Investigations on a degraded suspension bridge: damage characterization and rehabilitation

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Summary

This paper describes the experimental investigations and the planned rehabilitation programme of Teil Bridge in France. Soon after the sudden rupture of a cable near the anchorage, the bridge was closed to traffic. Inspections were carried out to understand the sources of this event and to assess the performance of cables and strand sockets. Prior to rehabilitation, the bridge safety was improved by strengthening each socket; the bridge was then re-opened to pedestrians and cyclists only. An acoustic emission system was installed during a full year period; events related to cable ruptures were accordingly monitored. Meanwhile, several other experimental investigations on steel and concrete materials (resilience, tensile steel strength, carbonation and chloride ingresses) were led to estimate the residual structural service life of the bridge and to plan repair actions. A major rehabilitation program was then scheduled with the change of all cables and sockets. This paper presents the different stages of these investigations and the rehabilitation process.

Keywords: Suspension bridge, cable rupture, acoustic emission, strengthening, rehabilitation.

1. Investigations and temporary safety measures

Fig. 1: The Teil bridge

The Teil bridge is a suspension bridge, built between 1947 and 1949; it carries the national road RN102 and crosses the Rhône river and the RD86 trunk road (Fig.1): it connects the Teil and Montélimar cities and 15,000 vehicles are using the bridge every day.

The bridge is 317 m long with a central span of 235 m and two simply-supported side spans of 41 m. The suspension is divided in two arrays of 16 (2×8) strands (Ø82 mm) composed of 217 steel wires (Ø4,73 mm). Two additional cables (157 wires, Ø61 mm) are installed on the side spans. The hangers are bars (Ø39 mm) for 15 short hangers, and cables (Ø40 mm-80 wires) for 28 long hangers. 43 hangers are installed on each cable array, spaced every 5.29 m.

The reinforced concrete slab deck is 9.30 m large and 18 cm thick: it is supported by two lateral riveted beams (2.4 m high) and the pylons are 27 m high.

On the morning of September 11th, 2007, the rupture of a cable was detected on the upstream right bank, roughly 4 cm inside the cable socket (Fig.2). The analysis of the wires in the broken area

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confirmed the presence of corrosion due to the deficiency of the socket sealing (defective zinc filling). The rupture was not subsequent to an overloading event.

Fig. 2: Broken cable

The bridge was immediately closed until to get appropriate safety decisions. The socket where the rupture occurred (No. 5, upstream right bank) was inspected to analyze the fracture surface. It comes that pitting corrosion is present over the full length that is not protected by painting.

The re-assessment studies had for objectives to check the stability of the bridge under live loads (assuming the rupture of a strand) and to verify the opportunity of repair actions. This consisted in calculating the safety coefficients of the degraded bridge, enhanced by a fatigue analysis of the steel structure. It comes that the safety coefficients are below 1.00 when more than two cables are broken. These results do not include the dynamic effects during a cable rupture, and assume the good condition of the other cables and their capacity to carry strength.

From these results, it was decided to re-open the bridge to pedestrians and cyclists only, re-opening to vehicles being postponed after strengthening. Re-opening was conditioned by the installation of a health monitoring system on the bridge. An acoustic emission system and anti-whipping devices were therefore installed on the bridge to prevent any rupture. In addition, an anti-whipping device was installed on the cables close to the anchors. It is composed of steel components that connect four cables together. This device has for purpose to avoid any cable whip that may cause injuries to pedestrians or vehicles on the underneath road. In the same time, sockets were reinforced by jaws that help to redistribute loading over the full socket block.

2. Rehabilitation of the Teil bridge

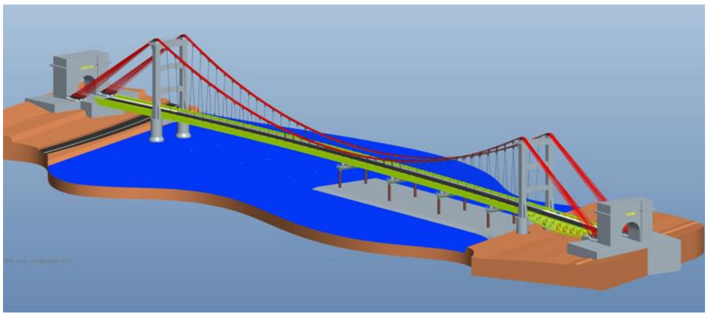

Fig. 10: General view of the bridge and temporary supports

Several options were analysed for the rehabilitation or the replacement of the Teil bridge. It was decided to replace the suspension cable by adding temporary supports. The construction of temporary supports has required the use of a dike par half-span in order to maintain an appropriate waterway. Each dike has facilitated the construction of a working platform for installing the piles, the crossheads and the stiffening trusses. The load sharing between the crossheads and the stiffening trusses is done by a load distribution beam that authorizes the load transfer compatible with the allowable stresses in the riveted structure. This induced to strengthen the webs to avoid any buckling. The disassembling operation for cables has firstly consisted in adding cables at the top of the pylons to ensure stability during works stages. The new stranded cables are made of galvanized steel wires. The sockets have been mounted in the factory by mechanical welding with a thick steel plate. The tensions in the new cables were adjusted to get the right geometry of the deck and the suspension cables and identical tensions in the hangers.