



# Advances and Future Trajectories of 3D Concrete Printing in the Construction Industry: A Systematic Review

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## Abstract

The construction industry worldwide is undergoing a significant shift, known as Construction 4.0. This change involves moving away from old methods that rely on manual labour and construction practices toward automated processes that use 3D printing and robotic arms. A key part of this change is Three-Dimensional Concrete Printing (3DCP), which replaces traditional on-site casting and layer-by-layer construction. 3DCP is a new technology that can transform construction. This paper gives a detailed literature review of the current state of 3D printing, including its different types, how it works, and new ideas in materials and mix designs. This study presents the properties of the materials used, especially how they flow, build up, and maintain their shape, which are essential for making strong structures without using forms. The paper also presents the advantages of 3DPC technology, including reducing construction waste by up to 60%, lowering labour-related costs, and speeding up projects by enabling 24/7 operations. Beyond the physical benefits, the research also examines how Building Information Modelling (BIM) can serve as a digital foundation for 3DCP, allowing smooth data transfer from design to the actual building. Even with all these advancements, significant challenges remain in scaling this technology from small-scale experiments to large-scale use. This review brings together recent studies to highlight ongoing problems: the uneven strength of structures-built layer by layer, the lack of standardized building rules, and the difficulty of verifying quality in real time. By examining the sustainability and cost-effectiveness of 3DCP, this paper outlines a research plan for the future. This plan highlights areas that need further study and suggest steps toward creating rules and standards, helping make 3DCP a key part of modern construction practices and sustainable infrastructure.

Keywords: 3DCP, BIM, Robotics arm, precast, modular housing

## 1. Introduction

The construction industry is one of the biggest sectors in the global economy, accounting for around 13% of the global GDP [1]. However, despite its size, it has been known to be a sector with low productivity, high labor intensity, and severe safety issues [2]. Conventional construction techniques are still labor-intensive and use temporary formwork, which contributes 35% to 60% of the total cost and is a major source of waste [3]. In addition, the construction industry has severe effects on the

environment, contributing close to 39% of global CO<sub>2</sub> emissions and 30-40% of resource consumption [4]. To address these challenges, the construction industry is increasingly adopting Construction 4.0, which is characterized by the digitalization and automation of construction processes [5].

Three-Dimensional Concrete Printing (3DCP) is a new technology employed in the construction industry to address the aforementioned challenges [2]. 3DCP is a technology that constructs buildings layer by layer based on digital 3D model data [6]. 3DCP represents a paradigm shift from conventional Construction Methods and mold-based construction methods, which provide unparalleled design flexibility, minimize material waste by up to 60%, and accelerate construction by 50-70% [7].

Unlike conventional methods, which are difficult to work with when there are complex geometries, 3DCP enables mass customization with a nearly constant level of manufacturing complexity, making it possible for architects to design complex, non-linear, and optimized structures [8]. The technological foundation for 3DCP was laid in the late 1990s through innovative methods such as Contour Crafting, D-Shape, and Concrete Printing [9]. Since 2017, the area has made substantial progress, with academic research and the use of the technology complementing each other. The technology has proved its efficiency in practice through global case studies, such as WinSun's ten houses printed by China in a day, the Office of the Future in Dubai, and several 3D-printed footbridges that exist in Europe and Asia. The above-mentioned developments show how the 3DCP technology is used for various purposes, such as disaster relief, military use, and affordable housing [3].

However, the industrial use of 3DCP faces significant technical and regulatory barriers [2]. The printing mixes must have a very accurate balance between their printability through nozzles and their layer-bearing capacity, which is a significant challenge to research in materials science [10]. The layer-by-layer printing technique brings about structural anisotropy, resulting in the absence of bonding between layers and reduced tensile strength [11]. The addition of reinforcement, which has been traditionally done through the use of steel rebars, is still a technical challenge, resulting in ongoing research activities in fiber-reinforced composites, cable-driven systems, and hybrid 3D-printed and cast concrete structures [3].

This review systematically aims to incorporate recent developments in 3DCP by integrating research studies from both academic and highly non-academic sources [7]. The evaluation reviews the present status of technological development in four significant areas, including printing systems based on gantry robotic and crane systems. The evaluation reviews sustainability outcomes, digital modeling integration, and material developments in terms of waste-based binders and geopolymers [3]. This research work establishes the future research agenda in 3D concrete printing by identifying the existing research gaps in quality control, structural verification, and long-term durability testing [2].

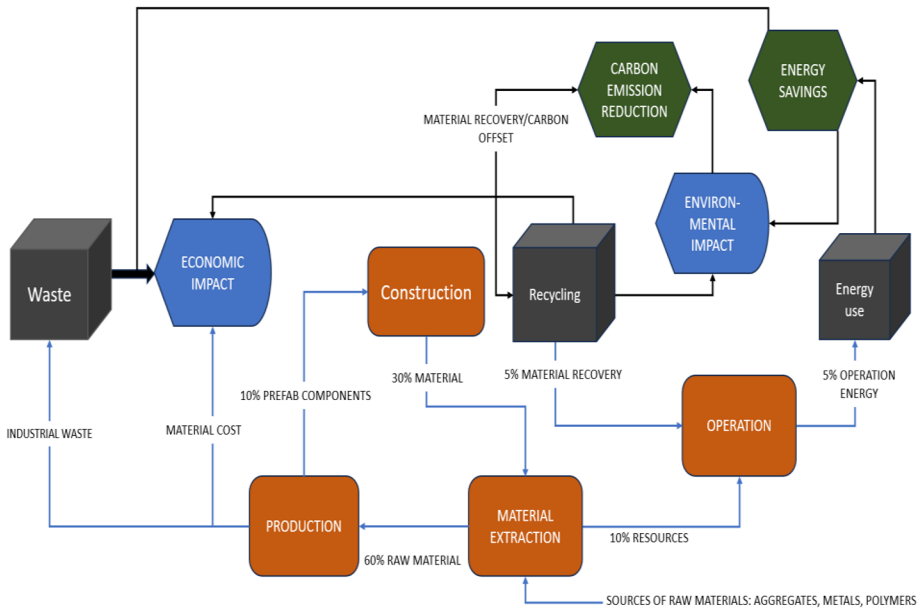


Fig.1: Sustainable 3D printing lifecycle

## 2. Types of 3D Concrete Printing Systems

Construction 3D printers are primarily categorized by their mechanical configurations and deposition techniques.

### 2.1 Mechanical Systems:

Gantry-operated 3D concrete printing systems use fixed metal frames to direct their printing equipment along three-dimensional Cartesian paths, which enable precise positioning. The robotic arm systems, which provide six or more rotational and translational movements, would allow operators to create non-linear shapes while achieving better surface results through their cutting-edge material application methods, including tangential continuity. Modular cable-driven and crane-mounted systems serve as flexible construction solutions that enable workers to build structures across large areas while maintaining easy mobility and requiring less heavy equipment to work in remote locations or small building areas. The research field has recently investigated swarm-based autonomous systems that use multiple robots to build structures through coordinated operations, thereby addressing the problems of scale and reach in traditional additive construction methods.

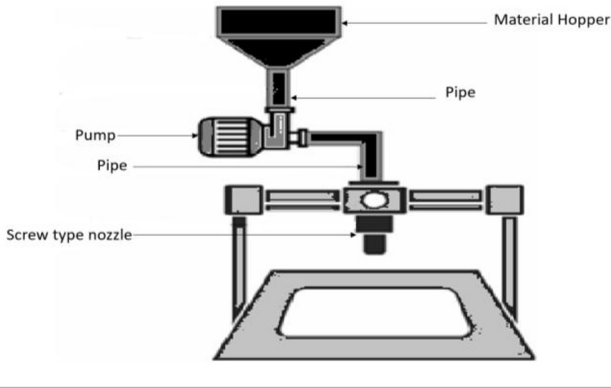


Fig.2: Representation of the printing mechanism in a 3D printer

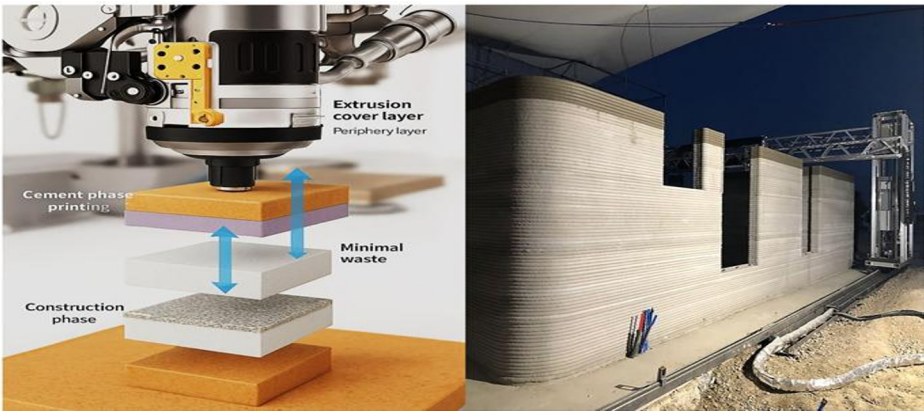


Fig.3: Extrusion-based concrete printing system, adapted from ICON Vulcan II [20],[22], a large-scale gantry-type 3D concrete printer actively constructing a building wall, printing a full-scale wall on-site (courtesy of M3 Design via ICON) [21]

## 2.2 Deposition Methods:

Extrusion-based material deposition modeling (MDM) involves continuously extruding viscous cementitious materials through a nozzle to form successive filaments. The method is currently the most common technique engineers use to construct load-bearing concrete structures. Binder jetting, in contrast, operates by selectively depositing a liquid binding agent onto a powder bed, such as sand or gypsum, enabling the fabrication of highly detailed and geometrically complex components with superior resolution. Shotcrete-based 3D printing (SC3DP) uses a different method, which sprays material through a pneumatic system to create layers that achieve better material compaction and stronger interlayer bonds than traditional extrusion-based techniques.

### 3. Printable Cementitious Materials For 3dcp

The "printing ink" is the primary factor that determines success in structural applications. 3D printing uses cementitious binders, which commonly include Ordinary Portland Cement (OPC); however, the binder's slow setting speed creates printing challenges that researchers are now investigating with alternative binders, such as sulphoaluminate cement (SAC), which enable fast setting and develop high strength during its initial stage. Researchers have conducted extensive studies to address sustainability problems and decrease carbon emissions from additive construction by investigating the use of industrial by-products, which include fly ash and ground granulated blast-furnace slag, and silica fume as partial cement replacements, and the usage of recycled construction waste and glass powder, and agro-based waste materials such as rice husk ash and teff straw. A printing process using a robotic-arm printer is shown in Fig. 4. 3D printing technologies extend their applications beyond cement-based systems, enabling the creation of non-concrete products, including polymers and metals produced through wire arc additive manufacturing (WAAM), as well as salt-based composites and earth-derived materials containing clay and cob, thus supporting sustainable construction practices and innovative architectural designs. Researchers developed a table that presents the technological specifications and materials used, as well as the main findings from different studies, based on research papers they derived from the source material. Some examples of different types of printing systems are shown in Figs 5,6 &7.

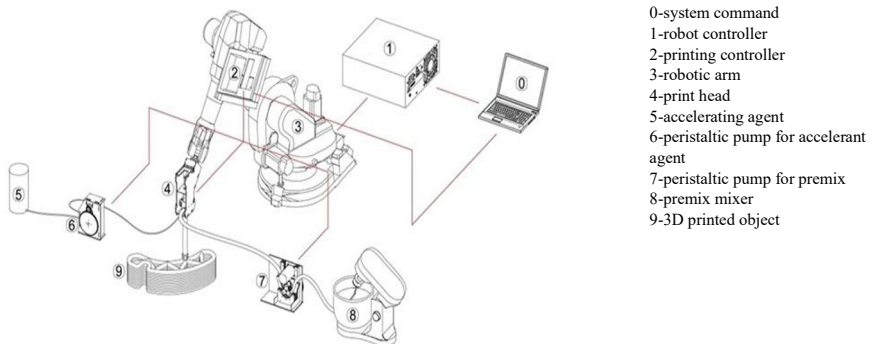


Fig. 4: Printing process using a robotic arm printer for setting on-demand concrete (adapted from [29]).

Table 1. Summary of Printing Systems, Material Formulations, and Research Outcomes in 3D Concrete Printing.

Author(year)	Machine Used	Material Used	Key Results/Outcomes
<b>Jia et al. (2023) J[1]</b>	Small-scale gantry printing machine (1m x 1m x 1m) with MAI@2 PUMP PICTOR 3D.	Earthen materials (soils GU, BM, BL, SG) mixed with sand and flax fiber.	GU and BL soils were identified as highly suitable; sand addition linearly reduces shrinkage.
<b>Jo et al. (2020)[2]</b>	Cartesian FDM prototype 3D printer with a linear servo motor (1m x 1m x 1m).	Cement paste, mortar, and PVA fiber-reinforced mixes.	Optimum water-cement ratio found at 0.30–0.32; 0.1% PVA fiber effectively prevents shrinkage cracks.
<b>Mawas et al. (2025)[3]</b>	Extrusion-based and Shotcrete 3D Printing (SC3DP) systems.	Concrete and Clay.	Established a robust deep learning (YOLOv11) pipeline for real-time filament height quality control.
<b>Pan et al. (2021)[4]</b>	Review of gantry (BetAbram P1) and 6-axis robotic arms (KUKA, Denso).	Concrete paste, UHPC paste, and powder-based materials.	3DP reduces construction waste by up to 60% and project costs by 35–60%.
<b>Azanaw (2025)[5]</b>	Extrusion-based 3D printing systems.	Hybrid 3D-printed and cast-in-place concrete systems.	Surface roughening/grooving improves bond strength by 27%; tooth-like interlocking is highly effective in resisting failure.
<b>Lyu et al. (2021)[6]</b>	X-Y-Z gantry robot with sit-on extruder.	Cement mortars reinforced with fibers (PE, basalt, steel).	Adding 0.5% basalt fiber significantly improves basic mechanical properties and structural anisotropy.
<b>Jianchao et al. (2017)[7]</b>	High-pressure pump system with a 50mm nozzle.	Ordinary Portland Cement (OPC) and Sulphoaluminate Cement (SAC).	SAC is more appropriate for rapid 3DP due to its shorter setting time and higher early strength.
<b>Vantghem et al. (2020)[8]</b>	Gantry/Robotic extrusion (for post-tensioned concrete girders).	3D-printed concrete (based on Wolfs et al. models).	Both Voxelization and Toolpath sweeping FEM models accurately predicted structural failure modes, such as elastic buckling.
<b>Shahzad et al. (2022)[9]</b>	Gantry and Robotic systems.	Concrete and fiber-reinforced concrete.	Identified a critical need for integrated reinforcement and multi-nozzle combinations to move beyond theoretical research.
<b>Tabassum &amp; Mir (2023)[10]</b>	Review of FDM, SLA, SLS, and Powder-based systems.	Cement-based binders, polymers, and powders.	FDM is cost-effective for small models; SLS and SLA provide superior strength and accuracy for structural elements.

<b>Banihashemi et al. (2025)[11]</b>	Gantry, Robotic arm, and Delta-type printers.	Geopolymer concrete and biodegradable polymers.	3DP technology reduces construction speed by 50% and aligns with circular economy principles.
<b>Wang et al. (2024)[12]</b>	Gantry and Robotic arms (bibliometric focus).	Geopolymer mortars (slag, fly ash) and construction waste.	Research trends are moving from feasibility studies toward mechanical property optimization and the use of low-carbon green materials.

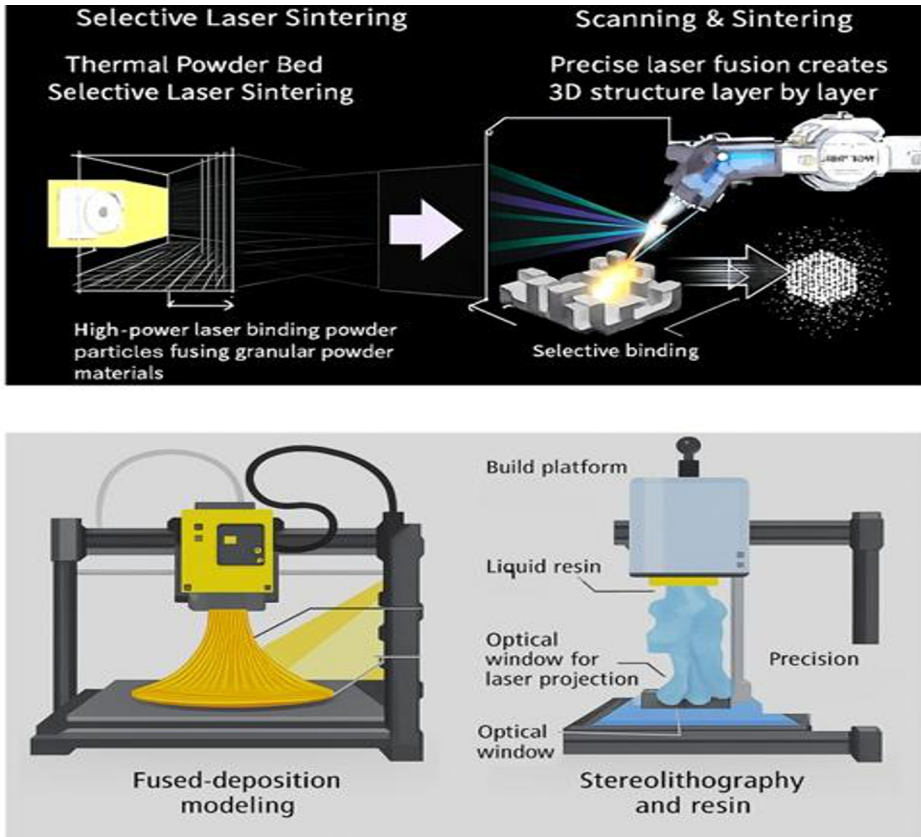


Fig.5: Powder-based printing system. Adapted from [23],[24], Plastic/polymer-based printing system. Adapted from [25],[26].



## 4. Mechanical Properties Of 3DCP

The mechanical performance of 3D-printed concrete (3DCP) is the primary determinant of its suitability for structural applications. However, it is fundamentally different from traditional cast concrete due to its process, which includes layer-by-layer fabrication [13],[12]. The absence of vibration and the creation of interfaces between filaments result in distinct characteristics, most notably structural anisotropy and variable interlayer bonding [13,14].

### 4.1 Structural Anisotropy and Directional Strength

One of the characteristic mechanical properties of 3DCP is anisotropy, whereby the values of strength and stiffness are direction-dependent when the load is applied [13,15]. Studies have grouped mechanical properties into three main directions: longitudinal (L), which is in the direction of the layers, transverse (T), which is perpendicular to the layers, and diagonal (D), which is at 45° [15]. The studies demonstrate that tensile strength in the vertical direction, which runs normal to the layers, is considerably lower than in the horizontal direction. [13]. Compressive strength also shows directional variation, but it remains the primary benchmark for regulatory approval, typically targeting 30 MPa at 28 days [5,13].

### 4.2 Interlayer Bond Strength

The “weakest link” of a three-dimensional printed structure is often the interface between the layers, especially when subjected to shear or tension loads [14]. The bonding strength between layers is affected by rheology, printing speed, nozzle height, and environmental factors [3,13]. The bonding between layers in three-dimensional concrete printing is greatly affected by the time lapse between the deposition of consecutive layers, as excessive time lapse may decrease the bonding strength due to evaporation of moisture from the surface and the setting of the previously printed layer [15]. To overcome this problem, several methods of bond enhancement, such as surface roughening, grooving, and the use of interlocking tooth-like geometries, have been shown to enhance interfacial bonding strength by as much as 42% by increasing the mechanical interlock [14]. The choice of cementitious materials is a crucial aspect that allows the structure to retain stability during the printing process. Sulphoaluminate cement (SAC) has better construction capabilities and enhanced layer bonding strength because of its faster setting time and development of greater strength during the initial stages of setting compared to Ordinary Portland Cement (OPC) [16].

### 4.3 Flexural and Tensile Performance

Owing to the brittle failure and low interlayer adhesion of 3DCP, the challenge of achieving sufficient flexural and tensile strength is quite prominent [13]. The incorporation of different fibers, such as polypropylene, glass, carbon, and basalt, has been recognized as an efficient approach to enhance the tensile and flexural properties of 3D-printed cementitious composites. The presence of fibers leads to enhanced properties of crack bridging and resistance to cracking because the carbon fiber-reinforced mixture has a compressive strength of 30 MPa, which exceeds the strength

of basalt and glass fibers with the same proportions. The combination of fiber reinforcement and composite methods, including steel micro-cable embedding and hybrid methods that combine 3D-printed shells with cast-in-place concrete cores, has been demonstrated to improve the tensile strength and load-carrying capacity, ultimately leading to enhanced structural stability of the printed material.

#### 4.4 Impact of Binders and Aggregates

The mechanical properties are also affected by mix design and the use of alternative materials: The addition of industrial by-products like fly ash, slag, and silica fume as supplementary cementitious materials (SCMs) has been shown to improve the rheological properties of 3D printed concrete [13]. However, researchers have noted that excessive use of certain waste materials can reduce early-age strength and delay the development of concrete's load-bearing capacity [13]. Furthermore, the use of recycled aggregates, specifically recycled sand, as a substitute for natural aggregates has been found to reduce the flexural stiffness and strength of printed structures, particularly when loaded from different directions due to the material's inherent anisotropic nature [13]. Environmental factors also play a decisive role in long-term durability; specifically, the mechanical properties of 3DCP—including both compressive and flexural strength—degrade significantly when exposed to elevated temperatures reaching 800°C, which remains a critical consideration for the fire performance and structural stability of the built environment [12].

#### 4.5 Failure Modes and Stability

The material requires enough green strength during printing to prevent both plastic collapse and elastic buckling which occurs when a structure reaches its critical height-to-thickness ratio. The Mohr-Coulomb failure criterion and other numerical approaches are becoming more common for behavior prediction because they enable researchers to simulate time-dependent changes in Young's modulus, cohesion and internal friction angles.

### 5. Durability Aspects Of 3DCP

The durability of 3D-printed concrete (3DCP) serves as the essential requirement for its long-term structural performance yet remains as the primary research challenge within this field. The microstructure and long-term performance of 3DCP face special vulnerabilities because it is exposed to environmental conditions immediately after placement, unlike traditional cast concrete, which uses protective formwork and mechanical vibration during construction.

#### 5.1. Shrinkage and Cracking Risks

A primary durability concern in 3DCP is the high risk of **shrinkage and cracking**. Because printed structures have a **high surface-to-volume ratio** and lack the moisture-retaining protection of formwork, they are prone to rapid water evaporation. This leads to:

Plastic shrinkage in 3D concrete printing arises from the rapid evaporation of water from the fresh material, a process significantly intensified by the technology's high surface-to-volume ratio and the lack of protective formwork [9]. This rapid drying can induce surface cracks before the concrete has fully hardened, potentially leading to structural instability or the complete plastic collapse of the printed structure [17]. Furthermore, drying shrinkage occurs over time as the loss of internal moisture causes substantial volume changes, which can damage the material's physical structure and reduce its overall strength [1]. According to research on earthen 3D printing, these problems can be avoided by modifying the mix design; in particular, it has been demonstrated that adding more sand reduces linear shrinkage. Plant additives, which contain flax fibers, create solutions for filling cracks while they reduce shrinkage except their implementation faces challenges because the printing system stops working when operators use extended time periods or high quantities of fibers. [1].

## 5.2. Interlayer Bonding and Environmental Ingress

The layer-by-layer nature of 3DCP creates **interfacial regions** that are more porous than the bulk material. These interfaces act as potential pathways for the ingress of deleterious substances:

The durability of 3D-printed mortar is heavily influenced by the chemical resistance of its unique layered structure, as evidenced by rapid chloride permeability test results that classify its chloride ion permeability as "medium." [16]. The porous interfaces formed between successive filaments during the printing process facilitate the migration of chloride ions into the concrete matrix, posing a significant concern for the long-term performance and structural integrity of marine structures [13]. The structure's weakest point, which engineers identify as layer boundaries, creates high porosity that enables faster carbonation. The material's increased permeability enables carbon dioxide absorption, which results in internal concrete pH reduction that increases the risk of reinforcement corrosion [12,14].

## 5.3. Resistance to Harsh Environments

The ability of 3D-printed structures to withstand extreme conditions is essential for their application in cold or chemically aggressive climates:

The three-dimensional printed concrete material tested through rapid freeze-thaw experiments which reached 200 freeze-thaw cycles showed no major weight reduction and no important decline in dynamic modulus, thus proving its suitability for application in cold weather conditions [16]. In order to further improve the durability of the material, the addition of air-entraining agents may also be required to further improve frost resistance, especially at porous layer interfaces, which are prone to water entry and deterioration [14]. The material has improved physical resistance properties when geopolymer binders are added, which provides better performance than that of normal Portland cement in 3DCP because the material provides better resistance to chemical degradation while maintaining its performance under various environmental conditions [2]. In addition, geopolymer-based systems also have better resistance to high-temperature conditions, which have excellent fire resistance and maintain structural integrity better than normal cement-based systems [14].

#### 5.4. Thermal and Fire Performance

One of the main advantages of 3D printed concrete is the inherent fire performance of 3D printed concrete, as the thick walls of 3D printed concrete provide better thermal insulation properties compared to other building envelopes [3]. Experimental and numerical evaluations have demonstrated that these multi-layered wall systems maintain their structural integrity for up to 2 hours even at 1000°C [14]. However, while the structure may remain standing, the material undergoes severe internal changes; research shows that the mechanical properties of 3DCP, specifically its compressive and flexural strengths, degrade significantly upon exposure to temperatures up to 800°C [6,12]. New ways of preventing damage due to high temperatures are being researched, and the ways that are being used include the incorporation of polyvinyl alcohol fibers and the use of geopolymers binders, as these ways successfully prevent the flaking and bursting of the concrete while maintaining better strength under thermal conditions [4].

#### 5.5. Impact of Material Innovation

The use of industrial by-products including fly ash and slag and calcined clays as Portland cement replacements creates an effective method to decrease carbon emissions from 3D-printed concrete. This method enables specific geopolymers binders to achieve CO<sub>2</sub> emission reductions between 60% and 80% [1]. These supplementary cementitious materials (SCMs) act as fine fillers, effectively occupying internal voids and increasing packing density, thereby densifying the microstructure and significantly enhancing the long-term durability and mechanical strength of the printed components [9]. At the same time, the application of waste aggregates such as recycled construction waste and glass powder helps to make 3DCP more circular economy-friendly by ensuring that large amounts of industrial waste are not disposed of in landfills [13]. Nevertheless, the results of experimental work have shown that overreliance on such alternative materials can be harmful, as it may lead to an increase in their porosity and a reduction in early-age strength [9]. Thus, the challenge of achieving industrial-scale viability has to be met by optimizing mix designs to ensure that the ecological advantages of waste use are not compromised by the strict rheological demands of additive construction [4].

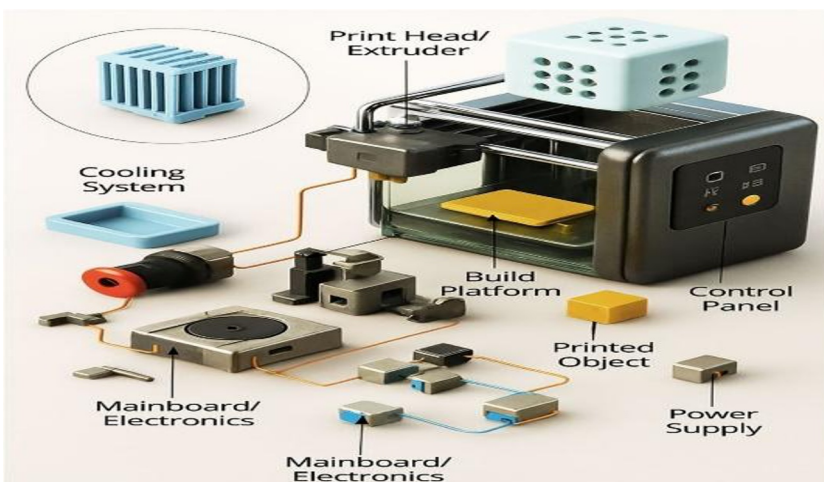


Fig. 8: Hybrid printing system. Adapted from [24],[29]

## 5.6. Future Trajectories in Durability Research

To facilitate mainstream adoption, future research must shift from macroscopic mechanical testing to **micro-scale characterization**. This includes:

The successful adoption of 3D concrete printing technology within mainstream industrial applications requires further research to establish permanent testing procedures which evaluate 3D printed structures under different actual environmental conditions for precise assessment of their durability and performance throughout their operational lifespan [4]. Simultaneously, there is an urgent need for standardization through the development of unified international building codes and protocols for testing chemical durability and corrosion resistance—testing that must be specifically tailored to account for the material's unique structural anisotropy and layer-based interfaces [4]. Furthermore, innovations in self-healing materials, such as the integration of encapsulation-based self-healing cast layers or innovative interfaces equipped with embedded sensors, offer a transformative approach to automatically repair microcracks that frequently form at layer boundaries, thereby significantly enhancing the long-term reliability and integrity of the built environment [14].

## 6. Application and Structural Aspects

3DP technology has various applications, which different fields have adopted. The Dubai Office of the Future and WinSun's multi-story residential buildings demonstrate how three-dimensional printing technology is applied in architecture and housing because it enables construction to be completed within 24 hours for some housing units. The Shanghai and Gemert and Venice locations use 3D printing technology to create footbridges which produce weight-bearing elements that use compression-based design principles to achieve optimal structural performance. The technology enables military forces to build safe structures for disaster relief operations, which include blast-resistant barriers and emergency shelters and defensive bunkers. However, aside from the construction industry, 3D printing has had a revolutionary effect on other sectors, such as the aerospace industry (where it is used to create lightweight components), the medical field (where it is used to create patient-specific implants), the automotive industry, the food industry, and the fashion industry. Some benefits of 3DCP are listed below in Fig.9.



Fig. 9: Various benefits of using 3DCP

## 7. Economic and Sustainability Aspects

The shift toward 3DP offers significant quantifiable benefits for the construction sector. Three-dimensional printing in construction offers substantial waste-reduction benefits by eliminating the need for conventional formwork and enabling highly precise, layer-by-layer material deposition, reducing overall construction waste by up to 60%. Significant efficiency gains are also achieved, as automated fabrication processes can shorten construction timelines by approximately 50–70% while simultaneously lowering labour requirements and associated costs by 50–80%. In addition, the increased automation inherent in 3D printing technologies enhances on-site safety by minimising human involvement in hazardous tasks, thereby reducing the likelihood of construction-related accidents and fatalities.

## 8. Critical Challenges and Research Gaps

Three-dimensional concrete printing presents multiple essential technical and regulatory obstacles despite demonstrating various benefits. The most critical problem with the material stems from structural anisotropy, arising from the layer-by-layer manufacturing method that creates weak interlayer bonds, resulting in much lower tensile strength along the printing path than within the layers. The main challenge arises from automated printing systems, which are extremely difficult to integrate with traditional building materials, such as steel rebar. Hybrid construction methods and fibre-reinforced cementitious composites show potential because researchers are developing automated reinforcement systems which demand complete standardization. 3D-printed buildings face global commercial challenges because building codes and design standards and testing methods do not have international acceptance which creates regulatory confusion that stops authorities and industry professionals from using the technology.

## 9. Conclusion

This review reiterates that Three-Dimensional Concrete Printing (3DCP) is a revolutionary technology in Construction 4.0, which tackles the most important inefficiencies in the construction industry, which consumes close to 13% of the global GDP and around 39% of the global CO<sub>2</sub> emissions. Compared to traditional construction techniques, 3DCP has the potential to decrease construction waste by as much as 60%, project duration by 50–70%, and labor-related costs by 50–80%, mainly due to automation and the removal of formwork.

Material efficiency remains the cornerstone of performance. Printable concrete materials usually aim to achieve a compressive strength of around 30 MPa at 28 days for structural applications, while other binders such as geopolymers have the potential to decrease CO<sub>2</sub> emissions by 60–80% compared to Ordinary Portland Cement-based materials. Nevertheless, overreliance on recycled aggregates or waste binders may impair early strength and structural integrity. From a structural perspective, the issues of anisotropy and the deficiency of interlayer bonding are still significant, and the tensile strength in the vertical orientation is often lower than that in the longitudinal orientation.

Methods such as fiber reinforcement and mechanical interlocking together with hybrid printed and cast systems have achieved interfacial strength improvements which range between 27 and 42 percent thus demonstrating effective pathways to strengthen

structural components. The durability tests show that the material can withstand 200 freeze thaw cycles while maintaining structural integrity for 2 hours at 1000°C, but the material will suffer degradation from mechanical forces when exposed to temperatures above approximately 800°C. The current state of technology requires extensive research to develop standardized international design protocols because existing testing methods do not provide adequate testing for long-term durability. The research needs to develop standardized testing methods which will include assessment of microstructural interfaces and implementation of AI systems for real-time quality control and testing of complete structural systems. 3DCP offers extensive technical capabilities which can lead to environmentally sustainable infrastructure development. 3DCP provides environmental advantages for building sustainable infrastructure through its advanced technical capabilities. The construction industry needs to address three critical issues regarding mechanical anisotropy and durability problems together with standardization requirements before 3DCP can achieve its goal of transforming from experimental status into established construction practice.

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