Damage Identification on an Iron Bridge Based on Spectral Analysis

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Summary

This paper reports about damage identification on a single-span iron bridge based on recorded ambient vibrations. Several local damage scenarios were imposed stepwise to the structure. Random vibration tests were conducted, and the induced dynamic response of the bridge in the undisturbed as well as in modified “damaged” conditions was recorded. The recorded vibrations were subjected to Operational Modal Analysis identification methods and to spectral analyses. It is shown that the shift of the relative cumulative spectral energy at different damage levels is an appropriate damage indicator. Thus, spectral analysis could be a promising tool for long-term vibration based structural health monitoring.

Keywords: Ambient response, damage detection, railway bridge, spectral analysis, structural health monitoring.

1. Test object

The test specimen is an old railway bridge, which was in use between 1903 and 2001. It was part of the north-west railway line of the Austrian Federal Railways (ÖBB), and located in Rohrbach, Austria. In 2011 the bridge was cut and transported to the Laboratory for Technical Testing and Research (TVFA) of the University of Innsbruck, where it was reassembled. Fig. 1 shows the bridge in its current condition and the dimensions of the structure.

Each of the structural elements exhibits a double T-shaped profile, which is composed of four L-shaped profiles and flat iron plates (of 9 to 11 mm thickness). Rivets join all iron parts. The cross girders were reconnected by high-strength friction grip fastenings.

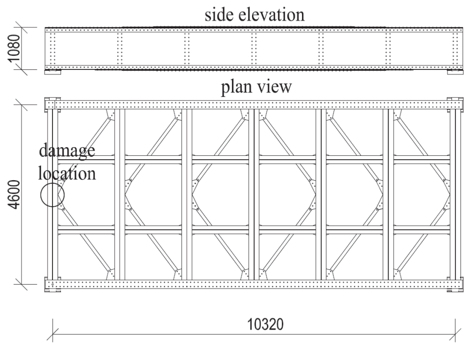

Fig. 1: Photo and side elevation, and plan view of Rohrbach bridge.

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2. Test procedure and experimental set-up

Modal parameters of the test object were determined from ambient dynamic bridge response for its original undisturbed condition and for three conditions referred to as “damages states”. In these damage states the bolts of the high-strength friction grip fastenings in the centre of a cross girder were released stepwise.

The bridge was equipped with up to four electro-dynamic shakers APS 400 Electro-Seis, providing approximately the desired white noise excitation. Persons walking randomly on the cross girders and crosstie girders were another source of ambient excitation, utilized in the second test campaign.

Up to ten uniaxial piezoelectric accelerometers recorded ambient vibrations in vertical direction. The test campaigns comprised several different set-ups of sensor positions involving reference sensors and roving sensors.

For identification of the modal parameters such as natural frequencies, mode shapes and damping ratios, an in-house MATLAB script was used (i.e. data-driven Stochastic Subspace Identification (SSI) procedure and Enhanced Frequency Domain Decomposition (EFDD) method).

3. System identification

3.1 Global modal parameters of the test object

A number of 10 global vertical modes could be identified by applying the SSI procedure on the recorded data. Additionally to the global modes of the test object some modes could be observed, which significantly affect the outer cross girders only. Thus, these “local” modes were monitored in the three considered damage states. Not only modal parameters were evaluated, but also the normalized cumulative energy distribution was investigated and set in contrast for different damage states. As shown in Fig. 2 this representation of the vibration energy distribution is capable of indicating structural changes, attributed to damage. The modal peak in the reference state at 49 Hz almost vanishes with increasing damage, while the vibration energy shifts to the lower frequency range.

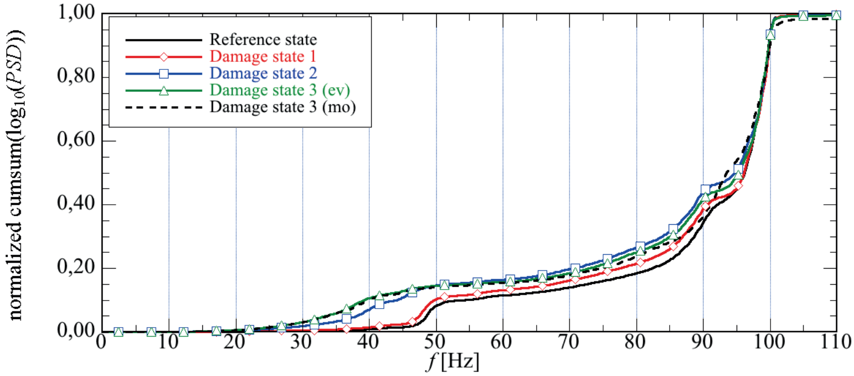

Fig. 2: Comparison of cumulative power spectral density

4. Conclusions

In this paper the results of a study on vibration based Structural Health Monitoring is presented. Global vertical mode shapes of the structure were identified by application of the Stochastic Subspace Identification method. Tests on the original undisturbed and on the modified bridge were conducted, aiming at simulated local damage. Changes in the shape of a particular local mode and reduction of the modal peak response in frequency domain reveal progressive local damage. Monitoring of the relative cumulative energy distribution shows that this quantity increases at low frequencies (range of 10 to 40 Hz) with a simultaneous decrease of vibration energy in the frequency range of the first local bending mode.