Research Status and Development Prospect of 3D Printing Concrete Materials

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Abstract: With the rapid development of computer-based 3D printing technology, the technology is widely used in all walks of life. Based on the introduction of 3D printing technology, this paper introduces the development of 3D printing technology in the construction industry. The performance requirements of 3D printed concrete materials and the commonly used 3D printed building materials are introduced. Finally, the problems still existing in 3D printing construction technology are summarized and the development prospects are put forward.

1. Introduction
In the third industrial revolution, 3d printing was considered an important symbol of rapid prototyping. Due to its outstanding advantages such as rapid prototyping, the technology is widely used in aerospace, biomedical, industrial manufacturing and other fields. In recent years, 3D printing technology has also made great progress in the field of architecture. 3d printed concrete technology is a new technology applied to concrete construction based on 3d printing technology. The main working principle is that under the control of 3d software, the configured concrete slurry passes through the extrusion device as preset. A good printing procedure by nozzle extrusion is printed to finally obtain the designed concrete component. In the printing process, 3d printed concrete technology does not require a support process during conventional concrete forming processes. This is the latest concrete moldless molding technology. 3d printed concrete construction technology is a combination of 3d printing technology and concrete construction technology. Compared with the traditional concrete construction process, the process can form components or structures without a template, and the printing process requires almost no labor, which greatly reduces the manpower and material resources during the construction process, and makes the construction process more green and greatly improved. The efficiency and safety of construction "breaks the barriers to the development of 3D printing technology."

2. 3D architectural printing technology
3D architectural printing technology is a rapid prototyping technology (rp) based on digital models. Special "ink" made of cement materials, admixtures, additives, special fibers and aggregates, using computer graphics to convert architectural models into three-dimensional designs, layer by layer, technology to add materials to printed buildings. The principle of 3d printing concrete technology is mainly to extrude the configured concrete slurry from the nozzle by pressing the device, and use the
control power of the three-dimensional software, and then print according to the preset printing program. Finally, the specific application and development prospects of 3D printing technology in the food industry were obtained. Unlike traditional concrete forming processes, 3D printed concrete technology is the latest in amorphous forming technology, omitting the die casting process and saving time. The new 3D concrete printing technology, the printing machine is controlled by computer software, using the highly controllable extruded cement as the substrate, and the solution in the high-precision hole printing on the concrete wall board. This new technology makes concrete buildings no longer confined to simple and common structural shapes, as well as complex and unique concrete components.

The preparation of printing materials is the core technology of architectural 3D printing. At present, printing materials are mainly based on concrete. In addition to meeting the performance requirements of traditional concrete, 3D printed concrete also needs to meet 3D printing performance, mechanical properties and durability requirements, such as extrudability requirements, bondability requirements, moldability requirements, and control of setting time and print strength. Wait for the request.[7] At present, there is still a lack of systematic research on the preparation of 3D printed concrete materials and their performance indicators and control methods.

3. 3D printed building technology and its requirements for building material properties

3.1 Strength requirements

Compared with conventional ready-mixed concrete, it is widely used in traditional buildings. The materials on 3D printed buildings are more demanding and require good strength, stiffness, crack resistance and plasticity printing materials. At present, the main material of 3D printing is concrete. Although its compression performance is good, the tensile and shear properties are poor, and the material is prone to brittle failure under the action of force.[8] At present, most of the buildings constructed using traditional building techniques are reinforced concrete structures. A specific material does not meet the structural stiffness and strength requirements and requires the cooperation of concrete and steel. Once the tensile stress exceeds the tensile strength of the material, cracks are likely to occur. If only concrete materials are used in the printing process and the reinforcing bars do not have a synergistic stretching effect, then brittle fracture will occur slowly for the entire building structure as long as cracks occur, until the structure is completely destroyed. Although existing materials are usually mixed with glass fiber or carbon fiber to increase their tensile strength, they also need sufficient tensile properties of the material itself. Secondly, the material should have better crack resistance to avoid external force and overall structural safety. Sexual influence.

3.2 Durability requirements

In 3D printed buildings, the durability of the building structure should also be guaranteed. There are many factors that affect the safety and service life of three-dimensional printed building structures, such as temperature, external force, and chemical action. In printed buildings, it is required to use a substrate with good impermeability and high strength. Ordinary Portland cement printing materials tend to have low strength and poor impermeability and thermal insulation properties. It is required to add admixture concrete or use other properties of good cement-based substrates to improve its performance to meet the durability of printed materials. For example, in areas with cold or high temperature poverty, cracks are likely to occur, and even large concrete areas will fall off. When this happens, the safety of the concrete structure is greatly reduced. It seems that when the 3D printed building structure breaks, leakage. Therefore, it is necessary to print a material having good leakproof and antifreeze properties to ensure the durability of the structure.

3.3 Workability requirements

As a building material, concrete plays an important role in the traditional construction industry, playing an important role in the emerging 3D printed buildings. "Development Status of 3D Printing Materials" At present, printing concrete, one of the three major manufacturing processes, has been in the field of
engineering construction, due to its good performance and controllable setting time, good application and development prospects. The performance of 3D printed materials has a very important impact on printing results. In the construction printing process, the printed materials must have good consistency, because the printed materials need to be output from the conveying pipe, and the printing materials are formed by a 3D printing head. Second, the printed material needs to have a faster setting time because the 3D printing process is fast, and each upper layer material will have a gravitational effect on the underlying material during the printing process. When the upper layer of material accumulates too much and the underlying printed material is not completely condensed and hardened, there is insufficient strength to support and the printed building material will be deformed. The curing time, fluidity, strength and consistency of the 3D printed material of the printed concrete paste material used to determine the consistency of the three-dimensional test are important guarantees for achieving key technologies for 3D printed materials. By precisely controlling these conditions, print continuity and safety can be guaranteed. For the existing concrete materials, the setting time is longer, the general initial setting time is 6-10 hours, and the final setting time is longer. For 3D printed concrete buildings, the 3D printing process has a shorter construction period, requiring the printed materials to be solidified in a relatively short period of time, which is convenient for construction. In addition, the newly formulated concrete generally has fluidity and cannot be printed and stacked during the printing process, which limits its use. The stacking can cause the 3D printing tube to become clogged due to the too much fluidity of the material. Therefore, 3D printed concrete requires proper fluidity. In addition, proper fluidity allows the concrete to exit the pipe to ensure rapid solidification after strength. In order to ensure that the printed material meets the requirements, a mixture (accelerator and water reducing agent) is usually added to the material. After the addition of the accelerator, the cement hydration process can be accelerated, the cement setting time can be shortened, and the concrete can have proper fluidity.

4. 3D printing concrete materials and processes

Only a few building materials are available for 3D printing. Through exploration and practice, the United States has successfully applied resin mortar, clay and concrete materials to three-dimensional printing construction techniques.[9] The researchers at Nanyang Technological University in Singapore successfully used fly ash, steel slag and some chemicals to make 3D printed geopolymers. In practice, China uses construction waste as a raw material for 3D printed concrete, uses advanced cement, and uses fiberglass and industrial tailings to recycle waste in construction projects.

At present, inorganic cementitious materials are three-dimensional main materials for printing concrete, such as Portland cement, dry mortar, clay, special gypsum material (grg), and are mainly organic materials represented by epoxy resins.[10] In order to meet the requirements of 3D printed buildings, we have to make the concrete mixture meet specific requirements.[11] The following is an analysis of a concrete composition. First, ordinary Portland cement may not meet the requirements for 3D printing demand strength and setting time, and further research is needed on this basis. Some scholars used sulphaaluminate cement or aluminate to modify Portland cement to achieve shorter set times and higher early strength. In addition, tree fingers, water glass, gypsum and geopolymers can be used as 3D printed concrete cement materials. 3D printed concrete is sprayed out of the nozzle. If the size of the aggregate is too large, the nozzle may be clogged. However, if the particle size is too small, the specific surface area of the aggregate increases, and the slurry required to encapsulate the aggregate increases, resulting in an increase in the heat of hydration of the cement. Therefore, it is very important to select a suitable aggregate particle size depending on the size of the nozzle. At the same time, the sand rate, gradation, mud content and other indicators should be strictly controlled.

Accelerators can accelerate the hydration process of cement and shorten the setting time of
cement. Adding a water reducing agent can make the concrete have better fluidity. However, existing admixtures still do not meet the comprehensive requirements of the specific requirements of 3D printing, so it is necessary to develop and adopt new composite admixtures. 3D printing concrete material is an important foundation for the development of 3D printing construction technology, and it is also a bottleneck restricting the development of this technology. According to the research progress and application status at home and abroad, the three-dimensional printing concrete materials will develop in the direction of green, light, high strength, fast hardness and early strength.[13-14]

5. Conclusion
At present, 3D printing technology is in the exploratory research and development stage. The thermal, seismic and compression properties of building materials are for further study. Therefore, some problems will inevitably arise.[15] Unlike traditional architectural structures, 3D printed building technology requires the design of a building model on a computer and then converts it into a physical object through an automated program. Therefore, design software has become an important part of the 3D printing construction technology preparation phase. How to realize the conversion between software and reality is an indispensable step in the development of printed concrete. “Development and application of 3D printing technology in the food industry” At present, the mechanical performance of 3D printing construction technology is still in the stage of flat expansion, which can be applied to the construction of low-rise large-area buildings. For high-rise buildings that are widely used, one-time printing is not possible, and can only be achieved by printing the preforms first and then assembling them. "Application and development prospects of 3D printing technology" For tall buildings up to tens of meters or even hundreds of meters, first of all, there must be a printer that meets the height of the building. Secondly, it is necessary to obtain the structural strength of the tall buildings and the problem of scattered steel bars in the building structure. A reasonable solution. 3D printed buildings have different requirements than building materials.

The vast majority of 3D printed buildings are made of high-strength special concrete materials. Ordinary cement may not meet the requirements of building performance and printing technology. It can be seen that the requirements for material properties of 3D printing must be taken into account.[16] The 3D printing building mainly uses the nozzle of the printer to spray the material to build the wall. This printing method not only requires the force and the machine molding characteristics, but also the quality requirements of the coarse aggregate and the fine aggregate are needed. High quality requirements and even new crushing processes are required. And the role of admixtures in ordinary concrete may be due to changes in materials, making it play a role in the specific system of three-dimensional printed buildings, and its mechanism of action may also change. Therefore, in order to realize the printing of three-dimensional buildings, materials are the first problem to be solved.

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