Influence of the distortional-lateral buckling mode on the load carrying capacity of thin-walled short channels

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Abstract

The presented paper deals with an influence of the distortional-lateral buckling mode on the load carrying capacity of thin-walled short channel profile subjected to the bending moment when the shear lag phenomenon and distortional deformations are also taken into account. The considered structure is assumed to be simply supported at both ends. The calculations employing the analytical-numerical method (SAM) and the FEM are referred to an experimental preliminary tests which were carried out for isotropic short channels. Both theoretical and numerical models were carefully verified and mutually relevance confirmed.

Keywords: short channel, bending, distortional-lateral mode, experimental tests, FEM

1. Introduction

Beams are the fundamental element in steel structures that carry loads - mainly via bending. In the majority of cases, a possibility to manage comparatively high loads by thin-walled beams is limited not by their strength only but mainly by their buckling strength.

The major development of research on stability of thin-walled isotropic structures took place in the 1970s and the 1980s. Since the late 1980s, the Generalized Beam Theory (GBT) was developed extensively. At that time numerous studies employing such theories as: GBT, FSM (Finite Strip Method) and DSM (Direct Strength Method) originated [1,2,3,5,6]. The new method was referred to as the constrained Finite Strip Method (cFSM). In many papers special attention was paid to the distortional-global interaction buckling [7,8].

Recently in our Department some experimental investigations were carried out for short composite channels subjected to bending in the web plane as there is a lack of investigations devoted to the buckling analysis of such channel sections. The results emphasized especially an effect of the global distortional-lateral buckling mode over postbuckling equilibrium paths. In [4], the impact of distorsional-lateral buckling on an interactive buckling of thin-walled steel short channel subjected to bending in the web plane was analyzed. In the performed analysis the analytical-numerical method (ANM) based on the Koiter's theory was employed and the results of computations were verified by preliminary experimental investigations.

In the frame of current paper which can be taken as an extension of work [4], some not published yet results of FEM numerical computations and laboratory tests will be presented. The experimental data was determined for two channel section profiles made of steel (t = 1.2mm) with the application of the digital image correlation system (ARAMIS). It allows to record a change of 3D geometry of loaded beam visible through a set of cameras. The measurement values of beam deformations (in-plane and out of plane) finally gave the map of displacements and strains. These were compared with the adequate FEM computations.

Thus the experimental results were used to verification and validation both numerical models employing ANM and FEM.

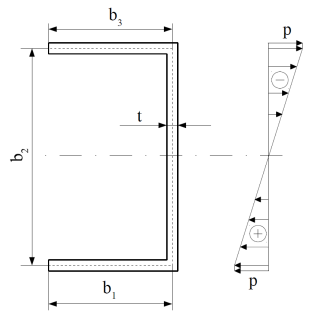

Figure 1: Thin-walled channel subjected to bending in the web plane [4]

2. Comparison of numerical and experimental results

A detailed analysis of the results was conducted for the thin-walled channel of thickness $t = 1.2$ mm with the following overall dimensions (Fig. 1) [4]: $b_1 = 40$ mm, $b_2 = 40$ mm, $l = 275$ mm. The channel is subjected to the bending in the web plane (thereby the upper flange is compressed, whereas the lower one is subjected to tension). Two specimens/models were made. The average values of material constants were determined directly in tensile tests [4], therefore: $E = 197$ GPa, $\sigma_Y = 475$ MPa. The sheet plate was cut with the waterjet method into dimension and the specimens were cold formed.

The tests were conducted on an Instron universal testing machine updated by Zwick-Roel and equipped with specially designed grips. The investigated channel section beams were subjected to pure bending. This type of load was applied in a four-point bending test. A scheme of the performed bending test with dimensions describing the span of support and the span of load is presented in Fig. 2. A special grip was designed and manufactured [4] to avoid stress concentration in the place

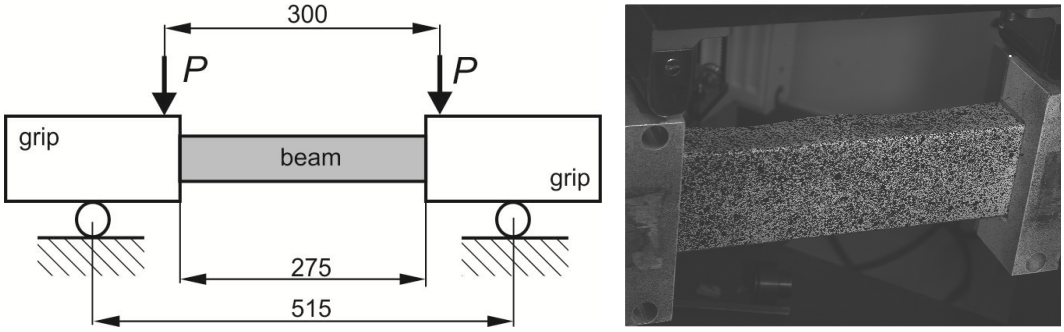

Figure 2: Scheme of the load and the support for four-point bending test (all dimensions in mm) [4]

where the beams were supported and loaded. The grips were used to provide the load corresponding to pure bending. During the experimental research the digital image correlation system (ARAMIS) was used. It allows to register the change of 3D displacements and strains of tested beam. The specimens were subjected to loading until failure. The values of applied loads and vertical displacements of the machine upper traverse were recorded concurrently. Next, these quantities were recalculated into values of the bending moment M [Nm] and the angle of rotation α [deg] at the supported edge of the investigated channel beam.

In Fig. 3 there is an exemplary comparison of experimental test results and analytical-numerical computations (ANM) taken from [4] (for more detailed analysis see [4]). The line (*T-1.2*) represents the theoretical performance curve for three-mode coupling buckling approach to control an increment in the external load. The experimental investigations do not show the phenomenon of jump as the theoretical considerations have suggested for the three-mode approach [4]. A shape of the theoretical curve can indicate a considerable effect of the distortional-lateral buckling mode on the interactive buckling, and thus, on the postbuckling equilibrium paths. The experimental curves (*E-3, E-4*) may correspond to other values of initial imperfections that the ones assumed in the theoretical considerations.

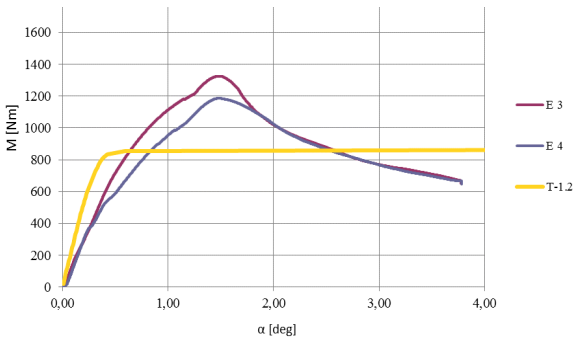

Figure 3: The results of bending moment M and the angle of rotation α for t=1.2 mm, where: E-3, E-4 - experimental curve for test no. 3 and 4, respectively; T-12 - theoretical curve for three mode approach (for $r=1$, $r=2$ and $r=3$) [4]

For numerical computations the Finite Element Method was employed (ANSYS package), as a broad and universal tool of modelling which allows to verify performed theoretical discussion. By the other side, the obtained experimental results have enabled the validation of both applied numerical methods - i.e., ANM and FEM. More details of this analysis will be presented during the conference CMM'2017.

3. Conclusions

The theoretical and experimental results should be treated as an introduction to a more thorough discussion - both in terms of theoretical considerations employing the analytical-numerical methods and the FEM, as well as further experimental investigations. Then, an influence of global modes on the interactive bucking of short channel members under bending in the web plane can be comprehensively described.

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