Case History

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Bridge Trials Verify Increased Bridge Serviceability With Archtec Strengthening

Extensive verification has long since been established for both the method of strengthening masonry arch bridges known as Archtec as well as for the use of ELFEN Finite/ Discrete Element analysis as a basis for assessment and design. This has included several full-scale tests.

Consistent with other contemporary work on masonry arches and current assessment/ design methods, the verification and testing which forms the current design basis for Archtec has focused primarily on predictions and comparison of ultimate strength. However, unlike other methods of arch assessment/design, Finite/Discrete Element analysis also allows the consideration of arch behaviour in the elastic range under service loads and some analytical work has been undertaken to investigate this although it has not been possible to fully verify this in the absence of the suitable test data.

In the course of discussions with the Bridge Owners Forum (BOF) - Masonry Arch Sub-group, regarding the more widespread adoption of Archtec, the benefit of a Supplementary Load Test to investigate the behaviour of un-strengthened and strengthened arches under service loads was identified. At meetings between the BOF, Gifford & Partners and Cintec, a bridge already ear-marked for Archtec strengthening and was selected for testing under service loads. The load tests, were carried out in two stages, before and after strengthening, and were undertaken using the guiding philosophy laid down in BA 54/94 - Load Testing for Bridge Assessment. The second of the two tests was completed on 1 March 2004.

Anchor prior to installation

VW gauges and LVDT

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The Bridge

Pop Bottle Bridge in South Lincolnshire is a skewed two-span brick masonry arch bridge. Each span is approximately 5.0m measured in the skew direction and rise at their crowns 2.3m. The barrel is built from three rings of brick with bricks laid to the English or Helicoidal Method and has a skew angle of 25°. The overall barrel thickness is 355mm. The central pier is 800mm wide and approximately 2.1m high. Using modified MEXE and mechanism analysis the live load rating of the bridge was originally calculated to be 13 tonnes. The construction and previous use of Pop Bottle Bridge make it an ideal representative of British arch bridge stock and the disused and dismantled railway permitted easy access for test instrumentation.

Objectives

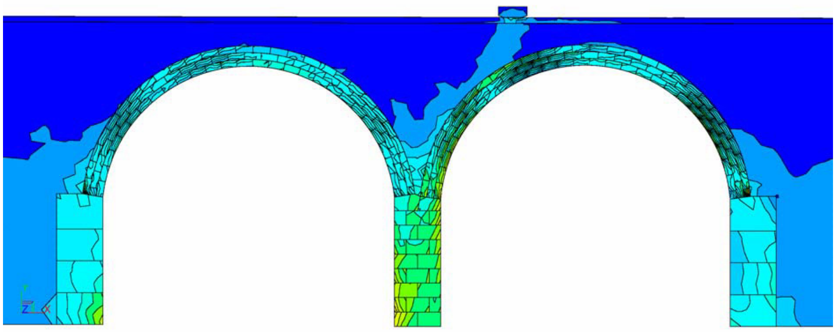
The primary objective of the Supplementary Load test was to demonstrate the efficacy of the Archtec strengthening system under service loads, namely:

i. To validate the use of the ELFEN Finite/Discrete Element analytical method to predict serviceability behaviour in un-strengthened and strengthened arches.

ii. To demonstrate that the retrofitted anchors contribute to the structural behaviour under service loads and that the effects are beneficial and measurable.

iii. The bridge was loaded before and after strengthening using two 18 tonne lorries in 28 different positions and instrumented to record intrados strains, vertical displacements and strengthened bridge anchor strains.

Loading using 11.5 tonnes single axles



Typical test simulation illustration principal compressive stresses: blue, green and yellow reveal increasing levels of compression

Conclusions

The following general conclusions can be drawn from the results of the two load tests, on the bridge in its unstrengthened condition and after being Archtec strengthened, and from predictions of their behaviour using numerical simulations:

i. Based on strain measurements, the Archtec anchors used to strengthen the bridge are stressed under working loads and are contributing to the bridge's stiffness.

ii. Archtec strengthening reduces tensile intrados macro strains and, therefore, reduces the likelihood of loosening masonry under cyclic live loads.

iii. Direct instrumentation of cracks and intrados macro strain measurements have demonstrated that Archtec anchors positioned across transverse cracks reduce cyclic opening and closing under repeated live loads. The main benefit of this behaviour would be the reduction in load cycle derived hysteretic damage; opening and closing of cracks under traversing traffic. Reducing this type of damage will almost certainly be beneficial to the bridge service life.

iv. Predictions of strain and displacement made with DE numerical simulations agree well with measured values, both masonry and anchors. Results are conservative because of skew behaviour, transverse load distribution and spandrel wall stiffening.

v. It has been demonstrated that Archtec strengthening can be designed not only for the ultimate limit state(4) (strength) but also for the serviceability limit state (deflections, strains and stress ranges).

In summary, the two principal objectives of the tests have been achieved;

- The validation of the use of the ELFEN DE analytical method to predict serviceability behaviour in un-strengthened and strengthened arches, and,

- The demonstration that the retrofitted anchors contribute to the structural behaviour under service loads and that these effects are beneficial and measurable.

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