Buckling in FDM 3D printed PLA elements: a DIC-assisted experimental investigation

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Abstract. In the recent years, a lot of works has been done to understand if, and in what extent, Fused Deposition Modelling (FDM) could be shifted from prototyping to manufacturing of small productions or individual components. Several authors investigated the tensile mechanical properties of FDM 3D-printed elements under specific printing parameters. Other ones identified the influence of some of those parameters on tensile mechanical properties. Less attention was paid to compressive ones. In this work, the authors studied how short-length Polylactic Acid (PLA) 3D printed specimens behaved under compression. Due to the anisotropy of 3D FDM printed components, the out of plane direction was investigated in 3D printing reference system. In this context, the authors specifically focused on buckling phenomenon. A wide range of low slenderness ratio was considered, inside which the relation between the critical stress and the slenderness ratio was studied. An extensive experimental campaign was conducted: 10 different slenderness ratios were considered, and 10 specimens per each ratio were printed, tested and analyzed. The square prism geometry was used in this study. This choice limited the number of directions in which the buckling deflection could have happened. As a further advantage, it allowed the use of a single camera Digital Image Correlation system for buckling observation. Through this technique, the authors monitored the maps of the transverse displacement throughout the compression tests. In shortest specimens the transverse displacement map appeared to be symmetric with respect to the longitudinal axis throughout the test, with a single or a double barreling compression mode. In longer specimens the transverse displacement map kept symmetric up to the maximum load; a lateral deflection appeared right after. Analyzing the transverse displacement vs. compressive load curves, the authors determined the compressive critical loads. No significant differences arose among the critical loads in the considered slenderness ratio range. The authors evaluated the capability of classical analytical models for buckling critical load estimation in isotropic materials to predict FDM 3D printed PLA failures. The Linear Euler model, the Tangent Modulus theory and the Johnson's formula were considered. The compressive mechanical properties and the tensile ones were determined before resorting to the listed models. FDM 3D printed PLA proved to have an asymmetric behavior in tensile-compressive properties: stiffer in traction, more resistant in compression. When the tensile mechanical properties were used in the above described models, the estimation of critical loads was unsatisfactory. On the contrary, the Tangent Modulus theory gave satisfactory but conservative estimations when the compressive mechanical properties were used in it.

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