
TRAFFIC SAFETY AND INFRASTRUCTURE PROTECTION

Structural Health Monitoring

Kistler's complete solutions and services
to monitor and protect bridge infrastructure

Content

| | |
|---|----|
| Protecting sensitive infrastructure with Structural Health Monitoring (SHM) | 4 |
| The easy way to monitor and protect your infrastructure: solutions by Kistler – from sensor to data | 6 |
| Kistler supports users with services throughout all project phases | 8 |
| Full data availability with Kistler's SHM cloud software platform | 9 |
| The KiDAQ data acquisition system – make your signals available digitally | 12 |
| Sensors – your monitoring system's nerve cells | 14 |
| Kistler's holistic solution to ensure traffic safety and protect infrastructure | 18 |
| Putting monitoring solutions into practice – with Kistler | 21 |



Protecting sensitive infrastructure with Structural Health Monitoring (SHM)

Bridges are backbones of the economy in every country in the world. These key elements of the traffic infrastructure usually consist of steel, cast iron and prestressed concrete – and nowadays, many of them are aging. It is very difficult to determine a bridge's stability merely by inspecting the structure from the outside. But thanks to Structural Health Monitoring (SHM), operators now have solutions to identify degradations of a bridge's structural integrity at an early stage – so they can take proactive and efficient steps to address these critical issues.

A bridge's structural integrity degrades naturally over time due to fatigue, cracking and corrosion. Also, increased traffic loads and harsher weather conditions place additional burdens on bridge structures. Critical structural deficiencies are present in an extremely high number of bridges built over 50 years ago as they approach (or even reach) the end of their service lives – but the same issues also affect many newer bridges that are not

properly maintained. Drastic measures such as closing a bridge or imposing heavy limitations on traffic must be avoided at all costs. This is why maintaining bridges to extend their service lifetimes and ensure their safety is an overriding priority for all operators. There are limits to what regular inspections and assumption-based structural models can achieve – and this is precisely where sensor-based bridge monitoring (SHM) comes into play.



Find out more about
SHM applications:

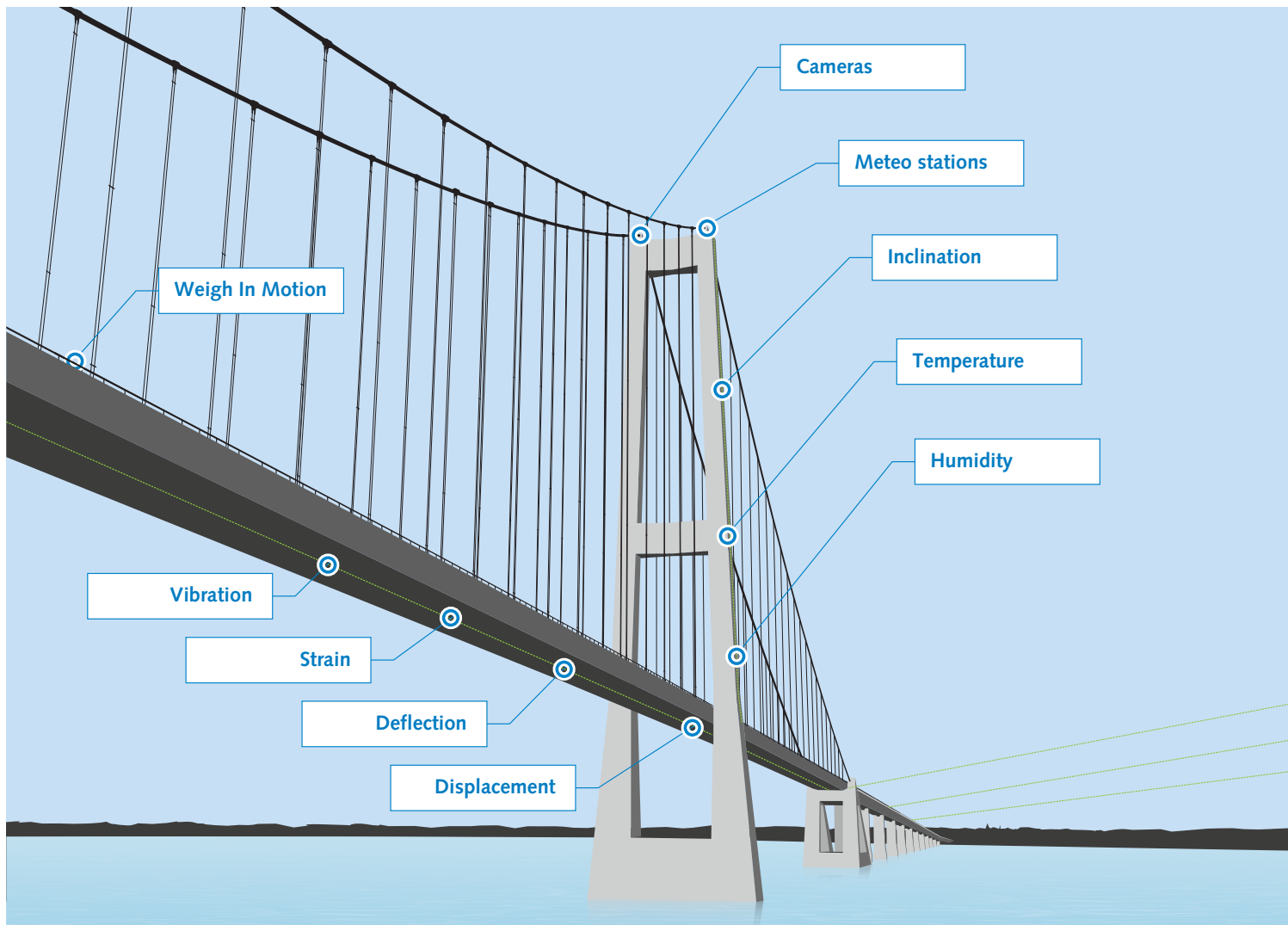


Sensor-based Structural Health Monitoring: the key to enhanced bridge safety

As an operator, you can gain unique advantages by opting for continuous sensor-based bridge monitoring to complement your conventional field inspections. SHM solutions deliver automatic monitoring on a 24/7 basis, with continuous measurements to track real bridge performance and traffic loading – so you can identify even the smallest variations as soon as they occur. Issues and faults are detected well before they can lead to more serious damage. You are kept continuously informed by relevant data supplied at regular intervals, and you are notified immediately whenever the monitoring systems automatically generate specific alarms.

SHM enhances bridge safety by delivering these key benefits:

- Condition ranking based on effective structural response
- Extension of remaining bridge service life (bridge lifespan)
- Damage detection at an early stage (lower maintenance and repair costs)
- Detection of structural deficiencies that are not visible during inspections
- Condition-based maintenance
- Continuous monitoring of real structural behavior
- 24/7 condition assessment to eliminate information shortfall between regular inspections



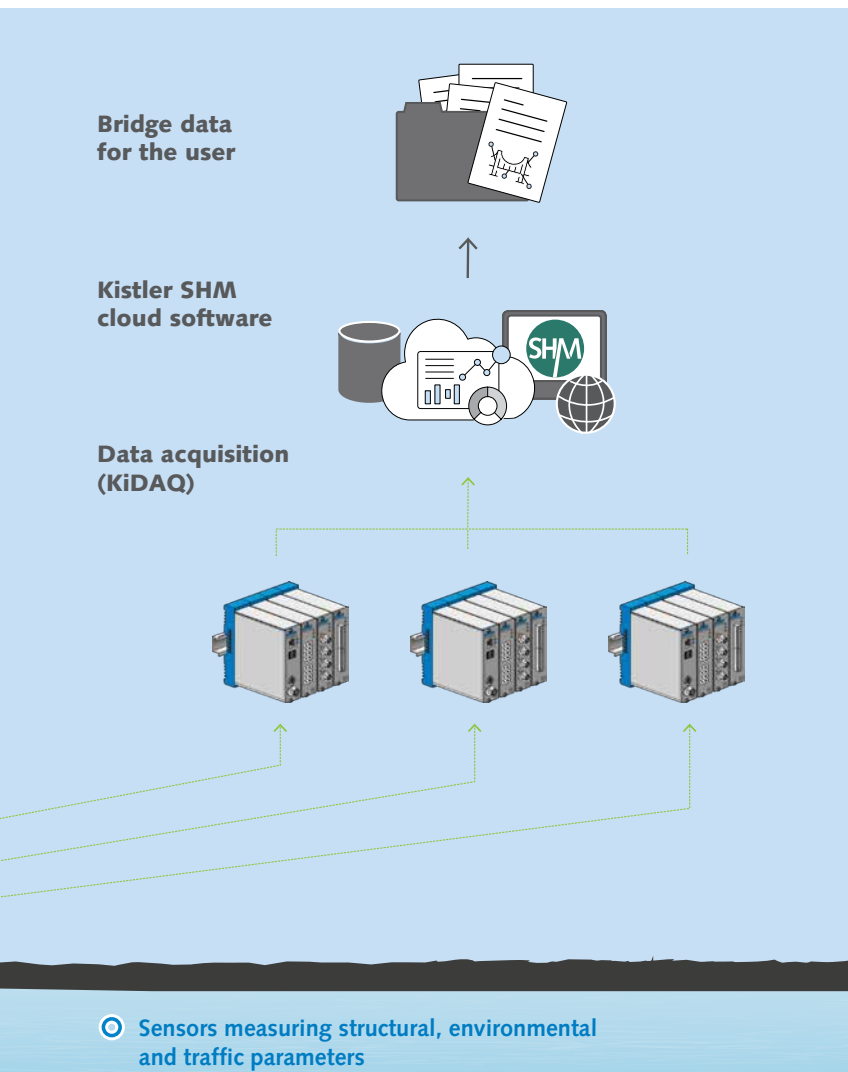
The easy way to monitor and protect your infrastructure: solutions by Kistler – from sensor to data

Backed by over 50 years of measurement technology experience, Kistler supplies fully customized monitoring solutions for bridges of all types – solutions that ensure seamless availability of highly reliable bridge structural data.

Kistler can supply a fully customized solution for any monitoring application. Our flexible components meet proven standards, and they combine technological reliability with expandability. Efficient integration guarantees the most reliable solution, delivered to you from one single source. Our solution architecture comprises a sensor layer, a data acquisition layer and, on top, a cloud software platform that acts as the user interface – with a range of functionalities such as data storage and processing, data visualization, notifications and reporting.

Kistler's own team of measurement technology specialists and structural engineering experts will support you, the user, with all the expertise you need to define and design your optimal monitoring application. What's more: our service engineers can be present on site to install and commission your solution.

Kistler's complete solution delivers automatic 24/7 monitoring of your structures. All measured parameters are collected continuously and stored securely in our SHM cloud software.



Benefits

- **Modular and customizable solution** for monitoring of any bridge structure
- **Complete solution** comprising software platform, data acquisition, and sensors
- Measures all **parameters related to structure, environment, and traffic**
- **Unmatched accuracy for dynamic measurements**
- High reliability of data – **complete solution from one single source**
- Compliant with **bridge monitoring guidelines** and **latest research insights**
- Measurement technology experts and structural engineers **ready to advise the customer**
- **Local service engineers** standing by to support deployments

You are able to identify even the smallest structural variations as soon as they occur. Issues and faults are detected well before they can lead to more serious damage. You are kept continuously informed by relevant data supplied at regular intervals, and you are notified immediately whenever the monitoring systems automatically generate specific alarms.



Our complete solution measures the key parameters related to the bridge structure, the environment and traffic. Specifically, these include:

Structural parameters

- Vibrations and oscillations
- Cracking (acoustic emissions)
- Strain and stresses
- Movement (displacement and tilt)
- Deflection

Environmental parameters:

- Wind
- Temperature
- Humidity

Traffic parameters:

- Traffic density on bridge
- Traffic loading on bridge
- Vehicle weights (gross vehicle and axle load)
- Vehicle distances
- Vehicle speeds

1. Infrastructure assessment



Selection of monitoring targets according to structural peculiarities (in cooperation with partners)

2. Planning and design



System design, integration, and customization based on multiple sensors

5. Continuous monitoring and maintenance



Assessment of bridge's structural performance over time (in cooperation with partners)



Maintenance and support



Spare parts



Periodic calibration

3. Installation



On-site startup assistance
Remote configuration

4. Data and equipment management



Real-time data acquisition and secured data storage



Data visualization, notifications, and alarms



Health status monitoring of equipment
Remote updates and upgrades



Kistler supports users with services throughout all project phases

Kistler provides a wide range of services that ensure optimal support for users in all phases of the project, and throughout the entire operation and service lifespan of our complete solution. Kistler offers you flexibility: you can source the services you require according to your specific project, your requirements, and your own expertise.

Thanks to Kistler's worldwide network of experts, you benefit from consulting and support throughout all phases of your project. Our range of services includes:

• Infrastructure assessment

The process starts with collecting customer requirements and defining project scopes. The monitoring targets are defined according to the structural peculiarities and criticalities, which are derived from an initial assessment of the infrastructure.

• Planning and design

Our team will design and integrate a monitoring system based on multiple sensors (for both static and dynamic monitoring). The result: a system that meets the unique requirements of each bridge, so you can count on accurate and reliable data collection for comprehensive structural analysis.

• Installation

Kistler's team is present on site to give you startup assistance that ensures a smooth and efficient installation process. Our technicians are there to guide you through the setup, calibration

and commissioning phases – so you can be sure your monitoring system will be up and running in next to no time.

• Data and equipment management

Also included in our solution: services to guarantee fully functional real-time data acquisition with secured storage. You benefit from customizable notifications and alarms that give you timely insights into the bridge's structural health. Plus: continuous monitoring of overall functionality (covering all systems and all sensor channels), so any malfunctions are reported automatically. And it's easy to implement updates and upgrades remotely.

• Continuous monitoring and maintenance

We collaborate with our partners to provide continuous monitoring of your bridge's structural performance. To ensure the longevity and accuracy of the entire monitoring system, we provide maintenance and support services including a remote support hotline, spare parts service with on-site support for repairs and replacements, and periodic calibration.



Full data availability with Kistler's SHM cloud software platform

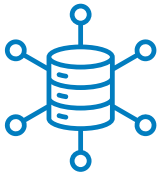
Our SHM software is a comprehensive cloud-based platform that enables multiple functions: distributed data acquisition, storage, structuring, visualization, indexing, and analysis.

Kistler's SHM software offers you a wide range of functionalities to ensure data availability at all times and from any sensor channel. Users can remotely configure all the measuring equipment installed on the bridge (sensors and systems). Sensor data streams are captured and stored securely, and visualization of relevant data can be tailored to your individual needs. As a user of our SHM software, you can continuously monitor key parameters related to your bridge's structure, traffic, and environment; you can also configure specific notifications or alarms to match your requirements. User-specific algorithm can be implemented in the same platform to ensure seamless data processing. Our platform can integrate data originating from sources of any type – not only from Kistler's KiDAQ units, but

also from any third-party systems. As an added advantage, the platform comes equipped with API interfaces for data transfer to higher operator-side data management systems. You benefit from usage-based pricing and scalable architecture so you can enjoy the full modularity and scalability of this platform. The SHM cloud-based software also leverages edge computing technology, with an on-site computer to manage and process huge amounts of data in real time. This feature enables our SHM solution to maintain the same performance, no matter whether your data is sourced from just a few sensors or several thousand: long-term data storage is guaranteed, and you can perform complex data processing operations and calculations in real time.

Summary of main SHM software functionalities:

Measurement data storage and visualization



- All measured data is buffered on the edge PC to guarantee full data availability – but only the data relevant to you is uploaded to the cloud.
- The data is aggregated 24/7 and visualized on an intuitive cloud dashboard – which you can adapt to your project's specific requirements.
- You are aware of all critical events thanks to the highest sampling rate, with triggering based on events or alerts; back-in-time-triggering is also available in case you missed something.

Notifications



- You are notified whenever an event occurs on your structure; with filtering, you can restrict notifications to events that are relevant to you – and you can be informed at any time, wherever you are.
- Notifications and events can be defined on the basis of sensor values and system status, and also for calculated channels.

Settings and configuration

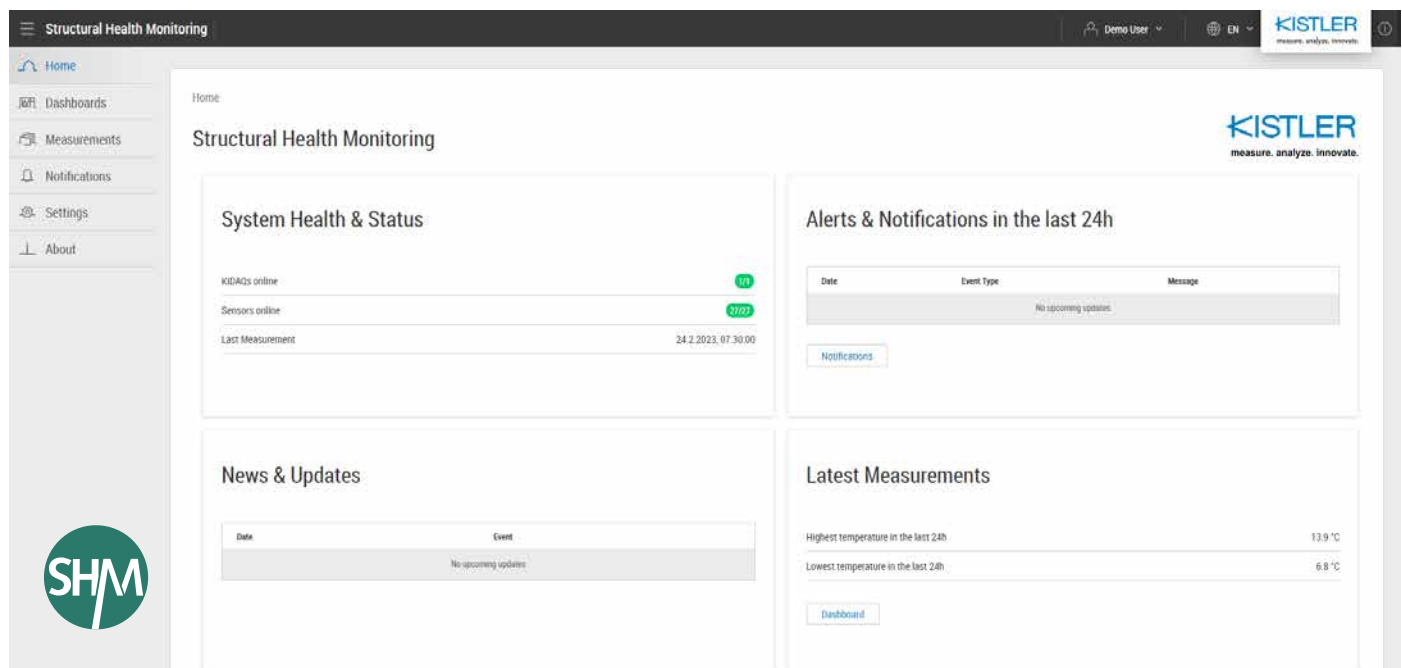


- The system is fully configurable from the cloud, with 100% remote control for all your data acquisition, edge computers, and other devices.
- We provide you with regular SW updates for all our devices – these can be applied remotely to ensure your system is always up to date and secure.

Health status monitoring

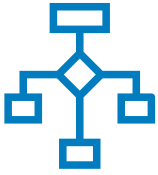


- All our sensors and devices are continuously monitored for abnormal behavior.
- Defects and anomalies are identified and flagged so you can easily locate them on the bridge.
- You can exclude flagged data from any further analysis to prevent incorrect conclusions.



Homepage of Kistler's SHM software platform with overview of main functionalities

Customer algorithm runtime



- Our solution includes an interface to run your own algorithm both on our real-time data and on the aggregated data.



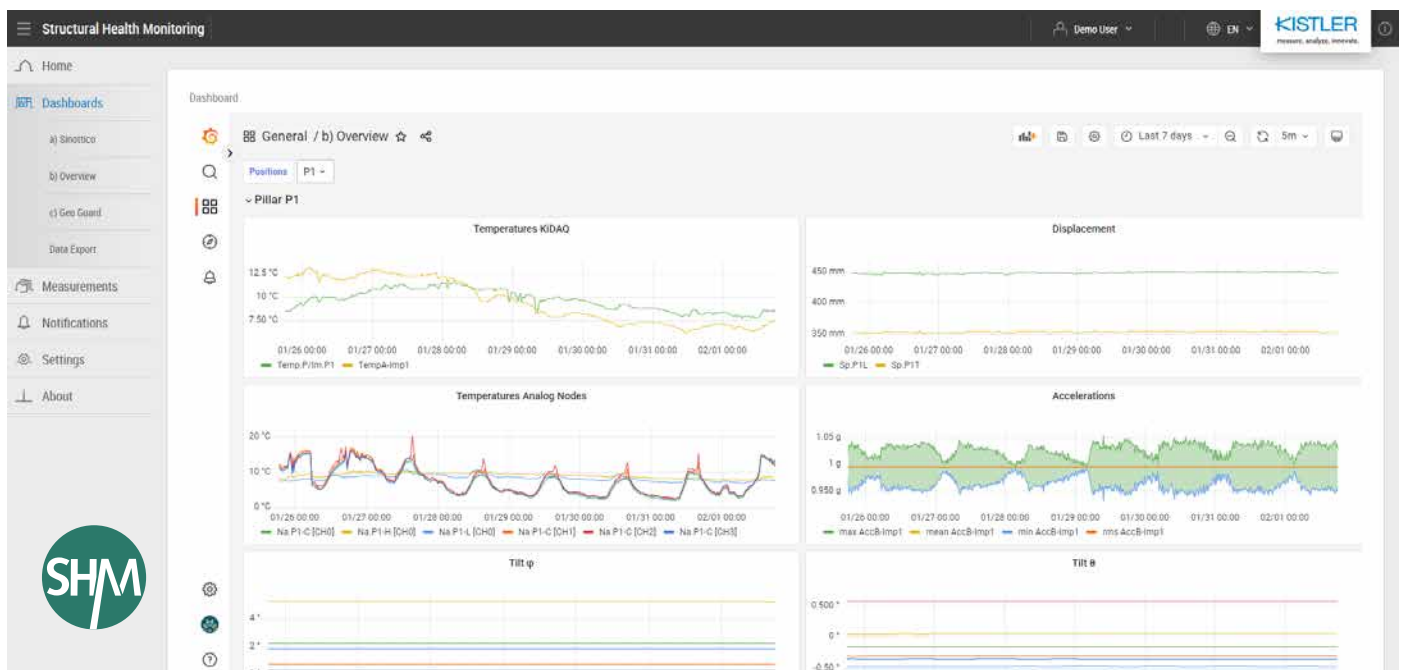
Access rights and security



- The web-based interface allows remote access to the bridge and its data from any location.
- Our granular OAuth 2.0-based access management system gives you full control over who can access your system, and at which depth.
- We continuously update the cloud SW – so you can rest assured your data will always stay secure and accessible.

Main benefits of our SHM software

- Open solution – **fully customizable** to meet each project's requirements
- **Data you can trust** – professional system architecture combined with advanced functions to ensure the highest standard of data quality
- **Data availability guaranteed at any time** – including local buffering to allow 'back-in-time triggering'
- State-of-the-art **data security**
- **Remote configuration and updates**
- **Open interface** – so customers can run their own structural analysis



Dashboard of Kistler's SHM software with visualization of selected live data channels (e.g. temperature, acceleration, displacement), customizable to individual needs



The KiDAQ data acquisition system – make your signals available digitally

Kistler offers KiDAQ – a unique integrated data acquisition system, highly modular and easily customizable to monitor any type of bridge with any type of sensor technology.

KiDAQ ensures comprehensive networking of sensors, and delivers high data quality thanks to high resolution, high sampling rates and precise data synchronization. Our KiDAQ data acquisition system features a modular design that gives you the flexibility to expand your solution as you wish. KiDAQ offers a wide choice of measurement modules covering over 20 different measurands and sensor interfaces (such as voltage, current, resistance, temperature, strain gauges, and many more). These modules are available in different housing variants to ensure maximum flexibility. The KiDAQ system also includes distributed measurement technology. Multiple KiDAQ units can be deployed and daisy-chained along the bridge to build a highly reliable distributed system, so installation becomes much easier.




You benefit from our measurement technology expertise throughout the entire measuring chain – from the sensors and signal conditioning all the way through to the software

- Highly reliable and precise digitalization of sensor data with no loss of information
- Most versatile and modular hardware concept
- Up to 19 measurement modules available for vast range of sensors (static and dynamic mode)
- Expandable as distributed systems (daisy chaining)
- Precise time synchronization with PTP
- Quick and easy remote configuration



A wide range of different measurement modules (up to 19) ensures full flexibility and modularity to interface with any type of sensor output.

KiDAQ housing options

| KiDAQ DIN Rail | KiDAQ Rack | KiDAQ Portable |
|---|---|---|
|  |  |  |
| <ul style="list-style-type: none"> Simple standardized mounting on DIN rail You can combine any number of measurement modules (from the list below) | <ul style="list-style-type: none"> Standard 19" housing for simple mounting in roadside cabinet Up to 13 measurement modules can be selected individually (from the list below) | <ul style="list-style-type: none"> Compact, robust housing for stationary and mobile measurements Up to 13 measurement modules can be selected individually (from the list below) Battery operation possible |

KiDAQ measurement modules overview

| Measurement module type | 5501A | 5502A | 5505A | 5506A | 5507A | 5509A | 5512A | 5514A | 5517A | 5518A | 5521A | 5522A | 5525A | 5526A | 5528A | 5529A | 5531A | 5534A | 5535A |
|---------------------------------|--|-------|-------|----------|----------|-------|-------|-------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|-------|-------|
| Analog input channels | 2 | 4 | 8 | 8 | 8 | 4 | 4 | 8 | 8 | 2 | 8 | 4 | 4 | 4 | 4 | 4 | - | - | - |
| Digital input channels | 2 | - | 2 | 2 | - | - | - | - | - | 4 | - | - | - | - | - | - | 4 | 8 | 6 |
| Sampling rate per channel (S/s) | 100 k | 20 k | 20 k | 20 k | 20 k | 100 k | 100 k | 20 k | 20 k | 20 k | 100 | 10 | 20 k | 100 k | 100 k | 100 k | | | |
| Analog signals | Voltage | ■ | ■ | ■ < 10 V | ■ < 60 V | ■ | | ■ | ■ | | | ■ < 80 mV | | | | | | | |
| | Voltage (isolated 1.2 kV) | | | | | | | | | | | | | ■ | ■ | ■ | | | |
| | Voltage (range up to 1.2 kV) | | | | | | | | | | | | | | ■ | ■ | | | |
| | Current | ■ | ■ | ■ | | ■ | | | | | | | | ■ | ■ | | | | |
| | Resistance | ■ | ■ | | | | | | | | | ■ | | | | | | | |
| | Potentiometer | ■ | ■ | | | | | | | | | | | | | | | | |
| | Pt100, Pt1000 (RTD) | ■ | ■ | | | | | | | | | ■ | | | | | | | |
| | Thermocouples | ■ | ■ | | | | | | | | ■ | | | | | | | | |
| | Thermocouples (isolated 1.2 kV) | | | | | | | | | | | | ■ | | | | | | |
| | Strain gauges | ■ | ■ | | | | | | ■ | ■ | | | | | | | | | |
| | Inductive full and half bridges | | | | | | | | | ■ | | | | | | | | | |
| | LVDT (displacement) | | | | | | | | | ■ | | | | | | | | | |
| | Piezoelectric sensors | | | | | ■ | | | | | | | | | | | | | |
| | IEPE sensors (Piezotron) | ■ | | | | | ■ | | | | | | | | | | | | |
| | MEMS capacitive sensors (K-Beam) | | | | | | | ■ | | | | | | | | | | | |
| | Piezoresistive pressure transmitters (PRT) | | | | | ■ | | | | | | | | | | | | | |
| Digital signals | Frequency | | | | | | | | | | | | | | | | ■ | ■ | ■ |
| | Pulse width | | | | | | | | | | | | | | | | ■ | ■ | ■ |
| | Counter signal | | | | | | | | | | | | | | | | ■ | ■ | ■ |
| | Time | | | | | | | | | | | | | | | | ■ | ■ | ■ |
| | Status | ■ | | ■ | ■ | | | | | ■ | | | | | | | ■ | ■ | ■ |
| | TEDS | ■ | | | | | ■ | | | | | | | | | | | | |



Sensors – your monitoring system's nerve cells

Sensors from Kistler capture a vast range of physical parameters such as acceleration, acoustic emissions, strains, stresses, loads, and many more. Our measurement experts select the right sensor for your specific measuring task and if necessary, we add sensors from qualified third-party suppliers to enhance your system. Kistler sensors meet the highest quality standards and deliver measurements with maximum precision – so you can rest assured there will be no errors due to noise, thermal drift or any other factors.

Acoustic emission sensors

Acoustic emission (AE) sensors offer a unique method of monitoring fatigue and cracking in bridge steel structures and stay cables.

When cracking takes place, material waves with frequencies of up to 1,000 Hz are released: these can be captured by Kistler's high-end acoustic emission sensors. Cracking can be identified in the initial stage before it can propagate and cause more extensive damage.



Features and benefits

- Can identify cracking/fatigue at an early stage
- Non-destructive testing
- Frequency range of up to 1,000 Hz
- Single-axis and triaxial
- Thermally stable, can measure at temperatures of up to 165°C



Accelerometers

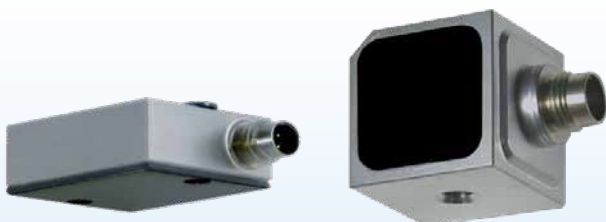
When studying and monitoring large structures such as bridges, dynamic response is a key element for assessing structural behavior. These bridge structures move very little, and they move slowly. To capture these movements precisely, the sensors must meet very demanding requirements as regards accuracy, thermal stability and low noise so that users can draw the right conclusions about structural health.

As the recognized expert in dynamic measurement technology, Kistler can provide best-in class accelerometers to measure acceleration and vibration. These sensors from our K-Beam family

are designed to measure with high accuracy in the very low frequency band, with no temperature errors (high thermal stability) and with an almost zero level of noise density.

When measuring other structures in a bridge (such as stay cables), higher frequency ranges are of interest – and Kistler's acceleration portfolio also includes products that can meet this requirement.

From the extensive range of Kistler accelerometers, we make sure that the most suitable product is selected to meet each customer's requirements.



8316A

8396A

Features and benefits

- Best-in class accelerometers from the K-Beam family
- Highest accuracy to monitor structural changes precisely over time
- No thermal drift (highest thermal stability)
- No signal distortion – lowest noise density
- Single-axis and triaxial
- Miniature design

Surface strain sensors

Piezoelectric sensors from Kistler can be used for high-resolution measurements of the strains acting on a structure. Surface strain sensors are simply attached to the structure with a mounting screw. These strain sensors are suitable for measuring dynamic and quasistatic strains; they have a very high measuring sensitivity, and thus they can detect smallest deformations of the structure.

Features and benefits

- Durable, no creep
- Simple to install
- Very high measuring sensitivity



9232A



9237B

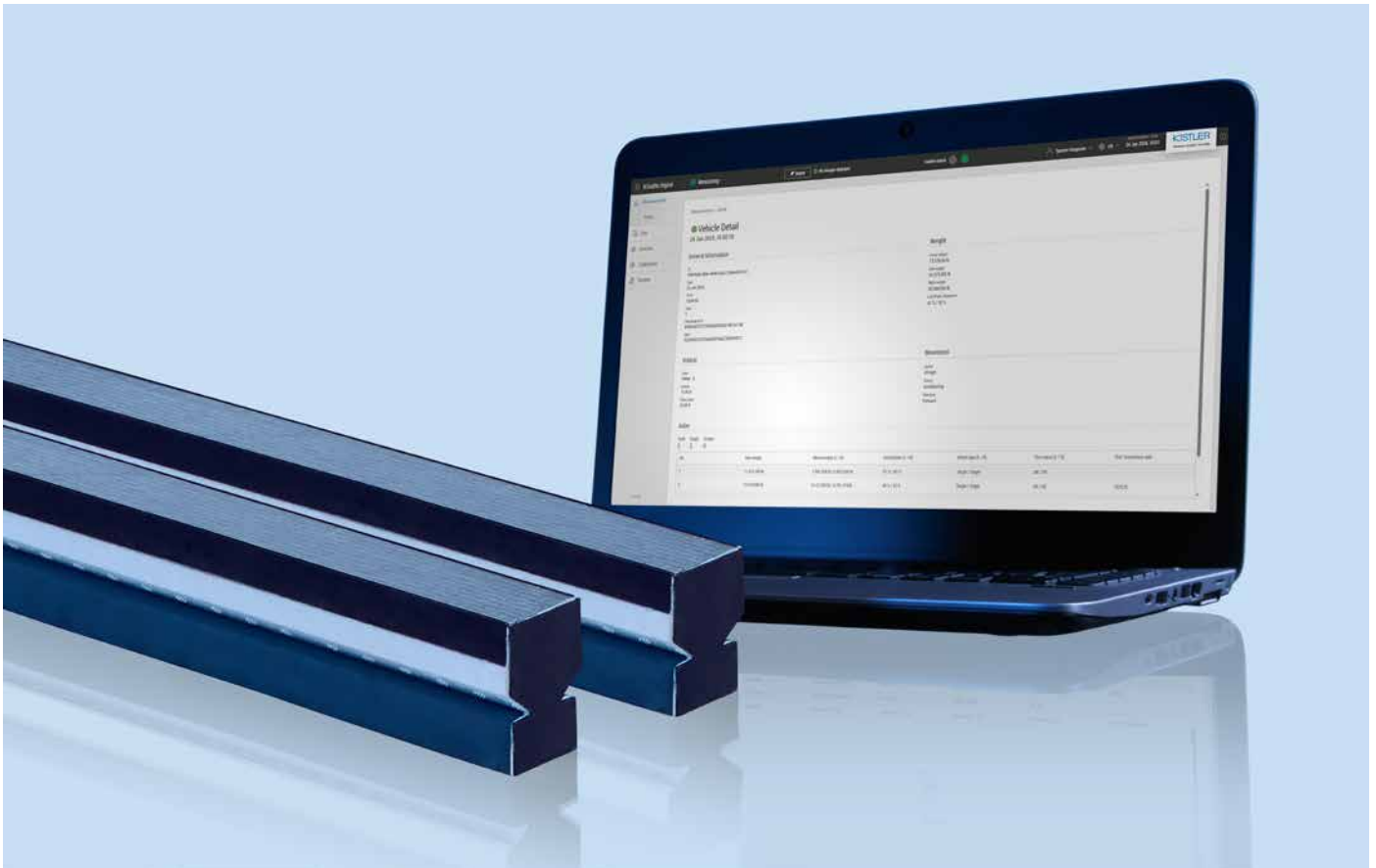
Flexible integration of third-party sensors and subsystems

Kistler monitoring solutions are designed to allow integration of sensors and systems from qualified third-party suppliers, including:

- Temperature and humidity sensors
- Weather stations
- Inclinometers
- Displacement sensors
- Others



Automatic weather station, with a weather monitoring system and video cameras for observation



KiTraffic Digital, the unique Weigh In Motion solution

Traffic sensors and Weigh In Motion

When monitoring bridges and performing structural analysis, consistent information on the real traffic loads passing over the bridge is essential. Traffic loads have a direct impact on bridge fatigue, so real traffic load analysis is an important factor when calculating a bridge's remaining service life. Kistler's Weigh In Motion (WIM) systems monitor traffic on a 24/7 basis to provide

users with relevant information on traffic loading: data is supplied on traffic volumes, vehicle weights and axle loads, vehicle distances, vehicle classes, and many more parameters. The core elements of these WIM systems are our unique Lineas quartz WIM sensors (installed in the road pavement) and the WIM Data Logger, which collects the traffic data.



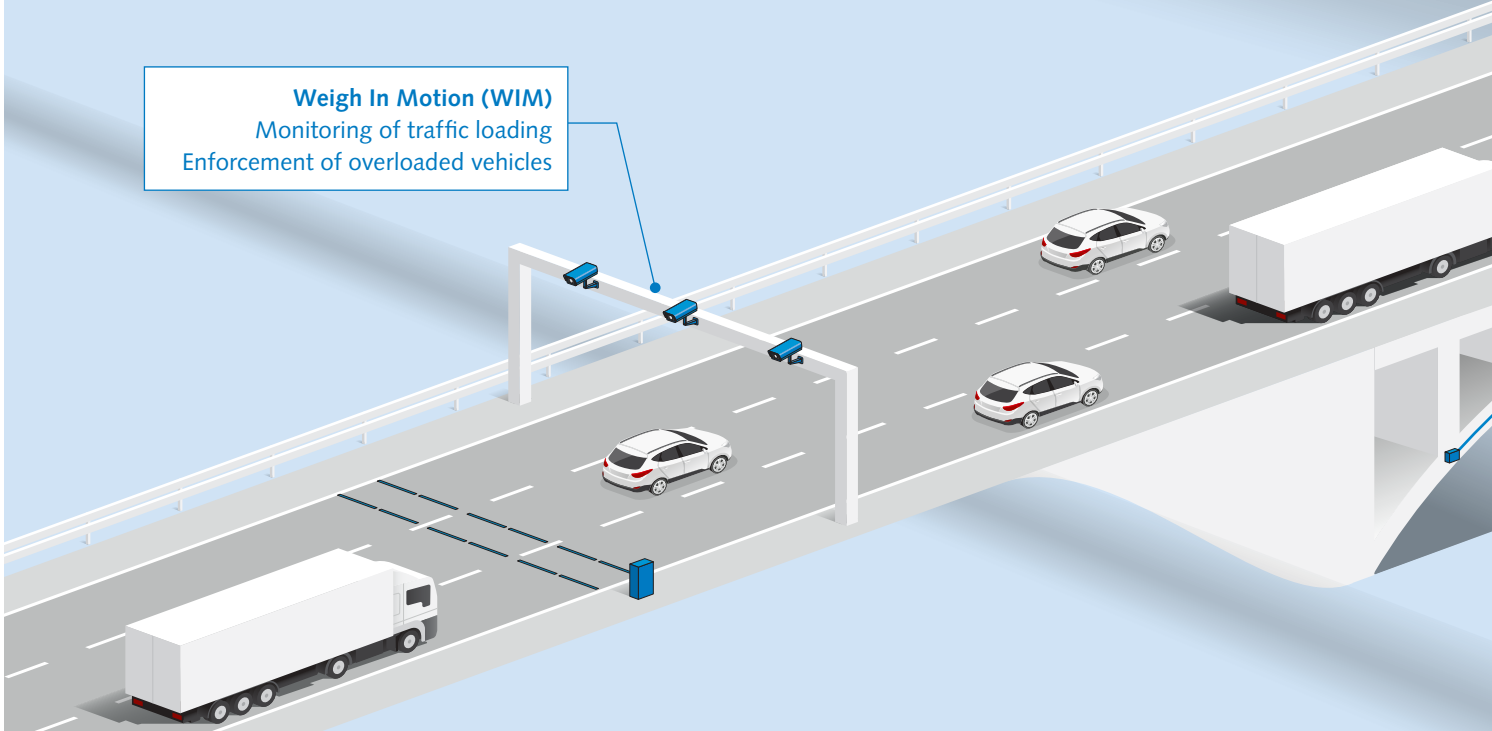
Features and benefits

- Essential traffic load information for structural analysis
- 24/7 traffic monitoring
- Accurate weighing of vehicles moving at any speed
- Unique quartz technology for highly reliable vehicle weighing
- Easy to install and operate
- Certified to the OIML R134 standard
- Compliant with COST-323 and ASTM E1318-09 standards

Bridge Structural Health Monitoring – combined with automatic vehicle weight and Speed Enforcement

Speed Enforcement
Monitoring of vehicle speed
Enforcement of speed limitations

Weigh In Motion (WIM)
Monitoring of traffic loading
Enforcement of overloaded vehicles

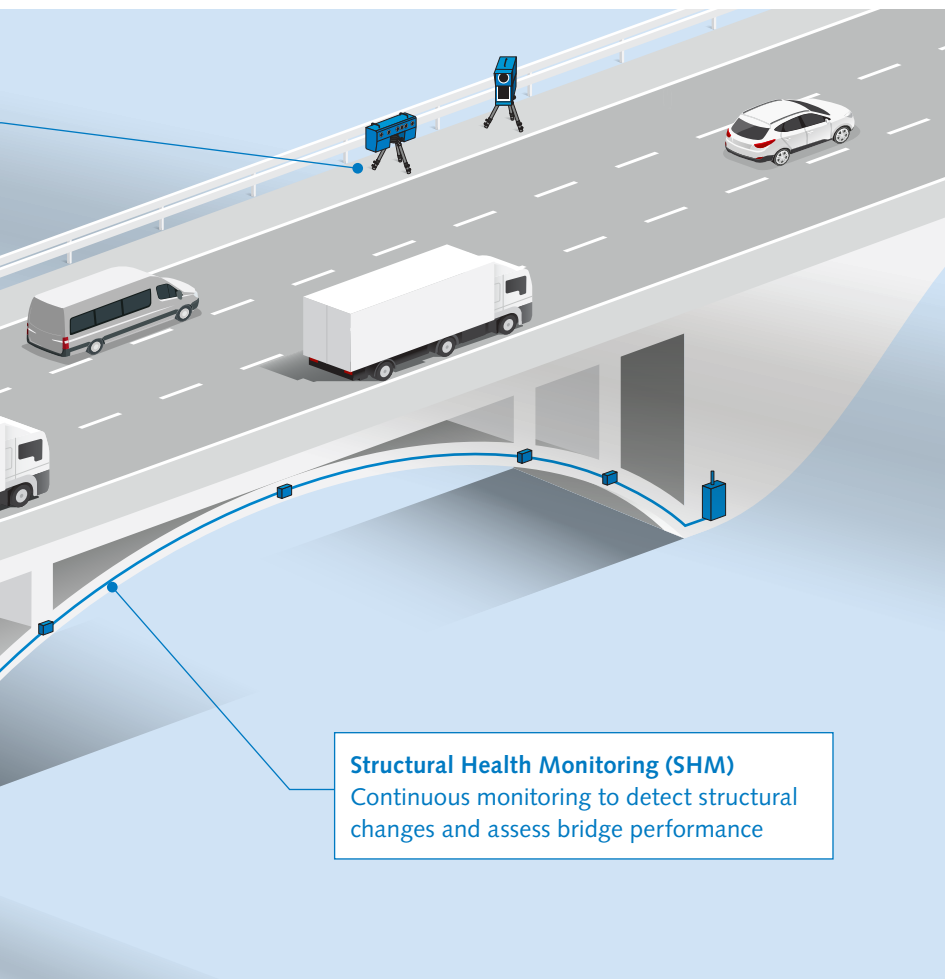


Kistler's holistic solution to ensure traffic safety and protect infrastructure

Bridge structures have limited service lifetimes – and they face growing challenges due to natural aging as well as major increases in traffic density and loading. Holistic solutions from Kistler take account of all relevant parameters to ensure effective protection for infrastructure. At the same time as monitoring the bridge's structure, our technology measures all vehicles passing over it on a 24/7 basis – so any vehicle violating the legal limits for gross vehicle weight, axle weight and speed can be identified and then prosecuted.

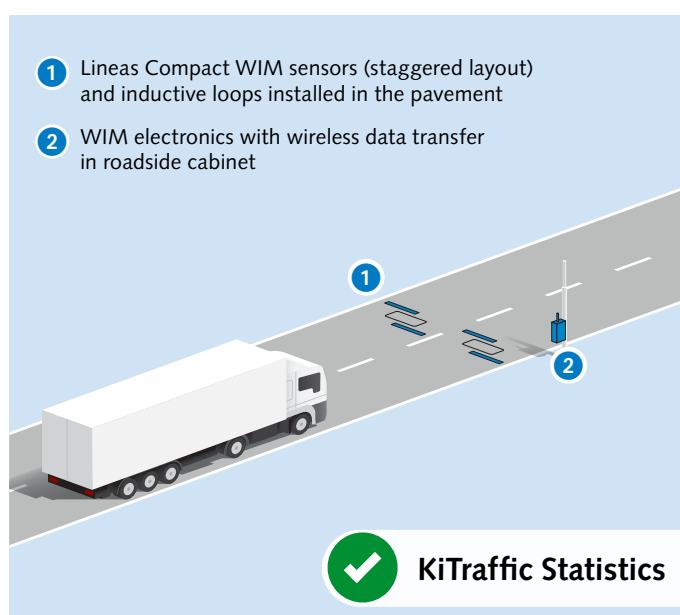
Traffic loads have a direct impact on bridge fatigue – so it follows that analysis of real traffic loading plays a critical part in assessing a bridge's fatigue and its remaining lifetime. When monitoring bridges and performing structural analysis, consistent information on real traffic loads and travel speeds is essential. Compliance with legal loading and speed limits is a key factor in ensuring traffic safety and the health of a bridge structure. Traffic load and speed limits are often imposed on bridges with structural deficiencies. A WIM system makes it easy to identify overloaded vehicles so violators can either be automatically fined, stopped and made to unload, or rerouted to an alternative itinerary: all these measures ensure highly effective protection for the bridge infrastructure.

Generally, when performing infrastructure assessment, dynamic weighing (WIM) enables comprehensive categorization of real traffic patterns, which serve as reference models and have better accuracy than the models from the guidelines. In addition, when dynamic weighing is conducted from the extrados, together with acceleration measurements also made there, it provides important information about the deformations occurring at different points in the bridge. Thus, the integration of local and global bridge measurements is very valuable additional information for assessing the structural integrity of the artifact, especially in the context of processing large amounts of data.

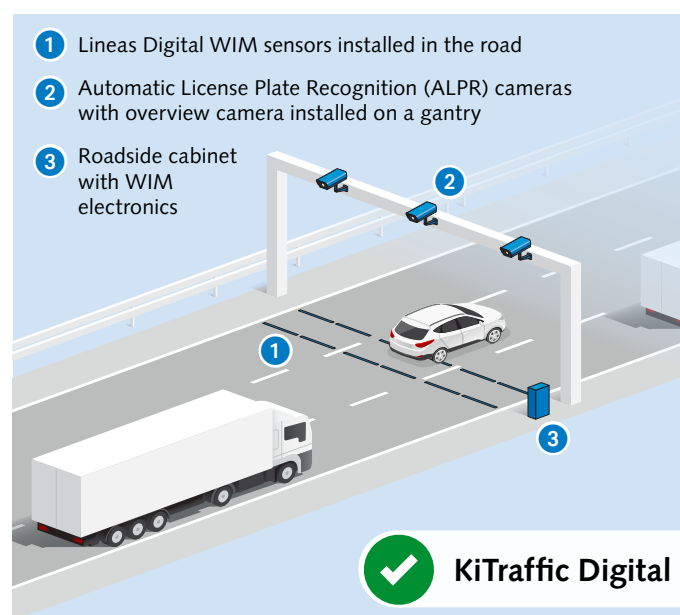


Benefits

- Your single-source supplier for holistic solutions that combine bridge structural monitoring with traffic law enforcement
- Improved assessment of bridge fatigue and remaining lifetime based on real traffic loading information
- Effective protection of bridges – overloaded vehicles are detected and prosecuted or rerouted
- Simple and effective enforcement of speed limits



WIM system for traffic loading analysis



WIM system for automatic weight enforcement

Weigh In Motion (WIM)

Users of Weigh In Motion (WIM) systems benefit from 24/7 traffic monitoring with automatic collection of key traffic parameters. Kistler's WIM systems are available with various degrees of precision, at prices to match each user's requirements: our portfolio ranges from simple WIM sites to collect statistics and analyze traffic loading (such as the KiTraffic Statistics system) to highly complex solutions for automatic weight enforcement (such as the KiTraffic Digital system).

Backed by more than 25 years of experience and with over 80,000 Lineas sensors installed in more than 50 countries, Kistler is your partner of choice for the most advanced technology and the highest level of expertise in WIM applications.

Kistler's WIM system automatically records these traffic parameters:

- Vehicle class
- Vehicle weight (gross weight and axle loads)
- License plate and overview picture
- Driving direction and driving lane
- Vehicle dimensions (height, length, width) and axle spacing
- Vehicle distances, speeds and traffic volumes
- Wheel and tire information (single/double wheel, underinflated tires)

Advantages of Kistler's WIM systems

- Highly accurate and reliable thanks to unique quartz sensor technology
- Long service lifetimes thanks to robust design
- Highly reliable in all weather conditions
- Long-term stability (no aging), insensitive to temperature variations
- Quick and easy sensor installation in road pavement
- Global footprint with over 80,000 installations in more than 50 countries
- OIML-certified system for direct fining of overloaded trucks (no need for static weighing)



Kistler's Speed Enforcement system (stationary installation)

Speed Enforcement

With Speed Enforcement systems by Kistler, users can efficiently measure the speed of any passing vehicle and automatically fine vehicles that exceed the speed limit. Our versatile systems provide both the flexibility and the precision you need when performing speed checks: Kistler solutions are widely used not only on bridges but also on secondary roads, open highways and construction sites. These measurement solutions combine unique optical measurement technology with cameras for reliable driver and license plate. Traffic violations can be identified quickly and efficiently thanks to the system's unique measurement base of just 50 cm. One single instrument can measure the speed of any type of vehicle in both traffic directions and across multiple lanes. Our user-friendly software application supports downstream evaluation and legal validation of the measured data. The same system can be operated as a portable unit (for mobile enforcement) or converted into a stationary measurement solution by installing the protective cases on the roadside.

Advantages of Kistler's Speed Enforcement

- Universal system for legally valid Speed Enforcement data
- Just one instrument can monitor traffic traveling in different directions
- Precise measurements with high hit rates – regardless of vehicle type or speed, even on multiple-lane roads
- Unique, easy-to-operate certified optical measurement technology
- Can be operated as a mobile or stationary enforcement system



Putting monitoring solutions into practice – with Kistler



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

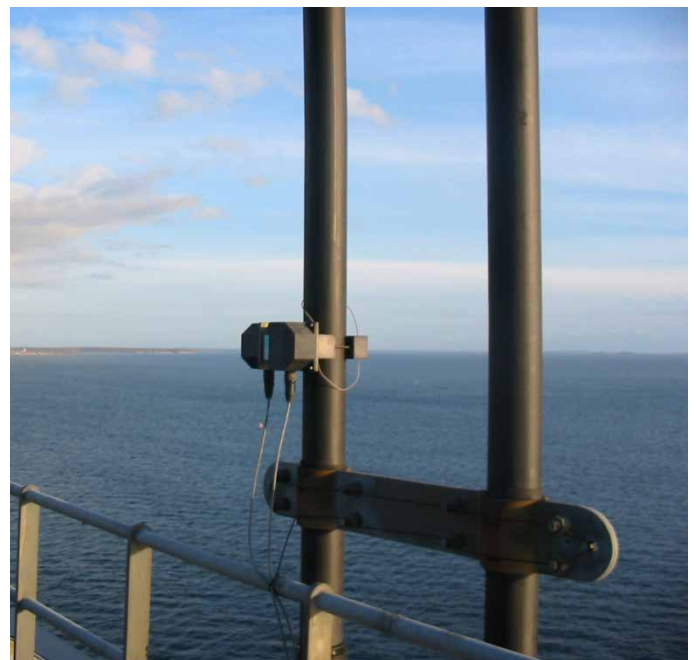
Great Belt Bridge, Denmark

Since 1998, Kistler technology has been operating successfully on Denmark's Great Belt Bridge to measure the structure's sway in the wind and the natural frequency of its suspension cables. Two types of Kistler measurement systems were installed on the East Bridge section, which ranks as one of the world's longest suspension bridges: one system measures the natural frequency of the vertical suspension cables, and another (housed inside the main span) covers the main bridge structure.

Kistler's solution combines special low-frequency K-Beam accelerometers with low-pass filters to cover frequencies of 1 Hz inside the bridge and 10 Hz on the suspension cables. Mechanical dampers were added for the sensors integrated in the main span, and efficient signal conditioning was a key design focus. Changes in natural frequency and swaying behavior are monitored continuously, and the measurements provide key insights into the bridge's structural behavior – one important result was a modification of the bridge construction in the initial phase of the project.

"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."

Erik Nielsen, Sales Engineer at Kistler



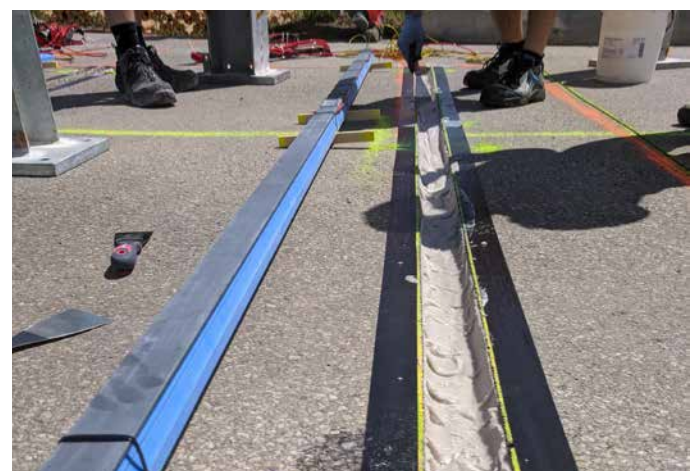
The measuring systems (including accelerometers, filters and transmission) on the vertical suspension cables were installed in special boxes to ensure long-term robustness under harsh weather conditions.



A view of the railway bridge in Austria previously damaged by heavy timber transportation – now protected thanks to the KiTraffic Statistics Weigh In Motion (WIM) system from Kistler

Road bridge over a railway line, Austria

Strain, fatigue and aging can affect bridges of all sizes. This small bridge over a railway on the access road to a village in the heart of Austria is near a large sawmill, so trucks carrying heavy loads of timber cross it every day. The result: visible damage to the bridge, with several cracks in its supporting structure. To address the problem, Austrian Federal Railways (ÖBB) called in REVOTEC, the Vienna-based bridge monitoring specialist and system integrator. In January 2020, REVOTEC launched a project that soon identified an effective solution: Kistler's KiTraffic Statistics WIM system – and it was installed within just one day! Reliable overload detection and vehicle classification now prevent any further overloading of the bridge. Vehicles weighing over 44 tonnes are penalized, and changes in the bridge's condition can also be tracked more accurately.



The Lineas sensors for the KiTraffic Statistics WIM system by Kistler are installed slightly below the road surface; they are coated with a special grouting compound to ensure long lifetimes.

“Automated bridge monitoring systems to measure supporting structures and axle loads are likely to become standard elements of the infrastructure, to allow real-time condition monitoring and predictive maintenance.”

Michael Vospernig, one of REVOTEC's two founders



Trucks carrying loads over the legal weight limit were causing stress on New York's Brooklyn-Queens Expressway.

Brooklyn-Queens Expressway, United States

Built over 70 years ago, the Brooklyn-Queens Expressway (BQE) in New York is a vital regional artery that connects Brooklyn with major access points to Manhattan, Queens and Staten Island. However, aging of the structure combined with an 11% increase in legal truck limits over the years prompted concerns about the BQE's safety – focused especially on the stretch known as the "Triple Cantilever". The New York City Department of Transportation (NYC DOT) responded by launching a project to quantify overweight truck traffic as the basis for an eventual direct enforcement solution. The DOT's traffic engineering partner C2SMART Center brought Kistler on board. During the pilot phase, the Weigh In Motion (WIM) system comprising Kistler Lineas quartz sensors and a Data Logger showed that 15% of the 25,000 trucks using the BQE each day were over the weight limit. In 2023, based on further high-accuracy data, the WIM site earned certification as the USA's first automated citation system for overweight vehicles. The result: one month after the WIM system went live, the daily number of overweight vehicles using the BQE was cut in half. This success opens the way for other U.S. states to protect aging infrastructure with automated direct enforcement technology.



Heavy traffic on the Brooklyn-Queens Expressway, looking north towards Brooklyn Bridge Park

"Kistler's technology and commitment to making the BQE direct enforcement initiative successful is second to none."

Hani Nassif, PhD, PE – Professor of Civil and Environmental Engineering at Rutgers University, Associate Director of C2SMART Center

Would you like to learn
more about our applications?

Explore now:



www.kistler.com/bridges

Kistler Group
Eulachstrasse 22
8408 Winterthur
Switzerland

Tel. +41 52 224 11 11

Kistler Group products are protected by various intellectual property rights. For more details, visit www.kistler.com

The Kistler Group includes Kistler Holding AG and all its subsidiaries in Europe, Asia, the Americas and Australia.

Find your local contact at
www.kistler.com

KISTLER
measure. analyze. innovate.