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Investigation of three-dimensional concrete printing (3DCP) technology in AEC industry in the context of construction, performance and design

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Abstract

Purpose: Three-dimensional concrete printing (3DCP) technology is still an emerging method in the construction industry and is currently the focus of interest for many researchers. Understanding this technology's current status and potential is crucial in guiding academic studies. In this context, this study aims to evaluate the current situation and potential of 3DCP technology in the AEC (architecture, engineering, and construction) industry.
Study design/methodology/approach: Within the scope of the study, bibliometric analysis was used, and 169 articles were reached in the Web of Science database according to the determined criteria. VOSviewer and bibliophily programs were used to determine the annual number of publications, countries' publication production, number of citations, keywords, and content analysis.
Findings: According to the results, the number of publications on 3DCP technology reached its highest level in 2022. China is the most productive country with 115 publications and the most cited country with 1136 citations. According to the findings based on the content of the reviewed articles, research on 3DCP technology is mainly focused on construction, performance, and design. In this context, 36% of the 50 most cited papers were focused on construction, 54% on performance, and 10% on design.
Originality/value: Within the scope of the TUBITAK 1002 project coded 122M876, it is aimed to form the basis of the project by investigating the importance of Construction, Performance, and Design in 3DCP in the literature.

Keywords: Additive manufacturing; 3D concrete printing (3DCP); Construction industry; Bibliometric analysis

1. Introduction

With the 4th Industrial Revolution, not only technologies but also the relationships of individuals/societies are changing, new economic values and models are being produced, and the traditional understanding of production and the factory is being transformed. The speed and deepening impact of this change, while offering new opportunities, also brings new potential problems. As a result of this situation, our daily practices and ways of learning and producing need to be rethought. (Sorguç & Kruşa Yemişcioğlu, 2020). This state of change and transformation impacts the field of architecture, as in many other disciplines. Today, the production methods of architectural structures are changing daily in this context. The additive manufacturing method (three-dimensional printing), one of the important technologies of Industry 4.0, is

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seen as a new and important method in producing building and building components in the building sector due to its many advantages.

Additive manufacturing technology, which is a manufacturing method in which the design geometries of products are obtained by separating them into minor parts and adding them point by point or layer by layer (Gibson et al., 2021), has an essential place in the field of architecture as well as in many sectors such as automotive, health and aviation. The use of concrete, which has an essential place in the construction sector, is becoming increasingly widespread (Bos et al., 2016). This technology combines CAD or BIM software, robotic arms, extrusion systems, and traditional and advanced materials in construction. 3D concrete printing buildings offer many advantages such as cost, waste and time reduction, safety, freedom to print aesthetic structures in designs, and minimization of environmental impact (Mansouri et al., 2022). In addition, it also provides benefits by offering an innovative solution in many aspects, such as material, environmental, and economic, compared to traditional construction (Bhattacherjee et al., 2021; de Brito & Kurda, 2021; Tinoco et al., 2022). There are many examples of applications of three-dimensional concrete technology in the construction sector in the world (Table 1) (Office of Dubai Municipality (Pessoa et al., 2021), The BOD[1], KampC[2], Tecla[3], Project Milestone[4]).

Table 1. Structures produced with three-dimensional printing technology (source: authors)



In addition to practical examples, there are also critical pioneering studies on this issue in academic research (Buswell et al., 2018; Craveiro et al., 2020; Daungwilailuk et al., 2021; Diggs-McGee et al., 2019; Duarte et

[1] https://cobod.com/projects-partners/the-bod-building/

[2] https://cobod.com/projects-partners/kamp-c/

[3] https://www.3dwasp.com/en/3d-printed-house-tecla/

[4] https://3dprintedhouse.nl/en/project-info/project-milestone/

al., 2021; Duballet et al., 2017; Gradeci & Labonnote, 2019; Heidarnezhad & Zhang, 2022; Heras Murcia et al., 2020; Hojati et al., 2022; Kazemian et al., 2017; Khan et al., 2020; Kruger et al., 2019; Zhang et al., 2018). However, the fundamental scientific understanding of the relationships between design, materials, process, and product is still being explored (Bos et al., 2016).

Three-dimensional concrete printing technology is still an emerging method in the construction industry, and its applications are currently the subject of much research. Analyzing the current status of 3DCP in building production is considered necessary in guiding academic studies on the potential and future of the subject. This study, which aims to evaluate the current status and potential of 3DCP technology in the AEC (architecture, engineering, and construction) industry, was examined using the bibliometric analysis method. The study consists of four stages. In the first section, information about the research literature is given within the scope of the subject. The study's methodology is mentioned in the second section, and the subject is examined under two main headings: data search/collection and analysis. The third section presents the findings of the study. This section analyzes the number of publications and citations of countries, keyword analysis, and content analysis of publications in depth. The last part of the study discusses the data obtained from the study.

2. Methodology

In this study, the bibliometric analysis method was used to identify, select, evaluate, and systematize the research literature on three-dimensional concrete printing technology in building production for the study and to create new perspectives for future studies. The selected articles were analyzed using quantitative bibliometric analysis, which is a statistical and applied mathematical analysis of bibliographic data and has been frequently used in recent years for the analysis, evaluation, and prediction of the status of different research areas (Žujović et al., 2022).

2.1. Data Search/Collection

Data collection was conducted using the Web of Science (W.O.S.) Core Collection database. The selected database covers many scientific publications, including some of the most important journals. Here, the scope of the literature was limited to peer-reviewed journal articles and reviews. At the same time, other types of publications, such as books or conference proceedings, were excluded due to the significant volume of scientific work published each year. In the W.O.S. database, 186 articles published in architecture and engineering in the "Construction & Building Technology or architecture" category were accessed using the keywords *'3D print* and concrete and architectural design or architect* or structure* or building design or construct*'*. The range of these publications covers studies between 2018 and 2023. This timeframe was chosen because 3DP technology is rapidly evolving and is relatively new in widespread use. Finally, only publications in English were included in this study. Table 2 summarizes the main parameters used in the W.O.S. database search and their corresponding information.

Table 2. Wos-based research criteria

Parameters	Information
Database	Web of Science (W.O.S.) Core Collection
	Software: RStudio-Biblioshiny, VOSviewer
Research Criteria	Keywords: 3D print* and concrete and architectural design or architect* or structure* or building design or construct*
	Web of Science Category: Construction & Building Technology or architecture
	Document Type: Article and Review
	Publication Language: English
	Publication year range: 2018-2023
	Research Area: Architecture, engineering

2.2. Data Analysis

The analysis of the publications accessed from the Web of Science database was obtained through VOSviewer and Biblioshiny. It was seen that three-dimensional printing technology is used in many fields, such as chemistry, the biomedical field, and the aircraft industry, and that there are publications in the W.O.S. database. For this reason, among the 186 publications accessed in the first stage, those not within the study's scope were examined in full text by considering abstract, content, and keywords, and articles unsuitable for further analysis were eliminated. In the final stage, 169 relevant publications in architecture and engineering were accessed. The outputs/analyses of these publications are included in the findings section.

3. Findings

Detailed data analysis (number of publications and citations of countries, keyword analysis, and content analysis of publications) are included in this section. The amount and distribution of the annual number of publications in a field are important in showing the direction of development of the subject and the scope of knowledge. Figure 1 shows the trend of the annual number of articles published in the last five years. Looking at the studies on three-dimensional concrete printing technology in the field of engineering and architecture in the last five years, from 2018 to the present, it is seen that there has been a continuous increase.

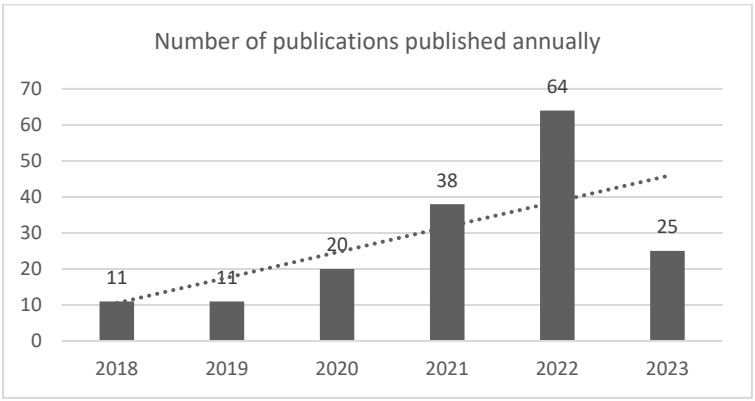
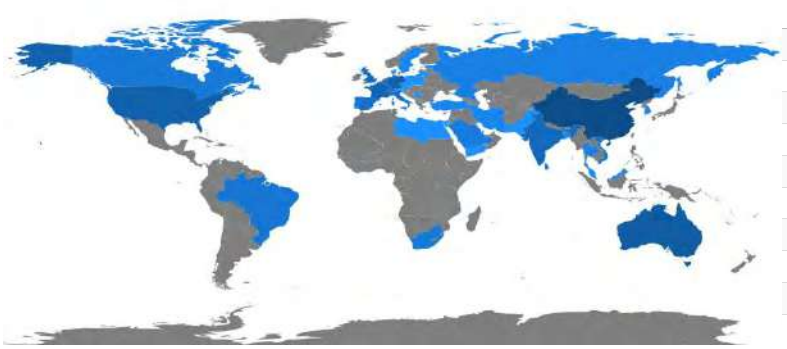


Fig. 1. Number of publications published annually

Until 2020, since three-dimensional concrete printing is still an emerging trend in the AEC sector, it is seen that research on 3DCP technology has gained significant momentum since this year. This situation shows that there are significant developments in the field and that it is reflected in publications as its applicability increases. Since the number of publications in 2023 covers the first six-month period, the annual number of publications cannot be known precisely. Figure 2 shows the number of publications made by countries on the subject. When we look at the top five countries, we see that China, Australia, Germany, America, and France are the top five countries. The U.K., Belgium, India, the Netherlands, and Singapore follow these countries. In this context, it can be said that China has the highest number of research on this subject and has an essential resource for the future of the subject. In addition, this situation in the number of publications also shows the importance that the country attaches to the subject.



region	Freq
CHINA	115
AUSTRALIA	38
GERMANY	29
USA	26
FRANCE	21
UK	15
BELGIUM	14
INDIA	14
NETHERLANDS	14
SINGAPORE	14

Fig. 2. Countries' scientific production (Biblioshiny)

3.1. Countries' Citations

The top 10 countries with the highest number of citations between 2018-2023 are shown in Figure 3. Accordingly, China ranks first with 1136 citations, followed by Australia, Belgium, the UK, Germany, the Netherlands, India, South Africa, Italy and Singapore.

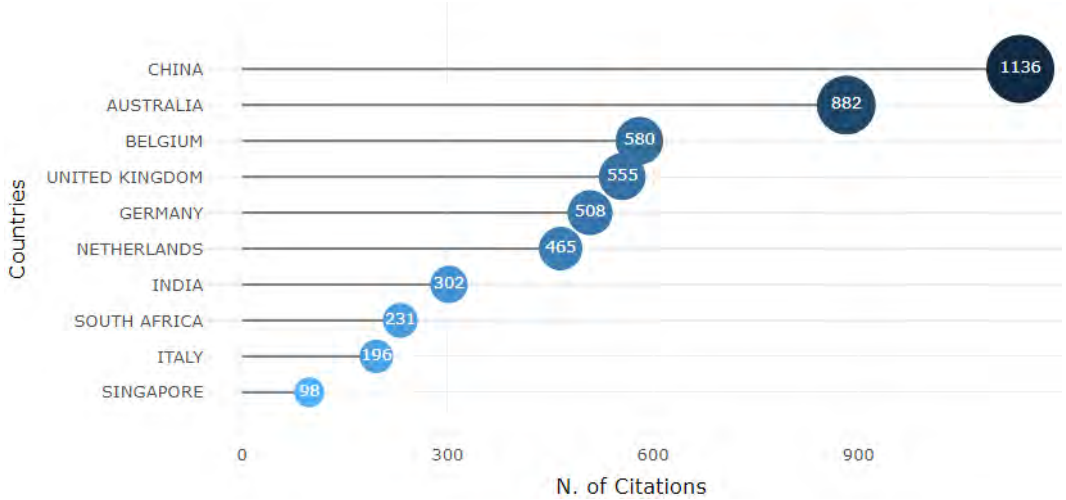


Fig. 3. Countries' citations (Biblioshiny)

3.2. Keyword Analysis

Keyword occurrence analysis can identify keyword clustering, clarify the development direction of the field, and summarize emerging research in an academic field (Žujović et al., 2022). Figure 4 shows a visualization of keyword cluster occurrences in the selected literature through the VosViewer program. Two counting methods are available for keyword analysis: binary and exact. The binary method only counts the presence or absence of a term without considering repetition within an article. On the other hand, the total count requires recording the occurrence of each word. The total count method was chosen for this study as it offers a more comprehensive analysis of the actual outputs of research topics (Žujović et al., 2022). According to this method (Figure 4), the analysis shows five different clusters (green, red, blue, purple, and yellow), each representing an area where 3D concrete printing technology is used. The green cluster is the most significant and complex due to the number of terms and links used. The terms "three-dimensional concrete printing," "additive manufacturing," "three-dimensional printing," "rheology," and "constructability," which form the backbone of this cluster, indicate that a significant proportion of the articles analyzed focused on research on the applicability of three-dimensional concrete printing at the interface of engineering and architecture.

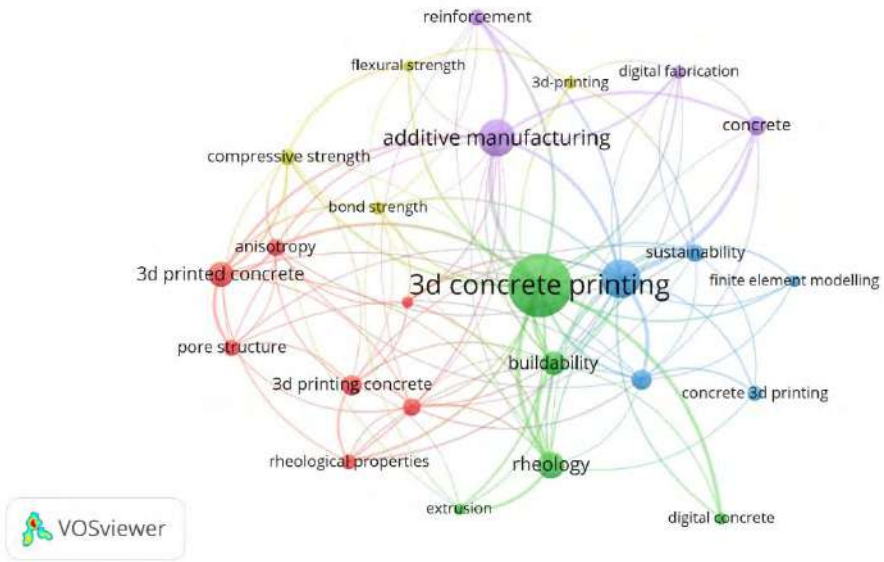


Fig. 4. Visualization of keyword cluster formations of identified publications (VOSviewer)

Figure 5 shows an analysis of the tripartite relationship of the publications selected within the scope of the study in terms of their authors, the keywords they use, and the countries in which they were published. Looking at the relationship between authors and their countries, China and Germany are associated with the most studies with these keywords. These countries are followed by Belgium, India, Australia, France, France, the U.K., the Netherlands and the U.S.A. When we look at the most trending keywords on the subject, the words construction, performance, strength, design, and behavior come to the fore. The limited number of studies on the fresh/fresh properties and behavior of the material, and thus the limited number of keywords, shows that this topic is still developing. This may indicate that future studies in these areas may be trending topics in the literature.

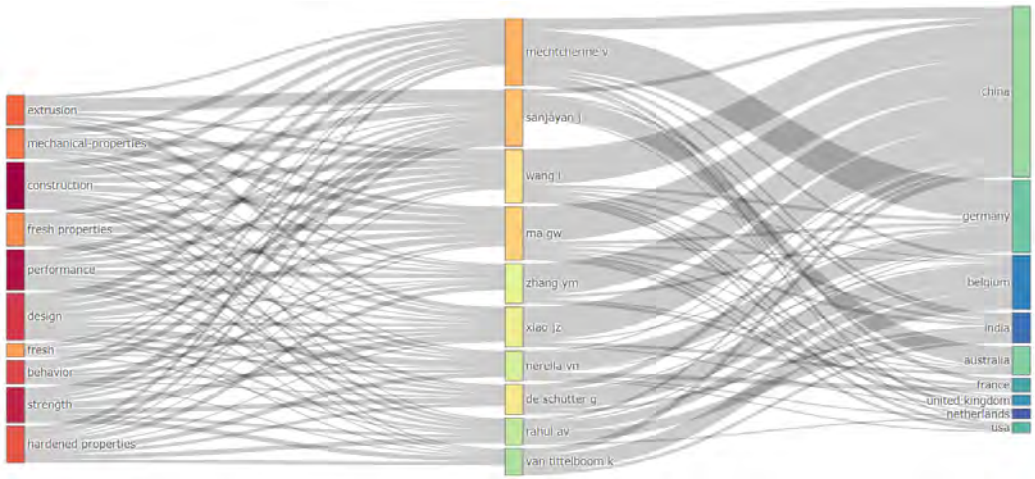


Fig. 5. The triple relationship between the authors of the publications, the keywords they used, and the countries of publication (Biblioshiny)

The analysis of the co-occurrence network made through Biblioshiny is shown in Figure 6. Accordingly, as a result of the bibliometric analysis of three-dimensional concrete printing technology in building production, it is seen that the research and development studies are grouped into two clusters: construction and performance. At this point, in the analysis of the two clusters, it is seen that the most essential keywords are construction, performance, and design. When the next sub-clusters are examined, it is seen that engineering-based keywords such as mechanical properties, strength, behavior, and extrusion emerge.

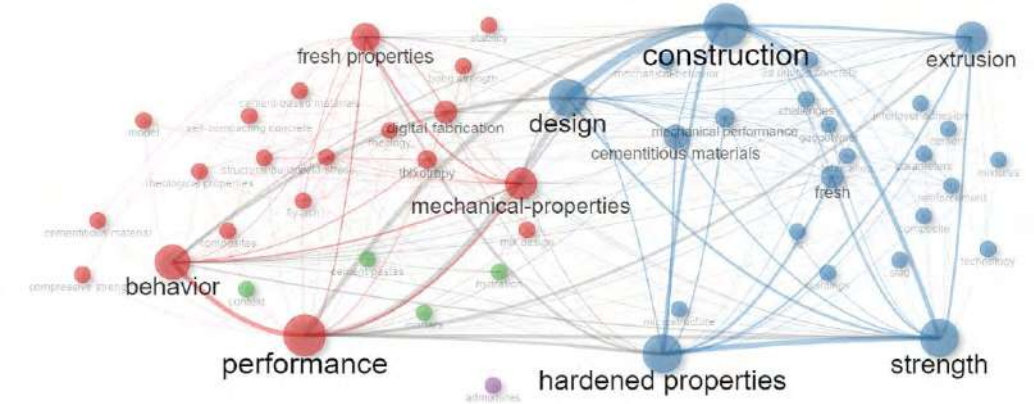


Fig. 6.Co-occurrence network (Biblioshiny)

When we look at the clustering by coupling analysis, another analysis of keywords that supports this situation, it is seen that this area is grouped into five groups (Figure 7). These five groups are shown in different colors (red, blue, green, purple, and yellow). When we look at the keywords belonging to the groups. Group 1 (red) ranks first with the keywords *construction, performance, and design*. These groups are followed by blue (construction, strength, mechanical properties), green (behavior, performance, design), purple (hardened properties, construction, extrusion), and yellow (behavior, composites, shrinkage cracking). A table showing the percentiles of each group in the same analysis is also given here (Table 3). In summary, it can be seen from Figure 7 that the studies on construction, performance, and design are in the first group and represent important studies/keywords on the subject.

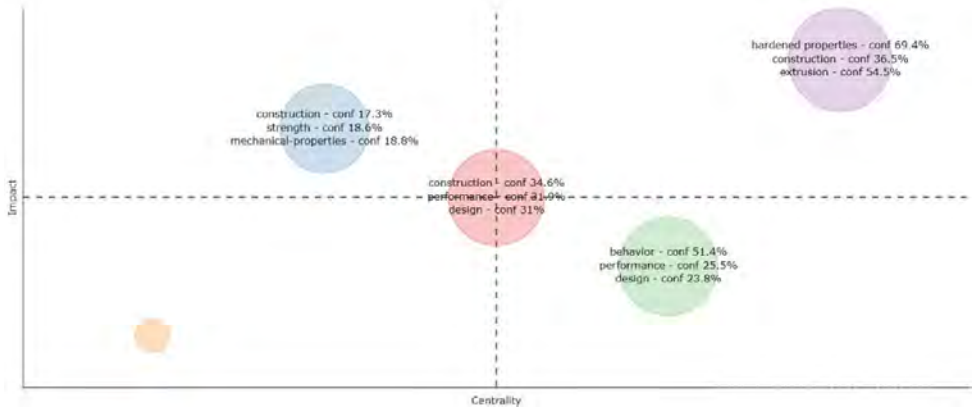


Fig. 7. Clustering by Coupling (Biblioshiny)

Table 2. Clustering by Coupling Table (Biblioshiny)

Keyword	group	freq
construction - conf 34.6% performance - conf 31.9% design - conf 31%	1	38
construction - conf 17.3% strength - conf 18.6% mechanical-properties - conf 18.8%	2	25
behavior - conf 51.4% performance - conf 25.5% design - conf 23.8%	3	45
hardened properties - conf 69.4% construction - conf 36.5% extrusion - conf 54.5%	4	60
behavior - conf 2.7% composites - conf 20% shrinkage cracking - conf 33.3%	5	1

3.3. Content Analysis

In this section, the content of the 50 most cited articles among the 169 publications selected for the study is classified into construction, performance, and design. This classification allows for more in-depth analysis by identifying the articles' main research topics and areas of interest. Table 4 presents data on the content of the top 50 most cited publications. According to the analysis, 36% of the studies are on Construction, 54% on Performance and 10% on Design. The research methods of the studies are divided into three categories *'experimental research, literature review, and review information supported.'* The most commonly used method is experimental research. When Table 4 is examined, while the titles of *'Mix Design, Printability, Buildability, Rheological Properties, 3DCP applications'* come to the forefront in Construction, the titles of *'Mechanical properties, Sustainability, Reinforcement, Hardened properties'* come to the forefront for Performance. As for Design, it is seen that keywords related to the structure and its components, such as *'column, shell structure, masonry, bridge'* come to the fore. Here, it is understood that the studies on performance are progressing simultaneously with the studies on construction. Literature studies and experimental studies of applications support each other and reveal the still-developing structure of the subject. The studies on performance are generally experimental and include applications in the laboratory environment, and it is seen that this situation creates an infrastructure for large-scale construction applications. It can be said that there are relatively fewer studies on design compared to construction and performance. It is thought that studies on *design* will have an essential place in the literature with the expansion of the application areas and possibilities of 3DCP in the future. In conclusion, it can be said that there is a strong relationship between construction, performance, and design and that there are essential potentials in determining future research areas.

Table 4. Classification of the top 50 most cited articles according to their content

Subject	Rank	References	Research Method			Keywords/Focus	Subject	Rank	References	Research Method			Keywords/Focus
			Experimental Research	Literature Review	Review Information Supported					Experimental Research	Literature Review	Review Information Supported	
Construction	1	(Nerella et al., 2020)	✓			Buildability, Economic viability	Performance	26	(Muthukrishnan et al., 2020)	✓		✓	Large-scale additive manufacturing, Sustainable concrete
	2	(Zhang et al., 2021)		✓		Mix Design, Printability		27	(Ye et al., 2021)	✓		✓	Ultra-high ductile concrete, Mechanical anisotropy
	3	(Hou et al., 2021)		✓		Mix Design, Printability		28	(Geng et al., 2020)	✓		✓	Mechanical property, Pore structure
	4	(Zhang et al., 2018)	✓			Mix Design, Buildability, Fresh		29	(Wang et al., 2021)	✓		✓	In-process reinforcement, Interlayer bonding
	5	(Rahul et al., 2019a)	✓			Mix design, Yield stress, Test methods		30	(Yu et al., 2020)	✓			Hardened properties, Void distribution, Anisotropy
	6	(Zhang et al., 2019)	✓			3dp, Thixotropy, Harden property		31	(Baz et al., 2020)	✓			Bond strength, Thixotropy
	7	(Muthukrishnan et al., 2021)	✓			Rheological Properties, Buildability		32	(Marchment & Sanjayan, 2020a)	✓			Reinforcement, Bar penetrations, Pull-out strength
	8	(Sanjayan et al., 2021)	✓			Rheological Properties, Buildability, Vibration		33	(Casagrande et al., 2020)	✓		✓	Compression tests, Failure prediction
	9	(De Schutter et al., 2018)		✓		3dpc technical, economic and environmental situation		34	(Yang et al., 2022)	✓		✓	UHPFRC, Mechanical properties, Anisotropy
	10	(Lowke et al., 2018)		✓		Particle-bed 3D printing techniques		35	(Sanjayan et al., 2018)	✓			Print-time interval, Inter-layer strength
	11	(Mechtcherine et al., 2019)	✓			3dpc, Large-scale, on-site application		36	(Wolfs et al., 2019a)	✓		✓	Hardened concrete, Bond strength, Interlayer adhesion
	12	(Kruger et al., 2019b)	✓			Buildability, Analytical modelling, Rheology		37	(Asprone et al., 2018)	✓		✓	Reinforced concrete, Flexural behavior
	13	(Jayathilakage et al., 2020)	✓		✓	Buildability, Yield stress, Mohr-Coulomb failure criterion		38	(Mechtcherine et al., 2018)	✓			Digital concrete construction, 3D-printed steel reinforcement
	14	(Souza et al., 2020)		✓	✓	3dpc's potentials, Large-scale buildings		39	(Kruger et al., 2019b)	✓		✓	3dpc, Rheology, Thixotropy
	15	(Xiao et al., 2021)		✓		3dpc, Large-scale fabrication, Printability		40	(Mohan et al., 2021)		✓		Rheology, Mechanical behaviour, Durability, Sustainability
	16	(Buswell et al., 2018)	✓			Rheology, Hardened properties, Geometric conformity		41	(Marchment & Sanjayan, 2020b)	✓		✓	Reinforcement, In-process embedment
	17	(Hosseini et al., 2019)				3d printing concrete, Interlayer interaction		42	(Ding et al., 2020)	✓		✓	Recycled sand, Hardened properties
	18	(Siddika et al., 2020)				3dpc, application, challenges		43	(Rahul et al., 2019b)	✓		✓	Porosity, Compressive strength, Flexural strength
Performance	19	(Bong et al., 2021)	✓			Mechanical properties, Rheology, Sustainability		44	(Bhattacherjee et al., 2021)		✓		Sustainability, Low carbon binder, Low energy binder
	20	(Al-Qutaifi et al., 2018)			✓	Mechanical properties, Flexural strength		45	(Malek Mohammad et al., 2020)			✓	LCA, environmental impact, sustainable construction
	21	(Wolfs et al., 2019b)	✓		✓	Fresh concrete, Mechanical properties, Finite element	Design	46	(Anton et al., 2021)	✓		✓	Bespoke columns, Concrete prefabrication, Concrete automation
	22	(Bai et al., 2021)	✓			Re-utilisation of solid resource, Sustainability		47	(Costanzi et al., 2018)	✓		✓	Shell structure, Adaptable mould
	23	(Wolfs et al., 2018)	✓			Fresh concrete, Mechanical properties		48	(Carneau et al., 2020)	✓		✓	Masonry, Cantilever, Vaults
	24	(Suiker et al., 2020)	✓			Structural failure Parametric, Optimization		49	(Xu et al., 2019)	✓		✓	Volume forming, Variable nozzle, Architectural ornament
	25	(Jayathilakage et al., 2019)			✓	Rheology, Flow,Yield stress		50	(Vantyghem et al., 2020)	✓		✓	Topology optimization, Bridge design

3.3.1. Construction

The first title for content analysis is 'Construction.' The publications in this section [1-18] mainly provide data on the process's research, design, application, and method development for products produced with 3DCP technology in the construction sector. When looking at the contents of this section, the keywords 'Mix Design, Printability, Buildability, Rheological Properties, 3DPC applications' come to the fore.

Challenges and potentials for construction: The construction of buildings and their structural components using 3D concrete printing is seen as a new and vital method that has made significant improvements over traditional construction methods due to its many advantages such as low cost, high efficiency in automated construction, freedom of design, time and reduction of labor cost and risk of injury during construction (Shahzad et al., 2022). Purposeful digitalization and automation of all necessary steps in the construction industry, from design and planning to the construction process, is the only viable solution to address the challenges of low productivity and increasing shortage of skilled labor (Mechtcherine et al., 2019). Souza

(2020) addresses and discusses the main operational parameters, feasibility, and prospects of the technology for 3DCP applications in large-scale buildings (Souza et al., 2020). De Schutter (2018) states that this technology offers many opportunities to improve the cost-effectiveness of construction processes compared to traditional construction methods (De Schutter et al., 2018).

Three-dimensional printing technology requires precise solutions in the process, linked to various parameters such as the scale of the project, the choice of printing materials, and the quality and strength of the post-printed parts (Ngo et al., 2018; Siddika et al., 2020). The printability of these products and their behavior after printing varies depending on essential parameters such as the properties of the materials, time, temperature, and printing method (Ngo et al., 2018). Among the main challenges for this method is optimizing the printing material with suitable properties for 3D concrete printing (Shahzad et al., 2022). 3DCP is being used in various construction projects as a new material with numerous advantages. Due to the increasing number of applications and the fact that the printing process is very different from traditional casting, mixed designs for printable concrete continue to be researched and developed (Zhang et al., 2021). Studies and standards for concrete mixes in 3DCP technology are not yet sufficient. In the literature, there are important studies on these mixtures in recent years (Hou et al., 2021; Rahul et al., 2019a; Zhang et al., 2021). Zhang et al. (2021) state that the development of design guidelines for mixes used in three-dimensional concrete printing (3DCP) compiled from existing literature is an important step towards contributing to the broader practicality of this new technology (Zhang et al., 2021).

3.3.2. Performance

The second heading for content analysis is 'Performance.' The publications in this section [19-45] are studied based on the topics related to 'Construction' and about each other and include research on the development direction of the method. This section mainly includes details on improving the constructability of mechanical properties, strengthening the performance of products produced with 3DP technology, and developing sustainable approaches for the future. The keywords *'Mechanical properties, Sustainability, Reinforcement, Hardened properties'* come to the forefront when looking at the topics focused on in this section.

Challenges and potentials for performance: There are studies on structural analysis and numerical modeling of the 3DCP process to assess the quality or structural integrity of the printed object (Wolfs et al., 2018). Rahul (2019b) discusses test methods to characterize the mechanical behavior of wall elements produced by three-dimensional printing. He makes recommendations for structural design according to the strength values obtained from the tests (Rahul et al., 2019b). The rheology of concrete plays a vital role in concrete 3D printing applications, where concrete is pumped at high pressure and extruded through a nozzle at low speed to form the structural component. In his study, Jayathilakage (2019) experimented with different test methods to measure the rheological parameters of different concrete mixtures (Jayathilakage et al., 2019).

In order to increase the sustainability potential of three-dimensional concrete printing applications, the decisions made during the material production phase are important (Bhattacherjee et al.,2021). 3DCP applications are considered a possible alternative to traditional concrete construction due to their potential to increase productivity and reduce the environmental impact of the construction industry. Life cycle assessment (LCA) studies have been conducted to evaluate its environmental benefits compared to traditional structures. However, there are limited studies on this subject (Mohammad et al., 2020). With 3DP, complex geometries increase with design optimization in the production of the building component, while at the same time, the use of manufactured concrete material decreases. As a result, it is expected that for structures with the same functionality, the concrete material produced by 3DP will perform better environmentally over the entire service life compared to conventionally produced concrete structures (De Schutter et al., 2018). For the development of 3D concrete printing in construction, a comprehensive and in-depth discussion is necessary as research from a sustainability perspective is limited (Ning et al., 2021).

3.3.3. Design

The third heading for content analysis is 'Design.' The number of articles here is the section with the least clustering. Here, there are mainly studies on the design and fabrication of structural components *(such as columns, bridges, vaults, and walls)* at the latest stage of 3DP technology. As 3DCP is an emerging trend, researchers continue to explore this technology by testing its geometric and structural potential (Žujović et al., 2022). The main focus of the studies on this topic [46-50] is to investigate the different application potentials of 3DCP technology for design.

Challenges and potentials for design: 3DP technology provides much flexibility and diversity in geometry in producing structures and structural components compared to traditional methods. This technology also enables non-traditional design methods such as topology optimization (Vantyghem et al., 2020). Design optimization in the production of the building component allows flexible geometries to be produced while at the same time reducing the use of the concrete material produced, thus reducing the cost (De Schutter et al., 2018; Vantyghem et al., 2020). As a result, the relationship between studies on environmental performance and design provides essential data on the potential in this field. It is thought that studies on the design and application of structures and building components produced with three-dimensional concrete printing in the construction sector will become important in determining the direction of future studies.

4. Discussion and conclusion

In this study, the bibliometric analysis method was used to identify, select, evaluate, and systematize the research literature on three-dimensional concrete printing technology in building production for the study and to create new perspectives for future studies. The study used the Web of Science (W.O.S.) Core Collection database to collect data. Analyses for 169 publications were obtained through Vosviewer and Biblioshiny databases. Looking at the studies on three-dimensional concrete printing technology in the field of engineering and architecture in the last five years, from 2018 to the present, it is seen that there is a continuous increase. Looking at the number of publications made by countries on the subject, it was seen that China has the highest number of research and is the most cited country. As a result of the bibliometric analysis of three-dimensional concrete printing technology in building production, it is seen that R&D research is gathered in two clusters: construction and performance. At this point, in the analysis of the two clusters, it is seen that the most essential keywords are construction, performance, and design. The content of the 50 most cited articles among the 169 publications selected within the scope of the study was classified into three categories: construction, performance, and design. This classification allowed for a more in-depth analysis by identifying the articles' main research topics and areas of interest. As a result, it can be said that there is a strong relationship between the three topics identified and that there is significant potential for identifying future research areas.

'Construction,' the first heading for content analysis, mainly provides data on the process's research, design, application, and method development for products produced with 3dp technology in the construction sector. When we look at the data belonging to the 'Performance' heading, it mainly includes details about the constructability, mechanical properties, strengthening of the products produced with 3DP technology, increasing the performance, and developing sustainable approaches for the future. The third heading for content analysis is 'Design.' Here, at the last stage of 3DP technology, there are mainly studies on the design and manufacturing of building components (such as columns, bridges, vaults, and walls). The main focus here is to investigate different application potentials for design at the point where 3DCP technology has reached. In this study, which aims to evaluate the current status and potential of 3DCP technology in the AEC (architecture, engineering, and construction) industry, it is seen that 3DCP is still an emerging field and

that more research and applications are needed in terms of 'design' in the AEC sector. The study is thought to provide important references regarding processes and trends in the sector.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest concerning this article's research, authorship, and publication.

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