

## **3D PRINTING IN CONSTRUCTION: BENEFITS AND PROBLEMS**

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### **Introduction, background and significance of 3D printing technology research.**

Traditional construction methods range from schematic design, architectural design, structural design and other sub-disciplinary design, to the construction of drawings, and then to the final completion of acceptance procedures are complicated, requiring a large number of human and material resources, and a long period of time to finally complete a building works. 3D printed building, only need to design a good model into the computer, with large 3D printing equipment, you can directly print out the building in a short period of time at once.

The concept of 3D printing can be traced back to 1860's Photosculpture and 1892's Topography. This technology has developed rapidly since the 1980's with the invention of various practical 3D printing technologies and 3D printers. This kind of printing is able to customize products to the owner's requirements based on data and modeling. In traditional industry, to manufacture something, a mold must first be opened and later cast to produce the final product. But 3D printing eliminates these complicated processes, the use of «mold» is actually the computer data, design and development staff with computer design model will be processed after the completion of the graphic information, and the processed data sent to the 3D printing machine, the printer in accordance with the established route of rapid prototyping.

3D printing technology as a rapidly developing additive manufacturing technology, coupled with the fact that in recent years. This technology has received extra attention, rapidly developed and applied and from technical personnel in various industries. 3D printing technology for construction projects is essentially an advanced automated construction technology with the following potential advantages: saving labor input,

reducing consumption of auxiliary materials, making the construction process safe and clean, building complex shapes at low cost, accelerating the construction product development cycle, and enriching the technical path of construction industrialization.

Traditional construction technology and 3D printing technology, compared with the amount of manual input, long construction cycle, heavy environmental pollution, serious waste of resources, prone to safety accidents, and produce more construction waste.

Therefore, this article aims to discuss how 3D printing is currently used in the construction industry and how it can be deepened and expanded to solve some of the problems that are difficult to handle with traditional construction technologies. By covering all aspects of the construction cycle and using actual cases, the feasibility of introducing 3D printing into the construction industry is discussed, while problems with existing applications of 3D printing technology are pointed out and improvement methods are proposed.

#### **Research methodology.**

The research method applied in this paper aims to briefly elaborate the concept of 3D printing technology, and its feasibility of application in construction engineering based on the application of this technology in construction engineering. Consider the existing examples and ideas of 3D printed building applications, and provide an outlook on the prospect of 3D printing technology applied in construction engineering through the analysis of the mechanical properties of 3D printed structures. The study of related literature and practices in China and abroad, as well as application methods, materials, and other aspects of 3D printing construction technology are discussed.

The advantages and disadvantages of 3D printing technology and the way it is used are analyzed through the study and analysis of actual construction cases in China and abroad.

Depends on the research, advantages and disadvantages of study and factual application on 3D printing in construction technology, authors would be concluded about research and new approach to solve some problems in this area.

Application of 3D printing technology in the construction industry.

Today's research shows 3 main application of 3D printing in construction phase:

### *Application in the pre-construction stage.*

Using 3D printing technology can intuitively and completely show the whole construction project. Everything depends on pre-construction systems and models. Regarding this system, in the design stage, every detail, every item and every link may have an impact on the quality and result of the building, and if the design is not reasonable, serious consequences are likely to occur. Every detail of building, construction model, materials, construction period and process would be planned before construction and would be programmed for printer in this stage. The printer program would show us 3D model in design and realization, its time laps and realization period and exact time for finishing project.

### **Application in the construction phase.**

In different building construction processes, as the building project unfolds, the auxiliary design functions of 3D printing models are applied, such as the processing of the subtle parts of the building entity, the embodiment of architectural style, such as the detailed interior and exterior decoration of the choice of materials, decorative style, the furnishings and decorative pieces of the entity's internal pattern, 3D printing can directly complete the construction of these auxiliary and structurally complex parts, so that the entire building content looks richer and more detailed.

In 2016, Apis Cor printed a 38 m<sup>2</sup> habitable house on site in a small Russian town in just 24 h. During the construction process, the exterior walls were filled with polyurethane filler and insulation for insulation, and reinforced glass fibers were placed to keep the house strong, all using 3D printing technology (Fig. 1).

### *Application in the later stages of the construction industry.*

In post-construction applications, 3D printing is often used to express the results of construction projects. 3D printing has a great practical value in the later beautification and maintenance of the building, in terms of building maintenance. This technology can be done more effectively and conveniently, while maintenance through human labor may consume a lot of time; so in this regard can save labor costs, as well as time costs, etc. 3D printed trim can express the complex overall structure, in the case of personalized and special occasions applications.



Figure 1. 3D printing house in Russia by Apis Cor company, Russia

### **Current 3D Printing systems in the construction industry.**

#### *Extrusion Curing Printing.*

Extrusion curing printing is a printing process in which a gel-like material is extruded from a nozzle and then built up in layers to a desired height. Some of the more representative extrusion curing printing processes are *contouring process* and *concrete printing*.

*Contour process:* Contour Crafting is an architectural additive manufacturing technology proposed by the research team of Behrokh Khoshnevis, a professor of industrial and systems engineering at the University of Southern California, in 2001. The hardware device for the contouring process consists of a giant three-dimensional extrusion machine for materials such as mortar mix, which prints precise, smooth building components by stacking the mix in layers and using a nozzle with a spatula. In the case of printed walls, for example, the contouring process prints the outer contour of the wall first, then the internal contour of the wall to form a truss-like structure, followed by reinforcement, and then finally backfills the wall cavity with cement material and insulation material to form the overall structure or component. During the printing process of the contouring process, the spatula near the nozzle simultaneously smoothed the outer surface with each layer of material sprayed and squeezed to ensure a smooth and flat surface of the components. After years of research and development, the contouring process has the tech-

nical possibility to automate the construction of large building components or even whole buildings using very little material [1].

*Concrete Printing:* Concrete Printing, also known as freeform construction, is a 3D printing technology for buildings introduced in 2005 by a team led by Professor Lim S of the Innovation and Construction Research Centre (IMCRC) at Loughborough University, UK. The core process is a concrete spray extrusion layered construction method, specifically based on the extrusion of cement mortar and the solidification process of the material itself, and adding a layer of reinforcement mesh for each layer of material printed, until the overall component is printed and the vertical reinforcement is implanted. Concrete printing technology has a higher 3D degree of freedom and a smaller resolution of the slurry deposition, thus providing better control over the internal and external geometry of the printed component. Concrete printing technology typically prints in sizes larger than 1 m, and in the last few years has developed the ability to print large components (2 m x 2 m x 2 m).

*Selective Bond Curing Printing.*

Selective bond-curing printing is the process of selectively bonding and curing powdered materials layer by layer with an adhesive to build. The process of building a solid. One of the more representative selective bond-curing printing processes is D-Shape printing.

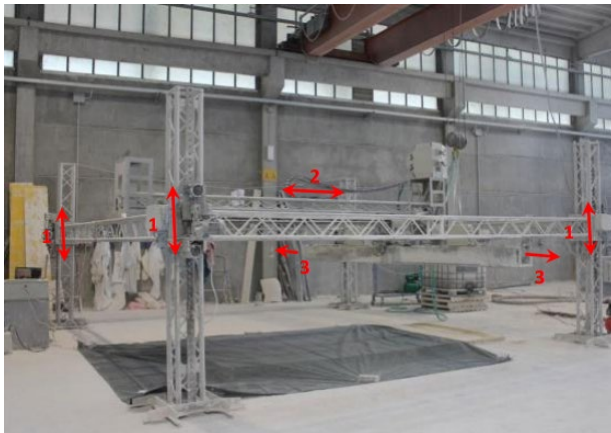


Figure 2. D Shape technology by Giant Frame

**Analysis of the current situation of 3D printing (main benefits and problems).**

*Main benefits and problems related to construction phas.*

3D printing technology in construction phase have many benefits like [3, 4]:

- quickly print new object;
- automatically install various facilities;
- more safe than traditional construction;
- more accurately work according to schedule;
- save energy, time and materials;
- needs a few workers to operate the computer and construction systems;
- this technology is closely related to BIM technology and building industrialization, and promotes each other;
- strong rapid prototyping capabilities, especially in the construction of non-linear complex-shaped buildings (Fig. 3);
- not require the use of formwork and scaffolding;
- could have done complicated architectural components;
- not need many structural systems like reinforces in many cases and building;
- process of construction with 3D printing technology has low-carbon, green, environmentally friendly features and effect;
- using and reuse building materials and eco-friendly materials.



Figure. 3. 3D printed isolation ward in Xianning Central Hospital in Hubei, China

This technology has some problems in construction phase like as:

- needs special regulation in project site and low possibility to use everywhere;
- low possibility in materials and finishing works;
- high cost of construction;
- low professional workers in this area;
- 3D printed house and slabs can only be cast-in-place or prefabricated slabs using reinforced concrete;
- there is no tensile effect of steel reinforcement because of a single material is used to complete 3D printing;
- for concrete-like materials, once cracks appear, the tensile capacity is lost, which can lead to continuous damage of the member;
- printing process requires the printing of materials through the transport pipeline and print head printing to shape, so the printing materials should have good compatibility [5];
- pressure and deformation related to layers form of construction process (print);
- no standard specification and technological cards for the acceptance of 3D printed building structures.

*Main benefits and problems related to 3D printer.*

3D printing technology has some benefits which related to use 3D printer like as:

- control of the material supply system and transmission system by computer;
- ensure the standard of material used;
- design flexibility regarding using computer graphics;
- realize the unmanned operation and more dimensional accuracy.

3D printing technology has some problems which related to use 3D printer like as:

- low sizing possibility of construction related to 3D printer character;
- high price of 3D printer and low possibility of using area and different materials;
- individual working programs and algorithms for every project.

### **Results.**

3D printing technology has been initially applied in construction projects and has the initial ability to manufacture structures [6], but there are still opportunities and challenges for its application in engi-

neering practice, and its further development requires the cooperation of the government, enterprises, and research units to jointly promote the application and popularity of 3D printing technology from policy support, application promotion, and technology development.

Printing buildings is far more difficult than printing anything else, and 3D printed buildings are still in the experimental stage, with many problems to be solved. 3D printed building technology is not yet able to print large buildings in one go, but is more likely to be assembled by printing components. There are still some technical issues to be solved in printing buildings, such as solving the problem of the «step effect» of printing in layers, the structural strength of large buildings, the shrinkage and deformation of materials, the coordination of printing rate and resolution, and the printing of reinforcing steel in buildings.

However, the use of 3D printing in the construction industry is relatively late compared to the development in other industries [7], and the degree of application is not as deep as in other industries. The distribution of 3D printing in the construction industry is still quite fragmented, and does not form a system and scale, and many of its practical applications have problems and need to be improved to be used. The application of 3D printing technology in construction projects has both opportunities and challenges, and requires the joint support of resources and technologies from multiple industries to promote its application and promotion in engineering practice.

### **Conclusion.**

The application of 3D printing construction technology in engineering construction is of great significance in the current situation. This technology is very suitable for emergency housing in especial situation like as construction in Pandemic situation or for poor people. In the future, the printer will be able to create houses suitable for human habitation, and after a natural disaster, it will be able to print out houses quickly and install various facilities automatically, which are better than disaster relief tents and mobile homes in terms of function and strength.

Future architectural design may no longer design the shape, but design an algorithm to create the building. For example, D-shape construction method, which prints «radioactive bugs» by selectively hardening each layer of powder with an adhesive (Fig. 4) [6]. The use



of materials such as ceramics and clay has begun to be explored, and many special materials such as fiber materials, composite materials, chemical materials, and smart materials may emerge in the future to meet the needs of 3D printed buildings.

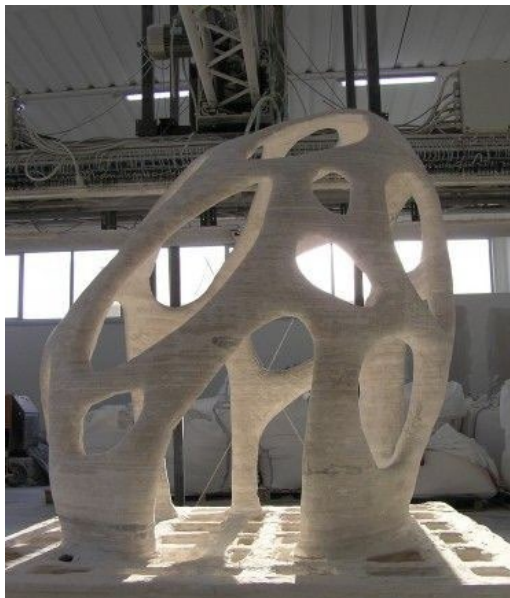


Figure. 4. 3D printed Radiolaria, Monolite UK Ltd.

New construction processes require new acceptance standards, and new building inspection techniques should have to be developed in parallel. All new technologies and techniques which help us to better construction is good, but for its implementation we shouldn't forget the main factor of our mission: needs to analyze it on human's life and healthy. This point of view needs more times and effort to analyze for 3D printing in construction.

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