Environmental Science and Pollution Research (2022) 29:71894–71910
https://doi.org/10.1007/s11356-022-20884-w

RESEARCH ARTICLE

A bibliometric analysis of research trends in life cycle assessment of fresh concrete and mortar during 1997–2021

Mohammad Reza Sabour[1] · Ehsan Asheghian Amiri[1] · Mohammadamin Akbari[1] · Amin Sadeghi-Sheshdeh[1]

Received: 13 November 2021 / Accepted: 12 May 2022 / Published online: 24 May 2022
© The Author(s), under exclusive licence to Springer-Verlag GmbH Germany, part of Springer Nature 2022

Abstract

The construction industry relies heavily on concrete as a fundamental material. According to the shift towards environmental sustainability in recent years, studies on life cycle assessment (LCA) of concrete and mortar and reducing their environmental impacts have increased significantly. This paper provides insights into studies performed in LCA of fresh concrete and mortar until 2021 by using a bibliometric method. To achieve this goal, 283 documents were selected from the Scopus database for bibliometric analysis. VOSviewer and Publish or Perish tools were used to perform bibliometric analysis and data visualization. Various aspects of existing documents, including top sources, countries, and authors, were analyzed. Citation analysis was conducted to identify articles with the most citations. Co-occurrence analysis has been used for analyzing keywords to identify research trends and future research directions. The number of studies in this area has grown significantly in recent years, according to the results. Among all subject areas, engineering and environmental science are recognized as the main areas of existing researches. *Journal of Cleaner Production* is one of the leading journals in this field. Among the productive countries, the USA is recognized as the leader. However, de Brito J. from Portugal is the most prolific author in this field. The most influential document in this field was written by Habert et al., which includes the highest citations among all documents. Keyword analysis indicates that "Fly Ash" has the most occurrence among all keywords. However, "Recycled Aggregates" recorded the highest annual average growth rate in recent years.

Keywords Green concrete · Concrete · Mortar · Life cycle assessment · Bibliometric analysis · Research trends

Introduction

Due to irregular extraction of natural resources, the construction industry disturbs natural balance and damages the environment. The construction industry is one of the industries with the highest emissions of greenhouse gases, which is responsible for 50% of raw materials consumption globally. Moreover, 40% of the consumption of raw stone, gravel, and sand; 25% of the consumption of virgin wood; and 16% of water consumption are allocated to this industry. This section is also responsible for approximately 40% of global energy use. Furthermore, the construction industry is responsible for generating half of all industrial waste (Marinković et al. 2017; Abdulkareem et al. 2019; Kirthika et al. 2020; Santos et al. 2021).

The construction industry relies largely on concrete as a fundamental material due to its excellent performance, such as high mechanical performance, durability, accessibility worldwide, adaptability to different structures, low cost, and low maintenance necessities throughout the lifetime of structures. These properties of concrete cause its consumption to be twice the consumption of other materials in this industry, and also after water, concrete is described as the world's most commonly used material (Gursel 2014; Jiménez et al. 2015; Ding et al. 2016; Petrillo et al. 2016; Marinković et al. 2017). Compared

Responsible Editor: Philippe Garrigues

✉ Mohammad Reza Sabour
sabour@kntu.ac.ir

Ehsan Asheghian Amiri
e.asheghian@email.kntu.ac.ir

Mohammadamin Akbari
m.aminakbari93@yahoo.com

Amin Sadeghi-Sheshdeh
aminsadeghi@email.kntu.ac.ir

[1] Civil Engineering Faculty, K. N. Toosi University of Technology, No. 1346, Valiasr Street, Mirdamad Intersection, Tehran 19967-15433, Iran

to other materials, environmental impacts of concrete are low, but because of its high production and consumption rate, the impacts of concrete structures are significant in the world (Marinković et al. 2014).

High consumption of natural resources (such as aggregates, cement, fossil fuels, and other energies), high emissions, and the significant amount of waste produced are some of the environmental impacts of concrete (Marinković et al. 2014). As one of the main concrete components, Portland cement is the major source of CO_2 emissions in concrete production (Chen et al. 2019). Due to the impacts of decalcination of limestone and the fuel needed to heat the kiln to 1450° C, approximately 5-7% of the global carbon dioxide emissions are released from the production of Portland cement (Bianco et al. 2021). Moreover, the annual consumption of aggregate is increasing to produce concrete (Napolano et al. 2016). Typically, aggregate makes up 70–80% of the produced concrete volume and plays a crucial role in its technical characteristics (de Brito and Saikia 2013). Hence, the loss of natural resources due to improper extraction to supply aggregate and cement for concrete production and its environmental impacts have become a global concern (Dabbaghi et al. 2021). In response to these issues, a variety of potential solutions have been studied to control the environmental problems caused by concrete production around the world (Gunasekara et al. 2020; Fernando et al. 2021).

Due to global sustainable development, to minimize the use of natural resources of raw materials and to control the rise in temperature to 1.5°C imposed by the Paris Agreement, the signatory countries undertake to investigate solutions for reducing greenhouse gas emissions (Bianco et al. 2021). Two fundamental methods of using recycled aggregates instead of natural ones and cementitious materials instead of Portland cement can be offered for reduction of emissions in concrete industry (Nikbin et al. 2016; Marinković et al. 2017).

Construction and demolition wastes (C&DW) are the heaviest and most voluminous wastes globally (Colangelo et al. 2020). Much of the concrete industry's dependence on non-renewable resources may be eliminated by using construction and demolition wastes as an alternative source of raw materials. Most of the construction and demolition waste (25-35%) is concrete waste that can be turned into recycled aggregate (RA) (Pradhan et al. 2019). Since some components of C&DW have a high resource value, there is a high potential for reusing and recycling them. There is a profitable market for aggregates derived from construction and demolition wastes in road construction, drainage, and other construction projects (Colangelo et al. 2020). Concrete made from recycled aggregates is known as RAC. Utilization of recycled aggregates could also help reduce the environmental issues associated with landfilling construction and demolition wastes (Pradhan et al. 2019).

Furthermore, reducing cement consumption in concrete production could be a reasonable solution to reduce emissions from this industry (Gunasekara et al. 2020). In this regard, the International Energy Agency (IEA) collaborated with the World Business Council for Sustainable Development (WBCSD) as part of the Cement Sustainability Initiative (CSI), which aimed to reduce cement's CO_2 intensity through a technology roadmap. Four main levers were identified by this roadmap to reduce CO_2 emissions: (1) Optimization of thermal and electrical efficiency; (2) use of low carbon intensity fuels in the process of cement production; (3) replacing lower carbon cementitious material instead of clinker; (4) secure capturing and storage of CO_2 (Hilton et al. 2019). In addition to minimizing CO_2 emissions, the development of sustainable green concrete includes two environmental principles: re-use and reduction (Gunasekara et al. 2020). As a result of conventional linear economics, many industries rely on a "take-make-consume-throw away" mentality, which leads to landfilled industrial side-streams (Abdulkareem et al. 2019). Industrial by-products can be used as cement substitute additives to reduce cement consumption and landfills needed. As a result, concrete production costs can be reduced, and landfill costs can also be diminished (Gunasekara et al. 2020).

Concerns about environmental degradation and resource depletion as well as excessive energy consumption in recent decades have led to the development of product life cycle analysis. In addition, quantifying the impacts of a building throughout its life cycle using experimental and comparable data derived from building performance indicators has become increasingly necessary for engineers, architects, builders, investors, and decision-makers (Santos et al. 2021). Life cycle assessment (LCA) is a standard protocol helpful for measuring materials' environmental impacts throughout their life cycle (Gursel 2014; Braga et al. 2017; Pradhan et al. 2019; Fernando et al. 2021).

The LCA method has developed over the past three decades into a powerful tool for assessing, comparing, quantifying, and enhancing products to minimize their environmental impacts and costs (Ding et al. 2016). This tool can provide an overview of each activity's environmental characteristics and compare different strategies by measuring and evaluating the environmental impacts of different activities (Cuenca-Moyano et al. 2017). The LCA evaluates the inputs and outputs of a system, and their impacts on ecology and human health, and interprets the assessment of results at all stages of a product or process life cycle (Dabbaghi et al. 2021).

With the growing trend of studies on LCA of concrete and mortar, there is a need for statistical analysis of existing studies in this field. Despite review studies and systematic analysis, no bibliometric study has been carried out in this field. Bibliometric analysis is an appropriate method to determine

the most productive countries, journals, institutions, authors, and conferences and helps us to know how the collaboration networks among authors, and countries are; which the most influential publications are; and what the research trends in the field of LCA of concrete and mortar are. Obtaining this information is easily possible using bibliometric analysis (Yang et al. 2020). Therefore, this study analyzes conducted researches in this subject until 2021 through bibliometric and social network analysis (SNA) methods based on the Scopus database.

The rest of the article is structured as follows: Data collection and topics related to bibliometric analysis are discussed in the "Materials and methods" section. The results of the analysis and answers provided to the above questions are presented in the "Results and discussion" section. The "Discussion" section discusses the general interpretation of results and explains the limitations of this study, and the "Conclusion" section deals with the conclusion.

Materials and methods

Bibliometric analysis

Bibliometric analysis has roots in the early twentieth century (Haustein and Larivière 2015). Bibliometric is a research method used in information science and libraries to measure statistical and quantitative analysis of articles (Li and Zhao 2015). Bibliometric method refers to quantitative analysis of books, articles, or other publications. In recent years, the bibliometric method used to depict the knowledge level, features, evolution, and emerging trends in each field of research and can be used to gain a better understanding of the past of a study area and anticipate its potential future (Zhang and Liang 2020; Guo et al. 2021).

This study focuses on the characteristics of published articles in this field, like publication trends over the years, main sources, productive countries, and authors. These characteristics are well presented and deeply investigated. Citation analysis has also been used to identify articles with the most citations. It can be concluded that documents with more citations have more impact on the topic. This method can be used to study the growth of resources in a certain period, measure the effects of scientific publications, and study the role of high citation documents (Luo et al. 2020). Co-occurrence analysis method has been used for keywords to identify hot topics and main research topics in this field (Zhang and Liang 2020).

Impact factor (IF) and h-index are also used to evaluate impact and quality of publications (Han et al. 2020). The journal's impact factor determines how many citations an article receives on average after passing 2 years of publication in that journal. This index results from dividing the number of received citations by the number of documents published in a journal in 2 years (Garfield 1994; Benzel 2017). Articles in journals with high IF are more likely to be cited than journals with low IF (Haddow 2018). The h-index evaluates the influence of sources like authors, journals, and countries and considers the number of documents published by a source and the number of citations received by that source. Based on the h-index, citations are a better indicator of an author's quality than the number of published articles (Hirsch and Buela-Casal 2014). The h-index is described as the highest value of H, in a way that the author/journal has published the minimum number of H documents, each cited at least H times (McDonald 2005).

Analysis tools

VOSviewer software is used for understanding the quantitative analysis and visualization of the received data related to the LCA of concrete and mortar. VOSviewer generates maps based on network data to visualize them (Van Eck and Waltman 2020). In VOSviewer, bibliometric networks are visualized based on distance, and the distance between two nodes shows the relationship between those nodes (van Eck and Waltman 2014). Identifying the most productive countries, institutions, and authors through co-authorship networks, recognizing the most cited publications and journals by generating co-citation networks, identifying the most used keywords and hot topics by producing keywords co-occurrence networks, and understanding the movement path of the subject of articles are possible with VOSviewer (Yang et al. 2020). Also, Publish or Perish software has been used. Total number of publications and citations, average citations per paper, citations per year, number of authors per paper can be identified by this software (Harzing 2016). It should be noted that the analytical results of Scopus have been used in some sectors.

Data collection

Data extraction

The Scopus database is used to gather the data for analysis. The Scopus database is an abstract and citation database that has been in operation since 2004 and contains more than 25,100 titles from more than 5,000 international publishers and provides the most comprehensive overview of the world's research results in social sciences, science, medicine, technology, and arts and humanities (Elsevier 2010).

The data were extracted from the Scopus database on March 30, 2022. The search string's design has been inspired by the search strings of previous bibliometric papers to ensure that all LCA-related results are included (Chen et al. 2014; Hou et al. 2015; He and Yu 2020). By searching the

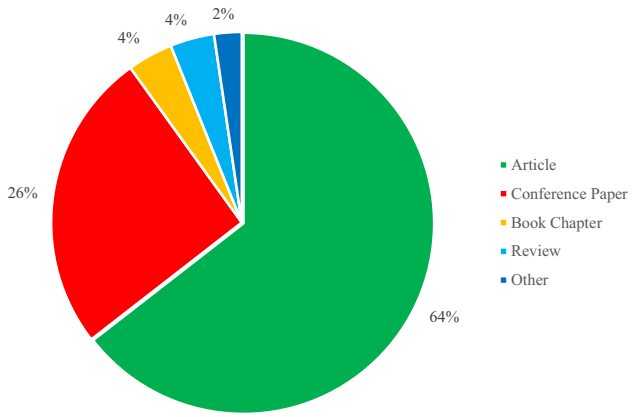

Fig. 1 Document types

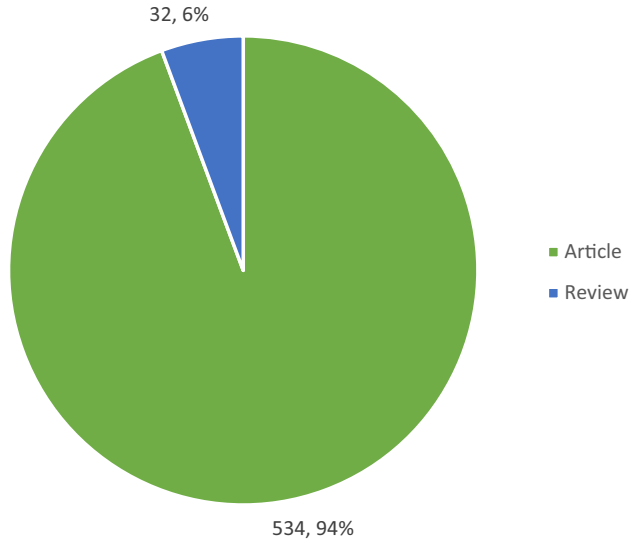

Fig. 2 Final data specifications

Scopus database in the period "from the beginning to 2021," 856 documents were obtained. Document types are summarized in Fig. 1.

Only English results are considered to achieve the appropriate data for in-depth statistical and qualitative analysis. To limit results to scientific articles, only article and review papers were considered, and other types of publications were omitted due to lesser acknowledgment in scientific contribution (Ye et al. 2020). Finally, 566 publications were obtained, which were the most appropriate data for further analysis (Fig. 2). The final search query is as follows:

(TITLE-ABS-KEY ("life cycle assessment") OR TITLE-ABS-KEY ("life cycle analys*") OR TITLE-ABS-KEY ("life cycle sustainability assessment*") OR TITLE-ABS-KEY ("life cycle sustainability analys*") OR TITLE-ABS-KEY ("life cycle inventory") OR TITLE-ABS-KEY ("life cycle inventory analys*") OR TITLE-ABS-KEY ("life cycle impact assessment") OR TITLE-ABS-KEY ("LCA") OR TITLE-ABS-KEY ("LCSA") OR TITLE-ABS-KEY ("LCI") OR TITLE-ABS-KEY ("LCIA") AND TITLE (concrete) OR TITLE (mortar)) AND DOCTYPE (ar OR re) AND PUBYEAR < 2022 AND (LIMIT-TO (LANGUAGE, "English"))*

Data refining

By considering the title of the papers and examining their abstract, the existing data were divided into 5 categories. The first category is related to LCA of fresh concrete and mortar, use of alternative materials instead of conventional ones, and their environmental impacts, including 283 documents; the second category is related to LCA of elements made of concrete, as well as concrete asphalt and concrete pavement with 96 records; the third category is related to LCA of concrete structures and bridges, and topics related to durability, sustainability, and environmental impacts resulting from concrete structures includes 83 records; the fourth category is related to comparative LCA studies of concrete and concrete structures with other structures or non-concrete materials with 47 records. Also, 57 documents are related to LCA of concrete recycling and aggregate recycling and other cases, which were found irrelevant to our study (the fifth category).

To measure our manual classifications' accuracy, VOSviewer was used (Fig. 3).

In co-occurrence analysis of author and index keywords, minimum cluster size and minimum link strength were set on 15 and 8, respectively, to make the categories more comprehensive and facilitate the detection of the most significant relevance between the keywords.

According to the co-occurrence analysis of author and index keywords, two clusters are formed where the thickness of links indicates the strength of the relationship between keywords. Cluster 1 includes keywords related to fresh concrete and mortar components and their properties, including binders, cementitious materials, lime, slag, sand, compressive strength, and durability. Keywords related to sustainable development and environmental issues related to fresh concrete and mortar, such as global warming, environmental protection, gas emissions, and carbon dioxide emissions, are also included in cluster 1. As can be seen, there are significant links between the keywords that make up cluster 1, and all of them are entirely related to the first category of manual classification.

On the other hand, the second cluster contains keywords that fall into categories 2 to 5 of the manual classification. For instance, keywords such as "concrete slabs" and "pavement" belong to the second category, "bridge" and

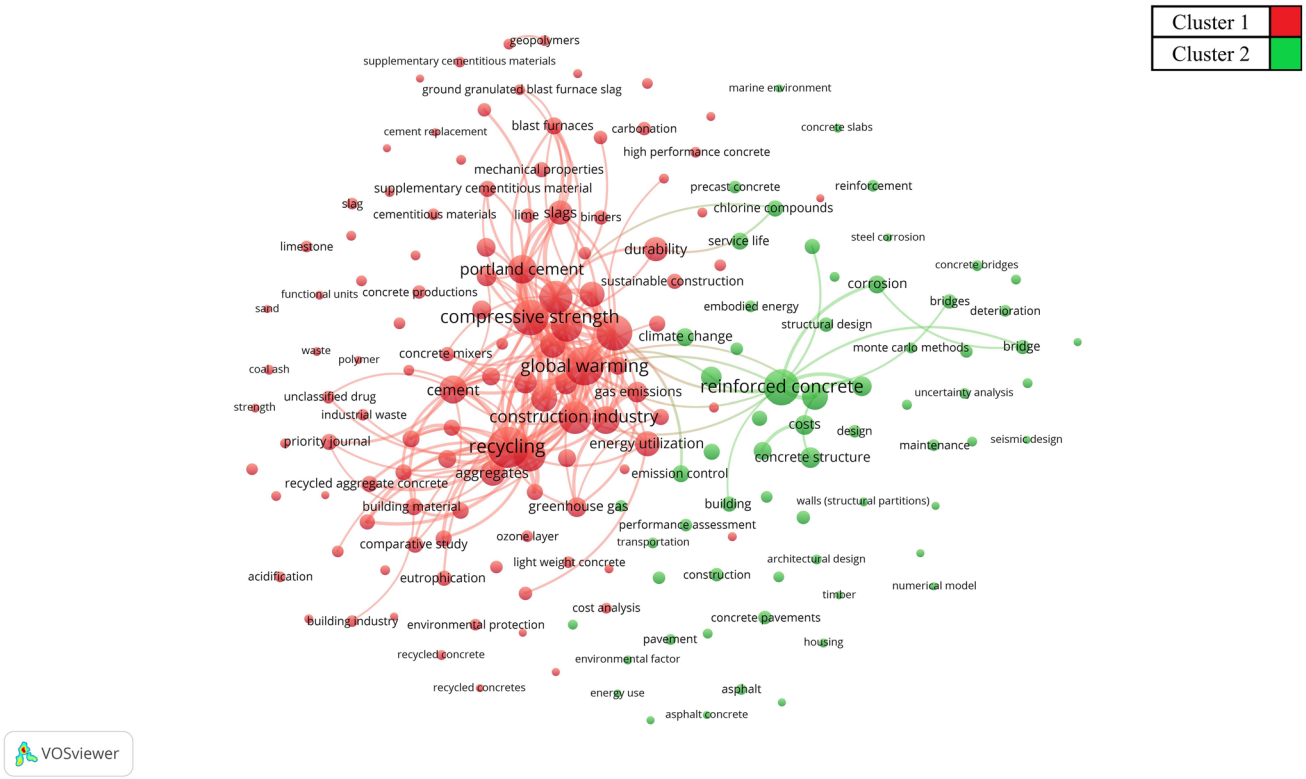

Fig. 3 Keywords co-occurrence analysis

"concrete structure" form the third category, "timber" as an alternative material to concrete takes place in the fourth category, and "maintenance" and "seismic design" are related to the fifth category of manual classification. Figure 3 clearly indicates that the relationship between the keywords of this cluster and cluster 1 is significantly limited, which implies that the studies of these two categories are not related to each other.

It should be noted that keywords related to recycled concrete aggregate, construction and demolition waste, industrial waste, and waste management, which have been named as data unrelated to this study (part of the category 5 of manual dividing), are in the first cluster beside recycled aggregate concrete–related keywords. This could be due to the direct relation and similarity in keywords used in these two different research areas.

Thus, according to reviews done, the accuracy of the manual classification can be ensured. Finally, to achieve the most accurate results related to this field, the first manual classified category, including 283 records, was considered for further analysis.

The process of collecting the final data is summarized as shown in Fig. 4.

N indicates the number of documents remaining after passing each of the mentioned filters.

Results and discussion

According to the Scopus database results, the first document of LCA studies in this field was published in 1997 under the title "Environmental life cycle inventory of Portland cement and concrete" in the *World Cement Journal* (Nisbet and Van Geem 1997). Based on Table 1, considering the small number of published documents in this field, it can be concluded that at first there was almost no focus on it, but gradually, more attention was paid, and the number of published documents increased significantly so that 79.86% of documents were published in the period from 2016 to 2021. Reasons for this growth can be attributed to the United Nations Climate Change Conference (Paris Agreement) and Sustainable Development Goals (SDGs) in 2015 (NRDC 2015; Schwan 2019). The average number of authors per paper is 3.97. As can be seen, the average number of authors per paper has consistently been above average since 2018. This indicator shows that teams with a larger population are currently working together, and most authors tend to publish papers more collaboratively. With the progress of studies in this field, the average number of references used in a paper has been growing. In addition to the growing trend of the average number of references

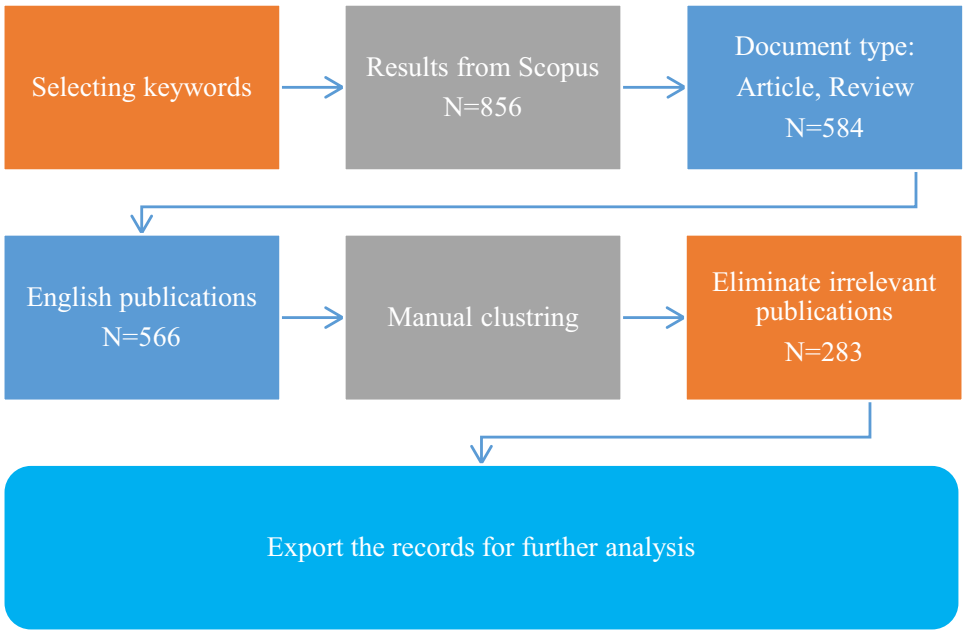

Fig. 4 Process of obtaining final data

Table 1 The characteristics of published documents in the field of LCA of fresh concrete and mortar

Year	TP[a]	AU[b]/TP	NR[c]	NR/TP	TC[d]	TC/TP
1997	1	2	0	0	16	16
1998	0	-	-	-	0	-
1999	0	-	-	-	0	-
2000	1	3	7	7	3	3
2001	0	-	-	-	0	-
2002	0	-	-	-	0	-
2003	0	-	-	-	0	-
2004	1	-	10	10	0	-
2005	3	3	18	6	22	7.33333
2006	0	-	-	-	0	-
2007	3	1.67	69	23	773	257.667
2008	1	1	60	60	8	8
2009	4	2.25	86	21.5	133	33.25
2010	6	3.67	226	37.6667	897	149.5
2011	3	2	100	33.3333	642	214
2012	6	3	225	37.5	540	90
2013	4	3.25	100	25	499	124.75
2014	15	3.80	488	33.5333	957	63.8
2015	9	4.22	343	38.1111	846	94
2016	27	3.37	877	32.4815	1229	45.5158
2017	26	3.46	1292	49.6923	1089	41.8846
2018	28	4.04	1327	47.3929	1051	37.5357
2019	43	4.23	1792	41.6744	879	20.4419
2020	37	4.24	2162	58.4324	645	17.4324
2021	65	4.74	5024	77.2923	232	5.87692
Total	283	3.97	14,206	50.1979	10,611	37.49

[a]Total number of publications

[b]Number of authors

[c]Number of references

[d]Total number of citations

used per paper in recent years, this index has witnessed a significant jump in 2021, indicating quality improvement of the content of new publications due to the broader review of results of previous studies.

According to Fig. 5, concerning the number of citations despite fluctuations, there are three peaks in 2007, 2010, and 2014, which show the quality of publications in these years, but with the growing trend of documents, the highest peak was in 2016. Then, the citation rate decreases with an almost uniform slope, this can be attributed to the short time elapsed since the publication of these documents, and it is predicted that the number of citations for documents published in these years will also increase.

Analysis of top subject areas

According to the Scopus database results, studies related to the LCA of fresh concrete have been conducted in 18 different subject areas, showing that this subject can be studied from different aspects and can be considered as a multidisciplinary area. As shown in Fig. 6, "Engineering" and "Environmental Science" are the two major subject areas with 166 (25%) and 152 (23%) related documents, respectively. "Energy," "Materials Science," "Business, Management and Accounting," and "Social Science" with 92 (14%), 90 (13%), 57 (9%), 30 (4%) records constitute other vital subject areas, respectively. Other subjects accounted for a total of another 12% of studies.

Existence of business, management and accounting, and social science as subject areas in our analysis can be related to environmental, economic, and social sustainability, known as three pillars of sustainability.

Analysis of top journals

Analysis results show that 84 different journals have published documents in the field of fresh concrete and mortar LCA. The most productive journals are shown in Fig. 7. *Journal of Cleaner Production*, with 54 publications, has been more active than other journals in this field. *Construction and Building Materials*; *Sustainability*; *Resources, Conservation and Recycling*; and *International Journal of Life Cycle Assessment* are included in the list of the most prolific journals with 29, 21, 19, and 18 documents, respectively. A total of 49.82% of documents in this field have been published in these five major journals.

As shown in Table 2, *Journal of Cleaner Production* has the highest number of documents in this field, and it also has the highest total citation, which shows the effectiveness and influence of documents published in this journal in LCA

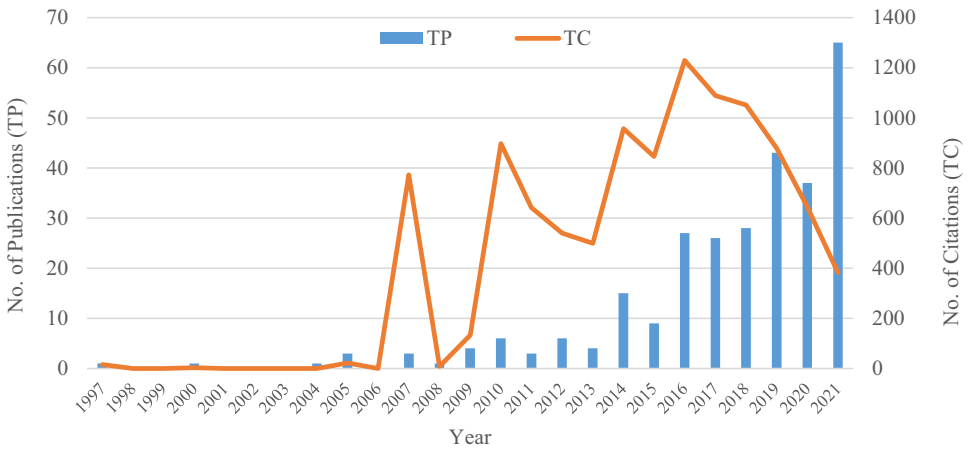

Fig. 5 Annual TP and TC per year for the period 1997–2021

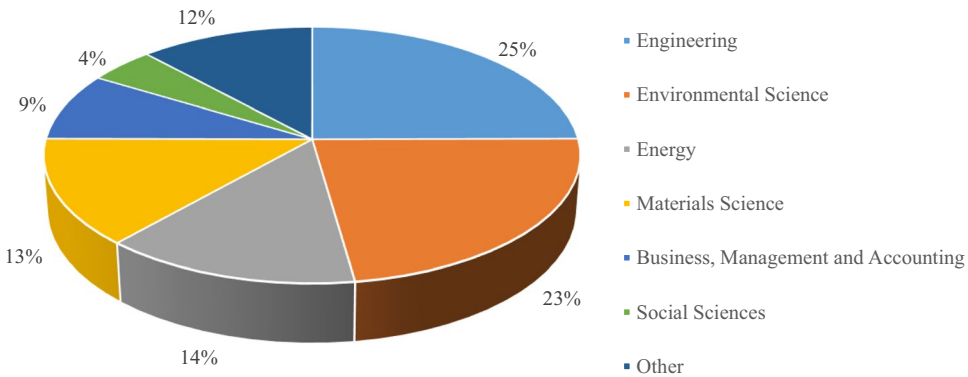

Fig. 6 Main subject areas

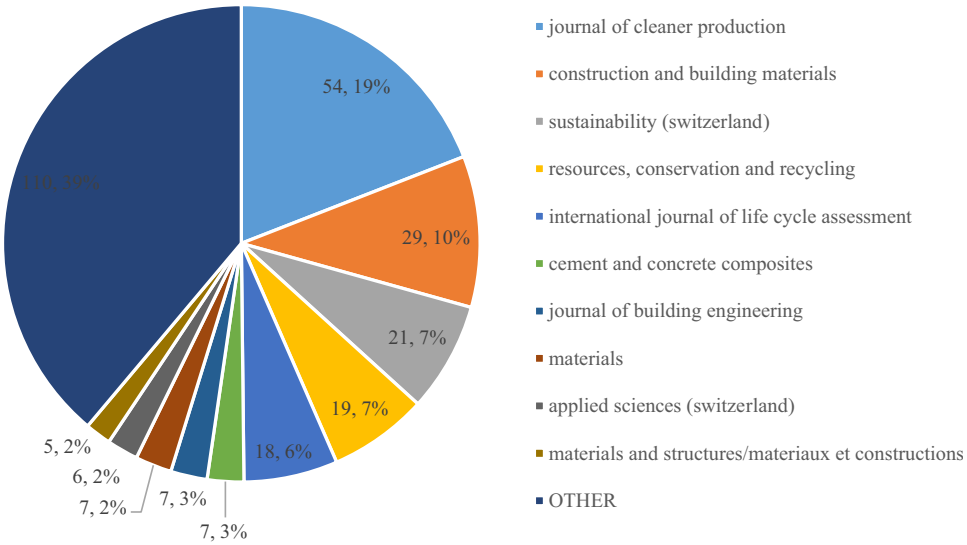

Fig. 7 Evaluations of journals in LCA studies of fresh concrete and mortar

Table 2 Properties of top 5 productive journals

No	Source	TP [a]	TC [b]	AC [c]	IF	h-index	Specific h-index
1	*Journal of Cleaner Production*	54	3207	59.4	9.297	200	29
2	*Construction and Building Materials*	29	885	30.5	6.141	170	18
3	*Sustainability (Switzerland)*	21	249	11.9	3.251	85	10
4	*Resources, Conservation and Recycling*	19	784	41.3	10.204	130	14
5	*International Journal of Life Cycle Assessment*	18	1366	75.9	4.141	105	15

[a]Total number of publications

[b]Total number of citations

[c]Average number of citations

studies of fresh concrete and mortar. However, in terms of the average citation for each document among the five major journals in this field, *International Journal of Life Cycle Assessment*, with an average of 75. 9 citations per paper, has the highest value. As mentioned earlier, the h-index and impact factor indicates the authority and influence of a journal. *Resources, Conservation, and Recycling* has the highest impact factor (10.204), followed by *Journal of Cleaner Production* (9.297), *Construction and Building Materials* (6.141), *International Journal of Life Cycle Assessment* (4.141), and *Sustainability* (3.251), respectively. *Journal of Cleaner Production* has the highest h-index (200), followed by *Construction and Building Materials* (170); *Resources, Conservation and Recycling* (130); *International Journal of Life Cycle Assessment* (105); and *Sustainability* (85), respectively. For further analysis, the h-index of journals is specifically calculated in this field, and the values are given in Table 2. From this point of view, *Journal of Cleaner Production* has the highest h-index value in this field. Evaluations show the effectiveness of *Journal of Cleaner Production* compared to other top and productive journals in this field.

Figure 8 also shows the productivity of five major sources over time. Among the five major journals, *International Journal of Life Cycle Assessment* has the most extended history of publishing documents in this field from 2005 until 2020, but there is no document published in this journal in 2021. Meanwhile, the growing trend of paper publication by *Journal of Cleaner Production* since 2013 is significant, and it reflects the fact that authors prefer to publish their related works in this journal.

Analysis of top countries/regions

According to analyses based on the Scopus database, 63 countries have conducted research in this area. A group of countries with more than five printed documents is depicted as a chart in Fig. 9, which shows that the USA is the leader. According to Table 3, the USA, with 41 records (about 10.68% of all reviewed documents), has conducted the most studies in this field, followed by China, Portugal, Australia, and India, respectively. h-index 21 for the USA in this field also indicates that in addition to the high number

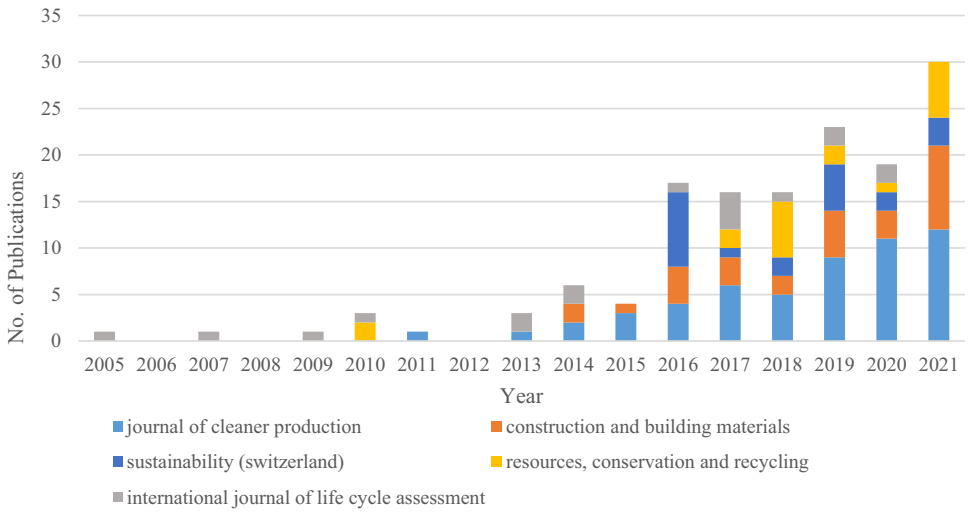

Fig. 8 Productivity of major journals over time

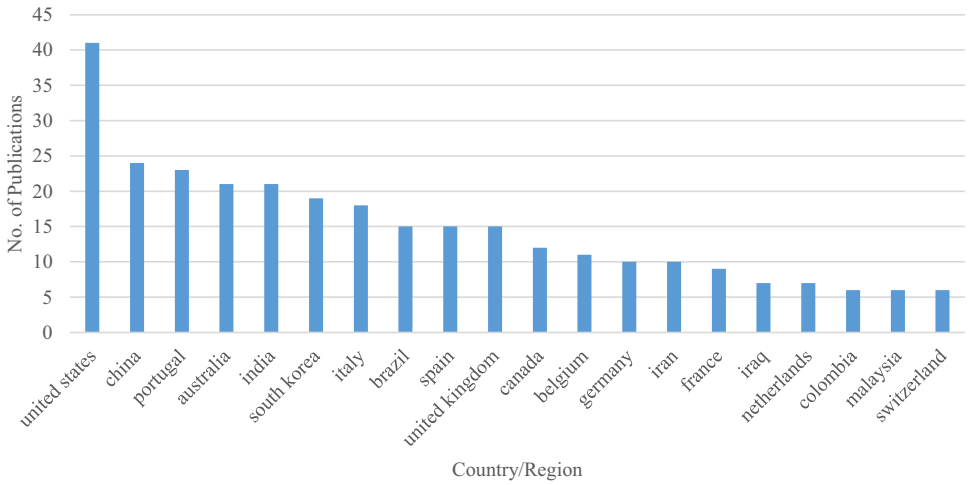

Fig. 9 Countries' productivity

Table 3 Properties of top countries

No	Country	TP[a]	%	Citations	Specific h-index
1	USA	41	10.68	1529	21
2	China	24	6.25	616	13
3	Portugal	23	5.99	697	13
4	Australia	21	5.47	1284	14
5	India	21	5.47	580	12
6	South Korea	19	4.95	922	11
7	Italy	18	4.69	396	9
8	Brazil	15	3.91	285	8
9	Spain	15	3.91	473	9
10	UK	15	3.91	477	10

[a]Total number of publications

of publications in LCA of fresh concrete and mortar, it also has the most significant impact in this field among other countries.

According to Table 3 and Fig. 10, it can be said that most studies in this field have been done in developed countries of the world, in which, in addition to producing products, special attention is paid to the sustainability aspects of that product. As shown in Fig. 10, the largest distribution of published documents in this field is observed in Europe, North America, and Eastern Asia.

The network of international cooperation in this field is illustrated in Fig. 11. According to the analysis, 104 links were detected between the top 46 cooperating countries, with a total link strength of 88.50. There are eight clusters of countries. Countries clustered together are depicted in a similar color. The clusters are consisting of the countries with the highest level of collaboration. The circle's size is directly related to the number of publications. Countries with a connection have a cooperative relationship. A thicker line between two countries means a stronger partnership. The USA has the strongest link in cooperation with other countries, with total link strength of 16 and 16 links. It also has the most cooperation with China, South Korea, and the

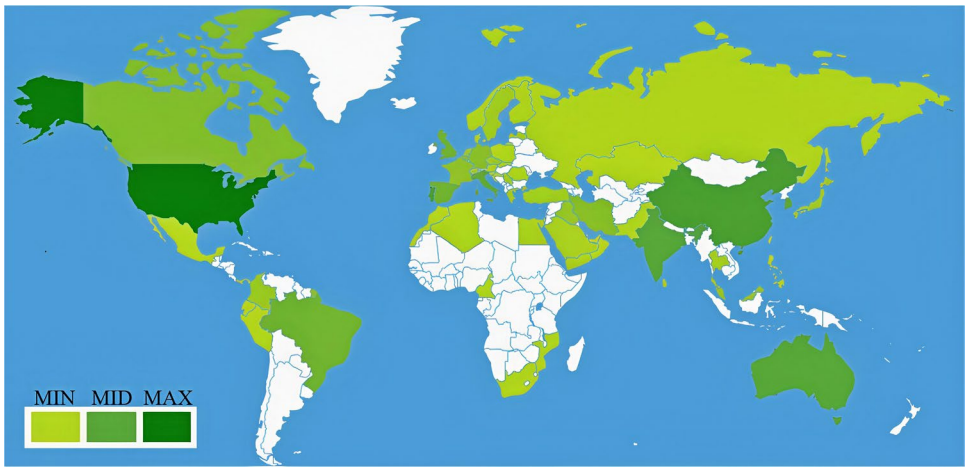

Fig. 10 Distribution map of studies in each country

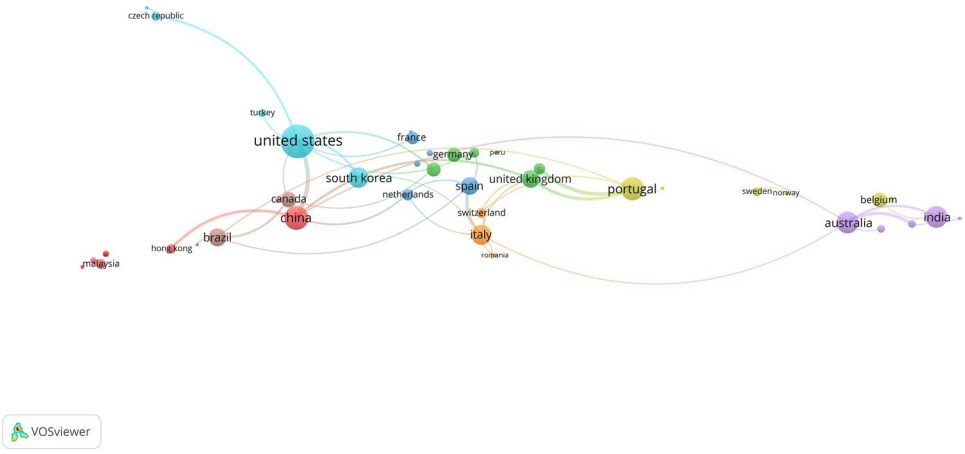

Fig. 11 International cooperation network among top countries

Czech Republic. The UK and China are in second place with a total link strength of 12, and 10 and 7 links, respectively. The UK has the most cooperation with Portugal, Iraq, and China, while China cooperated the most with the USA, Hong Kong, and the UK. The link strength of 4 between China and the USA shows that institutions and authors from these countries have recorded the most cooperation. In addition, Portugal and Italy, both with link strength of 11 and 9 links, ranked third in terms of cooperation with other countries.

Analysis of top authors

The analyses show that 856 authors were active in LCA studies of fresh concrete and mortar, of which 23 authors participated in more than 4 documents. According to Table 4, de Brito J. has published the largest number of documents among top authors. de Brito J. published 13 documents in this field since 2014 and has the highest h-index value of 93 among top authors. For further analysis, the authors' h-index is specifically calculated in this field. Moreover, de Brito J. has the highest specific h-index value, showing the great influence of his research in this field. Regarding the number of citations to documents, G. Habert with 1010 citations is superior to other top authors in this list, and Horvath A. and Van Den Heede P. are next with 655 and 650 citations, respectively. Comparing the number of citations to the number of documents, G. Habert, with an average of 202 citations per document, has better statistics than other authors in this list. Yang K.H. and Horvath A. rank next with 122.4 and 109.17 citations per article, respectively. This parameter also shows the effectiveness of this author's publications.

Figure 12 shows the main authors' collaboration network. According to Fig. 12, it is possible to differentiate the leading research teams that have cooperated more. Size of the circles indicates number of publications by the authors, and the connection between authors represents the collaboration's strength.

There were 165 links found among 64 main authors, with a total link strength of 60.50 by VOSviewer. de Brito J. has recorded the highest total link strength of 13 with a share of 13 documents and has the most links with other authors (20 links). Considering the link strength between the authors, as shown in Fig. 12, the links between de Brito J., Silvestre J.D., and Kurda R. are stronger and more distinct than other

Table 4 Top authors in the field of LCA of fresh concrete and mortar

Author	Institution	TP[a]	TC[b]	AC[c]	h-index	Specific h-index
de Brito J	Instituto Superior Técnico, Lisbon, Portugal	13	480	36.92	93	10
Kurda R	Instituto Superior Técnico, Lisbon, Portugal	11	314	24.16	21	9
Silvestre J.D	Instituto Superior Técnico, Lisbon, Portugal	11	413	37.55	34	8
Kim T	Korea Institute of Civil Engineering and Building Technology (KICT), Goyang, South Korea	10	235	23.5	11	9
Tae S	Hanyang University, Seoul, South Korea	9	444	49.33	20	8
Ostertag C.P	University of California, Berkeley, Berkeley, USA	8	314	39.25	24	7
Van Den Heede P	Universiteit Gent, Ghent, Belgium	8	650	81.25	17	8
Chae C.U	Korea Institute of Civil Engineering and Building Technology (KICT), Goyang, South Korea	7	152	21.71	9	7
De Belie N	Universiteit Gent, Ghent, Belgium	7	608	86.85	69	7
Monteiro P.J.M	University of California, Berkeley, Berkeley, USA	7	554	79.14	56	7
Horvath A	University of California, Berkeley, Berkeley, USA	6	655	109.17	14	6
Panesar D.K	University of Toronto, Toronto, Canada	6	128	21.33	26	4
Habert G	ETH Zürich, Zurich ZH,, Switzerland	5	1010	202	47	5
Hafez H	University of Northumbria, Newcastle, UK	5	49	9.8	5	4
Yang K.H	Kyonggi University, Suwon, South Korea	5	612	122.4	31	5
Biswas W.K	Curtin University, Perth, Australia	4	88	22	21	4
Caldas L.R	Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil	4	23	5.75	5	3
Cheung W.M	University of Northumbria, Newcastle, UK	4	114	28.5	15	4
Colangelo F	Parthenope University of Naples, Naples, Italy	4	150	37.5	38	4
Gursel A.P	University of California, Berkeley, Berkeley, USA	4	193	48.25	7	4
Miller S.A	University of California, Davis, Davis, USA	4	251	62.75	17	4
Petrillo A	Parthenope University of Naples, Naples, Italy	4	150	37.5	25	4
Zhang Y	Zhejiang University of Technology, Hangzhou, China	4	159	39.75	14	4

[a]Total number of publications

[b]Total number of citations

[c]Average number of citations

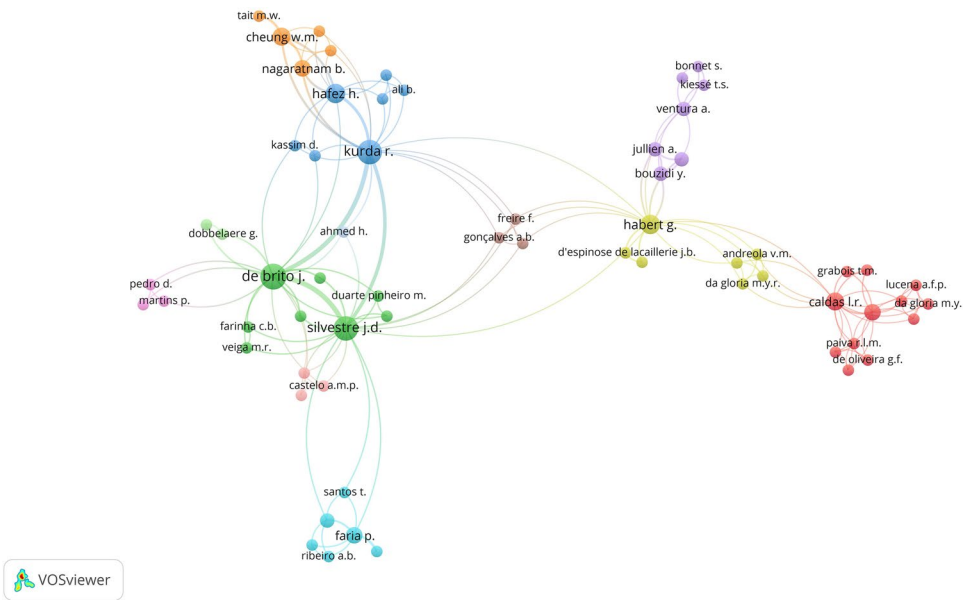

Fig. 12 Main authors' collaboration network

authors. The stronger link between these three authors is a testament to the remarkable collaboration of these authors in the articles related to the LCA of fresh concrete and mortar. In this regard, Table 5 shows the highest number of collaborations between the two authors. de Brito J. and Silvestre J.D. with 9 documents are ranked 1st in terms of the most collaborations between two authors.

Documents citation analysis

Citation analysis is a method of evaluating a publication's influence and quality. There were 10,611 citations to these 283 documents from 6449 publications in more than 150 different sources based on citation analysis results. According to the extraction date of documents for analysis, there are only 15 documents without citation, and there are 268 documents referenced at least once.

Table 5 Authors who have collaborated together more than five times

Author 1	Author 2	TP[a]
de Brito J	Silvestre J.D	9
Chae C.U	Kim T	7
De Belie N.D	Van Den Heede P	7
Kim T	Tae S	6
de Brito J	Kurda R	6
Horvath A	Monteiro P.J.M	5
Kurda R	Silvestre J.D	5
Hafez H	Kurda R	5

[a]Total number of publications

Table 6 shows the top 10 articles in terms of the maximum number of citations. The most referenced article is "An environmental evaluation of geopolymer based concrete production: reviewing current research trends" by Habert et al., in 2011, with 642 citations (Habert et al. 2011). The research team evaluated environmental impacts of geopolymer concrete production using LCA methodology and compared results with ordinary Portland cement (OPC) concrete. In terms of average citation, it can be seen that the mentioned document has the highest rate, with 58.36 citations per year.

Author's keyword analysis

The keywords chosen by authors indicate the purpose of the research and the subject of the documents. It helps readers understand the main content of documents and identifies research trends (Li and Zhao 2015). In this section, a set of author's keywords that are used more than 5 times in all documents has been selected to create a heat map to identify the hottest topics (Fig. 13). It should be noted that keywords such as "concrete," "life cycle assessment," and other keywords used in the search query are not included. General keywords such as "sustainability" and "environmental impact" that do not refer to a specific sub-category of researches have been omitted. In Fig. 13, colors indicate density. The red color shows the highest density, and the blue color shows the lowest density. Higher density means that researches related to these keywords are among the most important topics. It can be seen in Fig. 13 that keywords such as "fly ash," "compressive strength," "durability," "cement," "global warming potential," "carbonation,"

Table 6 Most cited documents of all time

No	Author	Title	Year	TC[a]	ACY[b]
1	Habert G	An environmental evaluation of geopolymer based concrete production: Reviewing current research trends (Habert et al. 2011)	2011	642	58.36
2	Flower D.J.M	Green house gas emissions due to concrete manufacture (Flower and Sanjayan 2007)	2007	471	31.4
3	Marinkovic S	Comparative environmental assessment of natural and recycled aggregate concrete (Marinković et al. 2010)	2010	382	31.83
4	Van Den Heede P	Environmental impact and life cycle assessment (LCA) of traditional and 'green' concretes: Literature review and theoretical calculations (Van den Heede and De Belie 2012)	2012	365	36.5
5	Yang K.-H	Assessment of CO_2 reduction of alkali-activated concrete (Yang et al. 2013)	2013	290	32.22
6	Chen C	LCA allocation procedure used as an incitative method for waste recycling: An application to mineral additions in concrete (Chen et al. 2010)	2010	259	21.58
7	Yang K.-H	Effect of supplementary cementitious materials on reduction of CO_2 emissions from concrete (Yang et al. 2015)	2015	245	35
8	Celik K	Mechanical properties, durability, and life-cycle assessment of self-consolidating concrete mixtures made with blended portland cements containing fly ash and limestone powder (Celik et al. 2015)	2015	228	32.57
9	Pade C	The CO_2 uptake of concrete in a 100-year perspective (Pade and Guimaraes 2007)	2007	217	14.47
10	Petek Gursel A	Life-cycle inventory analysis of concrete production: A critical review (Petek Gursel et al. 2014)	2014	176	22

[a]Times cited

[b]Average citations per year

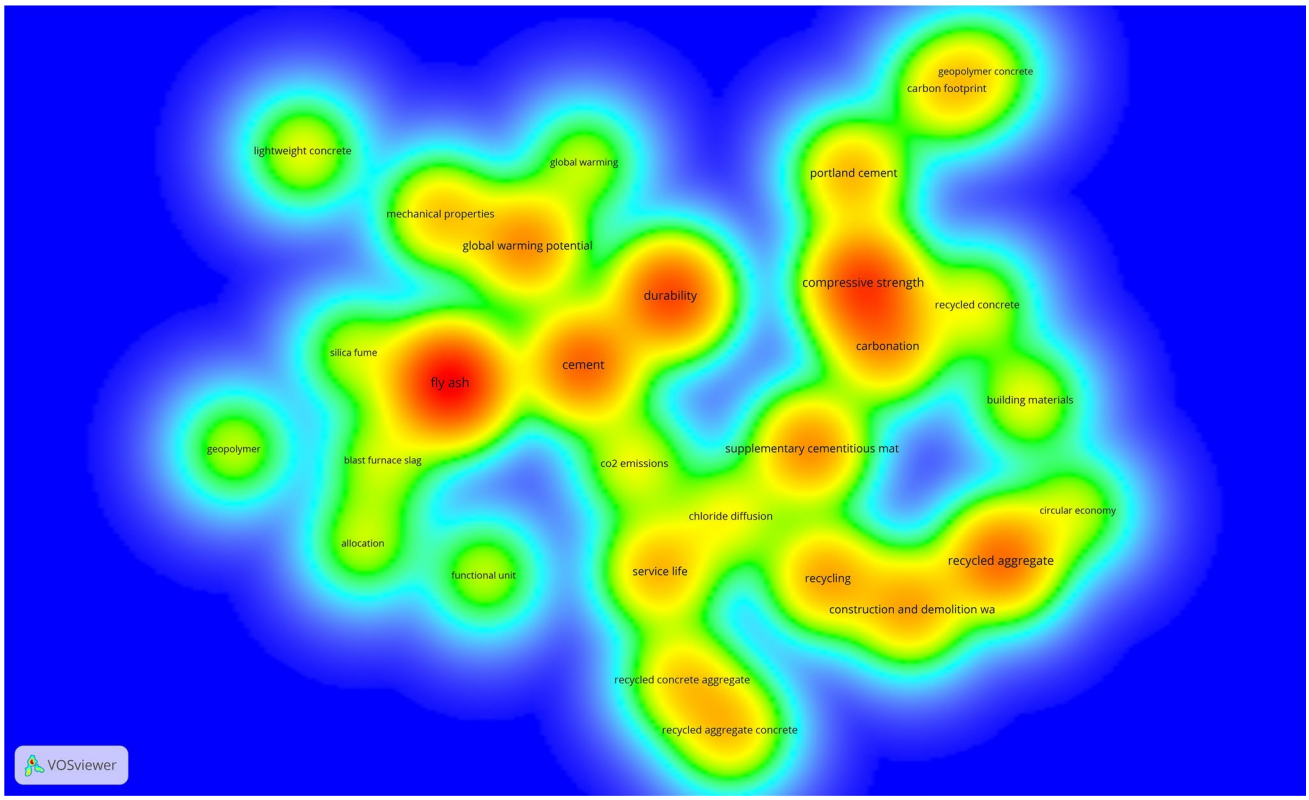

Fig. 13 Author's keyword heat map

"recycled aggregate," and "supplementary cementitious material" have a higher density than other keywords.

In the continuation of keyword analysis, a set of keywords with the same meaning were placed in one category, and the categories' occurrence rates were determined to achieve more accurate results. According to Table 7, the fly ash–related group still has the highest occurrence (47 times). Recycled aggregate, supplementary cementitious materials (SCM), CO_2 emissions, and compressive strength with 43, 31, 29, and 24 occurrences occupied the following ranks, respectively. Keywords in Table 7 generally indicate the focus of studies on using SCM and recycled aggregates as alternative materials in concrete and assessing and comparing the novel concrete's environmental impacts, strength, and durability against OPC concrete.

Figure 14 shows the growth trend in the use of grouped-keywords in Table 7 from 2015 to 2021. By calculating the average annual growth rate of the five most used keywords in the last 6 years compared to 2015, it is seen that "recycled aggregate" and "SCM" with average annual growth rate values of 5.5% and 3.83% have the highest value, respectively. This indicates an increase in the focus of researches from 2015 to 2021 in these areas. After mentioned keywords among the top 5 s, "FA," "CO_2 emissions," and "Compressive Strength" are ranked next from this point of view with average annual growth rate values of 1.83%, 0.83%, and 0.5%, respectively.

Discussion

In this study, quantitative and qualitative analysis of documents with the subject of LCA of fresh concrete and mortar was performed until the end of 2021 based on the bibliometric method. There has never been a comprehensive bibliometric study on this topic, according to the studies. According to the analysis results in this study, top countries, authors, journals, documents, and topics were identified. In this section, the research results are interpreted, and the limitations of the research are examined.

Interpretation of findings

Due to its high volume of global production, concrete is always known as a product that has significant environmental impacts. According to the findings of this study, the number of studies related to LCA of fresh concrete and mortar has grown significantly. Increasing market demand from the construction industry and, in line with it, reducing natural resources, increasing greenhouse gas emissions and waste

Table 7 Grouped-keyword occurrence

No	Keyword	Occurrence
1	**Fly ash** (biomass ash, biomass fly ash, coal fly ash, FA, fly ash, fly ash (FA), fly ash concrete, high volume fly ash concrete, high-volume fly ash, high-volume fly ash concrete, imported fly ash, recovered fly ash)	47
2	**Recycled aggregate** (aggregate replacement, aggregate replacement material, alternative fine aggregates, by-product aggregate, coarse marble waste aggregates, eco-aggregate, fine recycled aggregates, recycled aggregate, recycled aggregates, recycled coarse aggregate, recycled coarse aggregate (RCA), recycled coarse aggregates, recycled concrete aggregate, recycled concrete aggregates, recycled fine aggregate, recycled fine aggregate (RFA))	43
3	**Supplementary cementitious materials** (alternative cement, alternative cementitious material, bio-cement, cement replacement, cementitious materials, cementitious material production, eco-efficient cements, green cementitious materials, hybrid cements, partial cement replacement material, recovered SCM, secondary cementitious material, supplementary cementing material, supplementary cementitious material, supplementary cementitious materials, supplementary cementitious materials (SCMs))	31
4	**CO_2 emissions** (carbon dioxide, carbon dioxide (CO_2), carbon dioxide (CO_2) emissions, carbon dioxide emissions, carbon emission, carbon emissions, CO_2, CO_2–emissions, CO_2 emission, CO_2 emissions, CO_2 emission characteristic, low CO_2 emissions, reduce carbon emissions)	29
5	**Compressive strength** (compressive strength, compressive test, compressive tests, high early compressive strength, high early strength)	24
6	**Cost** (cost, cost analysis, cost estimation, costs, eco-costs, economic cost, environmental cost, full cost, LCA cost, LCC, life cycle cost, life cycle cost (LCC), life cycle cost analysis (LCCA), life cycle cost assessment, life cycle costs)	22
7	**Global warming potential** (global warming, global warming potential, global warming potential (GWP))	21
8	**Durability**	20
9	**Construction and demolition waste** (C & D waste, C&D, C&D waste, C&DW, CDW, construction and demolition waste, construction and demolition waste (C&DW)	18
10	**Geopolymer** (geo-polymer, geopolymer, geopolymer cement, geopolymer concrete, geopolymer concrete mixtures, geopolymer mortar, geopolymerization, geopolymers, self-healing geopolymer)	18
11	**Service life** (service life, service life estimation, service life prediction)	14
12	**Carbonation** (carbonation, carbonation absorption, carbonation process)	13
13	**Recycling** (recycle, recycled, recycling)	13
14	**Mechanical properties** (experimental testing of mechanical properties, mechanical performance, mechanical properties, mechanical strength)	13
15	**Recycled aggregate concrete** (recycled aggregate concrete, recycled aggregate concrete (RAC), recycled aggregates concrete)	12
16	**Transportation** (material importation and transportation, transport, transport distance, transport properties, transport scenario, transport sensitivity analysis, transportation, transportation distance, transportation impact)	12
17	**Carbon Footprint** (carbon footprint, carbon foot-print, life cycle carbon footprint)	9
18	**Blast Furnace Slag** (BFS, blast furnace slag, blast furnace slags, blast-furnace slag)	9
19	**Energy Consumption** (energy consumption, energy demand)	8

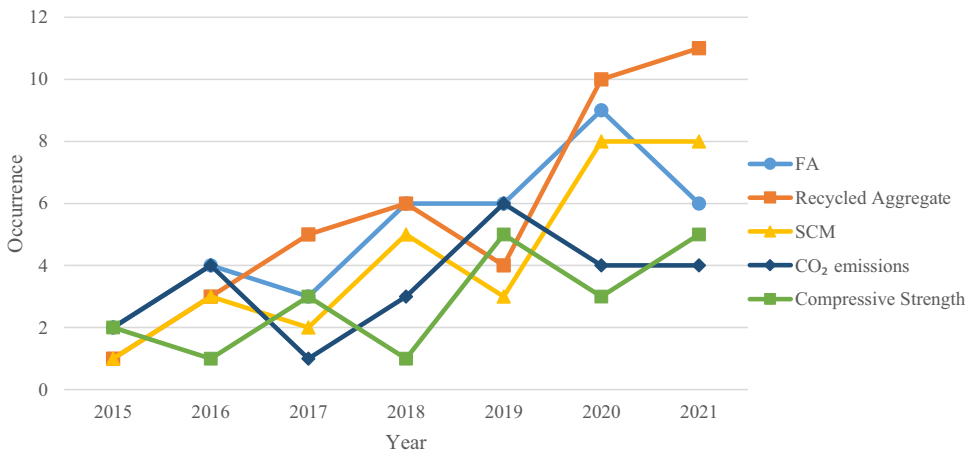

Fig. 14 The growth trend of the use of major keywords

products from this industry, and increasing attention to the sustainability aspects of productions in recent years can be reasons for this growth.

LCA studies of fresh concrete and mortar are usually used to evaluate these products' environmental impacts, and compare the impacts of using alternative materials in concrete and mortar to OPC concrete and mortars. Depending on the selected functional unit, compressive strength and concrete durability are also considered in evaluations. Considering that cement is known to be one of the most destructive materials in concrete and mortar for the environment, most of the LCA studies have been conducted on cement replacement and the use of SCMs. Studies on using alternative materials instead of natural aggregates, which make up a large volume of concrete and mortar, and studies involving the replacement of both cement and aggregates have also received considerable attention. Other subfields of study are also quantitatively smaller, such as studies considering all three aspects of sustainability (life cycle sustainability assessment (LCSA)), studies of transportation scenarios, life cycle cost (LLC), water consumption, and studies on life cycle inventory (LCI), functional units, and the methodologies used in LCA.

Limitation of the review

One of the limitations of this study is the resources of documents. In extracting documents in this study, only the Scopus database is used, and the data in other databases are not included. Several databases can be used to prepare documents in future studies to ensure results as much as possible. Also, the data analyzed in this study only included "article" and "review paper" written in English, and other types of documents and languages are excluded. However, reasons for applying these filters have already been mentioned, these filters can also be omitted to increase the statistical population under study. Finally, although high sensitivity has been applied in keyword selection to search and achieve the best results, it is also possible that different search queries affect the results.

Conclusion

In this study, the literature on LCA of fresh concrete and mortar has been reviewed based on bibliometric analysis.

According to the results of this study, significant growth can be seen in the publication of articles in this field in the last 7 years. Paris Agreements and SDGs in 2015 can be mentioned as reasons for the growth of studies in this field.

The reviewed articles included 18 different subject areas, which shows the multi-disciplinary nature of this field, and "Engineering" and "Environmental Science" are recognized as the main subject areas of existing researches in this field.

The most productive journals in this field are *Journal of Cleaner Production*, *Construction and Building Materials*, and *Sustainability (Switzerland)* with 54, 29, and 21 papers, respectively.

Among the productive countries in this field, the USA can be mentioned with 41 documents, followed by China and Portugal with 24 and 23 documents, respectively. In the meantime, the USA has the most cooperation with other countries.

The top researchers in this field are de Brito J., Kurda R., Silvestre J.D., and Kim T., with 13, 11, 11, and 10 documents, respectively. The most cooperation has taken place between de Brito J. and Silvestre J.D.

Based on the results of documents citation analysis, the 283 available documents have been cited 10,611 times. Furthermore, 268 of these documents were referenced at least once.

With frequency analysis of keywords, studies on "Fly Ash," "Recycled Aggregates," and "Supplementary Cementitious Materials" can be mentioned as hot topics in the LCA of fresh concrete and mortar. Among these, "Recycled Aggregates" and "SCMs" recorded the highest annual average growth rate with a value of 5.5% and 3.83% in recent years, respectively, which shows the increasing attention to using alternative materials instead of ordinary materials in recent research.

Acknowledgements The authors would like to acknowledge K. N. Toosi University of Technology for their valuable support throughout this study.

Author contribution Mohammad Reza Sabour, Ehsan Asheghian Amiri, Mohammadamin Akbari, and Amin Sadeghi-Sheshdeh have contributed equally. All authors read and approved the final manuscript.

Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability Not applicable.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

References

Abdulkareem M, Havukainen J, Horttanainen M (2019) How environmentally sustainable are fibre reinforced alkali-activated

concretes? J Clean Prod 236:117601. https://doi.org/10.1016/j.jclepro.2019.07.076
Benzel E (2017) Impact Factor. World Neurosurg 102:xv. https://doi.org/10.1016/j.wneu.2017.05.001
Bianco I, ApDafyddTomos B, Vinai R (2021) Analysis of the environmental impacts of alkali-activated concrete produced with waste glass-derived silicate activator – a LCA study. J Clean Prod 316:128383. https://doi.org/10.1016/j.jclepro.2021.128383
Braga AM, Silvestre JD, de Brito J (2017) Compared environmental and economic impact from cradle to gate of concrete with natural and recycled coarse aggregates. J Clean Prod 162:529–543. https://doi.org/10.1016/j.jclepro.2017.06.057
Celik K, Meral C, PetekGursel A et al (2015) Mechanical properties, durability, and life-cycle assessment of self-consolidating concrete mixtures made with blended portland cements containing fly ash and limestone powder. Cem Concr Compos 56:59–72. https://doi.org/10.1016/j.cemconcomp.2014.11.003
Chen C, Habert G, Bouzidi Y et al (2010) LCA allocation procedure used as an incitative method for waste recycling: an application to mineral additions in concrete. Resour Conserv Recycl 54:1231–1240. https://doi.org/10.1016/j.resconrec.2010.04.001
Chen H, Yang Y, Yang Y et al (2014) A bibliometric investigation of life cycle assessment research in the web of science databases. Int J Life Cycle Assess 19:1674–1685. https://doi.org/10.1007/s11367-014-0777-3
Chen X, Wang H, Najm H et al (2019) Evaluating engineering properties and environmental impact of pervious concrete with fly ash and slag. J Clean Prod 237:117714. https://doi.org/10.1016/j.jclepro.2019.117714
Colangelo F, Navarro TG, Farina I, Petrillo A (2020) Comparative LCA of concrete with recycled aggregates: a circular economy mindset in Europe. Int J Life Cycle Assess 25:1790–1804. https://doi.org/10.1007/s11367-020-01798-6
Cuenca-Moyano GM, Zanni S, Bonoli A, Valverde-Palacios I (2017) Development of the life cycle inventory of masonry mortar made of natural and recycled aggregates. J Clean Prod 140:1272–1286. https://doi.org/10.1016/j.jclepro.2016.10.029
Dabbaghi F, Tanhadoust A, Nehdi ML et al (2021) Life cycle assessment multi-objective optimization and deep belief network model for sustainable lightweight aggregate concrete. J Clean Prod 318:128554. https://doi.org/10.1016/j.jclepro.2021.128554
de Brito J, Saikia N (2013) Industrial waste aggregates. Green energy and technology. Springer London, London, pp 23–80
Ding T, Xiao J, Tam VWY (2016) A closed-loop life cycle assessment of recycled aggregate concrete utilization in China. Waste Manag 56:367–375. https://doi.org/10.1016/j.wasman.2016.05.031
Elsevier Content Coverage Guide. Elsevier, 2010
Fernando S, Gunasekara C, Law DW et al (2021) Life cycle assessment and cost analysis of fly ash–rice husk ash blended alkali-activated concrete. J Environ Manage 295:113140. https://doi.org/10.1016/j.jenvman.2021.113140
Flower DJM, Sanjayan JG (2007) Green house gas emissions due to concrete manufacture. Int J Life Cycle Assess 12:282–288. https://doi.org/10.1065/lca2007.05.327
Garfield E 1994 The Clarivate analytics impact factor - Web of Science Group. In: Clarivate Anal. 1994, https://clarivate.com/webofsciencegroup/essays/impact-factor/. Accessed 11 Feb 2021
Gunasekara C, Sandanayake M, Zhou Z et al (2020) Effect of nano-silica addition into high volume fly ash–hydrated lime blended concrete. Constr Build Mater 253:119205. https://doi.org/10.1016/j.conbuildmat.2020.119205
Guo Y-M, Huang Z-L, Guo J et al (2021) A bibliometric analysis and visualization of blockchain. Futur Gener Comput Syst 116:316–332. https://doi.org/10.1016/j.future.2020.10.023
Gursel P 2014 Life-cycle assessment of concrete: decision-support tool and case study application
Habert G, de d'EspinoseLacaillerie JB, Roussel N (2011) An environmental evaluation of geopolymer based concrete production: reviewing current research trends. J Clean Prod 19:1229–1238. https://doi.org/10.1016/j.jclepro.2011.03.012
Haddow G 2018 Bibliometric research. In: Research methods. Elsevier pp 241–266
Han R, Zhou B, Huang Y et al (2020) Bibliometric overview of research trends on heavy metal health risks and impacts in 1989–2018. J Clean Prod 276:123249. https://doi.org/10.1016/j.jclepro.2020.123249
Harzing A-W 2016 Publish or perish?, https://harzing.com/resources/publish-or-perish. Accessed 10 Feb 2021
Haustein S, Larivière V (2015) The use of bibliometrics for assessing research: possibilities, limitations and adverse effects. Incentives and performance. Springer International Publishing, Cham, pp 121–139
He X, Yu D (2020) Research trends in life cycle assessment research: a 20-year bibliometric analysis (1999–2018). Environ Impact Assess Rev 85:106461. https://doi.org/10.1016/j.eiar.2020.106461
Hilton B, Bawden K, Winnebeck K et al (2019) The functional and environmental performance of mixed cathode ray tubes and recycled glass as partial replacement for cement in concrete. Resour Conserv Recycl 151:104451. https://doi.org/10.1016/j.resconrec.2019.104451
Hirsch JE, Buela-Casal G (2014) The meaning of the h-index. Int J Clin Heal Psychol 14:161–164. https://doi.org/10.1016/S1697-2600(14)70050-X
Hou Q, Mao G, Zhao L et al (2015) Mapping the scientific research on life cycle assessment: a bibliometric analysis. Int J Life Cycle Assess 20:541–555. https://doi.org/10.1007/s11367-015-0846-2
Jiménez C, Barra M, Josa A, Valls S (2015) LCA of recycled and conventional concretes designed using the Equivalent Mortar Volume and classic methods. Constr Build Mater 84:245–252. https://doi.org/10.1016/j.conbuildmat.2015.03.051
Kirthika SK, Singh SK, Chourasia A (2020) Performance of recycled fine-aggregate concrete using novel mix-proportioning method. J Mater Civ Eng 32:04020216. https://doi.org/10.1061/(asce)mt.1943-5533.0003289
Li W, Zhao Y (2015) Bibliometric analysis of global environmental assessment research in a 20-year period. Environ Impact Assess Rev 50:158–166. https://doi.org/10.1016/j.eiar.2014.09.012
Luo J, Han H, Jia F, Dong H (2020) Agricultural co-operatives in the western world: a bibliometric analysis. J Clean Prod 273:122945. https://doi.org/10.1016/j.jclepro.2020.122945
Marinković S, Dragaš J, Ignjatović I, Tošić N (2017) Environmental assessment of green concretes for structural use. J Clean Prod 154:633–649. https://doi.org/10.1016/j.jclepro.2017.04.015
Marinković S, Radonjanin V, Malešev M, Ignjatović I (2010) Comparative environmental assessment of natural and recycled aggregate concrete. Waste Manag 30:2255–2264. https://doi.org/10.1016/j.wasman.2010.04.012
Marinković SB, Malešev M, Ignjatović I 2014 Life cycle assessment (LCA) of concrete made using recycled concrete or natural aggregates. In: Eco-efficient construction and building materials. Elsevier pp 239–266
McDonald K 2005 Physicist proposes new way to rank scientific output, http://www.physorg.com/news7971.html. Accessed 11 Feb 2021
Napolano L, Menna C, Graziano SF et al (2016) Environmental life cycle assessment of lightweight concrete to support recycled materials selection for sustainable design. Constr Build Mater 119:370–384. https://doi.org/10.1016/j.conbuildmat.2016.05.042
Nikbin IM, Aliaghazadeh M, ShCharkhtab, Fathollahpour A (2016) Environmental impacts and mechanical properties of lightweight concrete containing bauxite residue (red mud). J Clean Prod 172:2683–2694. https://doi.org/10.1016/j.jclepro.2017.11.143

Nisbet M, Van Geem MG (1997) Environmental life cycle inventory of portland cement and concrete. World Cem J 28:100–103

NRDC Paris climate change conference: Brazil. In: Issue Br. 2015, http://unfccc.int/meetings/paris_nov_2015/meeting/8926.php. Accessed 11 Feb 2021

Pade C, Guimaraes M (2007) The CO2 uptake of concrete in a 100 year perspective. Cem Concr Res 37:1348–1356. https://doi.org/10.1016/j.cemconres.2007.06.009

Petek Gursel A, Masanet E, Horvath A, Stadel A (2014) Life-cycle inventory analysis of concrete production: a critical review. Cem Concr Compos 51:38–48. https://doi.org/10.1016/j.cemconcomp.2014.03.005

Petrillo A, Cioffi R, De Felice F et al (2016) An environmental evaluation: a comparison between geopolymer and OPC concrete paving blocks manufacturing process in italy. Environ Prog Sustain Energy 35:1699–1708. https://doi.org/10.1002/ep.12421

Pradhan S, Tiwari BR, Kumar S, Barai SV (2019) Comparative LCA of recycled and natural aggregate concrete using Particle Packing Method and conventional method of design mix. J Clean Prod 228:679–691. https://doi.org/10.1016/j.jclepro.2019.04.328

Santos T, Almeida J, Silvestre JD, Faria P (2021) Life cycle assessment of mortars: a review on technical potential and drawbacks. Constr Build Mater 288:123069. https://doi.org/10.1016/j.conbuildmat.2021.123069

Schwan G (2019) Sustainable Development Goals: a call for global partnership and cooperation. GAIA - Ecol Perspect Sci Soc 28:73–73. https://doi.org/10.14512/gaia.28.2.1

Van den Heede P, De Belie N (2012) Environmental impact and life cycle assessment (LCA) of traditional and 'green' concretes: literature review and theoretical calculations. Cem Concr Compos 34:431–442. https://doi.org/10.1016/j.cemconcomp.2012.01.004

van Eck NJ, Waltman L 2014 Visualizing bibliometric networks

Van Eck NJ, Waltman L 2020 VOSviewer Manual version 1.6.16

Yang K-H, Jung Y-B, Cho M-S, Tae S-H (2015) Effect of supplementary cementitious materials on reduction of CO2 emissions from concrete. J Clean Prod 103:774–783. https://doi.org/10.1016/j.jclepro.2014.03.018

Yang K-H, Song J-K, Song K-I (2013) Assessment of CO2 reduction of alkali-activated concrete. J Clean Prod 39:265–272. https://doi.org/10.1016/j.jclepro.2012.08.001

Yang Y, Chen G, Reniers G, Goerlandt F (2020) A bibliometric analysis of process safety research in China: understanding safety research progress as a basis for making China's chemical industry more sustainable. J Clean Prod 263:121433. https://doi.org/10.1016/j.jclepro.2020.121433

Ye N, Kueh TB, Hou L et al (2020) A bibliometric analysis of corporate social responsibility in sustainable development. J Clean Prod 272:122679. https://doi.org/10.1016/j.jclepro.2020.122679

Zhang K, Liang QM (2020) Recent progress of cooperation on climate mitigation: a bibliometric analysis. J Clean Prod 277:123495. https://doi.org/10.1016/j.jclepro.2020.123495

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.