Additive manufacturing of cantilever - from masonry to concrete 3d printing

P. Carneau[a], R. Mesnil[b], N. Roussel[a], O. Baverel[a,c,d]

[a] Navier, UMR 8205, École des Ponts, IFSTTAR, CNRS, UPE, Champs-sur-Marne, France
paul.carneau@enpc.fr
[b] École des Ponts ParisTech, Champs-sur-Marne, France
[c] ENSA Paris-Malaquais, Laboratoire Géometrie Structure Architecture, France
[d] ENSA Grenoble, France

Abstract

This paper describes an approach of a process-aware exploration of the design space of building components constructed by extrusion of cementitious material (or concrete 3d printing). In an attempt to broaden the geometries that are being printed today, and to build cantilevers, vaults and domes without using temporary support (thus adding data to the 3d printing cartography developed in [2]), we look back at construction techniques used in masonry structures, a more ancient additive manufacturing process. A detailed analysis is made of the strategies developed for masonry and largely described by Auguste Choisy in [1], such as corbelling techniques, Nubian vaults, or creation of pendentives and squinches to cite a few.

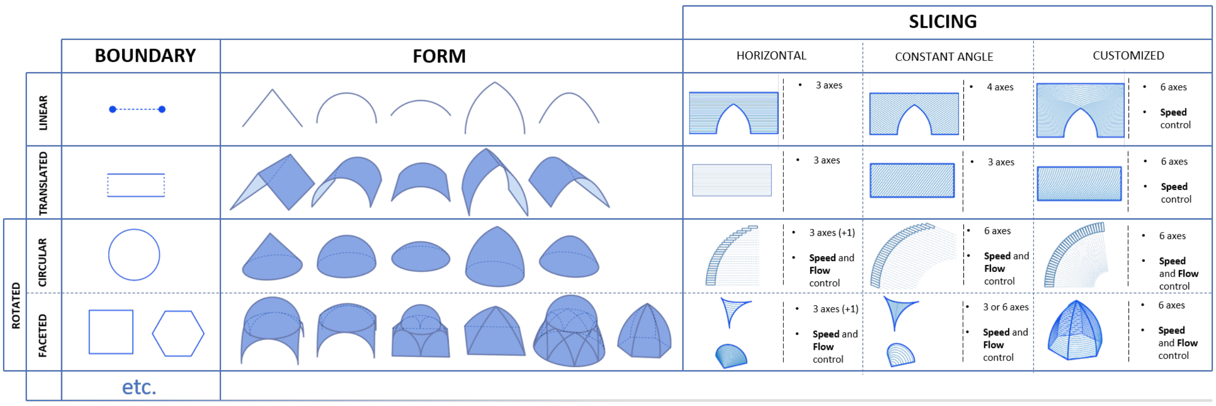

Figure 1: Framework of fabrication of 3d printed cantilevered structures inspired by masonry

We study then the potential of applying those strategies to concrete printing in terms of material, printing path, printing head orientation (depending on the degrees of freedom of the robot), and the targeted geometry which should get as closed as possible to the funicular of the weight of the object. This study exposes similarities between the two processes, like the advantage of orienting the layers normal to the global surface, and the discrepancies due mainly to the time constraint of extrusion between layers, governing the design of 3d printed structures, and the freedom provided by the use of the robot on the geometry control at the scale of the layer. The results are summarised in the table above (Fig. 1) and different cantilevered objects are eventually printed in our laboratory to validate the approach as shown in Fig. 2.

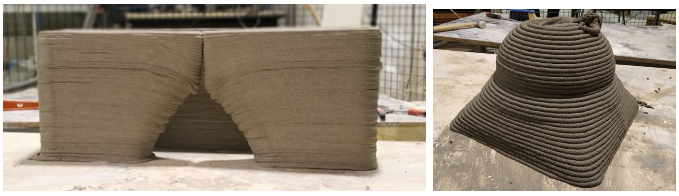

Figure 2: 3d printed arch using variable layer orientation (*left*) and dome on squinches (*right*)

References

[1] Auguste Choisy. *L'art de bâtir chez les Byzantins*. 1883.

[2] R. Duballet, O. Baverel, and J. Dirrenberger. Classification of building systems for concrete 3d printing. *Automation in Construction*, 83:247–258, November 2017.