Structural monitoring

Project References - Monitoring Systems



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Ponte Nanin (Switzerland)



Project description

During refurbishment works to this structure in 2004, over forty years after it was built, modifications to the bridge were carried out to accommodate increased traffic. These changed the bridge’s static system, with several of its pillars newly monolithically connected to its deck, meaning that all movement now occurs at one end.

Some of the bridge’s bearings, which were originally designed to allow sliding movement of the deck, were modified to now act as fixed bearings.

In order to provide ongoing confirmation that the impacts of the changes to the bridge’s structural system are as anticipated, and that the structure continues to function properly and safely, a monitoring regime was instigated.

mageba scope

The main concern following the refurbishment of the bridge related to the flow of forces through the structure.

By measuring the loads in the bearings and observing the force distribution in the bridge structure, these concerns could be immediately allayed based on initial measurements.

The permanently installed system was then adapted to prove the durability of the modified system on an ongoing basis, with particular attention to the structure’s bearings and expansion joints.

For added confidence, the system is equipped with an alarm feature, designed to notify the responsible engineer by email and SMS should any measured value ever exceed its threshold value.

Highlights & facts

mageba products:

Type:	RESTON®POT bearings ROBO®CONTROL automated SHM system
Measures:	Displacements, forces, structural temperature
Installati on:	2004, still operational

Structure:

City:	Mesocco
Country:	Switzerland
Completed:	1967
Type:	Concrete arch bridge
Length:	192 m
Designer:	Christian Menn

The bridge carries Highway A13 / E43 through the Swiss Alps, near the Italian border



A RESTON®POT bearing with a pressure sensor, enabling bridge deck forces to be measured



A solar panel on the bridge meets the system’s energy needs – ideal in remote locations



Dintel Harbour East Bridge (Netherlands)



Project description

The Dintel Harbour East Bridge, which opened in 2001, is located in the port of Rott erdam, one of the world's busiest ports. Together with the adjacent cable-supported West Bridge, it spans the waterway that leads to Dintel Harbour. It is a pre-stressed reinforced concrete structure, with a main span of 185m and side spans of 86.5m, and thus a total length of 358m.

In 2010, the bridge owner decided to undertake a very detailed assessment of the bridge's conditi on, and to closely monitor its conditi on on an ongoing basis. It was decided that a structural health monitoring (SHM) system should be used, to opti - mise both processes.

mageba scope

mageba supplied and installed a ROBO®CONTROL SHM system to supportthe bridge's short-term assessment and long-term monitoring needs.

A permanent "Advanced" system was de signed to monitor the structure's condition and performance, with a particular focus on weather conditions, traffic loading and the bridge's structural response to these influences.

In doing this it uses a range of sensors to measure displacement, inclination, strain, acceleration, traffic loading, solar radia-tion and structural temperature.

After installation, the system was calibrated by measuring the structure's response to loading, both static and dynamic, from a heavy truck of known weight.

Highlights & facts

mageba products:

Product:	ROBO®CONTROL SHM system
Type:	Permanent "Advanced"
Installation:	2005

Structure:

City:	Rott erdam
Country:	the Netherlands
Completed:	2001
Type:	Reinforced concrete road bridge
Length:	358 m
Owner:	Rijkswaterstaat

The bridge is located in Europoort, part of the port of the city of Rott erdam



Installation and calibration of the ROBO®CONTROL SHM system



A solar radiation sensor, as installed on the bridge



Steinbach Viaduct (Germany)



Project description

The Steinbach Viaduct in central Germany carries the A38 autobahn across the Steinbach Valley. It has a length of 372 m, with spans of between 54 m and 78 m, and a maximum height of 35 m. Its construction was completed in 2002, with expansion joints installed at both ends.

However, the bridge was not opened to traffic until several years later, in its first years carrying only the construction traffic involved in the construction of the motorway at either side. Due to the potential effects of the heavy construction traffic on the structure’s slim deck, it was decided to install an automated SHM system to monitor the traffic and its effects.

mageba scope

At the ti me of the bridge’s constructi on, TENSA®MODULAR expansion joints were installed in its deck – a 5-gap (LR5) joint at one abutment and a 6-gap (LR6) joint at the other. Several years later, a temporary ROBO®CONTROL monitoring system was installed, to monitor autobahn construction traffic. In addition to displacements, inclinations and strains, the high-tech system was designed to measure structure vibrati ons at frequencies of 100 Hz. This enabled vehicle weights and speeds to be deduced by comparing the resulting vibrations with those of vehicles of known weight and speed as recorded during system calibration. As a result, overloading of the bridge could be ruled out, enabling the owner to have full confidence in the bridge’s long-term performance.

Highlights & facts

mageba products:

Type:	TENSA®MODULAR expansion joints, ROBO®CONTROL monitoring system
Installati on:	2002 (expansion joints), 2005 (SHM system)

Structure:

Country:	Germany
Completed:	2002
Type:	Box girder bridge
Length:	372 m
Designer:	Leonhardt, Andrä & Partner

The viaduct is located in central Germany, near the city of Kassel



Installati on of a TENSA®MODULAR expansion joint on the bridge in 2002



The central computer of the ROBO®CONTROL monitoring system, installed in 2005



Danube Bridge Sinzing (Germany)



Project description

The deck support bearings of the Danube Bridge in Sinzing were observed to suffer unusually fast abrasion of their PTFE sliding discs, requiring disc replacement after just five years of service.

As a bridge bearing specialist, mageba was requested in 2007 to assess the problem and recommend a solution. It was suspected that the deck movements were higher than could be lastingly withstood by PTFE, and that the solution might therefore lie in the use of ROBO®SLIDE, a high-grade alternative to PTFE that offers far higher durability.

To support the approach, it was necessary to understand the deck's movements.

mageba scope

It was decided to make use of modern structural health monitoring (SHM) technology to evaluate the exact movements of the bridge deck during a two-week period. The short-term nature of the project made a ROBO®CONTROL "Portable" SHM system ideal for this purpose.

A clear correlati on between movement and temperature was established, with extrapolation of the recorded data indicating accumulated sliding distances of approximately 2.5 km per year. It could be concluded that these movements were the primary cause of the wear problem, and that the use of ROBO®SLIDE instead of PTFE would significantly prolong the life of the bearings – confirming the proposed solution.

Highlights & Facts

mageba products:

Type:	ROBO®CONTROL SHM system ("Portable")
Measuring:	Displacement, strain, inclination, temperature
Installati on:	2008

Structure:

City:	Sinzing
Country:	Germany
Type:	Highway bridge with continuous steel deck
Length:	1 km

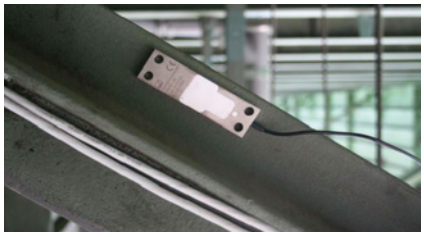
Rapid wear of PTFE sliding discs of the bridge deck's support bearings required explanati on



A longitudinal movement measuring sensor as installed at one of the deck's support bearings



Strain measurement on one of the bridge deck's steel members



Obermatt Bridge (Switzerland)



Project description

A timber bridge in Obermatt , Switzerland collapsed in 2005 during a fl ood period, and the cause of collapse could not be precisely determined. When it was rebuilt in 2007, it had a new safety feature: in the case of severe flooding, it can be raised by up to 70 cm to prevent damage from floating debris in the swollen river.

The main theory combined the impact of flood loading with poor timber strength resulting from high dampness.To mitigate the impact on the ti mber bridge industry, the University of Berne started a research project to demonstrate the durability of timber bridges if properly designed and maintained.

mageba scope

A ROBO®CONTROL automated monitoring system was installed in 2008, to measure the dampness of the bridge’s most critical elements over a period of several years.

The system was equipped with an alarm feature, offering immediate notification by email and SMS if a threshold value (25%) of timber humidity was exceeded.

The measurements showed that the moisture content of the bridge’s timber was within an acceptable range, and enabled the client to understand the bridge’s performance and to recognise any changes as they occurred. The project also provided evidence of the durability of properly designed and maintained timber bridges.

Highlights & facts

mageba products:

Type:	ROBO®CONTROL “Permanent” monitoring system
Measuring:	Moisture content
Features:	Alarm notification in case of exceeding of threshold value
Installati on:	2008

Structure:

City:	Obermatt
Country:	Switzerland
Type:	Timber road bridge
Length:	32 m
Collapsed:	2005
Rebuilt:	2007

The bridge crosses a river near Berne, Switzerland’s capital city



Sensors on the bridge’s timber deck measure moisture content



Installation of the ROBO®CONTROL automated monitoring system



Europa Bridge (Switzerland)



Project description

The Europa Bridge in Zurich was built in 1961–1962 to provide a new crossing of the Limmat river and a number of the growing city's important railway tracks and roads. With its overall length of over one kilometre it is one of Zurich's most important bridge structures.

In order to aid the planning of renovation works, relati ng to the bridge's expansion joints in parti cular, it was decided to install a structural health monitoring (SHM) system at one abutment in 2009, to survey the bridge's behaviour – in particular its movements and rotati ons. Temperature and humidity data was also required in order to calibrate and allow for the impact that changes in these variables might have.

mageba scope

A ROBO®CONTROL SHM system was installed in 2009. In a first phase of operation, high-frequency analysis at 200 Hz was carried out to assess the influence of traffic on the bridge's behaviour – which was found to be negligible. Rotations were also measured, and found to be very low about all axes - well within the range of sliding finger expansion joints, the type preferred by the owner for the easy maintenance, driver comfort and low noise benefits they offer.

The SHM system was then adapted to measure thermal movements during one complete year. With conditions in all seasons assessed, it was then possible to accurately determine the movement requirements of the new expansion joints.

Highlights & facts

mageba products:

Type:	ROBO®CONTROL SHM system
Sensors:	Displacements, rotations, structural temperature, humidity
Installati on:	2009

Structure:

City:	Zurich
Country:	Switzerland
Completed:	1963
Renovated:	2010
Length:	1100 m

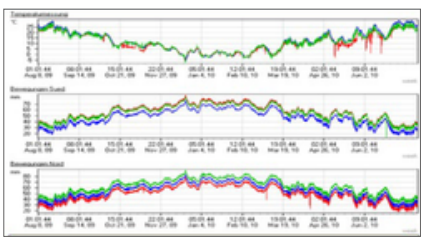
The bridge is located in Zurich, Switzerland's largest city



Installed movement measuring sensor with an accuracy of 0.1 mm



Presentation of measured data on mageba's web interface of Europabrücke monitoring system



Incheon Grand Bridge (South Korea)



Project description

At 12.3 km long with a main cable stayed span of 800 m, since 2008 the Incheon Bridge is one of the fi ve longest of its type in the world. Its 33.4 m wide steel/concrete composite deck will carry six lanes of traffi c 74 m above the main shipping route in and out of Incheon port and link the new Incheon International Airport on Yongjing Island to the international business district of New Songdo City and the metropolitan districts of South Korea’s capital, Seoul.
The cable stayed secti on of the crossing is 1,480 m long, made up of fi ve spans measuring 80 m, 260 m, 800 m, 260 m and 80 m respecti vely: height of the inverted Y main towers is 230.5 m. A 1.8 km approach span and 8.7 km viaduct complete the crossing, both constructed with precast prestressed concrete box girder decks. Foundations are drilled piles 3 m in diameter. Total cost is more than $1.4 bn, which is funded through a Private Partnership in Investment (PPI), the first in South Korea to involve an outside strategic investor.

mageba scope

The Incheon bridge is equipped with 76 mageba TENSA®MODULAR expansion joints. Largest expansion joint type LR24 (movement: 1,920 mm) equipped with ROBO®GRIP anti -skid surface, ROBO®SLIDE high grade sliding material and a ROBO®CONTROL remote monitoring system. Dimensions of each modular joint type LR24 (L×W×H): 16 m × 4.9 m × 0.8 m. The large dimensions and the weight of nearly 50 tons per joint, required special measures for the transport from Europe to Korea.

Highlights & Facts

mageba Products:

Type:	76 TENSA®MODULAR expansion joints (up to type LR24), ROBO®GRIP, ROBO®SLIDE, ROBO®CONTROL Permanent monitoring system
Features:	max. movement 1,920 mm
Installati on:	2009

Structure:

City:	Incheon
Country:	South Korea
Type:	Cable-stayed bridge
Length:	12.3 km

Incheon bridge: Link between Incheon Int. Airport and metropolitan districts Seoul



A mageba modular expansion joint in service



TENSA®MODULAR expansion joint type LR24 ready for installation



Run Yang Bridges (China)



Project description

The Run Yang – Nan Cha Bridge, opened in 2005, crosses the Yangtze River near the Chinese city of Zhenjiang. The cable supported structure, with a 1.49 km main span, total length of 2.5 km and 210 m high towers, is one of the longest suspension bridges in the world.

The excepti onal structure required excepti onal expansion joints to facilitate its enormous absolute deck movements, and these were supplied by mageba at the time of the bridge’s construction.

Several years later, mageba was also re-quested to assess the bridge’s larger-than-expected accumulated deck movements, in support of ongoing maintenance work and opti mised long-term performance.

mageba scope

TENSA®MODULAR expansion joints with 27 individual movement gaps (a world record) were installed in 2005, each joint facilitati ng 2160 mm of movement.

During the bridge’s first years in service, its expansion joints and bearings were found to be suffering from accelerated wear, and the cause of this wear was believed to be very large accumulated deck movements (the total distance moved by a point on the deck during a period of time).

A ROBO®CONTROL “Portable” system was used to evaluate the movements during a two-week period. This concluded that the movements greatly exceeded expected values, and enabled the bridge engineer to optimise planning of remedial works.

Highlights & facts

mageba Products:

Type:	TENSA®MODULAR expansion joints of type LR27, ROBO®CONTROL SHM Portable monitoring system
Features:	max. movement 2,160 mm
Installed:	2003–2009

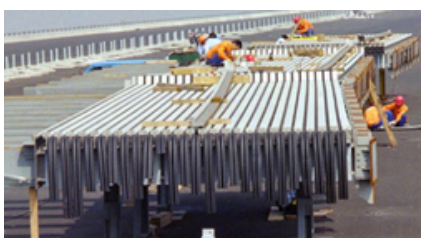
Structure:

City:	Zhenjiang
Country:	China
Built:	2005
Type:	Suspension bridge
Length:	2,500 m
Owner:	Jiangsu Provincial Yangtze River Highway Bridge Construction Commading

The bridges cross the Yangtze river near Zhenjiang



The enormous 27-gap TENSA®MODULAR joints during final assembly on the bridge due to size



View of the underside of a TENSA®MODULAR joint of type LR27, prior to installation



River Suir Bridge (Ireland)



Project description

The River Suir Bridge is part of the N25 Waterford Bypass route near the bend in the river at Granny. The cable-stayed bridge with 230m main span is the longest span bridge in Ireland. With its 112 m tall tower, it is a landmark structure for Waterford City and surrounding areas.The main structure consists of its tall tower with a series of stay cables which fan out from the top of the tower to support the main span at intervals of about 10 m. Corresponding cables fan to the back spans using the weight of the back span and anchor piles to balance the forces. The cable-stayed design removes the need for intermediate supports or piers in the river and permits a longer deck and a reduced deck thickness which means that there will be a great clearance for boats and craft to pass under the bridge.

mageba scope

mageba delivered 2 TENSA®MODULAR expansion joints of type LR7 with a total length of 27.80 m, which permit movements in all three directions and rotations about all three axis. The expansion joints were designed with shear studs for concrete connection.

Before opening to traffic, measurements on all 76 stay cables using a portable structural health monitoring system, providing data on actual cable forces and cable damping. Afterwards, a permanent health monitoring system was installed. The system includes 62 measurement channels in total. The data is automatically analysed on site and presented via the web interface, with an overview of the current situation and graphical representation of the overall performance to date.

Highlights & facts

mageba products:

Type:	TENSA®MODULAR expansion joints type LR7 Structural health monitoring system
Features:	with max. movement 560 mm
Installati on:	2009

Structure:

City:	Waterford
Country:	Ireland
Built:	2006–2009
Type:	Cable-stayed bridge
Length:	465 m
Constructor:	Waterford JV (Dragados)
Owner:	National Roads Authority

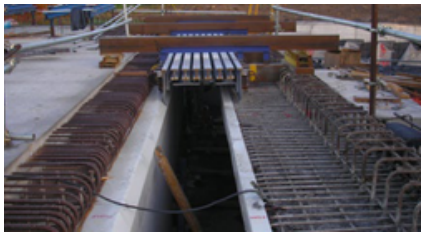
The bridge is located in the Waterford Bypass route near the bend in the river at Granny



Presentation of the measured data on a web interface



TENSA®MODULAR expansion joint at construction site ready for installation



Weyermannshaus Viaduct (Switzerland)



Project description

The Weyermannshaus Viaduct, which opened to traffic in 1977, forms part of a bypass motorway of Switzerland's capital city, Berne.

During a detailed visual inspection of the underside of the bridge after 40 years of service, considerable cracking was discovered at several coupling joints of the post-tensioned concrete deck.

Uncertainty about the time of crack appearance raised concerns about structural safety, with alternative theories suggesting that the cracking might have occurred many years previously due to concrete shrinkage etc. or more recently due to increased traffic loading. An assessment was required to ensure the structure's safety and identify any remedial work required.

mageba scope

It was decided to use a ROBO®CONTROL "Permanent" structural health monitoring (SHM) system to assess the bridge's response to traffic loading and temperature changes, enabling different theories/models to be assessed.

Following installation and calibration of the system, high-frequency (200 Hz) measurements were conducted during a period of one week in each season of a year. The system was then modified to assess long-term impacts.

As a result, a model based on the belief that the concrete could be considered "uncracked" could be confirmed, with fatigue analysis supporting a remaining life of at least several decades without the need for any major renovation work.

Highlights & Facts

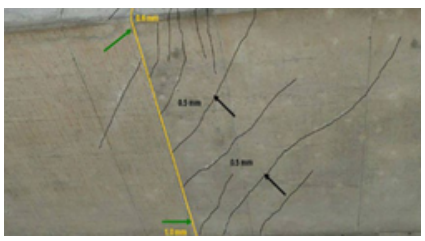
mageba products:

Type:	ROBO®CONTROL SHM system ("Permanent")
Measuring:	Crack widths, accelerations, temperatures
Installati on:	2010

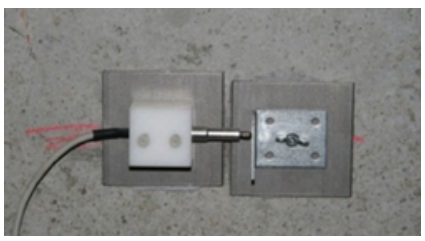
Structure:

City:	Berne
Country:	Switzerland
Type:	Post-tensioned concrete bridge
Completed:	1977
Length:	1 km

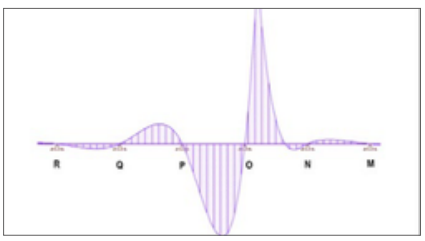
Cracking of concrete section at a coupling joint of the deck's prestressing cables



One of the ROBO®CONTROL SHM system's sensors, measuring crack width at one locati on



Comparison of actual and predicted influence lines confirmed "uncracked" theoretical model



Rhine Waterfalls (Switzerland)



Project description

The Rhine Falls in Schaffhausen, Switzerland is one of the region’s most important tourist att ractions and visitors marvel at the spectacle from a terrace at the castle of Laufen and several platforms on the cliff beneath it.

Rock anchors previously installed to stabilise the cliff showed unexpected force changes, leading to concerns that some sliding surfaces had developed.

To ensure the ongoing safety of the terrace, it was decided to install 11 additional rock anchors, together with a structural health monitoring (SHM) system to monitor anchor force changes and thus provide early warning of any future rock movements.

mageba scope

A ROBO®CONTROL “Permanent” SHM system was installed in 2010 to monitor the forces in the newly installed rock anchors. The system transmits all data to a central server, enabling the responsible engineers to monitor all anchor forces from their offices via a web interface.

The engineer set limitations for the anchor forces, which are implemented in the system’s alarm notificati on feature. Should any limitation value be exceeded, immediate notification will be sent by email and SMS to the engineer and the owner. This enables the owner to have confidence in the structure’s condition at all times, avoiding the need for much more extensive and invasive strengthening work.

Highlights & Facts

mageba products:

Type:	ROBO®CONTROL SHM System (“Permanent”)
Features:	Alarm feature ensuring immediate notification of any exceeding of predefined limitations
Installed:	2010

Structure:

City:	Schaffhause
Country:	Switzerland
Type:	Rock face with waterfall viewing platforms

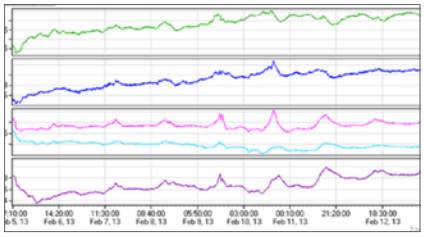
Scaffolding on the cliff face during installation of the SHM system, showing equipment locations



The sensors are discretely positioned and barely visible from the waterfall viewing platforms



Example of data presentation on the ROBO®CONTROL system’s web interface



Älvsborg Bridge (Sweden)



Project description

The Älvsborg Bridge, built in 1966, is a suspension bridge in Gothenburg, Sweden, connecting the north and south parts of the city across the Göta Älv river. The bridge has a total length of 933 m and a main span of 417 m.

To support the planning of bridge renovation works, including the replacement of critical components such as the large sliding finger joints at each abutment, the use of a structural health monitoring system was proposed – in particular, to quantify the structure’s actual movements and rotati ons, enabling the selecti on and design of new expansion joints to be optimised.

mageba scope

A ROBO®CONTROL “Permanent” SHM system was installed in 2011, with a network of sensors providing precise records of all movements and giving a detailed understanding of the bridge’s structural behaviour.

The data was used to conclude that bridge movements are less than had been expected. Such information was of great value to the bridge engineer in opti mising the planning of the bridge renovation works, particularly in relation to the selection and design of the new expansion joints.

The recorded data will also serve as a reference for future analysis and modification work.

Highlights & facts

mageba products:

Type:	ROBO®CONTROL permanent “Advanced” SHM system
Installation:	2011

Structure:

Country:	Sweden
Completed:	1966
Type:	Suspension bridge
Length:	933 m

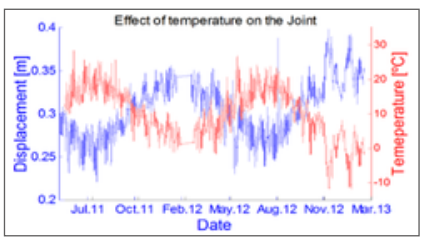
The Älvsborg Bridge crosses the Göta Älv river in Gothenburg, Sweden



The ROBO®CONTROL Box – the heart of the monitoring system on the bridge



Movements correlated with temperatures give a detailed understanding of bridge’s behaviour



Gleisbogen Bridge (Switzerland)



Project description

This elegant foot and cycle bridge was erected to connect pedestrian zones either side of a busy traffi c artery, and consists primarily of an arch-supported deck with 42 m span. Intensive construction activity is planned to take place in this area in the coming decade, including several high rise buildings. This will lead to uncontrollable ground settlements in the whole area, including in the immediate vicinity of this newly built structure.

mageba scope

A number of specialised components and services were required to ensure the correct construction of the bridge, with even load distribution, especially among its hanger cables, and to allow for adaptation in the future should ground settlements occur. Injectable lifting pot bearings were installed under the structure, to allow any future ground settlements to be countered. An automated monitoring system helped to ensure the even distribution of loading among the bridge's hanger cables. And spring disc dampers were installed at the bottom of each hanger cable to prevent vibrations of the deck.

Highlights & facts

mageba products:

Types:	ROBO®CONTROL "Portable"monitoring system
	RESTON®POT Lift bearings
	RESTON®SDD Spring Disc Dampers
Notable:	Support in achieving and confirming optimal construction for maximum durability of the structure
Installation:	2011

Structure:

City:	Zurich
Country:	Switzerland
Type:	Arch bridge
Length:	230 m

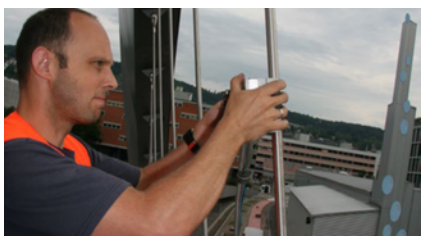
The bridge is located close to Zurich city centre



An inclined lifting pot bearing at one end of the bridge



Acceleration sensors - used to determine the load distributi on in the steel structure



Hunter Expressway (Australia)



Project description

The Hunter Expressway was originally proposed in 1988 but the construction started in 2010 after 22 years.

It provides a much needed east west link in the Hunter Valley, connecting Newcastle and the lower Hunter, hence reducing travel ti me by almost half an hour.

The Eastern Section from F3 to Kurri Kurri comprises three viaducts through the Sugarloaf Range. The viaducts have a total length of 787 m and are up to 47 m in height above the ground.

mageba scope

mageba supplied not only the spherical bearings, shear keys and modular expansion joints for the viaducts, but also a structural health monitoring system.

The installed RESTON®SPHERICAL bearings are all equipped with the mageba high-grade sliding material called ROBO®SLIDE and have a load carrying capacity of 30,000 kN.

The RESTON®FORCE shear keys transmit a total horizontal force of 8,500 kN.

The supplied TENSA®MODULAR expansion joints have a total length of 142 m and allow for a total displacement of 680 mm.

In 2013 a hydrostatic tube balance monitoring system has been in installed on all viaducts.

Highlights & facts

mageba Products:

Type:	60 RESTON®SPHERICAL bearings
	12 RESTON®FORCE shear keys
	12 TENSA®MODULAR expansion joints
	ROBO®CONTROL structural health monitoring system
Installation:	2011–2013

Structure:

Location:	Hunter, New South Wales
Country:	Australia
Built:	2010–2013
Type:	Viaduct
Length:	40 km
Builder:	Thiess

Location of the Hunter Expressway in New South Wales, Australia



A mageba TENSA®MODULAR expansion joint during installation on the first viaduct



The Hunter Expressway viaducts over Sugarloaf Range with its steep gullies.



Macdonald & MacKay Bridges (Canada)



Project description

The Angus L. Macdonald and A. Murray MacKay bridges are critically important structures for the city of Halifax, capital of the Canadian province of Nova Scotia.

They were opened to traffi c in 1955 and 1970 respectively, and several decades later, it was determined that both structures were in need of significant reconstruction / maintenance work in order to meet the demands of modern traffic for decades to come.

The Angus L. Macdonald Bridge, in fact, is receiving an entire new deck, and computer modelling of the deck, verified by measured data, is playing a key role in the design process.

The A. Murray MacKay Bridge, on the other hand, is retaining its existing deck, but is being subjected to significant renovation work.

mageba scope

Early in the project, it was determined that a fully automated ROBO®CONTROL structural health monitoring (SHM) system should be used to measure and record the movements and rotations of the bridge decks. The installed system has provided the data needed by the computer modelling of the new deck of one bridge, and assisted in the planning of remedial works of the existing deck of the other, enabling the bridge’s engineers to optimize their designs and minimize the life-cycle costs of the bridges.

In 2015, it was decided to install new TENSA®MODULAR expansion joints with up to seven gaps each (type LR7) at four axes of the Angus L. Macdonald Bridge, replacing the existing joints. These joints were designed for steel connecti on, and feature noise-reducing “sinus plates” surfacing.

Highlights & Facts

mageba products:

Type:	ROBO®CONTROL automated SHM system TENSA®MODULAR expansion joints of type LR3 & LR7 LS
Installed:	2012 (SHM), 2015 (joints)

Structure:

City:	Halifax
Country:	Canada
Type:	Suspension bridges

Angus L. MacDonald Bridge

Built:	1955
Length:	4,265 ft (1,300 m) Main span 1,447 ft (441 m)

A. Murray MacKay Bridge

Built:	1970
Length:	3,937 ft (1,200 m) Main span 1,398 ft (426 m)

Location of the bridges in Halifax, Nova Scoti a, Canada



Presentation of measured data (in graphic form) from the applied SHM system



Temporary plates at the point of future installation of the expansion joints



Wazirabad Signature Bridge (India)



Project description

The beautiful Signature Bridge over the Yamuna River, north of New Delhi, opened to traffic in November 2018.

It is a new cable stayed bridge across the Yamuna River in Wazirabad, Delhi. Its dramatic inclined steel pylon, at 154 m high, and elegant stay cable design, makes it a particularly attractive addition to the Wazirabad skyline.

As well as its pleasing aesthetic impact, the shape of the pylon enables it to provide, to a substantial extent, the stress balance required to support the deck.

mageba scope

The ROBO®CONTROL SHM system was installed to monitor the structure’s condition, behaviour and performance during both the construction and service phases.

In particular, it is designed to monitor the effects of weather, earthquakes and other environmental influences, and to detect and report any damage that may occur.

For this purpose, the SHM system uses a wide array of sensors (100 in total). The precisely measured data is made available to the bridge’s engineers in realtime, via a user-friendly interface, greatly improving the efficiency of monitoring work compared to manual methods.

Furthermore, mageba supplied modula expansion joints TENSA®MODULAR with up to twelve individual movement gaps each, accommodati ng longitudinal movements of up to 960 mm.

Highlights & facts

mageba Products:

Type:	TENSA®MODULAR expansion joints ROBO®CONTROL monitoring system
Features:	100 sensors
Installati on:	2013 / 2018

Structure:

City:	Delhi
Country:	India
Completed:	2018
Type:	Cable stayed bridge with composite deck
Main span:	251 m
Length:	675 m
Contractor:	Gammon JV
Designer:	Schlaich Bergermann JV

The bridge crosses the Yamuna River in the Wazirabad district of Delhi, India



A sensor on a stay cable, measuring high-frequency vibrati ons (up to 200 Hz)



The modular joints were fabricated at mageba’s Indian factory in Kolkata



Zoo Elephant House (Switzerland)



Project information

Zurich city's zoo has constructed a new park for its elephants, which opened in 2014. The 10,000 m^2 park includes a large housing unit consisting primarily of a wooden roof shell – the largest self-supporting wooden roof structure in Switzerland. A hot, humid environment will be maintained inside the structure, as prevailing in the natural habitat of the Indian elephant, whereas the outside shell needs to withstand the seasonally changing weather conditi ons of Switzerland.

Due to the roof's unusual design in terms of size, shape, and constructi on material, and the high humidity of the air underneath, it was decided to install a permanent automated monitoring system to provide conti nuous monitoring of the roof structure's anchorages and moisture levels.

mageba scope

mageba developed a monitoring plan for this demanding task. 24 humidity sensors, distributed over the enti re roof surface, measure the moisture content of the roof's timber, and the anchor forces arising in the roof's foundations are also measured. The effect of humidity is correlated to the structure in terms of stress, creep, shrinkage and other deformations, with possible thrust/traction in the anchorage area.

The measured values are displayed in real time on the system's web interface. The system also includes an alarm feature, offering automatic notification of exceeding of pre-defined limits in any parameters.

Highlights & facts

mageba products:

Type:	ROBO®CONTROL permanent SHM system
Features:	Anchorage force sensors, air and structural temperature and humidity sensors
Installed:	2013

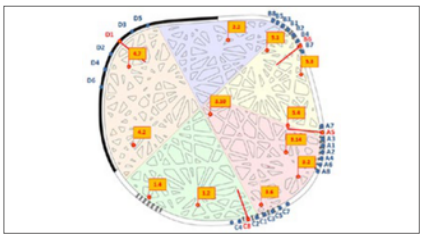
Structure:

City:	Zurich
Country:	Switzerland
Built:	2013
Type:	Wooden pavilion
Span:	110 m
Owner:	Zurich Zoo
Architect:	Markus Schietsch
Engineer:	Walt & Galmarini

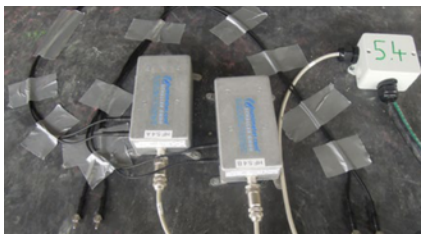
Zurich Zoo is located near Zurich city center



Layout of sensors on the wooden roof



Humidity sensors installed on the underside of the roof



Structural monitoring

Western Express Highway (WEH) Mumbai Metro (India)



Project description

The Mumbai Metro construction project began in 2008 and had been executed in order to meet the city’s rapid population growth.

Mumbai is the capital city of Maharashtra, the most economically developed state of India with a population growth rate of around 2% per annum (as per 2011). The main objective of the Mumbai Metro is to provide mass rapid transit services to people within an approach distance of between one and two kilometres, and to serve the areas not connected by the existing Suburban Rail network.

At the WEH junction, trains pass over the highway on a cable-stayed bridge and at the same time traffi con the highway crosses on another concrete bridge, making the junction a very complex intersection.

mageba scope

As shown on the picture above, the cable-stayed bridge is located over the highway bridge hence being built in a critical environment where any damage would cause significant repercussions. Therefore, the bridge had to be equipped with a system that is able to immediately react to any alarming impact.

The installed ROBO®CONTROL structural health monitoring system is mageba’s reliable product development to monitor the structure’s condition, behaviour and performance during operation. In particular, it monitors the pylon’s inclination, the cable’s vibration and tension, the deck’s deflecti on as well as the concrete’s deformation allowing any critical deviation to be detected and accordingly presented to the engineers in charge.

Highlights & facts

mageba Products:

Type:	ROBO®CONTROL permanent monitoring system
Features:	Straingauges displacement, laser, humidity sensors, accelerators, inclinometers
Installati on:	2015

Structure:

City:	Mumbai
Country:	India
Completed:	2011
Type:	Cable-stayed bridge
Length:	175 m
Owner:	Mumbai Metropolitan Region Development Authority
Contractor:	Mumbai Metro One Private Limited (MMOPL)

The project is located in Mumbai, one of the most bustling cities of the Indian subcontinent



Night-installation of a wind sensor



The cables have been equipped with accelerom-eters measuring its vibrati on and tension (see red circle)



Lavoitobel Bridge (Switzerland)



Project description

The iconic Lavoitobel Bridge, designed by the famous sculptor and architect Max Bill in collaboration with the structural engineer Mirko Robin Ros, is an historic arch bridge in the Swiss Alps and was constructed in 1966 and 1967. It spans the correspondent Lavoitobel valley and counts among Switzerland's famous representa-tives for bridge construction.

After a detailed and preventative revision by the region's Civil Engineering Department, the authority decided that this bridge does not cover today's traffic requirements. Several maintenance works have hence been planned in order to assure future structural safety.

The entire renovati on project comprised, amongst others, new bridge bearings as well improvements for its structural safety.

mageba scope

In order to verify that the adjusted structural design and load distribution operat-ed as planned, the responsible engineers decided to install an automated structural health monitoring (SHM) system to monitor the forces acti ng on the new bearings.

The RESTON®POT bearings were equipped with pressure sensors on the elastomeric pad, enabling the force acting on each bearing to be readily calculated by the connected SHM system. In the event of any sudden or unexpectedly significant change in the force acting on a bearing, or in the load distribution among the different bearings, the system will provide an immediate alarm notification.

Highlights & facts

mageba products:

Type:	ROBO®CONTROL permanent monitoring system
	RESTON®POT bearings
Features:	Pre-integrated sensors on the bearing's elastomeric pad
Installation:	2016

Structure:

Region:	Tamins (Canton Grisons)
Country:	Switzerland
Completed:	1967
Type:	Arch bridge
Length:	200 m (main span 105 m)
Owner:	Road Authority of Grisons
Contractor:	Road Authority of Grisons
Engineer:	Mirko Robin Roš
Architect:	Max Bill

The bridge is located in canton Grisons, a mountainous region in the south-eastern Swiss Alps



The SHM system installed externally with integrated solar panel and separate weather sensor



One of the verti cally oriented bearings at one abutment, equipped with load cells



Johan Sverdrup Field Centre (Norway)



Project description

The discovery of the Johan Sverdrup field has been made in 2010 and counts among one of the largest oil discoveries ever made on the Norwegian continental shelf. Named after the father of Norwegian parliamentarism, the Johan Sverdrup Field Center was discovered in 2010 as a direct result of Edvard Grieg field discovery made in 2007, which had proven the possibility of continuous oil-water contact over the entire southern part of the Utsira High.

The field covers an area of approximately 200 km^2 on the Utsira High in the central part of the North Sea and is being developed in multiple phases.

The project of interest is composed of four platforms connected together by three steel bridges. Each bridge is designed to withhold the enormous movements coming from the platforms, driven by extreme waves.

mageba scope

mageba is supplying RESTON®POT bearings to support the platforms' connecting bridges while accommodating specified movement and rotations. Moreover, four different systems of mageba's ROBO®CONTROL structural health monitoring technology evaluate the bearings' performance through:

- Inclination sensors
- Load measuring sensors
- Wire displacement sensors
- Inductive displacement sensors

The 12 ROBO®CONTROL acquisition units are installed at each bearing in the hazardous area of the fi eld's platforms and collect the data from the different sensors. A central computer server processes the measurements in realtime for further analysis and graphical presentation. All data is finally sent to the field's general control room.

Highlights & facts

mageba products:

Type:	RESTON®POT bearings of type TF and TE ROBO®CONTROL monitoring system „ Advanced"
Installati on:	2016–2017

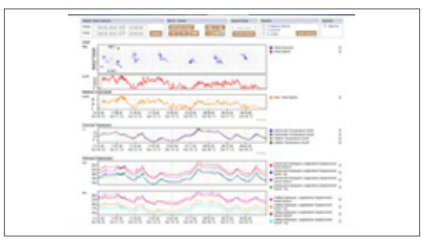
Structure:

Area:	Utsira High, 140 km west of Stavanger
Country:	Norway
Completed:	2017
Type:	Off shore platform
Owner:	Statoil, Lundin Norway, Maersk Oil, Petoro, Det norske oljeselskap
Contractor:	Aker Solutions ASA

Location of Johan Sverdrup oil field in the North Sea



Example of data presentation on a computer



Bearing production in Switzerland: the massive sliding plates feature 5.5 t weight and 3.2 m



Samuel De Champlain Bridge (Canada)



Project description

The Samuel De Champlain Bridge is located in Montreal, Canada, and replaced the old Champlain bridge over the St. Lawrence River. This crossing is one of the busiest in Canada with over 60 million vehicles and $20 Billion in internati onal trade passing over it on a yearly basis.

The $4.2 billion project consisted of two main bridges – the New Bridge on the St-Lawrence and the Île-des-Soeurs Bridge – fully opened for the traffic on June 2019.

The bridge, 3.5 km long, is a stayed cable bridge designed for a 125 years long service life. This has been possible by taking into consideration the smartest forethoughts and high quality products and materials for a challenging project of a structure subjected to apporx. 160,000 vehicles every day – sometimes in harsh weather conditions.

mageba scope

mageba provided Structural Health Monitoring service and modular joints for this iconic bridge.

In the course of the project duration, more than 50 embedded and 150 surface sensors are being installed on the bridge, allowing the Government of Canada to monitor displacement, corrosion, movements, temperature, stresses, strain and environmental conditions of the bridge over the next 30 years. This will most certainly optimize the maintenance supporting the owner to keep the structure at his best performances. Moreover, the ingenious system provides the ability to react instantly to changes and deterioration.

In parallel, the largest expansion supplied will span over 20 meters and cover upwards of 800 mm in movements (10 gaps).

Highlights & Facts

mageba products:

Type:	ROBO®CONTROL permanent Monitoring System TENSA®MODULAR expansion joints types LR8, LR9 & LR10
Features:	approx. 200 sensors
Installati on:	2016–2019

Structure:

City:	Montreal
Country:	Canada
Type:	Cable-stayed bridge
Completed:	2019
Owner:	Infrastructure Canada
Contractor:	SNC Lavalin, Dragados, Flati ron Canada, TY Lin, MMM Group Preliminary
Design:	Arup

The new bridge is located in Montreal, Canada, and is part of the government’s extensive corridor project



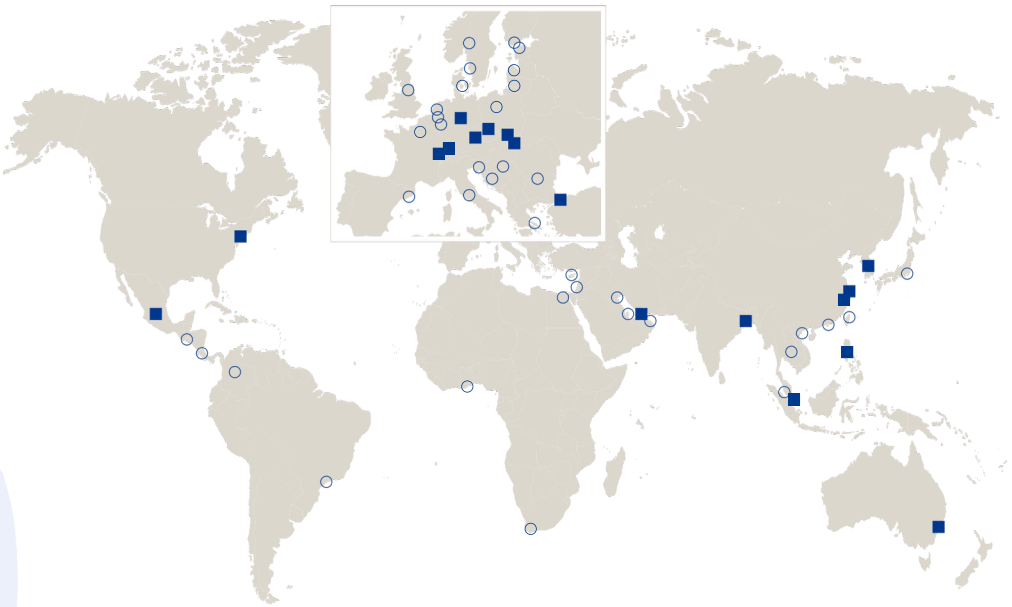
A TENSA®MODULAR expansion joint typ LR8 is being lifted into place



Corrosion Sensor installed on the pier starter reinforcement



engineering connections® – since 1963



■ Locations
○ Representatives

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