**3D Printing Set to Transform the Construction Industry**

It’s often claimed that 3D printing – known in the trade as “additive manufacturing” – will change the way we construct structures and buildings, from architecturally-driven geometric forms to functional, low-cost housing and emergency shelters. Additive manufacturing uses a combination of materials science, architecture and design, computation and robotics. This manufacturing technology aims to shorten the supply chain in the construction industry through the autonomous production of building components directly from digital models with a minimum amount of human intervention and temporary works. The key for its successful development and implementation is industry stakeholder collaboration involving materials science, architecture/design, computation, and robotics. There are fundamental interdependencies between the materials, the printing technologies, and both the scale and geometric complexity of any printed structure. For a given project, by understanding and optimising the mix design for fresh rheology of materials and providing sufficient adhesion/cohesion of the layer interface, the designer can incorporate geometric complexity and aim to minimise temporary works.

**Printable Materials**

There are many types of printable materials, but the most relevant for large-scale construction is concrete (i.e. cementitious based composites with small aggregate size). Printable feedstocks are typically made from a combination of bulk materials – such as soil, sand, crushed stone, clay and recycled materials – mixed with a binder such as Portland cement, fly ash or polymers, additives and chemical agents to allow the concrete to set faster and maintain its shape, as well as other constituents such as polymer fibres to control cracking. The setting time of the paste, the shape stability of first few layers and the interlaminar bonding between the layers, as well as the bulk behaviour of the materials must be thoroughly researched for a range of structural and environmental conditions to achieve a comprehensive understanding of the printable materials, curing mechanisms with the selected admixtures, temporary stability and structural performance. Focus should be on the fresh rheology and chemical additives/agents to optimise: 1) material formulations for reliable extrusion and, 2) accurate and consistent deposition in the printer system (see Fig. 1).

**3D Printed Structural Components**

The development of effective 3D printed structural load bearing components and the issues around reinforcing elements, their stability, strength and performance under gravity, lateral and environmental loads present a critical area of research for material scientists and structural engineers. The nature of 3D printing as a construction method is not suited to the use of conventional discrete reinforcement to achieve tensile strength and ductile failure mechanisms. Whilst this can sometimes be solved by combining 3D concrete printing with conventional casting and reinforcing techniques, this approach often does not offer tangible benefits over traditional construction methods. Alternative strategies which have been explored for the introduction of reinforcement include direct entrainment of metal cables in the concrete extrusion during printing, and the addition of fibres into the concrete mix.

The ability to form complex geometries enables the use of inherently strong and stable forms which can sustain loads, such as truss-like structures and double curvatures (see Fig. 2), however it is often the orientation and temporary stability of the structure during printing which is the limiting factor in application of more adventurous structural forms. Other options could include the development of 3D printed modular block systems that are uniquely tailored to specific geometries.

It is apparent that further collaborative research and development is needed to develop efficient structural systems that work harmoniously with specifically engineered materials to maximise the benefits of 3D printed technology and bring value to the construction market place.

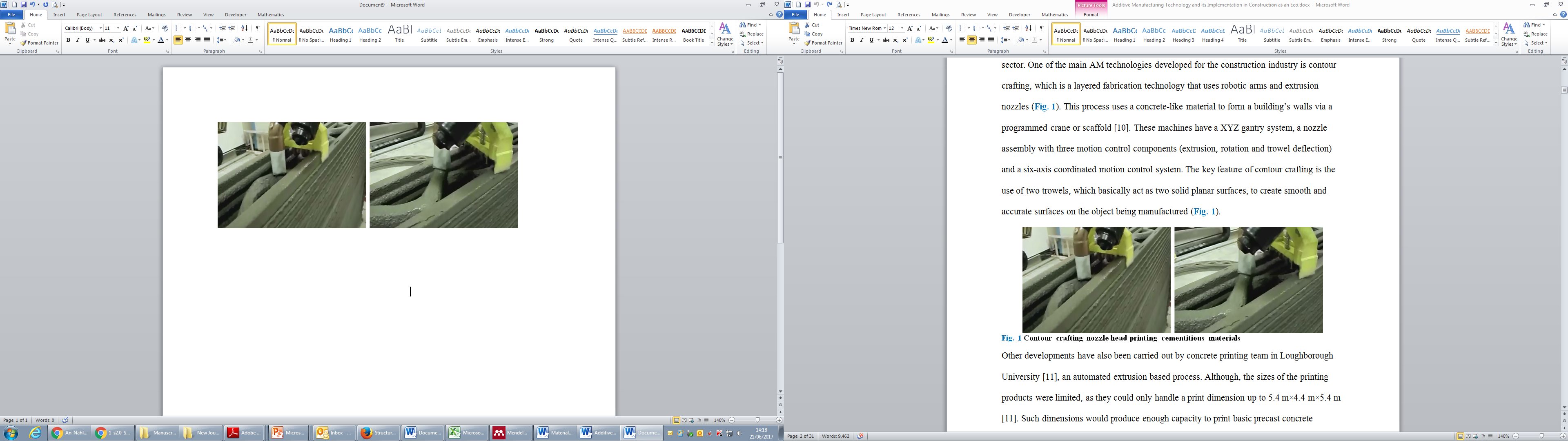


Fig. 1 - Contour Crafting nozzle head printing cementitious materials [1]

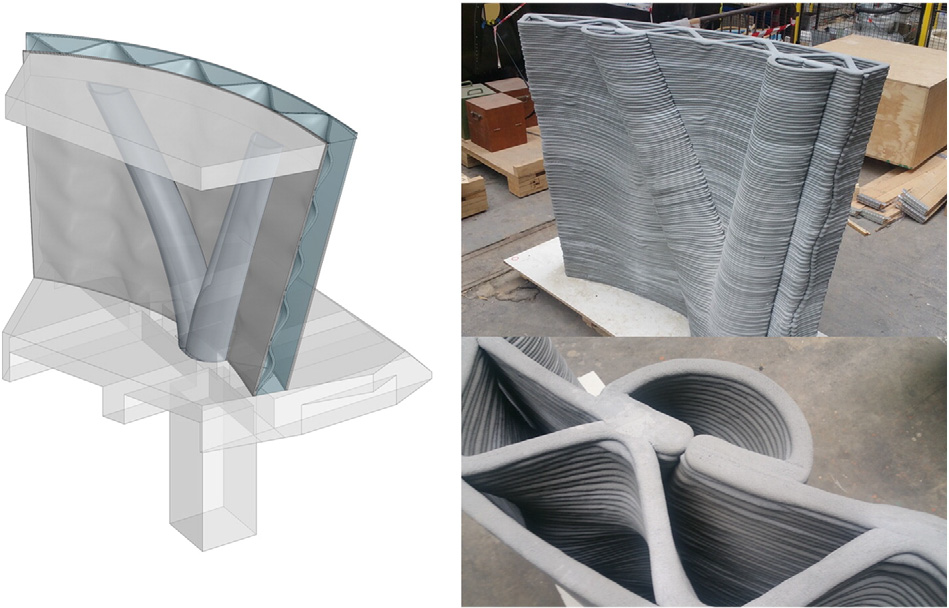
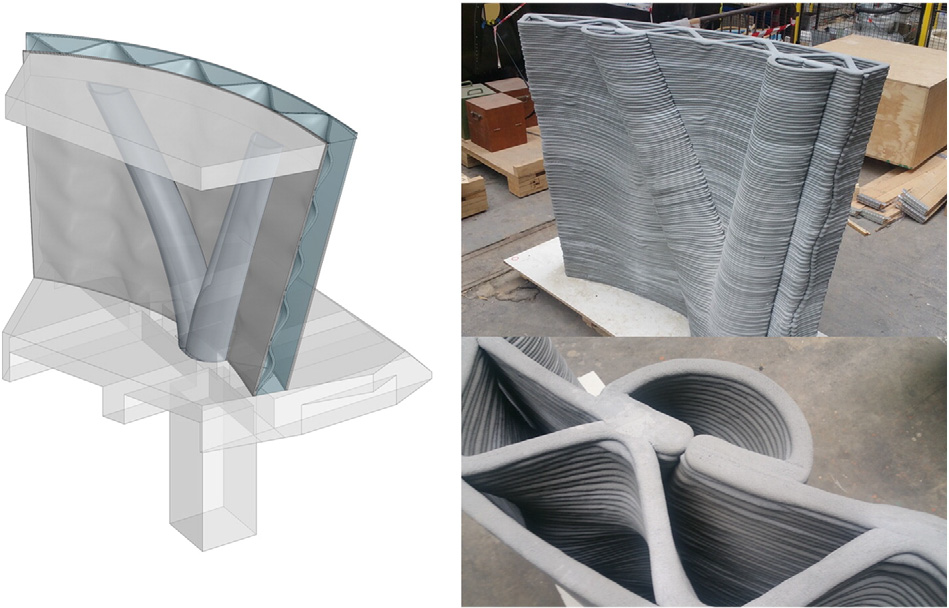


Fig. 2 The 3D printed concrete wall by Gosselin et al. [2]

**References:**

[1] S. Ghaffar, J. Corker, M. Fan, Additive manufacturing technology and its implementation in construction as an eco-innovative solution, Automation in Construction 93 (2018) 1-11. https://doi.org/10.1016/j.autcon.2018.05.005

[2] C. Gosselin, R. Duballet, P. Roux, N. Gaudillière, J. Dirrenberger, P. Morel, Large-scale 3D printing of ultra-high performance concrete - a new processing route for architects and builders, Materials & Design 100 (2016) 102–109. doi:10.1016/j.matdes.2016.03.097.