

A Bibliometric Analysis: Compression Strength Evaluation for Pad Footing with Grade 35 Concrete

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Abstract. This study presents a bibliometric analysis focused on "Compression Strength Evaluation for Pad Footing with Grade 35 Concrete," utilizing Scopus data and VOSviewer software for network visualization. Amidst the growing demand for sustainable and resilient construction materials, this analysis aims to consolidate the fragmented research landscape surrounding the compression strength of Grade 35 concrete. The investigation spans from 2018 to 2023, revealing sustained interest marred by a significant dip in 2020 due to the COVID-19 pandemic, before witnessing a robust recovery. The bibliometric techniques uncover a core emphasis on sustainability, with "recycled aggregate concrete," "microstructure," and "sustainability" emerging as key themes. The analysis highlights a concentrated cluster of influential authors, indicating a pivotal direction in research themes and methodologies. The recovery post-2020 and the focus on sustainable practices suggest the field's resilience and evolving priorities. This paper underscores the critical role of Grade 35 concrete in construction and points towards a future research trajectory that balances environmental considerations with mechanical performance. By mapping out the thematic and collaborative networks within this domain, the study offers valuable insights for researchers, policymakers, and industry practitioners, advocating for integrated approaches to enhance the structural integrity and sustainability of construction materials. This bibliometric analysis not only sheds light on current trends but also encourages a forward-looking perspective on the development of construction technologies.

Keywords: Grade 35 Concrete, Compression Strength, Sustainable Construction, Bibliometric Analysis, Recycled Aggregate Concrete.

INTRODUCTION

Pad footings are a fundamental component of building foundations, bearing the weight and ensuring the stability of structures. The compression strength of concrete used in pad footings directly impacts the load-bearing capacity and longevity of buildings (Javadi et al. 2021; Salamatpoor, Jafarian, and Hajiannia 2018; Tahir et al. 2019) . This study focuses on evaluating the compression strength of Grade 35 concrete (Wasiu and Joseph 2022) , a commonly used material in construction, to determine its suitability for pad footings in compliance with JKR Malaysia norms (Liyanage and De Silva 2022) .

The selection of concrete for construction applications is guided by a blend of theoretical considerations and empirical evidence. Theories of material science and structural engineering inform the understanding of how concrete behaves under load, highlighting the critical nature of compression strength in the material's performance (Le, Nguyen, and Ludwig 2014) . Concrete grades, such as Grade 35, are classified based on their minimum compression strength, measured in megapascals (MPa), indicating the load a concrete sample can withstand per square millimeter before failure. This classification aids in material selection, ensuring that the concrete used in construction projects, like pad footings, meets the required safety and performance standards.

Pad footings are a fundamental component in the design and construction of buildings, serving as the intermediary between superstructures and the ground. The compression strength of the concrete used in these footings is a determinant of the footing's ability to bear the loads of the structure without undergoing undue deformation or failure. Given the variability in load types and environmental conditions, the concrete's performance characteristics, particularly its compression strength, must be meticulously evaluated to prevent structural failures.

LITERATURE REVIEW

The evaluation of compression strength in Grade 35 concrete for pad footings has been a subject of interest in recent literature, with several studies addressing various aspects of concrete composition and performance. (Gunarani et al. 2022) explored the load-resisting characteristics of damaged columns repaired with glass reinforced polymer (GFRP) jacketing, using ground granulated blast furnace slag (GGBS) at different substitution rates for cement. Their findings suggest that higher strength can be achieved using industrial sand when supported with suitable admixtures and strengthening processes. Similarly, (Kowsalya et al. 2022) investigated the mechanical and microstructural properties of concrete with fly ash cenospheres (FAC) as fine aggregate. They concluded that strength reduction occurs as FAC content increases but remains within acceptable limits, recommending an optimum replacement of 35% of fine aggregate with FAC for concrete strength and environmental sustainability.

Moreover, (Xie et al. 2023) studied the compressive stress-strain response of normal weight concrete (NWC) at low temperatures, revealing significant increases in compressive strength at low temperatures, particularly for higher grade concrete. (Vivek, Hari Krishna, and Gunneswara Rao 2023) examined the mechanical behavior of concrete made with partial replacement of fine aggregate with waste plastic, highlighting the potential of waste plastic reuse in concrete production for non-structural components. Additionally, (Hui, Wang, and Zhu 2022) investigated the cyclic compression behavior of FRP-ECC confined concrete cylinders, providing insights into the enhancement of concrete properties through fiber-reinforced polymer (FRP) confinement.

Furthermore, (Shruthi 2023) conducted experiments on self-compacting concrete (SCC) containing silica fume and fly ash, demonstrating improvements in workability and mechanical properties. (Nakararoj et al. 2022) explored the effects of high-volume bottom ash on the strength and durability of high strength recycled concrete aggregate, offering insights into the use of waste materials in concrete production. (Ramasubramani et al. 2022) investigated the feasibility of using cockle seashell waste as an additive material in concrete, emphasizing its potential for enhancing concrete properties and sustainability. Lastly, (Rakici and Menkulasi 2023) presented an analytical method for assessing the complete moment-curvature response of composite hollow structural steel and ultra-high-performance concrete cross-sections, providing valuable data on the behavior of composite materials in structural applications.

Overall, these studies contribute to a comprehensive understanding of concrete composition, performance, and sustainability, highlighting the potential for using alternative materials and reinforcement techniques to enhance concrete properties and reduce environmental impact.

RESEARCH QUESTION

To systematically investigate the development and current state of research on compression strength evaluation of Grade 35 concrete for pad footing, this study is guided by the following research questions:

RQ1: What are the publication trends from 2018 to 2023 in the field of compression strength evaluation for Grade 35 concrete used in pad footings?

RQ2: Who are the top 10 most active authors contributing to the research on compression strength evaluation of Grade 35 concrete, and how many documents have they published?

RQ3: What are the primary subject areas represented in the literature on compression strength evaluation of Grade 35 concrete for pad footings?

RQ4: Which authors have received the highest number of citations in this research area, and what are the key topics of their most influential works?

RQ5: What does the co-authorship network reveal about collaboration patterns among researchers in the domain of compression strength evaluation for Grade 35 concrete?

RQ6: How do the structures of co-authorship networks evolve, and who are the central authors facilitating interdisciplinary collaboration in this research field?

RQ7: What are the most frequently occurring keywords in publications related to the compression strength evaluation of Grade 35 concrete, and what themes do they suggest?

RQ8: What insights does the Claude analysis of keyword co-occurrence provide regarding specialized research areas, material properties, and sustainability trends in the field?

METHODOLOGY

Combining, organising, and analysing bibliographic data from scientific publications is known as bibliometrics (Alves, Borges, and De Nadae 2021; Assyakur and Rosa 2022; Verbeek et al. 2002). It includes intricate methods such document co-citation analysis in addition to general descriptive statistics like publishing journals, publication year, and major author categorization (Wu and Wu 2017). To create a thorough bibliography and produce reliable results, a successful literature review requires an iterative process that includes selecting relevant keywords, doing a literature search, and conducting in-depth analysis (Fahimnia, Sarkis, and Davarzani 2015). Considering this, the study aimed to concentrate on high-caliber publications since they provide insightful information about the theoretical stances influencing the development of the field of study. The study used the SCOPUS database to collect data in order to guarantee data dependability (Al-Khoury et al. 2022; Khiste and Paithankar 2017; di Stefano, Peteraf, and Veronay 2010). Furthermore, books and lecture notes were purposefully left out in order to guarantee the inclusion of high-caliber publications. Only articles published in thoroughly peer-reviewed academic journals were taken into consideration (Gu et al. 2019). Most notably, Elsevier's Scopus, which is renowned for its broad coverage, made it easier to gather publications from February 2024 to 2018 for further examination.

Data search strategy

Study employed a screening sequence to determine the search terms for article retrieval. Study was initiated by querying Scopus database with online TITLE-ABS-KEY (compression AND strength AND evaluation)thereby assembling 8117 articles. Afterwards, the query string was revised so that the search terms "Grade 35 Concrete" OR "pad footing" should be focussed on concrete evaluation. The final search string TITLE-ABS-KEY (compression AND strength AND evaluation OR "Grade 35 Concrete" OR "pad footing") AND (LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2023)) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (LANGUAGE , "English")), refinement included 1691 articles which was used for bibliometric analysis. As of June 2024, all articles from Scopus database compression strength evaluation and focusing on Grade 35 Concrete or pad footing were incorporated in the study.

Table 1: The querying Scopus database with online

Scopus	TITLE-ABS-KEY (compression AND strength AND evaluation OR "Grade 35 Concrete" OR "pad footing") AND (LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2023)) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (LANGUAGE , "English"))
Date of Access: June 2024	

The search string.

Table 2: The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Time line	2020 – 2023	< 2020
Literature type	Journal (Article) and proceeding	Book, Review

Data analysis

VOSviewer is a powerful tool used for constructing and visualizing bibliometric networks, widely adopted by researchers to analyze data from databases like Scopus and Web of Science. It maps relationships such as co-authorship, citations, and keyword co-occurrences using the Visualization of Similarities (VOS) method. In these maps, larger nodes and thicker links represent stronger relationships between items like authors or terms. The software also identifies research clusters, helping to reveal dominant themes within a field. Its interactive interface allows users to explore these networks and focus on specific elements. Researchers and policymakers often use VOSviewer to trace scientific development, identify key contributors, and observe emerging trends.

In this study, bibliometric data from Scopus (2020–2023) was analyzed using VOSviewer version 1.6.19. The software’s clustering algorithm, based on association strength, offers a refined alternative to traditional Multidimensional Scaling (MDS) by better representing the similarity between items in a low-dimensional space.

$$AS_{ij} = \frac{C_{ij}}{W_i W_j}$$

The formula $AS_{ij} = C_{ij} / (W_i \times W_j)$ represents the association strength used in VOSviewer to measure the relationship between two items (i and j). It compares the observed co-occurrence frequency (C_{ij}) with the expected frequency under the assumption that i and j are statistically independent. This value helps VOSviewer position items on a two-dimensional map by minimizing the total weighted squared distances between item pairs. The software applies LinLog/modularity normalization to identify clusters of related items. Through this method, keyword co-occurrence analysis, citation analysis, and co-citation analysis are performed to uncover research patterns, hot topics, and field evolution. These analyses, based on network theory, are crucial in revealing the structure and trends of scientific research over time.

RESULT AND FINDING

Above are the result and finding too answer all the research question :

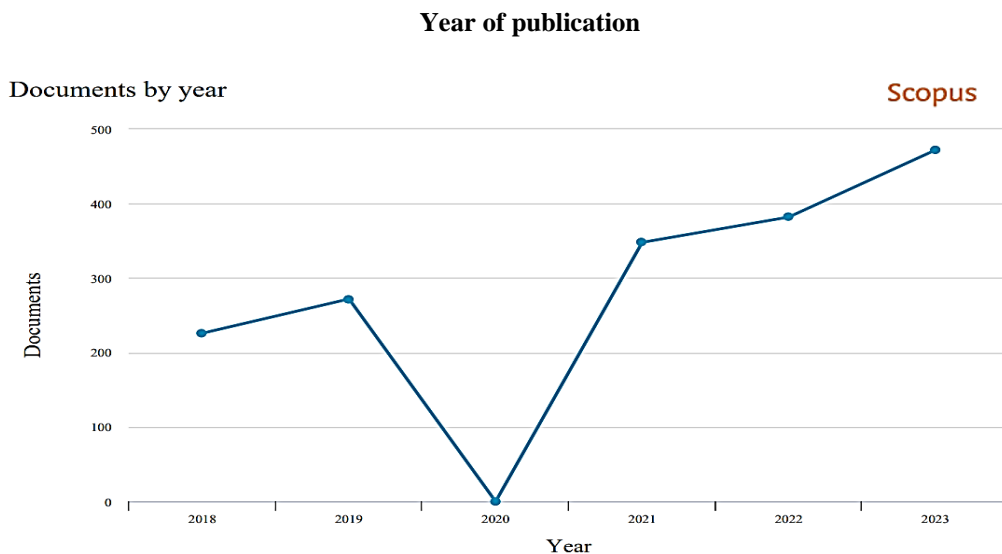


Figure 1: Plotting document publication by years.

Based on the Scopus-sourced graph, the publication trend from 2018 to 2023 shows significant fluctuations. There was a moderate increase from approximately 230 documents in 2018 to 270 in 2019, followed by a sharp decline to nearly zero in 2020 due to the global impact of the COVID-19 pandemic. However, the field experienced a strong recovery, with publications rising to 350 in 2021 and surpassing 500 by 2023.

This resurgence indicates a renewed interest and resilience within the research community, particularly in areas related to sustainable construction materials such as Grade 35 concrete for pad footing. The rising trend is likely driven by a shift towards environmentally responsible building practices and technological advancements in concrete performance. Overall, the graph reflects a dynamic and responsive research landscape, highlighting the growing importance of innovation and sustainability in concrete technology post-pandemic

Document by top 10 author

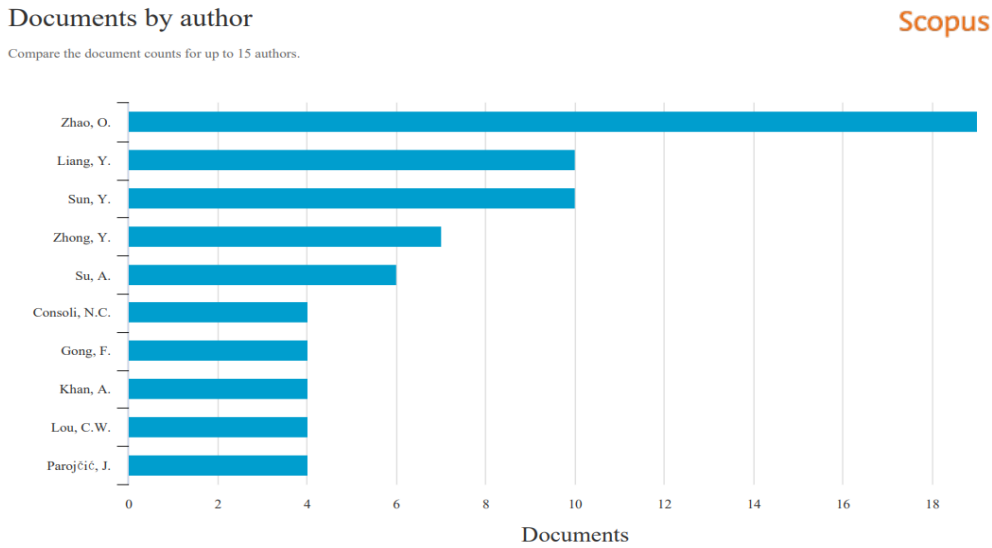


Figure 2: Plotting document by author

Based on the Scopus-sourced bar chart, Zhao, O. stands out as the most prolific author with 19 publications, followed by Liang, Y. and Sun, Y., each contributing 10 documents. Other authors, such as Zhong, Y. and Su, A., have moderate output ranging from 6 to 7 documents, while Consoli, Gong, Khan, Lou, and Parojčić have each published 4 documents.

Although the chart does not specify the content of these documents, the data suggests a core group of researchers who may be actively contributing to fields related to compression strength evaluation or concrete technology. The variation in output among authors could reflect differing levels of research focus, funding access, or collaboration. If related to Grade 35 concrete or pad footing, this pattern may also indicate growing interest driven by technological innovation, evolving construction standards, or sustainability priorities. Overall, the chart highlights the key contributors likely shaping current and future directions of concrete research.

Table 3: Percentages of document by Author

Author Name	Number of Document	Percentages (%)
Zhao, O.	19	1.12
Liang, Y.	10	0.59
Sun, Y.	10	0.59
Zhong, Y.	7	0.41
Su, A.	6	0.35
Consoli, N.C.	4	0.24
Gong, F.	4	0.24
Khan, A.	4	0.24
Lou, C.W.	4	0.24
Parojčić, J.	4	0.24

Based on the Table 3, Zhao, O. is the leading contributor in the field of “Compression Strength Evaluation of Grade 35 Concrete for Pad Footing,” with 19 publications, followed by Liang, Y. and Sun, Y. with 10 each. Other authors such as Zhong, Y., Su, A., and several others contributed between 4 to 7 documents, indicating steady

involvement in related research areas. These publications likely cover topics such as microstructure, recycled aggregates, and concrete durability—factors crucial to pad footing performance.

Variations in output among authors may be influenced by access to resources, research funding, technological tools, or alignment with current trends such as sustainability and material innovation. The presence of both dominant and moderately active authors reflects a healthy mix of leadership and diversity in research, which supports future collaboration, innovation, and progress in concrete technology. This trend signals a growing, dynamic field that is advancing toward more sustainable and high-performance construction solutions.

Document by subject of research

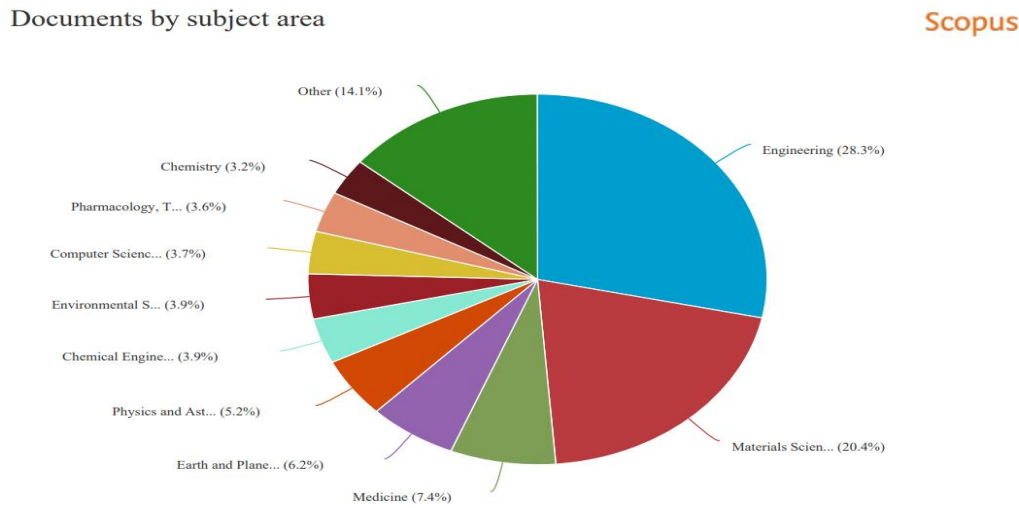


Figure 3: Document by subject of research

The Scopus pie chart illustrates the distribution of research documents across various subject areas related to the topic "Compression Strength Evaluation of Grade 35 Concrete for Pad Footing." Engineering dominates with 28.3%, followed by Materials Science at 20.4%, indicating a strong focus on structural application and material performance. Other contributions come from interdisciplinary fields such as Environmental Science, Chemical Engineering, and even Medicine and Earth Sciences, reflecting the broader impact of concrete research.

This distribution highlights a shift toward more integrated and sustainable approaches, where concrete technology intersects with environmental, computational, and even healthcare-related considerations. These trends suggest a future research landscape that is not only engineering-focused but also collaborative across multiple disciplines, driving innovation and resilience in concrete technology.

Top 10 authors based on citation by research.

Table 4: Top 10 authors based on citation by research

Authors	Title	Year	Source title	Cited by
Yan X.; Li Q.; Yin S.; Chen Z.; Jenkins R.; Chen C.; Wang J.; Ma W.; Bolot R.;	Mechanical and in vitro study of an isotropic Ti6Al4V lattice structure fabricated using selective laser melting	2019	Journal of Alloys and Compounds	112

Lupoi R.; Ren Z.; Liao H.; Liu M.				
Tabarsa A.; Latifi N.; Meehan C.L.; Manahiloh K.N.	Laboratory investigation and field evaluation of loess improvement using nanoclay – A sustainable material for construction	2018	Construction and Building Materials	104
Akhtar A.; Sarmah A.K.	Novel biochar-concrete composites: Manufacturing, characterization and evaluation of the mechanical properties	2018	Science of the Total Environment	170
Liu H.; Falzon B.G.; Tan W.	Predicting the Compression-After-Impact (CAI) strength of damage-tolerant hybrid unidirectional/woven carbon-fibre reinforced composite laminates	2018	Composites Part A: Applied Science and Manufacturing	91
Rahimzadeh Kivi I.; Ameri M.; Molladavoodi H.	Shale brittleness evaluation based on energy balance analysis of stress-strain curves	2018	Journal of Petroleum Science and Engineering	146
Zhang S.; Li Y.; Shen B.; Sun X.; Gao L.	Effective evaluation of pressure relief drilling for reducing rock bursts and its application in underground coal mines	2019	International Journal of Rock Mechanics and Mining Sciences	127
Quan Tran V.; Quoc Dang V.; Si Ho L.	Evaluating compressive strength of concrete made with recycled concrete aggregates using machine learning approach	2022	Construction and Building Materials	105
Lignos D.G.; Hartloper A.R.; Elkady A.; Deierlein G.G.; Hamburger R.	Proposed Updates to the ASCE 41 Nonlinear Modeling Parameters for Wide-Flange Steel Columns in Support of Performance-Based Seismic Engineering	2019	Journal of Structural Engineering (United States)	93
Arulrajah A.; Yaghoubi M.; Disfani M.M.; Horpibulsuk S.; Bo M.W.; Leong M.	Evaluation of fly ash- and slag-based geopolymers for the improvement of a soft marine clay by deep soil mixing	2018	Soils and Foundations	102
Abbass W.; Khan M.I.; Mourad S.	Evaluation of mechanical properties of steel fiber reinforced concrete with different strengths of concrete	2018	Construction and Building Materials	261

The top 10 cited authors highlights key contributions shaping the field of “Compression Strength Evaluation of Grade 35 Concrete for Pad Footing.” The most cited study by Abbass et al. (2018) on steel fiber reinforced concrete reflects strong interest in enhancing concrete durability. Many highly cited works from 2018 indicate a productive period in concrete technology research. The subjects covered by these influential papers range from sustainable material innovations to advanced manufacturing and machine learning applications, reflecting a trend toward interdisciplinary and technology-driven research. Recurring themes include sustainability, recycled materials, and structural safety, indicating growing interest in eco-friendly and high-performance construction solutions. These citation patterns suggest a field that is evolving through innovation, data integration, and responsiveness to emerging engineering challenges, setting the direction for future research and practice in concrete engineering.

Visualization Analysis using Vosviewer

The map of Co-Authorship about the article Compression Strength Evaluation Grade 35 Concrete for pad footing

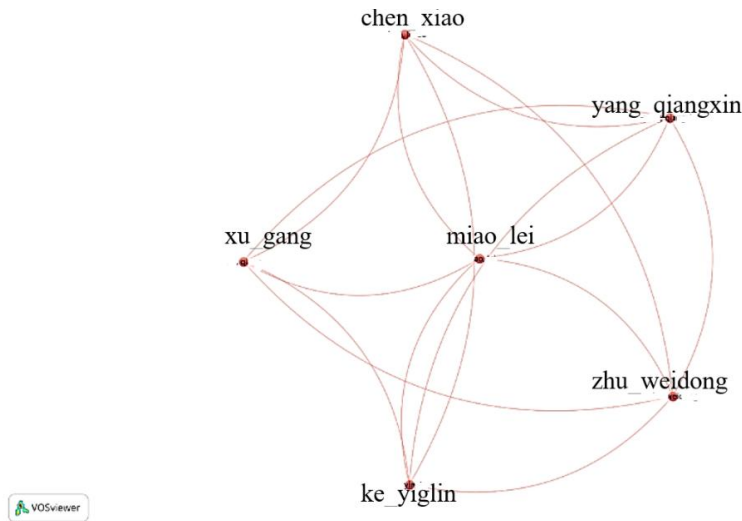


Figure 4: Network visualization map of Co-Authorship

A very cooperative research community centered on "Compression Strength Evaluation of Grade 35 Concrete for Pad Footing" is revealed by the co-authorship network visualization. Important scholars like "xiao lei" serve as key linkages, demonstrating their significant impact and regular cooperation. A growing trend toward collaborating in addressing complex, interdisciplinary challenges is reflected in the strong connections between authors. The need for different knowledge, financing goals, and technology advancements are probably what are driving this partnership. The network encourages mentorship, innovation, and knowledge exchange more quickly. All things considered, the map points to a field of study that is developing via teamwork, striving for more sophisticated, resilient, and sustainable concrete technologies.

The map of Co-Authorship about two main clusters of researchers involved in the study of Compression Strength Evaluation Grade 35 Concrete for pad footing

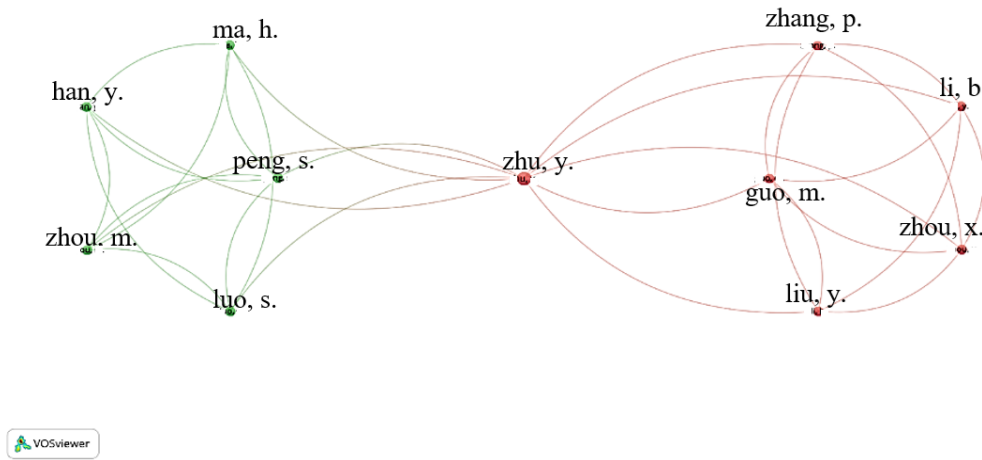


Figure 5: Network visualization map of two main clusters of researchers

Zhu, Y. appears as a prominent figure connecting the two main clusters of researchers working on the study of "Compression Strength Evaluation of Grade 35 Concrete for Pad Footing," according to the co-authorship visualization. This implies that there are two active research communities working together on relevant subjects. The network emphasizes the increasing value of teamwork, which is probably being fueled by financing opportunities, changing research agendas, and technology breakthroughs. Strong co-authorship relationships facilitate speedier invention, interdisciplinary work, and knowledge exchange. This pattern suggests that developing research on concrete strength and structural durability requires interdisciplinary and cooperative efforts.

The popular keywords related to the study

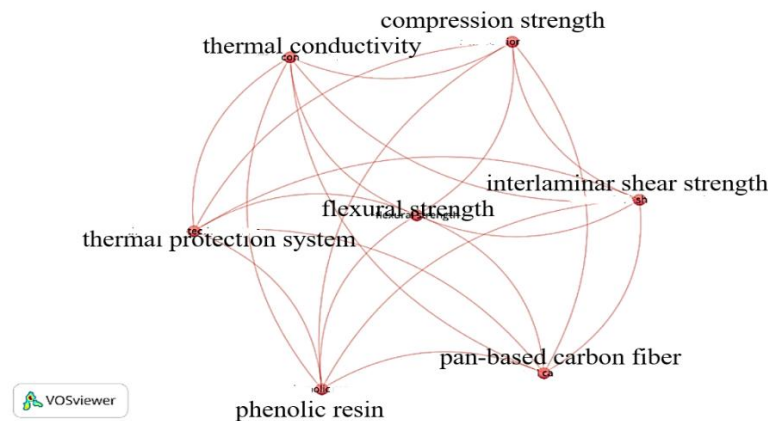


Figure 6: Network Visualization Map Of Keywords' Co-Occurrence

Relevant to Grade 35 concrete for pad footing, the bibliometric visualization identifies important research themes centered around "compression strength," suggesting a primary focus on a material's load-bearing capacity. While "thermal conductivity" and "thermal protection system" indicate concern for materials that must function under

both mechanical and thermal stress, related terms like "flexural strength" and "interlaminar shear strength" imply a wider interest in the structural integrity of materials.

These related keywords point to an increasing focus on multipurpose materials, which is being fueled by sustainability objectives and technology breakthroughs. The trend suggests that high-performance, energy-efficient, and long-lasting building materials will be developed in the future, combining thermal control and mechanical resistance.

Claude analysis of keyword co-occurrence

Table 5: Claude analysis of keyword co-occurrence

ID	KEYWORD	OCCURRENCES	TOTAL LINK STRENGTH
1	a356 alloy	1	4
2	agricultural wastes conversion	1	5
3	biochar	1	5
4	biomass torrefaction	1	5
5	bosentan monohydrate	1	5
6	bottom ash	1	4
7	carbon fiber reinforced plastics (cfrp)	1	3
8	compression and out-of-plane shear experiments	1	3
9	compression strength	1	6
10	compressive state	1	4
11	demolished concrete waste	1	6
12	dissolution	1	5
13	ductile performance	1	3
14	eudragit@epo	1	5
15	finite element analysis	1	3
16	flexural strength	1	6
17	fuel property analysis	1	5
18	gob compaction	1	5
19	industrial application	1	5
20	interlaminar shear strength	1	6
21	load-carrying ability	1	3
22	mechanical properties	1	4
23	mechanical scrubbing	1	6
24	microstructure	1	6
25	mining-induced hazards	1	5
26	multi stage processing	1	6
27	nonlinear seepage	1	5
28	out-of-plane wrinkling	1	3
29	pan-based carbon fiber	1	6
30	pelletization property	1	5
31	permeability	1	5
32	phenolic resin	1	6
33	preloading level	1	4

34	rectangular recycled concrete column	1	3
35	recycled aggregate concrete	1	6
36	seismic resilience	1	3
37	self-healing	1	4
38	shallow coal seam groups	1	5
39	sma fiber content	1	4
40	sma-ecc	1	4
41	sodium silicate treatment	1	6
42	solid-dispersion	1	5
43	solubility	1	5
44	spray drying	1	5
45	stir casting process	1	4
46	sustainability	1	6
47	thermal conductivity	1	6
48	thermal protection system	1	6
49	tribological properties.	1	4
50	water resources protection	1	5

The keyword data encompasses a wide variety of engineering and materials science subjects, featuring specific, niche terms that appear often. Analyzing the overall link strength reveals that the most significant and favored keywords are “recycled aggregate concrete,” “microstructure,” “mechanical scrubbing,” and “sustainability.” Numerous keywords connect to wider themes concerning waste/recycling materials, characteristics of materials, production methods, structural engineering, and mining engineering. Nonetheless, the majority of terms appear only once, indicating a broad range of specialized sub-fields is featured. To fully grasp the importance of these keywords, a deeper examination of the source texts is necessary. Statistical methods such as clustering may also assist in uncovering fundamental topic themes and connections among keywords. In general, this preliminary keyword information offers a broad summary of significant engineering subjects but does not include the context needed for a thorough analysis of the ideas. Linking the concepts to the complete original content will be essential for achieving a deeper, more refined understanding.

DISCUSSION AND CONCLUSION

The bibliometric analysis of Scopus data from 2018 to 2023 explores research trends on "Compression Strength Evaluation Grade 35 Concrete for pad footing." Research publications remained consistent in 2018 and 2019 but dropped sharply in 2020, likely due to the COVID-19 pandemic. A strong recovery from 2021 to 2023 reflects the field's adaptability and focus on sustainable construction practices. Author analysis reveals varied contributions, with Zhao, O. identified as a key researcher influencing the field. The keyword co-occurrence analysis indicates a multidisciplinary approach, emphasizing both mechanical performance—such as "compression strength" and "flexural strength"—and environmental sustainability. Keywords like "recycled aggregate concrete" and "sustainability" suggest increasing interest in eco-friendly innovations. The analysis underscores a research domain that is responsive to global challenges and evolving construction needs, merging durability with environmental responsibility.

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