Numerical and experimental studies on stability of laminated Z-profile under non-axial compression

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Abstract. A short, thin-walled column with open cross section is considered. It is made of carbon-epoxy laminate by the autoclave technique. A laminate consists of 8 layers of unidirectional prepreg. The column is subjected to compression. It is simply supported on both ends.The eccentric of the compressive load can be different to zero. The FEM numerical studies using the ABAQUS® software and experimental tests are performed in post-buckling and limit states, as well. Experimental studies are conducted to confirm results obtained from numerical calculations.

OBJECT OF STUDIES

A short thin-walled laminated Z-column, subjected to eccentric compression is considered. It is a typical thin-walled structure with perpendicular walls formed by flat plate elements connected on longer ends [1-3]. The column is made of carbon-epoxy laminate by the autoclave technique. This multi-ply composite consisted of 8 plies. A lay-up configuration is symmetric to the central plane of the laminate. The dimensions of the Z-column are shown in Fig. 1. The amplitude of geometrical imperfection is 0.05 mm. The carbon-epoxy laminate has the following mechanical properties: Young's modulus in fibre direction (i.e., direction 1) – 143528.5 MPa and in fibre transverse direction (i.e., direction 2) – 5826.3 MPa, respectively; Poisson's ratio in plane 1-2 – 0.36; shear modulus in plane 1-2 – 3845.5 MPa. The Z-column is simply supported on both ends [1-3].

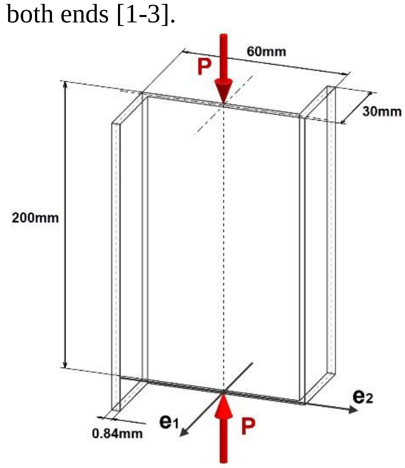
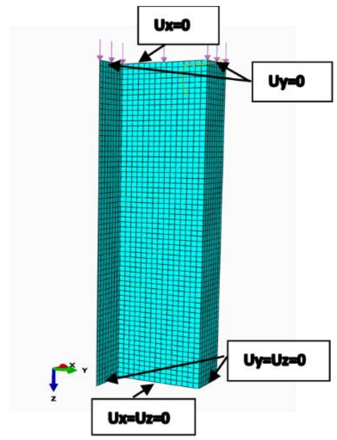


FIGURE 1. Dimensions of the sample in mm

METHODOLOGY

The experimental and numerical studies were performed to determine a buckling load of a laminate structure under compression. A eccentric of a compressive load can be different to 0 [4]. The experimental tests were performed on the Zwick 100 static testing machine at a constant velocity of the upper cross-beam maintained at 2mm/min and at room temperature. The specimen of Z-column had strain gauge extensometers fixed on both sides of a web of the longer wall of the column, at the points of predicted highest deflection. The simple support of the column's ends was done by special heads with ball support mounted on the testing machine bolts. Two special tables mounted on the holders of the testing machine can change the load eccentricity every 0.1 mm in two perpendicular directions. A series of experiments were performed for the following cases: axial load and non-axial load (i.e. the eccentric load in Direction 1 and in Direction 2 was 10 mm). The buckling load of a real structure was determined based on post-buckling equilibrium paths. Fig. 2 shows a test stand and the numerical FE-model of the Z-column.

(a)



(b)

FIGURE 2. Test stand (a) and FE-models of the Z-column (b)

CONCLUSIONS

The experimental studies on the Z-column under non-axial compression can illustrate the effect of compressive eccentric load on the buckling load and a limit state of a real structure. The experimental results enable a qualitative and quantitative analysis of the buckling and post-buckling states based on the parameters measured during the test. The experimental buckling load and post-buckling parameters were used to verify the FEM results. All results confirmed a significant influence of the non-axial compression on the buckling behavior of the real structure. The determined buckling equilibrium paths proved a change in the stiffness parameter of the thin-walled Z-column depend on the direction and eccentricity of the compressive load.

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REFERENCES

1. P. Rozylo, A. Teter, H. Debski, P. Wysmulski, K. Falkowicz, Appl Compos Mater **24**, 1251-1264 (2017).
2. H. Debski, T. Kubiak, A. Teter A., Thin Wall. Struct. **71,** 147–154, (2013).
3. H. Debski, A. Teter, T. Kubiak, Comp. Struct. **118**, 28–36, (2014).
4. P. Wysmulski, A. Teter, H. Debski, "*Effect of load eccentricity on the buckling of thin-walled laminated C-columns*" in *22nd International Conference on Computer Methods in Mechanics* 2017, AIP Conference Proceedings 1922(1), 080008 (2018).