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Characterization methodology in nondestructive structural monitoring of concrete bridges

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ABSTRACT

Monitoring of concrete bridges has been a common practice in recent years. Nondestructive measurement methods are one of the techniques for controlling the technical condition of bridges, especially when the structures are 50 years old or more. Within such context, one of the most commonly used techniques is the analysis of the dynamic response of the structure during its operative conditions. The measurement of displacements and accelerations resulting from excitation by natural road traffic or as a result of excitation with special exciters is the basis for modal analysis and classic material identification method. In this work, the dynamic analysis of bridges, whose structure has undergone significant deterioration and requires to be checked for technical conditions, is analyzed.

The most frequently sought parameters are material density, necessary to determine the self-weight of the structure, and material stiffness, which is most often deteriorated as a result of harmful chemical compounds and long-term cyclic loads. If one would like to take into account the different degree of deterioration in different parts of the bridge, then the task becomes not only poorly formulated, but also the optimization problem is often non-convex, which makes the identification of material parameters based on the measured dynamic responses difficult or even impossible. Determining the parameters of the model in such an inverse problem becomes possible when the static measurements are added to the set of dynamic data.

This paper presents a complete procedure for the mechanical characterization of a technically deteriorated bridge with the assumed geometry. The optimal selection of the location of accelerometers on the structure, as well as the accuracy ranges of individual configurations of measuring sensors, are presented. Moreover, easy to perform additional static measurements are proposed, in order to provide regularization of the inverse problem. Using the sensitivity analysis and advanced global optimization techniques based on Gaussian processes, the proposed methodology allows for the unambiguous and simultaneous determination of material densities and degraded stiffnesses in different, pre-selected parts of the bridge model. For all analyses, the finite element method, modal analysis and inverse methods using Gaussian processes are used. The full procedure is prepared by the authors in the Matlab environment and can be extended to any bridge geometry with any number of separated zones in which the concrete is deteriorated to varying degrees. The effectiveness of the procedure is checked on synthetic data and verified on the examples from literature data.

Keywords: characterization procedure, concrete bridge, Gaussian process, nondestructive structural monitoring.