Karlsruhe Institute of Technology

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Modal-based Structural Health Monitoring

Development of a methodology for damage analysis of bridge superstructures

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1. Motivation and Objectives

An efficient infrastructure is one of the most important prerequisites for a competitive economy. Bridge structures in particular are critical parts of the transport infrastructure network and can lead to considerable disruptions in passenger and cargo traffic due to the frequent lack of redundancy. In Germany, a considerable percentage of bridge superstructures are in a critical state of health. Therefore, the demand for suitable monitoring systems to detect damage processes at an early stage and to enable more targeted rehabilitation and repair measures is increasing. The aim is to support the subjectively influenced bridge inspections according to DIN 1076 by an objective, economical and reliable monitoring system in order to extend the life of existing bridges and to minimize maintenance costs. The modal parameters (natural frequencies, mode shapes and modal damping) of a structure are global parameters and are functions of the physical properties of a structure. Consequently, structural stiffness changes (damage processes) can be detected and localized using the modal parameters.

2. Approach

For the successful application of a modal-based monitoring system, it must be possible to distinguish between changes in the modal parameters due to structural changes (e.g. crack formation) and changes due to external influences such as spatially and temporally variable stiffness and mass ratios as a result of traffic loads. Within the framework of laboratory tests (Figure 1) on reinforced concrete beams, the sensitivity of the modal parameters with regard to increasing crack formation is investigated. Furthermore, the influence of an externally applied CFRP laminate reinforcement on the modal parameters was investigated. On the basis of in situ measurements on pedestrian bridges, especially the requirements on the measurement technique under real conditions as well as the scattering of the modal parameters due to external influences are analysed.

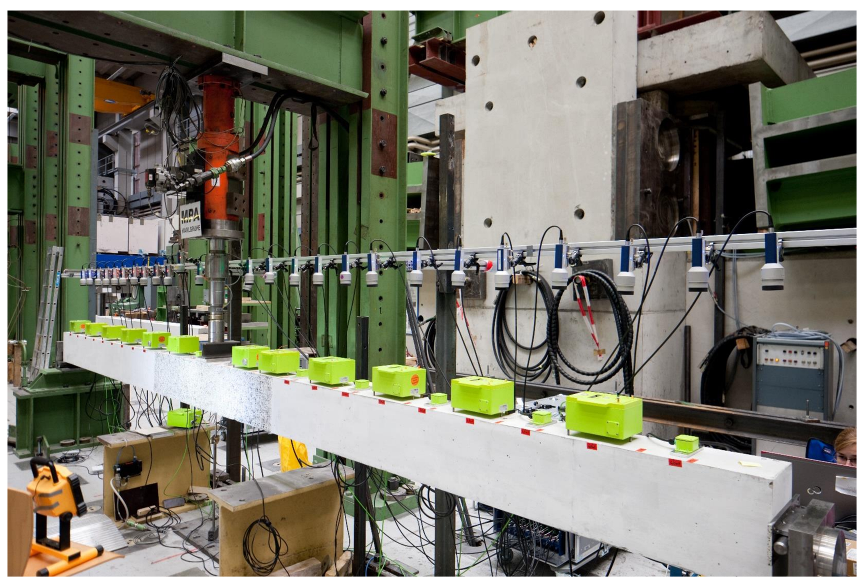

Figure 1: *left:* Laboratory tests; *right:* In-Situ measurement at a pedestrian bridge

Suitable methods for the detection and localization of structural stiffness changes and their performance will be evaluated using the measured data. In addition to metrological investigations, the various influencing factors are analysed by numerical simulations of vibration measurements and compared with the results of numerical modal analysis.

3. Results and Outlook

A modal based damage analysis of bridge superstructures is an efficient and economic possibility to detect and localize structural stiffness changes in an early stage. A combination of four different indicators has proven to be particularly powerful:

- Change of the natural frequencies
- Change of the mode shapes
- Change of the curvatures of the mode shapes
- Continuous Wavelet-Transformation (figure 2)

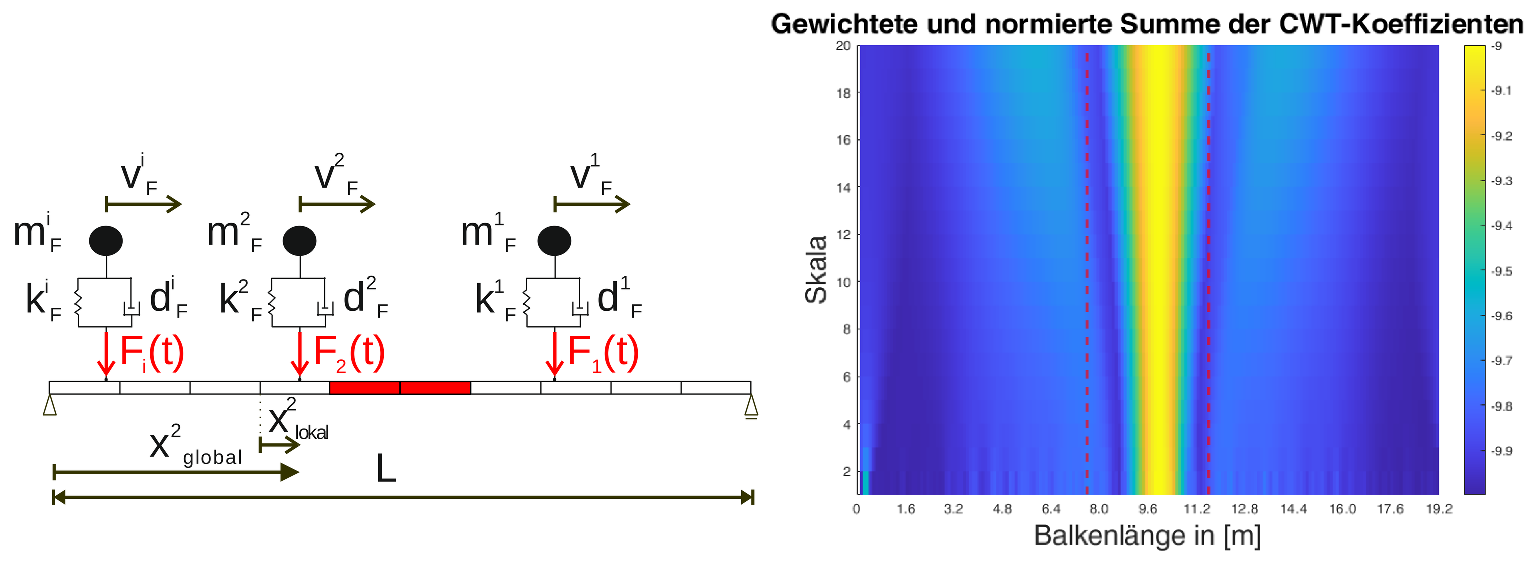

Figure 2: *left:* Numerical simulation of the pedestrian bridge with fictitious stiffness changes in the middle of the field taking into account the pedestrians passing by; *right:* Result of the wavelet transformation to locate the change in stiffness

It is possible to distinguish structural stiffness changes from external influences. Furthermore, the metrological requirements such as the sampling rate and the synchronicity accuracy can be shown numerically and experimentally, depending on the frequency range of the respective bridge superstructure.
In the further course of the research project pedestrian bridges as well as road bridges will be investigated metrologically. Furthermore, the suitability of the modal based monitoring system should not only allow early detection of structural stiffness changes but also a verification of bridge strengthening measures. In addition to the laboratory tests carried out on reinforced concrete beams with externally applied CFRP lamellas, the effects on the modal parameters are investigated by means of in situ measurements on two identical pedestrian bridges, which are reinforced i.a. by near surface mounted (NSM) carbon fibre reinforced polymer (CFRP) strips.

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