Reliability of the selected steel diagrid structures

Dissertation abstract

The subject of this dissertation is the reliability analysis of the selected steel diagrid structures. Due to their aesthetic potential, high adaptability, and increasing architectural popularity, it seemed therefore essential to examine their realizations and, additionally, compare the results with those obtained for traditional solutions having an orthogonal (or radial) grid. Since the diagrid system is understood as a single-layer lattice structure formed by surface triangulation (division using a triangular net).

Three groups often used in practice were examined: grillages, cylindrical vaults and domes. The analyses were only numerical and included using finite elements in the Autodesk Robot Structural Analysis Professional software. There, each compared structure was deterministically dimensioned in accordance with structural steel design standards, and then it was possible to obtain discrete results needed for further calculations. They were received from the analysis of linear stability, eigenvibrations and static, which includes second order effects (geometric nonlinearity).

The following state functions (and associated limit states) were considered: the maximum horizontal displacement, global and local deflections, the basic eigenfrequency, the extreme reduced stresses, as well as the critical coefficient. They were presented in separate, time-independent functions of each variable for the purpose of individual analysis of the impact of particular uncertainties. The following structures parameters were considered as random (with Gaussian distribution): (1) the coefficient of Young modulus e, (2) wall thickness t and (3) manufactured elements lengths l.

The global version of the Response Function Method (RFM) was used to determine all considered structural state functions depending on the random variables. A separate experiment was devoted to its error, where various approximations of trial points generated on the basis of several hundred selected reference composite functions describing the extreme quantities of a steel structure were analyzed. The final result was finding an appropriate criterion (between approximation and input discrete data) for the selection of the response function leading to relative *a posteriori* errors of less than 1%. Unlike the classic curve fitting issue, the accuracy of probabilistic moments was examined in the last stage of the above experiment, because they are used in further calculations.

The Cornell index was used as the reliability measure. It was calculated according to the first (FORM) as well as the second order reliability method (SORM). In receiving basic probabilistic moments occurring in it, special attention was paid to perturbation methods in this dissertation. They allow to obtain a continuous dependence of the final results on the input randomness, which in the context of the structure reliability comparing is particularly desirable. Therefore, the numerical convergence and accuracy of selected schemes with increasing perturbation order were examined, and verification was carried out using direct integration approach. Equivalents of previously known techniques that take into account the truncations of random variables have been developed. In addition, formulas were derived for the first four probabilistic moments of any order.

The largest values of decisive reliability indices (without considering steel masses) from the considered groups of structures were obtained for (a) the diagrid grillage with a large net constructed by equilateral triangles arranged in the longitudinal direction, (b) the lamella cylindrical vault with adding the bars parallel to its axis, and (c) the ribbed dome. Moreover, a way of taking total steel weight, by defining a normalized reliability indicator, has been proposed. Then, the most efficient from the groups of considered structures were: (a) orthogonal grillage with a large net, (b) orthogonal cylindrical vault and (c) geodesic dome.

The most important conclusion resulting from this dissertation is the confirmation of the thesis on the issues related to the steel diagrid structures. It has been confirmed that the use of appropriately high order perturbation methods allows obtaining any assumed accuracy in determining the value of probabilistic characteristics compared to the solution of the direct integration approach. This occurs under the condition that the response function is selected to ensure convergence in the given interval of the input coefficient of variation – $[0,0; \alpha_{max}]$. A way for selecting the order of the method leading to the achievement of numerical convergence and assumed accuracy of probabilistic characteristics has also been proposed.

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