FROM FULL-SCALE TESTING OF STEEL LATTICE TOWERS TO STOCHASTIC RELIABILTY ANALYSIS

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1. Introduction

Steel lattice towers are frequently used in wide range of civil engineering activities like telecommunication an the power industry. The main type of load in case of the high, slender tower structures is a wind action. Geometrical properties like: cross section of the tower (square, triangular, rectangular), spacing of the supports, convergence of the tower legs and above all the type and cross section of the structural members are determined mainly by the magnitude of the wind, horizontal load.

This paper is fully devoted to: description of the performed full-scale pushover test (wind, horizontal load simulation) and the studied 42 m tower structure (more details may be found in [1, 2]), presentation of the experimental results like failure mode, breaking force value and experimental buckling resistance value of tower leg, stochastic perturbation technique methodology, presentation of the reliability analysis (both in the First and Second Order Reliability Method) with respect to the random mean wind velocity.

2. Full-scale test of the steel lattice tower

The tower body was manufactured as a three-dimensional truss of a square cross-section and height equal to 42 m (see Fig. 1). Structure was divided into 7 sections. Up to the 36 m a.t.g.l. (6 sections) tower has a constant convergence of the legs. The highest sections takes a form of prism. The legs of the tower was made with using circular hollow sections (sizes from 114,3x6,3 to 60,3x3,6). The diagonal bracing members were constructed as a – circular and rectangular hollow sections as well as channel bars.

The pushover test was carried out in April 2015. The main objectives for the experiment were: an identification of the failure mechanism and failure mode, measurements of the strains in the tower legs as well as determination of the breaking external load that can be assumed as a structure experimental carrying capacity. The basic experimental results are presented in Table 1 below.

Figure 1. The general view of the tower (left), failure mode of the leg in the lowest section (middle and right)

Overall braking force value	113.2 kN
Experimental buckling resistance of the tower leg (CHS 114,3x6,3)	753.3 kN

Table 1. Basic experimental results.

3. Stochastic perturbation technique and reliability analysis

Stochastic perturbation method [3] is based on an expansion of the all random functions into the Taylor series of the required order. In this particular formulation, assumptions of the Gaussian probability density function is not necessary, because we can implement such an approach to the non – symmetrical density distribution as well. Expansion for the random axial force F with respect to the random wind velocity $v(\omega)$ can be expressed as:

(1)
$$F(v(\omega)) = F^0\left(v^0(\omega)\right) + \varepsilon \left.\frac{\partial F(v(\omega))}{\partial v}\right|_{v=v^0} \Delta v + \ldots + \frac{\varepsilon^n}{n!} \left.\frac{\partial^n F(v(\omega))}{\partial v^n}\right|_{v=v^0} \Delta v^n .$$

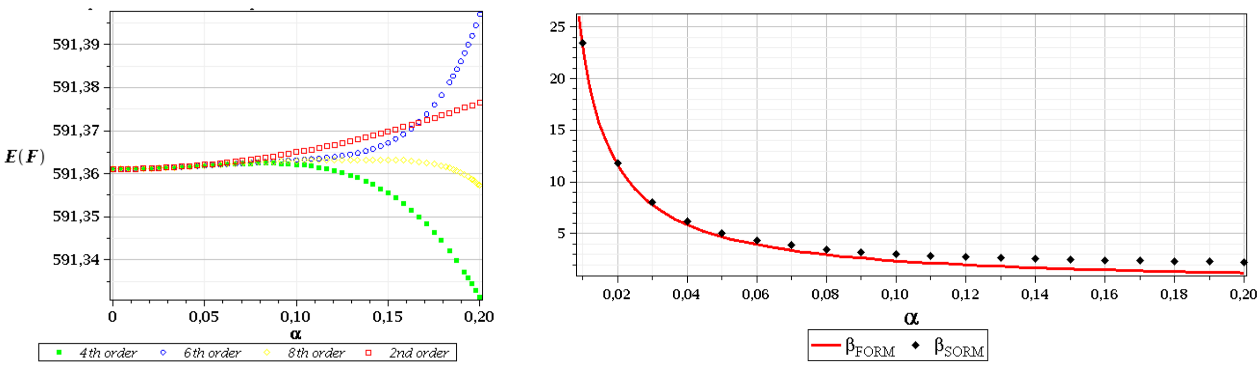

Figure 2. Expected values of the normal force F in the leg of the lowest section of the tower (left), reliability indices (FORM, SORM) with respect to the random wind velocity.

The calculations of the tower reliability were performed using the experimental data and computational FE modelling as well as the stochastic perturbation technique. The FEM model of the structure was created with respect to the supports susceptibility, geometrical imperfections and material properties. In the reliability analysis mean wind velocity was treated as a Gaussian random variable. In Fig. 2 there are presented results of: the expected values of the axial force in the lowest tower leg, and the reliability indices (FORM, SORM). The influence of the input wind velocity coefficient of variation α on the overall reliability may be found in the attached graphs. Also the differences between two computational approaches (FORM and SORM) are visible, especially for the values of α higher than 0.10.

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[3] M. Kamiński (2013). *The Stochastic Perturbation Method for Computational Mechanics*. Wiley, Chichester.