LONG-TERM EVALUATION VS. SHORT-TERM MEASUREMENTS : THE CASE OF THE RIDDES BRIDGES

Olivier Burdet
Senior researcher and lecturer
Swiss Federal Institute of Technology in Lausanne, Switzerland
olivier.burdet@epfl.ch

Jean-Luc Zanella
Research assistant
Swiss Federal Institute of Technology in Lausanne, Switzerland
jean-luc.zanella@epfl.ch

http://is-beton.epfl.ch

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1. INTRODUCTION

Bridge management is a very important part of the sustainable deployment of a quality infrastructure. In order to improve their assessment of the bridges condition, bridge management systems need to improve the information they handle. Presently, these systems mainly include geographical and administrative information complemented by the results from visual site inspections. To improve their efficiency, it is needed that additional information be incorporated, for example results from other types of evaluations of the bridge condition based on analytical models (reliability based for example), and results from site measurements. Such data is often available, at least in part.

Based on the example of the monitoring of the Riddes bridges, the paper shows that monitoring data, and in general measurement data, needs to be considered critically in the process of the assessment of bridge condition. While the results of a visual inspection have certain weaknesses, they also have a known track record in their ability to assess the actual condition of bridges. To the contrary, site measurements are inherently accurate, but the results themselves may be strongly influenced by temperature, environmental and other effects.

It is thus important to consider the quality of the data in the evaluation of bridges. In particular, environmental effects need to be taken into account when assessing the quality of the data on which the evaluation of the structure will eventually be made. Because hard data from site measurements is usually expensive and sometimes difficult to gather, the reliability of the collected data is often assumed to be satisfactory.

The case presented in the paper shows how effective measurements can be made to help in the assessment of an important structure in a relatively short time frame using a combination of electronic inclinometers, temperature sensors and hydrostatic leveling. While not directly applicable to all kinds of structures, the methodology presented can certainly be adapted to many situations. It is anticipated that this and similar methods will be developed that will deliver a high quality of information about structures, on the basis of which the management of bridges will evolve toward a decision process based on quality, accurate and verifiable data.

Figure 1: General view of the two Riddes bridges

2. THE RIDDES BRIDGES

The well known Riddes bridges were built in the late 1980’s by the balanced cantilever method for the main span of 140 m over the Rhone river. Because of this construction method, the longitudinal statical system has a hinge at mid-span. Over the years since their construction, both bridges have exhibited increasing downward deflections at the middle of the main span, as other similar bridges have in the past [1,2,3]. Some additional prestressing was added in spare ducts in 1997, with the effect of lifting the bridge. However, it was unclear to the owner what the actual behavior of the bridge was in its present condition. It was therefore decided in late 1999 to perform a close monitoring of the two bridges. The aim of the monitoring was to quantify the actual behavior of the bridges, to evaluate the efficiency of the previous retrofitting and to help in the decision process leading to a possible strengthening of the superstructure.

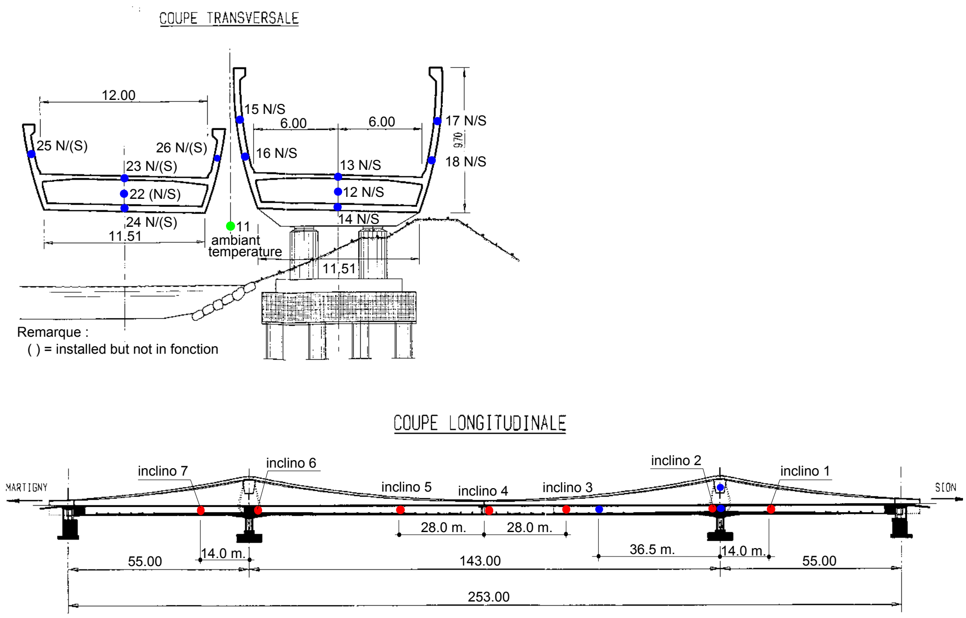

Figure 2: Instrumentation of the Riddes bridges : inclinometers and thermocouples

A network of 14 high-precision inclinometers and 20 temperature sensors (thermocouples) to measure the temperature in and around the bridges was installed in the twin bridges (fig. 2) [4]. Each inclinometer is placed in a rigid steel case allowing a precise positioning and permitting a full 180° rotation in an horizontal plane, which can be used to check and correct possible drifting of the instrument (fig.3).

This method, already used in several other bridges for short- and long-term monitoring, has the advantage of being fully automatic and delivering an absolute value (angular change) that can easily be linked back to the deflected shape of the bridge [5,6].

Figure 3: Inclinometer in its case allowing a full 180° rotation to compensate for drift

The entire setup is controlled by a central data acquisition computer located underneath the bridge. Angular and temperature measurements are taken once every minute. While this density of measurements is quite high, it allows the elimination of all spurious measurements, such as measurements made during the passage of a heavy vehicle. Special features of the inclinometers allow a simple identification of this type of event and an automatic filtering. Based on the angular measurements, the deflected shape of the bridge is reconstructed (fig. 4) and the mid-span deflection calculated.

3. PRELIMINARY RESULTS

As can be seen from figures 4 and 5, the bridges exhibit very significant displacement under the effect of daily temperature changes. It is not rare to observe daily movement with an amplitude of nearly 50 mm. Measurements made without a clear knowledge of this behavior can mislead into thinking that the bridge is either stable, or coming down at a rapid rate. Note that there are two time periods during the day (at about 8AM and 6PM) when the bridge is almost quiet, allowing more reliable measurements by conventional methods.

Figure 6 shows the calculated location of the mid-span of the South bridge over the period of observation starting in July 2000 (bottom curve), along with the ambient temperature underneath the bridge (top curve). The influence of daily temperature variations can be clearly seen (hairy look of the curves). The influence of seasonal temperature changes can also be observed. The white squares are measurements made on a monthly basis by an independent method: a hydrostatic leveling system, operated manually.

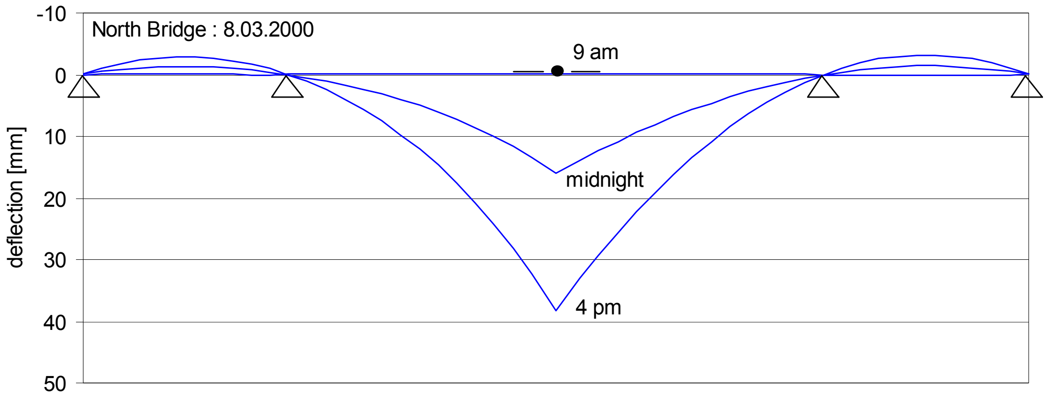

Figure 4: Longitudinal view of the deflections of the South Bridge relative to its position at 9AM on March 8th, 2000

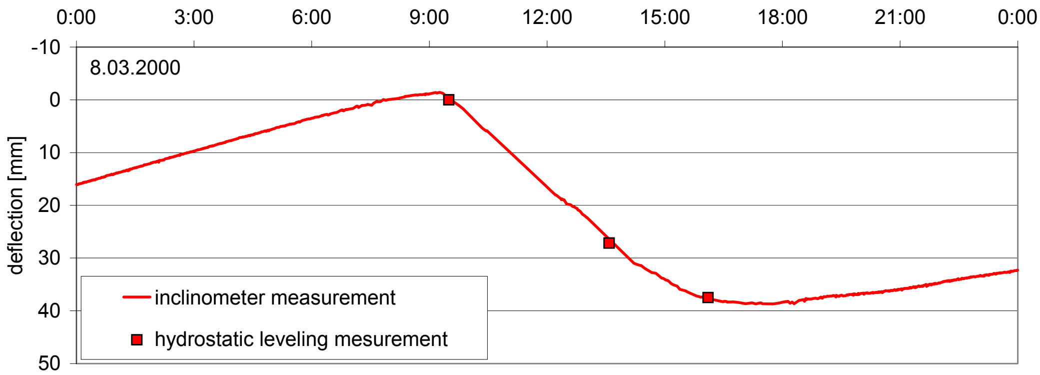

Figure 5: Reconstructed mid-span deflection of the South Riddes bridge over 24 hours on March 8th, 2000

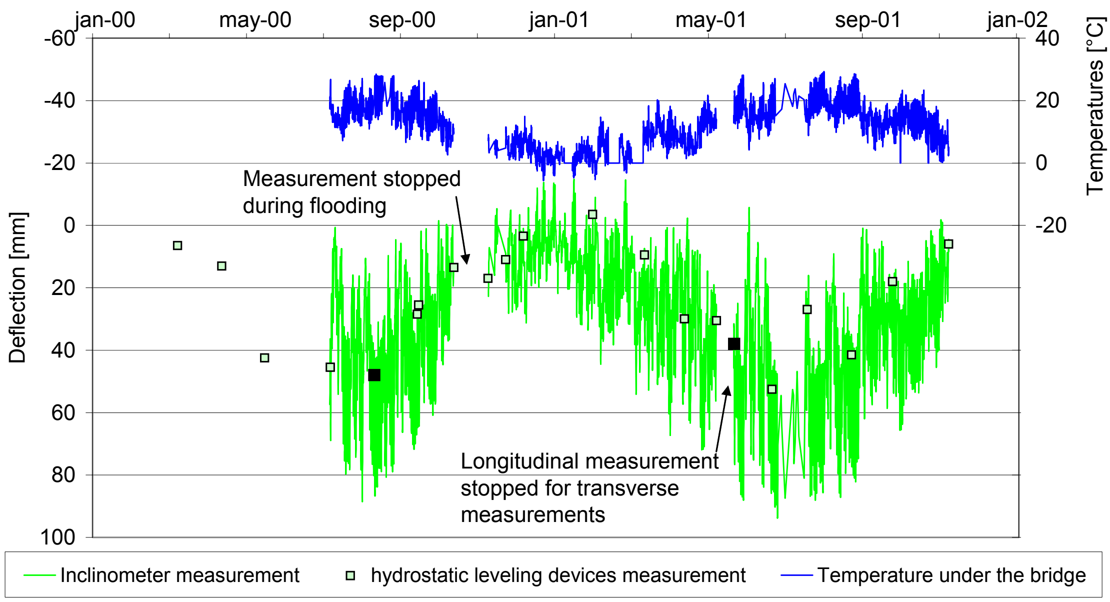

Figure 6: Calculated deflected shape of the South Riddes bridge over the period of monitoring

Because of climatic changes from one year to the next, even a comparison of the mid-span deflection of two consecutive years is not simple, as ambient temperature conditions vary. This is why a cancellation of the effects of temperature was attempted. Figure 7 shows the temperature-corrected position of the mid-span. A single set of correction factors was applied to the whole period of measurement. These factors directly link the mid-span deflection to the angular measurements, the ambient temperature and gradient at various locations within the structure. As can be seen from the figure, this correction strongly diminished both the daily and the seasonal temperature variations. From this data, it was concluded that the bridges are still descending somewhat, but at a very reduced rated, and that thus an intervention is not required in the near future. The bridges will be monitored for about another two years for a full confirmation, after what the monitoring system will be interrupted.

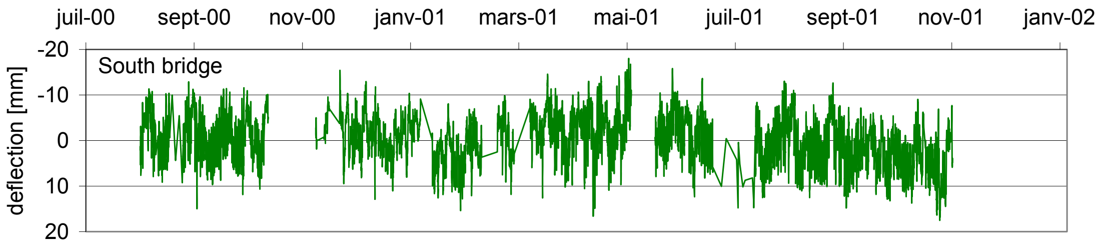

Figure 7: Deflection with temperature effect cancelled

4. USE OF MEASUREMENT DATA IN BRIDGE MANAGEMENT

For important or problematic bridges, additional investigations – possibly in the form of monitoring – are often carried out to increase the knowledge of the structure before a decision is made on possible options. While some type of data is relatively insensitive to the measurement technique and other effects, others are. This is particularly the case with strain and displacement-related quantities, which are strongly influenced by the ambient temperature and also by humidity. In the case of bridges that exhibit excessive long-term deflections, the measurement of the downward trend is strongly influenced by temperature, and convincing conclusions can only be drawn from very long measurement series, often in excess of five to ten years [2]. This means that data from this type of measurement should not be included in a bridge management system for a very long period of time, to avoid that false decision be made on insufficient data.

This is not always acceptable, as in the case of the Riddes bridges. Overcoming this difficulty means being able to compensate, at least in part, the effect of ambient climatic variations. This requires of course measurements of the climatic variables, but also a system of redundant measurements, so that incorrect data can be detected and eliminated. Few systems able are to perform this type of task.

For this approach to become routine, it will be necessary that on the one side bridge management systems able to incorporate not-so-reliable measurement data be developed, and on the other side that better and less expensive electronic sensors become available. The convergence of monitoring and bridge management hold strong promises for both.

5. CONCLUSIONS

The question asked by the owner of the bridges was to identify the long-term tendency of the bridge's deflections, but only using a short period of measurement. The system used for the monitoring of the Riddes bridges has exhibited a very good performance over its more than one year of operation, with only small interruptions of service and reliable results. The use of electronic inclinometers has allowed the identification and cancellation of ambient temperature effects, making the determination of the current condition of the bridges concerning its deflections clearer. Thus, in less than two years of measurement, the preliminary results presented here show that the bridges mid-span deflections is increasing only very slowly.

The deciding factors in the success of this operation were :

- use of the proven, stable technology (electronic inclinometers), complemented with a well established, independent system (hydrostatic leveling);
- careful measurement of the temperature condition of the structure, at the same frequency as the other measurements;
- large quantity of measurements, facilitating the identification of reliable data and permitting various numerical treatments.

Overall, there is a strong evidence that the use of automatic measurement techniques can be a powerful complement to traditional bridge management systems. On the other hand, however, one can wonder if the system proposed (high precision electronic inclinometers) is not better reserved for special cases, with simpler, cheaper measurements techniques being used for more normal cases. The answer may lay in the rapid evolution in the field of electronic sensors. If the cost of the sensors decreases, possibly because of their wider use, then it is not unthinkable to equip a large number of bridges with an automatic monitoring system, on the example of has happened in the field of automobiles over the past two decades. In all cases, there is a great need to carefully identify potential sources of inaccuracies in the measurements, and to take them into account in the bridge management system.

REFERENCES

[1] **BURDET O.**, *Load Testing and Monitoring of Swiss Bridges*, CEB Information Bulletin, Safety and Performance Concepts n° 219, Lausanne, Switzerland, **1993.**

[2] **BURDET O., BADOUX M.**, *Long-term deflection monitoring of prestressed concrete bridges retrofitted by external post-tensioning - examples from Switzerland*, IABSE Rio 1999, Rio de Janeiro, Brazil, **1999**.

[3] **PATRON-SOLARES A., GODART B., EYMARD R.**, *Etude des déformations différées du pont de Savines (Hautes.Alpes)*, Bulletin du Laboratoires des Ponts et Chaussées, 203, 91-103, Paris, France, **1996**.

[4] **BURDET O., ZANELLA J.-L.**, *Automatic Monitoring of the Riddes Bridges using Electronic Inclinometers*, IABMAS, First International Conference on Bridge Maintenance, Safety and Management, Barcelona, Spain, **2002.**

[5] **BURDET O.**, *Automatic Deflection and Temperature Monitoring of a Balanced Cantilever Concrete Bridge*, 5th International Conference of Short and Medium Span Bridges, Calgary, Canada, **1998.**

[6] **BURDET O., ZANELLA J.-L.**, *Automatic Monitoring of Bridges using Electronic Inclinometers*, IABSE, Lucerne Congress Structural Engineering for Meeting Urban Transportation Challenges, pp. 398-399, Zürich, Switzerland, **2000**.