
Modal analysis of road and rail bridges for damage detection and resonance prediction

Lutz Auersch*¹, Samir Said , and Rolf Rohrmann

¹BAM Bundesanstalt für Materialforschung u. -prüfung – Germany

Abstract

In the 1980s, the Federal Institute of Material Research and Testing started with modal analysis measurements of some bridges before and after repair. For one of the bridges, a structural health monitoring was installed 1994 which is still working up to now. It has been modified and extended several times. The monitoring was extended from the critical span to three neighbouring spans. A modal analysis of the whole bridge with seven spans have been done three times, twice together with EMPA of Switzerland. Additional calibration measurements have been done and additional evaluation procedures have been implemented for the monitoring of the steadily increasing loads from the road traffic. Additional sensors were installed such as strain gauges, crack-width and temperature sensors. The strong influence of the temperature on the natural frequencies has been studied over the years. Later, a temperature compensation has been established and a weak aging trend has been found in the monitoring data. Now, the bridge will be demolished and replaced by a new bridge. Some results of this long-term monitoring will be shown and possible damages (changes of the pre-stress or the support structure) will be discussed. A second application of modal analysis will be demonstrated: the prediction of the resonances due to passing trains. The response of a bridge to passing trains can be calculated in frequency domain as the multiplication of three spectra, the axle sequence spectrum of the train, the transfer function of the bridge, and the modal force spectrum of a single passing load. A resonance occurs if a maximum of the train spectrum coincides with the maximum of the bridge spectrum. The amplitude at this resonance is strongly influenced by the modal force spectrum which is identical to the frequency or wavenumber spectrum of the corresponding mode shape. Therefore, modal analysis from calculation, impact measurements, wind and train measurements are necessary for the prediction of the resonance occurrence and amplification/amplitude. Examples of mode shape spectra for single or multi-span bridges with simply supported or continuous spans will be shown, and some relations between mode shapes and resonance amplifications will be concluded.

Keywords: SHM, modal analysis, long, term monitoring, load monitoring, road bridge, rail bridge, train, induced resonance, mode, shape spectra

*Speaker