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BRIDGING THE KNOWLEDGE GAP

How Structural Health Monitoring helps protect the Great Belt Bridge in Denmark

The Great Belt Bridge in Denmark, one of the world's longest suspension bridges, benefits from Structural Health Monitoring and optimization thanks to measurement technology by Kistler.

Sensitive structures such as bridges need continuous monitoring – but how can this be achieved? The right measurement technology can detect structural changes well before infrastructure assets reach critical conditions. On the Great Belt Bridge in Denmark, a system from Kistler has been operating since 1998 to measure the structure's sway in the wind and the natural frequency of its suspension cables – key parameters for assessing the condition of this important fixed link.

Climate change is leading to weather extremes such as temperature shifts, heavy rain and strong winds, making it more likely that precious infrastructures will be pushed to their limits. Although aging bridges are especially subject to structural decline, condition monitoring can also help to protect built assets of all kinds – ranging from wind turbines to historical monuments. The right sensors to measure parameters such as acceleration are essential to collect data that provides insights into a structure's actual condition.

This is precisely the solution that was chosen for the Great Belt Bridge ("Storebæltsbroen") in Denmark. The section known as the East Bridge is one of the world's longest suspension bridges, with a free span of 1,624 meters and two pylons rising to 254 meters. Thanks to its vertical clearance of 65 meters, the East Bridge ("Østbroen") is just high enough to allow today's largest cruise ships to pass underneath it.

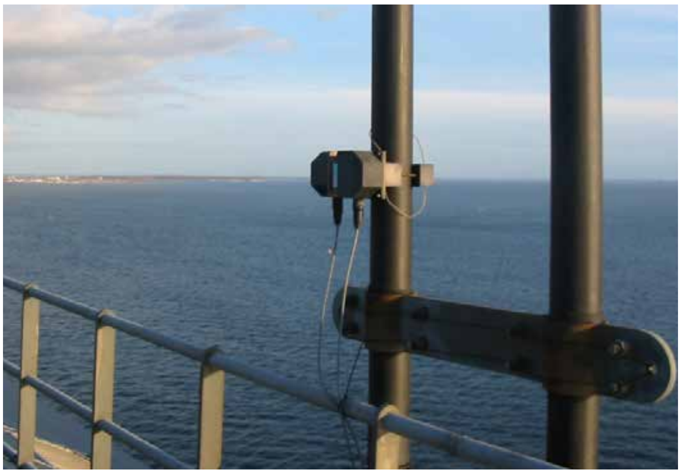
Special sensors to measure low frequencies

How is it possible to monitor the structural integrity of such a huge object? And what were the challenges? Erik Nielsen, Sales Engineer at Kistler, takes up the story: "Back then, we installed measuring systems of two types: one system to measure the natural frequency of the vertical suspension cables, and another inside the main span. The frequencies as well as the g-forces are very low here, so the main challenge was to isolate the signals from other vibrations such as those from vehicles crossing the bridge."

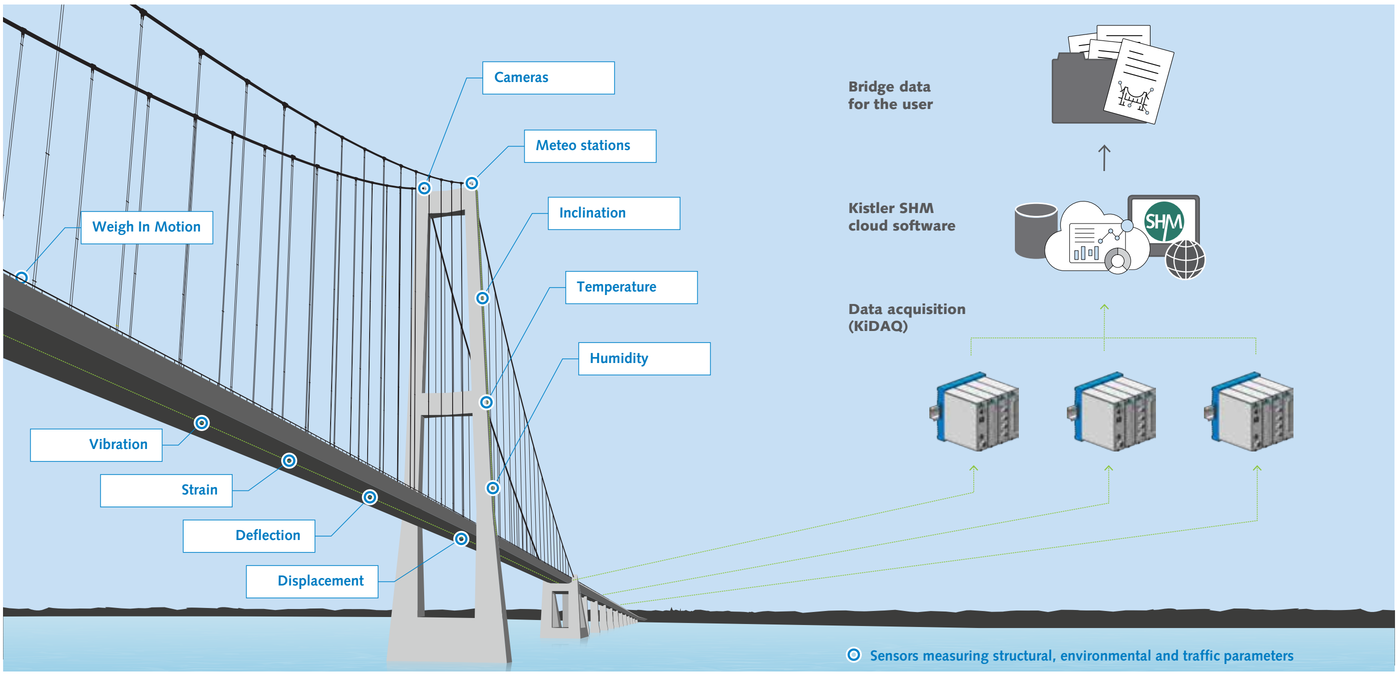
Kistler's solution met these requirements by combining special low-frequency K-Beam accelerometers with low-pass filters, to cover frequencies of 1 Hz inside the bridge and 10 Hz at the suspension cables. For further isolation of the signals from traffic-induced vibrations, mechanical dampers were added for the sensors integrated in the main span. Nielsen again: "Condition monitoring and Structural Health Monitoring applications generally require a strong focus on signal conditioning. To gain valuable data, you don't just need the right sensors – you also have to optimize the entire measuring chain, not only in terms of signal quality and transmission but also as regards data acquisition and evaluation."

Robustness and signal conditioning are key

To withstand the harsh weather conditions on the Great Belt strait, the sensors, filters and transmitters were installed in a special fiberglass-reinforced housing (shown in the photograph



The measuring systems (including accelerometers, filters and transmission) on the vertical suspension cables were installed in special boxes to ensure long-term robustness under harsh weather conditions.



The SHM system consists of a cloud-based software, the KiDAQ data acquisition system, and a wide range of sensors for measuring structural, environmental, and traffic parameters.

below). "These extremely robust boxes are still in good condition after 25 years," Nielsen adds. Transmission of the signals to the data acquisition system in the control center requires conversion to a current output (4–20 mA). "Some of the sensors needed cable lengths of over 800 meters, so we had to use special low-noise cables and sophisticated electronics. The total cable length for this installation is actually more than five kilometers!"

The measurement results provide insights into the bridge's structural behavior. The system of vertical suspension cables that support the steel rope for the main span resembles a huge harp. Nielsen concludes: "What's most important is to make sure the wind doesn't play a tune on these 'strings'. To achieve this, the bridge construction was modified at the very beginning of the project. Changes in natural frequency and swaying behavior can also indicate decay of the bridge construction and loss of its structural integrity."

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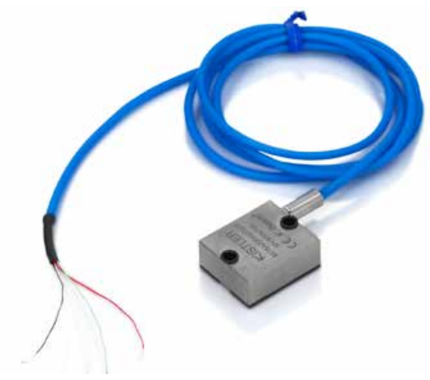
> Erik Nielsen, Sales Engineer at Kistler

Complete solutions from sensor to software
In the 25 years that have passed since the installation of sensor technology on the Great Belt Bridge, Kistler has equipped bridges all over the world with condition monitoring and Structural Health Monitoring solutions. But the scope of application for this technology is not limited to bridges – it can also help protect buildings and structures of many other types. Typical applications include power plants, wind turbines and historical buildings. As a complete solution provider, the Kistler Group now offers turnkey systems ranging from sensors, signal conditioning and DAQ to software and automated reporting. Kistler also offers end-to-end support for its products, from the initial concept and on-site commissioning through to 24/7 operation and maintenance services.



The K-Beam low-frequency accelerometer from Kistler, including special cabling, as installed on the Great Belt Bridge in Denmark.

At the monastery of Hosios Loukas in central Greece, a Structural Health Monitoring system from Kistler continuously surveils the integrity of the ancient buildings. This region is likely to be exposed to microquakes which are not perceptible at the surface and could weaken the structure without being noticed. K-Beam accelerometers accurately capture any change in the buildings' structural health. Signals are transmitted to the KiDAQ data acquisition system (also from Kistler) which enables data exchange with Athens. Thanks to this solution, the real-time 24/7 monitoring system – including automated reporting – ensures timely notification in case interventions are needed to maintain the historic buildings.

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