Feasibility Analysis on the Application of 3D Printing Technology on Municipal Roads

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Abstract: 3D printing technology is an emerging technology; it can be used in various fields and has successful cases in all areas. And at present, the widespread application of 3D printing technology in construction engineering is concrete pouring. In construction, the application of 3D printing technology greatly shortens the construction period and reduces the consumption of manpower and molds compared with traditional structure. However, due to various factors such as immature technology and material selection, most of these successful examples of buildings using 3D printing technology are middle and low-rise buildings. Because of the complexity of the construction project itself, then, we can try to show the advantages of 3D printing technology perfectly in other directions in the field of architecture. It is in road engineering, the primary material of our construction is all kinds of concrete, and the 3D printing technology of concrete in the whole field of the 3D printing technology has been relatively mature and can be widely used. Combining the characteristics of the construction technology, working procedure, and materials in the municipal road, the 3D printing technology can maximize the benefit of road engineering in the construction of the municipal road.

1. Introduction
3D printing, it's full name is additive manufacturing, the processes of material augmentation manufacturing are roughly divided into seven categories[1]: material extrusion, material injection, binder injection, powder bed melting, directional energy deposition, large barrel photopolymerization, and sheet lamination.

3D printing technology is used in three kinds of structures in the construction field principally[2]: masonry structure, concrete structure, and reinforced concrete structure. 3D printing technology has different characteristics in the above three structures, but there is a generality that 3D printing technology has always been used in masonry type of components. For example: in masonry structure, 3D printing technology can supersede traditional cement mortar and block to make it integrated; in structure, the construction technology and material in the construction technology of traditional concrete can be replaced by 3D printing technology; In reinforced concrete structure, the application of 3D printing technology on concrete is more similar to the traditional cast-in-place concrete construction technology and construction method, precast steel cage before cast-in-place concrete. However, the use of 3D printing technology to pre-set the steel cage and traditional cast-in-place components tied the shape of a slight change in the steel cage. For example: the Wall (see graph below: figure 1[3]). Meanwhile, 3D printing technology also has a way, is similar to the process
of prefabricated buildings[4], the use of 3D printing technology to print out the various components, and its technical means to assemble together.

But until now, 3D printing technology still can’t run through the whole construction process from beginning to end, and it can only occupy part of the construction process, example: reinforcement bar engineering. So far, at least, 3D printing technology has not been able to supersede the entire traditional steel engineering completely. Whether it’s the first building built using 3D printing technology or the latest building built using 3D printing technology, they always need to use other techniques to complete the project. However, compared with the construction field, the municipal road field is quite different. The technical specifications between municipal road engineering and construction engineering, construction technology, manual use (construction is mostly flowing water construction), material selection and use are not the same.

However, the construction technology of the municipal road is similar to that of the masonry technology, and to some extent, it gives the platform to the 3D printing technology show themselves. And in addition to the construction of some roads with high grade, high requirements, the construction of most municipal roads is only the spreading of three structural layers. In municipal road engineering, the laying of concrete pavement is the most common, and the working procedure of municipal road is not as cumbersome and complex as that of building. In other words, in construction engineering, concrete engineering is only part of the construction engineering. But in the municipal road engineering, the concrete engineering occupies a large proportion in the whole road engineering, it can be said that the concrete engineering is even the whole of the part of the municipal road engineering. Therefore, once the 3D printing concrete technology is applied in road engineering, not only the merits of 3D printing technology will show incisively and vividly, for the construction period, total cost and quality can have a qualitative leap, but also can achieve the real sense of 3D printing technology in the whole process of construction application.

2. The advantages and disadvantages of concrete 3D printing technology

2.1 Advantages:

2.1.1 Short duration and low cost:
In traditional concrete engineering, if we want to achieve the desired performance and shape of concrete engineering, we need to combine both formwork engineering and scaffolding engineering with concrete engineering. With the help of formwork to shape the concrete component, and we need to give the concrete time to condense to meet the required strength and performance. And the concrete building made using 3D concrete printing technology[5] does not need the assistance of the formwork, and can be formed in one body with the cooperation of all the printing equipment, which reduces the cost and labor of the formwork purchase, laying, demolition process.

Besides, the existing traditional technology, whether cast-in-place concrete members or precast
concrete members, in the pouring or laying of members, there is still controversy about the construction sequence and technology of some nodes. But 3D printing technology perfectly circumvents this shortcoming. Because 3D printing technology is almost perfect for the integration of structural molding, not to mention the processing of nodes.

2.1.2 Energy conservation, performance 1.2 Environmental Protection and energy saving, performance optimization:
As we all know, the reason why 3D printing technology has become a hot technology development direction, one is that the construction period is short, the cost is low, the other is to save materials, and the performance of components manufactured by 3D printing technology is also more optimized. In addition, 3D printing raw materials, the 3D printing building “ink” is also dedicated to the use of some building waste or other waste materials, and so on. In 2009, Yingchuang Company successfully developed "recycled stone" and "recycled sand" with mine tailings and construction waste materials, and produced 3D printed raw materials with new materials. So that resources can be recycled.

The research and development of new materials cannot only optimize the material performance to a great extent, but also improve its performance. For example: Shanghai Expo Center, Shanghai, China, 2600 large hall of people, this building uses special glass fiber reinforced gypsum board (GRG of the 3D printing), on the basis of it's own light weight, with good fire resistance and high strength. There are also 3D printing SRC (special glass fiber reinforced cement), 3D printing FRP (special fiber composite), Yingheng stone of the 3D printing (It is the natural stone made from mine tailings and construction waste) and so on.

2.2 Disadvantages

2.2.1 Restrictions on raw materials[6]

The 3D printing technology is still at the beginning phase, and 3D printing technology is still very difficult to produce finished products. In other words, to independently produce 3D Printing Raw Materials is not difficult, but to be able to fit the technical requirements of the production of 3D Printing Raw Materials is difficult. In the preparation of materials, the number of materials that can be produced in line with the technical requirements of 3D printing is very limited. In fact, not many 3D printing materials can be mature preparation.

2.2.2 The finished product is stepwise
3D printing technology is sublimated by the traditional 2D printing technology, that’s the reason why the 3D printing technology always has the characteristic that it always holds the 2D printing technology. In general, 3D printing technology is according to the 2D printing, but more advanced printer and the “ink” of the printing, that is, the raw materials needed for the building, are put into the machinery, and then the small sections of the raw materials are stacked together like milking oil by a small section by a special nozzle, so we can still see a layer of texture in the finished product, that is, step by step. (As shown in Figure 2)[7]
2.2.3 There is no significant cost reduction for projects that cannot use 3D printing throughout the entire construction process

In the overall construction of the construction project, we are not only the construction of concrete, but also the construction of other sub-projects. Concrete works are only a part of the overall construction, and in other sub-projects, many are 3D printing technology cannot be replaced, such as door and window works. Then in reducing the cost, we can only reduce and shorten the cost and duration of this part of the concrete project.

3. Craft of municipal roads

We collectively refer to municipal road works and road works as road works. So what's the difference between them? Generally speaking, we refer to the road project located in the urban area, which is connected with our daily life, as the municipal road project. Highway engineering is located in non-urban areas, the same road may be natural geological conditions in different areas of the road. They differ in design and service terms, but almost the same in construction techniques. However, outside the urban area, 3D printing technology cannot be reasonably used at this stage. Because of the constraints of resources and conditions, we can now apply it first on the municipal road.

3.1 Structure of municipal roads [8]

The construction process of municipal road engineering is simple and the construction technology is single. In the setting of the road surface, whether it is a flexible road surface or rigid road surface, there are only three kinds of structural layers, which are laid from bottom to top according to the order of cushion, base and surface layer. According to the different road conditions and design requirements, the number of layers of the structure layer will be added to meet the service life required by design under certain circumstances. Secondly, the road edge stone laying relative to the road surface, the requirements are not so strict, according to the design requirements to lay.

Municipal roads are generally classified according to their mechanical properties, and we divide them into flexible pavement and rigid pavement, which have different advantages and disadvantages. The flexible pavement has good ductility, but it is easy to deform under the action of repeated load, but even the deformation is more gentle than the rigid pavement. Rigid pavement has good durability and solidity, but high cost, and once deformation occurs, it is more obvious in use and appearance than flexible pavement.

3.2 Composition of municipal roads

Due to the different advantages and disadvantages of rigid pavement and flexible pavement, the most typical material used in flexible pavement is asphalt; the most commonly used material for rigid pavement is cement. Therefore, in the design and construction, we prefer to choose to lay semi-rigid and semi-flexible pavement, so that the advantages of the two types of pavement combined, more perfect to meet the design requirements. And the road edge stone materials, most of them are prefabricated blocks, or natural stone. So, no matter what type of pavement is used in road design, we can use the 3D printing technology of concrete instead of the traditional construction technology of concrete.

4. Conclusion: 3D printing technology is applied on the municipal road to maximize the benefit

4.1 In the construction process can save the process: in addition to the initial technical safety design, at the bottom, the field test line, geological analysis, and other steps can not be avoided. In the construction of municipal road works, the following steps can be omitted

4.1.1 Mixing and transportation of materials

When pouring the surface layer, you need to control the proportion of the material. However, under normal circumstances, most of the municipal road construction in the city, the road does not allow the
use of concrete mixing, but only allows the factory concrete mixing. 3D printing technology, only need to complete the municipal road engineering 3D printing technology required raw materials ready, then the raw material into the printing equipment, you can start the printer operation. For the use of road concrete road in the traditional process, you can omit the transport and matching materials, and the use of Municipal Road Works plant concrete can eliminate the transport process. So either way to get concrete, applying 3D printing technology will save on mixing and transport of materials.

4.1.2 Compaction and maintenance:
In the traditional construction techniques, the structure layer is spread according to the order of cushion, basement layer, and surface layer. In road design, according to the design requirements of different road grades, to strengthen the interaction between the basement layer and the surface layer, a connecting layer will be added between them in the road construction with high road grade. In the traditional construction technology, each structure layer is laid and compacted separately, in order to make each structure layer achieve the proper structural strength, we will give each structure layer corresponding maintenance time, so the period of construction is long, and if the construction period once encountered severe weather changes need to stop work rest. However, if the 3D printing technology is applied to the construction of municipal road works, these problems do not need to be considered. The material needed to put into each surface layer in the printing setting, the surface layer, the connecting layer, the basement layer, the cushion layer is integrated to carry on the spreading operation, does not need to carry on the compaction, and do not need the maintenance time. Because of the one body printing, there is no gap between the materials. It is not necessary to consider the maintenance of material strength, the bond between structural layers, the moisture content of materials, and so on, like the traditional construction techniques. In the construction process, it is not necessary to consider the road maintenance situation and maintenance period, and significantly shorten the construction period.

4.2 Economic cost reduction:
In the process of construction, the reduction of the construction process means the reduction of labor, the use of machinery, the shortening of the construction period, and the reduction of the cost. And 3D printing technology is not like traditional construction technology, cannot measure the specific amount of construction materials. In another aspect, the 3D printing technology should be capable of easily obtain the engineering quantity and the corresponding material quantity of the project when the building information modeling is built by computer. To compare with the traditional technology, 3D printing technology reduces the steps of material purchase and transportation, and combines with modeling technology to reduce the loss rate of materials, which cannot only eliminate the waste of materials, but also reduce the cost of materials. At the same time, because several construction steps and processes are eliminated, the time limit will be shortened accordingly, so the working hours of the workers will be reduced, and the labor costs will be greatly reduced. And the use of 3D printing technology, reduces compaction, laying, and other processes in the construction of the use of large machinery. The overall large reduction in labor, materials, and machinery costs, the cost of municipal road works will naturally reduce a very substantial amount.

4.3 The disadvantages of 3D printing can be perfectly applied to municipal road works:
3D printing technology has always had a weakness in the finished products of the past printing, which is commonly known as: stepped appearance. But this shortcoming, when the 3D printing technology is used in municipal road engineering, can be combined with the characteristics of municipal road engineering to make it into advantages. It is well known that when municipal roads are laid, considering the future use, to prevent cracks or warpage in the plate body under the action of shrinkage, we will set vertical intersecting transverse and longitudinal joints to divide the concrete slab into several rectangular plates. However, the 3D printing technology can put the transverse and longitudinal seams[9] into the information model when the previous drawings are designed. So when
3D printing technology is applied to municipal road engineering, we don't need to consider this problem again in the construction process like the traditional technology, but solve it in the design stage. Secondly, in order to increase the friction between the road surface and the passing cars and pedestrians, we will use a chainsaw to cut the regular joints on the road surface after the completion of the overall construction of the municipal road works. And the step property of 3D printing technology has increased the friction force to some extent. So in the municipal road works using 3D printing technology, we do not need to consider designing the saw seam separately.

4.4 Integration of construction
As previously said, so far,3D printing technology is not used in the construction field widely, that is the 3D building printing technology in most sections of construction engineering is not mature, many necessary raw materials, various new materials, new technology is still under discussion and research. So for the use of 3D printing in municipal road engineering, it can be called a steady step. The application of 3D printing technology in municipal road engineering can be said to maximize the benefits of the project. Because,3D printing technology can participate in the whole construction process of municipal road engineering. First of all, the use of municipal road engineering in the field of 3D printing is more mature 3D printing technology of concrete, so no material or technique is not available; secondly, the 3D printing technology of the step of the disadvantage, in the municipal road engineering can also "turn waste into treasure ". Finally, municipal road engineering for 3D printing technology absorption is prefect. It only plays the advantages of 3D printing technology, but also absorb and fuse the shortcomings of 3D printing technology. For future municipal road projects combining 3D printing technology, all the characteristics of 3D printing technology, they will be advantages. It can be said that the integration of 3D printing technology and municipal road engineering has achieved construction integration in the real sense.

To sum up, municipal road engineering can become a perfect combination of the 3D printing technology advantages of the entire construction sector. It not only combines the benefits of the short time limit, low cost, energy-saving, and environmental protection, but also can fully guarantee the related performance and engineering quality. Then, the combination of 3D printing technology and municipal road engineering is imperative, and it will become a milestone in future road engineering.

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