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WhP_Poya_SE_vA

STRUCTURAL HEALTH MONITORING AT THE PONT DE LA POYA, FRIBOURG

WHITE PAPER

Summary:

This white paper shows how Structural Health Monitoring (SHM), helps to improve the quality in the construction and long term monitoring at Poya.

	Name	*Function*	*Date*	*Signature*
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A	29/07/2013	Complete editing	Solexperts

Structural Health Monitoring (SHM)

Civil engineering structures are substantial to our daily life and traffic infrastructure. In particular, bridges are outstanding construction feats serving as backbones of roads and railway lines.

When building new traffic ways, bridges are usually the most challenging and cost driving elements in these projects. It is most obvious that these structures must be in good condition for long term use.

Structural health monitoring (SHM) is the process method used to observe the condition of a structural system and to detect changes in material conditions and geometric properties. It also includes changes to the boundary conditions and system connectivity, which adversely affect the system's performance. The SHM process involves the observation of a system over time. This is done by a combination of optical inspections, by taking samples and tests in laboratories (e.g. concrete), by field tests and last but not least by taking regular measurements with various types of sensors.

SHM is an important process during the construction of new structures and during the operation to reduce risks and cut down maintenance costs.

Ensure intact structures

When driving along a road or in a train, we obviously want to be aware that we are using an intact, safe infrastructure. This means that we are not in danger of breaking elements, falling parts or, in the extreme, collapsing structures. Examples of the latter are luckily rare, but – especially in large and complex structures - can occur very rapidly and accidentally. One of the best known examples in recent years is the collapse of the Mississippi River bridge in Minneapolis in 2007, when 13 people were killed. The collapse was caused by the sudden failure of under-sized and corroded gusset plates. Contributing to that design or construction error was the fact that additional concrete was an increased dead load after rebuilding measures and an insufficient check of safety functions and bridge deformation (http://en.wikipedia.org/wiki/I-35W_Mississippi_River_bridge, 17.09.2013)..

Bridge collapse in Minneapolis, August 2007

However, also smaller damages to a structure can lead to accidents and injure people. Irregular settlements or deformations of a bridge can lead to pitches, gaps and pot-holes. Especially with rain or ice this can lead to critical situations in traffic.

On motorways often speed limits reduce these risks. But still then wrong reaction of drivers can lead to traffic jams and to risks of accidents.

This shows that intact structures can prevent dangers. However, SHM is not only a matter of safety. It is also a question of being economic. Early detection of structural failures and problems and good maintenance of a structure will extend its' lifetime at reduced maintenance cost.

The GENESI SHM system

GENESI (**G**reen s**e**nsor **ne**tworks for **s**tructural mon**i**toring) is a newly developed autonomous and wireless data acquisition system for structural health monitoring and for the monitoring of natural risks (e.g. landslides).

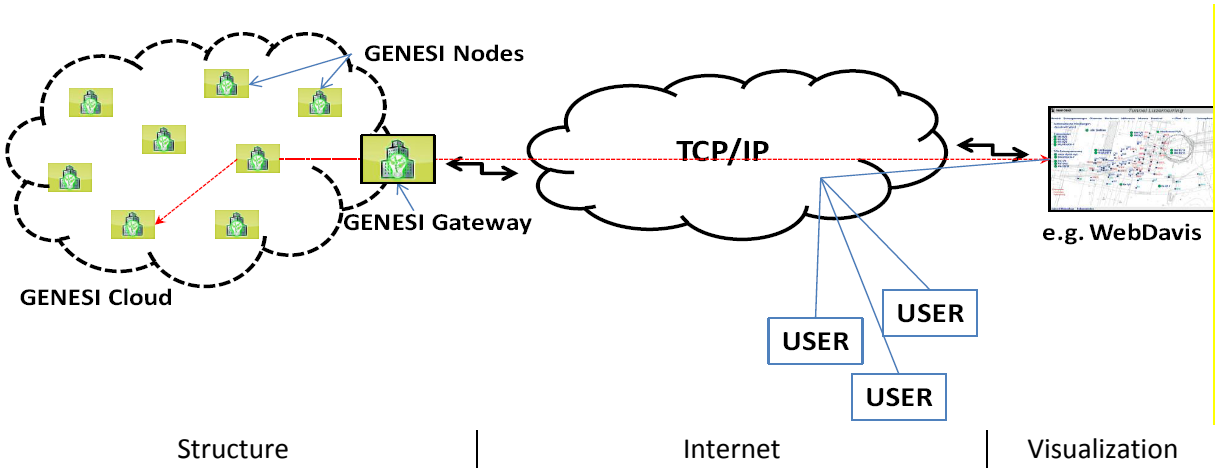
With partners from two leading and reputable SHM companies (Solexperts, Switzerland and Treesse, Italy) and from universities and research centers of Rome (Sapienza), Bologna, Twente and Cork (Tyndall), the system was designed to serve companies and authorities as the most modern and economic automated SHM system. It is wireless, supporting a large number of different sensor types and being flexible in installation and modification (extension and removing of nodes), GENESI is developed to monitor a structure during its full lifetime from construction to long term operation. With this functionality it can detect irregular behaviour and changes in the structure very early.

The development of the system has been supported by the EU (FP7 research project) GENESI and was assisted by authorities, planners and construction companies of Rome Metro B1, and Pont de la Poya (Fribourg, Switzerland).

GENESI offers the following features:

Data acquisition	Autonomous data acquisition system
Interfaces and sensors	Compatibility to all types of common SHM sensors: • Displacement (2x) • Inclination (2x) • Strain • Temperature • Pressure • Moisture • Wind • Various other types (analogue and RS485 interfaces)
Resolution	• 16 bit resolution for analogue sensing • Div. digital sensors connectable
Measuring rates	• Individual and flexible measuring rate for each connected sensor (30 sec to 86400 sec) • reconfiguration can be done remotely
Data Transmission and data access	• Wireless data transmission (2.4 GHz) between nodes (up to 150 m) to a gateway • GPRS data transmission to data server • Web Visualisation of the data
Network size	• Over 50 nodes in network with more than 100 sensors • Radio is repeated over several nodes, network can be enlarged to several 100 m in each direction
Lifetime	Designed for long term measurements of many years resp. decades
Powering	Node: • Batteries (lifetime >5 years in normal measuring rate) • Energy harvesting (solar and wind, lifetime > 10 years) Gateway: • 220 V power supply (standard)
Size	Nodes: 120 x210 x 90 mm (1.5 kg) Gateway: 400 X 250 x 120 mm (3.5 kg)
Others / Features	• Easy to extend and modify • No cabling and cable protection required between nodes and interfaces! • Low maintenance costs • High robustness: IP67

The GENESI network collects all data of the sensor connected to individual nodes and transmits data to the gateway. The gateway automatically transfers the data to an internet database where the data is stored (with backup) and can be accessed by all persons involved in the project over a WebDavis page with real-time graphs. In case a node is not available, net network reconfigures automatically.



Schematic example for a GENESI network

The GENESI SHM system is targeted at authorities, planners and construction companies. More features like adaptive data sampling (outlier detection) and alarming are under development.

Pont de la Poya monitored with GENESI

The Pont de la Poya bridge is a large suspension bridge that was built between 2009 and 2013 to bypass the historic city of Fribourg (CH) for road traffic. The overall length of the bypass is approximately 1.5 km, where 300m are in tunnel section and 850m are the suspension bridge. The bridge structure stretches across the river Saane at an average height of 70 metres above the valley floor. It bases on 10 pillars and 2 pylons reaching a height of 110 metres at maximum. The main distance between the pylons is 196 metres.

Historic town of Fribourg with the construction site of the Pont de la Poya in the background

The first prototypes of the GENESI network were installed at the Pont de la Poya in 2012 and 2013. Following measurements are taken:

- Strains in auxiliary stiff bars for the tunnel construction (excavation pit)
- Inclination of Pylons and pillars
- Bearing displacements (mainly due to temperature)
- Environmental parameters: Temperature, wind, Air pressure, Water levels, and soil moisture
- It is planned to extend the network with accelerometers on the linking part of the bridge

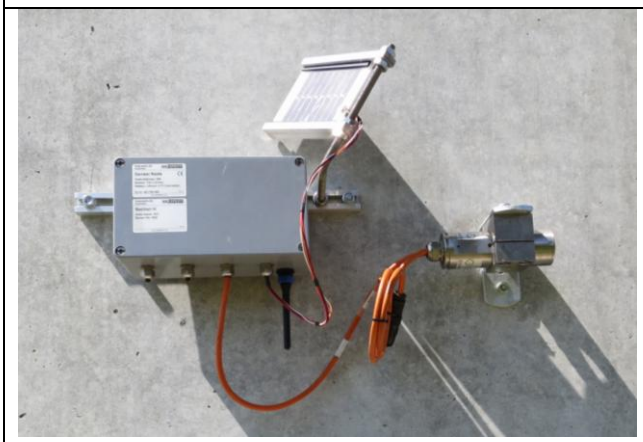
The GENESI SHM, already starting during construction, and later also during the operation of the bridge has the following purpose:

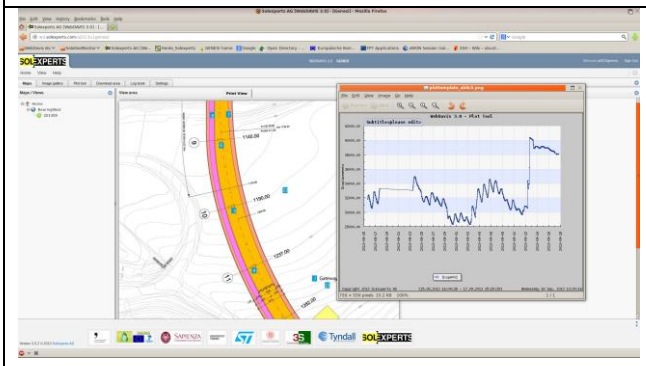
Element	Measurements	Purpose during construction	Purpose in operation
Stiff bars (in tunnel section)	Strains (VW-strain gages)	Detecting critical load states	Stiff bars are removed in final construction
Pylons	Inclinations	Detect critical situation due to construction (non-symmetric loading) and design faults	Detect irregular behaviour during operation, possibly caused by/after impacts (storm, earthquakes and traffic accidents) Detect deformation / bending due to aging (strain in tension ropes)
Pillars	Inclinations	Detect critical situation due to construction and design faults	Detect irregular behaviour during operation, possibly caused by/after impacts (natural and traffic accidents) Detect deformation / bending due to aging (e.g. strain in tension ropes or relocation of loads du to settlements)
Bearings	deformations	Not installed	Check design values and detect irregular behaviour (e.g. due corrosion and settlements)
Bridge section/ Carriageway	acceleration	Not installed	Detect impacts and irregular behaviour in oscillations
All section	Environmental parameters: Temperature Wind Pressures etc.	Detect environmental influence on bridge and on sensing elements	Detect environmental influence on bridge and on sensing elements

The big advantage of the GENESI system in the Poya deployment was that the system could be installed stepwise node by node without significant extra effort, according to the progress of the construction works. Furthermore there are no cables which take a long installation time, interfere with construction work and are likely to be damaged. After construction works are finished most of the sensors and nodes will stay in service. The gateway of the network will be simply moved from temporary containers to a service building.

With low power mode and energy harvesting the maintenance tasks for the SHM will be very low. When extraordinary events are happening or after irregular measurements, measurement intervals of nodes and sensor can easily be changed remotely.

User and project responsibles have continuous access to real time data via a Solexperts WebDavis Webpage.

	Bridge construction. GENESI system is extended over the complete structure
	GENESI node with inclination sensor and solar panel

	Installation of node on pillar
	WebVisualization and Online-Graph with Solexperts WebDavis

Please contact us for further information on the GENESI SHM system and questions regarding our monitoring systems.

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