Product Info

Bauwerkslager
Structural bearings

Dehnfugen
Expansion joints

Erdbebenschutz
Seismic protection

Bauwerksüberwachung
Structural monitoring

Bulach, October 15

Street smart

The integration of specially developed SHM technology into as-fabricated expansion joints has resulted in the advent of "smart" expansion joints

1. Expansion joints key ➔ SHM

The expansion joints which accommodate bridge deck movements while providing a driving surface for traffic are critical structural components, but much less robust than the structure as a whole, and must therefore be inspected and maintained accordingly. A key requirement of proper inspection and maintenance is, of course, good information about how these components are performing, and in particular, about the movements, both absolute and accumulative, to which they are subjected. Since all expansion joint types that are capable of accommodating large movements feature sliding surfaces between certain elements, deterioration of the sliding surfaces is a primary cause of expansion joint problems. Indeed, the performance and life expectancy of expansion joints are strongly dependent on the movements to which they are subjected.

Automated structural health monitoring (SHM) systems offer a highly effective way of addressing this need for information to support inspection and maintenance activities. They measure variables such as movements (including high-frequency), inclinations and temperature, and thus enable a proper understanding of the bridges' behaviour to be developed. Not only can they measure such variables to a degree of precision that far exceeds what can be achieved by any form of manual monitoring, they also perform this monitoring service around the clock, 365 days a year – meaning immediate notification, for example, of any event or development that might make the structure unsafe for traffic. And in doing so, they are in most cases far more efficient and cost-effective than the traditional manual approach. In addition to measuring and reporting enormous quantities of very detailed information which can serve many purposes, modern SHM systems can also process the data recorded, facilitating easier analysis by the responsible engineer. For instance, in assessing data

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for the purpose of identifying any possible anomalies which might indicate damage or deterioration, it is often desirable to eliminate the influence of known and accepted environmental factors, such as expansion and contraction due to temperature changes, from the data. Such regression analysis can be easily performed by modern SHM systems, presenting the relevant data alone on a curve, greatly simplifying its analysis. As a result, even very small changes due to damage or deterioration can be identified from anomalies in the curve's shape. SHM systems can thus play a pivotal role in improving the effectiveness of inspection, maintenance and investigation activities, thereby improving the performance of bridges and their key components and extending their service lives.

2. Development of "smart expansion joints"

SHM has been used successfully for a decade or more to monitor bridges and their key components, but as bridge designs develop, demands on these key components continually increase. This is certainly true for bridge expansion joints, e.g. with higher traffic volumes meaning more wheel impacts, in many cases higher loads, and more slender decks meaning more triaxial movements and rotations to be accommodated. To maximise the potential of modern monitoring technology in monitoring and maintaining bridge expansion joints, a new generation of "smart" expansion joints is being developed. These feature a fully integrated SHM system when they leave the factory. They are designed not only to monitor and report, providing clear information about the condition of the joints and supporting the planning of maintenance activities, but also to "learn" from what they have monitored and reported in the past. This enables them to "diagnose" the information they are currently recording and immediately report the results and any associated recommendations for action. This can enable remedial or precautionary actions to be taken at the most appropriate time, optimising expansion joint inspection and maintenance work and providing additional confidence when extending the life of an expansion joint that has seen many years of service – and thus minimising expansion joint replacement works and the resulting substantial owner costs and user impacts.

3. How "smart" joints work

The functioning of this new breed of expansion joint is based on the measurement of structure-borne vibrations. Pre-installed sensors at carefully selected locations on each joint measure even the smallest vibrations experienced by the elements to which they are connected, e.g. due to traffic loading, and record them at high frequency. The vibrations experienced by a new, properly installed expansion joint will differ significantly from those of an expansion joint that has suffered deterioration or damage – for example, as a result of impaired sliding movements at its sliding interfaces due to wear of the PTFE or UHMWPE sliding material. The characteristic vibration response of the perfectly functioning joint becomes replaced by a vibration response with a different signature, which can be easily identified by corresponding changes in data or graphic representations. Of course, this requires knowledge and comparison of different sets of data representing the condition and performance of the expansion joint at different times during its life to date, and this is where the new application begins to show how it might justifiably be referred to as "smart"; by analyzing historical data, it "learns" what vibrations are normal and to be expected, enabling it to automatically filter out any which have suddenly appeared or developed over time, and to highlight these as potential indicators of damage or deterioration. But it is not just this automated deficiency detection capability that makes the new application "smart"; it also processes and analyses the data further, enabling it to pinpoint the exact location and nature of the deficiency. As a result, the system supports the planning of maintenance activities, minimising manual inspection effort and enabling the timing of replacement of components to be optimised.

4. Case study: Taizhou

An example of the application of this new "smart" joint technology is the expansion joints of the Taizhou Bridge in Jiangsu Province, China. The Taizhou Yangtze River Bridge (ref. Taizhou Triple, Bd&e No. 66), constructed at a cost of USD 400 million and opened to traffic in 2012, is the world's longest-span bridge of its type: The three-tower suspension bridge, with two main spans of 1,080 m each and side spans of 390 m, crosses the Yangtze River where it has a width of 2.1 km. The ambitious construction project represented the first attempt to create a long-span multi-tower suspension bridge.

This extraordinary bridge required some extraordinary key components, such as its expansion joints. Modular expansion joints with 18 gaps each (and thus capable of accommodating 1,440 mm of longitudinal movement) were installed at each end of the deck. But these expansion joints are not just extraordinary because of their size and movement capabilities; they are also particularly noteworthy because one of them is the first "smart" expansion joint.

The expansion joint measures movements (including high-frequency and accumulative), rotations and temperature in enabling a proper understanding of the joint's and the bridge's condition and performance to be gained by the responsible engineers. It also measures structure-borne vibrations at a sampling frequency of 25.6 kHz, and processes these as described above for the purposes of damage/deterioration detection and evaluation.

Before the joint was entered into service, many artificial failures were created in order to simulate damages – for example, by removing one of the expansion joint's many small elements. During this testing and initial learning phase, the system was found to distinguish well between normal and "deficient" joint conditions, enabled the system to be fine-tuned to optimise deficiency detection.

The permanent monitoring system continually sends data to a remote server, including records of vibrations caused by traffic together with the associated modal frequencies. The occurrence of any significant anomaly causes an alarm notification to be sent to the responsible engineer by email and to appear on the system's web interface for further analysis. Site visits can then be arranged as required for detailed inspections and to take any actions needed to prevent further damage or deterioration.

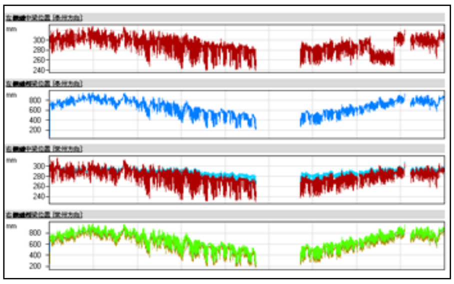
5. End

The integration of sophisticated structural monitoring systems in a bridge's expansion joints can offer great benefits to its asset management programme, by not only efficiently providing the data required for inspection, maintenance, design and investigation purposes, at any stage of a structure's life-cycle, but also "diagnosing" the data it records. Such systems also have the potential to help to assist in "training" general inspection systems for normal, "non-smart" expansion joints, which could be applied temporarily to support expansion joint evaluation and diagnosis work. "Smart" expansion joints are thus sure to play an increasingly significant role in bridge construction and maintenance in years to come.

Text: 9,363 characters

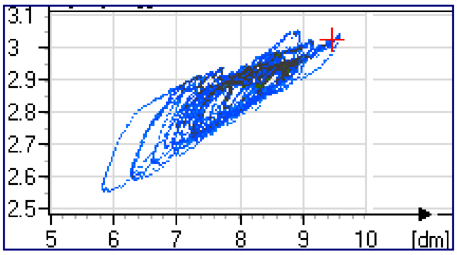
The new Taizhou Yangtze River Bridge (top) and a modular expansion joint on the Taizhou Bridge, viewed from below (bottom).

Photo: mageba



Example of recorded data (overall movements).

Photo: mageba



Correlation between displacements of a particular lamella beam (on the surface of an expansion joint) and the overall movements of the bridge. A 45° inclination of the correlation graph would indicate that these values are equal.

Photo: mageba

Fault simulation on a large modular expansion joint of the Taizhou Bridge. One of the steel stirrups, which connect the joint's surface beams to the support bars beneath with a pre-stressed sliding connection (consisting of a sliding bearing above the support bar and a sliding spring below), has been temporarily removed, enabling the vibrations experienced by this "damaged" expansion joint to be recorded.

Photo: mageba

An 18-gap modular joint of the Taizhou Bridge.

Photo: mageba

About mageba Group:

mageba is a Swiss company with its head office in Bulach, Switzerland. It is one of the world's leading suppliers of structural bearings, expansion joints and other high quality products and services for the transport infrastructure and building construction sectors. In the last 10 years, mageba has also significantly expanded its range of products and services relating to earthquake protection and structural monitoring.

The company was established in 1963 and today has over 800 employees worldwide, of which more than 100 are engineers. Some 120 people work at the head office in Switzerland.

mageba has subsidiary companies in Australia, Austria, China, Croatia, Czech Republic, Germany, Hungary, India, Mexico, Russia, Slovakia, South Korea, Turkey, United Kingdom and the USA. It is also exclusively represented in more than 50 other countries by authorised partner companies. mageba has to date supplied bearings and expansion joints for more than 20,000 structures, meeting even the exceptional challenges posed by a number of the world's largest bridges.

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