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Sensitivity analysis of steel plane frames with initial imperfections

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ABSTRACT

The article presents the sensitivity and statistical analyses of the load-carrying capacity of a steel portal frame. It elaborates a typical stability problem of a system comprising two single-storey columns loaded in compression. The elements of this system mutually influence each other, and this fact, in conjunction with the random imperfections, influences the load-carrying capacity variance. This mutual interaction is analysed using the Sobol' sensitivity analysis. The Sobol' sensitivity analysis is applied to identify the dominant input random imperfections and their higher order interaction effects on the load-carrying capacity. Majority of imperfections were considered according to the results of experimental research. Realizations of initial imperfections were simulated applying the Latin Hypercube Sampling method. The geometrical nonlinear solution providing numerical result per run was employed. The frame was meshed using beam elements. The columns of the plane frame are considered with two variants of boundary conditions. The dependence between mean and design load-carrying capacities and column non-dimensional slenderness is analysed.

1. Introduction

Along with the progress of structural design theories and the technological advancement of steelworks production, more and more large-scale and high-rise steel bar structures are implemented in modern structures. The issue of stability of these structures becomes more apparent due to the utilization of more slender members.

The frame stability requires that all structural members and connections of the frame have adequate strength to resist the applied loads where static equilibrium is satisfied on the deformed geometry of the structure. In order to determine the load-carrying capacity of an actual structure, it is necessary to take into consideration initial imperfections and to consider the geometrically nonlinear analysis.

In general, all imperfections are of random character. The reliability of steel structures depends on the variance of input imperfections which influences the evaluation of limit states of building structures. The attainment of limit states is generally a random phenomenon, which is examined in the field of reliability using probabilistic theories and mathematical computation models.

One of the most important characteristics occurring in probabilistic methods of reliability assessment of steel structures is the variance of the load-carrying capacity which is primarily given by the quality of production. Basic indicators of production quality include the yield strength, tensile strength, ductility and geometrical characteristics of cross sections; see, e.g., [1,2]. Relatively sufficient statistical information is provided for the material and geometrical characteristics of mass produced hot-rolled members of steel structures in comparison to other building branches. Scarcely measurable imperfections of steel plane frames include the inevitable initial crookedness of bar members (bow imperfections) and out-of-plumb inclinations of the columns (sway imperfections) in the same frame [3,4]. Some measurements have been made in connection with testing programmes [5], but very little data is available.

The frames depicted in Figs. 1 and 2 represent a typical stability problem of a structural system consisting of more members. The frames are typical lean-on systems which are characterized by the structural members tied or linked together in such a way that buckling of the column would require adjacent members to buckle with the same lateral displacement. The imperfection interaction effects can have a significant influence on the overall performance of the frames. The steel frame depicted in Fig. 1 has rotation and translation fixed boundary conditions of both column ends. The steel plane frame in Fig. 2 is similar to that in Fig. 1 with the exception that there is no rotation restrain at the column ends. The rotation fixed and rotation free conditions represent the two limits of real anchorage in practice. Let us denote the frame in Fig. 1 as Frame 1 and the frame in Fig. 2 as Frame 2.

In the presented paper, the effects of input imperfections on the load-carrying capacities of Frames 1 and 2 are evaluated

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