Media communiqué

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Preventing bridges from oscillating

Première in Dubrovnik

Unwanted oscillations – swaying – in bridges are primarily caused by wind, rain or traffic. In March 2005 and 2006, winter storms caused such extreme oscillations in the supporting cables of the Franjo Tudjman Bridge in Dubrovnik that they suffered damage. The bridge authorities therefore decided to have oscillation dampers installed. At the end of June this year a team of experts including researchers from Empa conducted an on-site study to determine how effective the dampers were in reducing cable oscillations. Initial results indicate that cable swing was reduced by a factor of ten, from peak values of 2 meters before installation of the dampers to just 20 centimeters afterwards. The Franjo Tudjman Bridge is therefore unique in that it is the first cable stayed bridge worldwide where commercially produced feedback-controlled «magnetorheological fluid dampers» have been installed and tested.

The Franjo Tudjman Bridge, which was completed in 2001, is built over a 6 km long stretch of sea north of Dubrovnik, Croatia. The asymmetric cable stayed construction has a 143 meter high pylon, to each side of which 19 cables are anchored, the longest being more than 220 meters in length. It was these long cables in particular which were affected by winter storms in March 2005 and 2006, during which wet snowfalls were accompanied by winds of up to 110 kmph. This caused the central regions of the longest cables to oscillate with amplitudes of up to 2 meters. These extreme values were probably caused by snow sticking to the cables developing a teardrop-shaped cross-section which greatly accentuated the lifting and downward forces exerted by the wind.

Magnetorheological dampers – a result of cooperation between Empa and its industrial partners

The bridge operator, Croatian Roads, and the cable manufacturer, DYWIDAG-Systems, therefore decided in 2005 to install a cable damping system from the Munich-based company Maurer Soehne. The dampers were intended on the one hand to ensure that the bridge could be kept open to traffic when the wind speed was at medium levels, and on the other to prevent damage to the cables at their anchoring points, thus maintaining the structural safety of the bridge. This was the first time that

an installation using magnetorheological fluid dampers (MR-dampers) has been fitted to a bridge on a commercial basis. The dampers adapt to the bridge oscillation characteristics – a control algorithm adjusts the damping force depending on the instantaneous amplitude of oscillation. This means that the more extreme the cable swings, the greater the damping effect exerted. Since MR- dampers continue to operate at a basic level even during electrical power outages, such systems are fail-safe. On the Franjo Tudjman Bridge the MR-dampers are installed vertically between the bridge deck and the cables, and are attached to the cable at a height of about 3.5 meters above the deck. The range of controllable force exerted by the damper was tuned to the actual requirements of the structure on-site by Felix Weber of Empa's Engineering Structures Laboratory. The control algorithm was also developed at Empa, and tested and optimized in the Construction Hall in Duebendorf.

Real-life on-site investigation

The aims of the measurements made on the Franjo Tudjman Bridge were to determine how well the MR-dampers actually functioned in reducing cable oscillations, and also to tune the control algorithm to suit the specific characteristics of the bridge. To do this the cables were brought to oscillation by hand, first without and then with the dampers fitted. The cable oscillation amplitudes and the movement of the damper piston were measured, as was the swaying of the bridge deck caused by heavy goods vehicles passing over it. The investigation showed that the self-damping of the cables – that is, without dampers – was rather at the lower limit for stayed cables of this kind, and when fitted with the regulated MR-dampers the damping increased by an order of magnitude. "We were astonished at how strong an effect the MR-dampers had on the cable damping. An increase in damping of a factor ten means a damping efficiency of 70%, which is very high!"

Experience indicates that this should be adequate to ensure that in future even under conditions of strong winds with wet snow the cables of the Franjo Tudjman Bridge will only sway with small amplitudes which will not prejudice its structural safety. Rough calculations show that the cable oscillation amplitudes even under "worst-case" conditions show not exceed 15 to 20 centimeters,

Next projects

The next step is to install a monitoring system on the Franjo Tudjman Bridge which will record oscillation data and allow the damping factor to be adjusted over the internet – in principle a remote control function. While the installation of the adaptive damping system developed by Empa and Maurer Soehne in Dubrovnik is nearly complete, there are 48 more MR-dampers and 224 more oil-dampers ready for use at Empa. They will be fitted to the Sutong Bridge over the Yangtze River in China to prevent it from oscillating. The Sutong Bridge, which will be finished in 2007, is a cable-stayed construction boasting the largest free span between two pylons in the world. Over the next few

months these dampers and their control systems will be tested at Empa and, following further tests in China, will be installed on the bridge.

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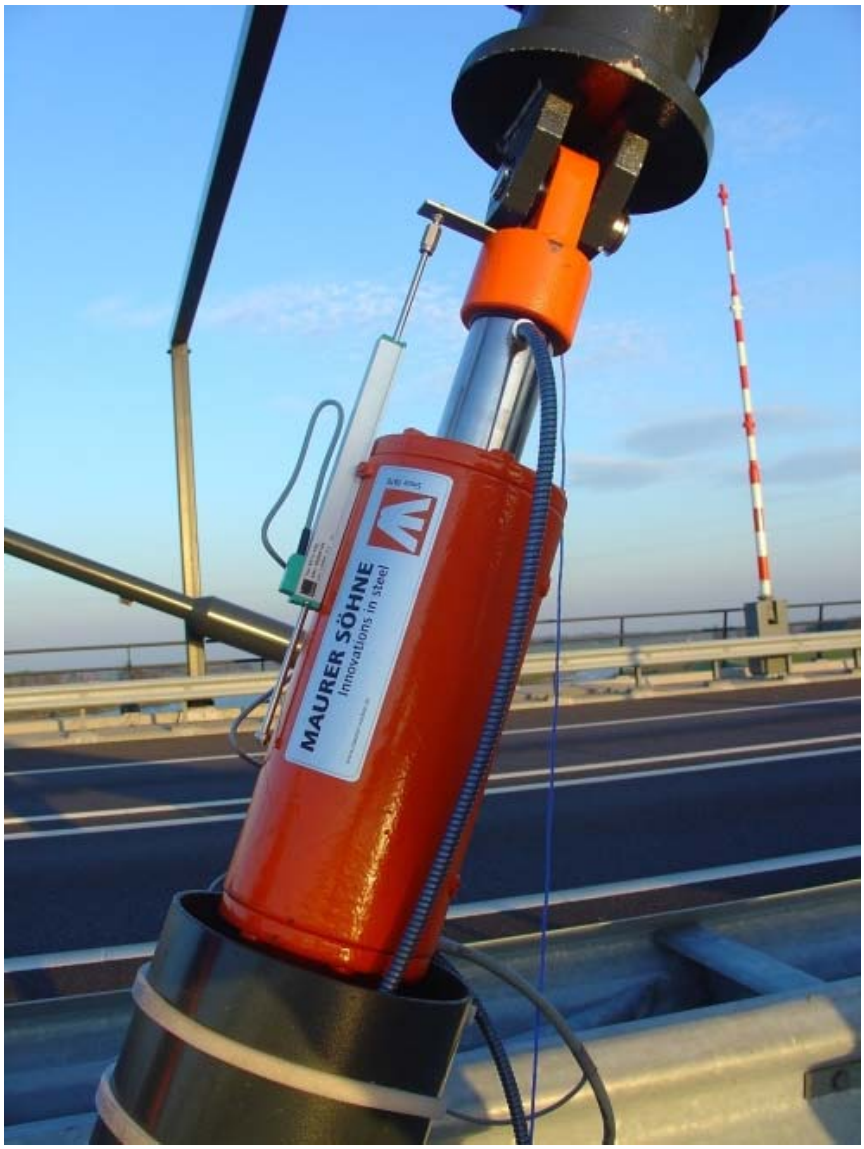
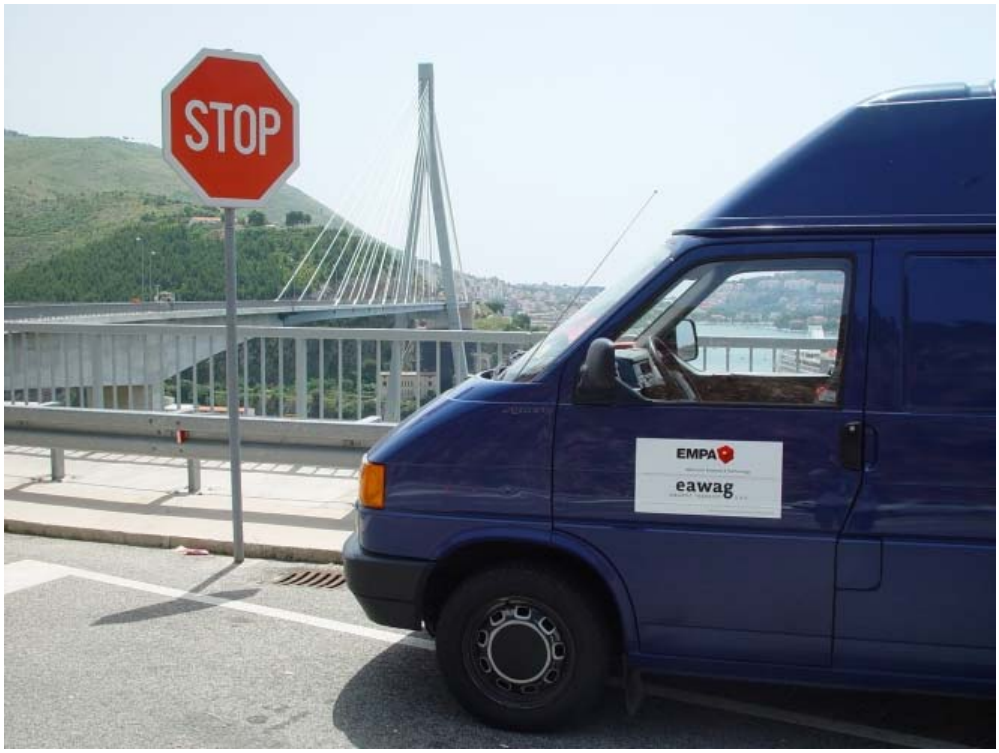


The magnetorheological fluid dampers are installed on the cable stayed bridge near Dubrovnik.



The Franjo Tudjman Bridge, a cable stayed construction near Dubrovnik, Croatia.