Test Methods

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Integrated System for Monitoring Bridge Structures

Comisu Cristian Claudiu
Technical University"Gh. Asachi" of Iasi, Romania

Summary

Use of integrated monitoring system for composite bridges ensures an increased structural durability and leads to a reaction of costs for inspection, repairs and rehabilitation. Integrated monitoring system assists and improves investigation and planning activities and allows optimized allocation of financial resources.

The permanent bridge monitoring system presents the following advantages:

- reduces the interferences with traffic;
- reduces the costs of access to the structure elements;
- allows monitoring of structural elements with difficult access;
- allows a precise real time assessment of bridges conditions;
- allows a precise evaluation of the degradation mechanisms and of their appearance;
- defines precise elements parameters of a bridge maintenance and repair strategy.

Use of integrated monitoring system for composite bridges secures a reduction of 25% of maintenance costs and increases by 10% the operation life of concrete bridges.

1. INTRODUCTION

The major part of the European infrastructure has reached an age where capital costs have decreased. But inspection and maintenance costs have grown such extensively, that they constitute the major part of the current costs. An ageing and deteriorating bridge stock presents the bridge owners with the growing challenge of maintaining the structures at a satisfactory level of safety, performance and aesthetic appearance within the allocated budgets.

Selecting the optimal maintenance and rehabilitation strategy within the actual budget is a key point in bridge management for which an accurate assessment of performance and deterioration rate is necessary. For this assessment, the use of a integrated monitoring system has several advantages compared to the traditional approach of scattered visual inspections combined with occasional on-site testing with portable equipment and laboratory testing of collected samples. For this reasons, attention is more and more focusing on the development of permanent integrated monitoring system for durability assessment of concrete bridges.

2. INTEGRATED MONITORING SYSTEM

The main scope of the research is to develop an integrated monitoring system for durability assessment of existing and new concrete bridges. The system must interface and integrate the actual practice mainly based on visual inspections and combines the response of a number of different reliable sensors, installed on the structure to monitor the progress of damage, with enhanced realistic deterioration models. The system and the sensors were developed to cover the parameters for the most important deterioration mechanisms: corrosion of reinforcement in bridges, carbonation of concrete, freeze-thaw cycles, alkali-silica reaction and mechanical damage, as well as the changes in the structures behavior and safety: static deformation, strains; crack widths and vibrations (frequencies, amplitudes, accelerations and vibration modes).

The progress of the various types of damage mechanisms can be predicted by monitoring the key physical and chemical parameters of the materials (such as temperature, humidity and pH for the concrete, measured on the surface of the structure and as a profile through the concrete thickness, and/rate of corrosion of reinforcement), and key mechanical parameters (such as strains, deflections, vibrations). As the sensors have to be permanently installed on the structure, they must present special characteristics of durability, easiness of installation and substitution, apart from being obviously low cost.

The next point concerns the acquisition of the data collected on site and their transmission to a remote PC. All data must fit into numerical models to represent and to predict the deterioration of concrete bridges. Finally, the last component of the integrated monitoring system is given by software able to help in assessing the strategies of intervention for the individual bridges.

The research is divided in 7 tasks (figure 1).

Task 1 describes the state of the art of current practice in the fields of inspections, monitoring and maintenance, both in European Community and in the USA, underlying advantages and possible disadvantages as well. It results in a number of requirements and system specifications for the integrated monitoring system from the end-user point of view.

Task 2 concerns the description and correlation of the most relevant deterioration mechanisms for the structures with the parameters that may be measured on site. The focal point is the determination of the critical levels of both the parameters of the models and of the corresponding measurable parameters.

Task 3 is related to the implementation of portable equipment to measure corrosion activity. This equipment may be used to support the current activity of monitoring and inspection of bridges.

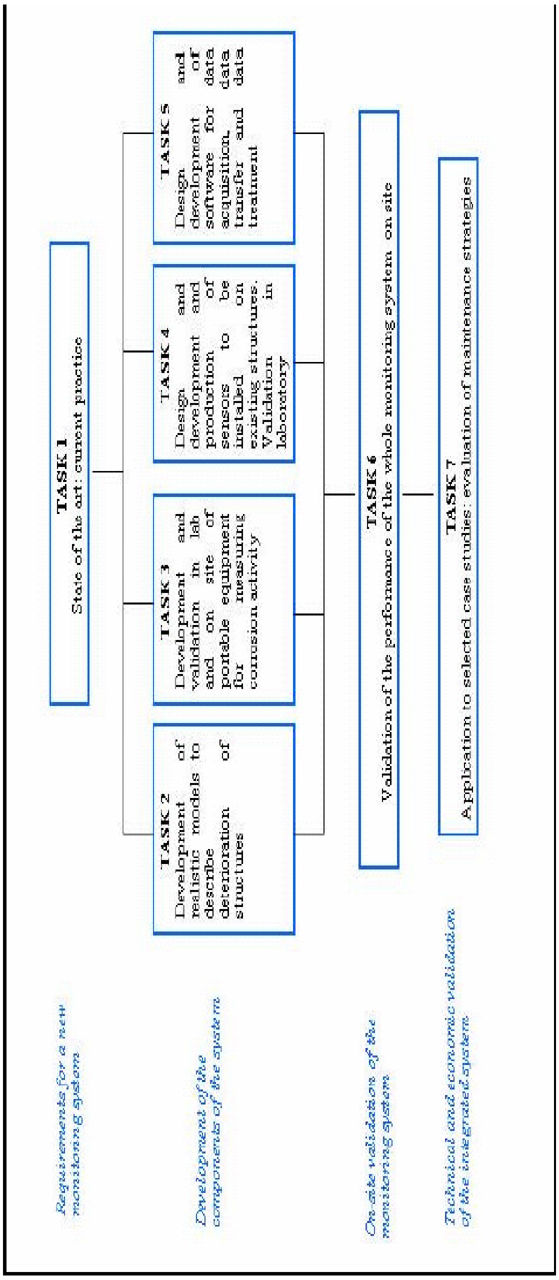

Fig. 1 The main tasks of the research

The objective of task 4 is the design, development and production of a number of sensors to be installed on the bridges to monitor their progressive deterioration. They have been firstly tested in laboratory where their performances have been compared to those of sensors and probes available on the market, to be next successfully installed and tested on an existing bridge.

Task 5 aims at designing and integrating the systems for data acquisition and transfer with the software for data treatment and analysis.

Task 6 represents the validation of the whole system that has been installed on an existing bridge in Romania. Data collected on site and transferred according to the results of task 5, are processed to evaluate the progress of deterioration, to define alarm thresholds and to establish maintenance strategies and compute the overall costs.

Finally, task 7 deals with the technical and economic validation of the entire integrated system, as it is necessary to evaluate the potential market for the developed system.

3. OPTIMAL MAINTENANCE STRATEGY

The bridge owners' main interest in permanent monitoring systems for durability and performance assessment of concrete bridges is to reduce the inspection, maintenance and rehabilitation costs as well as the traffic interference and yet still maintain a satisfactory level of safety, performance and aesthetic appearance.

The knowledge on the development of deterioration of structures, in both its aspects of initiation and quantification, is a key activity for the management of bridges, especially where it deals with the planning of maintenance and repair activities. It is particularly difficult to assess the conditions of bridges and to foresee the evolution of their damage as this process is affected by many factors, some of which interact and some of which have no measurable effects.

Permanent monitoring systems should therefore provide information that can be used as input for the decision making process (e.g. for estimating the extent and budgets for maintenance, rehabilitation and repair activities) such as probable deterioration mechanisms, estimates of the time for initiation and future development of deterioration, assessment of structural safety.

Permanent monitoring systems should be able to monitor the relevant deterioration mechanisms such as corrosion of reinforcement initiated by chloride ingress or carbonation, freeze-thaw damage and alkali-silica reaction damage. Ideally, one or more measurable key parameters that can describe the progress towards initiation and subsequent growth of damage should be identified for each deterioration mechanism as well as simple deterioration models allowing for prediction of the initiation and growth of damage. Furthermore, the structural performance and the effects of e.g. mechanical damage due to deterioration, vehicle impact, overloading or loss of prestressing should be covered by the monitoring system (table 1).

Table 1.

Process to monitor	**Relevant parameters**	**Location**	**Component of the system**	**Requirements**
- corrosion - freeze-thaw - alkali-silica reaction - mechanical damage	- humidity/moisture content - temperature - pH - chloride content - corrosion initiation/rate - permanent deflections - cracks - static and dynamic behavior (structural safety)	areas critical: - safety - development of deterioration	sensors /probes	- robust - accurate - durable - easy to install/operate
			empirical models	reliable trends of deterioration
			data acquisition	- automatic acquisition - adjustable frequency
			data transfer	remote communication site/office
			software for data treatment	-compatible with standard programs

To be effective, a permanent monitoring system must include a number of sensors installed on the structure, a data acquisition/transfer system and integrated software for analysis and treatment of information. They must have a long service life, be easy to install and to operate (traffic interference) and have a limited need for maintenance and calibration.

The data acquisition system should allow for adjustable measuring frequency (preferably on-line control), two-way communication between site and office, and send out warnings if parts of the system have stopped working. The software should be compatible with recognized standard programs. Results and data for daily operation or for research purposes should be easily accessible. The software should enable a simple and easy to understand presentation of the development of the monitored key parameters, i.e. the history, current situation and future development based on simple models for extrapolation to result in quick answers for the end users in the light of the management of bridges.

4. ADVANTAGES OF MONITORING SYSTEM

The integrated monitoring system should be able to help the end- user in his daily and long term management of the bridges.

The use of integrated monitoring systems has several advantages once the system is installed:

- Traffic interference is reduced

- The costs of access to the structure and resources for inspection and testing are reduced
- Structural elements with difficult access are easily monitored
- A more precise evaluation of the actual conditions of the structures with particular regard to the timely warning of the onset of durability and structural problems
- A more reliable prediction of the progress of damage as a function both of the measured parameters and of the application of realistic deterioration models, as well as a better understanding of individual deterioration mechanisms and their interaction
- An input for undertaking preventative actions for low levels of deterioration
- An input for defining maintenance and repair strategies (time and extent) as a function of the actual and foreseeable levels of deterioration
- A feedback on the effectiveness of repairs
- An evaluation of the need for further inspection and testing.

It is estimated that with the implementation of such integrated monitoring systems it should be possible:

- To reduce the operating costs of inspections and maintenance by 25%;
- To reduce the traffic-related costs by 30 % by reducing the number and extent of site inspections;
- To reduce the overall life costs of bridges by 10 % by applying the improved lifetime prediction models already from the design stage;
- The operator of the structures will be able to take protective actions before damaging processes start.

5. CONCLUSION

The integrated system for monitoring and assessment of concrete bridges will result in an improved knowledge of individual mechanisms and their interaction, and in early warnings of initiation and progress of durability and structural problems, thus finally reducing inspection, maintenance and rehabilitation costs as well as traffic delays.

This system may easily integrate and supplement the current practice in the field of inspection and testing and assist the end-user in the planning of maintenance programs. Additionally the operator of the structures will be able to take protective actions before damaging processes start. Their application will result in reduced costs of inspection and reduced interference to traffic.

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ISSN 1582-3024

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- Structural elements with difficult access are easily monitored
- A more precise evaluation of the actual conditions of the structures with particular regard to the timely warning of the onset of durability and structural problems
- A more reliable prediction of the progress of damage as a function both of the measured parameters and of the application of realistic deterioration models, as well as a better understanding of individual deterioration mechanisms and their interaction
- An input for defining maintenance and repair strategies (time and extent) as a function of the actual and foreseeable levels of deterioration
- An evaluation of the need for further inspection and testing.

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References

1. *Pardi L, Thøgersen F*-Smart Structures: An European research funded project", Proc.IABMAS 02
2. *Bäßler R., Mietz J., Raupach M., Klinghoffer O.* - Corrosion Monitoring Sensors for Durability Assessment of Concrete Structures", Proc. SPIEs 7th Internat. Symp. on Smart Structures and Materials, Newport Beach, article 3988 06 (2000).
3. *Bäßler R., Mietz J., Raupach M., Klinghoffer O.* - Corrosion Risk and Humidity Sensors for Durability Assessment of Reinforced Concrete Structures, Proc. EUROCORR 2000, London, article 100805 (2000).
4. *Goltermann P., Jensen F., Andersen M.E.* - Smart structures: Possibilities, experiences and benefits from permanent monitoring", Proc. IABMAS 02.
5. *Bäßler R., Mietz J., Raupach M., Klinghoffer O.* - Corrosion Monitoring Sensors for Durability Assessment of Concrete Structures, Proceedings SPIEs 7th International Symposium on Smart Structures and Materials, Newport Beach,article 3988 06, 2000
6. *Schießl P.; Raupach M.* - A New Sensor System for Monitoring the Corrosion Risk in Existing Structures. In: Second International Conference on Concrete Under Severe Conditions - Environment and Loading (CONSEC 98), Tromsö, Norway, 565 – 573, 21.- 24.06.1998

ISSN 1582-3024