# Mortar space truss pavillon with robotic extrusion

Romain DUBALLET*[,a], Nicolas DUCOULOMBIER*, Paul CARNEAU*; Léo DEMONT*, Romain MESNIL*, Olivier BAVEREL*, Jean-François CARON*

*Laboratoire NAVIER, UMR 8205, Ecole des Ponts, IFSTTAR, CNRS, UPE
6-8 Avenue Blaise Pascal, 77455, Champs-sur-Marne, France
romain.duballet@gmail.com
[a] XtreeE, Le Manille,18-20, rue du Jura, CP 40502, 94623 Rungis, France

We propose a space truss pavilion for IASS 2019 Manufacturing materials competition. It is made of reinforced mortar, thanks to a 3D printing process developed in our lab that mixes mortar extrusion and expanded polystyrene cutting. The extrusion process includes fiber reinforcement, allowing for tensile strength and ductility for the structure.

**Pavillon characteristics**

The pavillon is a curved wall, standing on an overall surface of 1m x 3m and with a 2.2 meters height. The bars have a diameter of 2.5 cm and the total weight is of 180 kg.

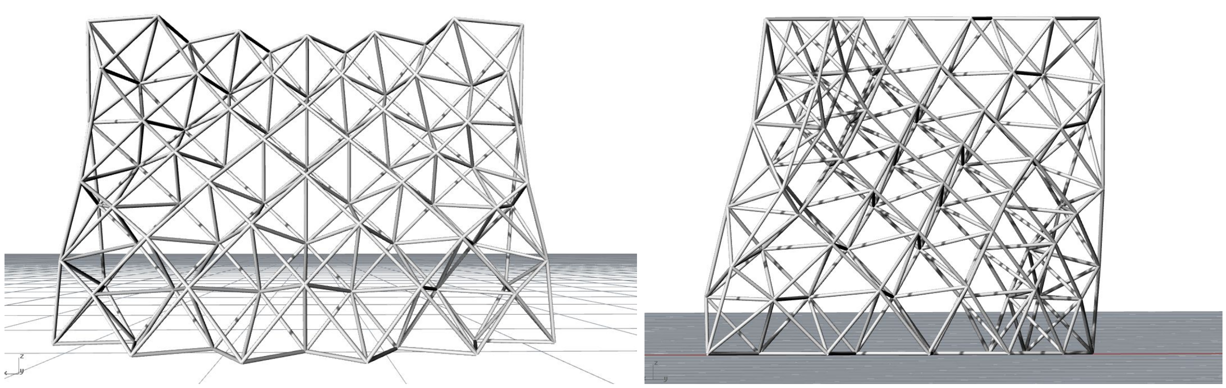

Figure 1 : Pavillon proposal

**Truss printing process**

The printing process has been described in last IASS conference in Boston by R. Duballet [1]. It consists in fabricating EPS blocks with a hot wire cutting process and then to progressively assemble them so they can support the mortar extrusion. Once assembled the blocks also protect the curing mortar. The mortar being printed on the blocks, it progressively acquire mechanical strength and become able to bear its own weight as well as the additional matter above. Yet the blocks support the printing, reducing the need for early age resistance for the mortar. On figure 2 are shown prototypes, the blocks alone one the left, and the truss inside on the right. Please note that this prototype has 5 cm bars, twice the considered diameter for the pavillion.

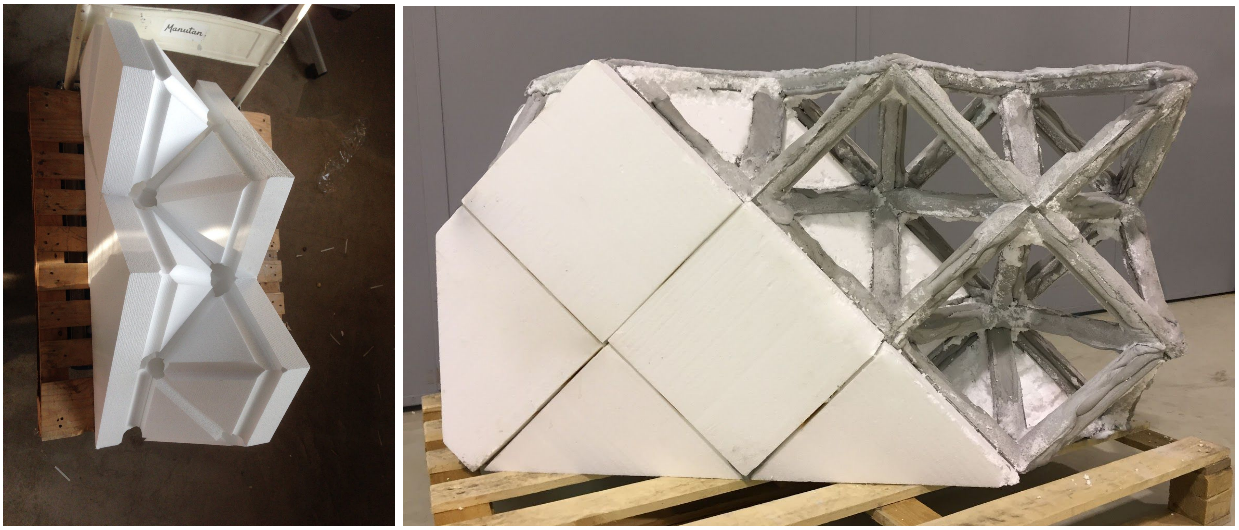

Figure 2 : Truss prototypes

**Structural checking**

A structural analysis was performed on Karamba 3D, in the same spirit as in [1], but this time taking reinforcement into account. The load cases, outside of self weight, are an horizontal pressure and a static horizontal point load to mimic an act of vandalism. The maximum tensile stresses in the structure does not go over 13 MPa, and they are the critical failure to check, compressive stress failure and buckling are away from the loading spectrum.

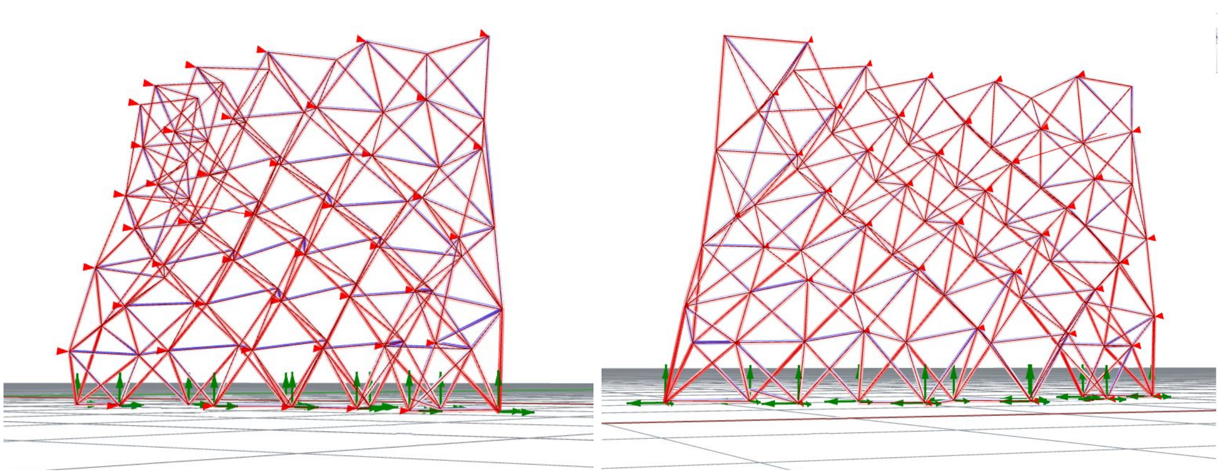

Figure 3 : Structural anaylis performed with Karamba 3D

**Reinforcement strategy**

Reinforcement is an open problem for concrete printing. Numerous questions need to be investigated to properly identify how it should be managed depending on the shape, the stress analysis or the process. In our proposal, we make a full use of the truss typology of our structure. Each bar will essentially work in tie or compressive stress. Therefore, reinforcement should act in the bar direction, which is also the printing direction. A recent study shows the potential of fibre alignment in fibre reinforced portland paste, even with a small amount of (1%-3%) in high performance matrix [2] and the extrusion process is known to align fibre. Preliminary application to additive manufacturing is promising [3]. Our team has developed a process that can incorporate 1-5% long fibres in a UHPC premix. Resulting material tensile stress strength in the printing direction is still to be tested, but should be much larger than 13 MPa. It is aimed to be around 50 MPa. This process will be then used to manufacture the structure and insure the structural integrity of our proposal.

**Transport**

Our proposal will not satisfy the transport rule for the competition for it will be made in our lab. We understand that this rule reflects a design cleverness demand, to limit environmental impact of transportation, a very important topic for the building industry. This manufacturing method is suited for in situ application, and we feel it would satisfy the intention behind the rule, since in theory no transportation would be necessary except for dry concrete. That is why we kindly ask the jury to allow us to derogate from the transport rule only.

**References**

[1] R. Duballet, O. Baverel, J. Dirrenberger, “Space Truss Masonry Walls With Robotic Mortar Extrusion”, *Structures*, (in press), 2018. https://doi.org/10.1016/j.istruc.2018.11.003

[2] M. Hambach, H. Möller, T. Neumann, et D. Volkmer, “Portland cement paste with aligned carbon fibers exhibiting exceptionally high flexural strength (> 100 MPa)”, *Cement and Concrete Research*, vol. 89, p. 80‑86, nov. 2016.

[3] M. Hambach et D. Volkmer, “Properties of 3D-printed fiber-reinforced Portland cement paste”, *Cement and Concrete Composites*, vol. 79, p. 62‑70, mai 2017.