ARTICLE FOR HIGHWAYS JOURNAL

ARCHTEC STRENGTHENING OF MASONRY ARCH BRIDGES
by G P Tilly and C L Brookes of Gifford & Partners

INTRODUCTION

Archtec is a novel method of strengthening masonry arch bridges where stainless steel reinforcing bars are inserted in the arch barrel and grouted into the masonry. The use of stainless steel and high performance grout ensures compatibility between materials and long term durability. Most importantly the bars and grout are contained within a 'sock' which protects the surrounding masonry from being displaced or otherwise damaged by the grouting pressure of three to four bar. During injection the sock is inflated and permits sufficient 'leakage' of grout to develop adhesive and mechanical bonding with the masonry resulting in structural connection. The efficacy of this connection is evaluated by pull-out tests. The reinforcement is positioned in the arch barrel in a longitudinal direction and tangential to the curvature. Depending on the condition of the structure, reinforcement may also be positioned in the barrel in a transverse direction.

Numbers and precise disposition of the bars are confirmed by numerical analysis using ELFEN, a non-linear discrete element program. This enables the composite behaviour of the reinforced masonry to be predicted and allows accurate simulation of the response to permanent and live loads.

In order to obtain confidence in the method of analysis it was checked against results of full-scale field tests to collapse on Torksey and Shinafoot bridges by TRL, and a strengthened model tested in the laboratory, also by TRL.

The features that follow illustrate three aspects of the scheme:

- The strengthening of a two ring arch at ¼ of the cost of an alternative
- The strengthening work on a listed bridge with the approval of English Heritage
- The analytical method that confirmed that a supposedly weak bridge did NOT need strengthening

HUNTS BRIDGE

Hunts bridge in North Scarle, is part of South Lincolnshire County Councils territory. It is a 45 degree 4.2m skew span humped back brick arch carrying a road over a stream. The arch is of two-ring construction. When assessed it was found to have cracking in the arch barrel, badly weathered brickwork and a load carrying capacity of 17 tonne. A replacement scheme was found to have problems of vertical alignment and an estimated cost of £100,000. After due consideration it was decided to strengthen the structure to 40 tonne load carrying capacity by the Archtec method.

Hunts Bridge

A scheme was designed having 18 reinforcement bars grouted into the barrel. The work was carried out from above the road surface during a period of exceptional rain when the water level rose and it would have been impossible to work from beneath the arch. The drilling of holes for the reinforcing anchors required high accuracy as the entry angle was only 9° to the road surface and the two-ring thick barrel left little scope for even minor errors. Road closures were minimised so that peak traffic at weekends, mornings and evenings was not affected. The strengthening was completed for £25,000 and enables the bridge to carry 40t vehicles.

AMBERSHAM BRIDGE

Ambersham bridge, the responsibility of West Sussex County Council, is a two-span structure across the River Rother. It has a three-ring elliptical arch barrel and cut sandstone voussoirs. The main 5.9m span was assessed as having a 9 tonne load carrying capacity. As a Grade II Listed Structure it required a method of strengthening having minimal effect on its appearance and approval by English Heritage. This was duly obtained and the work was completed in four days.

Ambersham Bridge

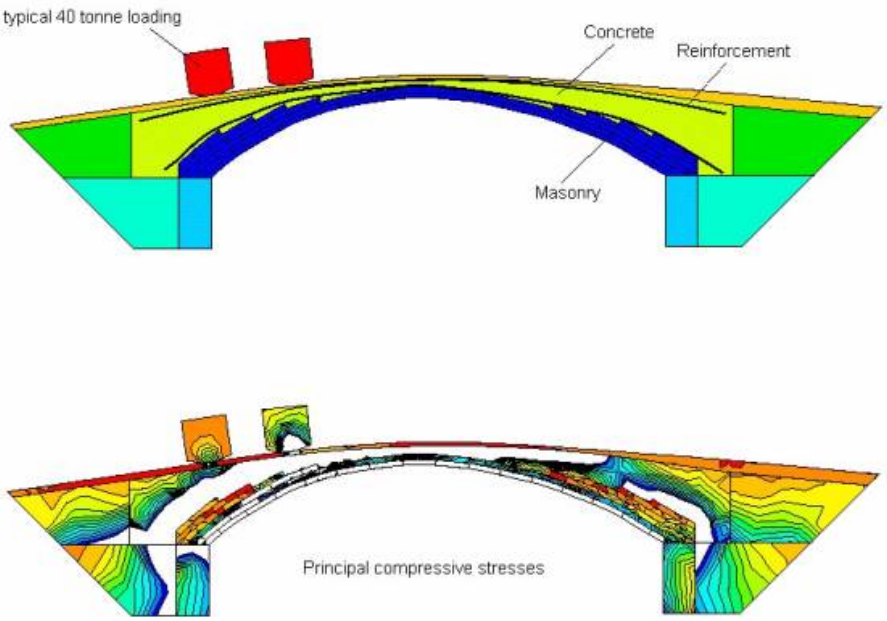
On this occasion one of the drilled holes broke through the soffit for a short length; this was subsequently made good. It was noted that for future work the reinforcement would be positioned so that drilling was less close to the surface. Also, for arches having friable materials such as sandstone or soft brickwork, the soffits should be treated beforehand using an approved consolidant to strengthen the surface locally without changing its appearance in any way. The consolidated material would then be sufficiently strong to stay in place where the drilling was close to the surface.

LYMM CANAL BRIDGE

Lymm Canal Bridge is in the Borough Council of Warrington and is a single brick masonry arch built over the canal with embankment approaches. This hump back bridge is skewed and tapered with a varying skew span between 8.7m and 11.4m. The bridge has been widened but more recently strengthened using a reinforced concrete saddle. During the construction of the saddle all of the fill and a number of brick rings near the crown had to be removed before concrete was cast directly onto the remaining brick barrel. The original assessment gave the bridge a 7.5 tonne live load rating. Both MEXE and the ARCHIE mechanism technique were used.

Lymm Canal Bridge

As part of the Archtec procedure, the strength of Lymm Canal Bridge was reassessed. It was recognised that the conventional calculations used to assess this bridge would not have been able to take account of the full composite behaviour of the saddle and the masonry arch. The bridge was certainly much stronger then the 7.5 tonne rating implied. To prove this a special assessment using the ELFEN discrete element technique was undertaken. The technique is unique to the Archtec team and is currently the only method of accurately predicting the true strength of composite arch barrels.



Discrete Element Numerical Model of Lymm Canal Bridge

Although copies of the original drawings of the saddle were available corings and trial pits were used to confirm the size and position of the reinforcement and to check the dimensions and condition of the concrete. Using this special assessment procedure it was possible to show that the bridge could carry full 40 tonne live loading and no further strengthening was necessary.

EXPERIENCE WITH ARCHTEC

Some 14 masonry arch bridges of various types have been strengthened during the past year using the Archtec method. A variety of problems have been successfully tackled; avoidance of congested utilities, dealing with friable masonry that can break away when drilling is close to the surface, and working from beneath the soffit. Interruption of traffic has been minimal and the strengthening does not change the appearance of the structures. Archtec is a state of the art system that provides an engineered solution to the 40 tonne challenge.