The role of SHM systems in planning bridge renovation works

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Summary

Bridges, like all structures, have a limited life expectancy, and require renovation and repair works at times during their lives in order to reach an expected age. When planning such works, it is very often of great benefit to know precisely how the bridge has performed in the past, as this will enable the renovation works to be optimised – with many benefits for the owner, the bridge's users and the environment. Indeed, analysis of the actual bridge can be sure to provide more relevant data than any scale model in a laboratory or computer model on a hard drive. The use of modern structural health monitoring (SHM) systems in this way is demonstrated by two current monitoring projects, both providing the data needed to optimise the renovation of bridges which are critically important to the cities they serve.

Keywords: Automated, monitoring, bridges, structures, inspection, maintenance, renovation.

1. Introduction

When a bridge needs to be renovated, the responsible engineers have at their disposal an important source of information which is not available to those who must design and build a new structure: the existing structure. Analysis of the performance of the existing structure's performance can provide a wealth of information which can be used to optimise the planned works. For example, the forces acting on the bridge's components and the stresses arising within them, and the movements and distortions to which they are subjected, can be accurately measured, allowing the renovation design work is based on reality and not theoretical, estimated values. This can yield many benefits, such as a simplified design, shorter construction time and less need for new materials – resulting in lower construction costs, less disruption to traffic and lower environmental impact.

Automated SHM systems offer an efficient means of collecting such data, providing continuous records of almost any variable that may be of interest. They can also be configured to analyse the data, and present the results in any desired format - for example, graphically as shown in Figure 1 or exported in tabular form for further analysis. Immediate notification by SMS or email of the reaching of predefined alarm values of any variable can also be provided. Such measurement and data processing power, and user-friendly features, thus have much to offer those who must plan and execute bridge renovation works.

Fig. 1: Presentation of data in graphic form, enabling trends and correlations to be established

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2. The contribution of SHM to the planning of bridge renovation works

When planning bridge renovation works, it is very often of great benefit to know precisely how the bridge has been performing prior to the renovation. Indeed, analysis of the actual bridge can be sure to provide more relevant and accurate data (relating to forces, movements, rotations, environmental conditions, etc.) than any scale model in a laboratory or computer model on a hard drive. By precisely assessing a structure's condition and diagnosing any problems that may have been identified, an SHM system can optimise the selected solution.

2.1 Monitoring of the Alvsborg Bridge, Gothenburg, Sweden

The Alvsborg Bridge, built in 1966 with a main span of 417 metres, is a suspension bridge over the Göta Älv river in Gothenburg. During the course of planning proposed renovation works, it was decided to use an SHM system to provide detailed information on certain key aspects of the bridge's performance, in particular in relation to its expansion joints. The system measures absolute longitudinal and transverse movements, horizontal and vertical rotations, accumulated longitudinal movements (at high measurement frequency to include all "micro-movements"), and the structural temperatures necessary to form a frame of reference for the measured movements and rotations. The data generated by the system provides a detailed understanding of the structural behaviour of the bridge deck, in particular in relation to thermal impacts and secondary bending moments. It can also be used to provide quantification of the new expansion joints' required movement and rotation capacities, enabling the most suitable type of joint to be selected (finger, modular or other). And it will enable the design of the joints to be optimised, eliminating overly conservative safety margins and facilitating the selection of the most suitable sliding materials.

2.2 Monitoring of the Angus L. MacDonald and A. Murray Mackay bridges, Halifax

The Canadian city of Halifax relies heavily on two structures in particular - the Angus L. Macdonald Bridge and the A. Murray MacKay Bridge, which connect the city across the sea inlet that divides it in two. The A. Murray MacKay Bridge was renovated in recent years, and similar renovation works, with similar changes to the bearing support of the deck, are currently being planned for the Angus L. Macdonald Bridge. The bridge will receive an entire new deck, and computer modelling, verified by measured data, will play a key role in the design process. It was determined that an SHM system should be used to measure and record the movements and rotations of the deck of the Angus L. Macdonald Bridge, providing the data needed by the computer modelling. It was also decided to monitor the movements of the previously renovated deck of the A. Murray MacKay Bridge, so that the effects of the renovation works (and in particular, the changes to the deck support system) can be accounted for in the planning of the proposed works. The system has already provided a very interesting insight into the movements of the A. Murray Mackay Bridge, showing that its deck moves a great deal in the longitudinal direction, with accumulated movements of up to 35 kilometres per year at one expansion joint (compared to just 700 m per year on the other bridge). This gives a strong indication of how the movements of the new deck will increase if it is supported in the same way as the previously renovated deck. The understanding of movements provided by the SHM system will thus play a crucial role in supporting the planning of renovation works of one deck and maintenance and possible adaptation works of the other.

3. Conclusions

It can be seen from the examples presented that SHM systems have a great deal to offer those who are charged with renovating bridges and their critical components. Such systems can be used to precisely diagnose and define the challenge which must be addressed, and thus optimise the selected solution, in particular when life-cycle costs are considered as they always should be [1]. Such technology is therefore sure to play an increasingly significant role in the bridge engineering world of the future; as society's demands for environmentally friendly construction become ever louder, full advantage must be taken of the efficiencies offered by modern SHM systems.

[1] SPULER T., LOEHRER R., O'SUILLEABHAIN C., "Life-cycle considerations in the selection and design of bridge expansion joints", *Proc. IABSE Congress on Innovative Infrastructures towards human urbanism*, Seoul, Korea, 2012.