IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

EVALUATING 3D PRINTING OF CONCRETE TOWARDS INDUSTRIALISATION

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Abstract: 3D printing technology has brought about significant changes in several industries, including the construction sector. The utilization of 3D printing technology in the construction sector, commonly referred to as additive manufacturing in construction (AMC), presents considerable potential for revolutionizing the industry by enhancing productivity, promoting environmental sustainability, and enabling more design adaptability. This study summarizes the findings of an extensive survey done within the construction sector to examine the implementation and anticipated outcomes of 3D printing technology.

Index Terms - **3D Printing Technology, Additive Manufacturing in Construction (AMC), Construction Sector Innovation, Implementation and Outcomes**.

I. INTRODUCTION

Over the past few decades, 3D printing, also known as additive manufacturing, has emerged as a technology of great interest to researchers worldwide due to its remarkable ability to transform digital designs into physical objects. This transformative process is achieved through the use of 3D printers, which convert three-dimensional digital models into tangible objects. Initially utilized primarily in industrial design and manufacturing, 3D printing has expanded its reach into various other fields, including medicine, food production, and construction. This diversification of applications underscores the versatility and potential of 3D printing technology.

The allure of 3D printing has not been lost on engineers and architects, who recognize its virtually limitless possibilities. As the construction industry has embraced this new technology, its applications have extended beyond rapid prototyping to encompass the actual production of entire structures. The idea of constructing buildings through 3D printing has become a tangible reality, frequently highlighted in mass media reports.

However, it's important to note that despite the significant strides made in 3D printing, especially in the construction sector, the technology is still in its early stages of development. Several technical limitations and challenges hinder its widespread adoption. In particular, within the construction industry, there is a pressing need for further research to address issues related to precise mechanical control, suitable printing materials, and the development of efficient dispensing systems for these materials.

The current state of 3D printing in construction reflects a promising but evolving landscape. Researchers and industry professionals are actively engaged in efforts to overcome these technical weaknesses and expand the technology's capabilities. The potential benefits of 3D printing in construction, such as cost-effectiveness, design flexibility, and reduced waste, make it a field ripe for exploration and innovation. As these challenges are addressed, the construction industry is poised to see even more significant transformations through the application of 3D printing technology, ultimately reshaping the way buildings are designed and constructed.

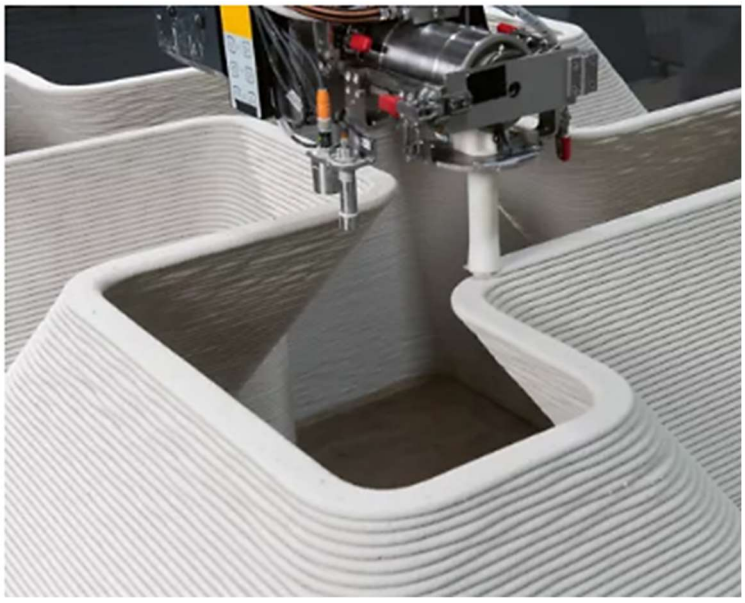

Figure 1: 3D concreted printing

II. 3D PRINTERS FOR CONCRETE

The advent of 3D concrete printing has emerged as a pioneering technology within the realm of construction, presenting novel approaches for the construction of structures characterized by heightened efficiency and precision. The selection of the suitable robotic system for 3D concrete printing is contingent upon several criteria, encompassing the specific application, scale of the project, and the chosen printing methodology. Let us now explore the three primary classifications of robots employed inside this captivating domain.

Gantry robots, also known as Cartesian robots, are a type of robotic system commonly used in industrial applications. Gantry robots serve as the primary machinery for 3D concrete printing. The systems are comprised of a movable gantry system that is equipped with mixing and deposition capabilities. The versatility of these robots spans over a wide range, encompassing small-scale laboratory models as well as large-scale printers that possess the capability to manufacture complete components or structures. Gantry robots are commonly constrained to vertical extrusions; yet, they possess several advantageous characteristics. These entities are widely recognized for their exceptional level of stability, which renders them a dependable option for complex undertakings. Furthermore, these systems may be readily expanded to accommodate bigger projects. Nevertheless, it is important to acknowledge that these robotic systems necessitate a size bigger than the buildings they are tasked with creating, hence potentially augmenting expenses associated with transportation and setup. Nevertheless, they continue to be the most manageable among various 3D printing technologies.

The cable-driven technology involves the suspension of the print head between many fixed locations within a frame. The present configuration affords increased geometric flexibility in comparison to gantry systems and presents the benefit of being more lightweight and easily transportable. Cable-driven systems have exceptional adaptability; nonetheless, meticulous design is required to prevent cable intersections with the printed structure. The novel methodology employed in 3D concrete printing presents novel opportunities in the realms of design and adaptation.

The utilization of robotic arms in 3D concrete printing exhibits resemblances to their application in assembly lines. The technology offers a six-axis movement capability, which grants it the greatest level of freedom compared to other 3D printing systems. The inherent flexibility of this approach enables the inclusion of not just concrete deposition, but also the integration of other elements such as rebar, as well as the execution of subsequent activities following the solidification of the concrete. Robotic arms are recognized for their inherent compactness, rendering them highly suitable for small-scale applications characterized by spatial constraints. The versatility and accuracy exhibited by these entities provide them a very beneficial option for activities necessitating complicated motions and the manipulation of diverse materials.

III. LITERATURE REVIEW

Tidd et al.'s perspective highlights a key aspect of innovation strategy within the construction industry. They argue that one of the primary strategies for fostering innovation in construction is to adopt and adapt technologies and practices from other sectors to bolster their competitive advantages. In essence, it's about leveraging external technological advancements to enhance efficiency, quality, and overall performance within construction.

3-D printing, also known as additive manufacturing, is a revolutionary manufacturing technique as described by Berman. It operates by creating objects layer by layer, utilizing a digital design as the blueprint. This process stands in contrast to traditional manufacturing, which often involves cutting or subtracting material. Instead, 3-D printing adds material incrementally, offering precision and customization like never before.

The core concept behind 3-D printing is the division of the digital design into cross-sectional slices or layers. The 3-D printer then proceeds to construct the object by adding one layer at a time, stacking them on top of each other. This layer-by-layer approach enables the creation of intricate and complex shapes that would be challenging or impossible to achieve through conventional manufacturing methods.

According to Bogue's (2013) description, 3D printing is an innovative method of manufacturing that enables the production of three-dimensional items based on digital models. In contrast to conventional manufacturing techniques, which often entail the removal of material from a solid block or the shaping of material into a desired form, 3D printing operates through an additive process. The process of 3D printing involves the incremental construction of items by adding material in specific locations, as opposed to the conventional method of subtractive manufacturing where material is removed from a solid block to get the desired shape.

IV. METHODOLOGY

The paper discussed in your query focuses on the findings of a questionnaire conducted within the construction industry to explore the use of 3D printing and the expectations associated with it. The research begins with a comprehensive review of existing literature to establish a foundation for their study. To gather data, the researchers developed an initial version of the questionnaire, which was designed to extract insights from professionals and stakeholders in the construction sector regarding their experiences and outlook on 3D printing technology. The study reached out to a sizable pool of potential respondents, consisting of 121 individuals involved in the construction industry. These participants likely included architects, engineers, contractors, and others who have a vested interest in construction processes. Following the data collection phase, the researchers compiled and organized the survey responses in Excel format. This format facilitates data analysis and graphical representation of the results. By using Excel, they were able to generate various visual representations such as charts, graphs, and tables, which can help convey the findings more effectively to the reader.

V. RESULT

The findings of this study delve into two critical facets of 3D-printing technology in the construction industry. The first aspect revolves around the current state and anticipated future adoption of 3D-printing in construction. The second aspect of the research focuses on the anticipated cost-related issues associated with 3D-printing in construction. This involves an examination of the financial considerations that construction companies and stakeholders might face when adopting this technology. It aims to provide insights into the expected expenses, cost savings, or any potential challenges and uncertainties related to the use of 3D-printing in construction projects.

Evolution of 3D Printing in Building and Construction

The questionnaire in question focused on exploring the utilization and integration of 3D printing technology. According to the findings presented in Figure 2, it becomes evident that a majority of the survey respondents had not yet engaged with 3D printing technology. Those who did have experience with 3D printing primarily employed it for purposes related to piloting and prototyping.

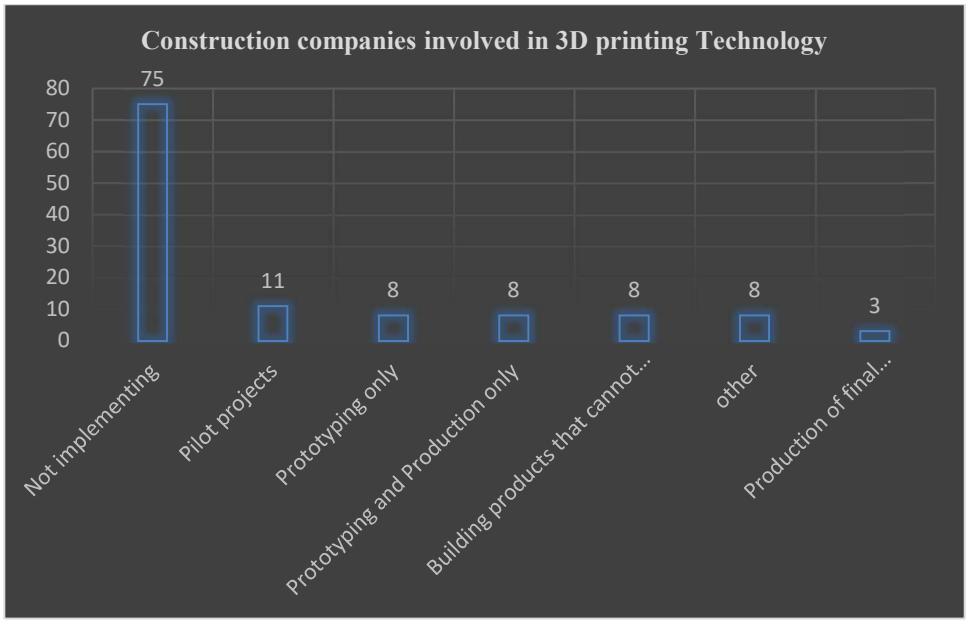

Figure 2: Construction companies involved in 3Dprinting Technology.

Figure 3 provides insights into the respondents' expectations regarding the potential applications of 3D printing. The prevailing belief among the survey participants was that 3D printing would find its most significant application in the creation of small or intricate parts, which could include decorative elements. However, it's worth noting that a subset of respondents also expressed optimism about the technology's potential for producing building blocks.

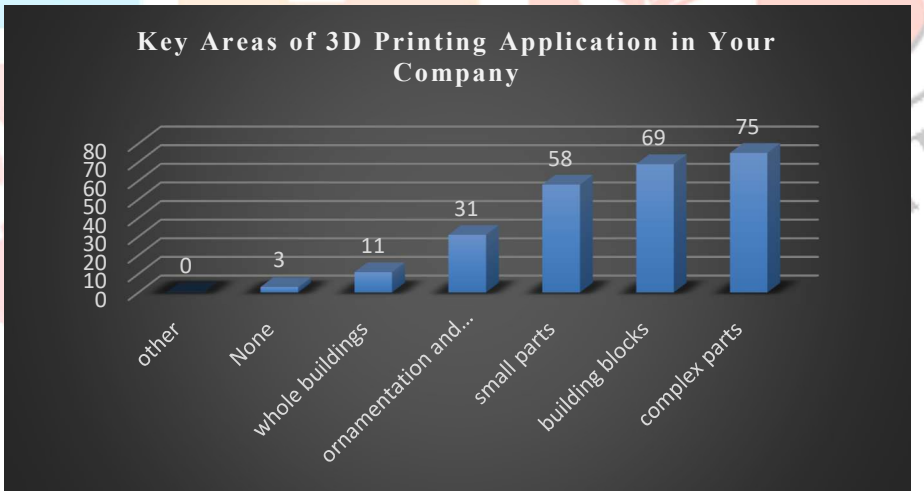

Figure 3: Key Areas of 3D Printing Application in Your Company

Exploring Financial Concerns

The survey went beyond just assessing the applications of 3D printing; it also delved into the cost-related aspects of this technology. Figure 4 in the survey results sheds light on the respondents' perceptions regarding the financial aspects of 3D printing.

One notable finding from Figure 4 is that the majority of respondents anticipated a substantial initial investment requirement for 3D printing. This suggests that many individuals or companies see 3D printing as a technology that may require a significant upfront capital expenditure, likely due to the cost of acquiring 3D printers and related equipment, as well as the need for training and setup.

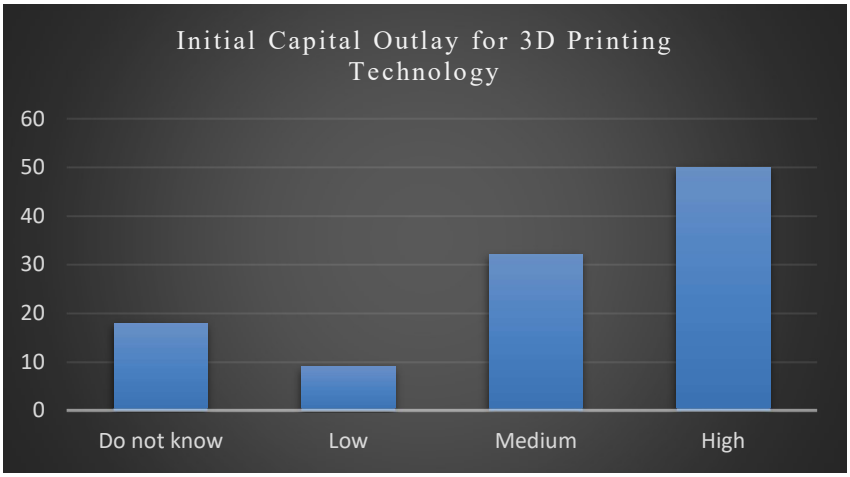

Figure 4: Initial Capital Outlay for 3D Printing Technology

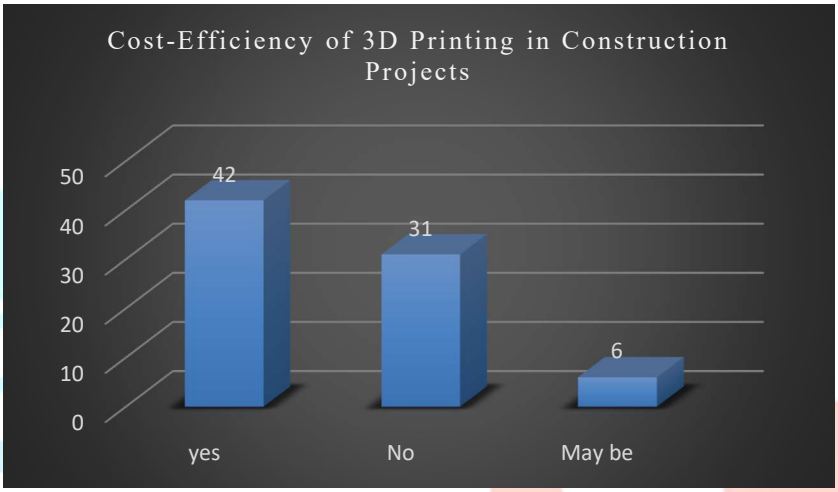

Figure 5: Cost-Efficiency of 3D Printing in Construction Projects

VI. Conclusion

This research highlights the construction industry's limited current engagement with 3D printing technology, primarily centered on prototyping and piloting. It also emphasizes the industry's positive outlook on the technology's cost-efficiency in the long run, despite the expected substantial initial investment. These insights provide valuable guidance for construction companies and stakeholders considering the adoption of 3D printing in their projects, indicating a promising trajectory for the integration of this technology into the construction sector.

VII. Acknowledgment

We would like to express our sincere gratitude to the editorial team at Rewires for accepting our manuscript. We also extend our appreciation to the research division of Dr. A. P. J. Abdul Kalam University for their invaluable support and access to research facilities, which enabled us to conduct our research effectively. We would like to express our sincere gratitude to the editorial team at Rewires for accepting our manuscript. We also extend our appreciation to the research division of Dr. A. P. J. Abdul Kalam University for their invaluable support and access to research facilities, which enabled us to conduct our research effectively.

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