Bending capacity of the innovative cold formed GEB profile

Agnieszka Łukowicz[1] **and Marcin Krajewski**[2] **and Dariusz Kowalski**[3]

[1]*Faculty of Civil and Environmental Engineering, Gdansk University of Technology*
Narutowicza 11/12 street, 80-233 Gdansk, Poland
e-mail: agnlukow@pg.gda.pl

[2]*Faculty of Civil and Environmental Engineering, Gdansk University of Technology*
Narutowicza 11/12 street, 80-233 Gdansk, Poland
e-mail: markraje@pg.gda.pl

[3]*Faculty of Civil and Environmental Engineering, Gdansk University of Technology*
Narutowicza 11/12 street, 80-233 Gdansk, Poland
e-mail: kowdar@pg.gda.pl

Abstract

The paper is focused on numerical study of bending capacity of the innovative cold formed GEB sections. Both linear buckling analysis and non-linear static analysis incorporating geometric and material nonlinearity were carried out. The computations were performed assuming imperfect shell model of the structure. As a result the magnitudes of buckling load and limit load with respect to GEB section height and thickness were obtained.

Keywords: cold formed profiles, bending capacity, open cross section

1. Introduction

In the recent years the cold formed steel sections have been frequently designed for metal structures. The optimal configuration of the dimensional parameters of the cross section may act definitely on the profile bearing capacity and the production possibilities. The innovative GEB section was invented to serve as a primary load-bearing member in fabricated steel panels and trusses. Stability of typical cold-formed open steel sections has been studied in the recent years [7], however, according to the European Standard requirements every new section shape should be tested [5,6]. The GEB member stability was investigated in [3,4]. Both numerical analysis and experimental tests for the sample GEB profile under bending were presented in [2].

The paper continues the previous research, presented in [2]. Procedures of linear buckling analysis and non-linear static analysis (geometric and material non-linearity) were performed for the shell model of the structure. In numerical research it was assumed that both the top wall width (55 mm) and the distance between vertical parallel walls (30 mm) were constant (Fig. 1). The cross-sectional height was assumed variable. The considered profile did not include braces along the element length.

2. Description of the GEB profile

The GEB profile was made of steel E = 178 GPa, f_y = 206 MPa. Material characteristics were determined using separate testing procedure [2]. The section length was L=6,0 m, the element was loaded every 1.5 m (Fig. 1c). The profiles situated in two different positions - Scheme A or Scheme B, were considered. In was assumed that the GEB section will be battened at loaded joints (only for Sch. A)

Twisting at the end supports was restrained. The sections of thickness equal to t = 2.0 mm or t = 3.0 mm were taken into account.

In the numerical analysis about 20 000 shell elements QUAD4 [1] of a GEB sections height h=100 mm (or 50 000 elements for h=300 mm) were applied. The loading was applied (arc-length method) in the form of concentrated forces situated at the top of the section. For the sch.A the RIGID links [1] were used as battens between the loaded (horizontal) walls. This type of stiffening (at loaded joints) is intended for the use in real structures.

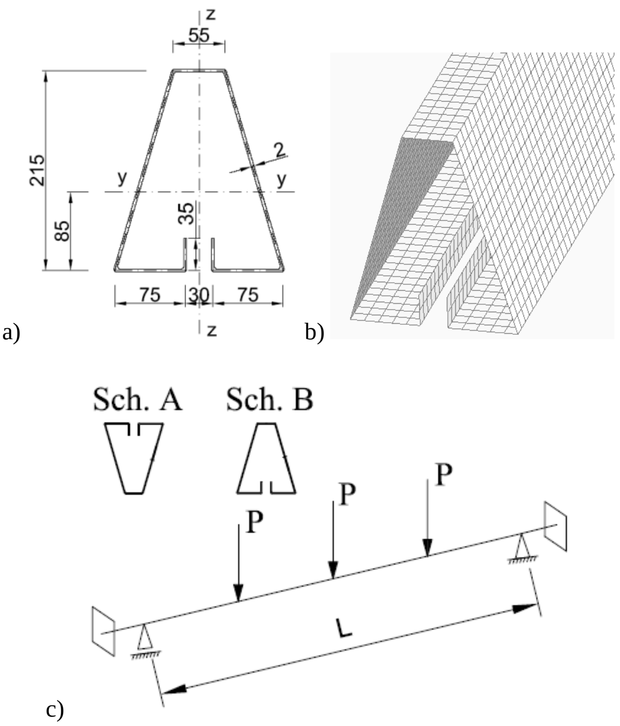


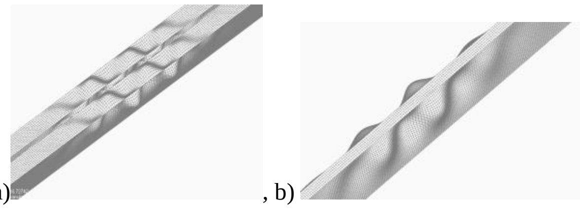
Figure 1: GEB profile: a) geometric details, b) shell model detail, c) static schema

3. Numerical analysis results

Based on linear buckling analysis (LBA) the critical load (the sum of all point forces) for the GEB profile subjected to bending was found. The results are presented in Table. 1. In most cases the buckling modes in the form of local flexural-torsional buckling in the middle of the span appeared (Fig. 2).

Table 1: The magnitudes of critical load [kN] with respect to GEB profile height, thickness and position

GEB height [mm]	Thickness 2.0 mm		Thickness 3.0 mm	
	Sch. A	Sch. B	Sch. A	Sch. B
100	269.9	116.5	499.9	383.8
150	500.4	122.6	1396.8	408.2
200	684.1	116.0	2114.3	383.6
250	909.4	112.4	3027.2	372.1
300	1104.2	109.3	3681.5	364.3



a) , b)

Figure 2: Buckled modes of the GEB profile (middle of the span) a) GEB h = 300 mm, sch. A, b) GEB h = 300 mm, sch. B (t= 2.0 mm)

The cases of nonlinear static analysis (geometric and material nonlinearity - GMNIA, bi-linear elasto-plastic body model)) were performed for the structure with an initial geometric imperfection. The imperfection in the form of arch curvature (perpendicular to y-y axis) was obtained from the results of linear static analysis. The maximum amplitude of imperfection was equal to L/500.

On the basis of the results the maximum magnitude of loading (limit load) was obtained .(Fig.3). The deformation of the profile (at its limit state) was presented in Fig. 4.

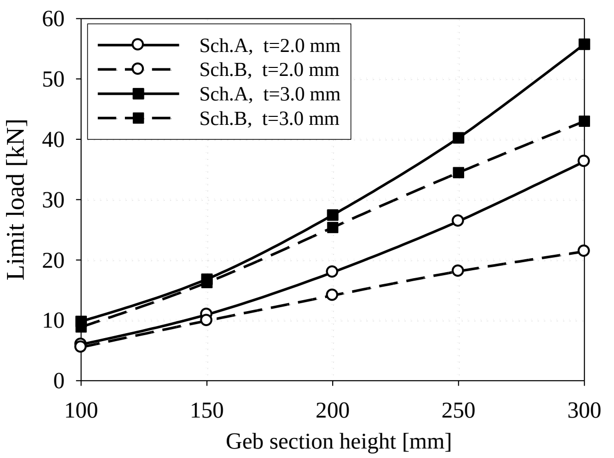
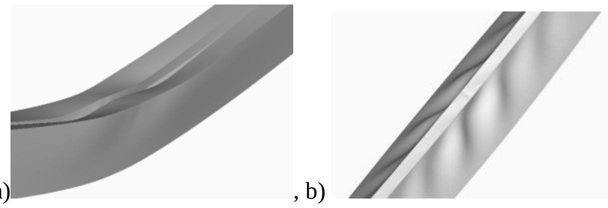


Figure 3: The limit load for the GEB profile due to section height with respect to thickness and position (sch. A, sch. B)



a) , b)

Figure 4: Deformation of the GEB profile at the limit state: a) h = 300 mm sch. A, b) h =300 mm sch. B (t= 2.0 mm)

4. Conclusions

The results of linear buckling analysis lead to conclusion that the critical load was rising significantly due to the increase of a GEB section height only for the GEB profile situated in the position of a sch.A. The second structural position (sch.B) makes the differences between loading magnitudes shift up to 10%. The critical load magnitudes for sch. B were significantly lower comparing to sch.A.

It is worth noting that there were no braces along the profile length and no global lateral-torsional buckling modes occurred, subjected to critical loads (LBA).

In each case the limit load obtained from non-linear static analysis (GMNIA) rose with the increase of a GEB section height. In the cases of a GEB section height equal h=100 mm and h=150 mm the bearing capacity of the profiles situated in position sch.A or sch.B were comparable (differences up to 9%).

In the presented analysis the profiles with an open cross section were considered and the distance between the webs rose significantly during the loading (sch.B). In this case a proper implementation of battens may significantly affect the GEB profile bending capacity.

References

[1] *Femap with NX Nastran*, Version 10.1.1. Siemens Product Lifecyde Management Software Inc., 2009.

[2] Łukowicz A., Urbańska-Galewska E.. Gordziej-Zagórowska M.. Experimental testing of innovative cold-formed GEB section, *Civil and Environmental Engineering Reports*, vol 16, iss.1, pp.129-140, 2015.

[3] Łukowicz A., Deniziak P., Migda W., Gordziej-Zagórowska M., Szczepański M., Innovative cold formed GEB section under compression, Proceedings of the XIII International Conference on Metal Structures - ICMS 2016, *Recent Progress in Steel and Composite Structures, pp.76-77, 2016.*

[4] Łukowicz A., Krajewski M., Stability of an innovative Cold-Formed GEB Section, *Engineering Transactions*, vol. 65, iss.1, pp. 45–51, 2017

[5] PN-EN 1993-1-1, Eurocode 3, *Design of steel structures.- Part 1-1: General rules and rules for buildings*, 2006.

[6] PN-EN 1993-1-3 Eurocode 3**,** *Design of steel structures. Part 1-3: General rules -Supplementary rules for cold formed members and sheeting*, 2006.

[7] Schafer B. W., Local, Distortional, and Euler Buckling of Thin-Walled Columns, *Journal of Structural Engineering*, vol.128, iss.3, pp. 289-299, 2002.