EasyChair Preprint

№ 12100

Innovation in Indian Housing: "Exploring 3D Printing's Potential in Construction"

Aftab Shaikh and Darshit Shah

February 13, 2024

Innovation in Indian housing: “exploring 3d printing’s potential in construction”

Aftab Javed Shaikh
M.Tech Scholar, Department of Civil Engineering
Parul Institute of Engineering and technology
Parul University, 391760
Vadodara, Gujarat, India
shaikhaftabjavid@gmail.com

Darshit Shah
Assistant Professor, Department of Civil Engineering
Parul Institute of Engineering and technology
Parul University, 391760
Vadodara, Gujarat, India
darshit.shah30367@paruluniversity.ac.in

***Abstract*— The construction industry, a bastion of tradition, is undergoing a paradigm shift with the advent of 3D printing technology. This research delves into the 3D printing construction potential in the unique context of India, addressing three fundamental objectives. Firstly, a meticulous examination of the awareness and perceptions surrounding 3D printing technology among diverse stakeholders is conducted. Secondly, the research comprehensively evaluates the advantages linked to the utilization of 3D printing technology in the Indian construction sector. Beyond architectural possibilities, the study investigates economic, environmental, and efficiency benefits, drawing insights from global case studies. Thirdly, the research anticipates constraints and hurdles associated with incorporating 3D printing technology into the Indian construction ecosystem. Regulatory frameworks, technical limitations, economic considerations, and cultural factors are analyzed to provide a nuanced understanding. The motivation behind this research is grounded in the recognition that understanding 3D printing's implications in construction is a pragmatic response to the evolving needs of a nation on the brink of transformative infrastructural development. As India aspires towards ambitious targets for smart urbanization, affordable housing, and sustainable infrastructure, the insights derived from this research aim to serve as a guiding compass for policymakers, industry professionals, and researchers alike. The significance of this research lies in its potential to bridge the gap between traditional practices and innovative technologies, offering a roadmap for sustainable and efficient construction practices in India.**

Keywords— 3DP, Indian construction industry, awareness, perception, Sustainable development, innovation, Advantages, Disadvantages.

I. INTRODUCTION:-

The construction industry, a bastion of tradition, is undergoing a paradigm shift as innovative technologies redefine the very essence of building processes. Within this transformative landscape, 3D printing technology stands out as a revolutionary force, offering novel prospects for construction efficiency, design flexibility, and sustainability. Against the backdrop of India's escalating infrastructure demands, this research embarks on a meticulous exploration of the 3D printing construction potential within the country, guided by three fundamental objectives. These objectives are strategically designed to unravel the intricacies of awareness, advantages, and challenges associated with the assimilation of 3D printing technology into the fabric of Indian building practices. It is also define as "a process of joining materials to make objects from 3D model data, usually layer upon layer."

ASTM identifies specific printing technologies within this definition, including Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), Stereo lithography (SLA), and others. The 3D printing (3DP) process, illustrated in Figure 1.1.First of all a cad model is prepared, which transformed into .STL format. After this model is converted into a 2.5D slices. Then saved data in SLC format transformed into a 3d object by the use of a 3d printer.

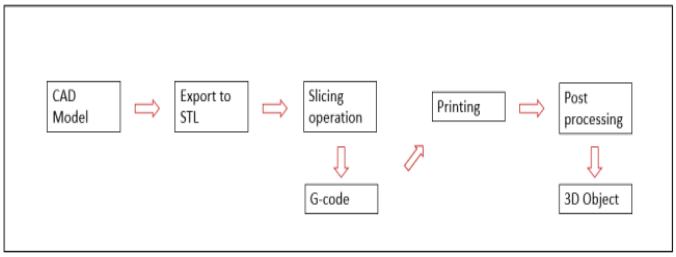

Fig. 1. 3D printing cycle

II. BACKGROUND:-

India, characterized by its diverse and expansive landscape, faces a multitude of challenges in meeting the growing demands for infrastructure development. With a population projected to surpass 1.5 billion by 2030, the need for rapid, cost-effective, and sustainable construction solutions has never been more pressing. Traditional construction methods, while time-tested, often struggle to keep pace with the burgeoning demands, leading to inefficiencies and resource-intensive processes. Against this backdrop, the emergence of 3D printing technology offers a glimpse into a future where construction is not just about bricks and mortar but a convergence of precision, speed, and sustainability.

III. NEED OF THE STUDY:-

This study is crucial due to the intersection of global advancements in 3D printing and the specific dynamics of the Indian construction industry. As 3D printing technology rapidly transforms the global construction landscape, there is a need to assess its feasibility and implications within the unique socio-economic, cultural, and regulatory context of India. This research addresses the existing gap in literature regarding stakeholder perspectives in the Indian construction sector and aims to provide actionable insights for informed decision-making. By understanding the challenges and opportunities specific to the Indian context, the study contributes to strategic planning, policy formulation, and targeted educational initiatives. Essentially, it emphasizes the crucial requirement for a elaborated comprehension of the integration of 3D printing in the Indian building sector.

IV. LITERATURE REVIEW:-

The literature suggests that 3D printing technology in construction has advanced significantly over the past decade. Researchers, such as Khoshnevis (2017) and Lim et al. (2018), have highlighted the ability of Utilizing 3D printing

to construct intricate structures layer by layer provides benefits in terms of speed, cost-effectiveness, and design flexibility.. These studies underscore the potential transformative impact of 3D printing on traditional construction practices.

Several global case studies have demonstrated successful implementations of 3D printing in construction projects. Notable examples include the work of Ma et al. (2019) in China, where 3D printing technology was utilized for constructing affordable housing, and the initiatives in Europe highlighted by Le, Austin, & Lim (2020), showcasing its potential in both residential and commercial applications.

Economic efficiency and sustainability are critical aspects of construction practices. Studies by Jiao et al. (2019) and Sanjayan et al. (2020) emphasize the potential economic advantages of 3D printing in terms of reduced material waste, labour costs, and construction time. Additionally, the environmental benefits of 3D printing, such as decreased carbon footprint and efficient use of resources, have been highlighted by scholars like Smith and Schischke (2018).

Understanding the perspectives of stakeholders is essential for successful technology adoption. Research by Wong et al. (2021) and Zhang et al. (2018) has investigated the attitudes and perceptions of various stakeholders, including architects, engineers, contractors, and policymakers, towards 3D printing technology in construction. These studies reveal varying levels of awareness, concerns, and expectations among different stakeholder groups.

While the potential benefits are evident, challenges and obstacles to the widespread utilization of 3D printing in construction should not be overlooked. Studies by Manogharan et al. (2016) and Mishra et al. (2019) have find regulatory hurdles, technological limitations, and cultural factors as potential impediments to the seamless integration of 3D printing technology in construction practices. The literature specific to 3D printing in the Indian construction industry is still emerging. Studies by Gupta and Ramanathan (2017) and Patel et al. (2020) provide initial insights into the challenges and opportunities faced by the Indian construction sector in embracing 3D printing technology.

In conclusion, the existing literature underscores the revolutionary ability of 3D printing technology in the construction industry globally. However, there is a need for more research specifically tailored to the Indian context, addressing the unique challenges and opportunities that the country presents. This literature review sets the stage for our research, aiming to contribute to this growing body of knowledge by exploring the 3D printing construction potential in India.

V. METHODOLOGY:-

This research employs a quantitative approach to assess the 3D printing construction potential in the specific context of India. The method is designed to systematically assess stakeholder awareness, perceptions, and expectations concerning 3D printing technology in the Indian construction sector.

A. Research Design:

A comprehensive literature review has been undertaken to grasp the viewpoints presented in both national and international studies. The examination of research gaps guides the formulation of questions related to stakeholder awareness, perception, challenges, and benefits associated with 3D printing. Then utilizing a structured Likert scale questionnaire survey to collect quantitative data. This approach allows for the efficient measurement of stakeholder perspectives and facilitates statistical analysis using the SPSS software.

B. Participants:

The participants in this study include professionals and stakeholders from the Indian construction industry, such as architects, engineers, contractors, and policymakers. The sampling method will be a combination of convenience and purposive sampling, aiming for diversity across roles and sectors within the construction industry.

C. Instrumentation:

The primary data collection instrument is a Likert scale questionnaire designed to measure stakeholder awareness, perceptions, and expectations related to 3D printing technology in construction. The questionnaire will consist of statements aligned with the research objectives, and participants will rate their agreement or disagreement on a Likert scale.

D. Data Collection Procedure:

Participants will be approached via online platforms (Google form), personal interviews and informed consent will be obtained before administering the questionnaire. The survey will be distributed using a secure online survey platform, ensuring anonymity and confidentiality. Adequate reminders will be sent to maximize response rates. To assess the present state of 3D printing in the Indian sector, a questionnaire was distributed to gather responses from diverse stakeholders in the construction industry, including contractors, developers/clients, consultants, end-users, and others. The questionnaire encompassed identified perspectives, advantages, and obstacles related to 3DP in order to formulate a comprehensive understanding. Additionally, interviews were conducted with various stakeholders to gain insights into their perspectives on the implementation of 3D printing technology in the construction sector.

E. Statistical Analysis:

The data gathered from the Likert scale questionnaire will be subjected to analysis using the Statistical Package for the Social Sciences (SPSS) software. Descriptive statistics, encompassing frequencies, means, and standard deviations, will be calculated to provide a comprehensive summary of stakeholder responses.

F. Ethical Considerations:

The study will uphold ethical standards by ensuring informed consent, confidentiality, and voluntary participation. Participants will be briefed about the study's purpose, and any potential risks and benefits associated with their involvement will be communicated to them.

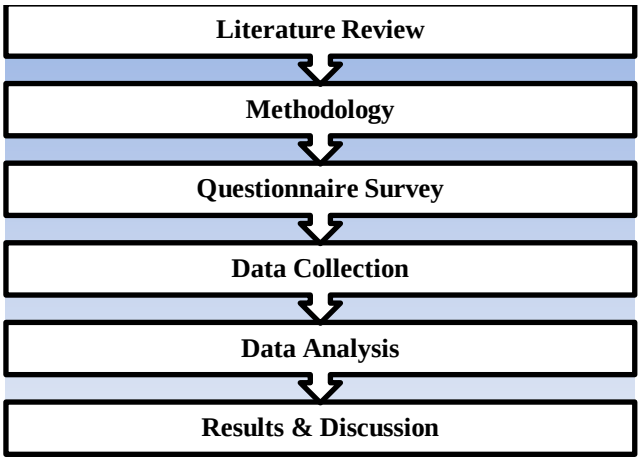

Fig. 2. Research Methodology

VI. Results and Analysis

The survey, consisting of Likert scale items, aimed to gather quantitative data on awareness, perceptions, and expectations regarding the adoption of 3D printing technology. The result is based on findings from the questionnaire survey which was included 30 questions aimed to find out the overall objectives of the research.

Total 70 survey participants indicated diverse representation across various roles within the construction sector . The role of the respondent were project manager (7.14%), office engineer (10.0%), site engineer (21.42%), contractor (14.28%) and end user (11.42%), and other (35.71) of which others included engineers, government professionals, academicians, researchers, and others. They exhibited a wide range of professional experience, with a majority being young professionals who had accumulated expertise ranging from 0 to over 15 years. Fig. 3 and 4 shows experience and roles of the respondent respectively.

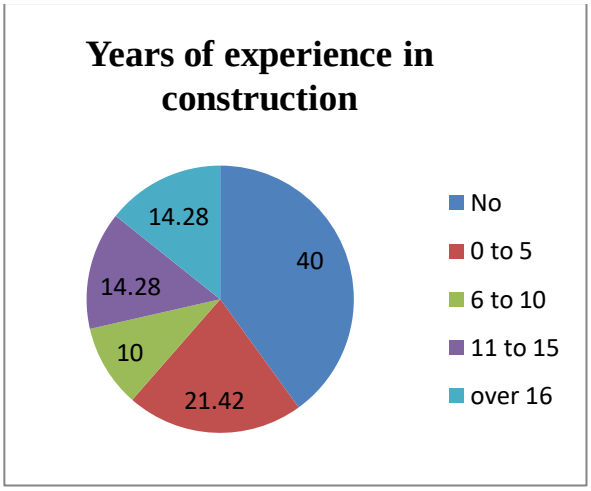

Fig.3 Experience of respondent

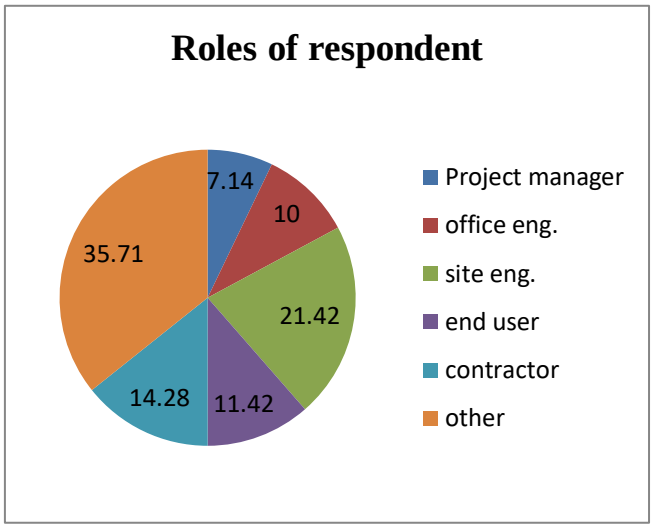

Fig.4 Role of respondent

Further the respondent were asked to provide ranks to the questionnaire statements according to their perspective on a scale ranging from 1 to 5, where 1 represents "Strongly Disagree," 2 stands for "Disagree," 3 denotes "Neutral," 4 indicates "Agree," and 5 represents "Strongly Agree."The data collected from offline and online sources then entered into SPSS software for further analysis.

Respondent were asked about their awareness, perception about 3d printing technique from set of statements. Stakeholders were inquiring about their perspective on 3d printing technique implementation in Indian construction market. Fig.5 to 7 shown the data collected for these objectives. Over 85% respondents were aware 3d printing technology and almost same amount of respondent agree on its application and utilization in construction industry. As per the table 2 respondents strongly believe that 3dp can revolutionize construction industry (mean value above 4). As per table 3 one can say that stakeholder firmly believe in the benefits of 3d printing (Mean value above 4). But they fear somehow that there is lack of support for implementation for this technique (Mean value less than 3).

TABLE I. Awareness

Statement	Minimum	Maximum	Mean
Aware about 3dp	3	5	3.77
Aware about its application	1	4	3.45
Aware about various industry utilization	1	3	3.22

TABLE II. Perception

Statement	Minimum	Maximum	Mean
Potential to revolutionize manufacturing process	3	5	4.15
Can contribute to healthcare	4	5	3.67
Environment consideration is important aspect	3	5	4.08

TABLE III. STAKEHOLDERS PERSPECTIVE

Statement	Minimum	Maximum	Mean
Can see the benefits of 3dp	3	5	4.55
Sufficient support for implementation for 3dp	3	3	2.13
Informed about its opportunities and challenges	3	5	3.95

Respondent were asked to rate various statements of advantages and disadvantages according to their knowledge. Most of the respondent agrees on that 3dp is beneficial technique for cost saving, less material wastage, product quality and for creative designs. On the other hand from the challenges or hurdles perspective respondent believes that initial cost, lack of standardization/guidelines, resistance to change and end user acceptability are the main hurdles for implementation 3p printing in Indian construction market.

TABLE IV. ADVANTAGES

Statement	Minimum	Maximum	Mean
To enhance product customization and personalization	3	5	4.11
Can lead to cost saving	4	5	3.99
Can lead to faster prototype and product development	4	5	4.32
Can improve product quality	4	5	3.87
Reduced waste material	4	5	4.67
Offer flexibility in complex design	4	5	3.65
Foster innovation and creative design	4	5	4.78
Can open new opportunity for product design and development	3	5	3.54
Can reduce construction time	4	5	4.79
Can reduce over dependency on labours	4	5	3.55
Can provide safer construction environment	4	5	3.89

TABLE V. DISADVANTAGES

Statement	Minimum	Maximum	Mean
Initial cost	4	5	4.92
Reliability and consistency	4	5	3.88
Lack of standard and code/guidelines	4	5	4.98
Complexity in operatingand managing	4	5	4.55
Concern about speed and efficiency for mass production	4	5	4.22
Material shortage	4	5	3.99
Resistance for change	3	5	4.86
Lack of awareness among stakeholders	3	5	4.10
End user acceptability	5	5	4.95
Not suitable for long period	4	5	4.69

VII. DISCUSSION

A. *Awareness and Familiarity:*

The reported high awareness level among participants aligns with the global trend of increasing recognition of 3D printing technology in construction. This heightened awareness can be attributed to technological advancements, exposure through industry events, and educational initiatives. However, the significant proportions reporting moderate and low awareness levels signal the presence of diverse knowledge gaps within the industry. Targeted awareness campaigns and educational programs are essential to bridge these gaps. Perceptions of 3D Printing Advantages: Stakeholders recognize the potential of 3D printing to reduce material waste, lower labour costs, and facilitate intricate architectural designs. However, the varying responses, expressing neutrality or disagreement, unveil areas of potential skepticism or lack of clarity. Qualitative investigations are warranted to delve deeper into the reservations or uncertainties voiced by this subset of stakeholders. By understanding their perspectives, industry stakeholders can tailor communication strategies and highlight specific advantages that address the concerns raised.

B. *Anticipation of Challenges:*

The expressed concerns regarding regulatory hurdles, technological limitations, and cultural factors mirror findings from existing literature. The identification of these challenges emphasizes the need for a comprehensive approach to technology implementation. Regulatory engagement, technological education and support, and cultural integration programs are imperative components of any successful implementation strategy.

C. *Implications for Implementation:*

The survey findings carry significant implications for the successful applications of 3D printing technology in the Indian construction sector. Addressing awareness gaps, understanding diverse perceptions, and mitigating anticipated challenges should form the foundation of any strategic roadmap for technology adoption.

A collaborative approach involving industry stakeholders, governmental bodies, educational institutions, and technology providers is crucial. Establishing a supportive ecosystem that addresses both technical and non-technical considerations is paramount for the sustainable integration of 3D printing in construction practices. The industry must proactively engage in initiatives that foster a conducive environment for embracing transformative technologies

VIII. LIMITATION AND FUTURE SCOPE

This study, while providing valuable insights into stakeholder perceptions of 3D printing technology in the Indian construction industry, has inherent limitations. The use of convenience and purposive sampling methods may introduce bias, limiting generalizability. The cross-sectional design restricts the observation of changes over time, and its relies on self-reported data through Likert scale responses may introduce response bias. The study predominantly employs quantitative methods, lacking qualitative depth.

Findings are specific to the Indian context, limiting generalizability to other regions, and the rapid evolution of 3D printing technology poses challenges to temporal generalizability. Limited exploration of subgroups, external influences, assumptions about technological literacy, and the subjectivity in perception measurements further contribute to study constraints. While the study acknowledges anticipated challenges with 3D printing adoption, a more detailed exploration of specific constraints was beyond its scope. These limitations highlight the importance of careful interpretation and point towards potential areas for future research to overcome these constraints.

IX. CONCLUSIONS:

This study yields valuable insights into stakeholder perspectives regarding 3D printing technology in the Indian construction industry. The findings provide a nuanced understanding of awareness levels, perceptions of benefits, and anticipated challenges linked to the adoption of 3D printing. The survey indicates a substantial 85% of participants reporting high awareness of 3D printing technology, signaling increased recognition within the industry. Positive perceptions regarding economic benefits, environmental sustainability, and architectural innovation were prevalent, with widespread agreement. Simultaneously, concerns about regulatory hurdles, technological limitations, and acceptance were identified. The study contributes to existing knowledge by presenting a snapshot of stakeholder attitudes specific to the Indian construction context. It builds upon global trends and offers localized insights that can guide strategies for the effective integration of 3D printing technology.

The challenges and opportunities identified in this study carry practical implications for industry stakeholders, policymakers, and technology providers. Tailoring adoption strategies to address the diverse needs of architects, engineers, contractors, and policymakers requires a nuanced understanding of their varying perspectives. The acknowledged limitations in this study offer guidance for future research endeavors. Longitudinal studies, in-depth qualitative investigations, and comparative analyses across regions and subgroups could further enhance our comprehension of the evolving landscape of 3D printing adoption in the construction sector. In summary, the study portrays a dynamic technological landscape within the Indian construction industry. Stakeholder perceptions reflect a delicate balance between optimism and caution, underscoring the importance of a holistic approach to technology adoption. As 3D printing continues to advance, collaboration among industry players, policymakers, and researchers becomes increasingly crucial. This study lays the groundwork for ongoing discussions and initiatives aimed at fostering a supportive ecosystem for the successful integration of 3D printing technology in the Indian construction sector.

REFERENCES:

[1] Kazemian, A., Yuan, X., Cochran, E., & Khoshnevis, B. "Cementitious materials for construction-scale 3D printing: Laboratory testing of fresh printing mixture." Construction and Building Materials 145 (2017): 639- 647.

[2] Hojati, M., Nazarian, S., Duarte, J. P., Radlinska, A., Ashrafi, N., Craveiro, F., & Bilén, S. "3D printing of concrete: A continuous exploration of mix design and printing process." 42nd IAHS world congress the housing for the dignity of mankind. 2018.

[3] Xia, M., Behzad N. and Jay S. "Printability, accuracy and strength of geopolymer made using powder-based 3D printing for construction applications." Automation in Construction 101 (2019): 179-189.

[4] Arunothayan, A. R., Nematollahi, B., Ranade, R., Bong, S. H., & Sanjayan, J. "Development of 3D-printable ultra-high performance fibre-reinforced concrete for digital construction." Construction and Building Materials 257 (2020): 119546.

[5] Marchment, T., and Jay S. "Mesh reinforcing method for 3D Concrete Printing." Automation in Construction 109 (2020): 102992.

[6] Ma, G., Salman, N. M., Wang, L., & Wang, F. "A novel additive mortar leveraging internal curing for enhancing interlayer bonding of cementations composite for 3D printing." Construction and Building Materials 244 (2020): 118305.

[7] Linyi Li a, Junsheng Yang a, Jinyang Fu, Shuying WanG, Cong Zhang c , Maolong Xiang a. "Experimental investigation on the invert stability of operating railway tunnels with different drainage systems using 3D printing technology."Journal of Rock Mechanics and Geotechnical Engineering 14 (2022) 1470-1485

[8] Asena KARSLIOĞLU, Mehmet Hanifi ALKAYIŞ, ve Mehmet İnanç ONUR."3D Printing Technology in Construction Sector: A Short Review." 2nd International Conference on Applied Engineering and Natural Sciences. March 10-13 (2022)

[9] Egor Ivaniuk a, Martin Friedrich Eichenauer b, Zlata Tošic´ b, Steffen Muller a, Daniel Lordick b, Viktor Mechtcherine a. "3D printing and assembling of frame modules using printable strainhardening cement-based composites (SHCC)." Materials & Design 219 (2022) 110757

[10] Patrick Bedarf a, Alessandro Dutto b , Michele Zanini c , Benjamin Dillenburger a. "Foam 3D printing for construction: A review of applications, materials, and processes." Automation in construction 130 (2021) 103861

[11] Alexander Lin a , Abhimanyu Goel a , De Hui Alwin Wong a , Charlene Yeo a , Jacky Chung b , Sze Dai Pang c , Chi-Hwa Wang d , Hayden Taylo , Harn Wei Kua a. "Compressive load-dominated concrete structures for customized 3D-printing fabrication." Automation in construction 141 (2022) 104467

[12] Hui Zhong, Mingzhong Zhang."3D printing geopolymers: A review." Cement and Concrete Composites 128 (2022) 104455

[13] Yiming Peng a, Cise Unluer b. " Development of alternative cementitious binders for 3D printing applications: A critical review of progress, advantages and challenges." Composites Part B. 252 (2023) 110492

[14] Izabela Hager, Anna Golonka, Roman Putanowicz. "3D printing of buildings and building components as the future of sustainable construction?" Procedia Engineering 151 (2016) 292 – 299

[15] Chiranjeevi Rahul Rollakanti , C. Venkata Siva Rama Prasad b. " Applications, performance, challenges and current progress of 3D concrete printing technologies as the future of sustainable construction – A state of the art review. " Materials Today: Proceedings

[16] Asena KARSLIOĞLU1, Mehmet Hanifi ALKAYIŞ 2 ve Mehmet İnanç ONUR 3. "3D Printing Technology in Construction Sector: A Short Review."2nd International Conference on Applied Engineering and Natural Science March 10-13, 2022

[17] Lotfi Romdhane and Sameh M. El-Sayegh. "3D Printing in Construction: Benefits and Challenges."International Journal of Structural and Civil Engineering Research Vol. 9, No. 4, November 2020

[18] Guowei Ma, Gang Bai , Li Wang a , Fang Wang a. Explosion resistance" 3D printing ultra-high perormance concrete based on contact explosion tests." International Journal of Impact Engineering 169 (2022) 104316

[19] Manogharan, G., Wankhede, G., Oraskari, R., et al. (2016). "A Review on 3D Printing: Technological, Materials, and Applications." Journal of Manufacturing Materials Processing, 4(1), 22.

[20] Khoshnevis, B. (2017). "Automated Construction by Contour Crafting—Related Robotics and Information Technologies." Automation in Construction, 16(2), 293-299.