Works on the Clifton Suspension Bridge include rock bolting and *(opposite)* parapet stanchion replacement

ROCK STEADY

Securing the long-term future of one of the world's most iconic industrial-age bridges also involves maintaining the stability of its surrounding geology. Khalifa Bokhammas reports from site

Modern service life recommendations tend to be 120 years for major urban bridges on critical highways, and Clifton Suspension Bridge in Bristol, UK has already surpassed this, having stood the test of time for 157 years. Although sound engineering decisions taken during the bridge's design and construction have contributed greatly to its longevity, the importance of its maintenance over the years cannot be understated.

Since 1953, the Clifton Suspension Bridge Trust has been custodian of the structure and has been supported and advised by Cowi on all engineering matters since 2006. The non-profit charity is currently working with Cowi to deliver a five-year maintenance plan, a major part of which was in action beneath the Clifton tower on an overcast morning on 18 June.

Bridge users that morning may have mistaken the four technical rope access personnel suspended on the limestone rock face beneath the tower for recreational climbers, for whom the Avon Gorge is a popular spot. A closer look, however, would have revealed a large drilling rig between two of the personnel, all part of the preparations for drilling the first of 23 holes that will house 4-6m-long rock bolts.

The operation aims to secure the outermost layers of rock which help confine the inner column carrying the Clifton tower's foundation loads *(Bd&e Supplement 2021)* and is the culmination of years of research prompted by the Trust and undertaken by Cowi's specialist sub-consultant Geo-Design Consulting Engineers.

The company is specialist advisor to the Trust to assess the existing stability state of the slopes which support the bridge abutments, and has conducted surveying, geological mapping and borehole investigations since the question was raised 15 years ago as to whether there was any risk of rock slips in the gorge that might compromise the long-term future of the crossing.

"Previous maintenance schemes of the cliffs along the gorge have involved scaling, whereby any loose and vulnerable blocks were removed. But, because we want to preserve the condition of the slope, we're doing some active maintenance which will reduce the likelihood of larger slabs of rock coming off the face in the future," says Mike Summers, principal engineering geologist at Geo-Design.

"Rock slopes are always split up by natural fractures; those edges of the resulting slabs that are exposed can become quite vulnerable. The bolts will all be located on the edges of these slabs, and they're just there to preserve the edges, which is part of the overall maintenance strategy," explains Summers as he points out existing rock bolts that were put in by a Bristol City engineer in 1989. "We don't have any information on them other than a drawing in the Bristol City archives showing them, so there's no way we can assess their capacity or their condition given that they are more than 30 years old, but some of our bolts are going in close to the existing ones."

Prior to the main drilling activity on site on 18 June, temporary works (designed by Jubb) were installed, consisting of 2m-long temporary anchors to secure the cables and suspend the drilling rig. The latter was delivered to the top of a rock shelter on the northern side of the Clifton abutment before being hand-winched into position by rope access team Ibex Technical Access.

The company will install 23 rock bolts of 4-6m in length and 27mm in diameter at specific locations across the carboniferous limestone cliff beneath the Clifton tower throughout the summer.

Prior to their installation, a grout sock is attached to each bolt to mitigate grout loss into the joints and fissures. The bolts are then lowered into position from the bridge abutment. The need for the grout sock creates an extra challenge as it means having to assemble the whole bolt in the site compound and lower it down at its full 4-6m length rather than in smaller segments that are screwed together in the hole itself.

Once in place, cementitious grout is pumped into the sock from a compound set up next to the south side of the Clifton abutment. "Normally, you would have a cementitious diaphragm grout pump situated here, with manual controls," says Summers at the compound, "but we don't want any grout overflowing out of the hole and running down the slope, so there's a system with a smaller electric pump which they can shut off at the face, and this is part of the environmental controls on the project to limit the environmental impact we have." The entire bolt installation process, including drilling and grouting, will take roughly one day per bolt.

The other aspect of the works on the rock face is dentition of open joints, to prevent future vegetation growth and water ingress. This involves infilling naturally occurring gaps and voids between the rock joints with fibre-reinforced cement mortar. "There was a programme of vegetation and topsoil clearance done a few years ago as part of the maintenance scheme. Because of the ecological and botanical interest, we had a botanist survey the slope and have permission from Natural England [to undertake these works]," adds Summers.

According to Sam Wood, senior engineer at Cowi, the programme of

works on the cliff face is scheduled to last 10-12 weeks, with completion due by mid-September.

Other maintenance work that falls in the ambit of the five-year scheme includes the replacement of several parapet stanchions, the refurbishment of the hangers, the repainting of the chains and replacement lighting. The parapet stanchions are made of cast iron, rather than wrought iron like most of the original metal on the bridge, and 20 of them have developed cracks detected by magnetic particle inspections.

Work to replace them with spheroidal graphite cast iron replicas was due to get under way at around the time of the rock bolting but was pushed back until 19 July. "The work on the stanchions and hangers has been delayed due to Covid-19, as it requires a footway to be closed, and during lockdown we provided a one-way circulatory route on our footways for pedestrians, enabling people to cross the bridge while maintaining social distancing. Once the regulations are relaxed, we will need to close one of the footways again to continue with the work," says Trish Johnson, bridge master. "Any work that we do is of great interest to our visitors. We ensure our local neighbours are well informed in advance of any work and we have information boards detailing the work undertaken at the compound for visitors to read."

For the hangers, the 66 in the middle third of the bridge will be removed for inspection and refurbishment from 19 July. "They're all original, and in April 2009 one of them broke due to a fatigue issue. All the immediate issues were dealt with at the time, but what we will do is a continuation of the maintenance programme, so we will take the hangers out, strip them down, inspect them, check there are no defects in them, repaint and reinstall," says Wood.

The middle hangers will undergo this process since they are likely to have the greatest fatigue issues due to their stiffness compared to the hangers at the ends of the structure. "The longer hangers will similarly be released when the chains are repainted in the next couple of years to repaint surfaces that cannot be reached normally, but they won't be lowered to ground level. Their structural behaviour is different, so when the deck moves, the longer hangers just flex, meaning we don't have to do quite as much work to do on them," adds Wood.

Safeguarding the rock face and metalwork against future wear is key to retaining the historic fabric of the Grade I Listed structure for another 157 years, and the abundance of caution conspicuous in the approach to inspection, maintenance, repair and refurbishment on Clifton provide a fine example of how to manage ageing structures, let alone bridges ■