A bridge to the future

Civil engineering: 3D printing technologies are being adapted for use by the construction industry to create buildings and other structures

INDUSTRY continues to find multiple uses for 3D printing, especially in rapid prototyping and for high-value, low-volume production in businesses such as aerospace. But one of the limiting factors is the size of the 3D printer itself: objects need to fit inside the machine to be built up layer-by-layer. Now some 3D printing systems are moving, so to speak, out of the box. That way they can be scaled up and used by the construction industry to print buildings and other structures.

A Dutch startup is even planning to print a bridge. MX3D, a company spun out by a furniture-maker, will use an external 3D printing system it has developed to print a footbridge across a canal in Amsterdam, once the city authorities have identified a suitable site and granted the necessary construction permits. The bridge (illustrated above) would have a span of up to 15 metres (49 feet) and be printed in steel in one go, rather than assembled from prefabricated sections.

For now the most common method of printing metal structures is selective laser melting, sometimes called laser sintering. This takes place inside a machine—the biggest is about the size of a car—which works autonomously. The process spreads a layer of metallic powder onto a base and then uses a high-powered laser to fuse particles together in the shape required for the first layer. The base is then lowered, a new layer of powder added and the process repeated, melting the second layer onto the first, and so on until the object emerges.

Each stage is controlled by computer software, which takes "slices" through a virtual version of the object and uses that information to run the printer. "Without such software, it would be impossible to print a complex bridge like this," says Tim Geurtjens, MX3D's co-founder.

The MX3D system employs industrial robots to build structures additively. The robot's arms are fitted with specially developed welding heads. Instead of producing blobs of molten metal to join parts together, the robots, in effect, keep welding—adding one drop of weld on top of another, and "drawing" out long rods of steel. To print the bridge, the robots will either sit on it, printing their own support structure as they go, or operate from barges moored on the canal below. Either way, the process is likely to take about three months. The project is being supported by Autodesk, an American producer of design and engineering software; Heijmans, a Dutch construction firm; and ABB, a Swiss-based maker of industrial robots.

The bridge will have a strong filigree-like structure that has been "optimised" by engineering software into its most efficient shape. This optimisation process (see box on next page) is becoming increasingly common in manufacturing because it results in lighter parts that require less materials, but remain as strong as those they replace. However, the designs often cannot be realised with conventional methods and can be made only with a 3D printer.

It is yet to be decided what type of steel to use to print the bridge. It could, says Mr Geurtjens, be standard or stainless steel. A "weathering" steel is also a possibility. This is a mixture of alloys which quickly forms a coating of brown oxidation to give a "rusty" look. Apart from the ageing effect, the coating inhibits further corrosion, in effect obviating the need for painting.

Homemaking

The use of 3D printing in construction is "no longer a novelty" in providing customised interior-decoration features, lighting effects and furniture, according to a recent report by Lux Research, a Boston consultancy. Interest is growing in printing large structural parts or even entire buildings because of the opportunities to save construction time and achieve a greater flexibility in design, the report found. But challenges remain, in particular developing printable construction materials and meeting building codes.

A number of collaborative projects, besides MX3D's bridge, could provide answers. Skanska, a giant Swedish construction company, is working with Loughborough University in Britain to develop a high-performance concrete-printing robot. A group of 3D-printed office buildings are planned for the Museum of the Future, which is being built in Dubai. And in America, Neri Oxman and her colleagues at the Massachusetts Institute of Technology's Media Lab are investigating a variety of 3D printing systems for construction, including one which uses swarms of small robots that extrude fast-setting materials to fabricate large structures.

Winsun, a Chinese company, has built a number of 3D-printed houses, including a five-storey apartment building. It uses a six-metre-high 3D printer to ooze a fast-drying paste made from a mixture of cement and recycled waste from construction sites. Under computer control, the giant machine deposits the paste layer-by-layer to create walls and other prefabricated sections of the building. These parts are then joined together at the construction site using steel reinforcing bars.

Printing complete buildings on site is the ultimate goal. A self-contained process to do that is being developed by Behrokh Khoshnevis at the University of Southern California. Called contour crafting, the process uses robots to print an entire building using locally gathered materials. Dr Khoshnevis is working with NASA on the project; the American space agency sees 3D printing as a way to construct accommodation and other infrastructure, such as landing pads and roads, on the Moon and Mars. The enormous cost of sending construction materials into space would be avoided by extracting useful stuff, including water, from the lunar and Martian surfaces. This would be mixed to produce a building material that could be deposited by the robots to form structures.

Instead of squeezing materials out like piping icing on a cake, contour crafting also shapes them with a pair of trowels next to the extrusion nozzle. It allows a greater variety of shapes to be formed. The printer can also produce the internal features of a building, such as tables and chairs. Dr Khoshnevis believes the technology could have a role back on Earth building structures in remote and hostile regions.

NASA is not alone in thinking that 3D printing may be the only practical way to build beyond the Earth. Foster + Partners, a London firm of architects, is working with the European Space Agency on a different system. It would use a rocket to transport to the Moon a tubular module that would unfurl to provide a domed support over which a robotic 3D printer would fabricate a protective shell using lunar material.

It will be some time before the multiplicity of skills used by labourers on a building site are replaced by a 3D printer. But in construction, as in other industries, the robots have begun to march. ■

"A Bridge to the Future," *The Economist*, September 5, 2015.