



ELSEVIER

Contents lists available at ScienceDirect

Thin-Walled Structures

journal homepage: www.elsevier.com/locate/tws

Sensitivity analysis of stability problems of steel plane frames

Zdeněk Kala*

Brno University of Technology, Faculty of Civil Engineering, Department of Structural Mechanics, Veveří 95, 602 00 Brno, Czech Republic

ARTICLE INFO

Keywords:
Structure
Frame
Steel
Strut
Stability
Imperfection
Sensitivity analysis
Reliability

ABSTRACT

The objective of the paper is to analyse the influence of initial imperfections on the load-carrying capacity of a single storey steel plane frame comprised of two columns loaded in compression. The influence of the variance of initial imperfections on the variance of the load-carrying capacity was calculated by means of Sobol' sensitivity analysis. Monte Carlo based procedures were used for computing full sets of first order and second order sensitivity indices of the model. The geometrical nonlinear finite element solution, which provides numerical results per run, was employed. The mutual dependence of sensitivity indices and column non-dimensional slenderness is analysed. The derivation of the statistical characteristics of system imperfections of the initial inclination of columns is described in the introduction of the present work. Material and geometrical characteristics of hot-rolled IPE members were considered to be random quantities with histograms obtained from experiments. The Sobol sensitivity analysis is used to identify the crucial input random imperfections and their higher order interaction effects.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

The reliability analysis of structural systems in the limit state methods is aimed at an assessment of safety and serviceability. Steel structures are composed of thin members and hence the problem of stability can prove to be one of the most important constituents of the safety. The stability loss is caused by the change of geometry of steel structures or structural components. Thus, to assess the structural stability, the equilibrium equations must be described under deformed geometry. This implies that the consideration of geometrical nonlinearity is inevitable for ultimate limit state analysis.

The behaviour of compressed members in the loading process leading to the ultimate limit state is influenced by initial imperfections generally divided into three categories: geometrical imperfections, material imperfections and structural imperfections [1,2]. The limit state theory for individual struts has been worked out and corroborated with experiments. However, isolated struts occur rarely in real structures. Generally, each structure is a system of members, which mutually influence each other by their behaviour. This interaction is most significant in structures with rigid joints (frame systems). On the contrary, this mutual interaction is small in truss structures and is generally neglected.

Within the division of structures into members and frame systems, we can accept the further division of initial imperfections into local (member) and global (frame systems) ones [1]. The local

imperfections include: initial straightness deviation of member axis, deviation from the theoretical layout of the hot-rolled cross section, load eccentricity, dispersion of the mechanical material properties, residual stress, etc. Global imperfections include initial inclination of any column in systems and imperfections in the realization of joints, connections, anchorage and other structural details, which are apparent in comparison with the theoretical assumptions introduced in the solution of idealized system.

One of the challenging issues in modern civil engineering analysis is the typically large number of random quantities defining the input and system parameters [3]. Most building structures are atypical and hence a higher number of measurements are conceivable from the statistical point of view just for local imperfections of mass produced members. The basic indicators of production quality include the yield strength, tensile strength, ductility and geometrical characteristics of hot-rolled IPE profiles which have been under long term statistical evaluation within the framework of non-commercially aimed research programmes, see e.g. [4,6]. Relatively sufficient statistical information on material and geometrical characteristics of mass produced members of steel structures is available in comparison to other building structures.

The frame depicted in Fig. 1 represents a typical stability problem of a system comprised of more members. The fundamental question in terms of safety of a structure is how significant is the effect of inevitable initial imperfections on the load-carrying capacity. An approach to make such problems tractable is to identify the most important sources of uncertainty and to focus attention primarily on those uncertainties of the input space. Such a method using the Sobol decomposition [7], global sensitivity analysis method, is proposed here. The Sobol decomposition is used to decompose the

* Tel.: +420 541147382; fax: +420 541240994.
E-mail address: kala.z@fce.vutbr.cz

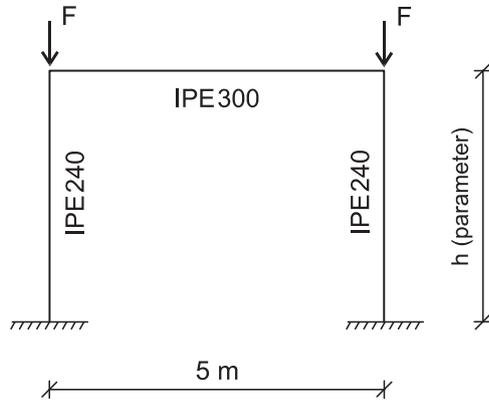


Fig. 1. IPE-section symmetric portal frame.

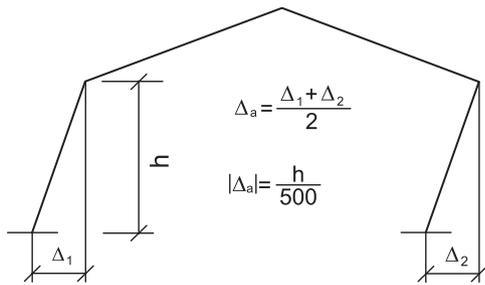


Fig. 2. Inclination of a single storey portal frame building.

variance of the load-carrying capacity into contributions of the individual input variables (initial imperfections).

The Sobol sensitivity analysis quantifies the relative importance of input imperfections in determining the value of load-carrying capacity. The crucial imperfections, which should be paid greater attention both in the modeling phase and in the interpretation of model results, are identified using sensitivity analysis. One of the advantages of the Sobol sensitivity analysis is that it enables the identification of interaction effects between input quantities on the monitored output. With the development of new concepts of the reliability analysis, these procedures can contribute to a qualitative improvement of the reliability analysis of structures.

2. Input random imperfections

2.1. Initial inclination of columns

Permitted inclination deviations of columns of a single storey portal frame are listed in the standard EN1090-2. The permitted deviation of mean inclination Δ_a of all columns in the same frame is $h/500$, see Fig. 2. This value is listed in the EN1090-2 for both Class 1 and Class 2.

The essential (normative) tolerances of inclination of each column have no specified limit; however, supplementary (informative) tolerances list the permitted deviations $|\Delta_b| = h/150$ for Class 1 and $|\Delta_b| = h/300$ for Class 2, see EN1090-2 and Fig. 3. Execution classes pertain to the production category and service category, in conjunction with the effect classes listed in Appendix B in the EN 1990:2002.

Inclination of each column is generally a random variable. In concordance with Figs. 2 and 3, let us denote the inclination of the left column as e_1 and that of the right column as e_2 . Let us assume that measurements of e_1 and e_2 were performed on a large number of real frames, with respect to the permitted deviations according to the EN1090-2. Let us assume that imperfections e_1 and e_2 are

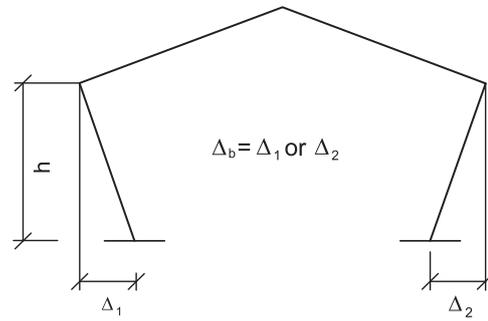


Fig. 3. Inclination of each column.

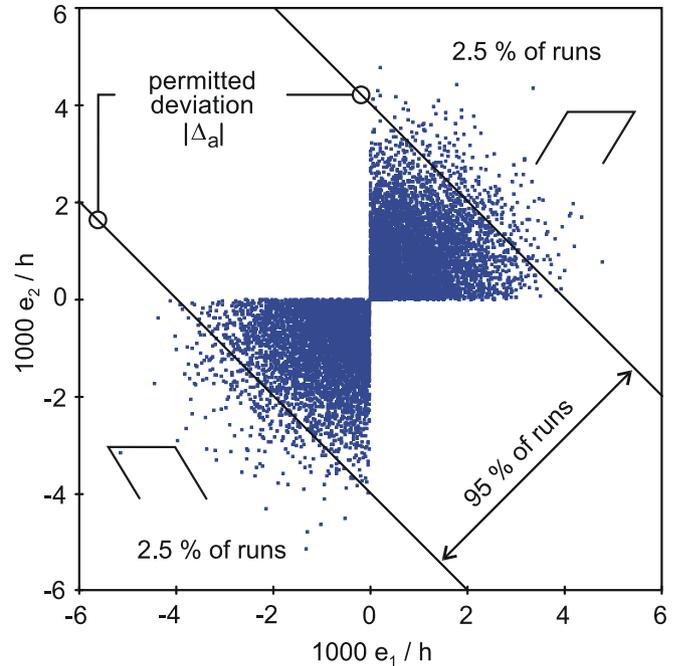


Fig. 4. MC runs, Case 1, $\sigma_{e_1} = \sigma_{e_2} = h/790$.

statistically independent random variables with mean values equal to zero, i.e., $\mu_{e_1} = \mu_{e_2} = 0$ (perfectly vertical columns). Let us further assume that 95% of realizations of e_1 and e_2 remain within the tolerance limits of the standard EN1090-2 and that both variables have a Gauss probability density function. Based on these assumptions, the first half of measured frames will have variables e_1 and e_2 of the same sign (Case 1), the second half will have variables e_1 and e_2 with opposite signs (Case 2). Analogously, let us introduce, for the permitted deviations Δ_a , Δ_b , random variables $e_a = (e_1 + e_2)/2$ and $e_b = e_1$ or e_2 . The problem was analysed using 20 000 runs of the Monte Carlo (MC) method, see Figs. 4 and 5.

Case 1: If we introduce $\sigma_{e_1} = \sigma_{e_2} = h/790$, then it holds with 95% probability that $|e_a| \leq |\Delta_a|$, see Fig. 4. At the same time, it holds for both classes that $|e_b| \leq |\Delta_b|$ with a probability which is higher than 95%.

Case 2: If we introduce $\sigma_{e_1} = \sigma_{e_2} = h/670$, then 95% of realizations of e_b will be found within the tolerance limit $\pm h/300$ (Class 2), see Fig. 5. Similarly, it holds that if we introduce $\sigma_{e_1} = \sigma_{e_2} = h/335$, then 95% of realizations of e_b will be found within the tolerance limit $\pm h/150$ (Class 1). The fulfillment of the condition $|e_a| \leq |\Delta_a|$ together with 95% probability leads to $\sigma_{e_1} = \sigma_{e_2} = h/430$, see Fig. 6. In order to secure reliability from the point of view of the limit states, it is necessary to consider a smaller (safer) standard deviation for Class 1. In practice, this means that for Class 1, we shall introduce $\sigma_{e_1} = \sigma_{e_2} = h/430$ and for Class 2, $\sigma_{e_1} = \sigma_{e_2} = h/670$.

متن کامل مقاله

دریافت فوری ←

ISIArticles

مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات