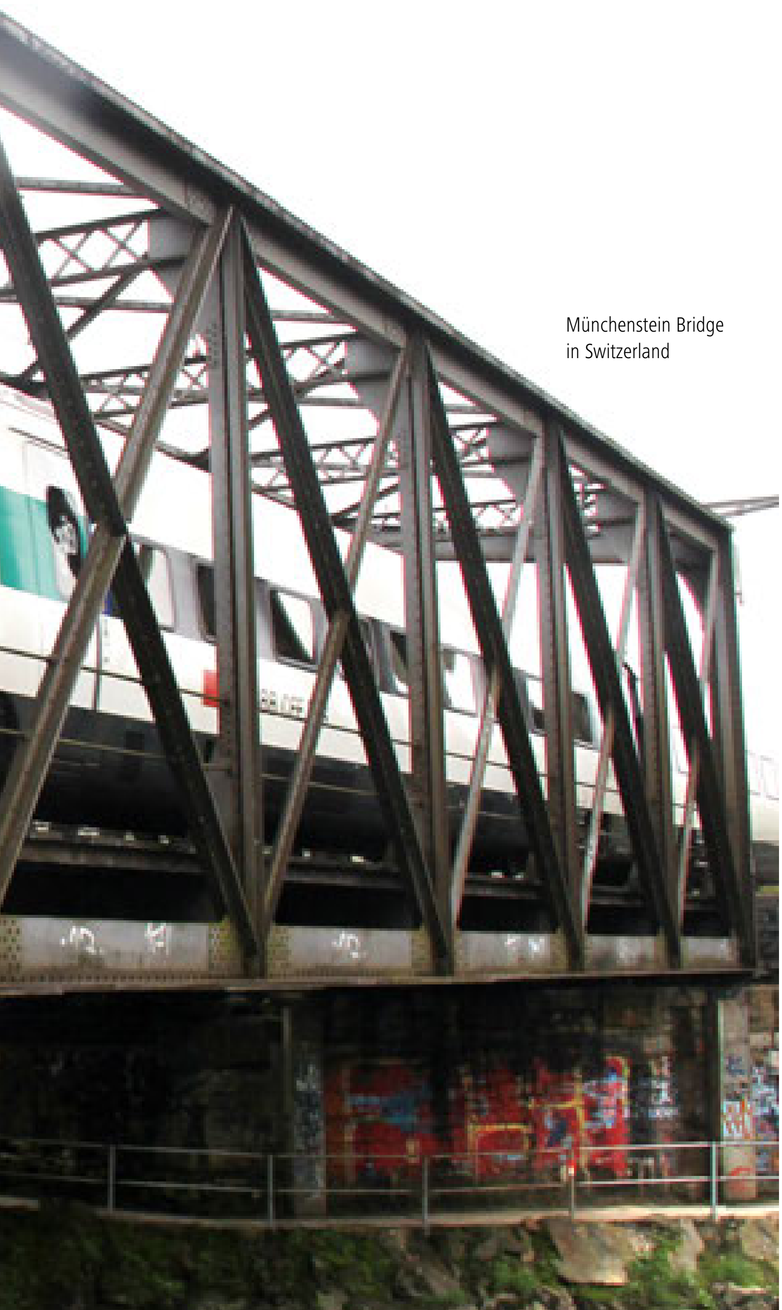
Resilience for aged bridges

An increasing number of steel bridges need to be replaced or repaired due to signs of fatigue. Researchers from Empa fortify the load-bearing elements with pre-stressed, fiber-reinforced plastic plates – a cost-effective alternative to building a new bridge. The recently patented method was now used on the 120-year-old Münchenstein Bridge.

TEXT: Martina Peter / PICTURES: Empa, Keystone



Münchenstein Bridge in Switzerland

Almost 70 percent of Europe's metal bridges are over 50 years old. 30 percent have even been in service for over a century. Many are in dire need of repair. The problem isn't necessarily cracks or visible damage, but rather tired material that no longer bears the load and thus poses a safety hazard. The reason: back in the 19th century, bridge builders assumed that their bridges would only be exposed to a fraction of the stress they are nowadays. Today's vehicles are considerably heavier and cross bridges faster and much more frequently than in the past. The consequence: some bridges have to be reduced to a single lane or closed entirely, which risks grinding the traffic to a complete gridlock.

Bucking the general trend of simply discarding ageing products and replacing them with new ones, an increasing number of bridges are being repaired nowadays. An established solution for concrete bridges is also used to mend metal bridges: extremely light, pre-stressed plates of carbon fiber reinforced plastic (CFRP) are "stuck on" like plasters, which prevents fatigue cracks from growing any wider or even forming in the first place. However, the plasters stick much less effectively to corroded metal surfaces or the uneven layers of several anticorrosion coatings applied over the years than to concrete surfaces. Moreover, rivets often prevent the plates from sticking properly. And the plates mustn't be screwed on, either, as irreversible structural changes are often not permitted on historic buildings.

Reinforcing load-bearing elements

The 120-year-old Münchenstein Bridge in the Canton of Baselland is a prime example. Nevertheless, researchers from Empa's Structural Engineering Research Laboratory came up with a patent solution. Teaming up with the Swiss Federal Railways (SBB) and S&P Clever Reinforcement AG, they developed a novel method in a CTI-funded project to demonstrate how the load-bearing elements of the 45-meter-long steel bridge can be reinforced with pre-stressed CFRP plates. The new, trapezoid "pre-stressed unbonded reinforcements" (PUR) were attached to two of the girders that were most affected by fatigue.

The pre-stressed CFRP plates are clamped to the ends of the transverse bridge girders. Saddles in the middle of the girder ensure that the bands are forced downwards until they are optimally stressed. Two V-shaped plinths are added to these points and the saddle can be removed again. If greater stresses are expected in future, the trapezoid system can be re-stressed by using larger plinths. Moreover, it can easily be dismantled again. After months of recording, a wireless sensor network revealed that the reinforcement of the two girders on the Münchenstein Bridge had worked perfectly fine.

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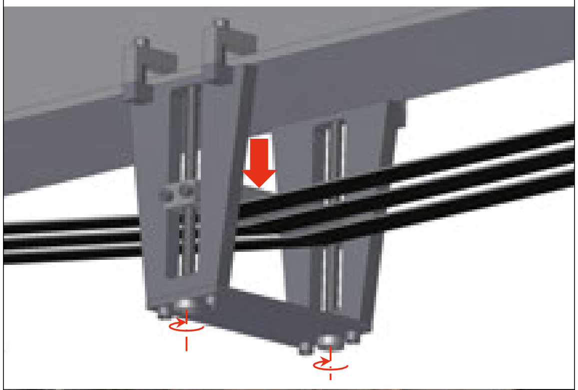
Fortifying old bridges with CFRP plates. How does it work?

First of all, the CFRP plates are clamped to both sides of the bridge with special brackets, then stressed with a special tool. Finally, two V-shaped brackets secure the plates and keep them stressed. If greater stresses are expected for the bridge later on, the system can be re-stressed by reapplying the tool and fitting larger V-wedges.

The system reduces wear and tear on bridges, which can extend their lifespan by 50 years and renders a quick rebuild redundant.



The PUR system now provides bridge operators with a swift, cost-effective alternative to bridge replacements. Wear and tear can be reduced to such an extent that, in theory, fatigue can be deferred indefinitely. While project head Masoud Motavalli is more realistic when it comes to practice, he remains confident: "A bridge reinforced entirely using this method will certainly last for the next 50 years, by which time we're bound to have devised new methods to repair ageing bridges."

Diagonal cracks and a flat PUR system

There are already two follow-up projects, one of which just got underway in Switzerland. It is backed by the Swiss National Science Foundation (SNSF), with EPF Lausanne as project partner. The aim is to examine diagonal and combined cracks with a view to improving our understanding of how we can prevent them from growing or even forming in the first place.

The second study recently began in Australia: the project headed by Xiao-Ling Zhao from Monash University and funded by the Australian Research Council focuses on the reinforcement of riveted metal bridges. The project partners are Swinbourne University, S&P Clever Reinforcement AG and VicRoads (the transport authority of the Australian State of Victoria). The aim is to develop a flat PUR system that can also be used on girders where there is not enough room for the patented trapezoid PUR system. At the end of the project, in 2017, Melbourne's Chandler Bridge is to be reinforced with the new system developed by Empa. //

The Münchenstein Bridge: Empa's faithful old friend

The cast-iron predecessor to today's Münchenstein Bridge collapsed in 1891 as a steam train was crossing it with ten wagons. 71 people lost their lives. Empa, which had just been founded a few years earlier, conducted the investigation into why the metal bridge constructed by Gustav Eiffel in 1875 came tumbling down after only 16 years. Empa's first CEO, Ludwig von Tetmajer, discovered that Euler's Column Formula, which had been used to calculate such structures thus far, needed correcting for compact girders (as used in Münchenstein).