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Experimental investigation of C-beams with non-standard flanges

P. Paczos

Institute of Applied Mechanics, Poznan University of Technology, Jana Pawła II 24 Street, Building A5, 60-965 Poznan, Poland

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ABSTRACT

The paper presents results of experimental investigations of stability and limit load of cold-formed thin-walled channel beams with non-standard flanges subjected to pure bending. Critical and limit loads were determined using a strength testing machine. Obtained results were compared with analytical solutions. The influence of non-standard flanges on the critical load and limit load was shown as well.

1. Introduction

This paper refers to experimental investigations of cold-formed thin-walled beams with non-standard flanges: channel beams (CFB), double-box flanges (DBFB — double box flange beam) and channel beams with open and close drop flanges (DrFB — open and close drop flange beam) made of a steel sheet. Those investigations were the continuation of earlier researches conducted in the Unit of Strength of Materials and Structures at Poznan University of Technology. They will give a better understanding of behaviour of thin-walled beams and may improve a designing process. The considered beams were simply supported and subjected to pure bending (Eurocode3 [5]).

New shapes of the cross-sections of thin-walled beams have been searched for in order to increase their strength. These problems have been studied since the middle of the twentieth century. They were described in many monographs, e.g. Vlasov [40], Bleich [3], Timoshenko and Gere [37], Trahair [39]. There are a lot of papers on these problems as well. In 1978 Hancock [10] used the finite strip method to study the local, distortional, and flexural-torsional buckling of I-beams that were bent about their major axis. In 2003 Hancock [9] presented a review of the papers on cold-formed steel structures that were published in 1999–2001. He also summarised the development of the North American Specification referring to the designing process of those structures. In 2009 Pham and Hancock [32] used the finite strip method to study the elastic buckling of channel beams with and without reinforcing lips subjected to shear forces parallel to the web of beam. Pi Yong-Lin et al. [33] in 1999 presented the inelastic lateral buckling of cold-formed Z-section beams. In 2000 Davies [7] described the development of technology and applications of cold-formed steel structures together with the related design procedures. In 2007 Trahair [38] presented an approximate method of predicting the second-order deflections and twist rotations of steel equal angle beams under biaxial or major axis bending and torsion. He showed a mathematical model of lateral–torsional buckling and a procedure for calculating the critical load. Magnucki et al. [20] studied simply supported thin-walled beams subjected to a uniformly distributed transverse load. They reviewed some strength, global and local stability problems as well. The results they obtained were compared with the solution of finite element analysis. In 2008 Macdonald et al. [14] described the main types of cold-formed steel members and discussed their particular characteristics that affecting their design. Schafer [34] reviewed the development and current progress of the Direct Strength Method for analysing cold-formed steel member. Basaglia et al. [2], Camotim et al. [4], and Dinis and Camotim [8] wrote a report on the use of a recently developed Generalised Beam Theory (GBT) and its finite element implementation. It was used to analyse the global buckling of 2d and 3d thin-walled frames and the local and global buckling of thin-walled members with arbitrary loading and support conditions. In 2009 Bambach [1] presented the investigations of compressed channel beams with simple stiffeners of flanges. He compared the results of tests with the recent Modified Effective Width Method and Direct Strength Method. Kwon et al. [12] described a series of compression tests conducted on cold-formed simple lipped channels and lipped channels with intermediate stiffeners of the flanges and web made of high strength steel plate. Magnucki et al. [22,26] studied cold-formed thin-walled channel beams with open and closed profiles of drop flanges. The analytical and the theoretical solutions of the elastic buckling problems were formulated and verified experimentally. Contemporary cross-sections of cold-formed thin-walled beams could be complex (combined). Numerical investigations were conducted by Cheng & Schafer [6], who verified their results by comparing them with experimental investigations. Contemporary studies in this field concentrate on global and local buckling of thin-walled beams, paying special attention to cold-formed beams. Numerical studies and some theoretical

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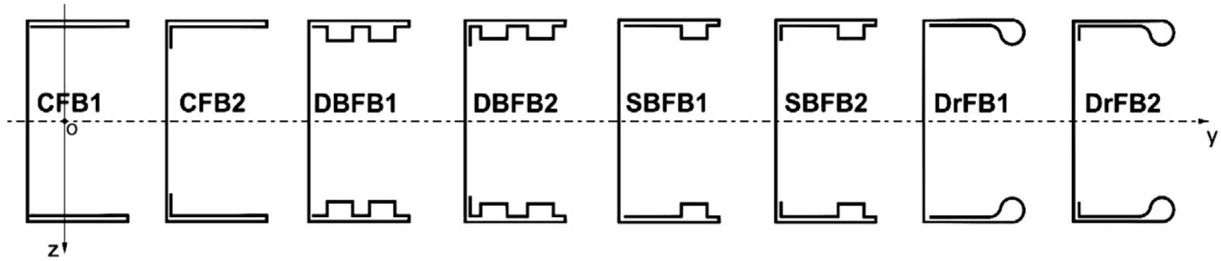

Fig. 1. Scheme of the cross-sections of the beams with non-standard flanges.

results of I-beams made of two cold-formed thin-walled channels were presented by Wadee and Gardner in [41]. They showed nonlinear, analytical relationships for all investigated beams subjected to pure bending. Moreover, the authors paid some attention to interactions between global and local buckling modes. The agreement between their numerical/theoretical results and experimental investigations conducted at the South African Institute of Steel Construction was satisfactory. The presented models correctly described collapse of beams because of local and global buckling in both qualitative and quantitative ways. The beams lost stability in the second point of bifurcation, which immediately led to buckling of compressed flanges. Afterwards the deformation of structure decreased with load and the beams tended to buckle because of lateral buckling. Experimentally the whole process was unstable and deformations appeared sequentially in the places where the beams were supported/reinforced or load was applied. This means that such beams are prone to imperfections and they should be considered when designing and analysing cold-formed thin-walled structures.

The considered shapes of cross-sections were shown in Fig. 1.

Numerical studies of channel beams with double-box flanges were described in [35,11] (finite strip method) and in [36] (finite element method). Comparison of theoretical results with experimental ones helps to improve mathematical models of beams. Such an approach was taken e.g. by Magnucki [19], who prepared also a review of works on steel cold-formed structures. Similar problems were analysed all over the world and some results in this field were presented by Magnucka-Blandzi et al. [17] and Paczos et al. [25,26]. They showed their own experimental and numerical investigations of thin-walled channel beams with non-standard cross-sections. Some analytical solutions were presented as well. Special attention was paid to the influence

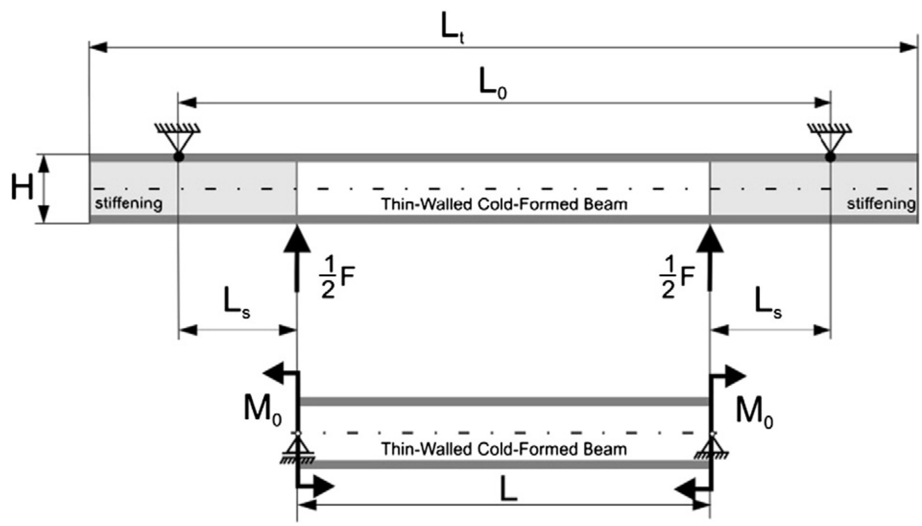

Fig. 2. Scheme of tested beams and a beam subjected to pure bending.

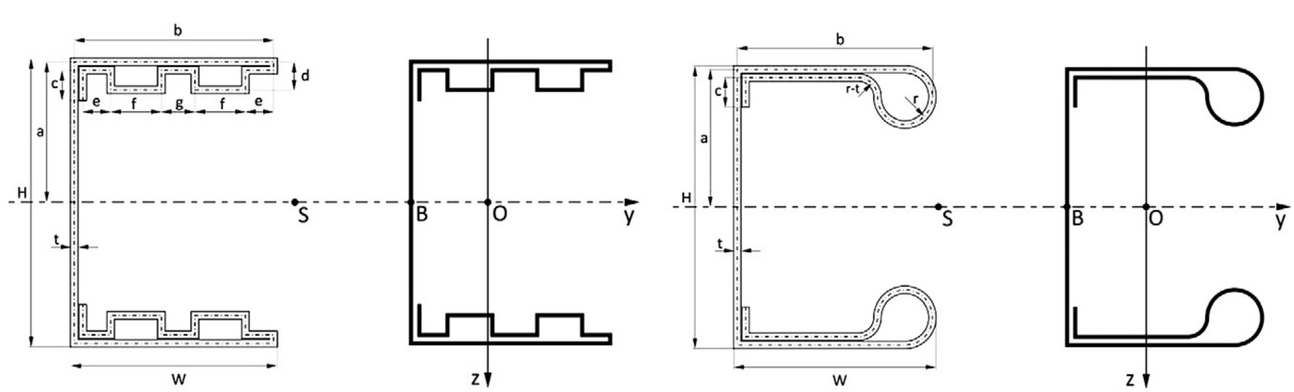

Fig. 3. Double box and drop flange cross-section.