An under-estimated hazard: all over the world, bridges are in the process of aging – so they need accurate monitoring.

Safety after the Genoa accident: preventive monitoring and protection of bridges with Weigh In Motion and accelerometers by Kistler

Infrastructures are continuously aging – and at the same time, traffic volumes are soaring. This creates a hazardous situation, but the right technologies can at least reduce the risk. On the one hand, vibration measurements supply valuable data about the exact condition of a bridge; and on the other, Weigh In Motion (WIM) systems make it possible to collect comprehensive usage data and restrict access as appropriate.

The Morandi Bridge near Genoa (Italy) collapsed in summer 2018. The four-lane viaduct was part of the A10 autostrada, an arterial route that carries heavy traffic. This accident in the heart of Europe claimed 43 lives and even today, its causes have not been clarified beyond doubt. Was a design error to blame? Was inadequate maintenance responsible? And, above all: could the accident have been prevented – and if so, how? We shall have to wait for the official investigative report by the Italian authorities to provide reliable answers to these questions.

The fact is that road bridges involve enormously complex and interrelated infrastructure problems. The Genoa accident is merely the tip of the iceberg: many other bridges collapse without claiming victims, or without attracting public attention. In the U.S. alone, for example, there are 578 000 highway bridges: most of them were built shortly after the Second World War, and they have an average lifespan of about 70 years. The situation is similar in Germany, where experts have been warning for decades that growing numbers of bridges are reaching their critical age, or are in need of restoration. How can these structures be monitored efficiently? How can their maintenance be properly targeted? And how can maximum safety be ensured for their users?

What is the real condition of the bridge?

There are three different ways to tackle these issues. The first approach is to protect the bridge by preventing heavy vehicles from crossing it. The impact of a vehicle on the road infrastructure is related to the vehicle's weight by a power of four, so this factor has an enormous influence on a bridge's life expectancy. A second method is to measure the vehicles' axle loads per unit of time: this approach provides information about

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the stress on the road paving and the structure as a whole. And thirdly, changes to the bridge itself can be monitored. Measurement systems based on accelerometers collect data about critical changes to the structure and "health" of the bridge: this method is known as structure health monitoring (SHM) or bridge health monitoring. By recording movements and vibrations, these systems permit conclusions about stress and possible corrosion of the structure. The Kistler Group offers tried-and-tested products that are suitable for all methods of bridge monitoring: products that help to preserve valuable infrastructure and make it safe. The summary below explains the technical basis and describes some examples of applications.

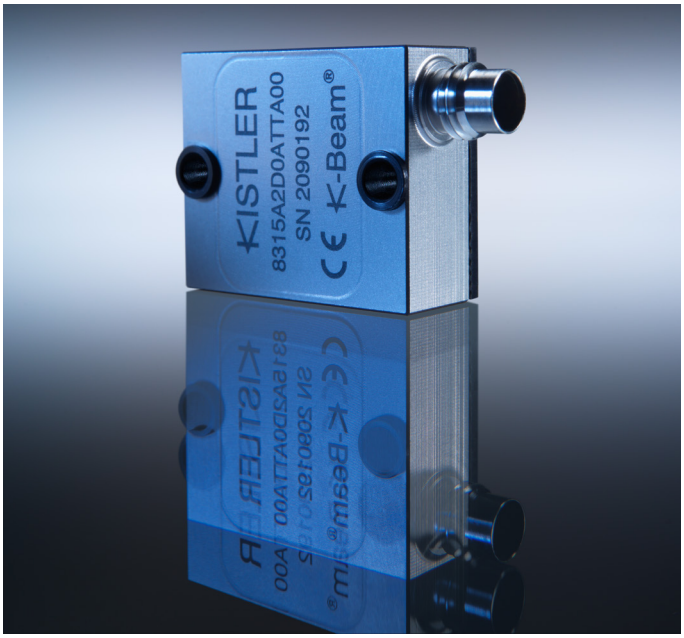
Kistler accelerometers specifically designed for bridge health monitoring are deployed on bridges worldwide to measure influences caused by traffic, wind, and temperature fluctuations. Measurement systems of this sort are installed on the Great Belt Bridge across the Baltic Sea in Denmark, and in bridges over the Yangtze River in China and the Mississippi in the U.S. For example, 26 Kistler accelerometers are operating on the Interstate 35W in Minneapolis (Minnesota), built in 2009 to replace the collapsed bridge over the river. Twelve of these sensors measure vibrations in the center of the concrete piers. 14 more accelerometers are distributed throughout the structure to perform longer-term modal analyses and in particular to monitor the structure's natural frequency: any significant changes to the natural frequency indicate possible damage.

The success of these measurements is critically dependent on factors such as measurement sensitivity, frequency range, temperature stability and linearity. Kistler's capacitive MEMS and piezoelectric IEPE sensors offer mature technologies to suit different application conditions: IEPE is ideal for smaller structures and higher frequencies, while MEMS is deployed for larger structures and DC or low-frequency signals. Additional parameters that require specification include cable lengths, EMC protection and temperature range/stability. For instance, Kistler's 8316A MEMS accelerometer has a frequency range of 0…1500 Hz, an operating temperature range from –55 to +125°C and possible cable lengths of up to 400 meters – with the added benefit of very low noise values.

Efficiently preventing damage due to overloading

Accidents such as those at Genoa and Minneapolis can likely be prevented in the future by deploying suitable accelerometers as components of integral measurement systems that also include anemometers (wind gauges), strain sensors, linear potentiometers, GPS and other equipment. Another key component of measurement systems for bridges is the Weigh In Motion (WIM) system, which delivers detailed information about stress exerted by commercial vehicles and their loads.

WIM systems by Kistler measure the weight of vehicles on the road while they are traveling. They are based on sensors that



Special accelerometers by Kistler provide insights into critical changes in bridges.

can be installed directly in the road paving for an unlimited number of lanes in each direction of travel, with immediate evaluation of the data acquired. Over 50 000 of our tried-and-tested Lineas brand quartz sensors are already in use worldwide: because they are based on the piezoelectric principle, they are outstandingly accurate, maintenance-free and stable over the long term. Lineas sensors are available in different lengths (1.50 m, 1.75 m and 2.00 m), and they can be integrated into various types of road paving. Once the sensors are installed, they reliably measure axle loads and the total weight of vehicles moving at both high and low speeds. Thanks to temperature-independent measurements with high accuracy (of up to 2.5%), users can collect comprehensive data on road use and loads; overloaded vehicles can also be directly prevented from driving onto bridges. Another benefit: prior to bridge reconstruction work, WIM systems provide critical information – for example, on whether traffic can safely be diverted onto one half of the road.

In addition to WIM sensors and the related evaluation and analysis systems, Kistler offers services tailored to optimize the equipment's functionality and lifetime. As well as remote and on-site support for calibration, the service portfolio includes identifying the optimal position for sensor integration: this is a key factor because – together with the physical condition of the road – it determines the system's subsequent performance data.

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