Al-Rafidain Journal of Engineering Sciences

Journal homepage https://rjes.iq/index.php/rjes

ISSN 3005-3153 (Online)

Research Trends and Performance Evolution of Sustainable Self-Compacting Concrete: A Systematic and Bibliometric Review

Samer S. Abdulhussein [1], Hussein K. Khalaf [1*], Raghad M. Kudadad [1], Mohammed Ali Abdulrehman[2], Ala Keblawi[3]

[1]Civil Engineering Department, College of Engineering, Mustansiriyah University, Baghdad, Iraq
[2]Department of Materials Engineering, College of Engineering, Mustansiriyah University, Baghdad, Iraq
[3]Department of Civil Engineering and Sustainable Structures, College of Engineering and Technology, Palestine Technical University–Kadoorie, Tulkarm, Palestine

ARTICLE INFO

Article history:
Received 17 March 2026
Revised 17 March 2026
Accepted 12 April 2026
Available online 14 April 2026

Keywords:
Bibliometric and Systematic Review,
Multi-Objective Optimization,
Supplementary Cementitious Materials,
Sustainable Self-Compacting Concrete.

ABSTRACT

Sustainable self-compacting concrete is an important material in the modern engineering construction sector due to its distinctive mechanical properties, ease of shaping, and significant contribution to reducing environmental impact. This paper provides a comprehensive systematic and bibliometric review of publications on this topic between 2010 and 2026. The systematic PRISMA-based approach was taken to define, filter, and examine the pertinent journal articles that are registered in Scopus. Bibliometric mapping techniques were used to gauge global research trends, publication development, dominant countries, and theme development. The results obtained indicate that the number of publications has increased considerably in the past 10 years, with the use of supplementary cementitious materials, recycled aggregates, and low-carbon binders as the main contributors. The most popular research topics are mechanical and durability performance, whereas the new research topics include rheology modification, fiber reinforcement, and life-cycle assessment. The review shows that there are crucial knowledge gaps concerning long-term sustainability, large-scale system application, and comprehensive sustainability assessment. The research has provided a knowledge map structure for research and practice, and has identified future research areas to improve high-performance sustainable self-compacting technologies.

1. Introduction

The Self-Compacting Concrete (SCC) is a remarkable improvement of concrete technology as it has better rheological behaviour and can therefore flow freely, self-compact, and self-segregate without mechanical vibration. These properties make the structures more constructable, enhance surface quality, and increase the filling capacity of densely reinforced structures [1]. This has led to extensive research aimed at streamlining the mechanical and durability performance of self-compacting concrete, particularly in terms of compressive strength, workability, and long-term structural behaviour [2]. Nevertheless, the swift internationalization of the cement manufacturing sector, which has been identified as one of the most significant sources of anthropogenic CO_2 emissions, has heightened concerns about the environmental impact of cement-based products [3]. In turn, recent literature has introduced supplementary cementitious materials such as fly ash and slag, recycled aggregates, and industrial by-products to minimize clinker content and improve resource efficiency [4]. Although solutions focus on promises to reduce carbon emissions, most studies to date have focused

* Corresponding author E-mail address:samersaeed@uomustansiriyah.edu.iq
https://doi.org/10.61268/zteneh43

on performance rather than sustainability goals [5].

The accumulating literature on sustainable SCC research in the past decade has created a discontinuous knowledge base, with material substitution, mechanical optimization, and more recently, machine learning-based strength prediction advancing independently of each other instead of being part of a unified sustainability strategy [6]. It is also worth noting that systematic lifecycle assessments, economic feasibility analyses, and multi-objective optimization methods remain insufficient in the current literature. Besides, no unified mapping of the intellectual development, thematic maturity, and research paths of sustainable SCC is available. This lack of a holistic outlook is a research problem of first importance: although more and more attempts are made to incorporate sustainable materials into SCC, the field lacks a single approach that simultaneously evaluates mechanical performance, environmental impact, and economic feasibility [3].

Hence, the purpose of the proposed research is to fill this gap by conducting a combined bibliometric and systematic review to map the development of sustainable SCC studies, to emphasize existing and emerging trends in the research, to assess material substitution policies and sustainability performance, and to outline the key gaps in the research. Through the combination of quantitative bibliometric effects and qualitative systematic findings, this paper will offer a comprehensive view of sustainable SCC development and will give some guidelines of how future multi-objective, sustainability-focused mix design models should look like [7].

2. Significance of research

This research adds new knowledge to fill the gap by conducting a combined bibliometric and systematic review to map the development of sustainable SCC studies, to emphasize existing and emerging trends in the research, to assess material substitution policies and sustainability performance, and to outline the key gaps in the research. Through the combination of quantitative bibliometric effects and qualitative systematic findings, this paper will offer a comprehensive view of sustainable SCC development and will give some guidelines of how future multi-objective, sustainability-focused mix design models should look like [7].

3. Materials and methods for systematic literature review

This The research protocol of the present study is a Systematic Literature Review (SLR) guided by the PRISMA 2020 guidelines to identify and interpret trends in research and performance changes related to sustainable self-compacting concrete (SCC). The SLR methodology offers a well-defined, open approach to the systematic collection, screening, and synthesis of pertinent journal articles. It will enable the establishment of predominant research topics, sustainability plans, performance trends, and knowledge gaps.

The PRISMA framework ensures methodological rigor by reducing selection bias and improving reproducibility. This is particularly necessary to unify scattered results on sustainable materials, supplementary cementitious materials (SCMs), recycled materials, mechanical performance, durability, and environmental concerns in SCC research. The process of the research, identification, and selection of the relevant studies was divided into the following steps:

- The search for predefined keywords based on self-compacting concrete, sustainability, and performance characteristics was carried out in a complete database search (Scopus) and covered publications between 2000 and 2025.
- The duplicates were eliminated, and the title and abstract were screened to eliminate irrelevant articles like conference papers, publications not in English, and articles that were not directly addressing the issue of sustainable SCC.
- Full-text articles were evaluated and found to be eligible according to pre-established inclusion criteria, i.e., relevance to sustainable

materials, mix design, rheology, mechanical performance, durability, and environmental impact.

- The extracted data were systematized and summarized to examine the trends in mix design strategies, mechanical and durability performance development, and sustainability-oriented innovations. conducted.

3.1. PRISMA 2020 protocol

The PRISMA 2020 protocol offers a systematic literature review methodology that is transparent, replicable, and well-organized. It allows researchers to select, screen, and determine the eligibility of studies, and to include pertinent studies from selected databases systematically, reducing selection bias and maintaining methodological rigor. PRISMA structure helps to improve reporting transparency and increase the reliability and reproducibility of review results.

- The systematic review was organized based on the following research questions in order to complete the objectives of this study:
What are the environmental, sustainability, and economic results of using sustainable self-compacting concrete and using conventional concrete?
- Which sustainable materials are used in self-compacting concrete, and what proportion of substitution and mix design strategies are most widely reported in the literature?
- What gaps in research are there, and what are the future research and development of enhancing the holistic environmental and economic sustainability of SCC?

Identification of a relevant database consists of two steps: first, identify the keywords, and then identify the databases. Identification of databases was conducted on the Scopus website. The Scopus database was used. The searching string for Scopus database is: TITLE-ABS-KEY (("self-compacting concrete" OR "SCC") AND ("sustainab*" OR "green concrete" OR "low carbon" OR "environmental performance" OR "supplementary cementitious materials" OR "recycled" OR "industrial. The screening criteria were carefully defined to select studies that directly address sustainable self-compacting concrete, including material substitution strategies, performance evaluation, and sustainability-related outcomes. Table 1 presents the screening criteria. And Fig. 1 presents the protocol to find related papers for systematic review.

Table 1 : Screening criteria

Criteria	Inclusion
Timeline	2010-2026
Document Type	Article journal
Keyword	"self-compacting concrete", "SCC", sustainability-related terms
Subject area	Materials Science
Access	Open access
Language	English

Based on the Scopus database search, 567 records were initially identified (Fig.1). Before the screening, 12 records were eliminated: 4 were non-English publications, and 8 were inaccessible articles, leaving 555 records for the title screening. The title screening phase cut 327 records deemed irrelevant to sustainable self-compacting concrete. This was followed by 228 records being screened on the abstract, out of which 153 were not retrieved or deemed untrustworthy to proceed with analysis. The number of full-text articles evaluated for eligibility was 75. In the process of full-text assessment, 40 studies were discarded due to certain reasons, such as the absence of the sustainability aspects (n = 14), the unavailability of the sustainable material substitution (n = 8), the absence of the environmental or economic analysis (n = 6), the inappropriateness of the paper to the review, (n = 5), and the incompleteness of the methodology data (n = 4). Finally, 35 articles were eligible and included in the systematic review. Table 2 presents the results of SLR.
As presented, the 35 articles selected in the systematic review have shown that the current trend in research on sustainable self-compacting concrete (SCC) is to improve mechanical performance and to use alternative

materials. A significant percentage of the studied literature used recycled aggregates, fly ash, GGBFS, industrial by-products, and fiber reinforcement, with major results including enhanced compressive strength, durability, and workability. The results demonstrate that sustainability modifications are effective in maintaining and improving structural performance, and thus material replacement methods have achieved equivalence in results compared to traditional self-compacting concrete.

Many studies related to sustainability outcomes have indicated a reduction in environmental impact through the replacement of cement with other by-products or industrial waste such as fly ash and slag. Economic factors were even less often discussed and this leads to the idea that the aspect of sustainability is still in some way underdeveloped and is driven by material factors rather than evaluation ones.

In addition, the methodological and strategic gaps of the synthesis of reviewed studies are regular. Regular drawbacks comprise inability of integrated environmental-economic constructs, inadequate long-term sustainability validation, absence of normalized sustainability measures, inability to apply at field scale as well as the necessity of multi-objective optimization strategies. These consistent white spots indicate that even with the fast increase in sustainable SCC studies the area is disjointed and in need of a framework that can be able to optimize simultaneously performance, environmental impact and practical applicability.

4. Methodology for bibliometric research

A bibliometric study was conducted to investigate the geographical distribution of research output and changes in the dominant research themes in sustainable self-compacting concrete (SCC). In particular, the analysis aimed to identify the most productive countries in this area and to trace the patterns of keyword co-occurrence to identify the core and emerging research topics. The country contribution research provides information on regional research interests and global patterns of cooperation, and the keyword analysis reveals the current thematic focus and changing trends in the literature. This two-fold attention allows one to see the macro-level picture of the development of sustainable SCC research and the scientific trends influencing its evolution. The same Scopus SLR database was used, but here all documents were included. The bibliometric analysis was performed using VOSviewer to visualize networks.

Fig.2 illustrates the bibliometric analysis protocol adopted in this study. The search was conducted in the Scopus database using a structured search string focused on sustainable self-compacting concrete, limited to English journal articles published between 2010 and 2024. After applying the inclusion criteria and removing irrelevant and non-related records, the final dataset used for bibliometric analysis consisted of 567 publications. Through this adopted protocol, transparency in data selection emerged.

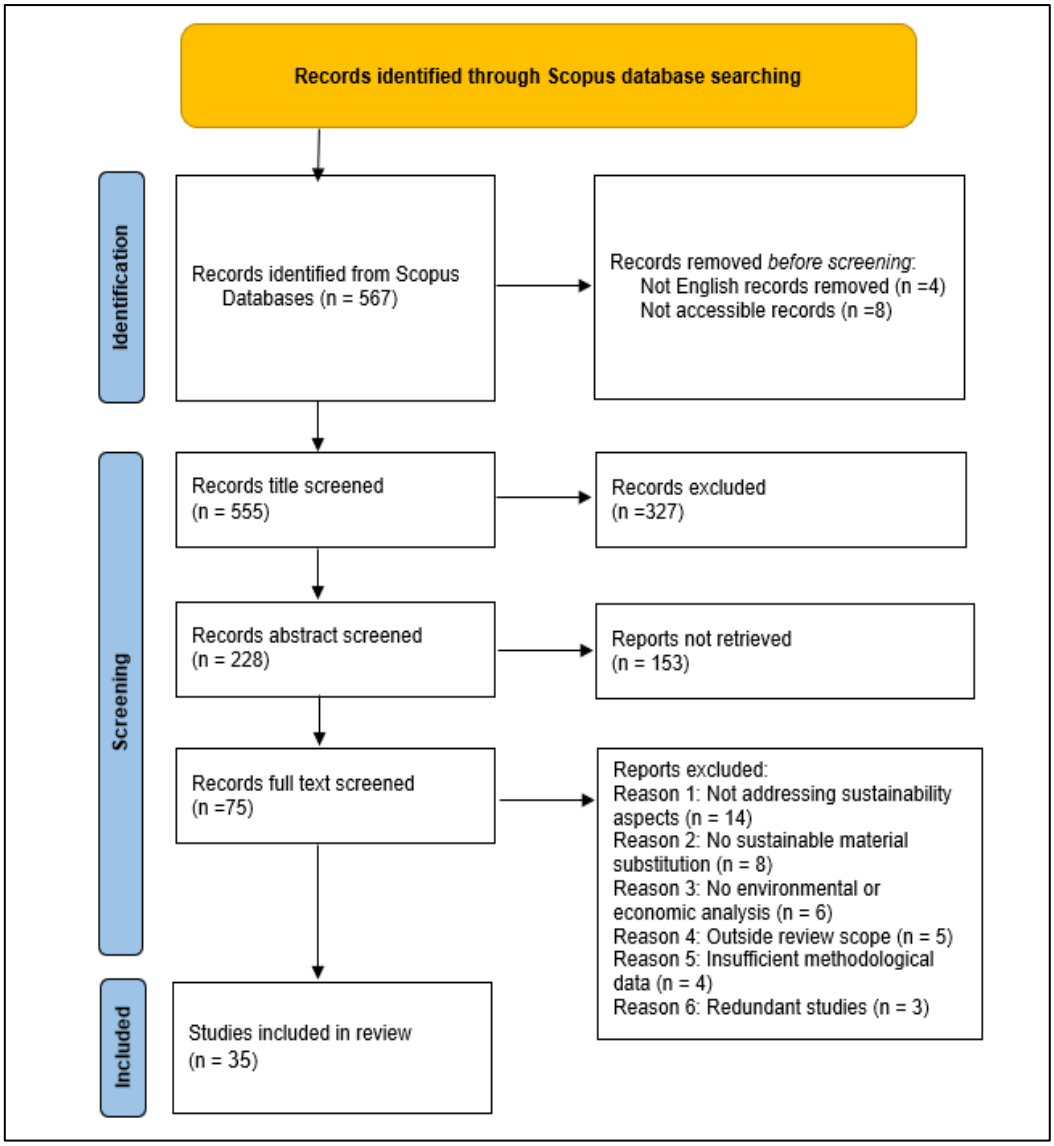

Fig.1. PRISMA Protocol.

Table 2. Characteristics and key findings of the 35 reviewed studies on sustainable SCC.

No.	Reference	Journal	Region	Sustainable Material Used	Integrated Effects of Use	Identified Research Gap
1	Abedi Mavaramkolaei, S. et al., 2026	Theoretical and Applied Fracture Mechanics	Iran	Recycled aggregates/materials	Enhanced mechanical performance	Lack of lifecycle assessment integration
2	Heshmati, M. et al., 2026 [2]	Sustainable Materials and Technologies	Australia	Fibres	Performance improvement reported	Limited long-term durability evaluation
3	Petrović, Ž. et al., 2026 [8]	Materials	Serbia	Recycled aggregates/materials	Enhanced mechanical performance	Insufficient economic cost–benefit analysis
4	Yu, Y. et al., 2025 [9]	Materials Today Communications	Japan	Sustainable modification	Enhanced mechanical performance	Need for large-scale field validation
5	Ahmadi, M. et al., 2025 [10]	Materials	Iran	Industrial/Waste by-products	Reduced environmental impact	Absence of standardized sustainability metrics
6	Naresh, T. et al., 2025 [11]	Structural Concrete	India	Sustainable modification	Performance improvement reported	The trade-off between strength and carbon reduction not optimized
7	Sousa, J.T.F.D. et al., 2025 [12]	Applied Sciences	Portugal	Industrial/Waste by-products	Performance improvement reported	Limited industrial implementation studies
8	Hussein, I.A. et al., 2025 [13]	Case Studies in Construction Materials	Iran	Recycled aggregates/materials	Performance improvement reported	No integrated environmental-economic framework
9	Zhang, J. et al., 2025 [14]	Case Studies in Construction Materials	China	Fly ash	Performance improvement reported	Durability under aggressive exposure not fully assessed
10	Dos Anjos, M.A.S.D. et al., 2025 [15]	Materials	Brazil	Fly ash	Reduced environmental impact; Improved durability	Scaling-up challenges remain unexplored
11	Bahmani, H. et al., 2025 [16]	Case Studies in Construction Materials	Iran	GGBFS / Slag	Performance improvement reported	Lack of lifecycle assessment integration
12	Skazlić, M. et al., 2025 [17]	Applied Sciences	Croatia	Recycled aggregates/materials	Performance improvement reported	Limited long-term durability evaluation
13	ElNemr, A. et al., 2025	Materials	United Kingdom	Recycled aggregates/materials	Improved workability	Insufficient economic cost–benefit analysis
14	Mazloom, M. et al., 2025 [18]	Structural Concrete	Turkey	Industrial/Waste by-products	Performance improvement reported	Need for large-scale field validation
15	Yan, X. et al., 2025 [19]	Materials	China	Recycled aggregates/materials	Performance improvement reported	Absence of standardized sustainability metrics
16	MohammadSalehi, A. et al., 2025 [20]	Construction and Building Materials	Iran	Industrial/Waste by-products	Reduced environmental impact; Improved workability	Trade-off between strength and carbon reduction not optimized
17	S, S.M. et al., 2025 [21]	Journal of King Saud University - Engineering Sciences	Malaysia	Fibres	Performance improvement reported	Limited industrial implementation studies
18	Mosafer, M. et al., 2025 [22]	Case Studies in Construction Materials	Iran	Sustainable modification	Performance improvement reported	No integrated environmental-economic framework
19	Arumugam, C. et al., 2025 [23]	Revista Materia	India	Industrial/Waste by-products	Performance improvement reported	Durability under aggressive exposure not fully assessed
20	Gharib, K.A.-A. et al., 2025 [24]	Materials and Structures	Egypt	Fibres	Performance improvement reported	Scaling-up challenges remain unexplored
21	Guessoum, M. et al., 2023 [25]	Construction and Building Materials	France	Recycled aggregates/materials	Performance improvement reported	Lack of lifecycle assessment integration
22	Kiran Bhat, K. et al., 2025 [26]	Case Studies in Construction Materials	India	Sustainable modification	Performance improvement reported	Limited long-term durability evaluation
23	Tyagi, R. et al., 2025 [27]	Materials Research Express	India	Recycled aggregates/materials	Performance improvement reported	Insufficient economic cost–benefit analysis
24	Hartono, J. et al., 2021 [28]	Case Studies in Construction Materials	Indonesia	Sustainable modification	Performance improvement reported	Need for large-scale field validation
25	Singh, T. et al., 2025 [29]	Materiales de Construccion	India	Recycled aggregates/materials	Enhanced mechanical performance	Absence of standardized sustainability metrics

26	Rutkowska, G. et al., 2025 [30]	Materials	Poland	Fly ash	Performance improvement reported	Trade-off between strength and carbon reduction not optimized
27	Alyaseen, A. et al., 2024 [5]	Materials Today Communications	Hungary	Recycled aggregates/materials	Enhanced mechanical performance	Limited industrial implementation studies
28	Sua-Iam, G. et al., 2024 [31]	Case Studies in Construction Materials	Thailand	Fly ash	Improved durability	No integrated environmental-economic framework
29	Saingam, P. et al., 2024 [32]	Case Studies in Construction Materials	Thailand	Fly ash	Reduced environmental impact; Improved workability	Durability under aggressive exposure not fully assessed
30	Shunmuga, P.R.S. et al., 2024 [33]	Case Studies in Construction Materials	India	Industrial/Waste by-products	Reduced environmental impact	Scaling-up challenges remain unexplored
31	Hosseini-Poul, S.-A. et al., 2024 [34]	Construction and Building Materials	Iran	GGBFS / Slag	Reduced environmental impact; Improved durability; Improved workability	Lack of lifecycle assessment integration
32	Akbulut, Z.F. et al., 2024 [35]	Materials	Poland	Fly ash	Reduced environmental impact; Improved workability	Limited long-term durability evaluation
33	Zhang, F. et al., 2024 [36]	Construction and Building Materials	China	Recycled aggregates/materials	Enhanced mechanical performance	Insufficient economic cost–benefit analysis
34	Hilal, N.N. et al., 2024 [37]	Journal of King Saud University - Engineering Sciences	Iraq	Nano-materials	Improved workability	Need for large-scale field validation
35	Liao, J. et al., 2024 [38]	Construction and Building Materials	China	Fly ash	Performance improvement reported	Absence of standardized sustainability metrics

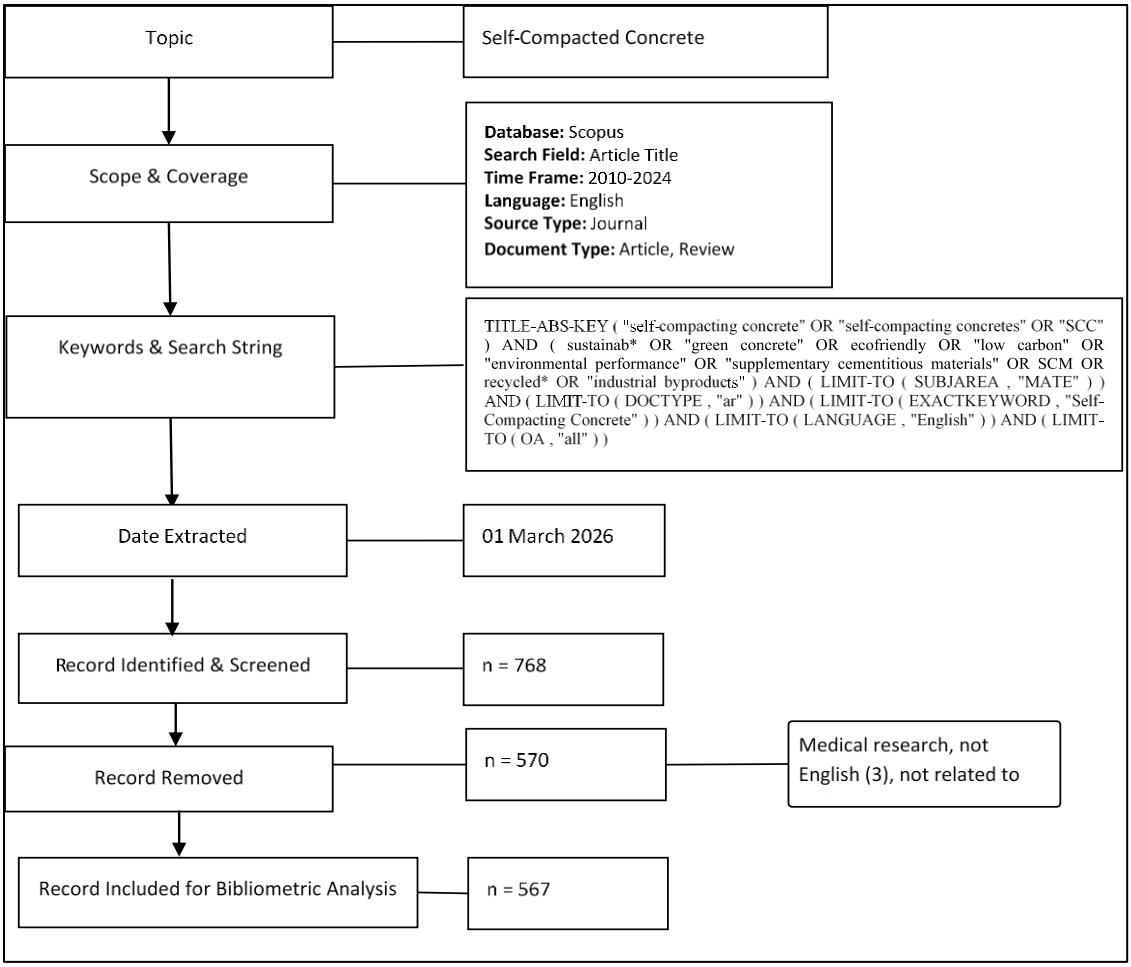

Fig. 2. Bibliometric Analysis Protocol.

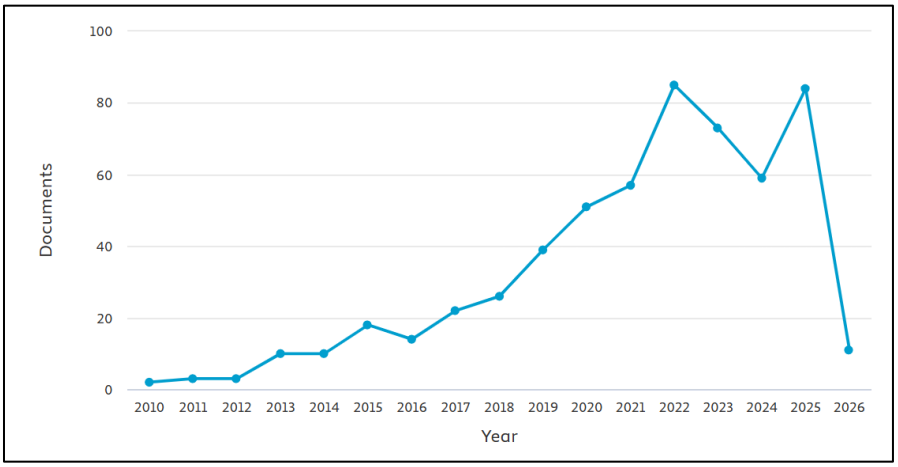

Fig. 3. Number of publications by year.

4.1. Trends in Publication

The results, as shown in Fig. 3, indicate a steady increase in the number of research papers published in Scopus databases from 2010 to the present. A small number was observed at (2010 - 2013), gradually increasing until 2018, culminating in a significant surge in 2019, during which over 50 scientific studies on the topic were published annually. Finally, the peak in these studies can be observed since 2022. The record number of published research papers during the period 2022-2025 demonstrates the growing interest in modern, sustainable building materials that align with global carbon emission reduction plans.

This has led the construction sector in modern engineering to focus on modern self-compacting concrete. Also, the rise in publications was driven by the development of supplementary cementitious materials (SCMs), recycled aggregates, and life-cycle assessment methodologies. The developments since 2020 are also indicative of a scientific paradigm shift toward sustainability-based material optimization and performance improvement, making sustainable SCC a research priority in sustainable infrastructure development.

4.2.Ground Contributing Country

Ground Fig. 4 presents the most contributing countries in these types of research. The bibliometric network demonstrates that China and India have the highest productivity in sustainable SCC research and they have the highest number of nodes and international collaboration connections. The country collaboration network has shown a significant input of some of the Arab countries especially Saudi Arabia, Iraq and Egypt, which shows the rising research interest on sustainable self-compacting concrete (SCC) in the Middle East region. Iraq is one of the most active Arab contributors among them, characterized by observable publication activity and collaboration with regional and international partners.

The high level of activity in Iraq in this area of research may be explained by several situational factors. First, Iraq is characterized by environmental and infrastructural problems, such as inhospitable climatic conditions, soils with high levels of sulphates, and wear resistance under hostile conditions. Such conditions mean that it will be necessary to develop long-term, sustainable concrete solutions, including SCC with additional cementitious materials and industrial by-products. Second, local waste materials and by-products are present, which promotes the investigation of cost-effective and resource-efficient construction options. Third, the demands and accelerated infrastructure development of the past few years, which have required reconstruction, have led to academic and practical research aimed at boosting performance and reducing environmental impact.

4.3. Terms Used in Publication

Fig. 5 presents the co-occurrence network of sustainable self-compacting concrete (SCC) research. The central node is the largest, and it is self-compacting concrete, which proves that it is dominant in the research area. Keywords closely related to high-frequency ones, such as mechanical properties, compressive strength, and durability, suggest that the latter is the central topic of SCCs research. Simultaneously, the prevalence of sustainability-related terminology, such as fly ash, recycled concrete aggregate, silica fume, and sustainability, is indicative of the high research activity on minimizing cement use

and improving environmental outcomes through supplementary cementitious materials (SCMs) and recycled resources. Moreover, keywords such as workability and rheology indicate technical issues related to preserving the fresh-state performance when using sustainable materials.

It is quite interesting to note that the emergence of machine learning reflects a recent shift toward intelligent mix design and predictive modelling. On the whole, the network demonstrates that research trends change significantly over time, shifting from performance-based assessment to sustainability integration and, more recently, to data-driven optimization methods, suggesting that SCC research is gradually shifting to a multidisciplinary, sustainability-oriented discipline. Fig. 5 shows how key research themes in sustainable self-compacting concrete have evolved over the years, with the most prominent ones outlined in time. Term frequency is drawn by the size of each marker, and the span of the horizontal axis shows the duration of the research activity. From the results, it can be concluded that the traditional performance-related topics, such as compressive strength, mechanical properties, durability, and workability, continue to hold traditional dominance, which can be attributed to the traditional performance-based character of SCC-related studies.

On the contrary, the traditional themes related to sustainability, such as the use of recycled aggregates and fly ash, continue to gain traction, while the last few years clearly show the rising trends for the new topics, namely, machine learning, carbon footprint, and multi-objective optimization, which indicate the strategic shift towards integrated approaches for sustainability and data science. To better understand the intellectual organization of studies on sustainable self-compacting concrete (SCC), a thematic map analysis has been carried out to examine the co-occurrence of keywords and the centrality-density relation. The strategy enables the identification of research topics in the field that are developed, developing, or inadequately developed. The thematic map offers a strategic perspective on current developments in sustainability-related research within the SCC, as well as key research gaps. On the whole, the thematic map shows that sustainable SCC research is undergoing a structural change, moving its performance-based studies toward sustainability integration and intelligent optimization. Nonetheless, the modern environment remains rather disjointed, and it is essential to create comprehensive evaluation frameworks that reconcile mechanical performance with environmental and economic sustainability. Integrated, lifecycle-based, and multi-criteria decision-making methods should thus be used in future research.

The thematic structure identifies the gaps found in both the bibliometric and systematic analyses. Although mechanical themes are prevalent as mature research topics, sustainability is still more associated with material aspects than with economic analysis and long-term ecological analysis. Machine learning tools play a pivotal role in the methodology, limiting the number of forts that appear in the main application. This helps alleviate the urgent need for multi-purpose tasks integrated with the environment and its environmental impact, which is the optimal design concept for sustainable construction using an automatically integrated device.

.

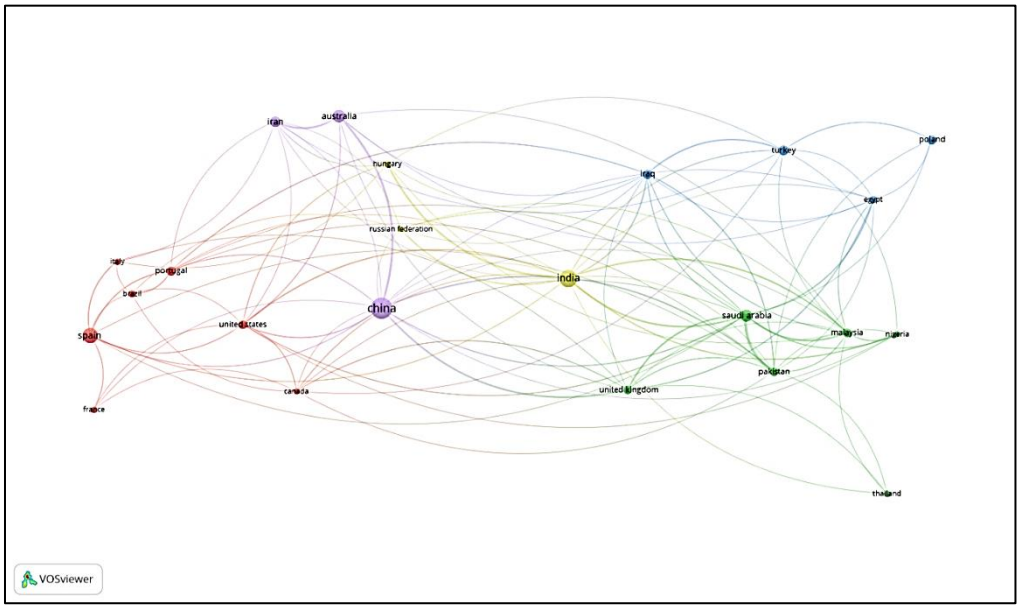

Fig. 4. The network visualization of the contributing countries

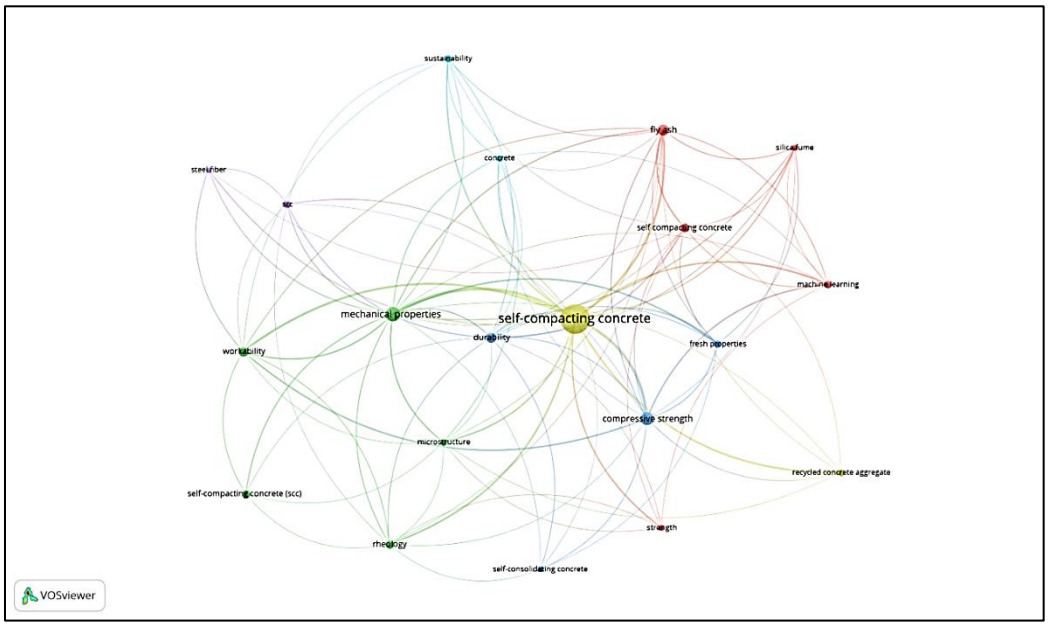

Fig. 5. The co-occurrence networks.

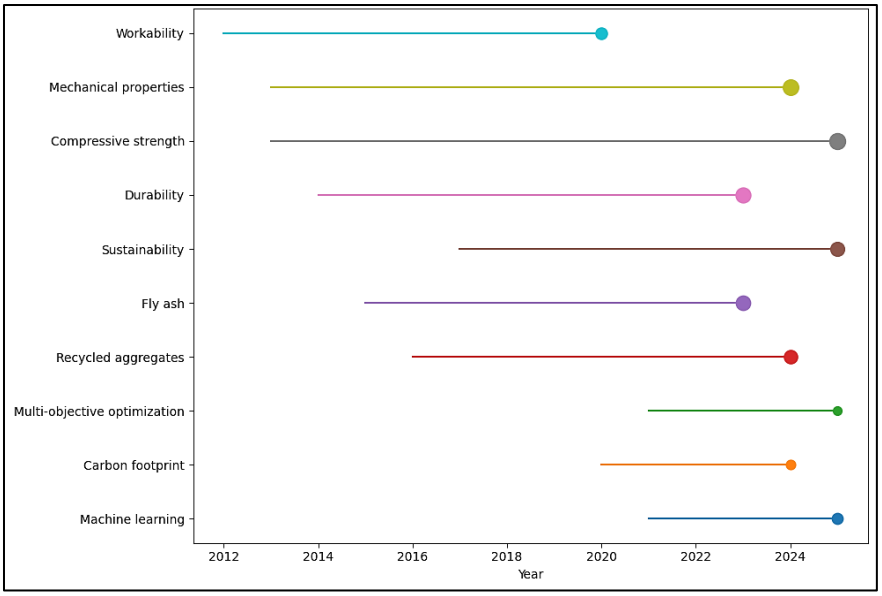

Fig. 6. Trend Topics in Sustainable SCC Research.

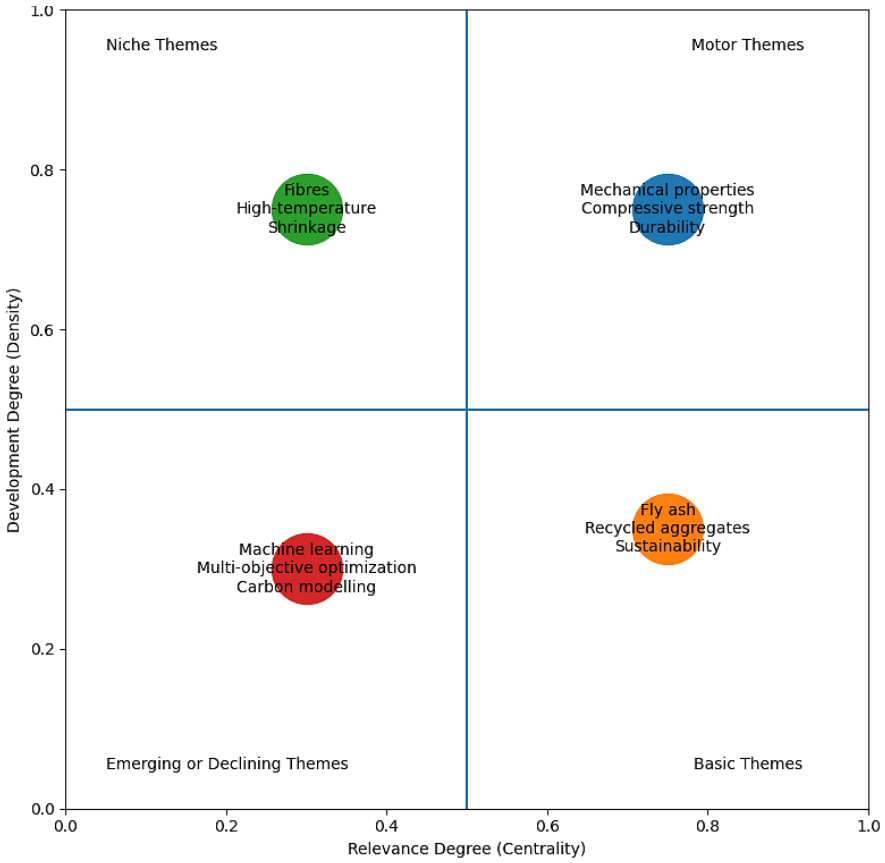

Fig. 7. Thematic Map of Sustainable SCC Research.

5. Properties Integrated research gaps and emerging trends in sustainable SCC

The search term co-occurrence analysis shows that although mechanical performance metrics, including compressive strength and durability, are predominant in the literature, sustainability-related terms are primarily associated with material replacement rather than with holistic evaluation systems. The current observation is consistent with the results of the systematic review of 35 selected articles, most of which focused on performance improvement with the use of additional cementitious materials, but only a few performed quantitative analyses of the environment or economy. Besides, the emergent nature of machine learning means a shift towards intelligent mix design, but it is mainly used to predict strength rather than to optimize holistically for sustainable operations. These results point to a major research gap in developing multi-objective frameworks that can effectively optimize the mechanical performance, the environmental impact, and the economics of sustainable SCC.

6. Discussion

The systematic and bibliometric analyses combined demonstrate a clear structure in the research on sustainable self-compacting concrete (SCC). Although a large body of literature indicates that using supplementary cementitious materials (SCMs) and recycled aggregates increases compressive strength, durability, and workability, the area is more performance-focused. The systematic review illustrates that the majority of experimental studies aim to sustain or improve mechanical efficiency, with most environmental and economic analyses being secondary or inferred indirectly from cement reduction rates rather than being determined directly. This demonstrates that the focus on sustainability in self-compacting concrete research relies heavily on raw materials rather than the framework.

7. Conclusion and Recommendations

This study presents a clear map of self-compacting concrete using modern bibliometric analysis and systematic review techniques. The results demonstrate that the mechanical performance of this concrete has been the primary focus of previous studies. Despite the introduction of sustainability approaches, such as replacing raw materials with different sustainable materials in the production of modern self-compacting concrete mixes, there is still a lack of consideration for the environmental and economic aspects of this type of research. Recent research topics indicate a gradual move in focus towards sustainability. However, there remains a significant shortage of data on the environmental impact, life cycle, and economic feasibility of concrete. This paper focuses on developing integrated data and systems to achieve diverse sustainability goals.

Future studies should target the economic feasibility, environmental performance in addition to the structural performance of self-compacting concrete, as having standardized evaluation procedures facilitates the adoption of this concrete in diverse application.

Declaration of Competing Interest

The authors declare that they have no financial interests or relationships that might appear to influence the work reported in this paper.

Data availability:

All data and limitations will be provided upon request

Acknowledgments

The authors thankfully acknowledge Mustansiriyah University.

References

[1] G. Long, Y. Gao, and Y. Xie, "Designing more sustainable and greener self-compacting concrete," *Constr. Build. Mater.*, vol. 84, pp. 301–306, Jun. 2015, doi: 10.1016/j.conbuildmat.2015.02.072.

[2] M. Heshmati, M. N. Sheikh, and M. N. S. Hadi, "Development of sustainable fibre-reinforced self-compacting geopolymer concrete with enhanced resistance to chemical attacks and shrinkage," *Sustainable Materials and Technologies*, vol. 47, p. e01874, Apr. 2026, doi: 10.1016/j.susmat.2026.e01874.

[3] F. Zhang, G. Zhao, D. Wang, J. Xiao, and T. Noguchi, "Mechanical and long-term shrinkage behavior of fully recycled self-compacting concrete," *Journal of Building Engineering*, vol. 112, p. 113849, Oct. 2025, doi: 10.1016/j.jobe.2025.113849.

[4] M. Benaicha, O. Jalbaud, and Y. Burtschell, "Investigating stability, homogeneity, and bleeding in self-compacting concrete: new experimental analysis," *European Journal of Environmental and Civil Engineering*, vol. 29, no. 5, pp. 901–915, Apr. 2025, doi: 10.1080/19648189.2024.2422361.

[5] A. Alyaseen, A. Poddar, C. V. Siva Rama Prasad, and H. Alahmad, "From waste to resource: Incorporating foundry sand in SCC for sustainable construction solutions," in *Alternative Cementitious Materials for Self-Compacting Concrete*, Elsevier, 2024, pp. 205–224. doi: 10.1016/B978-0-323-95139-5.00012-6.

[6] W. Zhu, Y. Meng, J. Xie, Z. Cai, Y. Lyu, and X. Xu, "Experimental Study on Abrasion Resistance of Self-Compacting Concrete," *Structural Durability & Health Monitoring*, vol. 19, no. 6, pp. 1733–1744, 2025, doi: 10.32604/sdhm.2025.070098.

[7] L. Duan, G. Xu, W. Deng, L. He, and Y. Hu, "The Influence of Mineral Powder Dosage on the Mechanical Properties and Microstructure of Self-Compacting Concrete," *Journal of Composites Science*, vol. 9, no. 6, p. 258, May 2025, doi: 10.3390/jcs9060258.

[8] Ž. Petrović, B. Milošević, M. Spasojević Šurdilović, A. Zorić, and D. Turnić, "Experimental Investigation of the Flexural Performance of Continuous Self-Compacting Concrete Beams with Natural and Recycled Aggregates," *Materials*, vol. 19, no. 2, p. 264, Jan. 2026, doi: 10.3390/ma19020264.

[9] Y. Yu, G. Wang, G. F. Huseien, Z. Zou, Z. Ding, and C. Zhang, "Intelligent prediction of compressive strength of self-compacting concrete incorporating silica fume using hybrid IWOA-GPR model," *Mater. Today Commun.*, vol. 45, p. 112282, Apr. 2025, doi: 10.1016/j.mtcomm.2025.112282.

[10] M. Ahmadi, E. Abdollahzadeh, M. Kashfi, B. Khataei, and M. Razavi, "Life Cycle Assessment and Performance Evaluation of Self-Compacting Concrete Incorporating Waste Marble Powder and Aggregates," *Materials*, vol. 18, no. 13, p. 2982, Jun. 2025, doi: 10.3390/ma18132982.

[11] T. Naresh, N. R. D. Murthy, M. Mallik, and V. Singh, "Performance assessment of concrete incorporating waste rubber powder as partial cement replacement," *Journal of Building Pathology and Rehabilitation*, vol. 10, no. 2, p. 138, Dec. 2025, doi: 10.1007/s41024-025-00646-0.

[12] J. T. F. de Sousa, M. A. S. dos Anjos, J. A. da S. Neto, E. C. de Farias, F. G. Branco, and C. Maia Pederneiras, "Self-Compacting Concrete with Artificial Lightweight Aggregates from Sugarcane Ash and Calcined Scheelite Mining Waste," *Applied Sciences*, vol. 15, no. 1, p. 452, Jan. 2025, doi: 10.3390/app15010452.

[13] A. S. Al-Rubaye, D. Shamil, A. Samir, and H. K. Sultan, "Sustainable Rehabilitation Strategies for Traditional Iraqi Homes: Mitigating Thermal Challenges with Innovative Materials," *International Journal of Sustainable Development and Planning*, vol. 20, no. 3, Mar. 2025, doi: 10.18280/ijsdp.200312.

[14] H. Wang *et al.*, "Bibliometric analysis of research on recycling dredged sediment as construction material during the past three decades: trends and focal points," *J. Soils*

Sediments, vol. 25, no. 6, pp. 2126–2151, Jun. 2025, doi: 10.1007/s11368-025-04030-w.

[15] M. A. S. dos Anjos, A. Camões, R. Malheiro, C. Maia Pederneiras, and L. K. S. Peixoto, "Experimental Study of Carbonation and Chloride Resistance of Self-Compacting Concretes with a High Content of Fly Ash and Metakaolin, with and Without Hydrated Lime," *Materials*, vol. 18, no. 2, p. 422, Jan. 2025, doi: 10.3390/ma18020422.

[16] H. Bahmani and D. Mostofinejad, "Microstructural characterization of alkali-activated concrete using waste-derived activators from industrial and agricultural sources: A review," *Case Studies in Construction Materials*, vol. 22, p. e04632, Jul. 2025, doi: 10.1016/j.cscm.2025.e04632.

[17] M. Skazlić, H. Mešić, and I. Gabrijel, "Experimental Analysis of Creep and Shrinkage of Self-Compacting Concrete with Recycled Concrete Aggregates," *Applied Sciences*, vol. 15, no. 8, p. 4309, Apr. 2025, doi: 10.3390/app15084309.

[18] A. ElNemr and R. Shaltout, "Rheological and Mechanical Characterization of Self-Compacting Concrete Using Recycled Aggregate," *Materials*, vol. 18, no. 7, p. 1519, Mar. 2025, doi: 10.3390/ma18071519.

[19] L. Huang *et al.*, "Organic Electrochemical Transistors: From Lithography to Large-Scale Printing," *Adv. Electron. Mater.*, vol. 11, no. 3, Mar. 2025, doi: 10.1002/aelm.202400474.

[20] A. Mohammadsalehi and D. Mostofinejad, "Utilization of marble, granite, and travertine sludge as sand replacements in self-compacting concrete with low-carbon binder: Rheological, mechanical, and environmental evaluation," *Constr. Build. Mater.*, vol. 494, p. 143307, Oct. 2025, doi: 10.1016/j.conbuildmat.2025.143307.

[21] J. S. Yalli *et al.*, "A Systematic Review for Evaluating IoT Security: A Focus on Authentication, Protocols and Enabling Technologies," *IEEE Internet Things J.*, vol. 12, no. 12, pp. 18908–18928, Jun. 2025, doi: 10.1109/JIOT.2025.3545737.

[22] S. S. A. B. Padavala, V. Noolu, Y. Paluri, D. Harinder, and U. K. Akula, "Performance evaluation of concrete blended with industrial and agricultural wastes reinforced with hybrid fibres – a feasibility study," *Sci. Rep.*, vol. 15, no. 1, p. 6662, Feb. 2025, doi: 10.1038/s41598-025-86737-x.

[23] W. Xu, Z. Chen, Y. Liang, S. Tu, and F. Ning, "Mechanical properties and constitutive model of basalt-fibre-reinforced coral aggregate seawater concrete under triaxial compression," *Magazine of Concrete Research*, vol. 77, no. 19–20, pp. 1160–1172, Oct. 2025, doi: 10.1680/jmacr.25.00109.

[24] A. Gholami, M. Hosseini, M. H. Boskabady, M. Gharib, and Z. Gholamnezhad, "Memantine, A NMDA Receptor Inhibitor Attenuate Lipopolysaccharide-Induced Lung Inflammation and Oxidative Damage in Mice," *Rep. Biochem. Mol. Biol.*, vol. 14, no. 1, pp. 19–28, Apr. 2025, doi: 10.61882/rbmb.14.1.19.

[25] M. Guessoum, F. Boukhelf, and F. Khadraoui, "Full Characterization of Self-Compacting Concrete Containing Recycled Aggregates and Limestone," *Materials*, vol. 16, no. 17, p. 5842, Aug. 2023, doi: 10.3390/ma16175842.

[26] K. Bhat P, R. C, and B. B. Das, "Enhancing sustainability with ternary blended cement and fine aggregate in self-compacting lateritic concrete with supplementary materials," *Case Studies in Construction Materials*, vol. 23, p. e05179, Dec. 2025, doi: 10.1016/j.cscm.2025.e05179.

[27] R. Tyagi and P. K. Goyal, "Performances of self-compacting concrete incorporating recycled fine aggregate," *Mater. Res. Express*, vol. 12, no. 8, p. 085701, Aug. 2025, doi: 10.1088/2053-1591/adf696.

[28] N. H. Aswad, W. Mustika, Tachrir, and Y. D. Hartono, "The behaviour of self-compacting concrete (SCC) with nickel slag as fine aggregate towards seawater curing," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 622, no. 1, p. 012030, Jan. 2021, doi: 10.1088/1755-1315/622/1/012030.

[29] S. Singh and V. Anand, "Optimizing self-compacting concrete with steel slag and fiber additions: enhancing fresh, mechanical, durability, and microstructural properties,"

Asian Journal of Civil Engineering, vol. 26, no. 2, pp. 683–699, Feb. 2025, doi: 10.1007/s42107-024-01214-6.

[30] M. Drissi, O. Horma, and A. Mezrhab, "From coal waste to construction resource: evaluating the physical and thermomechanical performance of masonry mortar incorporating fly ash," *Journal of Building Pathology and Rehabilitation*, vol. 11, no. 1, p. 57, Jan. 2026, doi: 10.1007/s41024-025-00735-0.

[31] G. Sua-iam and N. Makul, "Characteristics of non-steady-state chloride migration of self-compacting concrete containing recycled concrete aggregate made of fly ash and silica fume," *Case Studies in Construction Materials*, vol. 20, p. e02877, Jul. 2024, doi: 10.1016/j.cscm.2024.e02877.

[32] P. Saingam *et al.*, "Synergizing Portland Cement, high-volume fly ash and calcined calcium carbonate in producing self-compacting concrete: A comprehensive investigation of rheological, mechanical, and microstructural properties," *Case Studies in Construction Materials*, vol. 21, p. e03832, Dec. 2024, doi: 10.1016/j.cscm.2024.e03832.

[33] P. R. S. Vembu and A. K. Ammasi, "Eco-efficiency evaluation of sustainable self-compacting concrete using magnesite mine waste," *Case Studies in Construction Materials*, vol. 20, p. e02765, Jul. 2024, doi: 10.1016/j.cscm.2023.e02765.

[34] S. Etli and T. Yılmaz, "Comprehensive study on the role of mycrisparite in enhancing strength, stability, and microstructural traits of self-compacting mortars," *European Journal of Environmental and Civil Engineering*, vol. 29, no. 9, pp. 1701–1718, Jul. 2025, doi: 10.1080/19648189.2024.2441966.

[35] Z. F. Akbulut, D. Yavuz, T. A. Tawfik, P. Smarzewski, and S. Guler, "Examining the Workability, Mechanical, and Thermal Characteristics of Eco-Friendly, Structural Self-Compacting Lightweight Concrete Enhanced with Fly Ash and Silica Fume," *Materials*, vol. 17, no. 14, p. 3504, Jul. 2024, doi: 10.3390/ma17143504.

[36] F. Zhang *et al.*, "Axial compressive and long-term shrinkage behaviors of self-compacting recycled concrete reinforced with recycled glass fiber," *Constr. Build. Mater.*, vol. 455, p. 139158, Dec. 2024, doi: 10.1016/j.conbuildmat.2024.139158.

[37] N. Hilal, N. Hamah Sor, M. Hadzima-Nyarko, D. Radu, and T. A. Tawfik, "The influence of nanosunflower ash and nanowalnut shell ash on sustainable lightweight self-compacting concrete characteristics," *Sci. Rep.*, vol. 14, no. 1, p. 9450, Apr. 2024, doi: 10.1038/s41598-024-60096-5.

[38] J. Liao, Y. Zheng, H. Li, Y. Yu, and Y. Zhou, "Tension stiffening and cracking behavior of FRP-reinforced self-compacting concrete with high-volume fly ash (HVFA-SCC)," *Constr. Build. Mater.*, vol. 456, p. 139219, Dec. 2024, doi: 10.1016/j.conbuildmat.2024.139219.