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Analysing the Impact of Additives on the Strength Parameters of 3D Printed Concrete

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Abstract: 3D Printing is an additive manufacturing process. 3D concrete printing is an innovative construction technique that uses computer-controlled machines to create structures layer by layer. This method allows for intricate designs and shapes to be produced with precision. The process is efficient and can reduce material waste, making it a sustainable option for construction projects. It doesn't require the use of formwork and also requires less labour. Silica sand is a waste product of the foundry and paint industry. It is known for its uniform particle size, which can result in a more consistent and even finish in construction projects. Additionally, silica sand is free of impurities like clay and organic matter, making it ideal for use in manufacturing high-quality concrete and mortar. Its angular shape also provides better bonding properties, improving the overall strength and durability of the construction material. It can be a viable alternative to river sand in the production of concrete. Our project deals with the use and optimization of silica sand as an alternative to river sand in the production of 3D Printed Concrete.
Keywords: 3DPC, Pumpability, Rebound Hammer, Sand Silica, ACC ALFI, ACC(107)

I. INTRODUCTION

3D printing construction technology also known as additive construction, refers to the process of using 3D printing techniques to build structures layer by layer. It is an innovative approach to building construction that has the potential to revolutionize the industry by offering faster, more cost-effective, and customizable construction solutions. This technology involves the use of large-scale 3D printers that can deposit various materials such as sand, cement, fly ash, admixtures to construct buildings, houses, bridges, and other architectural elements. In this project River sand, sand silica, cement, fly ash has been used to build the sample to enhance the properties of that concrete by using various admixtures. Additives play a crucial role in modifying the properties of 3D printed concrete. These additives aimed at enhancing strength, durability, workability, and other performance metrics. Understanding the impact of additives on the strength parameters of 3D printed concrete is vital for optimizing the printing process and ensuring structural integrity in real-world applications. This paper aims to analyze the effects of different additives on the strength parameters of 3D printed concrete. By systematically evaluating the influence of various additives on compressive strength, durability and other relevant parameters, we can gain insights into their effectiveness and potential synergies. Moreover, this analysis can inform the development of optimized additive formulations tailored to specific construction requirements and printing technologies. Ultimately, the findings of this research will not only contribute to the academic understanding of 3D printed concrete but also have practical implications for engineers, architects, and construction professionals seeking to leverage additive manufacturing technologies for sustainable and resilient infrastructure development.

A. Problem Identification

Traditional concrete construction methods often encounter challenges in achieving optimal strength parameters while maintaining efficiency and cost-effectiveness. Factors such as pumpability, extrudability, and buildability significantly influence the success of 3D printing concrete structures. Existing gaps in additive analysis and its impact on strength parameters necessitate a systematic investigation to address these challenges. The present innovation aims to bridge these gaps by comprehensively analyzing the impact of additives on the strength parameters of 3D printed concrete.

B. Objectives of Project

1) To investigate the influence of admixtures on 3D printing process parameters such as pumpability, extrudability, buildability.
2) To develop various concrete mix design by adjusting properties of sand silica to achieve desired strength parameters.
3) To Investigate and evaluate the parameters of 3D printed concrete.

II. IDENTIFY, RESEARCH AND COLLECTIDEA

A. Research

By optimizing concrete mix designs and incorporating suitable admixtures, the innovation seeks to enhance pumpability, extrudability, and buildability while ensuring desirable strength characteristics. Through meticulous experimentation and data analysis, the innovation addresses limitations in traditional construction methods and offers a viable solution for efficient and customizable concrete construction.

B. Introduction

3D printing construction technology also known as additive construction refers to the process of using 3D printing techniques to build structures layer by layer. It is an innovative approach to building construction that has the potential to revolutionize the industry by offering faster, more cost-effective, and customizable construction solutions. This technology involves the use of large-scale 3D printers that can deposit various materials such as sand, cement, fly ash, admixtures to construct buildings, houses, bridges, and other architectural elements. In this project River sand, sand silica, cement, fly ash has been used to build the sample to enhance the properties of that concrete by using various admixtures.

This paper aims to analyze the effects of different additives on the strength parameters of 3D printed concrete. By systematically evaluating the influence of various additives on compressive strength, durability and other relevant parameters, we can gain insights into their effectiveness and potential synergies. Moreover, this analysis can inform the development of optimized additive formulations tailored to specific construction requirements and printing technologies.

C. Methodology

Following are the various steps that we decided to use for the successful conduction of our project. The steps are mentioned in detail below.

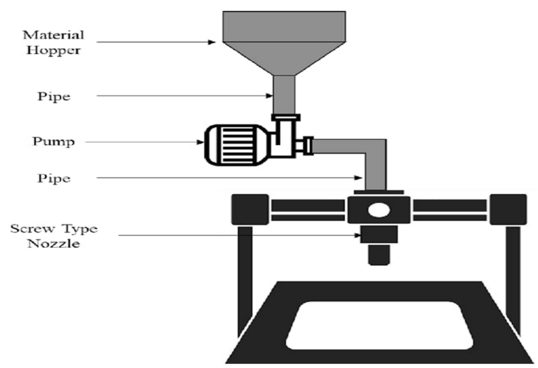

Fig.1 Nozzle

D. Mechanism

The mechanism involves the precise layering of construction materials based on Newton’s law obeys, digital designs. Key components of the 3D printer and their functions includeExtruder: Deposits and layers the construction material.

1) Build Platform: Supports the printed structure during construction.
2) Controller: Manages the movement of the extruder and build platform.

E. 3D Printer Components

1) *Extruder:* Responsible for feeding and melting the construction material.
2) *Build Platform:* The surface on which the construction material is deposited layer by layer
3) *Controller Board:* Manages the movement of the extruder and build platform, ensuring precision.
4) *Supply:* Provides the necessary power for the entire 3D Printing process.
5) *Nozzle:* Nozzles come in various diameters, commonly Ranging from 0.2mm to 1.0mm. The nozzle diameter affects layer resolution and printing speed. Smaller nozzles(e.g., 0.4mm) are often used for detailed prints, while larger nozzles may be used for faster, less detailed prints.
6) *Mixing Pump:* A mixing pump, is not a standard component in most 3D printers. However, some specialized 3D printers do exist that incorporate multiple extruders or hot ends, allowing for the mixing of different filaments.

7) *Pressure Pump:* Pressure monitoring contributes to the overall safety of the 3D concrete printing process by ensuring that the equipment operates within safe limits and that there is no risk of over-pressurization.

Fig.2 3D Printer

F. Materials

Sand silica, Cement, Fly ash, VMA, VTNB, Water, ACC107, ACC ALFI, River sand

Fig.3 Admixture

G. Data collection

1) Software used

AutoCAD can be used in 3D printing construction technology, but it's not necessarily the ideal choice.

2) AutoCAD's role

- Capable of 3D design: AutoCAD can create detailed 3D models, which is a requirement for 3D printing.
- Exporting for 3D printing: It can export your designs in STL format, a common file type used in 3D printing.
- Limited 3D printing features: Compared to software specifically designed for 3D printing, AutoCAD lacks features for optimizing models for printing (e.g., checking for printability or adding support structures).

Fig.4 Nozzle

H. *Controlling*

Using sensors embedded within the concrete during the 3D printing process is an emerging technique to achieve greater control and quality in construction. Here's how it works

Sensor Types

- Pressure Sensors: Placed near the nozzle or within the printing line, these monitor the flow of concrete. Consistent pressure ensures proper deposition and identifies blockages that could ruin the print .
- Height Sensors: These can be ultrasonic or laser-based and measure the deposition height of each layer. This feedback allows for real-time adjustments to the nozzle distance for a uniform and precise structure

I. *Motors and Movement:*

Similar to traditional 3D printers, concrete printers use stepper motors or servo motors to control the movement of the print head (nozzle) along the X, Y, and Z axes. Stepper motors offer precise movement in specific increments, ideal for building up layers of concrete. Servo motors provide more control over speed and position, which can be beneficial for complex printing paths.

J. *Control System*

1) A central control unit, often a computer running specialized software, receives the 3D model data (usually converted to a toolpath).
2) This software translates the model into a series of instructions for the motors, specifying the precise movement for each layer of concrete deposition.
3) The control unit sends these instructions to the motor drivers, which regulate the power delivered to the motors, ensuring they move according to the program.

K. *Working mechanism*

The mechanism involves the precise layering of construction materials based on Newton's law obeys, digital designs. Key components of the 3D printer and their functions include:

1) Extruder: Deposits and layers the construction material.
2) Build Platform: Supports the printed structure during construction.
3) Controller: Manages the movement of the extruder and build platform.

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Fig.5 Nozzle

L. Design

Selecting proportion of concrete mix for casting cube

- Cement – 1 kg
- Sand silica -2 kg
- Fly ash – 200 gm
- VMA – 5%
- ACC107 – 2 ml
- ACC ALFI – 2 ml

Casting of cubes by adding admixture (ACC107), Proportion are given in the table.

Fig.6 proportional trial sample

Casting of cubes by using admixture (ALFI)), proportion are given in the table

TRIALS	CEMENT (gm)	FLY ASH (gm)	SAND SILICA (gm)	VMA (gm)	VTP (ml)	ACC ALFI (ml)	WATER (ml)	TIME (sec)
1.	400	100	1000	1	1.5	4	250	25
2.	400	100	1000	1	1.5	5	250	30
3.	400	100	1000	1	1.5	6	250	45
4.	400	100	1000	1	1.5	1	250	45
5.	400	100	1000	1	1.5	2	250	60
6.	400	100	1000	1	1.5	3	250	30

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Fig.7 Cube

Casting of cubes by adding admixture (ACC107), proportion are given in the table
Casting of remaining cubes, proportion are given in the table.

TRIALS	CEMENT	FLY ASH	SAND SILICA	VMA	VTP	ACC ALFI	WATER	TIME
7.	400	100	1000	1gm	1.5ml	4ml	250	25sec
8.	400	100	1000	1gm	1.5ml	5ml	250	30sec
9.	400	100	1000	1gm	1.5ml	6ml	250	45sec

M. Test on cubes (Compression strength)

Quality control in 3D printed concrete ensures the material meets required strength standards, maintaining consistency and reliability in construction. By understanding compressive strength, manufacturers can optimize concrete mixes for better performance, reducing material usage while maintaining integrity. Verifying that printed concrete can withstand expected loads is crucial for structural safety and durability. Process validation ensures the layer-by-layer deposition does not compromise material strength, establishing confidence in new techniques. Meeting regulatory standards and building codes is essential, as is providing data for predictive models to design efficient and resilient structures.

312WQ	Date of casting	Size (cmxcmxcm)	Date of testing	weight	Compression
3	03/01/2024	16X4X4	31/01/2024	604	197
5	03/01/2024	16X4X4	31/01/2024	616	160
7	03/01/2024	16X4X4	31/01/2024	626	118
10	03/01/2024	16X4X4	31/01/2024	589	174
11	03/01/2024	16X4X4	31/01/2024	589	188
12	03/01/2024	16X4X4	31/01/2024	613	153

N. Prepare Model on 3D Concrete Printer Prototype.

Prepare model with the help of 3D printing machine and taking trial 1st by using following mix proportions
(After mixing and analysis mixture adding more water and admixtures for suitable workability of concrete into the pump and pipe)

Description	Trial 1	Trial 2	Trial 3
Sand Silica (kg)	10	10	5
Cement (kg)	4	5	7.5
Fly ash (kg)	1		
Water (lit)	2.5	2.5	3
VTNB (ml)	15	15	15
VMA (gm)	10	15	25
ACC 107 (ml)	10		
River sand (kg)			5

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- Water – 500ml
- ACC ALFI – 5ml
- VMA – 5gm

Fig.8 Trial

III. TEST AND RESULTS

A. Rebound Hammer Test On Castings

The rebound hammer method provides a convenient and rapid indication of the compressive strength of concrete by means of establishing a suitable correlation between the rebound index and the compressive strength of concrete.Castings were made of the 50% replacement of silica sand to river sand. Non-destructive testing was done using a rebound hammer. All readings were taken at 0° inclination.

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Fig Rebound Hammer test perpendicular to the layers

B. *Flexural Testing of Moulds*

Flexural testing in 3D printed concrete is crucial as it measures the material's ability to resist bending, which is essential for evaluating structural performance under various loads. This test helps ensure the concrete can withstand tensile stresses, contributing to the overall safety and durability of the structures. It also aids in optimizing material formulations and validating the printing process, ensuring that the final product meets required strength standards and industry regulations.Flexural testing was done on samples with standard size of 160×40--×40mm. Testings were done parallel as well as perpendicular to the layers.

Fig. Flexural test perpendicular to the layers

Orientation	Reading (0° inclination)	Average
1) Perpendicular to Layer	43,40,43,42,40,45,40,43,44,44	47.8 MPa

IV. CONCLUSION

From our work on this project called as 3dpc. We conclude the point on that topic.

1) After casting and testing the 6 block to finalize the proportion is silica sand is a viable alternative to river sand. 50% replacement of river sand by silica sand yields the highest compressive and flexural strength.
2) After 3-D printing trials, finally its achieved 0.5 water content ratio, VMA & VTMB admixture 1-10 % of cement.
3) After successfully printing and casting, we perform the test and we got better result than conventional concrete.
4) After taking the rebound hammer test to the layer of sample, we got the proper reading for future cracks. • Therefore, we finalise that this proportion can be used for the construction using 3D printer

A. *Future Scope of the Work*

1) This project also can be used in future by changing the Nozzle diameter.
2) The Durability test test like RCPT & Freeze-thaw can be done in future.
3) Additional alternate materials used in 3D concret

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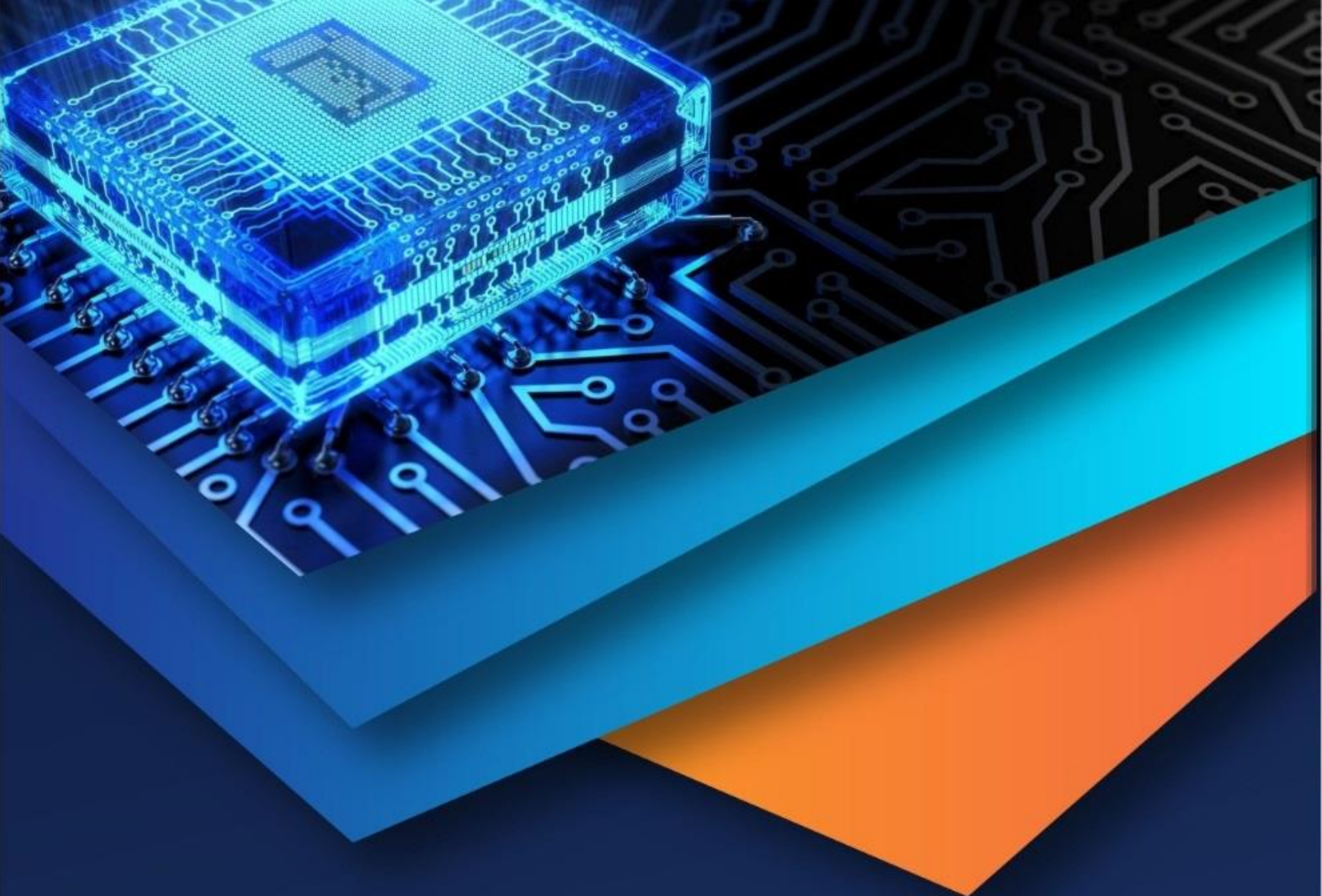

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