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Strength analysis of eccentrically loaded thin-walled steel lipped C-profile columns

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ABSTRACT: The work includes the results of numerical parametric study into the influence of load eccentricities with regard to major axis on post-buckling behaviour and load-carrying capacity of thin-walled cold-formed steel lipped channel section columns subjected to eccentric compression. The study was carried out by using the finite element method (code Ansys) with considering a full material nonlinearity. The analysis has been conducted for nine columns differing from thicknesses and dimensions. In analysis, five thicknesses and two lengths of columns were taken into consideration. Some chosen results of numerical simulations have been compared to experimental results. The analyses showed that the decrease in maximum load in a dependency on eccentricity value and considered variant can be even 3 times minor in a comparison to the load-carrying capacity of axially loaded column.

KEYWORDS: thin-walled steel structures, load-carrying capacity, eccentric load

1. Introduction

Thin-walled cold-formed steel (TWCFS) sections commonly are regarded to have mono-symmetric or point-symmetric shapes. They can have usually stiffening lips on flanges and/or intermediate stiffeners in wide flanges and webs. Both simple and complex shapes of profiles can be manufactured for structural and non-structural applications. The problem of buckling loads and the load-carrying capacity of TWCFS structures subject to simple loading systems (pure bending, uniform compression, e.g.) has been solved with a good accuracy based on the theory of thin-walled structures as well as in design code specifications as EN 1993-1-3 giving accurate predictions for the buckling load and ultimate strength of TWCFS structures especially under concentric axial compression. Based on literature, one can find a few reported results of both theoretical and experimental study on the structural behaviour of TWCFS columns under eccentric compression particularly with respect to major axis bending. The first results of eccentric compression on TWCFS members were shown by Rhodes and Harvey in 1977 [1]. Quite lately, Wysmulski et al. in proceeding [2] showed the results of channel section columns made of multiply laminate loaded with very small eccentricities. Zhao et al. in papers [3, 4] performed experimental investigations on columns with box-type and L-type sections made of aluminium alloy subjected to eccentric and stainless steel circular hollow sections under combined loads. Meng and Gardner in [5] investigated the influence of yield strength on the in-plane stability and design of structural steel square and rectangular hollow section beam-columns under compression plus uniform bending. Kotełko et al. in [6] presented results of local plastic failure mechanisms for columns of the lipped channel section subjected to eccentric compression with respect to the minor axis. The continuance of aforementioned paper was work elaborated by Borkowski et al. [7] relating an experimental program into the post-failure behaviour of TWCFS members subjected to eccentric compression about the minor axis. They tested samples under compression load with a wide range of positive and negative eccentricities.

2. Objective of investigation

The subject of the present study is to assess to the behaviour of TWCFS columns with a lipped channel cross-section under eccentric compression about the major axis, as shown in Figure 1. The typology of considered columns is inserted in Table 1. The dimensions of the columns to be studied were defined in order to classify these members in class 4 (EN 1993-1-1:2005). The class 4 of members means that local buckling will occur in such members before the attainment of yield stress in one or more parts of the cross-section.

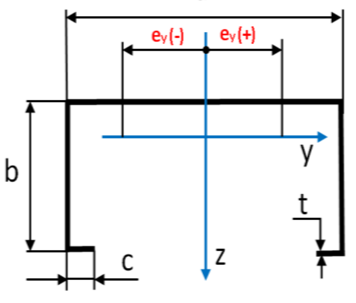

Fig 1. Drawing of cross-section of analysed columns

The columns with dimensions included in the Table 1 were subjected to an eccentric load with the wide range of eccentricities from 0 (in case of axial compression) to maximally 160 mm (in a dependence of column dimensions).

Table 1. Typology of columns

Description of variant	*a* (mm)	*b* (mm)	*c* (mm)	*t* (mm)	*L* *(mm)*
Model 1	150	60	20	2	450
Model 2	150	60	20	1	450
Model 3	150	47	16	2	450
Model 4	150	47	16	1.5	450
Model 5	150	47	16	1	450
Model 6	250	100	25	3	600
Model 7	250	100	25	2.5	600
Model 8	250	100	25	2	600
Model 9	250	100	25	1.5	600

3. FE model

FE calculations were performed by using commercial FE Ansys 18.2 software [8]. Adequate discrete models of the structure was built based on the 4-node 181-shell (Fig. 2). The size of finite element was assumed to be 2 mm. The nonlinear analysis was conducted for large strains (full stress-strain material characteristic for thickness 2 mm – Fig. 3) and deflections on the basis of Green-Lagrangian equations. The number of substeps for the single calculation was ranged from 400 up to 50,000. The maximum number of iterations for each substep was set up to 5000. The load was realised by using master nodes connected to the edge nodes.

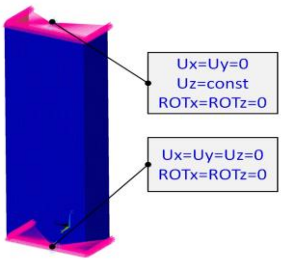

Fig. 2. FE discrete model with boundary conditions

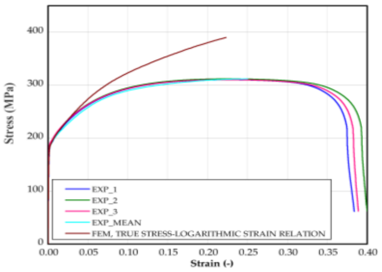

Fig. 3. FE discrete model with boundary conditions

4. Results

The Fig. 4 shows the full equilibrium paths as force (F) vs. shortening (S) for Model 1 by taking into account the eccentricities from 0 to 120 mm. It is seen the decrease of load-carrying capacity by 2.5 times relating to axial compression of steel member. The Fig. 5 presents the load-carrying capacities for Model 2 achieved numerically and experimentally, together with code recommendation (EN 1993-1-3). A good consistency has been obtained between numerical and experimental results. Code prediction occured to be conservative.

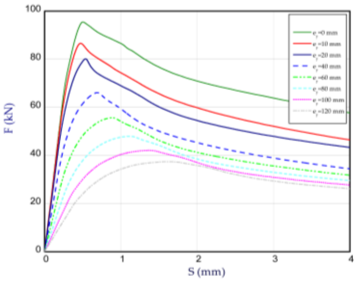

Fig. 4. Force vs. shortening of eccectric compression for Model 1

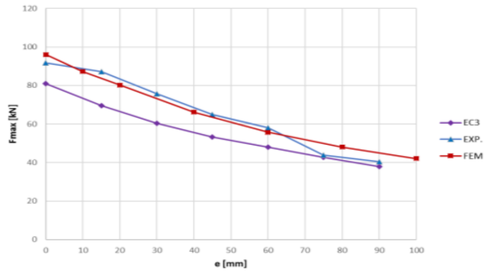

Fig. 5. Load-carrying capacities obtained by FEM calculations and experiment

5. Summary

The work deals with assessing the behaviour of a few TWCFS structures under eccentric loads. Based on results, it was stated:

1) the essential decrease in load-carrying capacity is observed for eccentric loaded columns,
2) in case of variant, different work paths have been attained.

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