Structural failure during extrusion-based 3D printing processes

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ABSTRACT

This contribution studies failure by elastic buckling and plastic collapse of wall structures *during* extrusion-based 3D printing processes. Results obtained from the parametric 3D printing model recently developed by Suiker [1], among which closed-form expressions useful for engineering practice, are validated against results of dedicated FEM simulations and 3D concrete printing experiments, see also [2]. In the comparison with the FEM simulations various types of wall structures are considered, which are subjected to linear and exponentially-decaying curing processes at different curing rates. For almost all cases considered, the critical wall buckling length computed by the parametric model turns out to be in excellent agreement with the result from the FEM simulations. Some differences may occur for the particular case of a straight wall that is clamped along its vertical edges and subjected to a relatively high curing rate, which can be ascribed to the approximate form of the horizontal buckling shape used in the parametric model. The buckling responses computed by the two models for a wall structure with imperfections of different wavelength under increasing deflection correctly approach the corresponding bifurcation buckling length. Further, under a specific change in material properties the parametric model and the FEM model predict a similar transition in failure mechanism, from elastic buckling to plastic collapse. The experimental validation of the parametric model is directed towards walls manufactured by 3D concrete printing, whereby the effect of the material curing rate on the failure behavior of the wall is explored by studying walls of various widths. At a relatively low curing rate, the experimental buckling load is well described when the parametric model uses a linear curing function. However, the experimental results suggest the extension of the linear curing function with a quadratic term if the curing process under a relatively long printing time is accelerated by thermal heating of the 3D printing facility. In conclusion, the present validation study confirms that the parametric model provides a useful research and design tool for the prediction of structural failure during extrusion-based 3D printing. The model can be applied to quickly and systematically explore the influence of the individual printing process parameters on the failure response of 3D printed walls, which can be translated to directives regarding the optimization of material usage and printing time.

REFERENCES

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