Energy
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Project

Monitoring of concrete constructions

How healthy is a building or a bridge?

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If buildings were monitored by sensors, they could be renovated in a more targeted manner – making them more cost-effective and environmentally friendly. Their service life could also be extended.

The Chillon Bridge was renovated with ultra-high-performance fibre reinforced concrete. *Source:* Eleni Chatzi

At a glance

- Monitoring would help to ensure that buildings and bridges are only renovated when they are really in need of renovation.
- The data obtained could be used to find critical points on building structures and carry out targeted maintenance work there.
- One material that would be ideally suited for such targeted reinforcements is ultra-high-performance fibre reinforced concrete (UHPFRC).

The construction of new infrastructure facilities is energy-intensive and causes increased CO_2 emissions – alone through the production of common building materials such as steel and concrete. The service life of infrastructures is limited to a greater or lesser extent depending on the type of construction: for example, bridges in Switzerland have a service life of 50 to 100 years. They are then taken out of operation as standard – whether the building structure would have lasted longer is often unknown. Researchers at ETH Zurich and the EPF Lausanne have therefore tested the use of a monitoring system on Swiss building structures. This approach is forward-looking and environmentally friendly because it prevents demolition, premature new construction and the disposal of building rubble.

The decisive factor, however, is that buildings and bridges can be reinforced on a more targeted basis if they are equipped with sensors that collect information about forces, deformations and vibrations. This is referred to as structural condition monitoring.

Sensors measure the response and performance of structures during operation with the aim of diagnosing their condition and automatically predicting faults. Time series analyses and machine learning are used for this purpose. The installation of sensors thus makes it possible to make the infrastructure perceptible.

During their investigations, the researchers have, in particular, examined the properties and manageability of ultra-high-performance fibre reinforced concrete (UHPFRC). Compared to normal concrete, it is easy to use, very resilient and durable. It is therefore also particularly suitable for selectively reinforcing specific points in a building structure. In order to test the monitoring and use of UHPFRC, the researchers examined three building structures.

The Chillon Viaduct

In 2014, damage was discovered on the Chillon Viaduct, a two-kilometre-long concrete bridge in the canton of Vaud. In order to reinforce the building structure in the affected areas, a 45-millimetre- thick layer of UHPFRC was poured onto the original concrete. The bridge was then equipped with sensors and monitored for three months in a first phase. Deformations and vibrations caused by road traffic and environmental influences as well as micro-damage in the material were measured. The monitoring is being continued in order to obtain information on long-term behaviour. The researchers were able to gain important insights from this work: in the warm months, for example, more minimal damage was suffered by the bridge than in the cold months. The use of the bridge also played an important role: during peak times there was more damage than outside these hours. Above all, however, the researchers concluded that the concrete structure could safely support the road loads and that the UHPFRC reinforcement had extended the service life of the bridge and increased its load-bearing capacity.

The Buna Bridge

The Buna Bridge in Croatia had been part of the Croatian railway network since 1893. In 2010, however, the nine-metre-long building structure was decommissioned. Researchers at ETH Zurich investigated the bridge with the help of measurements and reinforced it with a UHPFRC plate. For this purpose, they dismantled the bridge and transported it to the laboratory in order to find out possible weak points in the construction both before and after the renovation. The tests revealed that the bridge would still be strong and safe enough to carry trains. Calculations also showed that the service life of the bridge can be extended by at least 40 years by reinforcing it with UHPFRC.

House Du Pont

House Du Pont is an eight-storey building dating back to 1913 that stands in the heart of Zurich. The building needs to be modernised – this has turned out to be difficult, however, because it is a listed building: the facade and supporting structure including the ceilings must remain untouched. The use of UHPFRC reinforcement was also considered here and tested on an experimental basis. The renovation work will be carried out from spring 2020.

Environmentally friendly and cost-efficient

The tests show that through monitoring the maintenance of buildings and facilities is more targeted and sustainable than is the case with conventional methods. The building material UHPFRC proves to be an energy- and CO_2-saving alternative to conventional concrete. This building material makes it possible to considerably extend the service life of existing infrastructures through targeted reinforcements. New CO_2 emissions and energy consumption for the demolition of a building structure and the production of building materials for the new construction of a replacement building can thus be avoided. Apart from the energy and CO_2 efficiency of UHPFRC in selective applications, its economic factor is of great importance: based on the example of the Chillon Bridge, a renovation using traditional methods would have cost CHF 1,000 per square metre of bridge area – and a new construction would have cost up to CHF 2,000 to CHF 3,000 per square metre. Reinforcement with UHPFRC, on the other hand, cost only CHF 300 per square metre. Even under consideration of long-term maintenance and material durability, UHPFRC proves to be a more cost-efficient material than conventional concrete.

The researchers therefore recommend carrying out structural monitoring prior to renovation or modernisation measures in order to check and assess the current condition of the building structure. In this way, effective and sustainable measures and construction technologies can be identified – and these are also environmentally friendly.

Produkte aus diesem Projekt

- Big Data im Bauwesen
  Date of publication: 22.09.17
- Getting More Out of Existing Structures: Steel Bridge Strengthening via UHPFRC
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