PH.D. THESIS ABSTRACT

Dynamics of slender steel structures under stochastic load

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The present Ph.D. thesis deals with reliability of slender steel engineering structures subjected to dynamic stochastic effects. Structural dynamics is considered using steel chimneys and lattice telecommunication towers as examples that fall within the scope of the thesis given both their geometrical characteristics and wind actions, which are essential for the behavior of such structures and are examples of both strongly stochastic and dynamic loads.

The first section of the thesis provides an in-depth review of the state of the art regarding the issues considered in the thesis. Issues concerning the estimation of wind actions are addressed, destructive tests of tower structures carried out around the world are mentioned, and issues regarding structural dynamics, optimization and reliability are discussed. Knowledge of design solutions applicable to lattice telecommunication towers is summarized and clearly systematized with a strong emphasis on technological requirements. Commonly used solutions are listed, described and shown in numerous photographs. Considerations regarding the design, construction and reinforcement of such structures based on engineering practice are also given.

The next section of the thesis describes a pushover test of a full-scale tower structure that was carried out. This is a result of cooperation with dr hab. inż. Jacek Szafran (B.Eng., Ph.D., D.Sc.) as part of his research project *"Networks Towers Reinforcement Cost Optimisation"*. Pre-test preparations, the structure of the tower tested and the performance of the experiment are described in detail. The results of the test and the information obtained, including the structure failure mechanism and cross-section forces in each component of the tower, gathered by means of strain gauges attached to these components, are discussed. This section also presents the results of laboratory tests of material characteristics of steel obtained in a static tension test, and describes a geodesic survey carried out, including leveling the tower's spot footings during the experiment and monitoring displacements of its core during and after the test.

The main part of the thesis describes numerical experiments regarding the steel stack and lattice towers related to the estimation of reliability of engineering structures using dynamic analysis and considering stochastic loads. Numerical examples include both solid-section and shell models using non-linear elastic-plastic analysis of the components concerned. Particular attention was paid to the calibration of calculation models based on measurements of the structures taken before and during the destructive tests, which resulted in adding supports of adequate flexibility and geometrical imperfections to the models. It was observed that providing a correct representation of a model in the calculation software has a major impact on test results, particularly in terms of structure displacements. The numerical experiments also employed data on the tower failure mechanism obtained during full-scale tests which indicated that the buckling resistance of a leg is critical for the reliability of the structure. It was verified whether the accuracy of the generalized stochastic

perturbation method is sufficient to use it for examining dynamic issues, taking into account the non-linearity of a structure. Consideration was given to various types of conditions which lead to exceeding the required reliability level of a structure, including the conditions for the ultimate limit state (buckling resistance of legs, yield stress of joints) and the service limit state (displacements of the top of the structure). Differences between the static approach to structural reliability and the dynamic analysis were observed. Particular attention was paid to the effects of the excitation function fluctuations on the structural response.

The last step was to implement a procedure to determine coefficients for loads affecting the structure such that the structure meets the requirements at the relevant level of safety (reliability) that is indicated by the reliability index established by means of the perturbation analysis using stochastic loads. To this end, an algorithm was used to calibrate partial safety coefficients which are commonly used in the standard-based approach to provide a relevant safety level of a structure being designed. This procedure was developed with dynamic issues in mind and is meant to facilitate the process of designing structures that feature a certain level of reliability according to the engineering practice.

The summary section of the thesis lists a number of observations made on the basis of the numerical experiments conducted and presented in the thesis as well as conclusions drawn from the research. It was found that it is reasonable to estimate the reliability of light-weight slender engineering structures, particularly lattice telecommunication towers, using dynamic analysis with stochastic loads; at the same time, the current engineering know-how, available computer-based techniques, continuous developments in calculation methods, and advantages of using such solutions are arguments for using the probabilistic analysis to estimate the structural reliability.