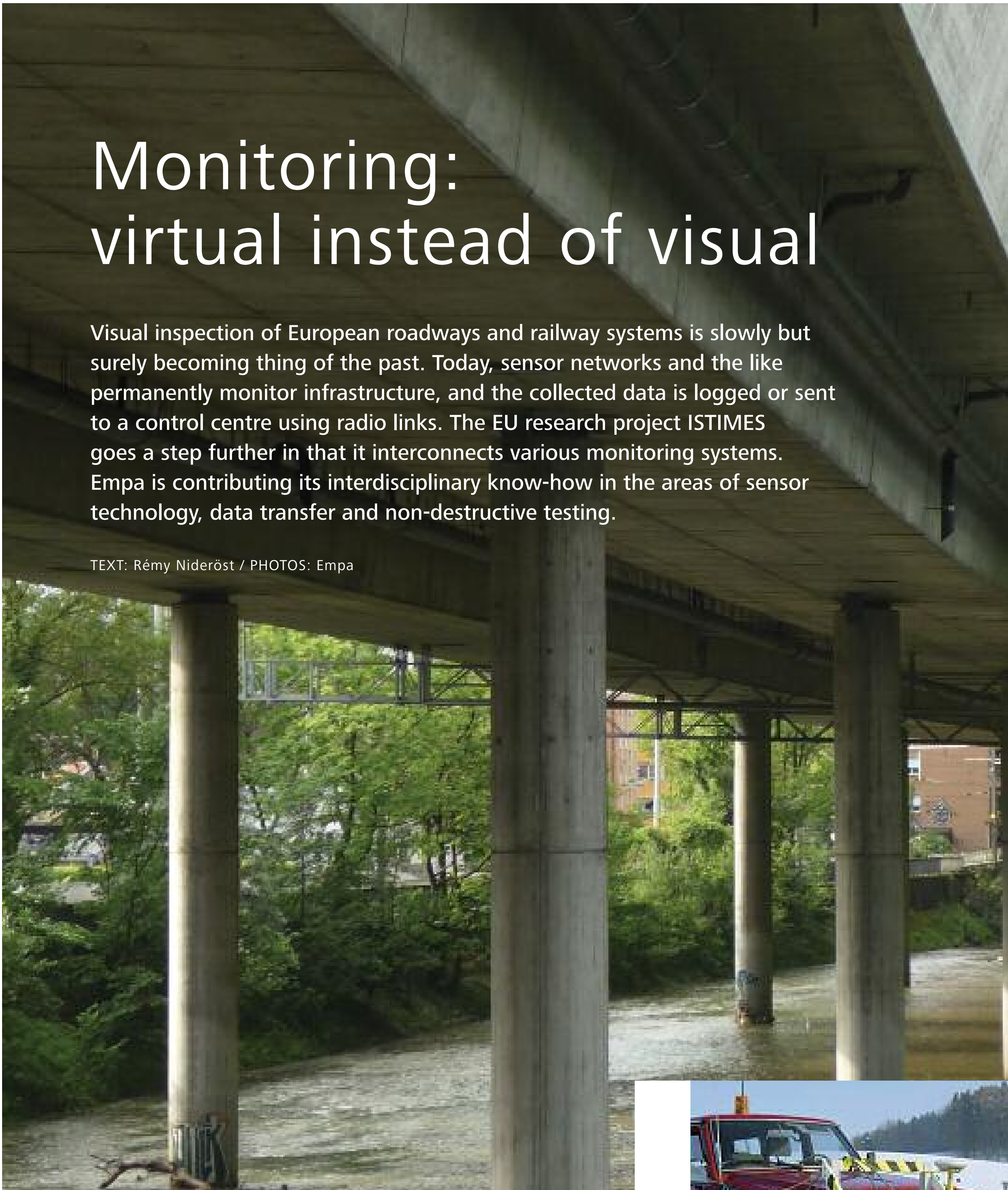
Monitoring: virtual instead of visual

Visual inspection of European roadways and railway systems is slowly but surely becoming thing of the past. Today, sensor networks and the like permanently monitor infrastructure, and the collected data is logged or sent to a control centre using radio links. The EU research project ISTIMES goes a step further in that it interconnects various monitoring systems. Empa is contributing its interdisciplinary know-how in the areas of sensor technology, data transfer and non-destructive testing.

TEXT: Rémy Nideröst / PHOTOS: Empa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Europe runs a tightly woven and heavily travelled network of roads and railways. On motorways, for instance, heavy traffic regularly leads to congestion and also causes road damage. Moreover, in Alpine regions, bridges and tunnels "suffer" under harsh weather conditions. The same holds for the railway network; ever more trains are travelling faster and putting the infrastructure to the test. Continuously monitoring all these transport routes for damage is a difficult assignment – from the standpoint of finances, personnel and because of the associated impairment of the traffic flow.

Although visual inspections and destructive tests such as bore holes continue to play an important role, today much of the monitoring is fully automated and non-destructive. On heavily travelled stretches as well as on bridges and in tunnels, integrated sensors often continuously measure loads and register possible changes.

For instance, loads on the stay cables supporting Winterthur's "Storchenbrücke" are measured and the data is transferred over a radio link directly to Empa in Dübendorf where it is evaluated. This bridge is being monitored in particular because two of its two dozen stay cables are not made of the usual steel but instead consist of considerably lighter and noncorrosive carbon-fibre reinforced polymers, an Empa development and a world's first when the bridge was erected in 1996.

Automation – taken to the extreme

The EU research project ISTIMES (Integrated System for Transport Infrastructure surveillance and Monitoring by Electromagnetic Sensing), which was launched at the end of 2009, is taking this concept a great deal further. During the next three years, this project, which is being sponsored as part of the Seventh Framework Programme, will develop an integrated monitoring and surveillance system for transport infrastructures. It is based on various electromagnetic sensors which monitor parameters such as temperature, moisture, vibrations or motion, all of which will be integrated into an automated network. Research institutes, public authorities and corporate partners from seven European countries are participating in the project, with Empa being the sole Swiss "representative". The project's goal is to create a reliable monitoring system which will then be built into and tested on two structures, a motorway bridge (the Sihlhochstrasse in Zurich) and a rail tunnel in the southern Italian region of Potenza.

Empa contributes its ground penetrating radar know-how

A first key task consists of determining which data are at all meaningful and therefore should be transmitted and evaluated. Empa is leading this work package, while the entire project is being managed by the Italian consortium TeRN (Earth Observation and Natural Hazard Technologies Consortium), which invited Empa to join ISTIMES. This is not least because of Empa's highly regarded work in the area of non-destructive testing of transport infrastructure by means of ground penetrating radar, a technology that will play an important role in the project.

The process is based on an electromagnetic signal which is radiated from an antenna. The signal's reflections, which arise at a boundary layer such as the underside of the road pavement, are logged and evaluated. The mobile system allows efficient examination of roads and bridges with minimal disruption to the traffic flow. The radar studies indicate, for example, the thickness of the asphalt layer or the condition of reinforcements in the concrete. And in railway lines, ground penetrating radar can be used, for instance, to detect the condition and thickness of the ballast bed. In future, such ground penetrating radar is also expected to be built into buses or trains so that the condition of a section of transport infrastructure can be studied continuously; on the Sihlhochstrasse the ground penetrating radar might, for instance, be mounted on a metropolitan bus.

Warnings – before something happens

In addition, the other ISTIMES partners are adding their expertise to the project. For example, a Norwegian company is delivering important optical elements for certain sensors. A Romanian company specialises in aerial photographs which, combined with altitude measurements carried out by satellites, provide information about changes in the terrain. With such systems, the ISTIMES monitoring system could, for instance, issue an early warning if a hill and a bridge standing on it are about to slide. //

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The Sihlhochstrasse, an elevated motorway in Zurich, one of the research targets in the EU project ISTIMES.

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Mobile ground penetrating radar system from Empa for the monitoring of roads and bridges.

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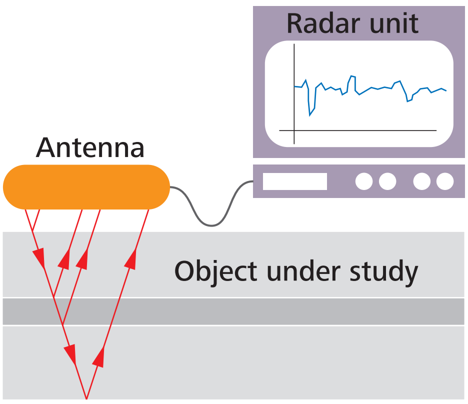

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How ground penetrating radar works: an electromagnetic signal radiated by an antenna penetrates the object under study and is reflected, for example, at a boundary layer. These reflections are received by the antenna and provide information about the structure of the layers.

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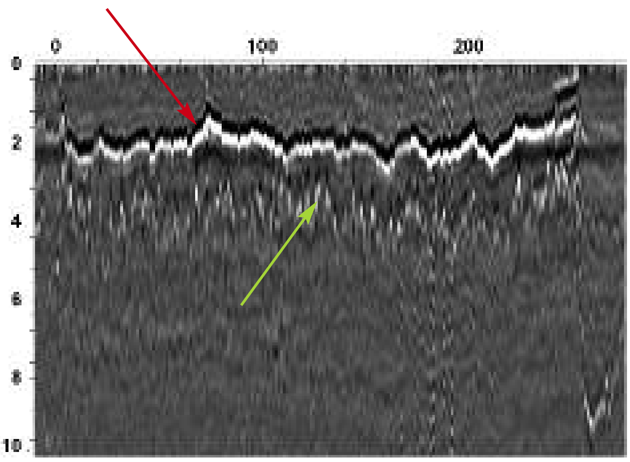

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An approximately 300 m long radar longitudinal profile of a bridge: the red arrow indicates the asphalt-concrete transition, the green arrow the upper reinforcement layer. In this way, the thickness of the asphalt and the depth of the reinforcement layer in the concrete can be determined.