Structural Identification to Improve Bridge Management

James-A. Goulet
PhD. Student
Swiss Fed. Inst. of Tech.
Lausanne, Switzerland
James.Goulet@epfl.ch

James-A. Goulet**,** born 1984, received his civil engineering and M. Sc. degree from the Univ. of Laval.

Prakash Kripakaran
Post-doctoral researcher
Swiss Fed. Inst. of Tech.
Lausanne, Switzerland
Prakash.Kripakaran@epfl.ch

Prakash Kripakaran, born 1979, received his masters and doctorate degrees in civil engrg. from North Carolina State Univ.

Ian F. C. Smith
Professor
Swiss Fed. Inst. of Tech.
Lausanne, Switzerland
Ian.Smith@epfl.ch

Ian F. C. Smith, born 1955, received his civil engrg. degree from the Univ. of Waterloo, Canada and his PhD from the Univ. of Cambridge, UK.

Summary

This paper presents results from static loads tests performed on the new Langensand Bridge built in Switzerland. A systematic study of over 1000 models subjected to three load cases identifies a set of 11 candidate models through static measurements. Predictions using the set of candidate models are homogenous and show an averaged discrepancy ranging of 4 to 7% from the displacement measurements. All candidate models have values for material proprieties that are close to expected values. This finding confirms that the behaviour of the structure conforms to the design expectations. Comparing the candidate model set to a design model that takes into account only main structural elements shows that the structure has approximately 30% reserve capacity with respect to a typical deflection risk scenario according to Swiss codes. The population of candidate models may be used to understand and predict the behaviour of the full bridge prior to its completion.

Keywords: Structural Identification, Bridge behaviour, Static Measurement, Multi-Model, data interpretation

1. Introduction

Bridges are designed according to codes that specify conservative limits on loading and material properties. Behaviour models used in design, while leading to safe and serviceable structures, are not intended for data interpretation and long-term management of the structure. During the design stage, engineers make conservative assumptions regarding aspects such as the composite behaviour and support conditions. Behaviour models using these assumptions often underestimate the load-bearing capacity of the bridge. This paper presents results from static loads tests performed on the new Langensand Bridge in Lucerne, Switzerland.

Building on previous research, this paper presents results of the multi-model system identification approach applied to a new bridge. The following sections describe the multi-model approach and how it is applied to the Langensand Bridge. Next, a general description of the load tests is given. Information about the type of acquired data, model generation and uncertainties are also provided. Section four contains results from structural identification and compares the multi-model approach to a “model-updating”.

2. System identification using multi-model approach

The multiple-model system identification method developed at EPFL is explained in the following section. At the beginning of candidate model identification process (prior to load tests), thousands of a-priori behavioural models are generated based on design hypotheses and assumptions. The set of model parameters consists of quantities such as elastic constant, bearing device stiffness and section thickness. Using this a-priori model set, sensors are placed using an algorithm developed at EPFL [1-3]. The objective of this process is to find sensor types and locations that will discriminate between the largest numbers of candidate models.
After placing sensors on the bridge, data is acquired from load tests. All uncertainty sources coming

https://doi.org/10.2749/222137809796078261

from measurements are combined with modelling uncertainties into a threshold that is specific to each sensor and each load case. This threshold value determines whether or not a model is selected as a candidate. The identification process is iterative. If no candidate models are identified or if new facts are discovered during the identification process, the initial hypotheses are modified and new models are generated. The predictions of the new set are then compared to the measuremens. When candidate models are found, they may be used to confirm or reject initial hypotheses, quantify bridge reserve capacity and assess factors affecting bridge behaviour.

3. Case study: Structural system identification of Langensand Bridge

The new Langensand Bridge in Lucerne (Switzerland), is being built in two phases to avoid traffic interruption on the existing bridge. Load tests were performed after the completion of the first phase when only the first half of the bridge was built. Understanding the structural behaviour of this bridge is not straightforward due to its high slenderness ratio (>L/30), a cross section of non-uniform shape and the presence of an important skew at abutments. Sensors selected to perform the static-loads test are: displacement measurements taken in six locations with optical devices, two inclinometers placed near the abutment and fibre-optic sensors placed at five locations on the bridge. A cross-section of the bridge is presented in Figure 1.

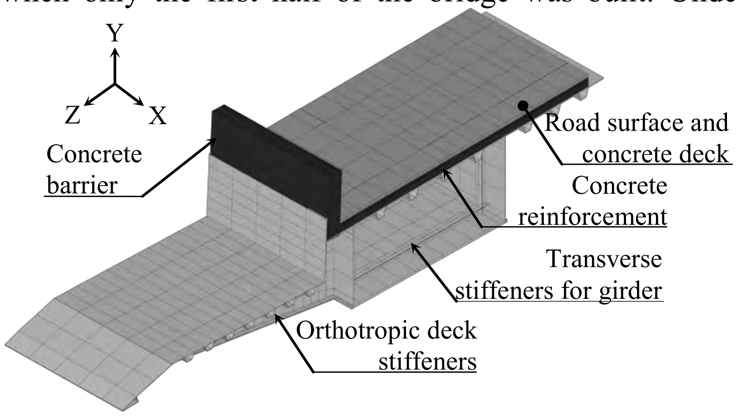

Figure 1 – Cross-section of the first half of Langensand Bridge

4. Results

Candidate models representative of the measured behaviour are given in Table 2. From a model set (composed of 1000 models) 11 candidate models are identified using static measurements. The predictions from the candidate set correspond to the displacement and rotation measurements with an average accuracy ranging from 4% to 7%. Strains are more difficult to assess. The deviations range from 15 to 22% compared to those measurements. The predictions from the model set provide ranges within which the real behaviour of the structure is expected.

5. Conclusions

The tests demonstrate the applicability of the multi-model approach for bridge structures. The set of candidate models improves understanding of the bridge behaviour. These models are able to predict the service behaviour of the structure to within 7% of measured values.

6. Acknowledgements

Collaboration with the designers of the Langensand Bridge - Gabriele Guscetti and Claudio Pirazzi (Guscetti & Tournier), was important for successful completion of the load tests. The authors also acknowledge input from Dr. R. Cantieni and the help we received from his team when taking the measurements. Finally the authors would like to thank – I. Laory and P. Gallay for their help during load testing. The city of Lucerne provided logistics support, the trucks for the load tests and the deformation sensors. This research is funded by the Swiss National Science Foundation under contract no. 200020-117670/1.

7. References

[1] KRIPAKARAN, P., et al., *Optimal sensor placement for damage detection: Role of global search*. Dexa 2007: 18th International Conference on Database and Expert Systems Applications, Proceedings, ed. A.M. Tjoa and R.R. WAGNER. 2007, Los Alamitos: Ieee Computer Soc. 302-306.

[2] KRIPAKARAN, P., et al. Measurement System Design Using Damage Scenarios. in ASCE International Workshop on Compution in Civil Engineering. 2007: ASCE.

[3] ROBERT-NICOUD, Y., B. Raphael, and I.F.C. Smith, *Configuration of measurement systems using Shannon's entropy function.* Computers & Structures, 2005. **83**(8-9): p. 599-612.