Comparison of Construction with Traditional Method and 3D Printing Technology

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Abstract- ***3D printing concrete is an emerging technology in additional form-work during construction and also the human resource required is comparatively which structures are made only using concrete in layers with the help of Software. With this technology, even geometrically intricate structures, heavy load bearing structures and hydraulic structures can be made easily in no time with less wastage of materials and minimum costs. It does not require any less. It is a sustainable technology which can also be used for aesthetic purpose. 3D printing (3DP) is a promising new technology that has the potential to not only be an effective means of increasing project efficiency and profitability in the field, but also have positive environmental impacts. However, as it exists today, this technology is highly limited by size, material, skilled labor, and industry reluctance. The 3D printing technologies, comparing to traditional techniques of constructing the buildings, could be considered as environmental friendly derivative giving almost unlimited possibilities for geometric complexity realizations. This is a research paper on 3D printing and the various materials used in 3D printing and their properties which become a notable topic in technological aspect. Also, see the advantages of 3D printing as compared to additive manufacturing.***

Indexed Terms- ***3D Printing, Best Practices, Limitations, 3D printing concrete, formwork, sustainable technology, minimum cost, environmental impacts, additive manufacturing.***

I. INTRODUCTION

The current construction industry has serious issues with sustainability. In general, the current construction methods and materials are not environmentally friendly. The entire construction process, including off-site manufacturing, transportation of materials, installation and assembly, and on-site construction, emits huge amounts of greenhouse gases and consumes large quantities of energy. In addition, conventional concrete made by ordinary Portland cement (OPC) is not sustainable. Manufacture of OPC is highly energy and carbon intensive.

The significant amount of wastage generated in the construction is another challenge. Formwork is a significant source of waste, since all of it is discarded sooner or later, contributing to a generally growing amount of waste in the construction industry.

Furthermore, the conventional approach of casting concrete into a formwork limits geometrical freedom for the architects to build in various geometries, unless very high costs are paid for bespoke formworks. Rectilinear forms not only limit the creativity of the architects, but they are also structurally weaker than curvilinear forms owing to stress concentration. Another challenge is the slow speed of construction. The concrete construction often comprises many steps including material production, transportation, and in-situ manufacture of formwork, and each step is time consuming.

Application of three-dimensional (3D) printing techniques in concrete construction could solve the aforementioned challenges. 3D printing technology is recently gaining popularity in construction industry. In the last few years, different 3D concrete printing (3DCP) technologies have been explored. The inhibitions in the use of 3D printing in construction come from technical, economic and social point of view. The technical inhibitions involve the assembly and production of 3D printer and development of materials with suitable properties.

II. HISTORY OF 3DP

3D printing (sometimes referred to as Additive Manufacturing (AM)) is the computer-controlled sequential layering of materials to create three-dimensional shapes. It is particularly useful for prototyping and for the manufacture of geometrically complex components. It was first developed in the 1980s, but at that time was a difficult and expensive operation and so had few applications. It is only since 2000 that it has become relatively straightforward and affordable and so has become viable for a wide range of uses including product, design, component and tool manufacture, consumer, electronic, plastic, metalworking, aerospace engineering, dental and medical applications, and footwear. The sales of AM machines or '3D printers' has grown rapidly and since 2005, the home use of 3D printers has become practical. Systems developed for the construction industry are referred to as construction 3D printers. A 3D digital model of the item is created, either by computer-aided design (CAD) or using a 3D scanner. The printer then reads the design and lays down successive layers of printing medium (this can be a liquid, powder, or sheet material) which are joined or fused to create the item.

A. Approach of 3D Printing Construction with Construction Management:

Design uniformity is an essential part of creating affordable and constructible buildings. However, clients in recent years have begun requesting more unique and less uniform buildings and concept designs, which are often abandoned because of the extra costs involved. This constraint on original thinking can be overcome by large-scale 3Dp methods that are able to deliver non-repeating components at a cost effective price provided relatively low volumes of production are required Of this aspect, Pegna (1997) notes that, because the technology offers on-site construction automation, it would be able to reduce the dependence on labour and hence reduce the risk of injuries and weather stoppages. As a result, it is estimated that the technology would be able to reduce construction costs by up to 30%.These techniques are also able to drastically reduce the lead-time to production as well as the cost of design and manufacture of more complex parts that would be difficult or impossible to make with more traditional construction methods.

B. 3-D Printing in Construction:

The basic steps involved in 3D printing construction are as shown in Fig. 3D CAD model with building information / BIM model is developed. This model is sliced layer by layer with all the components to required thickness. This layered arrangement also known as stereo lithography files is given as an input to the 3D printer assembled as per requirement. After this step, the actual printing process is carried out and the building is printed in layers by any one of the chosen methods.

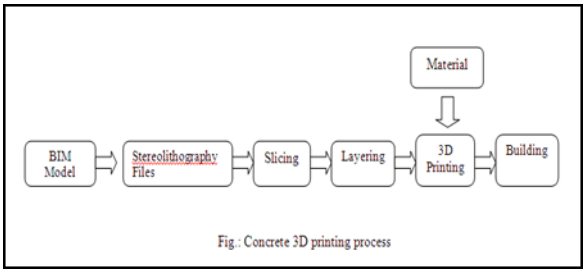

Fig.: Concrete 3D printing process

A. Printable Materials:

In recent years, various construction materials for 3D concrete printing materials have been developed. These materials can primarily be classified into 3D printable plain concrete, 3D printable geopolymer, 3D printable fiber reinforcement concrete, 3D printable rapid hardening materials and 3D printable earth-based materials. For successful 3D printing, high-quality final properties such as compressive strength, flexural strength, have to be targeted. However, considering that the material needs to continuously flow through the print head and has to gain strength immediately to carry its self-weight and weight of the added layers, the fresh properties and the strength gain properties should also be targeted. Since the printing process requires a continuous, high degree of control of the material during printing, high performance building materials with properties such as low to zero slump concrete, high static viscosity within the nozzle and low viscosity after extrusion, are preferred in the fresh properties. Various studies have been carried out around the world to improve the fresh properties, printability and mechanical properties of the materials used.

B. Types of 3 D Printing:

There are various types of 3 D printing currently existing and certain types are more suitable for construction than the others. The major types of concrete printing suitable for construction are Contour crafting, concrete printing and D Shape.

- Contour crafting: It is fabrication technique in which the concrete is crafted layer by layer and was developed by Khoshnevis (2004) in California. This is the most promising 3D printing technology and allows the fabrication of the complete house in situ. Two or more nozzles move simultaneously along the gantry and simultaneously print various components of the structures. This method also enables the printing of accessories and conduits along with the buildings. The Potential areas of applications for contour crafting are: i) low income housing or emergency sheltered housing and ii) architectural buildings involving complex shapes.

- Concrete printing: It is an extrusion based printing process in which the nozzle extrudes material while moving in a predetermined path in a continuous process. There are three categories of concrete printers presently available and widely used in real time construction viz. gantry, robotic and crane system along with a printing nozzle with continuous supply of materials. Gantry has a fixed height of operation whereas the cranes are adjustable in vertical direction. Robots typically have a fixed dimension and are difficult to scale up however they accommodate all operational direction and enable continuous and complete in-situ printing.

- D shape printing: It uses layers of powders and adhesive sprinkled on it at desired locations. In D shape printing the powder material is laid and compacted to required thickness. Then the binder is injected at required places using a nozzle. Once the hardening is complete, the loose powder can be removed and the hardened model can be taken separately. Additive manufacturing techniques including ink jet printing and laminated object printing are also binder jetting and are used in construction. These methods are more suitable for polymers, metals and ceramics.

III. EFFECT ON TIME, COST AND ENVIRONMENT OF CONVENTIONAL CONSTRUCTION METHOD

Construction industry plays a key role in socio-economic development of any country. Nowadays construction industry is rapidly growing because of increase in standard of living, demands of infrastructure projects, changes in consumption habits, as well as natural increase in population. This growth has contributed significantly in waste generation.

i. Effect of Construction Materials: The materials used in building construction also have a serious impact on the environment. First of all, many of the materials used in the construction of buildings are produced in a non-sustainable way. The factories that make the materials produce damaging CO2 emissions. Then there's the issue of transportation. Materials that are not produced locally are often shipped from across the country or even from overseas. The transportation required for shipping these materials has a considerable impact on air quality. There is a huge environmental impact associated with the extraction and consumption of raw materials for the use of building materials. Not to mention the actual production of those materials in their final form. According to the USGBC, 40% of the world's raw materials are used in the construction of buildings.

ii. Waste from Building Construction and Demolition: The destruction and renovation of buildings result in a large amount of waste. Building waste often includes concrete, metals, glass, plastics, wood, asphalt, bricks and more. This waste is often disposed of in either landfills or incinerators. Not only does this pollute the land and the air, but the transportation required to remove such waste has a major impact on the environment as well. According to the Environmental Protection Agency, there were already over 170 million tons of debris generated in the construction and demolition of buildings in the U.S. alone in 2003. 61 percent of which were produced by nonresidential buildings.

IV. CONVENTIONAL METHOD VS 3D PRINTING

Globally construction industry has highest carbon impacts which accounts for 40% of global energy consumption, 38% of carbon emission as well as 12% of water eutrophication. Thus, there is great demand for decarburization in this industry. 3D printing or additive manufacturing has emerged as a potential solution to reduce the energy demands, water wastage and carbon emissions. 3D printing in construction context is an innovative technology that creates 3D objects by reproducing physical objects with continuous layers. Recently, from polymer and steel the industry has leaped forward using concrete with potential applications in the construction engineering. Anecdotally, these technologies proved to reduce production time, minimize wastage and reduce labor costs significantly. The current challenges in 3D printing commercialization are lack of standard building codes, large scale investment, functional performance and architectural designs. In this research, concrete prototypes were printed for tests and a comparative study was established with the conventional manufactured concrete to analyze performance standards, cost benefits and lifecycle assessments. Future scope of this research is to develop a performance standards based on benefits for large scale implementation in construction industry.

ADVANTAGES:

- Environmentally friendly: You can use raw soil and natural waste from the rice production chain for 3D printing. Theoretically, the material for a 3D printed house can also be plastic – and we've got plenty of that.
- Inexpensive: Large-scale industrial buildings can be constructed for a relatively low price.
- Shorter construction periods: 3D printing shelters, for example, can be beneficial for victims of natural disasters.
- Uncommon shapes: 3D printing can generate shapes that are impossible or too expensive to manufacture otherwise.
- Otherworldly potential: NASA already has plans to use 3D printing for colonies on Mars.

LIMITATIONS:

- Though the cost of construction maybe reduced by 3D printing, the cost of the printers is huge this is a drawback.
- Skilled laborers who can work efficiently with the 3D printers and CAD are required.
- 3D printers consume high amount of energy. According to a research it has been shown that it consumes about 100 times more electrical energy than the conventional methods.
- Since the size of the printers is huge it creates problems in the onsite storage.

CONCLUSION

3D printing in construction context is an innovative technology that creates 3D objects by reproducing physical objects with continuous layers. The basic research will be a comparative study comparing 3D construction printing with traditional methods of concrete usage. 3D printing technologies may improve the time and cost management in construction, lean construction, green approaches, and sustainability in construction industry. This finding indicates that studies in 3D printing technology field will be more valuable in the near future. The concept of contour crafting, allowing in-situ printing of dwellings may require the new architectural approach to building design. This technique will require development of new materials appropriate for 3D printing process, but also considering sustainability issues, materials in which traditional concrete ingredients will be replaced with environment friendly ones. Creating the buildings with complicated shapes, may become one of the biggest advantages for most architects. Their imagination will be able to defeat previous obstacles related to limitation of traditional techniques of building.

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