Feel the strength of Cintec Rail's support

Cintec Rail, part of the Cintec International Group, has developed a proven method of assessment, repair and strengthening for masonry arch bridges.

There are around one million masonry arch bridges in use throughout the world today, principally carrying road and rail. European railways alone account for 200,000.

These bridges are a vital asset and their replacement cost is almost incalculable. Despite their ancient form, masonry arches are notoriously difficult to accurately assess - their overall behaviour is complex, deriving from the interaction of individual parts, blocks, bricks, mortar and fill.


Typical 3D laser survey

Cintec International has supplied anchors and reinforcement for the past 22 years, to Network Rail and previously British Rail, as well as county councils and local authorities, either directly or via its approved contractor network. Cintec and its partner companies are able to offer a complete diagnostic service on all masonry and stone bridges and structures, from initial assessment, and a finite element design process through to anchor installation and completion.

Recent work took place at three locations in Scotland: Crawick and Enterkin viaducts and Keith Haughs bridge.

In 2009 Network Rail's Framework team instructed Carillion to carry out site investigations and develop designs on two masonry arch viaducts on the Glasgow and South Western (GSW) rail route at Crawick and Enterkin. This route is the main alternative to the West Coast Main Line connecting Glasgow to the South and carries a high percentage of freight and local passenger traffic.

Both structures suffered from similar defects – namely longitudinal cracks at the arch barrels behind the spandrel walls. However, in addition, Enterkin suffered from deformation of the parapet wall. The design was for a fully developed reinforced U deck with through ties to stabilise the viaducts and extend their service life.

Historic documents and drawings provided enough detail on the make-up of the structures. Internal spandrel walls backing on to the arch barrels support stone slabs for the deck.

The original structural voids had been filled with concrete and all arches on the structures have longitudinal cracks behind spandrel walls. The cracks went from springer to springer on the outside of the bend on the line carrying most freight.

Design development work began on the Crawick structure in 2009, and given the make-up of the structures, it was decided that the Cintec system would be ideally suited. The instruction to start developing the design for Enterkin followed later that year.

Real-time monitoring at Crawick revealed the cracks were widening so the programme was brought forward. The implementation of ties was started in January 2010 and completed within four months, with the installation of the Enterkin ties starting shortly afterwards.

It was important to quickly establish what was underlying the ballast and confirm that the void filling had taken place, so a number of site investigation techniques were used including:

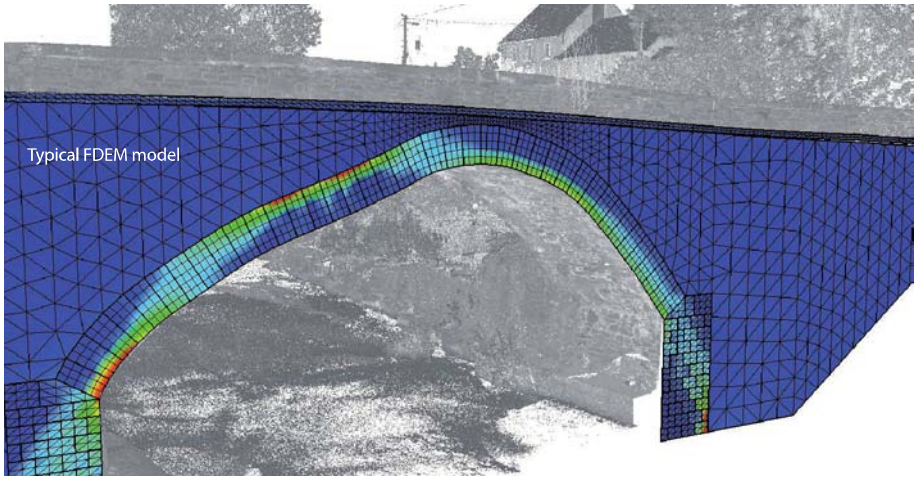
- Coring work
- Excavation of ballast in confined location
- Laser scan of the Enterkin parapets
- Radar scan at Enterkin
- Panda probe testing

The Permanent Way team established from trial pitting that there was an excess of ballast on the structures. Over the years this had increased the loading and partly caused the current problems. A case was made to Network Rail for lowering the track, and it was subsequently lowered by 300mm at Crawick and around 250mm on the up line at Enterkin.

How the Cintec anchor works

The Cintec system comprises a steel section in a mesh fabric sleeve, into which a specially developed cementitious grout is injected under pressure. The flexible sleeve of woven polyester restrains the flow and expands to about twice its normal diameter, moulding itself into


Installation process – drilling from above



the shape and spaces within the walls, providing a mechanical bond.

The two viaducts have similarities and differences: Both have the Cintec anchor system tying the structure back together to form a single mass; both have in situ slabs. However, Crawick uses the existing haunch while Enterkin uses L-sections and its parapet is tied back.

The project has used several site investigation techniques both traditional and new. All work was done by rope access and carried out without disrupting trains. A close relationship was established with the suppliers in developing the design, and the company has gained valuable experience that will stand it in good stead for tendering on viaducts requiring similar repairs .

Keith Haughes bridge

One of the first road over rail bridges to be strengthened using the Archtec system was Keith Haughes bridge in Scotland, a single-span brick masonry arch which carries a trunk road across a network rail line. Earlier assessments had indicated insufficient strength to provide the required trunk road live load rating.

A further assessment, including SV196 abnormal loading, resulted in the selection of Archtec strengthening and, alongside other remedial work the project was completed in 2010.

Minimal disruption to road and rail traffic was key. Since it was a small-scale construction activity with no movement of bulk materials, the work could take place in short possession periods, and techniques such as laser scanning and 3D modelling enabled accurate planning.

Archtec technology now used for rail bridges

Archtec has been used on highway bridges for nearly 15 years. Now, the technology is being used for railway bridges and is set to introduce similar benefits.

The motivation for developing Archtec was the introduction of 40/44 tonne vehicle load rating - as a cost effective alternative to traditional assessment and strengthening routes.This drive continues, particularly overseas, but increasingly in response to rail traffic rather than road. It is now also recognised as an alternative, affordable and sustainable solution to traditional saddling, or in some cases bridge replacement, by improved use of mostly existing materials.

A significant research programme has been behind Archtec over the years, including advanced analysis, full-scale tests, monitoring of bridges, and importantly the formation of a team including academics, engineers/ analysts, project managers and specialist contractors to deliver the service. The team is a partnership of several specialists: Cintec International, Rockfield Software and a team from Ramboll UK (formerly Gifford).

Internationally, around 250 bridges have now been strengthened, with many more assessed and found to be adequate.

Calculating the strength of arch bridges

There are several existing methods of assessing the strength of ancient masonry arches but their generalised use is limited. Finite Element analysis has been used successfully but modelling materials to obtain realistic behaviour is challenging.

Instead, the Finite/Discrete Element Method (FDEM), which involves the automatic computation of interacting bodies, is applied in the Archtec processes. As with the application of Finite Elements, the generalised approach also means that any geometric form of masonry can be simulated. As a result, there are no restrictions to the arch bridge arrangements that can be considered, for instance the number of spans, rings and piers. Similarly any type of loading from highways, railways and even ground movements can be applied.

The application of FDEM represents a step change in the sophistication that can now be applied to the structural analysis of masonry arch bridges. Not only can it be used to accurately assess strength but also to determine bridge deformation, including important non-linear effects, making it possible to assess behaviour at both strength and serviceability limit states.

Strengthening weak bridges

Arches conventionally fail by the development of four hinges leading to a mechanism. The design basis for Archtec strengthening is to locate reinforcement, to improve bending strength where hinges are predicted to develop. By providing additional strength in this way the arch barrel is better able to resist live load, and peak compressive stresses in the masonry are reduced compared with similar un-strengthened cases.

The same procedure is applied to more complex bridge arrangements including multi-span arches, although failure mechanisms and reinforcement positioning requires different locations to be considered in the design.

The method of strengthening involves the installation of Cintec anchors, which have been developed to allow the retrofitting of stainless steel reinforcement around the circumference of the arch barrel. The reinforcement is then grouted into holes precisely drilled into the bridge with a diamond coring rig to provide a shear connection with the masonry. It is this shear connection and method of grouting within a fabric sock that is vital to giving the required bond strength. Installation can be made from the road surface or, in the case of multi-span structures, from below.

Once the work is completed there is no evidence of major intervention to the bridge, a characteristic that is particularly important for historic structures. RP

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