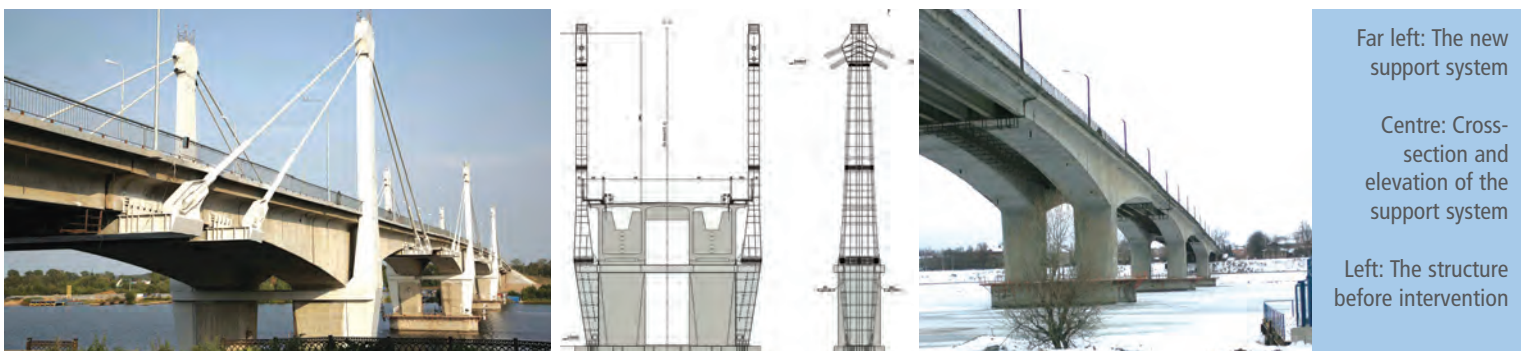


FINDING NEW STRENGTH

Strengthening of a defective bridge in the Tver region of Russia involved installation of new towers and cables to support the main spans. **Alexey Surovtsev** and **Yury Devichinsky** report



Far left: The new support system

Centre: Cross-section and elevation of the support system

Left: The structure before intervention

An unusual strengthening method has been used in Russia for the first time, on a concrete bridge over the River Volga, which was suffering with excessive deflection due to problems with the original design codes. The bridge in Kimry, north of Moscow, is located on the shortest route between Tver and Yaroslavl and carries motorway connections that link some of the main cities of the region to Moscow.

The crossing was built in 1978 and has two main spans of 128m length, two side spans of 80m, and two approach spans of 18m at one end, and three of 32m at the other. The road width is 15m and it has pedestrian walkways, one at each side, each 2.25m wide. In plan view the bridge is arranged on a straight alignment and in elevation it has a gradient of 0.05 to 0.40%. The length of the riverbed and flood plain is 554m. The total length of the crossing including the approaches is 905m. The river is crossed by spans which consist of T-shaped box frames – each 95m long - with 33m-long drop-in spans which are connected by hinges to the cantilevers of the box frames. On the right bank of the river, the approach structure which crosses the flood plain has three spans of 33m and a buried abutment. The intermediate piers of the bridge, which are on piled foundations above the level at which ice floes are predicted, consist of two columns, one per box. Lighting columns are on both sides of the carriageway beyond the kerb stone, in the footways. The two main 128m-long spans serve as navigation spans.

Soviet standards that were developed in the 1960s, and were used to design this bridge, allowed for levels of compressive stress that were too high for the concrete grades of the time and did not correctly predict the creep value. Consequently, most large-span prestressed concrete bridges built at the time are now suffering with unacceptable deformation. In this case, the box beams had sagged more than 300mm and the deterioration this caused in the concrete in the lower slab required immediate action.

When the structural defects were identified, engineers decided that strengthening of the bridge was urgently required, and a reduction in traffic speed limit and increase in spacing of vehicles had to be imposed. The rate of deflection of the midspan of the structure had risen to almost 20mm per year between 2001 and 2005, with its total sag over the 21 years of operation having reached 400mm.

Driver comfort was badly affected by the considerable deflection of the structure, and

the bottom flanges of the T-shaped frame box girders were in an unsatisfactory state, with reinforcement bars deteriorated, and the concrete overstressed. Before the start of reconstruction a detailed survey was carried out on the bridge using non-destructive technology including vibration diagnostics.

The Russian Scientific Research Institute of Transport Construction Industry carried out the vibration diagnostics survey with the aim of estimating the actual behaviour of the bridge structure and defining the value of the integral prestressing of the box beams and the status of the piers. The diagnosis recommended that heavy loads of more than 20t should not be allowed to travel along the bridge centre-line.

The losses of prestressing in the tendons of the box beam deck had reached up to 30% due to the strain in concrete and glued joints. Moreover, the assessment of the durability of the cantilevers and suspended beams showed that without repair, and with existing traffic levels, the structure might reach a 'pre-emergency' state in just a couple of years, with all the beams of the cantilever part of the deck in terms of ultimate limit state.

Two main rehabilitation strategies out of five alternatives were reviewed by consultant Institute Strojproect under a project that started in 2004; engineers were limited in their options for a bridge under such conditions. The compressive stresses in the support zone of the cantilever in the lower slab of the box beam and the tensile stresses due to the lateral force in the web exceed the bearing capacity of the material in most cross-sections. Under different load combinations, this also applies to the upper slab of the box beams. It is necessary to add structural elements that can accommodate a considerable proportion of the forces and in this way, raise the sagging spans.

The first bridge rehabilitation strategy proposed replacing the reinforced concrete suspended beams with steel ones to reduce the dead weight, installing additional stressing tendons inside the boxes, levelling the elevation profile of the top slab using lightweight concrete, and strengthening of the box walls and bottom flanges as well as a number of activities aimed at repairing cracks. The works had to be carried out in two stages without disrupting the public and pedestrian traffic.

The second option involved converting the existing structural form to a balanced cable-stayed system, strengthening of the T-shaped frame cantilevers and creating a system by which the forces would be transferred via the cable stays to the new towers.

The second option was chosen, as it had all the advantages. It was much cheaper than the other options, enabled traffic operation to be maintained on the bridge throughout the whole reconstruction period and predicted that the sagging would be considerably decreased – a prediction which was confirmed after construction. The main structural elements of the original bridge only required cosmetic repairs, with the main work being carried out to the most critical zones at local level. The work was carried out by contractors DTF Mostootryad-90 and OAO Mostotrest and cost approximately €13 million.

Three pairs of new towers were installed at the three main piers, from which cables provide support to the two main spans, and the adjoining side spans. These were installed to rest directly on the existing pile caps of the riverbed piers, both on the upstream and the downstream sides. The steel towers are 37m high, have a variable cross-section and are strengthened with stiffeners. The bottom part of the tower rests on the pile cap of the existing pier and is connected to the pier by anchors. The head includes the fixed anchors of the cable-stay system.

Steel transverse diaphragms, or pick-up beams, were installed under the T-frame cantilevers, in order to transfer the forces from the spans to the cables. Due to the presence in cross-section of two T-shaped frames connected by the carriageway slab it was a complicated task to ensure an even force distribution across the pick-up beams. Under each pair of cable stays a dedicated pick-up beam was installed with individually defined characteristics of flexural and tensional stiffness. At the initial phase of cable stay tensioning, the forces from the pick-up beams were transferred to the two internal walls of two concrete box beams and only when the desired prestressing force was achieved, the outer walls of the box beams could be wedged. A cable-stayed system from Vorspann-Technik was used for the project. The VT31-150 stay cables are placed close to the towers, with VT55-150 stay cables further away.


The sequence of cable tensioning took into account the fact that no load-bearing rebars were present in the lower slab of the boxes and that no tensile forces could be allowed in

the concrete at any stage of reconstruction. The balanced tensioning of the cables started with those adjacent to the towers and then the ones furthest away and was performed using strand by strand tensioning to help avoid torque in the towers.

Two stages of traffic management were all that were needed to implement the works; the first stage of reconstruction took place with traffic on the bridge centre-line. During the second stage the traffic moved to the two lanes located on the upstream and downstream sides of the bridge.

Great care had to be taken during tensioning of the stay cables as any negative stresses occurring in the bottom flange of the concrete box frames cantilevers might have caused an immediate loss of stiffness. For this reason, continuous monitoring of the bridge had to be carried out to obtain reliable data on the level of the stress increment in the bottom flanges. The design stresses and the measured stresses were more or less identical.

The new cable-stay system helped to even out the stresses in the top and bottom edges of the T-shaped frame cantilevers that were caused by dead loads, and partially level the elevation profile by raising the cantilevers by an average of up to 100mm. As part of the rehabilitation work, the hinges of the suspended spans were repaired, as were the beams of the flood valley spans. Levelling of the elevation profile on the suspended superstructures was completed using lightweight concrete reinforced with nano-modified basalt microfibres and fireclay hollow microspheres as aggregate.

Thus, in the process of reconstruction the tasks of improving the elevation profile of the bridge and evening out the stresses in the structure were successfully carried out. The adopted system made it possible to increase the load-bearing capacity of the superstructure to the value required to accommodate the current loads. As a result, all traffic limitations could be lifted. The bridge was reopened to traffic at the end of last October 

Alexey Surovtsev is deputy to the general director, and technical director of Institute Stroiproect; Yuri Devichinsky is chief project engineer.