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Experimental Analysis of Lateral Torsional Buckling of Beams with Selected Cross-Section Types

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Abstract

Currently used design methods for solution of lateral torsional buckling are based on critical moment approach. This solution is also implemented in design codes but it is limited for use of single symmetric cross section only. The analytical solution of mono symmetric cross-section by critical moment is patterned on the theory of thin walled elastic beams by Vlasov [1]. In spite of the fact that this theory is known for many decades, the practical elaborated approach for solution of asymmetrical cross section is still the actual problem to solve.

Nowadays the FEM based numerical models are the powerful instrument for detailed analysis of such kind of structure. However, there are still problems with definition of all imperfections and boundary conditions. Also the modelling of load effects during the loading procedure remains usually difficult. The most valuable source of information is the experiment.

The goal of research which is presented in this paper is the experimental and theoretical analysis of cross section which can be asymmetrical. Particularly there are experimental test of several beams of selected cross-section shapes described and analysed. The main idea of those experiments was to observe the differences in behaviour between single symmetric cross-section and the slightly asymmetric one. Results of those experiments will serve as a base for further theoretical part of the research.

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1. Introduction

One of the special type of general buckling is the lateral torsional stability. It occurs when the beam is transversely loaded in the plane of the main stiffness of cross section and by the same time the transverse deflation along the beam length is not prevented. The deflection transverse to initial bending plane gradually rises while the rising load is applied. The compressed part of the cross section is inclinable to deviate in the direction of minimal resistance while the tensioned part of the cross section stabilize the stiffness of cross section and inflicts the torsional displacement. This state is characteristic by spatial deformation covering the flexural bending and the torsional displacement.

1.1. Aiming of the analysis

Two differential equations of fourth order can be used for solution of lateral torsional stability problem [1,2]. The partial component of the solution of these equations is the critical bending moment. This approach is nowadays implemented in Eurocodes [3], but there it is limited only to monosymmetric cross-sections.

The goal of the theoretical part of this analysis is to find the analytical solution which can be used also for the asymmetrical cross-sections. This solution will be verified by experimental research, which is the main aim of this article.

2. Preparation and realization of experiments

The preparation of experimental analysis was done with the focus on the observation of differences between the real behaviour of the monosymmetric and asymmetric cross-section. Therefore the four slightly different welded I sections were selected. The geometrical difference of cross-sections was made by movement of one of the flanges according to Fig. 1.

Five test were made for each configuration of cross-section. Test specimens are marked as H1A, H1B, H1C, H1D and H1E for monosymmetric cross-section and by the same way H2A to H4E for all asymmetric cross-sections. All results are described in graphs below.

2.1. Experiment configuration

Experiment configuration is shown in Fig. 1a and Fig. 2. The test equipment and verification methodology of flexural torsional beam buckling has been developed by J. Melcher and M. Karmazínová [4],[5],[6]. In principle it is the four point bending test. Beams were welded together from plates of 6 mm thickness. 4 mm welds were used. The main material was the basic structural steel S235. Strength and strain characteristics were verified in a laboratory. The yield strength of steel was $f_y = 327\ MPa$ and the value of ultimate strength was $f_u = 458\ MPa$.

Tested specimens were prepared according to geometry displayed in Fig.1. The beam is loaded in two points in the thirds of length. The length of specimens was 3020 mm. Both ends of the beam were fixed in the hinge extensions with pins. This connection ensures the free rotation in the plane of loading.

There were four strain gages installed to the cross-section located in the middle of the span. Each strain gauge was placed in the middle of thickness of the flange. The values of applied force and also the displacement in five points were measured. Deformation in both supports and in the middle of the span were measured to obtain the vertical deflection of beam (W3, W4 and W5). The displacements of both top and bottom flange in transversal direction (W1 and W2) were measured to obtain the rotation of the cross section in the middle of the span too.

Potentiometer pick offs WPS-250-MK30-P10 and inductive picks HBM WA10-T were used for measuring deformations. All strain gauges were the same type HBM LY11 3/350. All data were measured by HBM MGC+ station.