Bridge Repair by External Prestress: The Gibe Crossing in Ethiopia

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Summary

The Gibe bridge is located between Addis Ababa and Jima along the homonymous highway connecting the two Ethiopian cities. The bridge is made of a continuous, 4 span, reinforced concrete girder of 120m length and 9.6m width. The structure has 4 longitudinal beams, of variable height, connected by reinforced concrete diaphragms at piers, quarter spans and midspans.

The bridge, built in 1976-1977, suffered major damage from a terrorist bombing in the 80's. The bombing caused the collapse of a whole section of the deck that had to be re-cast in situ. The bridge has been used since then with load restriction with an alternative crossing available a few hundred metres downstream along the old road built by the Italians in '30. This latter crossing was an old steel truss girder built by the English in the '40 that collapsed in the fall of 2006 when a dozer crashed into the upper bracing of the main steel girders causing the spectacular collapse of the whole structure. Rehabilitation and strengthening of the concrete bridge became, all of a sudden, vital and urgent as it stands as the only connection between the agricultural South Western region and other parts of the country.

The Ethiopian Government contacted Salini Costruttori SpA, a contractor presently engaged in constructing hydropower projects in Ethiopia, with a request for technical assistance. Salini Costruttori SpA decided to perform the bridge strengthening as a contribution to the Country, and asked Integra to devise a fast, reliable and economic method to carry out the operations. The proposed solution makes use of external prestressing to increase the girder strength by closing the extended crack pattern and reducing bending and shear forces in the deck. The works, performed while the bridge was in service, were completed in three months and the bridge opened back to traffic without load restrictions in November 2007.

Keywords: concrete bridge retrofitting, external prestress, shear resistance.

The strengthening design

The severe damage suffered by the Gibe bridge deck would not allow for a simple retrofitting aimed at repairing cracks and spalled area. The lack of alternative crossing also called for a strengthening solution that could be implemented with the bridge open to traffic. Since the piers and foundations were in good shape, a screening of the different options was therefore carried out in order to identify the most simple and cost effective solution to strengthen the deck. The continuous deck configuration with variable height suggested the use of external prestressing as the most effective means to counteract bending and shear forces due to dead and live loading while introducing compressive stresses to seal the beam shear cracks. The deck depth and the diaphragms

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provided an optimal configuration for the cables to be deviated using steel saddles fixed to the concrete structure. Six cables with 12 (06”) strands could be easily spun under the deck, two on each side of the internal beams and one each on the inner side of the lateral beams. The cables are continuous over the whole length of the deck (120m circa) and anchored on the deck slab near the abutments. Cables are deviated using steel saddles and steel pipes directly glued onto the existing concrete sections. Only in few cases (mainly at the anchorages), additional cast in situ concrete blocks were required to allow for a safe transmission of the cable forces to the existing concrete sections.

Special care has been taken in the correct positioning of the deviation elements. Previous experiences suggested to check their correct positioning using a nylon rope before the saddles were glued and the strands were spun. Forces arising from strands jammed into the deviators can be as high as the tensioning force and therefore much higher than the local resistance of the concrete section. This was certainly the case for the Gibe bridge diaphragms that are insufficiently reinforced and therefore could only take the upward design deviation forces and would not bear any tangential ones. The 6 cables tensioned to 1000 MPa apply a total compression force of 1000 ton. The vertical component at the deviation points varies between 20 to 30 ton (upwards) for the 4 intermediate diaphragm along each span and from 70 to 110 ton (down-wards) at piers and abutment.

The combined action of bending moments and axial forces induced by the external prestressing suffice to counterbalance the permanent load effects. All sections along the deck are therefore fully compressed under dead and permanent load alone. Strengthening by post-tensioning is also particularly efficient with respect to shear because of the force vertical component of the inclined cables and the frictional contribution to the concrete shear resistance provided by the compression forces.

The principal advantage of the adopted solution is the extreme simplicity of its implementations. The steel saddles and deviation pipes were manufactured in shop and brought to site fully finished. The design of such pieces was optimized so that could be handled by two persons (max 80 kg). Installing of the saddles only required epoxy resin and small fasteners to hold them in place before the resin hardened and the prestressing forces pushed them against the concrete section. From the Gibe experience the following conclusion can be drawn:

- Concrete structures do often have large strength reserve, sometimes underestimated by the current codes. These strength reserves can be used when retrofitting damaged or deteriorated structures prolonging their service life.
- Strengthening of concrete structures by external prestress is generally very efficient. These structures, even when severely damaged, do benefit from a dramatic increase of strength when prestressed. The same beneficial effects are hardly obtained without prestressing as with standard FRP applications.
- Use of steel carpentry to couple the concrete structure to the external tendons is particularly efficient a sit is both robust and ductile. Installation is also easy, fast and cost efficient.