Comparative Study of 3-D Printing With Conventional Method of Construction for Buildings

Jahanwi Kumari[1] Rachit Beohar[2] Parshottam Sarathe[3] Padma Pandey[4]
[1,2]Student [3,4]Assistant Professor
[1,2,3,4]Department of Civil Engineering
[1,2,3,4]Oriental Institute of Science & Technology, Bhopal, India

Abstract — This paper provides a review of the 3D concrete printing technology has taken growing strides, which enables design optimization in the field of construction. This process is not just faster and 30% cheaper but it also is more environment friendly compared to the traditional methods of construction. Experts claim that they already get the brownie points for better flexibility in design, reduced construction costs, more efficient use and application of materials and greater levels of sustainability by reducing the waste types. A detailed description of the work done by the students of oriental institute of science and technology Bhopal (Madhya Pradesh) in developing a Portland cement based 3D printable formulation has been discussed. Finally, the material in digital fabrication that require further research and attention are also highlighted in this paper.

Keywords: 3D Concrete Printing, Digital Fabrication, 3D Printable Concretes

I. INTRODUCTION

Digital printing of concrete is based on the principle of 3D printing technology or additive manufacturing. The prevalent processes of digital printing are extrusion-based printing, binder jetting, mesh mould approach (cutting and welding), smart dynamic casting, etc. The additive process in construction with automation is suggested by Pegna (1997) and further developed by Khoshnevis (2004) 3D printing for concrete construction. In 3D concrete printing, both industry and academia are progressing simultaneously.3D printed concrete is a special mix of concrete, specifically prepared to flow with ease through the nozzle of the printing equipment. The structures built with 3D printed concrete are created on the fundamentals of layering, with each layer deposited on a previous layer of pumped concrete. The 3D printing technology prevalent processes of digital printing are extrusion-based printing; Extrusion-based printing is done by a layer-wise deposition of fresh concrete. It depends on the properties of concrete such as pumpability, extrudability, buildability, and open time. Pumpability is the ease of transport of materials through the system, i.e. from the mixer to nozzle. Extrudability is the ease of extruding concrete through the nozzle at a given rate. Buildability is the ability of the printed concrete to retain the imposed loads of subsequent layers without deformation.

3D Concrete printing technology becomes very popular due to its wide scope of applications and developing very rapidly throughout the world. Conventional construction methods take a longer time to complete the construction while by using 3D concrete printing method, it can be completed in a very short time. Different types of skilled and unskilled labour are required at different stages in conventional method, while very less manpower needed in 3D concrete printing methods. High quantity of material wastage is observed in the conventional method, while very less or no wastage is found in the 3D concrete printing method. However, even having many benefits over the conventional construction methods, still, the 3D concrete printing technology is in his earlier days and required technical investigation on many points. In the early stage, this technology was very complex and also more expensive but with the development in technology, 3D printing technology becomes simple and less expensive so very commonly used in all types of industrial applications. Nowadays, to produce appropriate advanced printing material for a 3D printer for various applications has become an ultimate targeted area for many companies worldwide. 3D printing technology is known as additive manufacturing technology. The use of concrete as an inking material in the 3D printer currently under investigation by the researchers for industry applications technological advancement made possible to print actual full-scale structures with a 3D printer on-site today. Hence, 3D printing has become an advanced method of construction, by utilizing appropriate binding material.

II. MATERIAL USED:

The mix is to be designed considering the three major characteristics of 3D concrete printing, namely pump ability, extrudability and buildability. Different researchers developed different mixes for 3D printing. The ingredients of the concrete mix are similar to those found in other concrete mixtures: water, cement, and fine aggregates but not coarse aggregates. We developed the new design mix with discarded glass, which is replacement of certain percentage (%) of fine aggregate .The success of the recipe lies in the texture and consistency itself. A workable consistency lowers the chances of pressure buildup that can block the nozzle or damage the printing equipment. Hence, for building purposes, the consistency is kept similar to that of aerated dough.

The requirement of the mix depends on the applicability as well as printing constraints. The designed mix and the properties considered for designing are summarized. The property of the material is listed below in the table.

S.No.	MATERIAL	QUANTITY
1.	Cement	1980 kg/m^3
2.	Class F Fly ash	495 kg/m^3
3.	Sand (max. size 2mm)	2598 kg/m^3
4.	Water	1056 kg/m^3
5.	Superplasticizer (polycarboxylate ether-based)	1.98 kg/m^3
6.	Methylcellulose	6.18 kg/m^3
7.	Discarded glass (replacement of sand) (max. size 2mm)	1116 kg/m^3

Table 1: Material Quantity

III. METHODOLOGY:

The printing procedure starts with the 3D model being sliced into layers according to the desired thickness, within the machine range (5-10mm layers). Each layer is then translated into the instruction code for the movement of the material deposition heads, and the printing process can start. The first layer of dry-mixed sand and magnesia cement is deposited on a flat surface, and leveled according to the selected layer thickness. A layer of binder is deposited on top of a layer of dry-mix powder, exactly where the printed object should be created, according to the specific instructions dictated by the software. As soon as the binder is in contact with the powder, it starts the hardening process, which will eventually solidify the material. The binder is deposited only on the areas of the powder layer that should contain the printed object, while no binder is applied to the rest of the powder bed, which remains unbound, and acts only as a support for the following layer that is coming on top. The process is repeated until all the layers of the print have been made. The object is then left for curing and then ready to be taken out the next day.

A. Mechanism of 3D Printing Machine –

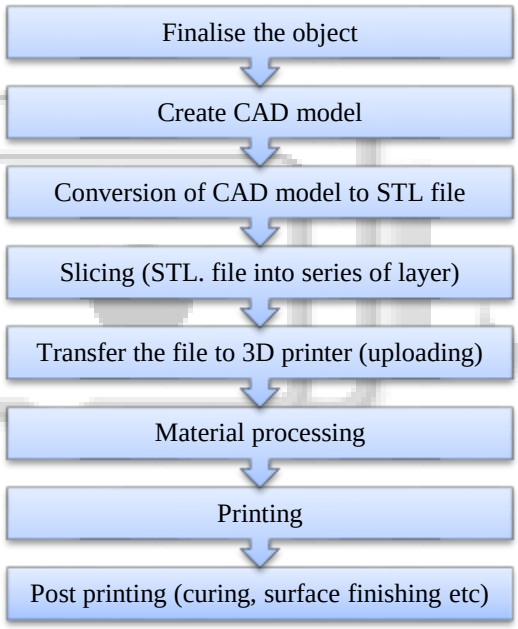

Fig. 1: Flowchart of Mechanism of 3-D Printing

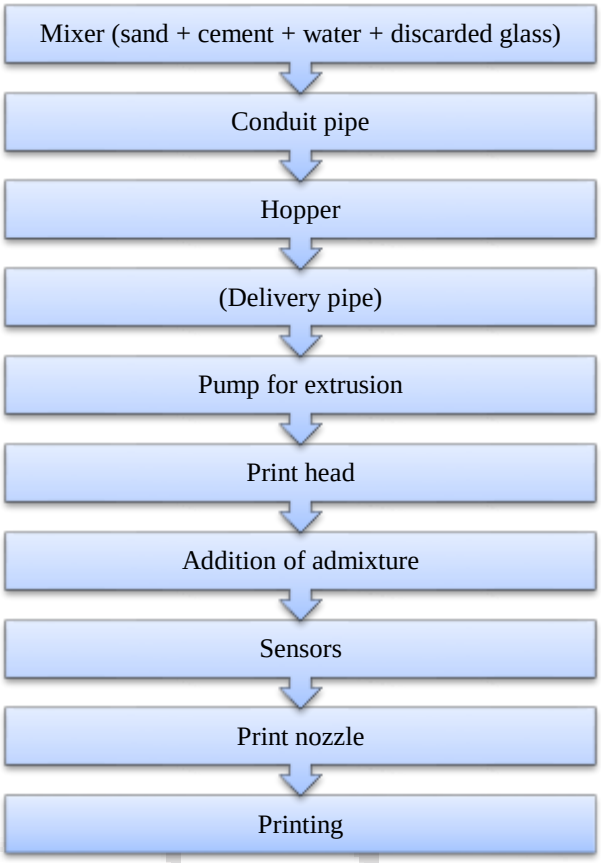

Fig. 2: Flow Chart of Material Processing in 3-D printing

IV. RESULTS & DISCUSSION:

In our experimental study we got:

S.No.	Item Discription	Conventional Method	By 3D Printing Method
1.	Labour cost	High	Less
2.	Time	Time taken	Less time taken
3.	Environmental impact	High pollution	Less pollution
4.	Perfection	Less accuracy	High accuracy
5.	Production cost	High	Less
6.	Quality	Create more waste subtractive process will compromise on precision.	Lighter and smaller amount of waste higher precision with layer by layer manufacturing.
7.	Design	Less innovative design due to cost constraints.	Allows for easy yet inexpensive innovation in design.
8.	Compressive Strength	33 N/mm^2 (28 days)	35.10 N/mm^2 (28 days)
9.	Quality control	Average	Good

Table 2: Comparative Study b/w Convetional Method VS 3D printing Method.

The traditional construction technology not only has environmental friendly problems such as noise and dust but also has resource-saving problems such as large template quantity and low construction accuracy. In addition, the traditional construction technology has an insurmountable technical bottleneck in the construction of special-shaped buildings. Building 3D printing technology can effectively overcome many problems existing in traditional construction technology and provide unlimited possibilities for the construction of special- shaped buildings. Concrete 3D printing technology is one of the most important technical Categories of building 3D printing. In this study, the research status and progress of concrete 3D technology were reviewed from the aspects of equipment system, materials, defect control, and application scenarios. On this basis, the development foreground was prospected.

Although there are many kinds of building 3D printing technologies, only the concrete 3D printing technology can adapt to the traditional concrete construction habits and is easy to achieve large-scale printing. The more simple and rapid support method in the printing process makes the concrete 3D printing technology a widely used building 3D printing technology. Many research institutions and enterprises have carried out research on it, mainly focusing on the research of concrete materials, the development of printing equipment and system, the quality, and path optimization of printing molding. The concrete 3D printing technology is derived from a construction method of free-form components based on the layer-by-layer superposition of cement materials proposed by Pegna in 1997. The free-form printing is realized by selective deposition of sand and silicate cement materials, then the printed components are steam cured, and finally the printing process is realized. In 2001, Khoshnevis et al. proposed the construction printing technology of "Contour Crafting." In 2007, Paul et al. improved the contour crafting and proposed "CC-cable-suspended." In 2008, Lim et al. proposed a similar technology based on concrete jet extrusion pile forming, named "Concrete Printing." In recent years, 3D concrete printing technology has increasingly become the forefront of academic and industrial circles. Many institutions and enterprises have participated in this research, which has promoted the technology from experimental research to industrial application.

V. CONCLUSIONS:

The 3-D printing is a very effective technology in construction industry. It has significantly improved the conventional construction industry. The 3D printing plays an important role in construction industry by reduced costs and fewer construction errors.

REFERENCES:

[1] Shantanu Bhattacherjee (2020) Indian Concrete Journal 94(9):825, "Projects: Development of cementious materials for additive manufacturing: 3D printing of concrete".
[2] Rahul, A. V., Santhanam, M., Meena, H., and Ghani, Z. (2019a). "3D printable concrete: Mixture design and test methods
[3] Wolfs, R. J. M., Bos, F. P., and Salet, T. A. M. (2019a). "Hardened properties of 3D printed concrete: Te in uence of process parameters on interlayer adhesion." Cement and Concrete Research, Elsevier, 119, 132–140.
[4] Markin, V., Nerella, V.N., Schrö, C., Guseynova, G., and Mechtcherine,V. (2019). "Material Design and Performance Evaluation of Foam Concrete for Digital Fabrication." Materials, 12(15), 2433, DOI: 10.3390/ma12152433.
[5] Rahul, A. V., Santhanam, M., Meena, H., and Ghani, Z. (2019b). "Mechanical characterization of 3D printable concrete." Construction and Building Materials, 227, 116710 concrete. Construction and Building Materials, 227, 116710.
[6] Ugent (2019). "Sustainable concrete mixtures for the 3D printing of breakwater units." Universiteit Gent
[7] Vantyghem, G., De Corte, W., Shakour, E., and Amir, O. (2020). "3D printing of a post- tensioned concrete girder designed by topology optimization." Automation in Construction, 112, 103084.
[8] Heever, M., Bester, F. (2018). "3D Printing of Concrete with-in the South African Building and Construction.

