IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.301

Volume 3, Issue 7, April 2023

# 3D Printed Houses

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**Abstract:** *The construction industry is expected to go through large transformations since construction automation is anticipated to drastically alter standard processing technologies and could lead to possible disrupting technologies such as 3D concrete printing (3DCP). While 3D printing techniques have been successfully applied in a wide range of industries such as aerospace and automotive, its application in concrete construction industry is still in its infancy. 3DCP can allow freeform construction without the use of expensive formwork, which in return offers excellent advantages compared to conventional approach of casting concrete into a formwork. In the last few years, different 3DCP technologies have been developed. This paper presents the current progress of 3DCP technologies.*

**Keywords:** 3D printing technology, 3D printing applications, construction industry

## I. INTRODUCTION

3D printing is a process by which physical objects are created by depositing materials in layers based on a digital model. All 3D printing processes require software, hardware, and materials to work together. The first 3D printer was invented in 1983 by Charles W. and over the last decades, 3D printing has become one of the fastest growing technologies nowadays. In its early days, it was very complicated and expensive technology. Over the years, 3D printing started to be present in everyday life and printers became commonly used in industrial practice. 3D printing can also be referred to as 'additive manufacturing,' especially when referring to its use within a manufacturing setting, and many individuals will use both phrases interchangeably. As the technology continues to grow, 3D printing technology can be used to create everything from prototypes and simple parts to highly technical final products such as airplane parts, life-saving medical implants, automobile and even artificial organs using layers of human cells.Emerging technologies are shaping our societies. Digitalization is affecting a myriad of aspects, from how people interact with each other to how they search for and buy products. The Fourth Industrial Revolution encompasses a novel technology that has the potential to make fundamental changes to the ways products are made and distributed: 3D printing (3DP).3DP might revolutionize the way products are made by disrupting manufacturing patterns, creating novel visual forms that were never possible before, enabling mass customization and offering new pathways to increase the circularity of products. At the same time, 3DP may provoke unintended consequences, such as potential workforce displacement, impacts on trade volumes and supply chains, fiscal and non-fiscal challenges to customs at borders, and room for intellectual property and legal violations.

The hype over 3DP adoption, including the prediction of "print at home anything", has not become reality. Consumer 3DP has not gone beyond do-it-yourself enthusiasts, and 3DP revenues were less than 0.1% of global manufacturing revenues in 2018. At the same time, 3DP global revenues have been rapidly growing at an average annual rate of 26.9% over the last 30 years (Wohler's Associates,2019).

The future of 3DP is evolving and, as such, its impact on different realms is unknown. This White Paper explores these realms and serves three functions. First, it presents broad scenarios of how the future might look like in five areas – manufacturing, trade and customs, supply chains, legality and the environment – if 3DP becomes more widely adopted. Second, it suggests leading indicators to monitor, predict and prepare for higher 3DP adoption. And third, it discusses the relevance of existing policy instruments through the lens of 3DP to point to policy changes that might be needed in the future.

## II. MATERIALS AND METHODS

### 2.1 Materials

**A. IN BUILDING ON DEMAND IN COPENHAGEN (COBOD).**

**Materials:** Concrete mix consisting of cement, sand and other additives

- In collaboration with FORCE technology, COBOD developed a strong and sustainable concrete mix using recycled material.
- They used a mixing pump that automatically filled dry material mix from the mixer.
- After this, water was added to the mix to keep the pump filled.

**B. WASP: GAIA**

**Materials:** Natural material mix consisting of 25% soil, 40% straw chopped rice, 25% rice husk, and 10% hydraulic lime.

- It is the first 3D printed mud house made from naturally available materials.
- The 3D printing of this earthen structure used a material mix consisting of soil, lime and rice fibers. The mix was made homogeneous and workable by mixing it thoroughly in a wet pan mill. The extrusion was done by a Crane WASP 3D printer.
- Finishing was done by shaving clay lamina on a monolithic wall. It was then smoothed and oiled with linseed oils.

**C. TVASTA**

**Materials:** Concrete mix based on ordinary Portland cement, but with lower water- cement ratio and consisting of cement, sand, and other additives**.**

- IIT Madras, created a specialty concrete that was affordable as well as sustainable. It is like the basic Portland cement but with a lower water-cement ratio.
- Amorphous metal fibers or plastic fibers are used along with the cement, based on the application.
- The structure made by them has 12 mm rebar on all four corners for secure attachment. It is also present in the hollow sections of the structure to provide tensile strength.
- The structure was specifically designed and 3D printed with hollow sections so that while wiring and plumbing, the walls are not damaged.

### 2.2 Method

**A. Contour Crafting**

- Contour Crafting (CC) is one of the oldest still existing concrete printing techniques. The first publications on the technique by Khoshnevis (University of Southern California) can be found in 1998 and much progress has been made since.
- Contour Crafting is a method of layered manufacturing, using polymer, ceramic slurry, cement, and a variety of other materials and mixes to build large scale objects with smooth surface finish. The smoothness of the extrusion is achieved by constraining the extruded flow in the vertical and horizontal direction to trowel surfaces.
- The nozzle may consist of multiple outlets, i.e., one for each side, and others for the inner (core) of a wall structure (*Fig.1)*. This way a co-extrusion of multiple materials is also possible. By deflecting the nozzle, non-orthogonal surfaces such as domes and vaults can be created (Khoshnevis, 2004).

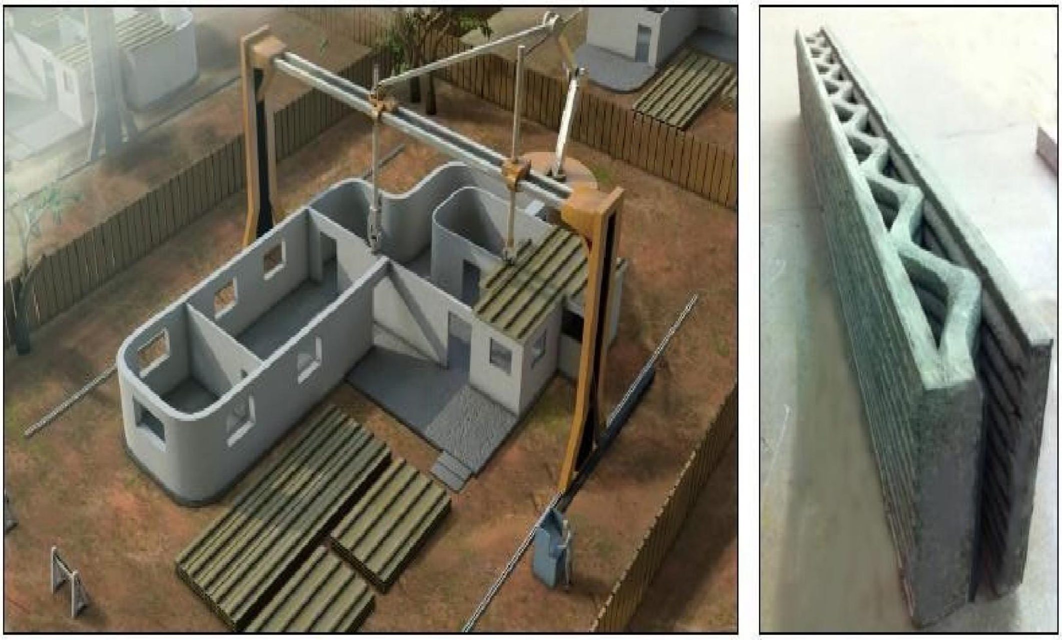
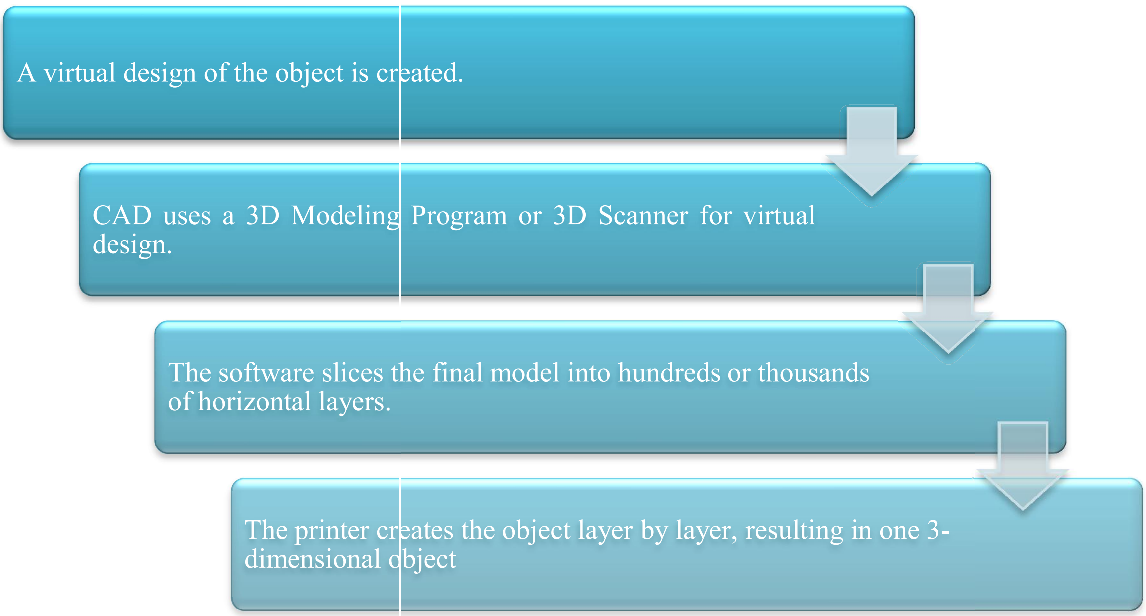


**Figure 1:**Contour Crafting by University of Southern California (contourcrafting.org, 2014)

## III. MODELING AND ANALYSIS



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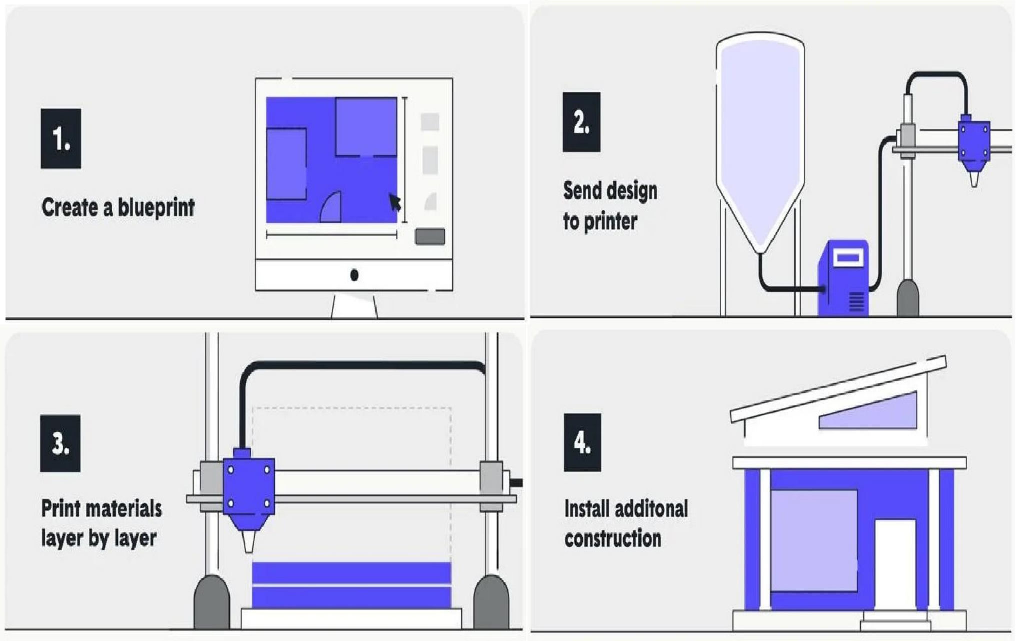


**Figure 2:** Process of 3d Modelling

## IV. 3 D PRINTING APPLICATIONS IN BUILDING INDUSTRY

### 4.1. BIM (Building Information Modeling)

BIM is a digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition. (RIBA and CPIC) "a coordinated set of processes, supported by technology that adds value through creating, managing and sharing the properties of an asset throughout its lifecycle. An innovative and collaborative way of working that is underpinned by digital technologies which support more efficient methods of designing, creating and maintaining the built environment.The construction industry has been facing a paradigm shift to (i) increase: productivity, efficiency, infrastructure value, quality and sustainability, (ii) reduce: lifecycle costs, lead times and duplications, via effective collaboration and communication of stakeholders in construction projects.Building Information Modeling (BIM) seeks to integrate processes throughout the entire lifecycle.If used appropriately, BIM can facilitate a more integrated design and construction process and generate substantial benefits. For instance, fewer design coordination errors, more energy efficient design solutions, faster cost estimation, reduced production cycle times and lower. BIM introduces a new work paradigm offering powerful perspectives for the integration and coordination of different domains and the processes involved in the design, construction and operation of buildings. The base schema for the BIM data is Industry Foundation Classes, an international standard for the exchange of BIM data, which provides a generic data schema covering among others architectural, building service and structural elements.

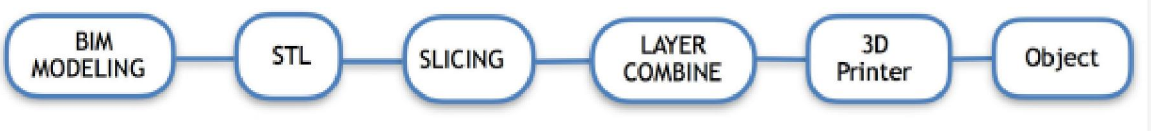


**Fig. 3D Printing Step**

### 4.2. 3D Printing Overcomes Construction Constraints

In the last decade, engineering research teams have been experimenting with using 3D printing to build components of buildings and entire homes, via 3D printing. The printing is done with what we could call "super-size printers", which use a special concrete and composite mixture. This mixture is much thicker than regular concrete, allowing it to be selfsupporting as it sets.This opens up a whole new realm of possibilities for architects everywhere. Much like the freeform design of The Bird's Nest in Beijing, China, 3D printed architectural components are totally unfettered by typical design constraints. The ability to use curvilinear forms, rather than being cost and process limited to rectilinear forms, opens a whole new realm of design. It is a commonly understood truth that rectilinear forms (rectangular forms) are one of the weakest structural forms imaginable. On the other end of the spectrum, the humble egg, which is totally curvilinear, is one of the most efficient structures in nature. A minimum of material, crafted into a shape where there are no straight edges, providing simple consistent curve, makes it the strongest structural design possible. 3D printing offers the practical possibility of using these curves in common structures.

## V. FUTURE SCOPE

There is a wide range of views about where the technology could be headed. Although 3D printing is still in its early days in all industries, the potential benefits seem to be driving the technology forward. Some suggest 3D printers will be used mainly to print building components and panels either in factories or on site, while others envision 3D printing as a transformative technology that could revolutionize the construction industry.

## VI. CONCLUSION

Technology of 3D printing is still young and presents lot of limitations, but there are high expectations and hopes for the future of 3D printed buildings and building components. Versatile applications of 3D printers and the development of new filament materials that could possibly ensure different properties to provide transparence, thermal insulation, or strength are under development.

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. 3D printing may transform nowadays architecture, nevertheless, this technique should be developed taking into consideration sustainability issues both for material selection and construction method.

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