Winsun

Demonstrating the Viability of 3D Printing at Construction Scale
The challenge

Construction today is deeply entrenched in traditional processes that are unproductive and uneconomic.

Construction has remained fundamentally unchanged throughout history. Vertical projects still require workmen to add layers of building materials, either wood, bricks, or concrete, one on top of the other. This approach is ill-suited to the modern age in three key respects.

First, it keeps productivity low. Just when a productivity boost is desperately needed: our era of rapid urbanization demands a surge in affordable, high-quality housing and infrastructure. Over the last 50 years, productivity in construction has barely risen, while most other industries have seen tremendous gains.

Second, construction today is heavily reliant on the skills of individuals. In many developed countries, such skills lack prestige and demographic change has reduced the size of the workforce. Accordingly, labour costs are high and the demand for new construction cannot easily be met. In many developing and emerging countries, construction projects often proceed with a low-skilled workforce and the quality and the useful life of buildings is often compromised as a result.

Third, traditional construction methods produce large amounts of waste, noise and dust, in defiance of modern environmental standards.

The idea: 3D Printing

Construction units such as walls or columns can be prefabricated off site by means of 3D printing, which has the potential to be used for other applications in the future.

Yingchuang Building Technique (Shanghai) Co. Ltd, or Winsun as it is known, started off as an advanced building materials supplier. The company was specialized in complex interior decor (for opera houses, for example) and non-standard exterior structures. It has more than 125 national and international patents across its various product lines.

The company has made a point of continuously enhancing its materials and moulding technology. When it reached the limit of what is possible with traditional materials and technology, it ventured into large-scale 3D printing – a move aimed at further improving its production processes, increasing its design options and reducing waste.

The company’s entry into 3D printing began as early as 2005, with the invention of a spray nozzle, one of the key components of its first, and still widely used, 3D printer. The spray nozzle was used to experiment with cement and other advanced materials. Driven by Chairman and Founder Ma Yihe, a materials engineer, the company kept refining the technology and the materials composition to improve outcomes, enable material collection and output control. In addition, in 2008, the company developed the first continuous 3D printer with integrated collection, data analysis of materials and a printing-output control system. A third major achievement was setting up the world’s largest 3D-construction printer, some 10 metres wide, 6.6 metres high and 150 metres long.

In 2013, thanks to its expertise in materials and experience, Winsun succeeded in 3D-printing a residential house for the first time and more specifically, a batch of ten houses, making global headlines. The technique uses a special ink made of cement, sand and fibre, together with a proprietary additive. In a kind of pre-fabrication approach, the company prints the walls in the factory and assembles the building on site.

The basic process begins with the client’s design (in the form of a Computer-Aided–Design (CAD) 3D model). The spray nozzle adds the material layer by layer, each layer being between 0.6 and 3 centimetres thick, until a wall of the desired shape and size is completed. The technology is able to produce hollow structures, accommodate piping, wiring and insulation as specified. The finished wall parts are transported to the construction site, installed on traditional foundations and reinforced with traditional steel structures or cement in keeping with regional building regulations. The unpolished walls can then be supplemented with various fittings or finishes according to customer preferences.

In principle, the applicability of the technology seems unlimited. Winsun is already developing prototypes for use in infrastructure assets, such as columns for bridges or pipes for water systems. It will no longer be necessary to erect temporary formwork on the construction site. Instead, 3D-printed moulds (“printed formwork”) are installed and filled with reinforced concrete. Winsun also has plans to apply its technology to the construction of high rises (buildings of 100 metres or more), by using a mobile printer that could print directly on the construction site.
The 3D-printing revolution is cutting construction times and costs in a significant way, increasing quality and environmental standards and offering a glimpse into the imminent transformation of the industry.

By using 3D printing technology, Winsun has increased productivity and made it possible to realize significant cost savings. A standard house can now be built for about $30,000.

In particular, by printing the walls in a factory prior to assembling the building on site, Winsun can greatly increase the speed of construction. New buildings can now rise one storey per day, which is much faster than standard construction processes. For example, construction of a two-storey 1,100 sqm mansion took one day of printing, two days of assembly, with internal bar structures erected in advance, requiring three workmen only.

Winsun’s technology is also far more environment-friendly than conventional reinforced concrete. In keeping with the circular economy or closed-loop concept, it can source 50% of the ink material from construction waste or mine tailings. What’s more, the printing process minimizes waste in the actual construction process and Winsun’s modular dry construction method is dust-free. Overall, the Winsun approach saves 30-60% of material relative to traditional construction. So, the technology has particular appeal for advanced economies, where labour costs and environmental standards are high.

For developing and emerging countries, this technology offers a further advantage. It can mitigate the shortage of skilled construction workers and improve the quality and accuracy of the end product.

One final benefit is that Winsun’s technology enables greater freedom of design. Clients now have a wider range of design options. Buildings can now be tailored to individualized customer needs and specialized applications and applications, which to date had only been possible with costly and labour intensive formwork.

Since 2014, when it printed its first ten houses, Winsun has developed a number of prototypes to showcase its technology, including a mansion of 1,100 square metres, a six-storey apartment building, an ancient-style traditional Chinese house, a wave-shaped house and smaller movable buildings.

Arguably the most important showcase project is the company’s first 3D-printed office. Recently opened in Dubai for the Dubai Future Foundation, the building was printed in Suzhou, cut in pieces for shipping and transported to Dubai, where it was assembled and finished within a couple of weeks. Compared to traditional on-site construction, the Winsun process saved about 80% on construction costs, 60% on labour costs and 60% on waste. Winsun partnered with the international design and engineering firm Gensler on the project for structural engineering. Interestingly, Winsun is also the supplier of Dubai’s 3D-printed “Smart Palms”, which provide not only shade, but also decentralized WiFi and charging stations.

However, Winsun has now advanced beyond testing and prototyping and it is already scaling up its technology. To date, the company has sold more than 100 houses of various types, many of them in Dubai, the largest with a floor space in excess of 5,000 square metres. The company is also negotiating with the Egyptian and Saudi Arabian governments over the construction of thousands of affordable homes, as well as a local Saudi factory. The prototype for a simple affordable house, developed together with design and engineering specialist Gensler, has already been marketed in Africa. Here as elsewhere, the ideal delivery model for Winsun is based on turnkey contracts, whereby the company leverages its 3D printing technology to the full, for the exterior, structural component and for the interior, including decor and even furniture.
The barriers to innovation - and solutions

Scepticism and lack of knowledge about the potential of 3D printing in construction among designers, architects and developers requires Winsun to educate the market via prototypes.

The main barrier facing this transformative technology is the scepticism of designers, project developers, governments and end-users. For those with a conservative mindset, it seems just too good to be true that high-quality buildings can be constructed via 3D printing.

In response, Winsun has been investing heavily in producing prototypes for various applications to showcase the new technology and demonstrate its technical feasibility. The company realized very early on that it can win clients over by inviting them to visit the factory so that they see the prototypes with their own eyes. To show the viability of 3D printing for high-rise construction, the company is going to buy land near Shanghai and erect a demonstration building more than 100 metres high and with 200,000 square metres of floor space.

Designers today are still-unwilling or unable to recognize the potential of 3D printing. To overcome this resistance, Winsun is collaborating with architects at the Cornell Design Institute, Tongji Design Institute or Jiaotong University and educating them to incorporate the new possibilities of 3D-printed design into their work. In the future, Winsun also plans to set up a cloud-based platform to connect the company and its clients to designers. Designs will be uploaded on the platform for clients to review, make an initial choice and request a virtual model or printed prototype to be viewed in an exhibition centre. Once approved, the final design is sent to the 3D printing factory. Winsun is also raising awareness and creating enthusiasm by training architects with its textbook on 3D printing in architecture.

Another major impediment to scaling up Winsun’s technology is the lack of explicit regulation for 3D printing. Most building codes and procurement standards simply make no mention of 3D printing technology and in response, Winsun is pursuing a two-pronged approach. First, it creates a “minimum viable product,” combining its 3D-printed building components with traditional beams, columns, insulation and structural fillings to comply with existing building codes in China or elsewhere. (The codes generally set standards for reinforced masonry up to a building height of 66 metres and for concrete above 66 metres.) Second, Winsun is actively setting standards and shaping the regulatory environment for 3D printing, working closely with China’s national construction department to amend existing building codes that are still focused on classic brick and mortar masonry. Thanks to this collaboration, construction standards and building codes for 3D printing construction are evolving.

In summer 2016, the Chinese State Council and Ministry of Housing and Urban Development indicated that they will actively study 3D printing construction technology and begin to adopt it in the real estate market.

Given industry scepticism and environment restrictions, Winsun needs to select its markets wisely. Germany is a key target and a promising launch pad for Winsun’s global expansion, in view of its high environmental standards, abundant recycling of construction waste and wide experience in manufacturing. Other promising markets are Australia and the Middle East, Saudi Arabia and Dubai, a hub for 3D printing, would be strategic partners. Dubai’s objective is to gain a 25% share of 3D printing in construction by 2030.

To exploit the technology fully and gain maximum benefit from scaling up, Winsun needs to produce large volumes. Accordingly, the company has developed an ambitious plan for expanding its 3D printing technology nationally and globally via so-called dream factories. These are approximately 100 franchise factories (owned and operated by partners), located throughout China, that recycle materials locally from urban waste and produce 3D-printed components for 5,000,000 square metres of construction per year. These dream factories would also supply ink to a number of smaller production capacity “Ant Factories” that would print prototypes for clients and serve as local exhibition spaces for pre-ordered designs. The first dream factories in Shanghai is now in the planning stage as is a 3D printing creative park (exhibition space) in Baotou. Winsun will continue its R&D efforts to rapidly scale up production, while also forging close ties with local partners.

Another Winsun strategy for scaling up is through partnerships. The company president, Ma Yihe, aims to form a 3D-industry alliance with Chinese and international real estate and construction companies, thereby securing additional capital (equity investment) for the company’s global expansion programme. Winsun will also form partnerships with mining firms to access their mining residuals.

Some barriers to pre-fabrication cannot be overcome easily and will need a workaround. In remote regions with poor road infrastructure, building sites might prove inaccessible to large pre-fabricated components transported from distant factories. So, Winsun is studying the potential of using smaller, mobile printers to operate directly on site.

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If you do not believe it is possible, we will print a prototype.
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Ma Yihe, President and Chief Executive Officer, Yingchuang Winsun, People’s Republic of China
Lessons Learned

- **Shape the regulatory and market environment**
  Being at the forefront of 3D printing in construction, Winsun is actively shaping the regulatory environment, working closely with construction departments and regulators on regional and national level to adapt and enhance building codes.

- **Develop minimum viable products early on to demonstrate the power of technology and stake a claim to the market**
  In the absence of specific regulation, Winsun created a viable and adaptable prototype, which once adapted by means of steel structures and insulation material, was considered compliant with existing regional building codes.

- **Reduce scepticism by providing vivid proof of concepts and dispel diffidence through training**
  In the face of widespread scepticism among designers, developers and clients, Winsun has energetically set out to educate the market and demonstrate the viability of its technology by creating impressive prototypes and actively publicizing them. Moreover, the company liaises with architects and designers to train them and instill the 3D printing approach into their design thinking.

- **To extend your reach, seek partners – but make sure they are the right partners**
  Innovative technologies often struggle to gain acceptance. Winsun is putting considerable effort into identifying the most promising markets, picking optimal partners to leverage the technology’s benefits and expanding its target clientele.