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Comparative Studies of 3D Printing with Conventional System in Load Bearing Structure

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***Abstract:** With the use of software, structures may now be built entirely out of concrete by 3D printing them in layers. With the use of this technology, even complex geometric structures, massive loadbearing structures, and hydraulic structures may be quickly and cheaply created. During construction, it doesn't require any additional formwork, and the amount of labour needed is also rather low. It is an environmentally friendly technology that can also be utilised for decorative purposes. Charles Hull created this technology in 1984. This article discusses current trends and approaches for employing 3D printers in the construction industry. Angle of twist per floor for various storeys.*
***Keywords:** Comparative analysis, Load Bearing structure, Fusion 360,*

I. INTRODUCTION

In a 3D printing process, materials are deposited in layers to produce actual objects based on a digital model. Software, gear, and materials must all function together in order for 3D printing to be completed. Charles W. created the first 3D printer in 1983, and over the previous few years, 3D printing has become one of the fastest-growing technologies available today. It was an extremely expensive and complex technology in its early years. Over time, 3D printing began to permeate daily life, and printer usage in industry increased significantly. Many people will interchangeably use the terms "additive manufacturing" and "3D printing," especially when discussing their use in a manufacturing environment. As technology develops further, Using layers of human cells, 3D printing technology can be used to create anything from simple prototypes and parts to highly technical finished products like aeroplane parts, life-saving medical implants, automobiles, and even artificial organs.

Subtractive Manufacturing, a method of removing extra pieces of raw materials for a final product through cutting, grinding, rusting, and melting, is a manufacturing technique that uses Computer Numerical Control (CNC). In contrast, 3D Printing, also known as Additive Manufacturing [1], is a cutting-edge technology that uses a computerised numerical control model to combine layers of printed material into three-dimensional creatures.

The process of layering and superimposing to create three-dimensional items without the need of moulds is known as 3D printing. In 1989, Massachusetts Institute of Technology researchers Emanual Sachs and colleagues were the first to patent the concept of 3D printing. A important turning point in the development of 3D Printing technology occurred in the 1990s when Charles W. Hull of the USA created a Rapid Prototyping system that can produce produced parts. Governments all around the world have steadily implemented strategies and regulations to encourage the advancement of 3D printing technology since the turn of the twentyfirst century.



China's 3DPrinted Houses



Dubai's 3D Printed Office

A. Need for 3D Printing Technology in Construction

Due to a strong belief in the effectiveness of conventional procedures, materials, and rules, the construction industry has been sluggish to adopt new techniques and innovations. The construction sector has one of the lowest productivity increases when compared to other industries because no innovation or change is proposed to grow the business.

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B. Purpose of the Research

The goal of the study for the building sector, 3D printing offers creative, adaptable, low-volume, sustainable, and affordable solutions. Buildings and structures today need to be more adaptable in their design and construction while also being cost-effective.

C. Scope of the Project

In the sector of construction, 3D printing can be employed for a variety of additional tasks outside building structures. A type of 3D printing called "binder jet" uses powder and binding ingredients to create objects. However, the structure's precision and appearance might not be well defined.

D. Problem Statement

The cost of building a structure would be significantly reduced by the use of 3D printing technologies because they require fewer materials and prevent material waste. As fewer workers are needed, the cost of accidents and injuries is also decreased, which further lowers labour costs.

Designs that are uploaded as CAD files can be printed right away. As a result, 3D printers enable quick development of structures. They may produce a single-story building in 12 to 24 hours.

E. Aim

"To study the comparative analysis of 3D-printing with conventional system in Load Bearing structure"

F. Objectives

1) 3D printing offers the construction industry creative, adaptable, affordable, low volume, and sustainable alternatives.
2) Buildings and structures require more flexibility in their design and construction while still being cost-effective in light of current trends and needs (Mellor et al., 2014).
3) The socioeconomic aspects that may have an impact on the application of 3D printing in building will be investigated and studied in this study.
4) Assessing them can assist experts and researchers in creating useful strategies for managing and using the technology in the future, hastening the adoption process.

II. LITERATURE REVIEW

The 9th International Conference on Sustainability in Energy and Buildings, SEB-17, was held from July 5-7, 2017, in Chania, Crete, Greece. Mehmet Sakin and Yusuf Caner Kiroglu presented their paper, "3D Printing of Buildings: Construction of the Sustainable Houses of the Future by BIM."

The paper describes a cutting-edge method for printing buildings in three dimensions for future sustainable homes. With the development of the 3D printer, a new construction method called 3D printing was born. In this article, the most recent technologies were discussed, with a focus on contour crafting as a potentially game-changing method for the construction sector. There are many benefits to this technique, including decreased costs and time, less environmental pollution, and a decline in accidents and fatalities on building sites. In compared to conventional construction methods, the integration of Building Information Modeling with 3D printing is addressed.

1) Mohamed M. I., Manju R., Deepika R., Gokulakrishnan T., Srinithi K., International Journal of Recent Technology and Engineering (IJRTE), Volume 8 Issue 2S8, August 2019, a study on 3D printing concrete.

In this study, we discuss the new technology of 3D printing concrete, which enables the construction of structures solely from layers of concrete with the aid of software.

With the use of this technology, even complex geometric structures, massive load-bearing structures, and hydraulic structures may be quickly and cheaply created.

During construction, it doesn't require any additional formwork, and the amount of labour needed is also rather low. It is an environmentally friendly technology that can also be utilised for decorative purposes. Charles Hull created this technology in 1984. This review article explores current trends and uses of 3D printing in the construction industry.

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2) Best Practices and Applications of 3D Printing in the Construction Industry, Jake Kidwell.

A cutting-edge technology called 3D printing (3DP) holds great promise for improving project effectiveness and profitability on the job site as well as having favourable effects on the environment. The size, material, specialised labour, and industrial resistance of this technology as it is today, however, severely restrict its potential. This study examines forward-thinking 3DP businesses that have successfully applied this technology on a broad scale. In order to outline the best applications and practises given the current limitations of the technology, this paper will examine the current applications of 3DP in the construction industry.

3) The Application of 3D Printing Techniques in the Manufacturing of Cement-Based Construction Products and Experiences Based on the Assessment of Such Products, by Guillermo Sotorro Ortega, Javier Alonso Madrid, Nils O. E. Olsson, and José Antonio Tenorio Ros.*

With the premise that standardisation supports a technology's viability, this article proposes qualitycontrol tests and an assessment technique to demonstrate that regulation is not a barrier to the usage of an innovative product, such as 3D printing. The information is based on the authors' experiences developing three 3D printing research projects, including the techniques and outcomes. This study also explores the possibility that 3D printing materials may perform better than conventional ones.

4) Development, Obstacles, and Future Prospects of 3D Concrete Printing Technology, Amit Kumar D. Raval and C.G. Patel, International Journal on Emerging Technologies 11(2): 892896(2020).

The paper discusses the various opportunities that 3D concrete printing technology offers. Even though this technology has numerous advantages, risk and problems are also highlighted in this study because it is still in its early stages and has many restrictions. In the study, environmental issues are also covered. etc. were discovered in order to satisfy the demands of on-field applications. The potential uses of the 3D concrete printer in the field are also assessed, as well as their future potential.

5) A. V. Rahul, Manu Santhanam, and Shantanu Bhattarcharya, "Concrete 3D Printing: Progress Worldwide and in India."

The progress of digital fabrication techniques in academia and the construction industry is reviewed in this paper, with a focus on extrusion-based 3D printing. The development of a Portland cementbased 3D printable formulation by the research team at IIT Madras is described in detail. Finally, this report also highlights the areas of digital fabrication that need additional study and focus.

III. RESEARCH METHODOLOGY

A. State-Of-The-Art Of 3d Printing Of Concrete

1) Procedure Static Analysis

Joseph Pegna proposed the first attempt to use cement-based materials in a 3D printing process. Currently, three 3D printing technologies—contour crafting (CC), D-shape, and concrete printing—are available for public usage and are geared toward the building industry. These three methods are effective in producing components of huge sizes and are appropriate for use in the construction industry.

The layered-based procedure is the same for all three stages. Instead, every one of these methods was created for various materials and uses.

2) Contour Crafting (CC).

To switch from the traditional technique of construction to a layer-bylayer manner, the contour crafting (CC) construction process was created. Dr. Behrokh Khoshnevis created CC, a layered construction technique, to automate the building of all the components of a house, including the electrical, plumbing, drywall, and insulation. Construction cost reduction (CC) decreases construction costs, speeds up construction, increases architectural design flexibility, and creates a welcoming environment. Based on the amount of time and effort the instrument expended as well as the materials needed to construct the structure, the cost of construction can be determined. Once the structure model has been converted to a stereolithography (STL) file and a tool path has been determined, the overall construction time may be calculated.

The position, direction, speed, and feeding rate of the nozzle during the duration of construction must be expressed in a tool path of CC for any specific building. The CC machine receives these data in the form of a number of machine tasks. Then, for each machine task, the path with the lowest cost is found.

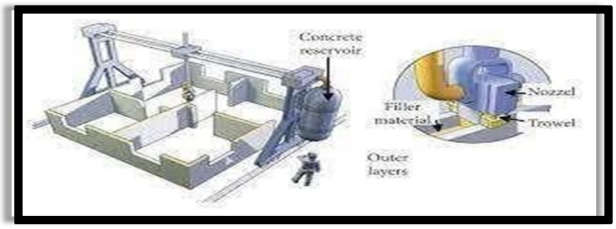


FIG 1 : Contour crafting in construction operation

3) D-Shape.

The binder jetting approach, which is powder deposition that is solidified with a binder, is the foundation of the D-shape process. After compacting each layer of material to the necessary thickness, the binder is subsequently deposited where the portion is to be solid using the nozzles attached to the frame. When the component is finished, the loose powder bed is cleaned.

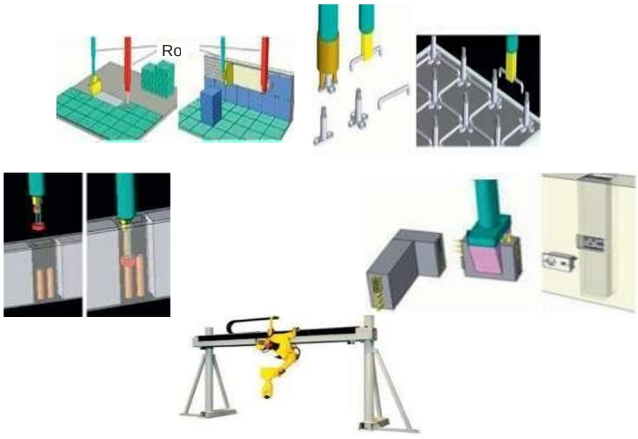
4) Concrete Printing

The extrusion of cement mortar is known as concrete printing. Greater control over internal and external geometries is possible thanks to the process's development, which preserves 3D freedom while having a lower resolution than deposition.

B. Automated 3D Printing Features

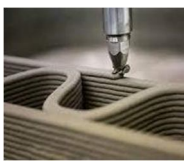
The slow production, poor quality, low safety, and a lack of competent personnel are all potential problems for the construction business. Some Japanese construction firms are turning to technology to help them cope with the manpower crisis. As a result, they either created single task robots to replace straightforward labour tasks or fully automated systems that can build skyscrapers made of steel or buildings made of steel-reinforced concrete utilising prefabricated components. More than 89 single-task construction robots and 11 fully automated construction systems were created as a result. Although productivity, safety, and quality have all increased thanks to robotics, conventional construction methods are still used. It is expensive to automate traditional construction, such as placing bricks with a robot.

For instance, installing reinforcements and putting together ties and studs are labor-intensive tasks. The installation of steel reinforcement into each layer is planned using the CC process as indicated in:



Materials mixed in Specialize Concrete:

- ✓ 33% -40% of cement
- ✓ 0%-8% of inorganic powder
- ✓ 32% -38% of tailing machine-made sand
- ✓ 2.5% -3% of a high- molecular polymer
- ✓ 0.1% -0.5% of a water reducing agent
- ✓ 16.7% -20% of mixing water



In order to create an inorganic composite material, a mixture of thixotropic, volume stabilising, and other additives is added. The inorganic composite material is then pumped directly into a 3D printer where it may be used for building.

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A control concrete (Mold-cast Specimens) exhibited an estimated density of 2250 kg/m3, strong strength (107 MPa in compression, 11 MPa in flexure, and 3 MPa in direct tension), and comparatively low drying shrinkage of 175 m (cured in water) and 855 m (cured in a chamber at 20 °C and 60% relative humidity) at 184 days. Contrarily, well-printed concrete had a density of 2350 kg/m3, a compressive strength range of 75–102 MPa, a flexural strength range of 6–17 MPa, and a tensile bond strength ranging from 2.3 to 0.7 MPa, decreasing as the printing time gap between layers rose.

The implications for mix proportions are discussed together with the effects of the layering technique on density, compressive strength, flexural strength, tensile bond strength, and drying shrinkage.

There were a lot fewer voids in the concrete that was well printed.



Chemical Admixtures for 3D- Printing

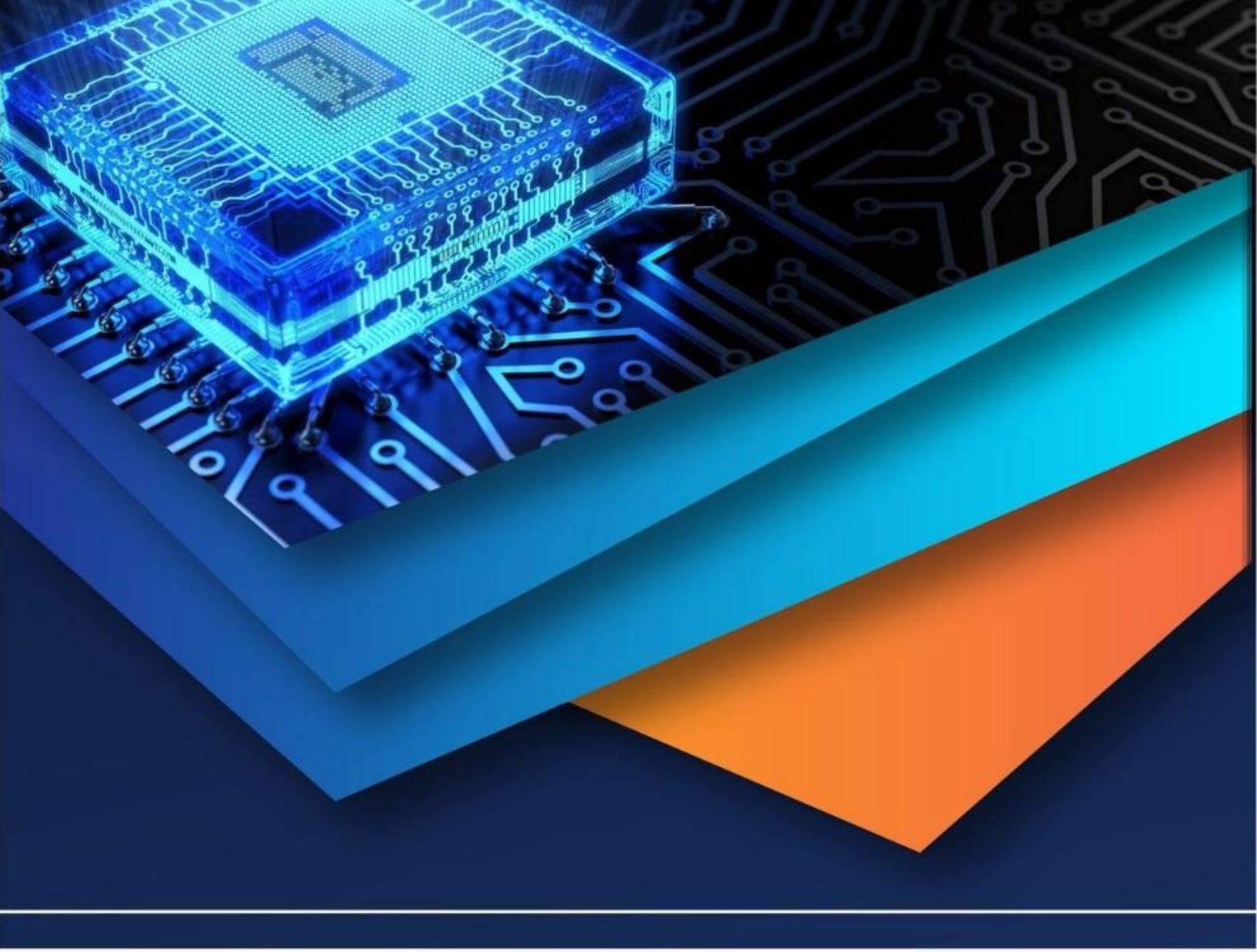
- Common shotcrete accelerators (calcium formate, sodium silicate, sodium aluminate, or aluminium hydroxy sulphate) are admixed in order to do this.
- The following effects are attained through the use of chemical admixtures and mineral additives: pumpability of the ink; structuration and shape stability of the deposited ink; thixotropy to prevent particle sag; adhesion between individual deposited layers; rapid strength development; shrinkage control.

IV. ACKNOWLEDGEMENT

In order to verify that 3D-printed objects meet quality standards, a battery of universal tests must be established. Depending on the intended usage, the printing technology utilised, and the materials, each product will undergo a different kind of test. Since additive and subtractive manufacturing in three dimensions is a novel technology, it is not covered by current standards. This does not prevent the proposal of an evaluation approach to guarantee the quality of such products. Some of the existing standards can be used to assess the performance of the new materials, but it is unclear how these standards may be applied, necessitating the creation of new tests and procedures in addition to a suitable methodology. Materials, tools, and design are closely related to one another. Assessments should encompass all the steps and procedures, not just the finished goods. The techniques and findings in this article are based on the authors' experience in the development of three 3D printing-related research projects, which, while a first step, show how much work needs to be done.

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