Rheological Control of Concrete for 3D Printing

Mary Lilliman (M.Lilliman@lboro.ac.uk)

Simon Austin, Steve Edmondson, Steven Christie

School of Civil and Building Engineering

Loughborough University

Concrete is integral to some of the most well-known buildings in the world, including many of those that have been standing since Roman times. However, traditionally concrete buildings are built using formworks that are expensive and time consuming to build and that only allow for structures with controlled geometries. To build concrete structures with greater architectural freedom, better build quality and at a lower cost (both at an economic level and with regards to injuries to construction personnel) alternative construction methods need to be sought. In light of this, construction-scale additive manufacturing processes are becoming a more and more viable alternative to traditional construction methods.

Additive manufacturing processes have been successfully used in the manufacture of medical devices, and in the automotive and aerospace industries. Probably the best known of these techniques is fused deposition modelling whereby molten thermoplastics are extruded onto a surface, allowed to set and then additional layers extruded on top. If the thermoplastic is replaced with mortar, the process is very similar to the concrete printing technique developed at Loughborough University.(Lim et al. 2011)

In order for this technique to work the rheology of the mortar has to be carefully controlled: it must be able to be pumped and then each bead must be able to hold its shape when extruded during the printing process.(Le et al. 2012) A further complication is that the bead must hold its shape when another bead is printed on top of it. Good inter-layer adhesion must also be maintained, to ensure maximum strength of the concrete structure being built. Therefore a range of different additives must be used in order to carefully balance these requirements. Calculating the proportions of additives to be used is a balancing act. For example, too much retarder could lead to a mortar that doesn't set, or takes a long time to set, which is not ideal if many layers are to be printed as quickly as possible. Not enough retarder will lead to setting in the pipes, pump and print head, which will mean delays while these are cleaned, and possibly extra cost if replacement is required.

Getting the mortar to have the required rheological parameters, for as long as possible, and at as low a cost as possible, is a key research area for unlocking the full potential of 3D concrete printing.

Le, T.T. et al., 2012. Mix design and fresh properties for high-performance printing concrete. *Materials and Structures*, 45(8), pp.1221–1232. Available at: http://www.springerlink.com/index/10.1617/s11527-012-9828-z [Accessed November 5, 2013].

Lim, S. et al., 2011. Development of a viable concrete printing process. In *Proceedings of the 28th International Symposium on Automation and Robotics in Construction (ISARC2011)*. pp. 665–670.