Measuring 40m long by 3.2m wide, the Kolding bridge is a cable-stayed design supported by eight stays. The load-bearing structures, bridge deck and handrails are all made of GFRP profiles. The bridge was assembled in the factory into three modules, which were then transported by semi-trailer to the erection site and lifted into place. With the bridge weighing less than 12t, erection was completed in just 18 hours with only minimal impact on rail services.

Tornsberg believes that in future, fibreglass will be competitive with conventional building materials: "The greatest potential lies in pedestrian bridges and bridge deck replacement. This is because fibreglass has a high strength-to-weight ratio, which offers advantages in terms of deck lightness and easier handling. In future, fibreglass will also become increasingly popular in special projects where the load on the substructure is already at maximum or where there is a need for high corrosion resistance, for example offshore"

A project to design a new footbridge over the River Seine in Poissy, France, along the line of the former 14th century crossing is being led by Ney & Partners for client SMSO. The 300m-long crossing is intended to respect the



remaining piers of the historic structure while adopting the same structural principle of multiple continuous arched spans. It will offer residents on the opposite side of the river direct access to Poissy railway station. The proposed footbridge is part of a masterplan which also incorporates the transformation of Robinson Island into a public space for cultural events and festivities and the restoration of a bay on the right bank of the Seine which was covered over in the 19th century. Ney & Partners is working with Strates, SCE and Atelier Roland Jeol éclairage. The estimated cost of the bridge is US\$17.5 million and it is proposed to be completed by 2022.

A slender pedestrian bridge designed by Moxon Architects and engineer Arup has just been completed near King's Cross Station in London, for the King's Cross Central Limited Partnership. The 38m-span bridge crosses the Regent's



Canal between Camley Street and the new Gasholder Gardens. It is made of 15mm-thick steel plate and achieves a minimum depth of 400mm at each end. The form of the bridge precisely matches its bending moment, making it a direct demonstration of where steel is required in the beam. By locating the structural depth above deck level the design maintains a clear view of the canal to the south and the air draught is maximised. The main contractor for the project is Carillion and the bridge was fabricated by SH Structures in North Yorkshire. The complete 55t assembly was lifted into place using a 750t-capacity mobile crane.

Construction of the new footbridge at Sofiero Castle in Helsingborg, Sweden is expected to be finished before the end of this year. The concept design for the bridge by Dissing & Weitling Architecture, structural engineer Schlaich Bergermann & Partner and landscape architect Becht was the winning entry in an invited competition in 2015. The steel structure is 56.8m long and 2.6m wide and crosses a ravine in the castle grounds. Contractor Danish Bladt Industries won the detailed design and build contract and is fabricating the bridge ready for it to be assembled on the site and lifted into place later this year.



Knostrop Weir footbridge which has been designed by Knight Architects and Mott MacDonald, is due to be completed next month (September). It will create a new pedestrian and cycle link across the River Aire in the city of Leeds, UK as part of a wider cycle network. Cantilevering piers supported from the new weir cradle a sinuous deck form and plan curvature creates widened deck areas as overlooks. Construction of the project is being led by contractor Bam Nuttall with the fabrication of the bridge deck completed by SH Structures this summer. The bridge is a 70m-long steel beam construction supported on three piers that bear onto the new concrete weir structure below.

