A Review Paper On Design And Development Of Various Cement Mortars Combinations In 3D Printing In Construction

Saurabh S. Wagaj UG Student, SVERI's COE,Pandharpur India, wagajss1213@gmail.com
Swapnil S. Patil UG Student, SVERI's COE,Pandharpur India, swapnilspatil@coep.sveri.ac.in
Prathmesh D. Machale UG Student, SVERI's COE,Pandharpur India, pdmachale@gmail.com
Pravin S. Dubule UG Student, SVERI's COE,Pandharpur India, pravindubule1@gmail.com
Ganesh K. Pawar UG Student, SVERI's COE,Pandharpur India, ganeshp8012@gmail.com
Premsai G Siddham, Asst.professor, SVERI's COE,Pandharpur India, premsiddham@gmail.comChetan R Limkar, Asst.professor, SVERI's COE,Pandharpur India, crlimkar@coe.sveri.ac.in

Abstract - The use of 3D printing technology in construction is revolutionizing the industry by enabling the creation of complex and customized architectural structures. Central to this process is the development of cement mortars specifically designed for additive manufacturing. This review consolidates current research on the formulation, properties, and performance of cement mortars used in 3D printing. Cement mortars for 3D printing must exhibit unique characteristics, including appropriate flowability, setting time, and mechanical strength. Innovations in material composition, including the use of various cementitious materials, additives, and fibers, have been explored to enhance these properties. Adjustments to rheological properties, such as viscosity and extrudability, are critical for successful printing. Research has also focused on optimizing setting and curing processes to improve the durability of printed components.

Key findings include the development of new additives and admixtures that enhance the printability and long-term strength of the mortars. Advances in sustainability, such as the incorporation of recycled materials and reduction in carbon footprint, are also highlighted. Future research should address standardized testing methods, long-term performance evaluation, and the integration of digital design tools. This review provides a comprehensive overview of the current state of cement mortars for 3D printing, offering valuable insights for researchers, practitioners, and industry stakeholders aiming to advance construction technology.

Keywords —3D Printing, Cement Mortars, Additive Manufacturing, Construction Technology, Material Science, Rheology, Sustainability.

I. INTRODUCTION

The 3D printing is a trending concept in world. In which 3D printing in construction industry is a new concept to work and develop. There are many researchers and scholars working on concept of 3D printing with deviations in certain materials, application technologies, printing methodology on global scale, which also includes The design formulations and optimization. In prototypes, very few researchers are working on large scale design and development of 3D printer in construction. The researchers have worked with many combinations of mix designs, optimization, structural performance assessment of prototypes.

This review papers aims on identifying the gaps after studying and reviewing all the research papers. This review also aims for adopting the objectives and suitable methodology for identified gap.

II. LITERATURE REVIEW

In India the 3D printing technology is now introduced withvery less amount of research contributed. The Indianresearchers are working on 3D printing technology Qi Deng. et.al, research underscores the potential of waste glass powder as a key ingredient in the

 DOI : 10.35291/2454-9150.2024.0387

development of 3D-printable mortar. The findings support its viability as a sustainable alternative in construction, with promising mechanical and durability characteristics. Ongoing research and optimization are necessary to fully realize its application in the industry.

1] Zeina Malaeb et al, this work highlights the importance of both machine and mix design in the advancement of 3D concrete printing technology. The integration of innovative machinery and optimized concrete formulations is essential for realizing the full potential of3DCP in modern construction practices.

2] Valery Lesovik et al, the combination of steel and polypropylene fibers in 3D-printed mortars represents a promising advancement in the construction industry. By leveraging the strengths of both fiber types, these mortars can offer enhanced mechanical performance, durability, and flexibility, making them suitable for a wide range of applications. However, challenges remain in optimizing the mix design for printability and ensuring uniform fiber dispersion. Ongoing research is focused on addressing these issues and expanding the potential of 3D printing in construction. This review highlights the innovative potential of fiber-reinforced mortars in 3D printing and underscores the need for further studies to refine material formulations, printing techniques, and application methods.

3] Haidong Tu et al, The integration of waste materials into 3D concrete printing represents a significant advancement in sustainable construction. Materials like fly ash, slag, recycled aggregates, plastic, and biomass ashes offer promising alternatives to traditional concrete ingredients, reducing environmental impact and enhancing the longterm performance of 3D-printed structures. While advancements in mix design and material properties have been substantial, future trends will likely focus on optimization through technology, multi-material capabilities, and regulatory development.

4] Jun Ho Jo et al, the development of a 3D printer for concrete structures requires addressing numerous challenges related to material formulation, hardware development, and printing techniques. Laboratory testing of cementitious materials is essential for optimizing the properties needed for printability, structural integrity, and durability. Advancements in mix design, extrusion control, and real-time monitoring systems have contributed to improving the feasibility and quality of 3D-printed concrete structures. Looking forward, trends like sustainable materials, AI integration, and smart concrete will continue to shape the future of 3DCP, allowing for more widespread adoption in theconstruction industry.

5] Mohamed Ibrahim et al, “Mohamed Ibrahim's article "3D Printed Concrete Using Portland Pozzolana Cement-Fly Ash Based" focuses on the application of Portland Pozzolana Cement (PPC), which uses fly ash as an additional cementitious material, to 3D concrete printing (3DCP). It would examine the advantages and difficulties of employing PPC in 3D printing, as well as the mechanical characteristics of cementitious materials based on fly ash and their effects on structural performance and sustainability.

6] Jay G. Sanjayan et al, “Effect of Surface Moisture on Inter-Layer Strength of 3D Printed Concrete" by Jay G. Sanjayan most likely looks into how different moisture contents on concrete layers that have already been printed out have an impact on the bonding between layers in 3D concrete printing (3DCP). Since 3D printing requires the layer-by-layer deposition of cementitious material, the strength and integrity of the printed structure depend greatly on the bonding between layers. One of the most important factors influencing the mechanical performance of the construction is the amount of moisture present on the previously printed layers.

7] Venkatesh Naidu Nerella et al, Mix design for 3D printable concrete is a complex, multidisciplinary challenge that involves balancing the material's rheological properties, setting behavior, and mechanical performance. Innovations in cementitious materials, admixtures, and reinforcement techniques are continuously evolving to improve the printability, buildability, and structural integrity of 3DP.

8] Shaodan Hou et al, “Three key areas in the field of 3D concrete printing (3DCP) are covered in "A Review of 3D Printed Concrete: Performance Requirements, Testing Measurements, and Mix Design" by Shaodan Hou. These are the performance requirements that determine the success of printed structures, the various testing techniques used to evaluate their performance, and the complexities of mix design for 3D printable concrete.

9] Viktor Mechtcherine et al, The concrete Print3D concept represents a transformative step in large-scale digital concrete construction. By leveraging advanced technologies and innovative practices, it holds the potential to redefine the construction landscape, addressing key challenges in sustainability, efficiency, and design flexibility. Continued research and collaboration across disciplines will be essential to fully realize the benefits of this pioneering approach to concrete construction.

10]Jianzhuang Xiao et al, Large-scale 3D printing in concrete technology is at a pivotal moment, with substantial advancements already achieved and exciting opportunities on the horizon. Continued

 DOI : 10.35291/2454-9150.2024.0387

research into materials, methods, and applications will be crucial for overcoming current challenges and unlocking the full potential of this innovative construction technique. Emphasizing sustainability and technological integration will position large-scale 3D printing as a cornerstone of future construction practices.

11]Tuan D. Ngo et al, Additive manufacturing represents a transformative technology with vast potential across multiple industries. While significant advancements have been made in materials, methods, and applications, challenges remain that must be addressed to fully realize its capabilities. Continued research, innovation, and collaboration among industry stakeholders will be essential to overcome these challenges and propel the future of additive manufacturing.

12]Shantanu bhattacherjee et al, An important step toward more ecologically friendly building techniques is the incorporation of sustainable elements into 3D concrete printing. Even though there are still obstacles to overcome, more study and creativity can improve the functionality and suitability of these materials, opening the door for a sustainable future in the building sector. Emphasizing collaboration between material scientists, engineers, and industry stakeholders will be crucial to maximizing the benefits of sustainable materials in 3DCP.

13]Birachi Panda et al, For 3D printing concrete to be successful in the construction business, the qualities and processing of the building materials are essential. Even if there have been great strides, widespread adoption still requires addressing the issues of material variability, technological know-how, and standardization. Unlocking the full potential of 3D printed concrete will require ongoing study and innovation, opening the door to more effective and environmentally friendly building techniques.

14]Marcelo Tramontin Souza et al, 3D printed concrete presents a promising solution for large-scale building projects, combining innovative materials and techniques to enhance construction efficiency. Understanding the interplay of rheological properties, printing parameters, chemical admixtures, and reinforcement strategies is critical for optimizing performance. Furthermore, the economic and environmental prospects of 3DPC highlight its capacity to change the construction sector and move toward more environmentally friendly methods. To fully reap the benefits of this technology, stakeholders will need to work together and conduct additional research.

15]Domenico Asprone et al, 3D printing of reinforced concrete elements represents a significant innovation in the construction industry, combining advanced technology with modern design principles. While challenges remain, particularly in standardization and material consistency, the potential benefits in terms of efficiency, sustainability, and design flexibility make it a promising avenue for future research and development. Collaboration among engineers, architects, and material scientists will be essential to fully leverage the advantages of this technology in building practices.

16]Mehmet Sakin et al, 3D printing technology, when combined with Building Information Modeling, presents a transformative opportunity for the construction of sustainable houses. By optimizing design, reducing waste, and enhancing collaboration, this approach can lead to more efficient, cost effective, and environmentally friendly building practices. Continued research and development, along with proactive regulatory adaptations, will be essential to fully harness the potential of 3D printing in creating the sustainable houses of the future.

17]Manu K. Mohan et al, Extrusion-based concrete 3D printing represents a significant advancement in construction technology, with material selection playing a critical role in its success. Understanding the properties and performance of various concrete mixes is essential for optimizing the printing process and ensuring structural integrity. As the technology evolves, ongoing research into sustainable and innovative materials will be vital in shaping the future of construction, making it more efficient, costeffective, and environmentally friendly.

18]R.J.M. Wolfs et al, The early age mechanical behavior of 3D printed concrete is a critical area of study that impacts both structural integrity and construction efficiency. Through a combination of experimental testing and numerical modeling, researchers can gain valuable insights into how these materials perform during their formative stages. Continued advancements in both material science and modeling techniques will be essential for optimizing the use of 3D printed concrete in the construction industry, ensuring that printed structures meet safety and performance standards from the outset.

19]Yunsheng Zhang et al, The success of additive manufacturing in the construction industry is largely dependent on the innovative qualities of new 3D printing concrete inks. By focusing on workability, rheological behavior, and proper formulation, researchers can develop inks that facilitate efficient and reliable printing processes. Continued innovation and research in this area will be essential for advancing the technology and expanding its

 DOI : 10.35291/2454-9150.2024.0387

applications in sustainable construction practices.

III. RESEARCH GAP

The optimal mix design of mortar with refined uniform material formulation using sustainable material like GGBS is limited and the performance is not satisfied. Although some of papers include the scope of research in utilization of sustainable cementitious material and their optimization.

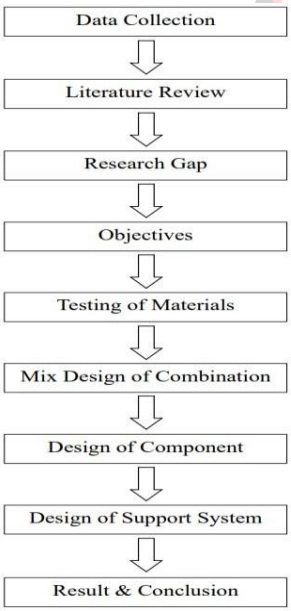
Some papers have done research on printing methodologies and application technology but there is scope in working with optimized smart technology for printing and application in construction industry.

As many researchers are working the design and development of 3D printing, there is a major scope on working the effect of moisture content on surface playing important role in interlayer bonding

IV. PRAPOSED OBJECTIVES

1. To Calculate and optimize combinations of mix design of mortars.
2. To Design the various components of 3D printingassembly.
3. To Design supporting framework of 3D printer.

V. PRAPOSEDMETHODOLOGY



VI. EXTENDED OUTCOMES

Because it makes it feasible to fabricate intricate structures and geometries that are challenging or impossible to create with conventional construction methods, 3D printing has the potential to completely change the construction sector. The pursuit of minimizing construction time and manufa - turing costs has prompted research into 3D concrete printi as a novel approach to the building process.

The compatibility of the available materials presents one of the main obstacles for 3D printing of concrete. Researchers have studied the use of various cementitious combinations, including those comprising silica fume and graphene nanoplatelets, to improve the mechanical properties of the printed mortar.

REFERENCES

[1] Deng, Q., Zou, S., Xi, Y., & Singh, A. (2023). Development and Characteristic of 3D-Printable

Mortar with Waste Glass Powder. *Buildings*, *13*(6), 1476.J. U. Duncombe, "Infrared navigation—Part I:

An assessment of feasibility (Periodical style),"

IJREAM Trans. Electron Devices, vol. ED-11, pp. 34– 39, Jan. 1959.

[2] Malaeb, Z., AlSakka, F., & Hamzeh, F. (2019). 3D concrete printing: machine design, mix proportioning, and mix comparison between different machine setups. In *3D Concrete printing technology* (pp. 115-136). Butterworth-Heinemann..

[3] Lesovik, V., Fediuk, R., Amran, M., Alaskhanov, A., Volodchenko, A., Murali, G., ... &Elistratkin, M. (2021). 3D-printed mortars with combined steel and polypropylene fibers. *Fibers*, *9*(12), 79..

[4]Tu, H., Wei, Z., Bahrami, A., Kahla, N. B., Ahmad, A., &Özkılıç, Y. O. (2023). Recent advancements and future trends in 3D printing concrete using waste materials. *Developments in the Built Environment*, 100187.G. R. Faulhaber, "Design of service systems with priority reservation," in *Conf. Rec. 1995 IJREAM Int. Conf. Communications*, pp. 3–8.

[5]Jo, J. H., Jo, B. W., Cho, W., & Kim, J. H. (2020). Development of a 3D printer for concrete structures: laboratory testing of cementitious materials. *International Journal of Concrete Structures and Materials*, *14*, 1-11.G. W. Juette and L. E.

[6]Zeffanella, "Radio noise currents n short sections on bundle conductors (Presented Conference Paper style)," presented at the IJREAM Summer power Meeting, Dallas, TX, Jun. 22–27, 1990, Paper 90 SM 690-0 PWRS.

[6] Ibrahim A, M., & Kumar N, S. 3D printed concrete using Portland pozzolana cement-fly ash based. In *E3S.*

[7] Sanjayan, J. G., Nematollahi, B., Xia, M., &Marchment, T. (2018). Effect of surface moisture on inter-layer strength of 3D printed concrete. Construction and building materials, 172, 468-475.

[8] Zhang, C., Nerella, V. N., Krishna, A., Wang, S., Zhang, Y., Mechtcherine, V., & Banthia, N. (2021). Mix design concepts for 3D printable concrete: A

 DOI : 10.35291/2454-9150.2024.0387

review. *Cement and Concrete Composites*, *122*, 104155.

[9] Hou, S., Duan, Z., Xiao, J., & Ye, J. (2021). A review of 3D printed concrete: Performance requirements, testing measurements and mix design. *Construction and Building Materials*, *273*, 121745.

[10] Mechtcherine, V., Nerella, V. N., Will, F., Näther, M., Otto, J., & Krause, M. (2019). Large-scale digital concrete construction–CONPrint3D concept for onsite, monolithic 3D-printing. *Automation in construction*, *107*, 102933.

[11] Xiao, J., Ji, G., Zhang, Y., Ma, G., Mechtcherine, V., Pan, J., ... & Du, S. (2021). Large-scale 3D printing concrete technology: Current status and future opportunities. *Cement and Concrete Composites*, *122*, 104115.

[12] Ngo, T. D., Kashani, A., Imbalzano, G., Nguyen, K. T., & Hui, D. (2018). Additive manufacturing (3D printing): A review of materials, methods, applications and challenges. *Composites Part B: Engineering*, *143*, 172-196.

[13] Bhattacherjee, S., Basavaraj, A. S., Rahul, A. V., Santhanam, M., Gettu, R., Panda, B., ... & Mechtcherine, V. (2021). Sustainable materials for 3Dconcrete printing. *Cement and Concrete*

Composites, *122*, 104156.

[14] Tay, Y. W. D., Panda, B., Paul, S. C., Tan, M. J., Qian,

S. Z., Leong, K. F., & Chua, C. K. (2016, August). Processing and properties of construction materials for 3D printing. In *Materials Science Forum* (Vol. 861, pp. 177-181). Trans Tech Publications Ltd.

[15] Souza, M. T., Ferreira, I. M., de Moraes, E. G., Senff, L., & de Oliveira, A. P. N. (2020). 3D printed concrete for large-scale buildings: An overview of rheology, printing parameters, chemical admixtures, reinforcements, and economic and environmental prospects. *Journal of Building Engineering*, *32*, 101833.

[16] Asprone, D., Auricchio, F., Menna, C., & Mercuri, V. (2018). 3D printing of reinforced concrete elements: Technology and design approach. *Construction and building materials*, *165*, 218-231.

[17] Sakin, M., &Kiroglu, Y. C. (2017). 3D Printing of Buildings: Construction of the Sustainable Houses of the Future by BIM. *Energy Procedia*, *134*, 702-711.

[18] Mohan, M. K., Rahul, A. V., De Schutter, G., & Van Tittelboom, K. (2021). Extrusion-based concrete 3D printing from a material perspective: A state-of-the-art review. *Cement and Concrete Composites*, *115*, 103855.

[19] Wolfs, R. J. M., Bos, F. P., & Salet, T. A. M. (2018). Early age mechanical behaviour of 3D printed concrete: Numerical modelling and experimental testing. *Cement and Concrete Research*, *106*, 103-116.

[20] Zhang, Y., Zhang, Y., Liu, G., Yang, Y., Wu, M., & Pang, B. (2018). Fresh properties of a novel 3D printing concrete ink. *Construction and building materials*, *174*, 263-271.

 DOI : 10.35291/2454-9150.2024.0387