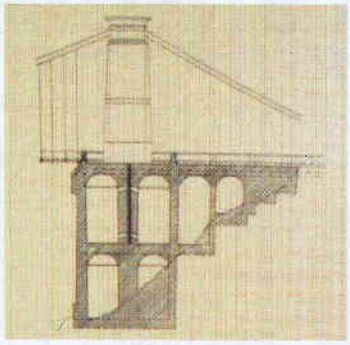
CLIFTON SUSPENSION BRIDGE

The Clifton Suspension Bridge is a grade 1 listed structure. It was designed by Isambard Kingdom Brunel and spans 214m (234 yards) from tower to tower across the Avon Gorge. Opened in 1864 it remains a testament to 19th Century engineering. Previously thought to be solid, in 2002, an electronic survey of the sandstone abutment supporting the 26m (28.5 yards) high tower provided evidence of 12 vaulted chambers. Arranged in two tiers - they are interlinked by narrow tunnels and shafts just 0.6m in diameter. The purpose of the chambers is unclear. However, with each chamber measuring on average 11m (12 yards) high by 15m (16.4 yards) long - they would have offered a considerable saving in material.

In order to gain a discreet access to these chambers and after engineering surveys confirmed that the abutment was structurally safe, work began on forming a permanent door for maintenance access. An exploratory core found the walls to be solid with an overall thickness of 1,800mm (70"). It comprises two sandstone skins with lime mortar in between.

In spring 2003, work commenced to form a doorway 12m (13 yards) below the level of the footway, approximately half way down the abutment where the wall returns to tie into the side of the gorge. The work began with the stitch drilling of 70 holes to a length of 1,800mm (70"), each with a diameter of 102mm (4"), in order to create an opening approximately 2,000mm (79") high by 830mm (33")wide.



Following this, 20 Cintec stainless steel rebar anchors were used to pin together the external and internal sandstone blocks cut through by the opening. These 16mm (5/8") diameter solid circular section anchors, measuring 1,500mm (59") long, were installed at an angle and at 300mm centres around the doorway. The anchors were inserted in 40mm (1 1/2") diameter predrilled holes, oversized to accommodate expansion of the anchor sleeve with grout. In order to maintain the aesthetics of the bridge the anchors were in set by 200mm (8") to ensure they would not be visible on the external sandstone face, achieving a sympathetic invisible bond around the new opening in the listed structure.

Falcon Structural Repairs of Portishead - UK, undertook the stitch drilling and anchoring to create the new doorway, it required eight days to cut the opening and just two days to install the Cintec anchors. The work was approved by English Heritage as well as the local planning authorities.

Chamber of secrets

When hidden chambers were discovered in one of the abutments of the world-famous Clifton Suspension Bridge in Bristol, engineers had to create a structurally stable point of access for inspection and maintenance.

The bridge is protected as a Grade I listed building – it was designed by Isambard Kingdom Brunel and opened in 1864 and is now owned by the Clifton Suspension Bridge Trust.

An electronic survey of the footway on the north side of the Leigh Woods tower in 2002 suggested the possible existence of a shaft extending down through the 52m-high abutment. A shaft had been found two years earlier on the south side, thought to be part of the drainage system. Excavation of the new shaft and subsequent investigation by abseiling specialists revealed much more.

The sandstone abutment supporting the 26m high tower at the Leigh Woods end of the bridge had been thought to be solid, but was found to house a honeycomb of 12 vaulted chambers. They are arranged in two tiers – an upper tier of seven chambers and a lower tier of five - and interlinked by narrow tunnels and shafts just 0.6m in diameter.

The purpose of the chambers is unclear; original plans for the bridge held by Bristol University do not show the design of the abutment. However, with each chamber measuring on average 11m high by 15m long - the largest being 17.25m by 5.6m by 10.8m high - they would have offered a considerable saving in construction material.

The Trust wanted to create a permanent access into the chambers, but because of the bridge's protected status, this had to be approved by English Heritage as well as the local planning authorities, Bristol City Council and North Somerset County Council.

After surveys confirmed that the abutment was structurally safe, work began on forming a permanent door for maintenance access. Firstly, an exploratory core was put through the abutment wall, which was found to be solid with an overall thickness of 1800mm. It consists of two sandstone skins: the outer measuring 600mm wide, the inner 300mm wide, with lime mortar in between.

Earlier this year, work started to form a doorway 12m below the level of the footway, approximately half way down the abutment where the wall returns to tie into the side of the gorge.

Patented structural anchoring technology to stabilise and reinforce the new opening was supplied by Cintec International, and Falcon Structural Repairs stitch-drilled the opening and installed the Cintec anchors, working as subcontractor to Nimbus Conservation.

A total of 70, 102mm-diameter holes were stitch-drilled to a length of 1800mm to create an opening approximately 2000mm high by 830mm wide. To pin together the external and internal skins of sandstone blocks, 20, M16 Cintec stainless steel rebar anchors, measuring 1500mm long, were installed at an angle and at 300mm centres around the doorway. The anchors were recessed into the opening by 200mm to ensure they would not be visible on the external sandstone face of the listed structure.

Cintec anchors consist of a steel section encapsulated in a mesh fabric sleeve or 'sock'. An oversize hole is drilled through the structural elements to be secured. The Cintec anchor is inserted and Presstec cementitious grout is pumped under low pressure through the anchor body into the sock. The use of a cementitious grout provides simple compatibility with original stone and brick materials.

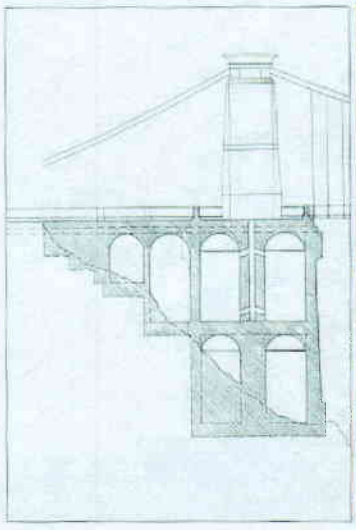
This flexible, polyester sock constrains the flow and moulds the anchor to the internal contours of the wall, providing a strong mechanical bond. The large surface area of the expanded anchor provides sufficient intrinsic reinforcement along its entire length without the need for unsightly patress plates on the exterior of the structure. Cintec's invisible mend is therefore particularly suitable for achieving sympathetic restoration work on listed structures.

The 16mm diameter solid circular section Cintec anchors were inserted in 40mm diameter predrilled holes, oversized to accommodate expansion of the anchor sleeve with grout.

After completing the stitch-drilling to open up the doorway in eight days, Falcon completed the Cintec anchoring process in just two.

Another advantage of the Cintec system is that it prevents delamination and movement of infill between masonry skins, without the need to stabilise using in situ concrete. While pinning the adjacent blocks together, the close spacing of the Cintec anchors effectively creates a bond around the new opening. This eliminates the need to bond the sides of the new opening using in situ concrete, which requires additional time-consuming and expensive work.

This represents a slightly unusual application for Cintec anchors, which are more commonly used to reinforce arch spans in bridges and viaducts in the form of a dedicated system called Archtec. Cintec anchor technology is approved by The National Trust, English Heritage and Cadw for the restoration of all types of listed structures ■



Below left: Cross-section of the abutment showing the chambers

Below middle: Cintec anchors were inset by 200mm into the drilled openings

Below right: The 20 Cintec anchors were installed around the perimeter of the opening before extraction of the sandstone