Affordable remote monitoring system for bridge structures

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Summary

Bridge owners need to obtain an understanding of the condition of their structures due to rigid safety demands and also the increasing age of many bridge structures, which makes it harder to assess whether the structures are compliant with the latest safety demands. In addition, some of these structures might have been built on unstable ground or be subject to harsh environmental conditions. Therefore, in many cases there is a need for structures to be monitored continuously and to pick up relevant data such as change in bridge movement, forces in the abutments or others, which might indicate a critical condition. The traditional bridge inspection is either not capable of picking up this kind of data or the inspection interval is not sufficiently tight to give an early warning. In other words a market has developed for a product, which can achieve continuous monitoring at reasonable cost to the owner. mageba has recognised this need and developed an economical monitoring unit which is solar powered and transmits data via GSM. Hence, it can be installed even in remote locations. The measured data is then transmitted to mageba, where it is analysed and then the data is presented graphically on a secure internet portal. From this portal the data can also be downloaded for further analysis. In case a critical event occurs, an alarm message is sent directly from the bridge via SMS or from the internet portal via Email and early action can be taken. An example of this monitoring unit in use on a bridge structure in the Swiss Alps is given in this paper. In summary mageba has developed a standardised low cost monitoring unit, which facilitates easy monitoring of bridge structures and allows for early remedial action ranging from emergency inspections to road closures.

Keywords: remote monitoring, structural assessments, GSM/GPRS, force measurement, movement monitoring, data analysis
1. Introduction: Why is there a need for economical monitoring systems

Many of the ‘of the shelf’ bridge structures build in the 1960ies were designed or build to an insufficient standard so that there is an increased chance that they are now deficient. Therefore, a close monitoring and inspection regime is required to determine the point of intervention (refurbishment).

At the same time the owners (Highway departments) have the responsibility to maintain their structures at an adequate level of safety. In many cases, this can only be achieved by frequent inspections. However, the inspection cost may accumulate to several times the cost of the basic version of Robo®Control, which is of the order of only a few 10’000EUROS and additionally reduces greatly the need for inspections. Robo®Control is a fully automatic and very robust bridge remote monitoring system, which can be installed even at remote locations (Fig. 1 Ponte Nanin, Switzerland).

The great advantage of the system lies in the fact that Robo®Control helps to determine the exact intervention date and the cost of refurbishment, which can be quite considerable, depending on the project, can be allocated for in the budget.

Furthermore, a very tight measurement interval of relevant compared to ordinary inspections is possible. Therefore, the overall cost for inspection, maintenance and repair is reduced greatly compared to a traditional monitoring regime.

Apart from measured parameters on bridge bearings, expansion joints and shock absorbers, characteristic bridge parameters and loads can also be measured and calculated, for example the natural frequency.

2. Possible applications of Robo®Control

The system consists of a data transmission unit, the so called Robo®Control box (Figure 2), a power supply and the array external sensors, which are installed at prominent locations throughout the bridge. The key element of the box is a digital measurement card developed by mageba and GSM/GPRS modem, which are encased in a robust stainless steel box.

The sensors and the power supply are connected to the box, which then starts to transmit the measured data to a central server. A wide range of relevant data can be measured with this flexible and modular system. Its robust components are designed for continuous operation over years. It can be used to measure strain, pressure, movement, temperature, tilting, vibration, dilatation and deformation of structures. Due to its modular design, other measurement systems can be incorporated.

It can be operated via a mains-independent power supply (optional). The data transmission via GSM or GPRS modem and the data processing and analysis is carried out by mageba at a central server. The data is presented via a secure internet portal (Download in CSV format possible, which can be read with MS-Excel). The main advantage is that it is tried and tested: the system has been installed at three bridges in Germany and Switzerland and is working satisfactory.
3. Affordable high tech at bridges

The installation of each remote monitoring unit is planned by mageba in cooperation with the client. The parameters to be measured, the location of each sensor and the kind of sensor are then determined and summarised in an installation plan (see Figure 3). The choice of sensors and their location is strongly dependent upon the structure and the materials from which it is constructed. By taking all of these parameters into consideration, mageba ensures that the system is able to monitor the relevant parameters.

The Robo®Control system can be installed independent of the conditions found at the bridge site, because its components can be powered by solar-energy. The system guarantees a power supply of 24 hours a day, 365 days a year even during a bad weather period. Figure 4 depicts the installation of a solar panel for Robo®Control. The solar panel is always installed at places with difficult access to protect it from vandalism.

The solar panel is dimensioned so that Robo®Control can operate even during night and winter, the data stream is guaranteed. In the event of using mains power and data intensive measuring methods, power is taken from the electric mains; however, a batteries bank is used to achieve a temporary redundancy, avoiding operation failure without prior warning.
4. Measurement types

The solar-operated version of the system Robo®Control performs measurements automatically at a 10 Hz frequency and records them each 15 minutes. Power intensive measurements with high measurement frequencies (up to 100 Hz), for example vibration measurements, are electric mains voltage operated.

Force measurements are carried out on bridge bearings through preinstalled force measuring devices; however, they can also be retrofitted through mageba developed processes (to be resolved on site). Figure 5 shows a mageba installation engineer carrying out a check on site.

Fig. 5 On-site check of Robo®Control Box

Displacement measurements on expansion joints are carried out by additional displacement sensors, which can be retrofitted and are based on ultrasonic or magnetostrictive measurement technology.

Vibration measurements can be performed either with conventional strain gauge or fibre optical sensors. Temperature measurement can be done through several temperature sensors. Other sensors, for example anemometers, cameras or inductive loops can be integrated on demand (see Fig. 6).

The solar-operated power supply, the sensors and the Robo®Control-Box are installed by mageba engineers. The client should make sure that the access to the bridge components is possible.

Fig. 6 Picture of web cam taken by Robo®Control for evidence securing
5. Installation and Calibration

In general, cable fastening to the bridge is performed by means of cable clamps. This way an economic installation process is facilitated. Most of the measuring devices are pre-calibrated and Robo®Control does not need to be calibrated on site. However, it is possible to get a deviation from a theoretical expected value, particularly because of an alarm value set-up. In this case, the set-up should be adjusted later. For other measuring methods, especially when structural classification is required, the system should be calibrated after installation at the bridge site. In this situation, mageba experts assist on planning and performing all necessary tests.

6. Comfortable Data Analysis

Fig. 7 Data management with Robo®Control

Very often a monitoring system is installed somewhere, but the results or the measured data are not analysed or viewed properly as it is very inconvenient for the user.

mageba has recognised this drawback and focused on proper presentation of the measured data. This starts with a proper concept of data management (see Figure 7) and culminates in a concise web page where the data is presented. Data compression on site is performed and configured in agreement with client or bridge engineer (recording of values only every 15 minutes, average, etc.). However, data transmission from the site and data polling takes place at least once a day so that an up to date picture of the bridge can be obtained any time.

The data transmitted by the Robo®Control box is then displayed graphically on the internet where it can be viewed over a secure internet portal (see Figure 8). The data is presented as comprehensive x-y diagram or histogram.

What is more, data download for further analysis is possible at any time via Internet by authorized user with login and password. This state of the art presentation makes it possible for the bridge to be monitored from anywhere in the world.
Furthermore, boundary and alarm values are given by the client. If any measured value exceeds or falls below the predefined alarm values, an email or SMS message will be sent immediately to the client. This is important when the website is not controlled anytime.

7. Conclusions

mageba has recognised the need of the bridge engineers to monitor old bridge structures continuously, over a long period of time and within budgetary constraints.

The amount of data delivered by a measurement system has to be filtered and channelled properly so that relevant information is recognised immediately and in time.

Robo®Control, a small and robust measurement unit with modular design can be used on almost any bridge structure even at remote locations without power supply or communication network as it is independent of power mains and transmits data via GSM.

The data itself is displayed graphically for any desired period on the internet and can be viewed from anywhere. What is more, should some boundary values be exceeded, an alarm message is sent automatically and appropriate action can be taken.

The overall system fits well within the budgetary constraints of bridge owners and allows postponing the point of intervention by increasing the confidence in the bridge behaviour. Thereby, the resources available for maintenance and repair can be addressed much better than when a conventional approach is used.