QUICK FIX

Replacement of an old wooden bridge in St Petersburg was completed earlier this year. Tatiana Gurevich and Yuri Krylov report

Rising traffic levels and development demands led to an old tramway bridge being rebuilt as a cable-stayed crossing in the Russian city of St Petersburg. The new Lazarevsky Bridge across the Malaya Nevka was opened to traffic earlier this year, replacing an old wooden structure which was built for trams but recently had only been used by pedestrians.

The bridge is located in Petrograd district and connects Krestovsky and Petrogradsky Islands along Pionerskaya and Sportivnaya Streets, both of which are importanat links for local traffic. When it was built in 1949, the crossing was called the Koltovsky Bridge, after the adjacent Malaya Nevka river embankment. But in 1952, it was renamed to commemorate the legendary Russian admiral Mikhail Lazarev. The embankment and the bridge were redesignated the Admiral Lazarev Embankment and Lazarevsky Bridge respectively.

Built to the design of engineer VV Blazhevich, the original bridge had 11 spans, the central one being a single-leaf drawspan. It was originally designed for trams and was the only tramway bridge in the city at that time. Its total length was 141m and its width was 11m, the deck consisting of metal baulks and wooden plank flooring. The timber post piers rested on piled foundations of steel pipes. But in 2002 the tramway was closed and since then, the bridge has only been used by pedestrians.

Its location meant that Lazarevsky Bridge served the western part of the city – the Petrograd districts including Krestovsky island. All the road traffic to Krestovsky island used the main Krestovsky Bridge which as a consequence was considerably overloaded. Since the Lazarevsky Bridge carried no vehicular traffic it was not considered part of the road network of the district. But plans to build a new stadium at the Seaside Victory Park on Krestovsky Island just 3km from the bridge site meant that a reliable transport connection to the rest of the city was required. The local authority decided that reconstruction of the Lazarevsky Bridge was the best way to provide this.

The size of new bridge was determined based on the predicted traffic levels, taking into account the prospective development of the district. According to the forecast, the annual average daily traffic intensity on Lazarevsky Bridge will rise to 16,000 vehicles per day by 2025. Peak loads occur during major sporting events at the stadium when the bridge will be required to help relieve the area of traffic within one hour. This traffic flow includes 4,500 to 5,000 cars, so even if the Petrovsky Bridge were to be rebuilt, the Lazarevsky Bridge needed two lanes of traffic in both directions in order to do this.

Taking into consideration the fact that the timber structures of the bridge had been in use for more than 55 years, if the bridge reconstruction had been restricted to the widening and strengthening of the existing superstructure and piers, it would not have ensured the longevity of the fixed bridge and might have led to high operation costs. Another consideration was that the appearance of a multi-span structure with bulky piers would not have fitted into the architectural style that is emerging with construction of modern buildings on Krestovsky Island and the adjacent embankments.

As a result, the decision was taken to completely demolish the existing bridge and replace it with a new structure on the same alignment. As part of the project, some of Sportivnaya Street on the right bank had to be widened, and improvement of the adjacent area was also included.

The history of the project dates back more than a decade to 1998, when JSC Institute Strojproect won the tender to carry out a feasibility study into the reconstruction of Lazarevsky Bridge and its approaches.

Even at this time, the architect Igor Serebrennikov had developed an original architectural concept of the bridge which involved use of a cable-stayed system. This concept was approved by the city's committee for development but financial problems meant that the design was suspended for seven years before it resumed.

In 2003, the project was included in the target programme of design and survey works, and the tender for design development was officially announced. Again these works were awarded to JSC Institute Strojproect. The reconstruction design was completed in 2007 and was received positively by the State Expert Review Board; construction began at the end of that year.

The structural concept of the bridge was approved based on the comparison of technical and economical options. One of the main restrictions was the strict limitation on the superstructure construction depth. On the one hand, it was limited by the need to maintain underbridge clearance for navigation, while on the other hand the deck level was governed by the height of Admiral Lazarev Embankment, which could not be raised, according to the requirements of the committee for protection of monuments.

To meet these almost incompatible conditions it was necessary to make the longitudinal profile of the deck with a vertical curve of radius 1,000m, a radius which is allowable only for very constrained conditions. But even with this minimum vertical curve radius, the limitation for the deck construction depth remained fairly strict – it had to be 1.4m at the maximum. This condition could be met either by a classic five-span continuous beam scheme or by a cable-stayed system. The costs of both options are practically the same but the cable-stayed option was preferred as it was considered more attractive from the architectural point of view. Another benefit was that it would take less time for construction as there was no need for intermediate piers to be built in the river bed.

The unconventional appearance of the structure, particularly the shape of the tower and its asymmetric arrangement with its single span, put demands on the design abilities of the engineers from JSC Institute Strojproect, requiring them to cope with non-standard problems. One such problem was the need to provide the required rigidity to the deck while at the same time minimising its weight in order to decrease the moments in the tower elements and balance the system. Hence a single-span cable-stayed bridge with steel deck, orthotropic carriageway slab and a steel tower was selected for construction. The deck is supported by two rows of stays, with five stays in each row. The cable stays pass through the tower and are anchored in the reinforced concrete slab of the counterweight which is located beyond the bridge abutment on Krestovsky Island. The front arch of the tower, which is inclined towards the riverbed, carries the dead anchorages by which means the cable stays and backstays are secured. Tensioning of both sets of cables was carried out by means of active anchors located at the deck and in the counterweight slab. To minimise the total width of the deck, the anchorages are removed to the front surfaces of the main beams. The optimum force distribution in the tower elements was obtained by means of the arch shape that became sharper and elongated in the transverse section of the bridge.

The deck consists of a system of longitudinal and transverse H-beams connected via the orthotropic slab with its U-shape stiffeners. The anchorages are located along the transverse beams. At the tower, the deck is rigidly fixed and at pier one it rests on Maurer spherical bearings. The steel part of the deck is made of low-alloy steel grade 10 and 15 and the tower of steel grade 10 (400MPa).

The cable stays are VSL standard monostrands and each one is made up of from 50 to 73 strands. The total length of strand used in the bridge is about 31km.

Meanwhile the bridge deck pavement consists of two layers of asphalt/concrete 40mm and 50mm placed over the Technoelastomost-S membrane waterproofing layer.

The pier foundations are formed of high pile caps resting on bored piles driven deep into the bearing stratum of firm clay. Above the foundation top, the piers are made of cast in situ concrete and faced with granite.

Construction was carried out by Mostootryad No 75, a branch of OAO Mostotrest No 6, while the steel deck structure was manufactured by JSC Zavod Metallokonstruktsiy and the steel tower structure was manufactured by NPO Mostovik.

For development of the detail design the specialists of automation division of the Institute prepared complex 3-D models of the tower and cable stay anchorages in PRO-E software which were used for analysis and as a basis for the fabrication of the structures by NPO Mostovik. The use of this successful PRO-E modelling enabled the complicated tower structures to be manufactured within a relatively short time.

The bridge under construction showing temporary supports

Taking into consideration the constraints imposed on the bridge construction, JSC Institute Strojproect suggested some modifications to the detailed design. One such proposal was to replace the cable backstays of the tower with rigid ties made of low-alloy steel grade 10 which would be fixed rigidly at the tower arches and counterweight. Temporary supports would be installed under the deck anchorages

These modifications allowed the erection of the back-stays to be considerably simplified, and would also eliminate the need to tension the backstays, cutting in half the time for the cable-stay installation.

In addition it meant that the cable-stays supporting the deck could be tensioned in a single operation, once the asphalt and concrete pavement had been installed on the bridge. Analysis included successive tensioning of cable-stay pairs from the longest pair down to the shortest pair with the subsequent final tensioning of the two longest pairs. Apart from the forces, the vertical displacements of the deck at the 'breakaway' points on the temporary supports had to be controlled. The actual tensioning works were carried out in compliance with the design solutions. The data on the forces and displacements at each stage were handed over by the general contractor to the designers, and if necessary, the required corrections were introduced to the design. On the whole, the calculated data showed a high correlation with the actual parameters.

In fact it took the general contractor only 17 months to complete construction of all the works involved in the bridge construction. The new cable-stayed bridge has fitted harmoniously into the surrounding landscape. By avoiding placement of intermediate piers in the riverbed it was possible to open up views along the Malaya Nevka. The arch tower acts as a symbolic gateway to the island and stands out distinctly against its background of sky and trees. The architectural expressiveness of the bridge is determined by the general asymmetrical composition and the dynamic shape of the tower formed by two inclined arches, a light and gently-curved deck, and the elegant outline of the cable stay arrangement. At night time, the appearance of the bridge is highlighted by architectural lighting

Tatiana Gurevich is project manager and Yuri Krylov is head of the structural steel department at JSC Institute Strojproect