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Sensitivity Analysis in Advanced Building Industry

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Abstract

The paper deals with the Sobol's sensitivity analysis of load–carrying capacity both of building structural members and steel plane frames. The sensitivity analysis was used to identify those initial imperfections that significantly influenced the load–carrying capacity (model output). Whereas higher order sensitivity indices are practically negligible for separate members, the higher order interactions can play, for a system composed of those members, an important role. With greater sophistication of the system, also the demanding character of numerical calculation increases. The Latin Hypercube Sampling method was utilized for the analysis. For a separate member, the computational model was formed by analytical solution, for the calculation of the load–carrying capacity of steel plane frame, the geometrical nonlinear finite element solution providing numerical result per run was employed.

Keywords: Building; Sensitivity; Structure; Steel; Concrete; Imperfections;

1. Main text

The present paper is aimed at the Sobol's sensitivity analysis of the load–carrying capacity of a steel column under compression, a steel–concrete column under compression and a steel plane frame with columns under tension and compression. The fundamental question lies in the determination of initial imperfections and in the analysis of their influence on load–carrying capacities of structures. Thematically, the paper is focused on the Sobol's sensitivity analysis of limit states of structures (Kala 2009). The results of sensitivity analyses are applied in the building industry, and also in the process of introducing the Eurocodes, within the framework of activities linking with the work of technology commissions CENT/TC250, into the system of national technology standards. The standards for designing of structures are based on the probabilistic concept of limit states; its objective is to ensure satisfactory design reliability (Kala 2007).

Generally, all material and geometrical characteristics of structures are of random character (model inputs). Sufficient experimentally obtained information on the material and geometric characteristics is available (Kala *et al*. 2009). The strut is produced having the shape affine to eventual buckling, with deflection at mid length denoted as e_0. The mean value and kurtosis of the amplitude e_0 are zero (Kala 2009). The Gaussian distribution with standard deviation derived from the condition that 95 percent of the realizations of random variable e_0 occur within the

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tolerance limits of standard EN 10034 was considered for this imperfection e_0. For a steel frame, the system imperfections the statistical characteristics of which can be derived according to EN 1090–2 can influence the load–carrying capacity to a large extent. The identification of statistical characteristics of all initial imperfections will be presented. All the input material and geometrical characteristics are independent random variables.

The Timoshenko solution has been used as the analytical solution of the load carrying capacity of column under compression (Timoshenko 1961). In comparison with the Timoshenko solution, the geometrically nonlinear solution of the frame load–carrying capacity is relatively difficult and time demanding with regard to CPU computer time. The geometrical nonlinear solution was elaborated, programmed and optimized by the author of this paper (Kala 2005). The load–carrying capacity was solved by the nonlinear Euler incremental method combined with the Newton–Raphson method. The frame geometry was meshed by beam elements with initial curvature in the form of a parabola of the 3rd degree. The sensitivity analysis (first order sensitivity indices) of load–carrying capacity (random output Y) to input imperfections (random inputs X_i) was evaluated according to (1).

$$S_i = V\left(E\left(Y|X_i\right)\right)/V\left(Y\right) \tag{1}$$

The Latin Hypercube Sampling method was utilized for the sensitivity analysis. Results of the Sobol's sensitivity analysis of the members under compression show remarkable differences of the influence of initial imperfections in dependence on length (slenderness) of the member. An elaborate study of Sobol's sensitivity coefficients has proved that higher order interactions can be practically neglected. For steel plane frames the first order sensitivity indices and the second order sensitivity indices were calculated. As the interactions of the third order, and of the higher ones, did not show any important influence, they were not calculated. For the steel plane frames, large influences of system imperfections, as well as their interactions to load–carrying capacity were proved; the interaction intensity of higher orders depends on the height of the frame columns above all.

The results of sensitivity analyses can be of great contribution and prospective, in particular for industrial production. Generally, input random parameters may be divided into two basic groups (Kala 2005). The first group includes those variables the statistical characteristics of which can be positively influenced in production (yield strength, geometric characteristics) and those that are not sufficiently sensitive to changes in production technology (e.g., variability of Young's modulus). Another application can be seen in relation to the supposed revision of the Eurocodes in 2015, and further on, to some newly formed European technology prescriptions concerning the building industry. The way of future research work will tend to the application of more demanding calculation models, and to more modern methods of the sensitivity analysis calculation, and of probabilistic reliability analyses which will guarantee satisfactory calculation accurateness and time availability of solution, taking the CPU time of computer into consideration (Saltelli *et al.* 2004).

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