Media communiqué

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Empa technology will keep the longest cable-stayed bridge in the world from severe vibrations

A smart cable damping system for cable-stayed bridges

Technology transfer to the Far East: in January Empa researcher Felix Weber and his industrial partners tested for the first time their newly developed, smart cable damping system on site. The "smart" damping system adjusts optimally the damping force to the actual vibration amplitudes and stay cables properties. It is designed to prevent the cable-stayed Sutong Bridge over the Yangtze River from dangerous cable vibrations. The cables are up to 540 m long since the Sutong Bridge has the largest free span - 1080 meters between pylons - of any cable-stayed bridge in the world.

Severe cable vibrations result from combined wind-rain effects and traffic. In March 2005 and 2006 during strong winter storms, the 222 meter long stay cables of the Franjo Tudjman Bridge nearby Dubrovnik, Croatia, vibrated with estimated amplitudes of 1-2 meters. This caused damage on the cable shell and even on some strands. As a result, the load capacity safety of the cables and therefore of the bridge were reduced. In cooperation with the industrial partner Maurer Söhne of Munich, Empa has developed an adaptive cable damping system. It consists of feedback controlled magnetorheological fluid dampers (MR dampers) whose damper force depends on actual vibration amplitude. The amplitude is measured by a displacement sensor at damper position. Based on that signal and in combination with cable properties, the micro controller calculates the optimal damper force which is imposed to the MR dampers. This ends up in a damping system that provides maximum damping to the cables for the entire expected vibration range. Moreover, the damping system may be called failsafe since MR dampers also produce a certain amount of damping during a power break down.

The controllable damper force range is designed to optimally match the stay cable properties and expected vibration amplitudes by Felix Weber of the Structural Engineering Research Laboratory of Empa. The control algorithm was also developed at Empa. It was tested and optimized on a model cable in the "Bauhalle" in Duebendorf. In June 2006, the adaptive cable damping system was installed on the Franjo Tudjman Bridge and tested by Empa researchers on site. The measurements confirmed the high effectiveness of the controlled MR dampers. Cable vibrations were damped by a factor of ten which means that the worst case amplitudes of 1-2 meters observed during the storms 2005 and 2006 would now be reduced to 10-20 centimeters.

China, Sutong Bridge: Empa know-how goes east!

Just after completion of this first damping project of a real stay cable bridge, Felix Weber had to test and optimize prototypes of 48 MR dampers and 228 oil dampers at Empa which were designed for the Sutong Bridge across the Yangtze River in China. This cable-stayed bridge is currently under construction and will have a free span of 1080 meters between the pylons which will be the largest free span world wide. The tuning of the MR dampers and control algorithm was of high priority since these dampers are to be connected to the longer stays of 480-540 meter length. Although the oil dampers are to be installed on the "shorter" cables of 150-470 meters length, also these damper were optimized. In this case, Felix Weber determined experimentally the optimal oil mixture and bypass valve positions of these dampers. After successful completion of the tests, the dampers were sent to Shanghai. At beginning of January 2007, Felix Weber and his colleagues from Munich, Hans Distl and Wolfgang Fobo, traveled to China too. Their task was to demonstrate the damping performance of their adaptive cable damping system to the Chinese client on a 228 meter long cable as used on the Sutong Bridge.

Measurements under difficult circumstances – 30 tests in one and a half days

After some "initial difficulties" – the dampers were locked in the Customs for eight days, so that Weber's team had to shift their return flights two times – the engineers could finally start to work, however, under great pressure to finish on time. "We only had one and a half days to perform all the tests – not the best situation", comments Felix Weber. First, they checked if the dampers and the associated control hardware had survived the journey undamaged. After successful check, the next task for Felix Weber, Hans Distl and Wolfgang Fobo was to demonstrate the dampers really perform as promised by the Maurer and Empa. This was done on a 228 meter long test cable on the test site of the Chinese cable manufacturer «Fasten». This cable represents the cable number 10 of 34 of the Sutong Bridge. Felix Weber, Hans Distl and Wolfgang Fobo mounted the dampers to cable at three different positions - 6.0, 6.6 and 7.8 meters from the anchor – and tested the damping at each position for the first three cable eigenfrequencies. Therefore, Hans Distl had to excite the cable at mid span, quarter point and at one sixth of the entire cable length using his own muscle power. The use of a metronome guaranteed that Hans Distl excited the cable at the correct eigenfrequencies, at which the largest amplitudes may be expected.

The test results showed that the feedback controlled MR dampers even performed slightly better than those on the Franjo Tudjman Bridge. This was mainly the result of fine tuning of the control algorithm at Empa by Felix Weber and Hans Distl. The main feature of this adaptive damping system is that the high damping performance is achieved at all three damper positions and independently of the actual vibration frequency and amplitude. During a power break down, the damping of the MR dampers is reduced to approximately 50% but only for small vibration amplitudes.

As expected, the damping efficiency of the oil dampers was slightly smaller than the one of the feedback controlled MR dampers since the tuning of the oil dampers represents a compromise. “Passive dampers, such as these oil dampers, can be optimally adjusted only to one vibration frequency and for one damper position at the cable. In contrast, the feedback control algorithm of the MR dampers takes cable properties, damper position and vibration amplitude into account,” explains Felix Weber. His test report has already been sent to the Chinese client. If the client is convinced by the powerful damping system in the same way as Felix Weber and his colleagues of Maurer Söhne, the dampers could already be installed on the bridge by the end of this year.

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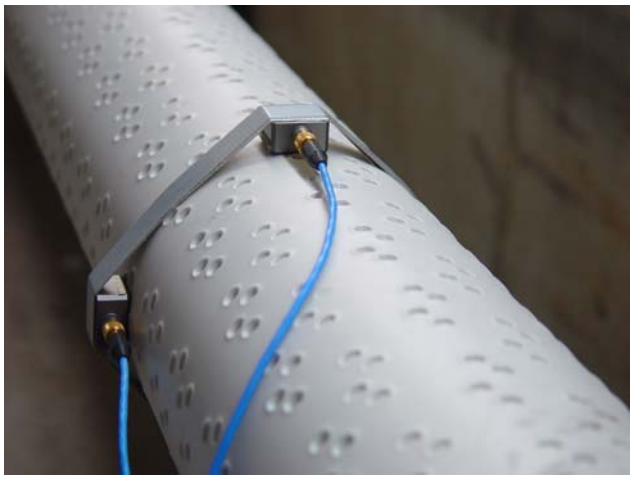
Connecting the MR damper to the control hardware.

The 228 meter long bridge cable is transported to the test set-up.



Measurement of vertical and horizontal cable vibrations using accelerometers.

Mounting the MR damper to the test cable at 6.6 meters from the anchor.

Measuring cable damping with feedback controlled MR damper.

Erecting the 228 meters long cable no.10 on the Sutong Bridge over the Yangtze River.