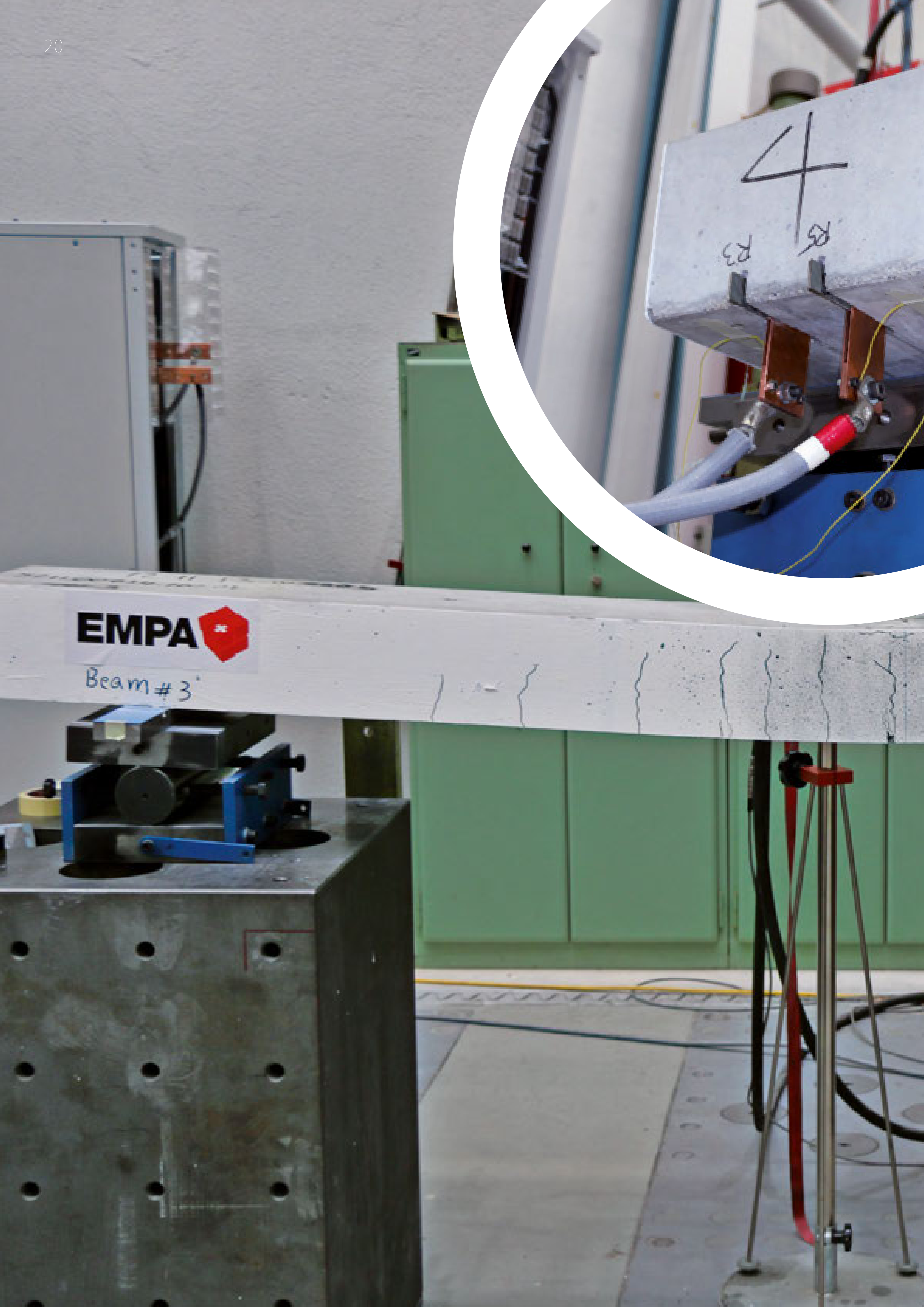
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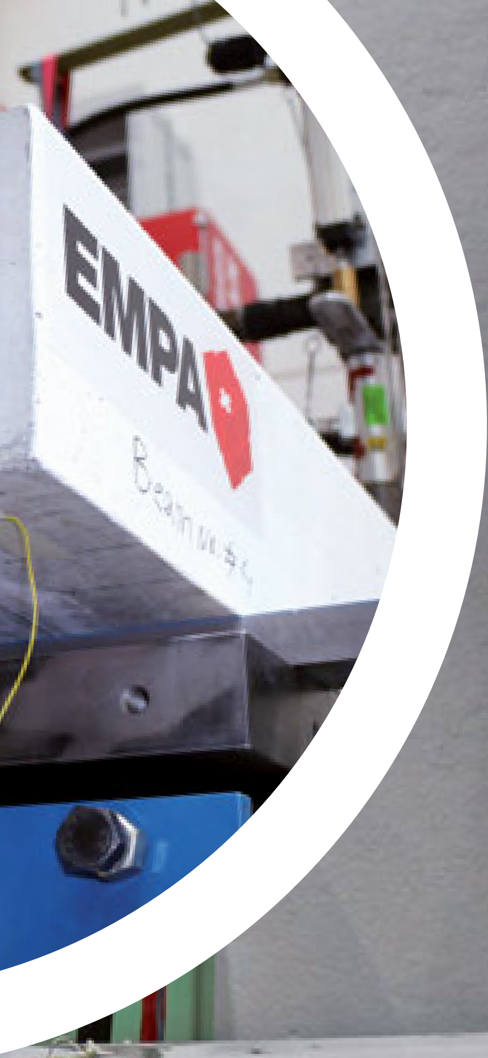
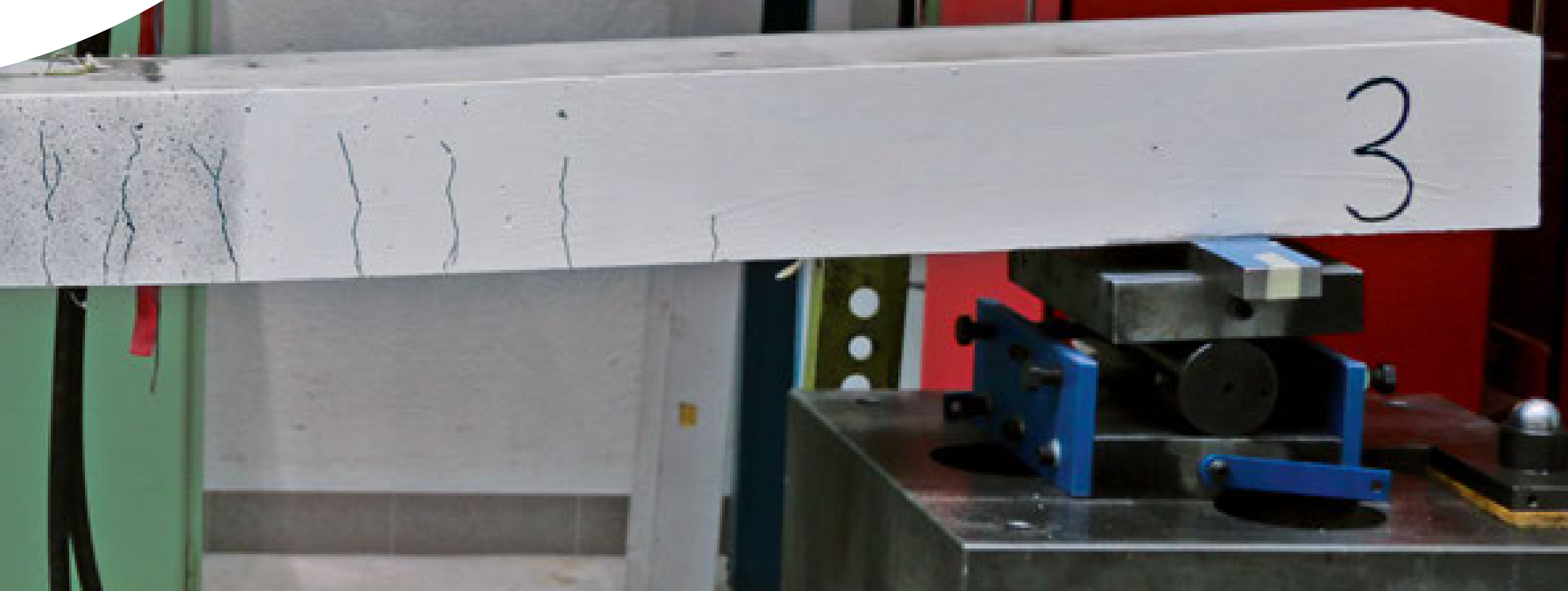


A shape-conscious alloy

When the frame of a pair of glasses is bent out of shape, it's not that easy to return it to its original form. If, however, your spectacles are made of a shape memory alloy then you don't have a problem. Just place the frame in hot water and bingo! – they're as good as new again. Empa researchers have now shown that these materials can also find applications in the building industry.

TEXT: Martina Peter, Remy Nideröst / PICTURES: Empa, TU Freiburg



Shape memory alloys, or SMAs, possess the ability to return to their original shape after being severely deformed, either spontaneously or following the application of heat. This makes them useful materials, not just for making spectacle frames but also for technical applications such as thermostats, stents and micro-actuators. Other applications in the construction industry are conceivable too, for example in the reinforcement of bridges.

If a concrete beam is cast with reinforcing rods made of an SMA material, these can then be "activated" through the application of heat. They attempt to return to their original shape, but because of their concrete sheath they cannot do so, thus exerting a pre-stressing force on the beam. This effect can be used, for example, to pre-stress a complete bridge span. In order to generate the necessary force the SMA rods must simply be

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heated by passing an electric current through them. This obviates the need for using elaborate tensioning systems and jacket tubes, as used in conventional pre-stressing techniques.

The nickel titanium alloys used to make spectacle frames or stents are not very suitable for use in the construction industry. Iron-based SMA products are much more attractive, since both the raw materials and the processing costs are far cheaper. However, to date one problem has remained a stumbling block: to activate the memory effect the materials currently used must be heated up to 400° C, which for applications involving concrete or mortar, or other heat sensitive materials, is too high. Empa researchers led by Christian Leinenbach of the Joining Technology and Corrosion Laboratory have now succeeded in developing a novel iron-manganese-silicon SMA alloy which is activated at just 160° C, a temperature much more suitable for use with concrete. The material science researchers “designed” a range of virtual alloys using thermodynamic simulations, and then selected the most promising combinations. These were then manufactured in the laboratory and their shape memory characteristics tested, with great success. Several of the new materials met the construction engineers’ requirements, an important milestone on the path to providing economic shape memory steel alloys for industrial applications – in other words, manufacturing them by the ton.

The long road from laboratory to finished product

Christoph Czaderski, of Empa’s Engineering Structures Laboratory, believes that iron-based SMA materials have a promising future in the building industry since the process of pre-stressing is simpler and therefore cheaper than in conventional techniques. In addition they may allow engineers to create pre-stressed structures which are impossible or very difficult to achieve using conventional techniques. These include the use of short fibre concrete, near surface mounted laminates, column wrapping and ribbed armouring steel. A feasibility study financed by the Commission for Technology and Innovation (CTI) recently showed that it is possible to produce the new alloys on an industrial scale, not just a few kilos for laboratory use. The manufacturing process has been developed in collaboration with Leoben University (Austria), the Technical University Bergakademie Freiberg (Germany), and the German company G. Rau GmbH.

The working of cast ingots, each about 100 kg in weight, into thin strips around 2 mm thick or ribbed armouring steel rods at temperatures over 1000° C calls for high degree of technical knowledge, and the appropriate infrastructure. The working process also needs to be adapted for use with the novel alloys.

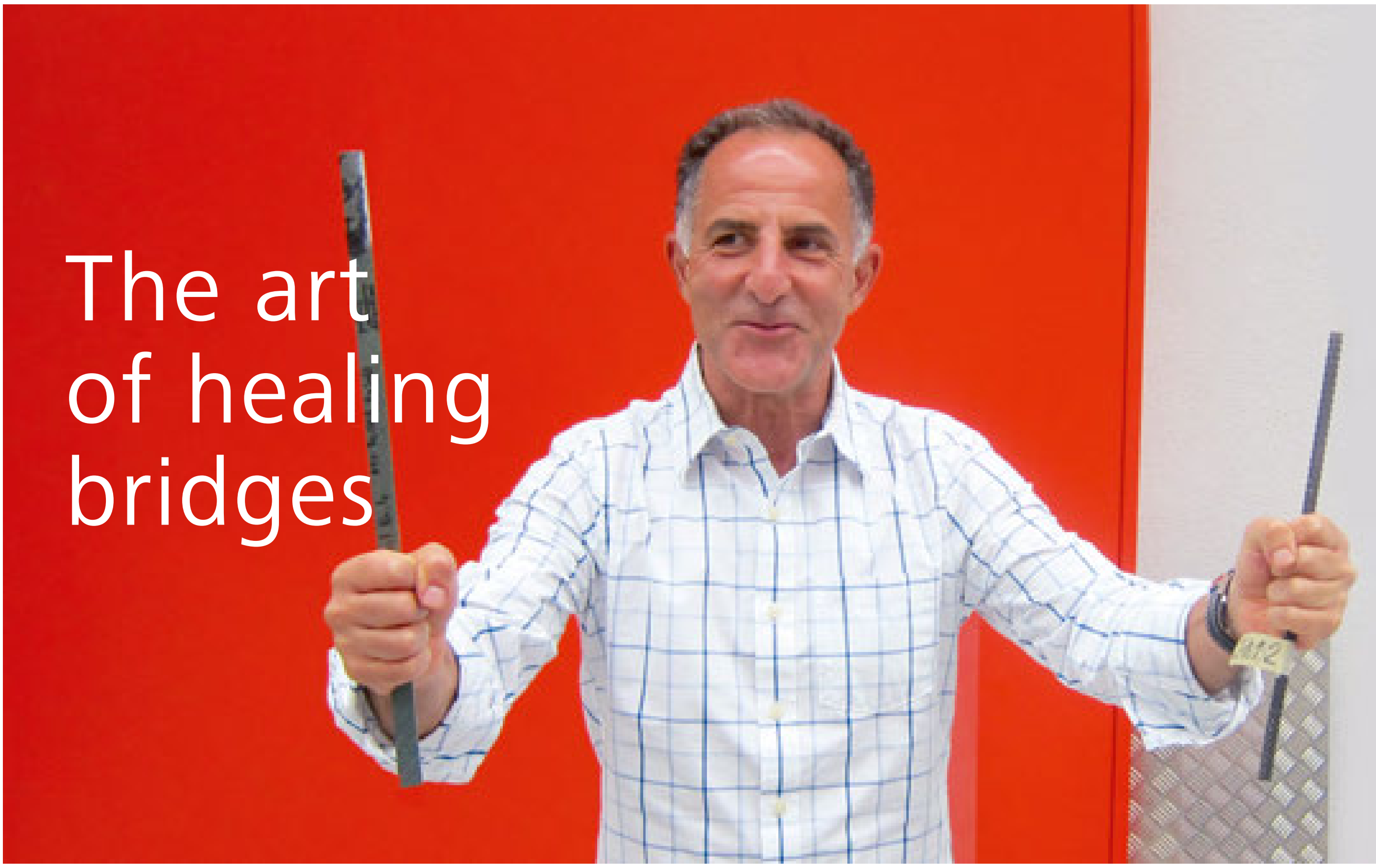
To carry forward the developments made at Empa, a start-up company, re-Fer AG, has been set up. This will in future produce and distribute iron-based SMA for the construction industry. The cost of the new products is expected to be about the same order of magnitude as that for stainless steel based materials. //

How shape memory steel is formed (top to bottom): the ingot is heated in TU Freiberg’s special furnace before the steel is milled while still hot. Once cool, a machine strikes ribs into the steel. Empa technicians set two shape memory steel lamellae into a reinforced concrete beam. Thermal image: the electrically heated steel reaches a temperature of 160° C within the concrete beam andcontracts. Load test for the pre-stressed concrete beam once it has cooled down goes to show: the experiment was a success.

Video
Shape memory alloys – demonstrated in the lab.

http://youtu.be/eWgOa0Y4R_I

The art of healing bridges



Germany is currently embroiled in a hot debate on the badly needed refurbishment of ailing roads and motorways – especially bridges. In many places, road bridges should be reduced to a single lane to avoid stressing them unduly. At Empa, Masoud Motavalli is developing solutions to get old bridges back in shape.

INTERVIEW: Martina Peter / PICTURE: Empa

Mr. Motavalli, are Switzerland's bridges as poor as Germany's?

Fortunately not. In Switzerland, we have a continuous monitoring system in place. If something needs repairing, it gets repaired. But it isn't just Germany that has a problem with its bridges. In the US, around a quarter of the country's 600,000 bridges or so are thought to have shortcomings and be in urgent need of repair. 50, 60 years after the structures were built, the concrete is often damaged and the metal corroded.

Is it due to bad material that was used back then?

No, you couldn't say that. Material tires. Besides, the material was stressed far more than initially expected. Just think of how much the traffic has ballooned in the last 50 years.

How can an old bridge be brought back up to scratch?

We've been investigating various repair methods and developing practicable solutions for years. Around 20 years ago, in a world first, Urs Meier and his Empa team stuck carbon-fiber-reinforced polymer cables (CFRP) to a damaged reinforced concrete bridge and thus saved the Ibachbrücke near Lucerne from collapse. Today, we even reinforce steel bridges with pre-stressed CFRP cables. But instead of sticking them on, we clamp them to steel sections, which enables us to attach them to places where sticking would be difficult, such as where bolts are poking out. And if need be, CFRP cables can be removed or replaced easily, discretely and without damaging the structure. Incidentally, this is precisely how we strengthened a railway bridge constructed by Gustave Eiffel in a recent project with the SBB. (Note from the editor: in 1891 there was a railway disaster in Münchenstein in the Canton of Basel-Land when a bridge built by Gustave Eiffel collapsed. In one of its first ever studies, Empa revealed that an unsuitable formula had been used for the calculation).

Are there other methods?

We also want to use more alloys with a "memory" to repair bridges (see previous article). This already works very well on a smaller scale. In the near future, we'll be carrying out tests on roughly seven-meter long concrete beams reinforced with shotcrete that has been fortified with smart alloys. We're interested in how much energy is needed for the "smart metal" reinforcement to make the bridge sound again. Ultimately, we also want to know how we can best implement this in practice. With the right measures, the lifespan of a bridge can thus be extended for a good 50 years – regardless of what went on before. //