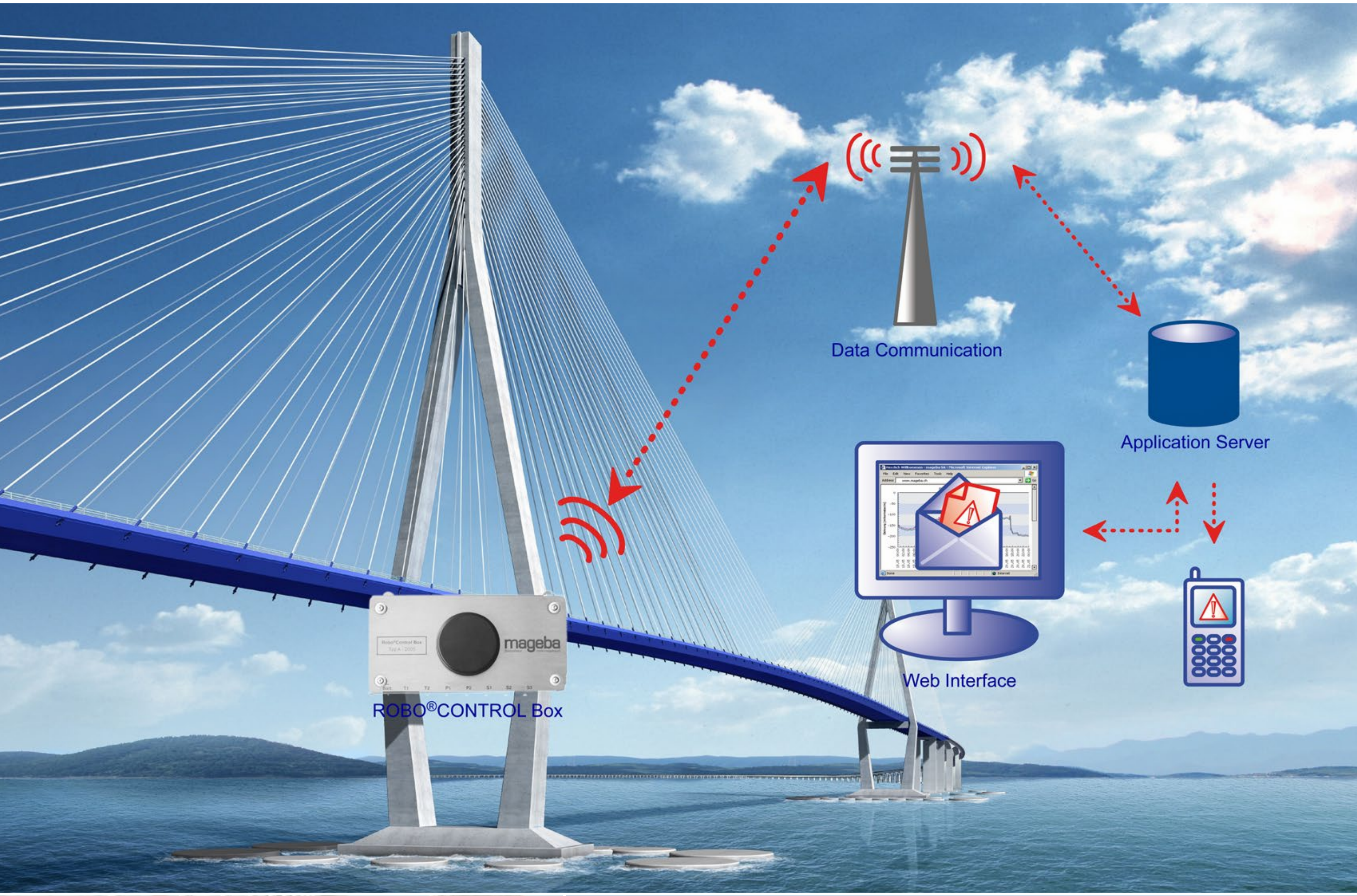
Structural monitoring

Infrastructure | Buildings | Industrial structures

ROBO®CONTROL – Monitoring Solutions

Portable and Permanent Systems



Tailor-made Service Categories

Table of contents

Services Provided

Safety Monitoring

Main drivers are specific concerns of the client regarding the stability or usability of a structure. mageba offers complete solutions to monitor the critical elements of a structure, including immediate alarm notification of significant changes.

Inspection & Measurement Services

Structure owners’ needs for detailed condition assessment can be fulfilled by mageba’s inspection services. Relevant data is monitored and assessed and the overall condition of the structural elements is summarised in detail.

Structural Health Monitoring

Tailor-made solutions for long-term monitoring of structures are offered by mageba to assess the overall behavior of the structure. SHM systems provide crucial information to the owner to optimize length of service and life cycle costs.

Consulting Services

Remedial works often change the load scenarios and the static system of a structure. Assessment of the actual conditions before renovation, using the experience of mageba’s global network, allows recommendations for new structural components to be made.

1 Installation of a 3D-acceleration sensor
2 Preparing for inspection service

Varied Uses and Benefits

Applications

ROBO®CONTROL's efficient and reliable automated data collection offers benefits to many fields of engineering, such as:

- Bridges
- Tunnels
- Buildings
- Dams
- Substructures
- Mining
- Historic protection
- Environmental applications

Benefits for End-users

Owners & Authorities

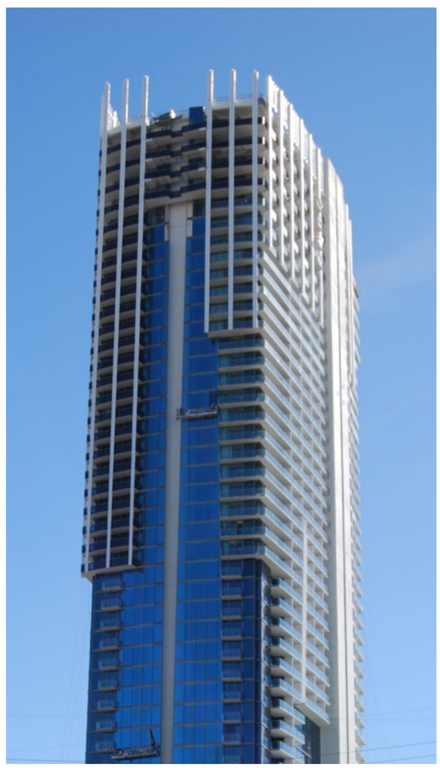
- Enhanced safety of overall structure and its critical elements
- Risk minimisation by Safety Monitoring - immediate notification of changes
- Increased lifespan of structure and reduction of life cycle costs
- Improved investment planning
- Optimization of maintenance activities
- Efficient support for structure inspection department
- Risk management: Properly defined and measurable risks

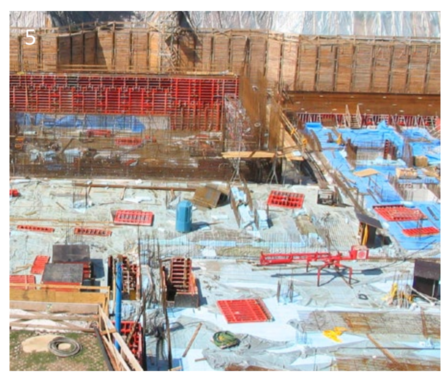
Designers & Engineers

- Verification of designed / expected structural performance
- Confirmation of design parameters
- Model updating to optimize design calculations
- Increase of design experience and technical excellence

Construction Companies

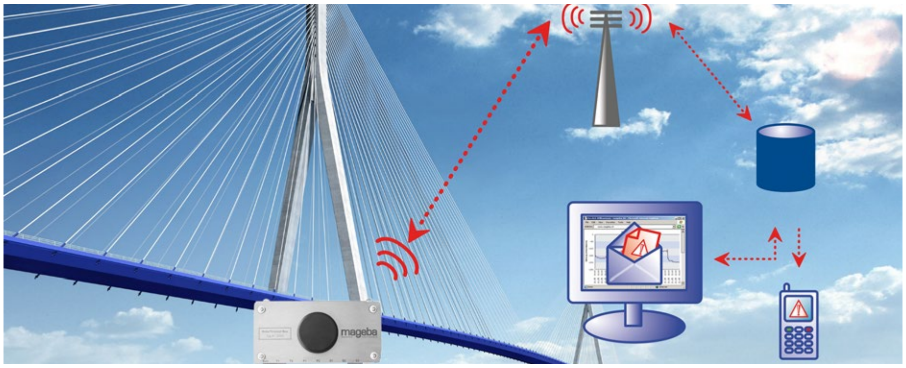
- Proof of properly executed construction work
- Optimization of construction processes





1 Protection of historical buildings
2 Detailed monitoring of vital elements of high-rise buildings
3 Safety monitoring of tunnels
4 Structural monitoring of dams
5 Surveillance of foundations
6 Updating of structural modeling

Overview of Systems



ROBO®CONTROL Systems

Permanent Systems

for long-term monitoring and investigative applications, featuring permanent power supply and transmission of data to a central server

Portable Systems

for short-term investigative applications

"BASIC"

- Limited to static monitoring applications at low frequencies
- The number of sensors that can be integrated is limited

"ADVANCED"

- Dynamic and static monitoring missions possible at all frequencies
- Unlimited number of sensors can be integrated

"PORTABLE"

- Dynamic and static monitoring tasks possible at all frequencies
- Measuring time limited due to battery capacity

ROBO®CONTROL “BASIC”

ROBO®CONTROL Systems		
Permanent Systems		Portable Systems
“BASIC”	“ADVANCED”	“PORTABLE”

Main Features

- Components designed for continuous, remote and independent operation
- Data transmission via GPRS / GSM to mageba’s or client’s server
- Alarm function possible (notification of pre-defined events and load cases)

Infobox

Measuring Frequency	> 0 – 1 – 500 Hz
No. of sensors	0 – 20 – >100
Required investment	0 – 25,000 – 50,000 – 200,000 EUR
Yearly cost	0 – 500 – >1,000 EUR/year
Power supply	Solar panel ✓ Mains / grid ✓ Battery ☐
Data memory	Server
Data presentation	Internet Browser
Alarm notification	E-Mail ✓ SMS ✓
Warranty	1 year
System maintenance	System may be purchased

1 Applied system at Incheon Grand Bridge, South Korea
2 User-friendly web interface
3 Installation of ROBO®CONTROL Box

ROBO®CONTROL “ADVANCED”

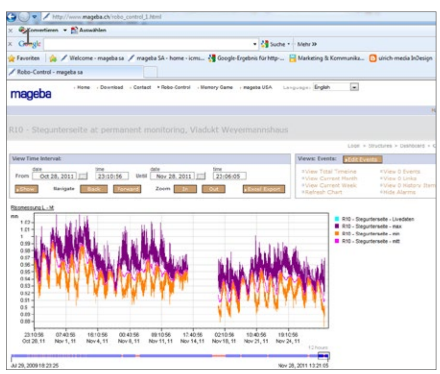
ROBO®CONTROL systems		
Permanent systems		Portable systems
“BASIC”	**“ADVANCED”**	“PORTABLE”

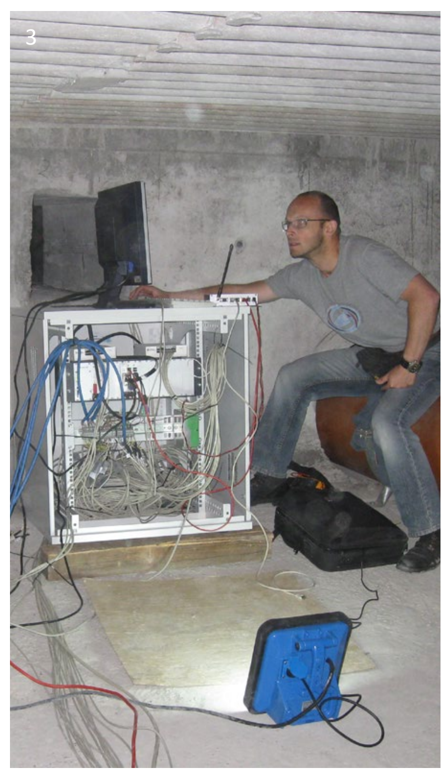
Main features

- Components designed for continuous, remote and independent operation
- Data transmission via GPRS / GSM to mageba’s or client’s server
- Alarm function possible (notification of pre-defined events and load cases)
- Tailor-made solutions

Infobox

Measuring Frequency	> 0 – 1 – 500 Hz	
No. of sensors	0 – 20 – >100	
Required investment	0 – 70,000 – 200,000 EUR	
Yearly cost	0 – 500 – >1,000 EUR/year	
Power supply	Solar panel ☐ Mains / grid ☑ Battery ☐	
Data memory	Server	
Data presentation	Internet Browser	
Alarm notification	E-Mail ☑ SMS ☑	
Warranty	1 year	
System maintenance	System may be leased	





1 Online presentation of measured data
2 Integration of any type of sensor or application, for example webcams
3 Installation on site

ROBO®CONTROL "PORTABLE"

ROBO®CONTROL systems		
Permanent systems		Portable systems
"BASIC"	"ADVANCED"	**"PORTABLE"**

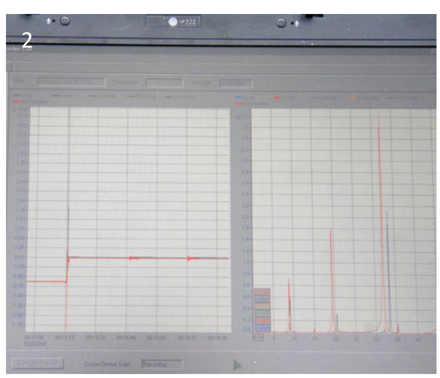
Main features

- Robust electronics for repeated, temporary use
- No connection to power grid required (operates by battery)
- Flexible arrangement of all system components to suit project requirements

Infobox

Measuring Frequency	> 0		500 Hz
No. of sensors	0	10	>100
Required investment	0	25,000	200,000 EUR
Yearly cost	No transmission costs		
Power supply	Solar panel ☐	Mains / grid ☐	Battery ☑
Data memory	USB Stick, Local		
Data presentation	Internet Browser		
Alarm notification	E-Mail ☐	SMS ☐	
Warranty	Not applicalbe		
System maintenance	Not applicalbe		

1


2


3


1 Removable storage device (USB stick)
2 Viewing of data from USB stick on laptop computer
3 Easy transport and use of "PORTABLE" system

Measurement devices at a glance

Sensors

Today, virtually any physical parameter can be measured with extremely high accuracy, and the information technology generally exists to transmit the large volumes of data often generated.

Sensors are widely available and frequently used to measure all types of movement, 3D acceleration, GPS positioning, tilting, structural temperature, vibrations and environmental conditions.

Force sensors

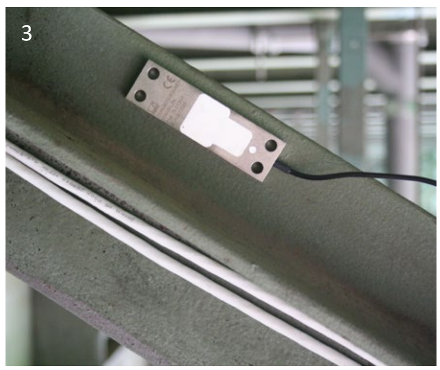
- Various types of load cell can be integrated
- Load cells of all major stay cable and anchor suppliers can be connected
- Integration of mageba pot bearings with measuring devices is possible

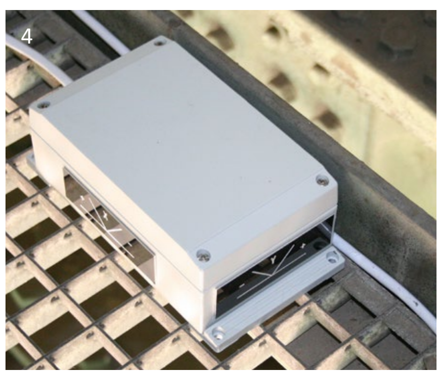
Strain and tilt sensors

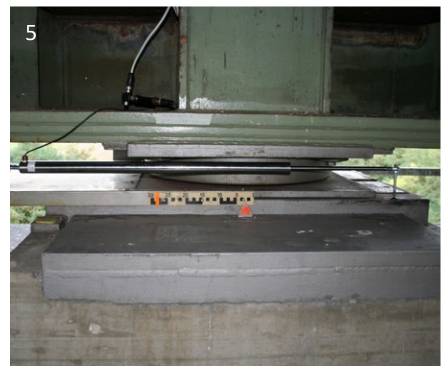
- Strain in steel elements measured by strain gauge devices, incremental changes are measured at the surface
- Integration of sensors into a structure during construction for absolute values
- Tilting of structures or elements measured

Movement sensors

- Inductive movement sensors for small changes (e.g. concrete crack monitoring)
- Cable winch sensors for larger movements (e.g. bearing and expansion joint movements)
- Extreme degree of accuracy (~1µm) possible due to highly sophisticated devices







1 Instrumented pot bearing
2 Typical load cell
3 Strain gauge
4 Tilt sensor
5 Movement sensor on a bearing
6 Inductive movement sensor measuring crack width

Acceleration and vibration

- Stay cables: sensors to measure modal frequencies and forces
- System identification by 3D-Acceleration sensors
- Vibration sensor integration to assess dynamic influences on the structure

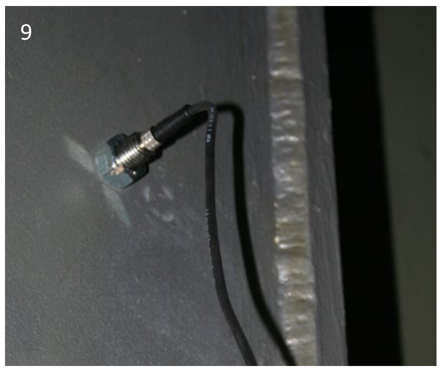
Structural temperature sensors

- Devices for measurement of steel temperature, externally applied
- Concrete temperature measured by integrated sensors (installed during construction or inserted into drilled holes)

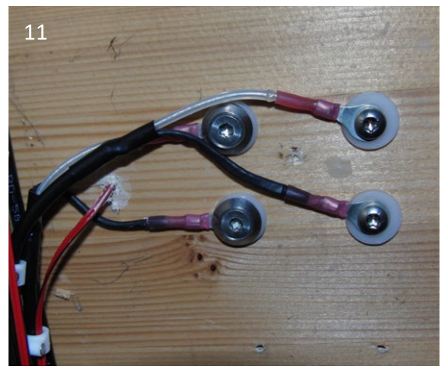
GPS position monitoring and meteorological surveillance:

- High precision GPS devices available, with accuracy as required by project
- Meteorological surveillance required for most projects (air temperature, humidity etc.)

7



9



11

8

10

12

13

7 3D acceleration sensor
8 Vibration measurement
9 Temperature measurement
10 Concrete temperature sensor
11 Dampness sensor
12 Wind and air temperature sensor
13 GPS position sensor

Durable and open sourced technology

State-of-the-art system

mageba's monitoring systems are independent of any technology preferences, using the best and most economical technology available to suit monitoring purposes:

- Only 'open-source' software
- Only hardware that is available on the free market is used

Power supply

ROBO®CONTROL monitoring systems can be powered regardless of the conditions found at the bridge site:

- Any electricity source available at the bridge (e.g. street lighting) is sufficient for the operation of the system
- Back-up batteries for cases of interrupted power supply can be integrated if required
- In remote locations, power needs can normally be fulfilled by solar energy with a battery back-up system, guaranteeing power 24 hours a day, 365 days a year

Data transmission

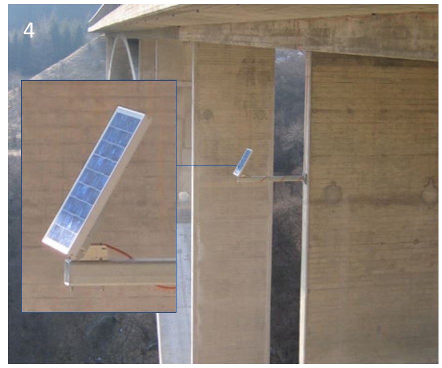
For the transmission of data from sensors to the central computer on-site, the majority of projects use wires, barely visible on the structure.

Wireless systems

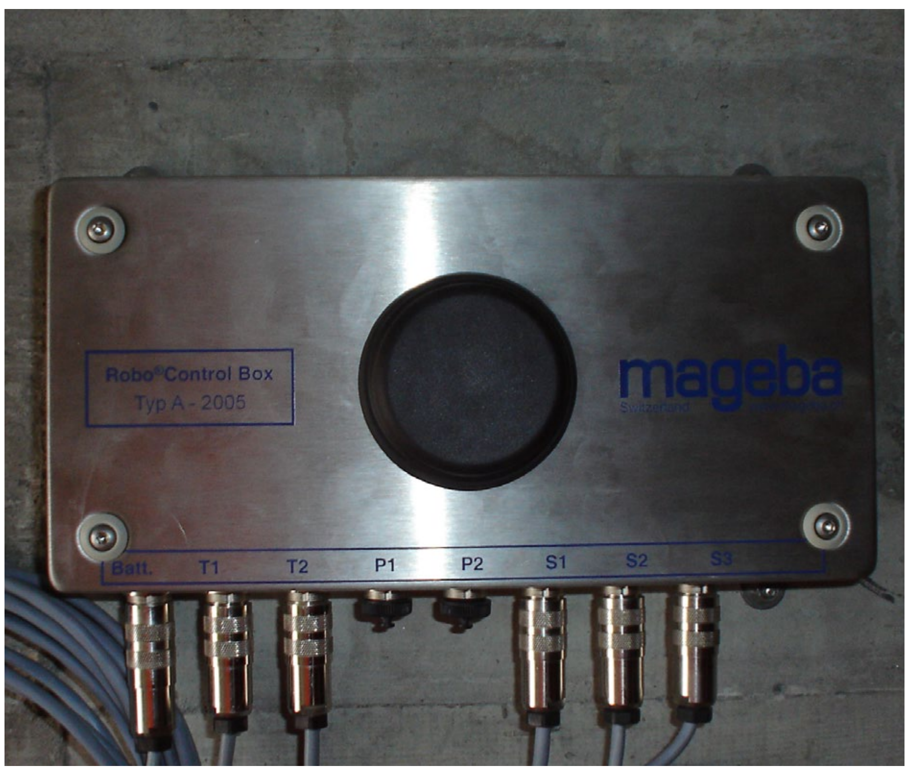
The use of sensors with wireless transmission of data offers the following benefits:

- Increased speed of installation
- Damage to the structure can be more easily avoided
- Positioning of sensors can be easily adapted

It has to be considered that the battery life of sensors is currently limited to applications of up to one year. Therefore, some maintenance visits to the bridge may be required for long-term monitoring purposes.



1 Wired sensor
2 Wireless 3D-acceleration sensor
3 ROBO®CONTROL box
4 Remote system powered by solar energy



Case study

Rhine Waterfalls (Switzerland)

Problem statement

The Rhine Falls in Schaffhausen, Switzerland is visited by hundreds of thousands of tourists every year. It is one of the region's most important tourist attractions and visitors marvel at the beautiful scenery from a terrace at the castle of Laufen.

Rock anchors installed to stabilize the rock wall below the castle showed unexpected force changes, leading to concerns that some sliding surfaces had developed. To ensure the ongoing safety of the terrace, additional rock anchors with measuring devices were installed, with a ROBO®CONTROL system monitoring anchor force changes.

This enables the responsible design engineer to draw conclusions about the rock wall's movement behavior, ensuring appropriate action can be taken if required.

Description of the structure

The rock wall of particular interest is about 66 ft (20 m) high and was stabilized with 11 additional rock anchors. The installation conditions were challenging due to high exposure, noise and dampness.

Monitoring approach

A ROBO®CONTROL permanent "BASIC" system was connected to the installed rock anchors, its flexibility allowing compatibility with the load cells of the anchors.

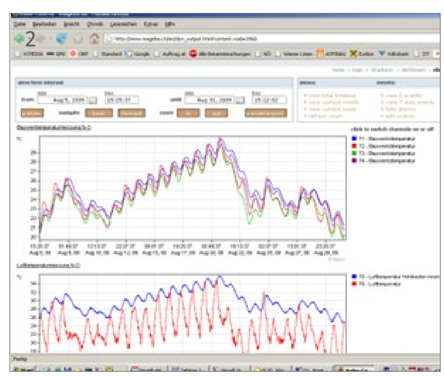
After the system calibration had been successfully conducted, the long term monitoring was set up, transmitting all data to a central server. The responsible authorities and design engineers are then able to monitor all anchor forces from their own offices, via a web interface.

The designer set some critical limitations for the anchor forces, which are implemented in the alarm notification feature of the ROBO®CONTROL system. Should any alarm value be exceeded, immediate notification will be sent by email and SMS to the designer and owner.

Outcome and benefit for the customer

It could be concluded that the rock wall has been well stabilized by the additional rock anchors. The forces are now very stable and rock movements are negligible.

And although movements may develop in the future, the ROBO®CONTROL system's alarm feature gives the local authority the confidence it needs to safely manage one of Switzerland's most frequented and spectacular public terraces.



1 Barely visible sensors at rock anchors

2 Graphical presentation of data on the web interface, including immediate alarm notification

Case study

Obermatt Bridge (Switzerland)

Problem statement

This timber bridge collapsed in 2005 during a flood period, and the cause of collapse could not be precisely determined. The main theory combined the impact of flood loading with poor timber strength resulting from high dampness.

To mitigate the impact on the timber bridge industry, the University of Bern started a research project to demonstrate the durability of timber (if designed, maintained and monitored adequately).

In addition, the project should prove that remote long-term moisture monitoring of timber bridges is more cost-effective than the frequent site visits which are generally required for non-monitored timber bridges.

Description of the structure

The bridge crosses the Ilfis River between the villages of Obermatt and Emmenmatt in the Swiss Alps. It has two lanes and average daily traffic of approx. 2,400 vehicles, and when it was rebuilt in 2008, it had a new safety feature: in the case of severe flooding, it can be raised by up to 27.5 in (70 cm) to prevent damage from floating debris in the swollen river.

Monitoring approach

In cooperation with the University of Bern, the dampness of the crucial elements of the bridge shall be measured over a minimum period of three years. The key features of the system include:

- Reliable long term measurement of timber moisture content at crucial locations, especially in the area between the superstructure of the bridge and its pavement.
- Immediate alarm notification by email and SMS if threshold values of the timber humidity are exceeded (> 25%)

Outcome and benefit for the customer

The measurements to date show that the timber moisture content of the bridge lies within an acceptable range. The long-term monitoring system will enable the client to understand the structural performance of the bridge and to recognize any changes as they occur. The system‘s alarm settings ensure automatic notification should timber moisture content ever rise unexpectedly. And it is hoped to prove the durability of well designed, maintained and operated timber bridges.

1

2

1 Installed devices to monitor timber moisture content

2 On-site system calibration

Case study

Incheon Grand Bridge (South Korea)

Problem statement

The design of this exceptional bridge required deck expansion joints with extraordinary movement capacity 75.6 inch (1,920 mm). The bridge engineers required verification of:

- the forecasted movement behavior of the bridge and
- the overall functionality of the modular expansion joints on an ongoing basis

Description of the structure

At 7.6 mi (12.3 km) long and with a main cable stayed span of 2,625 ft (800 m), the new Incheon Bridge is one of the five longest of its type in the world.

Its 109.6 ft (33.4 m) wide steel/concrete composite deck carries six lanes of traffic 243 ft (74 m) above the main shipping route in and out of Incheon port and links 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 section of the crossing is 4,856 ft (1,480 m) long, made up of five spans measuring 262 ft, 853 ft, 2,625 ft, 853 ft, and 262 ft (80 m, 260 m, 800 m, 260 m and 80 m) respectively.

Monitoring approach

In order to measure the movement of the cable stayed bridge section and the performance of the 24-gap modular expansion joints, a ROBO®CONTROL remote monitoring system measures the longitudinal and transverse movements of the deck at the joint.

The system measures the longitudinal movements of the first, second and last lamella beams of the joint, and the entire gap width. It also measures deck rotations and air and structural temperatures.

Outcome and benefit for the customer

Measurements to date allowed the following conclusions to be drawn:

- The predicted design movement and rotation behavior of the bridge deck was confirmed
- The exceptional expansion joint is performing very well, with no impacts and with satisfactory opening and closing of all gaps.

1 Installation of exceptional LR24 expansion joint

2 ROBO®CONTROL box as installed

Case study

River Suir Bridge (Ireland)

Problem statement

The design of the cable stayed bridge was determined to be critically dependent on the dynamic behavior of its cables. The costly installation of stay cable dampers shall be assessed in two steps:

- Assessment of the characteristics of each stay cable by temporary measurements to determine its natural frequency, damping and tension
- Assessment of the ongoing structural health of the bridge to confirm that there is no need for permanent damping of the stay cables, and thus save the expense of costly damping systems

Description of the structure

The River Suir Bridge is part of the N25 bypass of the city of Waterford. The cable stayed structure has an overall length of 1,526 ft (465 m), with individual spans of 131 ft, 230 ft, 295 ft, 755 ft, and 115 ft (40 m, 70 m, 90 m, 230 m and 35 m, and a width of 100.4 ft (30.6 m). Its concrete pylon has a height of 314 ft (95.6 m) above the deck, and the bridge was completed in September 2009.

Monitoring approach

Before opening to traffic, mageba performed measurements on all 76 stay cables using a ROBO®CONTROL "Portable" system, providing data on actual cable forces and cable damping. Afterwards, a ROBO®CONTROL "Permanent" monitoring system was installed by mageba. The system includes 62 measurement channels in total. The data is automatically analyzed on site and presented via the mageba web interface, with an overview of the current situation and graphical representation of the overall performance to date.

Outcome and benefit for the customer

Thanks to the data provided by the monitoring system, it could already be concluded that it will not be necessary to install dampers on all cables, resulting in great financial savings for the client. However some selected cables may be fitted with well-specified dampers at a later date.

1 Presentation of measured data on web interface

2 Wind sensor as installed on the top of the pylon

Case study

Weyermannshaus Viaduct (Switzerland)

Problem statement

During a detailed visual inspection of the underside of the bridge, considerable cracking was discovered at several coupling joints of the post-tensioned structure. Uncertainty about the time of crack appearance raised concern about structural safety. In order to ensure serviceability for another 35 years of operation, mageba was contracted to install a remote, long term monitoring system. The project was conducted in cooperation with the responsible renovation engineer that was already planning other remedial works such as replacement of bearings, joints and drainage systems. The monitoring data would serve in determining appropriate remedial works for the structure.

Description of the structure

The Weyermannshaus Viaduct is part of the national highway network of Switzerland and a key element of the bypass highway of the Swiss capital Bern. It was built in 1974 - 1977, with a main length of approximately 0.6 miles (one kilometer). The concrete structure is longitudinally post-tensioned and both highway directions are structurally connected together.

Monitoring approach

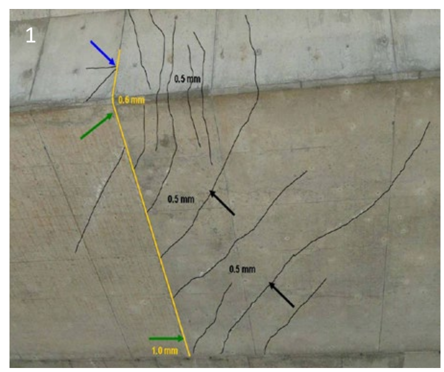
A ROBO®CONTROL permanent "ADVANCED" system was needed to fulfil the project requirements. In order to support the calculations of the engineer, changes in crack widths due to known traffic loads and temperature variations had to be monitored. It was decided to proceed in three steps:

1. Calibration measurements:
   Single load scenarios with a 40t truck were simulated at different speed levels.
2. Traffic load impact:
   Measurements at high frequency (200Hz) were conducted to assess the impact of actual traffic loading during a period of one week in each season of a year.
3. Long term monitoring:
   Installation of a permanent monitoring system to assess long-term impacts, with all data presented via a web interface.

Outcome and benefit for the customer

1. Structural safety and serviceability were confirmed to be satisfactory under current loading conditions.
2. A fatigue assessment confirmed another 35 years of operation for the main structure.
3. No major rehabilitation works are required.

1



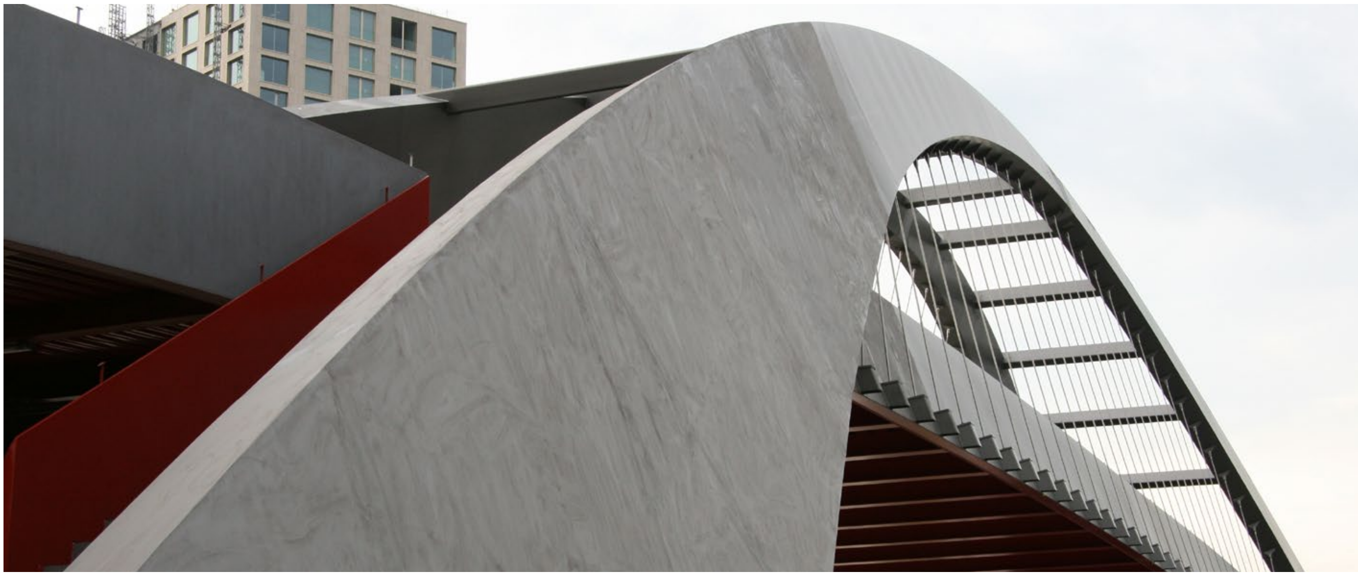
2

1 Cracking of concrete section at coupling joint of cables

2 Calibration measurements: 40t truck passing to simulate a single load scenario

Case study

Gleisbogen Bridge (Switzerland)



Problem statement

Intensive construction activity is planned to take place around the Gleisbogen Bridge in Zurich in the coming decade, including several high rise buildings. This will lead to uncontrollable incremental settlements in the whole area, including in the immediate vicinity of this newly built structure.

The question arose if such settlements could lead to uneven load distribution among the hangers of the bridge. This would affect the durability of the structure, as steel arch bridges are sensitive to uneven loading.

Description of the structure

This elegant foot and cycle bridge was erected to connect pedestrian zones on either side of a busy traffic artery, and consists primarily of an arch-supported deck with 138 ft (42 m) span and with access ramps and stairs at each end.

Monitoring approach

A ROBO®CONTROL "Portable" system was used to determine the forces in all hangers. Based on the measurement results, immediate recommendations for fine-tuning of the new structure could be given on-site. The main goal is to avoid any restraints and unforeseen loads.

The project process was defined by the design engineer as follows:

- Measurement of initial forces in hangers
- Discussion of results on-site
- Corrections, by

  a) either increasing or decreasing the tension in each individual hanger, or

  b) adjusting the height of the bridge using the bridge's RESTON®POT lifting bearings
- Control measurements after fine-tuning to check the effectiveness of the corrections

Outcome and benefit for the customer

It could be confirmed that the force flow through the as-built structure, following fine-tuning of cable tensions on-site, is as intended, with even distribution of loads among the structure's hanger cables.

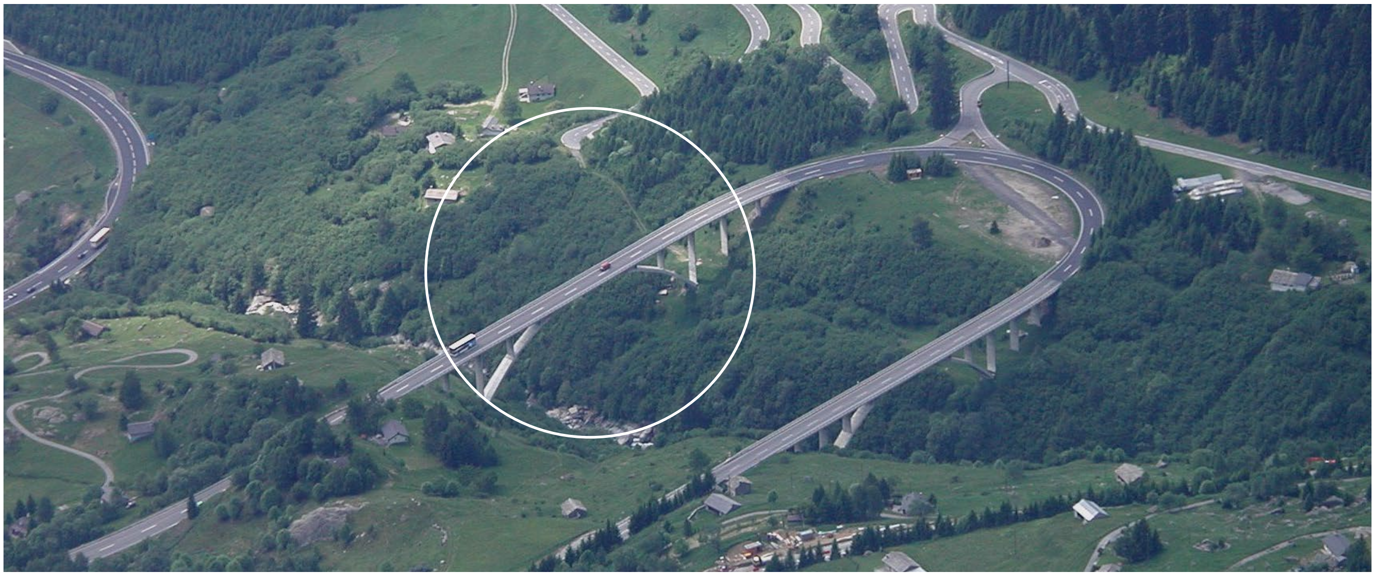
Furthermore, the data recorded will serve as a reference for future analysis and adjustments.

1 Installed sensor to determine the force flow through the structure

2 Discussion on the bridge to define immediate actions

Case study

Ponte Nanin Bridge (Switzerland)



Problem statement

During refurbishment works in 2004, modifications to the bridge were carried out to accommodate increased traffic. These changed the static system of the bridge, with several of the bridge's pillars newly monolithically connected to its deck, meaning that all movement of each bridge 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, preventing movements and thus resisting the forces that would have caused such movements in the past.

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.

Description of the structure

The twin arch bridges of Pont Nanin in the Swiss canton of Graubünden were constructed in 1967, using the same formwork, to create an important new connection in the mountainous area of the famous San Bernardino Pass. The monitoring system is installed at the lower bridge.

Monitoring approach

The main concern following the refurbishment of the bridge related to the "flow of the 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, with particular attention to the structure's bearings and expansion joints.

Outcome and benefit for the customer

The monitoring system installed at Pont Nanin still provides confidence on an ongoing basis that the structure continues to function safely and well. It therefore confirms the design of the engineers who were faced with the challenge of adapting the statical system of an existing structure. The system thus validates the approach which was deemed most suitable for economic reasons, but which necessitated such validation in order to minimize all residual risks, more efficiently than could be achieved by an alternative manual inspection regime.

1 Installed sensor to determine bearing displacements

2 Independent power supply with solar panel at remote location

Structural monitoring

Case study

Danube Bridge Sinzing (Germany)

Problem statement

A consulting monitoring project was carried out at the Danube Bridge in Sinzing, Germany in December 2007 in order to collect data to explain unusually fast abrasion of the bridge's sliding bearings. The bridge features twin steel girder decks supported by pot bearings on eight piers and the abutments.

Bridge inspections had revealed that the PTFE material of a number of the bridge bearings was significantly worn after only five years of service. Recommendations for appropriate remedial works were requested of the mageba project team.

Unusually large movements of the bridge under traffic loading were surmised to be the cause of the accelerated wear. The extent of the movements had to be understood, in order to implement sensible remedial works.

A modern high-grade polyethylene sliding material, ROBO®SLIDE, offers an alternative to PTFE in sliding bearings, with enhanced characteristics including far higher durability than PTFE. It was therefore decided to monitor the bridge's movements and determine if new bearings featuring ROBO®SLIDE would offer a satisfactory solution.

Monitoring approach

A short-term analysis to evaluate the exact movements of the bridge deck over its bearings was required, and since manual measurements cannot offer the precision required, an automated system was necessitated. The short-term nature of the project made a "Portable" system ideal for this purpose. Mageba offered the assessment of the data during a two-week recording period.

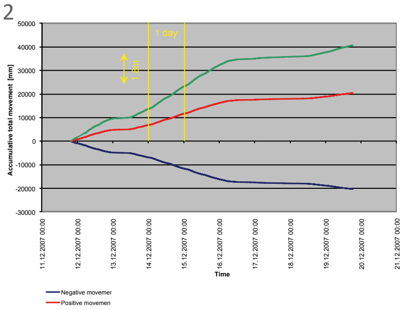
Outcome and benefit for the customer

A clear correlation between longitudinal displacement and temperature was evident, with extrapolation of the recorded data indicating accumulated longitudinal sliding distance of approximately 1.6 mi (2.5 km) in one year. It could be concluded that excessive movement was the primary cause of the wear problem, and that use of ROBO®SLIDE instead of PTFE would significantly prolong the life of the bearings.

A detailed understanding of the behavior of the bridge was obtained from this temporary and relatively affordable monitoring system, enabling the bridge owner to have confidence that the proposed solution to the problem of premature bearing failure will have long-term success.

1

2



1 Removed PTFE discs showing significant abrasion

2 Cumulative longitudinal movements at one bearing

Case study

Run Yang Crossing (China)

Problem statement

After completion of construction and opening to traffic, unexpectedly large movements of the structure were observed, which resulted in excessive wear on bearings and expansion joints. Especially the sliding materials and the elastomeric control springs of the bridge's expansion joints showed clear signs of accelerated wear.

An inspection and measurement project was initiated, using a "Portable" system to quantify movements and to better understand the structure's overall behavior.

Description of structure

The Run Yang Bridge is located about 186 mi (300 km) west of Shanghai on the route between China's Zhenjiang city in the south and Yangzhou city in the north. The bridge contains both cable stayed and suspension structures.

The cable suspended section with its 0.93 mi-long (1.49 km) main span, a total length of 1.6 mi (2.5 km), and 689 ft-high (210 m) towers, is the fourth longest suspension bridge in the world.

Monitoring approach

The local bridge engineer required measurements of the following characteristics over a period of two weeks:

1. Accumulative movements
2. Absolute movements at bearings and expansion joints
3. Incremental rotations at joints
4. Event counting of load cycles at expansion joints
5. Environmental data to enable assessment of meteorological impacts

Comparison of the measured movements with the theoretical design movements of the bridge model would allow evaluation of the unforeseen bridge movements. A special focus was placed on the impact on the sliding materials of the bearings and expansion joints.

Outcome and benefit for the customer

The monitoring system was used to conclude that the movements at the suspension bridge greatly exceeded expected values. The bridge engineer could use the information provided to plan remedial works to improve the structural performance and to prevent excessive wear of the bearings and expansion joints, for instance by the addition of damping devices, which can be easily installed on a finished structure during operation.

1

2

1 mageba modular expansion joint with exceptional movement capacity of 85 in (2,160 mm)

2 Movement measurement at bearing

Turnkey solutions offered

Clarification of objectives

In order to achieve maximum value for the customer, it is critical that requirements are carefully analyzed before commencing work.

Clients, designers and mageba's monitoring team must clearly define the monitoring system's purposes and the benefits of the obtained data. Ideally, the measured values can be directly integrated in the designer's calculation model.

In addition, close ongoing cooperation with the responsible structural engineer is beneficial in order to ensure that sensible and useful results continue to be achieved. Cooperation with specified engineers and experts will always be supported by mageba.

Any monitoring system must be tailored to suit the specific conditions and features of the individual structure. To achieve optimal results, mageba should be involved in the project development at an early stage, ideally right from the beginning of the conceptual approach.

Project requirements

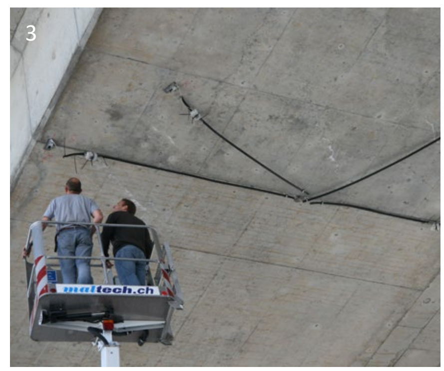
In addition to the clear definition of objectives, the following items should be agreed when placing an order for a monitoring system:

- Layout of system
- Arrangements for data management
- Definition of engineering tasks and responsibilities
- Contract for data transmission costs (if any)
- Service contract requirements to ensure long-term performance

Delivery

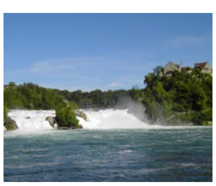
Fabrication and pre-setting of the system begins as soon as the customer has approved mageba's final proposal. Delivery time is highly dependent on type and size of the applied monitoring system.

Installation typically takes a few days, depending on the complexity of the system and local access condtions, and the process of protecting the system from environmental conditions, vandalism, and theft.



1 Safety monitoring in operation at the Rhine Waterfalls to monitor the rock wall behavior
2 Close cooperation between clients, designers and mageba's monitoring team
3 Inspection of monitoring system after installation by mageba experts

References ROBO®CONTROL Monitoring

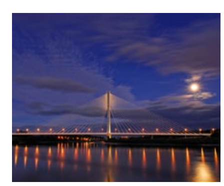

Rhine Waterfalls (CH)


Weyermannshaus (CH)

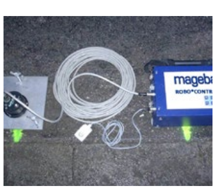

Steinbachtal Bridge (DE)


Alvsborg Bridge (SE)


Dintelhaven Bridge (NL)


River Suir Bridge (IR)

mageba ROBO®CONTROL Monitoring Systems


"Portable"


Permanent "BASIC"


Permanent "ADVANCED"

mageba-group.com

engineering connections®

mageba North America Corp. - 1384 Broadway, 5th Floor - New York, NY 10018 - USA - T +1 212-644-3335 - info.us@mageba-group.com