History and structural features

After many years of temporary repair, the decision was made to fully restore the wooden Ponte degli Alpini bridge in the Veneto region of Italy. *GDI* gains in insight into the complexity of the piling work needed as part of the project

Above: A steel frame work was used to support the wooden Ponte degli Alpini bridge while the two underlying bents were completely removed, allowing the construction of the remaining foundation micropiles for the starlings and the installation of the stainless steel truss structure supporting the bents

The Ponte Vecchio (Old Bridge), or Ponte degli Alpini is one of the rare examples of an Italian, fully-covered timber bridge. Located in the town of Bassano del Grappa, in the Veneto region of north-eastern Italy, it was built at the end of the 12th century over the Brenta River and was redesigned in 1567-69 by the famed Renaissance architect Andrea Palladio.

Over its history, it has been repeatedly destroyed and rebuilt, as a result of floods and war. The bridge was sabotaged and collapsed in 1945, during the last weeks of WWII, and then rebuilt in 1948 with the contribution of the Italian mountain infantry corps (called Alpini, hence the name Ponte degli Alpini). Severely damaged by a flood in 1966, it was rebuilt again and continued to undergo reconstruction and repairs, following the original design drawings by Palladio.

The Old Bridge is a timber structure of unique size and complexity at 66m long and 8m wide, it is divided into five 13m long spans. The load of the structure is supported by four timber pile bents and two masonry abutments. Each bent is made of eight oak timber piles, arranged in equal spacing and covered with horizontal timber planks called 'filagne'. The piles are connected on their top by a cap beam that supports the timber columns and struts connected to the bridge superstructure.

Before 1819, the timber piles forming the bents were standing directly in the bed of the Brenta River. The ground beam was a major structural innovation introduced by the post-Napoleonic reconstruction in 1819-21. With the introduction of the 9m long and 60cm wide timber beam, the number of timber piles forming the bent remained unchanged, while the number of piles driven into the riverbed and supporting the ground beam was increased to 15 per each bent.

This foundation concept was preserved over the years (and various reconstructions that involved repair, replacement or addition of the foundation timber piles) until the early 1990s. During 1990 four pairs of 8m deep drilled shafts capped with a stainless steel cover were constructed and connected to the ground beam to support the bridge bents. The load of the bents could thus be partly transferred on the drilled shafts, while part of the load was still supported by the timber poles driven into the riverbed during previous centuries.

Each bent includes one upstream and one downstream starling (rostro in Italian). The rostri are shaped to ease the flow of the water around the bridge, reducing the damage caused by erosion or collisions with flood-borne debris. The starlings are built of timber poles driven into the riverbed, topped by a sloping beam and covered on the sides with filagne to form an organic whole with the bents.

All the starlings were reconstructed after disastrous flooding in 1966, as well as the deck and the wooden superstructure of the bridge. At the same time, one 10.5m deep drilled shaft was constructed just upstream of each bent and connected to the cap

beam on top of the bent piles with two steel tie rods to improve resistance against the strong flow.

Despite all these measures, the horizontal loads of the water flow and the deterioration of the underwater timber elements of the bridge have caused, in recent years, critical deformations of the bridge foundations.

The reinforcing foundation elements introduced from 1965 to 1990 were no longer able to support, through the severely deteriorated timber ground beam, the vertical loads transferred from the four bridge bents.

Starting in 2013, the sinking of the bridge structure became evident. In the summer of 2015, the bridge was sinking by an average of 4-5cm per month, putting the bridge at serious risk. The further collapse of one of the bents in 2018 caused the bending of the bridge. Temporary works were deployed to prevent further damage and avoid the closure of the bridge. Major restoration could no longer be postponed.

THE PROJECT

The project is part of the strategic plan launched by the Italian Ministry of Cultural Heritage and Activities and Tourism in 2015. It is one of the most complex reconstruction projects currently underway in Italy, with a total value of over €6 million (US$7.1 million). It involves the reconstruction of all parts of the Old Bridge, with the focus on the structural aspects.

The goal of the project is not only to guarantee the load-bearing function, but also to obtain an overall improvement in the structural behaviour of the bridge where it is exposed to the stresses of water flow and seismic activity.

Instead of adopting a purely conservative approach, based on the addition and repair or replacement of timber piles, the project has introduced into the bridge's foundations some innovative elements made of state-of-art materials.

The load of the timber bents is now transferred to the ground through an 11.5m long and 1.2m high stainless steel truss structure weighing 7t. The truss rests on top of the eight drilled shafts built in 1990 and on two new concrete plinths supported by micropiles (one upstream and one downstream of each bent). In this new foundation design, the truss replaces the deteriorated 19th-century timber ground beam that lost its load-bearing capacity. Six steel bracing rods that connect the ground beam and the cap beam of the bent piles are added on each side to improve stability of the bents and their resistance.

Further foundation works focus on the starlings: due to the poor state of preservation of the timber piles, they will be replaced by micropiles with permanent stainless steel casings in the upper section. The portion of the starlings above water level will be rebuilt using new timber as well as original timber where possible.

The tie rod connection between the cap beam of the bent piles and the drilled shafts located upstream of each bent will be also be restored with the addition of a steel profile reinforcing the sloping leading edge of the starlings and protecting the tie rods.

The new steel elements introduced by the project will remain under the water level and/or hidden from view thanks to the filagne covering the bents, which will be reconstructed according to original specifications. In this way, the project aims to tackle the structural problems that have endangered the bridge throughout the centuries, while preserving the original form and character of the iconic masterpiece by Palladio.

THE FOUNDATION WORKS

Works for the new bridge foundations began in November 2018 on the east banks of the river. The particular difficulty posed by the engineering works was that they had to be planned, designed, operated and maintained in a challenging fluvial environment located in the historical centre of Bassano. The bridge serves as an essential connection between the west and east ends of the town and is an attraction for tourists from all over the world. It was, therefore, a mandatory condition that the bridge should remain open for pedestrian crossing during the execution of the works, with temporary disruptions kept to a minimum.

The bridge stands on an alluvial plain, characterised by the predominant presence of gravelly sediments in a sandy matrix with occasional sands and gravels of fluvioglacial origin in the upper layers. Hydrological conditions suggested limiting construction operations time, splitting the schedule in two years.

Construction works in the riverbed were only allowed in the period between December and April, when the water level drops and the risk of flooding is lower. A cofferdam of earth and rock-fill was set up from the banks upstream allowing the river flow to bypass the foundation area. Water was pumped out to create a dry working environment.

The contract for the execution of the foundation works was awarded to Micron Srl, based in the nearby Trentino region. In the first time frame (from December 2018 to April 2019) works were carried out on the two bents of the left bank of the Brenta River.

After temporary works were put in place, the project posed immediately one of its biggest challenges: the construction of a supporting framework for the bridge superstructure. The steel framework permitted to remove the bents for the time needed for ►

"The project aims to tackle the structural problems"

After years of water erosion the bridge's original wooden foundations were so weak the bridge was beginning to sink

After installation, the new steel micropiles were then clad with wood to replicate the look of the bridge's original design

the installation of the new bridge foundations. At the same time, it allowed straightening of the bent bridge, bringing the deck back to its original height.

A series of micropiles with a diameter of 250mm were installed to a depth of 8m to support the steel framework and hydraulic jacks used for the lifting operations. After the steel framework was placed under the bridge deck, the lifting was carried out using 12 jacks. Thanks to electronic control units, the lifting was accurately performed at millimetre intervals, acting simultaneously on two bents in diversified steps.

"The bridge was brought back to its height in February 2019. Lifting operations started on Tuesday morning and were completed Wednesday in the afternoon. These were the only days when the bridge remained closed. The deck could be lifted 28cm on the first bent and 48cm on the second one, causing no damage to the bridge superstructure," says Nicola Capasso, owner of Micron Srl.

RIG CHOICE

With the steel framework supporting the deck, the two underlying bents were completely removed, allowing the construction of the remaining foundation micropiles for the starlings and the installation of the stainless steel truss structure supporting the bents. A total of 50 micropiles cased with stainless steel tube in the upper section were constructed to accommodate the timber poles of the starlings.

"The timber for the reconstruction was partly recovered from the original bridge"

The micropiles were installed using DTH drilling method with a Comacchio MC 22. Double drill strings were connected through a casing top driver on the rotary.

"Our choice fell on this type of rig due to its high production rates," explains Capasso. "A major advantage was given by the patented Comacchio cuttings diverter. Since the space on site was limited and there were many different teams involved at the same time, it was important to ensure that the drilling cuttings were kept under control.

"Obviously, operating in a fluvial environment, you always have to deal with the variability of the river flow. Part of the foundation design was modified after the storms that almost caused a flooding of the Brenta River and lowered the riverbed level in the autumn of 2018. Then, during the execution of the works, the heavy rains in early February 2019 flooded the construction site, just a few days before the date set for the lifting of the steel framework supporting the bridge. The water had to be pumped off-site and the lifting operations were postponed for a couple of days," remembers Capasso.

Once the new foundation elements were installed, the project moved to the next stage: the complete reconstruction of the two timber bents and four starlings.

The timber for the reconstruction was partly recovered from the original bridge elements, while part was supplied new. Parts that were of crucial importance from a structural point of view and/or are very exposed to the water flow and/or difficult to access for maintenance and repair were replaced. The use of new timber elements was kept to a minimum for the parts of the bridge above the water level. To allow this, an extensive survey was carried out by specialised technicians before construction began. It identified the wood species and the resistance class and the degree of humidity of all the timber elements of the bridge, and to map the extent and rate of their degradation.

The second time frame to which foundation works were restricted went from December 2019 to April 2020, involving the two bents on the west bank of the Brenta. Their reconstruction entailed fewer difficulties, thanks to their better state of preservation.

Just as like the year before, a cofferdam was first built in the riverbed upstream of the bridge and the same steel supporting frames were used to remove the bents and install another 50 micropiles, with the same technology adapted the previous year on the east side bents.

The construction works went on during the spring, despite the coronavirus outbreak. New safety protocols were implemented to reduce the risk of infection but work never stopped in the bed of the Brenta River. The temporary restriction of the river flow caused by the cofferdam had to be kept within the established time frame, in order to avoid risks of flooding in case of heavy spring rains.

By mid-May, the bents were completely restored and the cofferdam removed, thus definitively closing the operations in the riverbed. Reconstruction of the deck, of the balustrades, columns and the trusses went on during the summer, working step by step in order to avoid the closing of the pedestrian crossing. The plan is to complete the project by the end of March 2021.