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Short communication

Sustainable approach of using sugarcane bagasse ash in cement-based composites: A systematic review

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A R T I C L E I N F O

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Mechanical properties
Durability

A B S T R A C T

Cement-based composites (CBCs) are the widely used construction materials, and cement is their main ingredient. The production of cement consumes a considerable amount of energy, releases a substantial quantity of CO_2 to the environment, and causes depletion of natural resources. Thus, utilizing sugarcane bagasse ash (SBA) in CBCs in place of cement might be a sustainable approach. In this review, two approaches have been adopted, namely, scientometric analysis and a thorough manual review of the use of SBA in CBCs. A scientometric analysis can deal with huge bibliometric data without complications. This study retrieved journal articles and review articles on SBA utilization in CBCs available at the Scopus database from 2007 to 2021 and performed a scientometric analysis using a suitable software tool. The aim of the scientometric analysis was to ascertain the current state of research and to identify relevant publication fields, sources with the most publications, the most frequently used keywords, the most cited articles and authors, and the countries that have made the greatest contribution to the field of SBA utilization in CBCs. Additionally, the influence of SBA on the fresh and hardened properties as well as durability properties of CBCs are comprehensively discussed. It was found that the top publication source is construction and building materials with 36 publications, the author with most publications is Bahurudeen A with 14 articles, and the country having the highest contribution in the relevant field is India with 110 publications. Furthermore, the addition of SBA in CBCs as cement replacement was found to be beneficial in terms of sustainability aspects and performance of composites. This study also highlighted the limitations associated with SBA utilization in CBCs and reported recommendations for future studies.

1. Introduction

Globally, cement-based composites (CBCs) are the materials most commonly used in construction [1–6]. Their popularity is due to a variety of factors, including their ease of acquisition, resistance to water, thermal resistance, and adaptability to a range of sizes and shapes [7–13]. CBCs are used in the construction of all types of civil engineering structures [14]. CBC is frequently made up of three

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primary components: cement, aggregates, and water [15]. After water, CBCs have believed the next highly used material on Earth [16]. Cement production is increasing at a rate of 2.5% per year, having risen from 2300 million tons in 2005 to 3500 million tons in 2020 [17], and is expected to reach 3700–4400 million tons by 2050 [18]. After steel and aluminum, cement is the third material worldwide that is most energy-intensive [19]. Unfortunately, manufacturing cement results in massive emissions of greenhouse gases such as CO_2 into the air, which is a major contributor to climate change [20]. It is projected that the manufacture of cement alone generates 1350 million tons of greenhouse gases per year [21]. Three major sources of CO_2 emission are involved in the manufacture of cement: approximately 325 kg/ton CO_2 is produced during fuel combustion furnace, approximately 525 kg/ton CO_2 is produced during the decarbonation of limestone, and approximately 50 kg/ton CO_2 is produced during the consumption of electrical energy [22]. Each ton of cement requires approximately 80 units of electricity and raw materials of about 1500 kg [23]. The supplementary cementitious materials (SCMs) are used in CBCs to reduce CO_2 emissions [24–30]. Agriculture waste products such as sugarcane bagasse ash (SBA), olive oil ash, corn cob ash, sawdust ash, rice husk ash, and palm oil fuel ash, as well as industrial by-products like fly ash, silica fume, red mud, tailing, coal gangue, and slag, are presently being utilized as SCMs in several applications [31–43]. Due to the contamination of water and air, the discarding of these waste materials in landfill areas poses a severe threat to the natural environment [44]. When used as pozzolanic materials in CBCs, these waste materials may improve the mechanical and durability properties of the composites [45]. Also, utilization of waste materials in CBCs will help promote sustainability in construction.

SBA is a by-product of the sugar industry. After the sugar is extracted from sugarcane, a larger fibrous waste material called bagasse is left behind [46]. When bagasse is burned at a specific temperature, a huge quantity of ash is produced, known as SBA [47,48]. After fibrous bagasse is burned at approximately 600–800 °C, the ash produced is rich in amorphous silica with excellent pozzolanic properties [49]. Bagasse ash's amorphous silica content makes it an excellent cement substitute in concrete [46]. Generally, it was discovered that the SBA could be used as a pozzolanic material because of its greater amount of amorphous silica and alumina [50]. The amount of silica in the ash varies depending on a variety of factors, including the burning method and temperature, the type of soil used to grow sugarcane, and raw material properties [51]. Sugarcane is projected to be cultivated in 121 countries [52], with 15 countries accounting for 86.2% of the total area and 87.4% of total production. India, Brazil, Pakistan, Thailand, United States, China, Argentina, South Africa, Bangladesh, Cuba, Philipines, Columbia, Australia, Mexico, and Myanmar [52]. Additionally, it is estimated that global sugarcane production exceeds 1.50 billion tons per year [53]. Roughly 26% of fibrous bagasse waste is generated after the extraction of sugar from sugarcane [44], and this industry generates 400–500 million tons of bagasse annually [54]. Bagasse with a 26% moisture content comprises 0.62% remaining ash and 50% moistness [55]. That is, just 6.2 kg SBA is left behind when 1-ton dry bagasse waste is burned at 300–600 °C temperature [56]. The sugar mill's entire production chain is depicted in Fig. 1. After sugarcane juice is extracted, sugarcane bagasse waste is left behind, which contains nearly 50% of the sugarcane's quantity. Bagasse is frequently used as a fuel for power generation. SBA is the final waste product of this process. Thus, utilization of SBA is CBCs would be a sustainable approach.

In this study, two methods have been adopted, including scientometric analysis and a thorough discussion on the utilization of SBA in CBCs as a sustainable approach for construction materials. Scientometric analysis can deal with vast data without making any further complications. Traditional manual reviews are inadequate to establish a profound and reliable correlation among various sections of the literature. Scientific mapping and network visualization of bibliographic coupling, co-occurrence, and co-citations are currently among the most challenging aspects of contemporary research. To address the fundamental shortcomings of traditional manual reviews, this study employs scientometric analysis in conjunction with traditional manual reviews to achieve the following objectives: (1) To identify the sources with maximum publications, co-occurrence of keywords, authors collaboration, mostly cited authors and articles, and regions participating actively in the research of SBA in CBCs for sustainability in construction. (2) To discuss the effect of SBA on the fresh and hardened properties of CBCs, incorporating SBA as cement replacement, and the durability properties of CBCs with the addition of SBA. (3) To identify limitations associated with the use of SBA in CBCs, and possible solutions. (4) To suggest future studies based on extensive literature review.

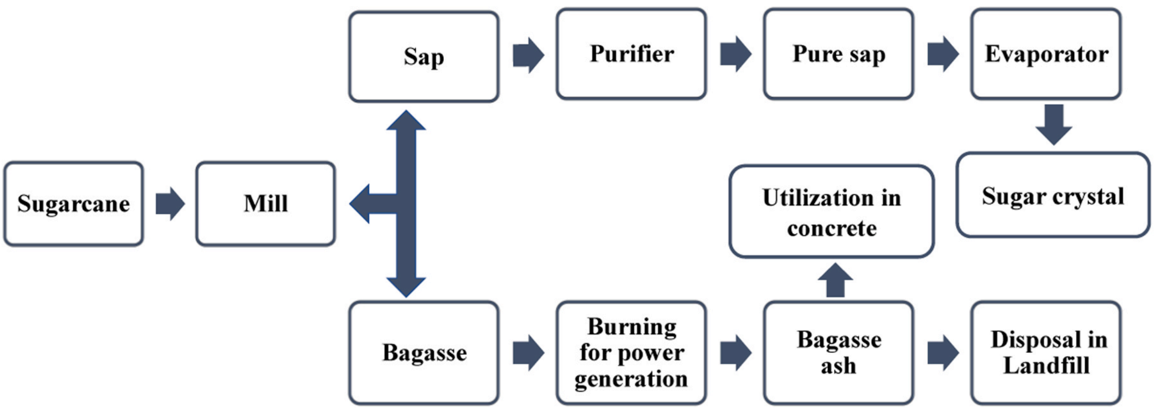


Fig. 1. Process of bagasse ash extraction from sugarcane.

2. Significance of current research

Recently, extensive research has been conducted to determine the factors that contribute to construction's sustainability, and some useful conclusions have been reached. Review studies conducted so far are mostly manual reviews. This study employs scientometric analysis in conjunction with the traditional manual review on the use of SBA in CBCs as a sustainable strategy. SBA is a waste material that causes environmental and human health problems when disposed of in landfills. Therefore, SBA is reviewed in this study for its utilization in construction materials to protect the environment and human health. Researchers from diverse geographical locations may benefit from the graphical representation based on a scientometric review when forming research alliances, forming joint ventures, and sharing breakthrough technologies and ideas as a result of this research. Additionally, the advantages of utilizing SBA in construction are discussed in this study. The effect of SBA on the fresh, hardened, and durability properties CBMs and their sustainability benefits are discussed in detail. Additionally, various restrictions on the use of SBA are discussed, as well as possible remedies. Finally, future research is recommended.

3. Methodology

Two strategies have been adopted in the current research: a scientometric analysis of the bibliometric data [57–61] and a traditional manual review on the utilization of SBA in CBCs. The major reason for establishing a scientometric review method is that researchers' subjective analyses of civil engineering studies have been demonstrated to be prone to error. Scientometrics, on its own, produces a more rational and less skewed result, as it is unaffected by any individual's perspective [62–64]. This study reviews and articulates the research of the last two decades. This study employs maps and connections between bibliometric data to quantify research progress, resulting in a quantitative assessment.

In the current study area, numerous articles have been published, and it is critical to locate the most accurate database. Web of Science and Scopus are the two most effective, comprehensive, and objective databases for conducting literature searches [65]. Scopus provides a broader coverage of bibliometric data and more up-to-date data than Web of Science [65–67]. The bibliometric data for the current analysis on the use of SBA in sustainable construction were compiled using Scopus. The Scopus search was carried out in June 2021. The search keyword in Scopus, "bagasse ash in concrete", resulted in 353 articles. To eliminate irrelevant articles, data refinement options were used. Only the "article" and "review" from the "document type" drop-down menu were chosen. From the "source type", only "journal" was selected, while the "language" was chosen as "English". The first document on the current study field was found in 2007. The "publication year" limit was set between 2007 and 2021. "Engineering, Material Science, and Environmental Science" was selected from the "subject area", for further analysis. After applying these filters, the resulting articles were 220. Previously, researchers from a variety of fields used comparable methods [68–70]. Scientometric reviews employ science visualization, a technique initiated by scholars for analyzing bibliometric data for a variety of purposes [71]. It describes the difficulties researchers face when conducting manual reviews and also establishes a link between sources, keywords, authors, articles, and countries within a given research area [72]. Scopus data was exported in the Comma Separated Values (CSV) format for analysis using a suitable software tool. VOSviewer (version: 1.6.16) was used to create the science mapping and visualization. VOSviewer is an open-source visualization application that is widely used in a variety of fields and comes highly recommended in the literature [73–77]. As a result, the VOSviewer was used to accomplish the objectives of the current study. VOSviewer was used to conduct the analysis, with the "type of data"

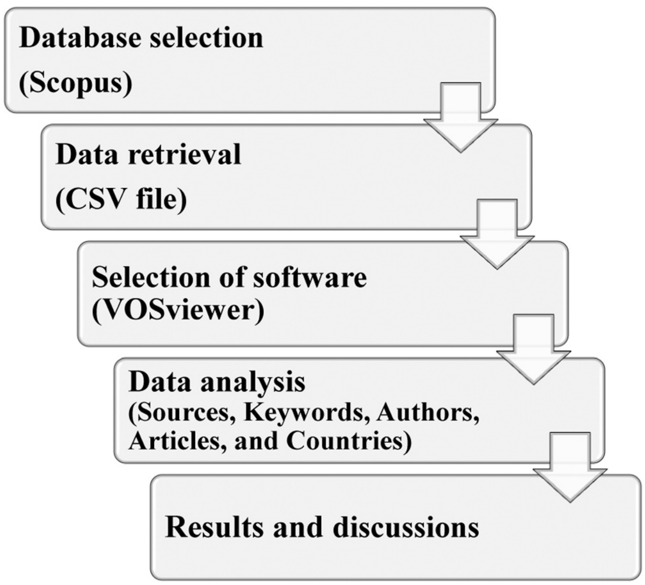


Fig. 2. Scientometric analysis sequence.

set to "create a map from bibliographic data" and the "data source" set to "read data from bibliographic database files." The Scopus CSV file was imported into VOSviewer and analyzed in a few simple steps while maintaining data consistency and reliability. The sources of articles, mostly occurred keyword, most cited authors and articles, and regions participations were analyzed as part of the science mapping review. Maps were used to depict various parameters, their relationships, and co-occurrence, while tables summarized their quantitative values. Fig. 2 illustrates the sequence of the scientometric analysis.

4. Discussions on scientometric analysis results

4.1. Relevant subject areas and yearly publication trend

The Scopus analyzer was used to conduct a search of the Scopus database in order to identify the most relevant areas of research. Engineering, Materials Science, and Environmental Science were determined to be the top three fields in terms of document count, accounting for 38.5%, 22.8%, and 10.5% of total documents, respectively, as illustrated in Fig. 3. These fields comprise approximately 71.8% of all documents searched in the Scopus database. For the overall documents, journal articles and review articles were compared. Journal articles accounted for 90.9% of the total, while review articles accounted for 9.1%. From 2007 to 2021, Fig. 4 depicts the yearly publication trend in the current study field. Up to 2016, a gradual increase in the number of publications on the use of SBA in concrete was noticed. However, there has been a noticeable increase in the last five years (2016–2021). It's fascinating to realize that scholars are increasingly focusing their research on sustainable construction methods.

4.2. Mapping of sources in the relevant field

Source mapping enables the visualization of development and innovation analysis. These sources provide access to data that is constrained by predefined, unique constraints. It is possible to apply the research pattern sequentially in the analysis area by initializing the mapping of research origins. This analysis was conducted using Scopus bibliometric data in the VOS viewer. The "analysis type" was chosen to be "bibliographic coupling," and the "analysis unit" was chosen to be "sources". The minimum number of documents required for a source was set at 5, and 9 of the 84 sources met this criterion. The leading sources/journals that publish at least 5 documents containing data on SBA in concrete for sustainable development are listed in Table 1, along with their citation counts and total link strength. Construction and building materials, international journal of civil engineering and technology, and journal of cleaner production are the top three journals in terms of document count, with 36, 21, and 16 documents, respectively. Construction and building materials receive the most citations (1241), followed by cement and concrete composites (931) and journal of cleaner production (683). The yearly publication pattern of top sources/journals and their scientific mapping are depicted in Fig. 5. This information was gathered in the course of establishing a network of research sources. It is worth noting that this type of research would serve as a foundation for future scientometric reviews in the current field of study. Additionally, previous manual reviews were deficient in terms of science mapping detail. The trend in the yearly publication of the top journals is depicted in Fig. 5(a). The participation of construction and building materials is from 2009 to 2021. While the contribution of journal of cleaner production in the current study area is from 2013 to 2021. However, the international journal of civil engineering and technology participated from 2017 to 2018; after that, no articles were found in the present study area. Similarly, the international journal of applied engineering research contributed from 2014 to 2017. As can be seen, the number of publications increased noticeably in the last five years, particularly for construction and building materials and journal of cleaner production. Fig. 5(b) depicts the network visualization of a

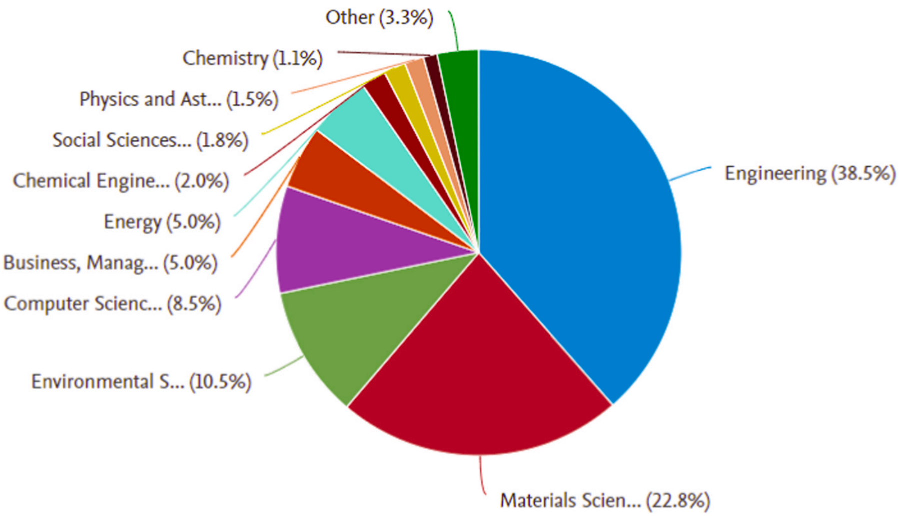


Fig. 3. Subject areas containing relevant publications.

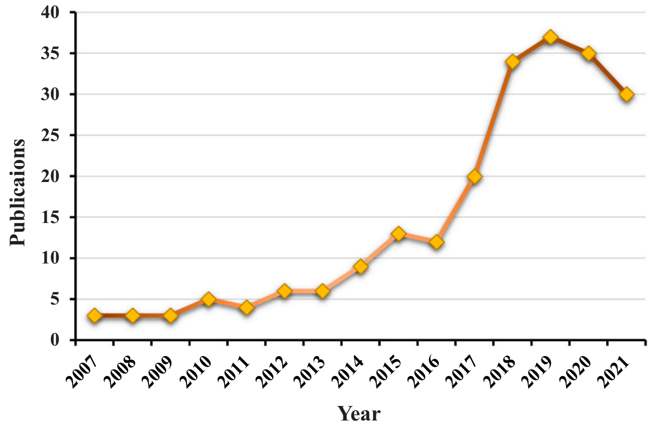


Fig. 4. Annal publication pattern on utilization of bagasse ash in concrete.

Table 1
Sources of relevant published articles.

S/N	Source	Documents	Citations	Total link strength
1	Construction and building materials	36	1241	3756
2	International journal of civil engineering and technology	21	38	458
3	Journal of cleaner production	16	683	2216
4	International journal of applied engineering research	8	15	124
5	International journal of innovative technology and exploring engineering	8	3	259
6	Journal of materials in civil engineering	8	198	1002
7	Materials	8	82	1353
8	Cement and concrete composites	7	931	1373
9	Materials and design	5	334	577

journal with at least 5 articled published. The size of the node in the figure corresponds to the journal's article count contribution; a larger frame size indicates a greater contribution. For instance, construction and building materials have a larger node size than the other journals, indicating that this journal has the greatest influence in the current study area. Additionally, nodes (sources) with the same color display clusters of related nodes discovered via VOSviewer analysis. For example, the red color denotes a cluster containing construction and building materials, materials, journal of cleaner production, cement and concrete composites, and journal of materials in civil engineering. Clusters are formed based on the scope of research outlets or the number of times they are co-cited [78]. The number of articles in the current study area that contain co-citations is indicated by the connection links between the research sources. Additionally, the link strength indicates the number of times two journals have been cited in the same article. For example, construction and building materials (total link strength: 3756) contained the most references to other sources of research. In a cluster, nodes (sources) that are closely spaced together have stronger connections than those that are further apart. For instance, the construction and building materials is closely linked to journal of cleaner production and cement and concrete composites than to the journal of materials in civil engineering.

4.3. Keywords co-occurrence

The crucial materials in research are keywords because they identify and represent the fundamental field of the research domain [79]. The "type of analysis" for that analysis was chosen as "co-occurrence," and the "unit of analysis" as "all keywords." A keyword's minimum number of occurrences was set to 10. Due to these constraints, only 55 of the 1525 keywords met the criteria. Table 2 summarizes the top 20 keywords that appeared most frequently in the research articles in the current study field. According to the researcher's study, the top five most frequently occurring keywords are bagasse, compressive strength, concretes, bagasse ash, and sugar-cane bagasse. The co-occurrence visualization of keywords networks is depicted in Fig. 6, along with their connections to one another and the density associated with their correlation frequency. In Fig. 6(a), the size of the keyword node indicates its frequency, while its location indicates its co-occurrence in publications. Additionally, the visualization shows that the aforementioned keywords have bigger nodes than the others, indicating that they are the most important keywords in the study of SBA utilization in concrete for sustainability. In the network, clusters of keywords have been colored differently to indicate their co-occurrence in various publications. Four clusters were identified, denoted by the colors green, red, blue, and yellow. For instance, a green cluster contains bagasse, compressive strength, bagasse ash, portland cement, recycling, aggregates, binders, etc. As illustrated in Fig. 6(b), distinct colors indicate the density concentration of keywords. The color's order of density is red, yellow, green, and blue, with red having the highest and blue having the lowest density. For example, bagasse, compressive strength, and concretes have red marks in the density

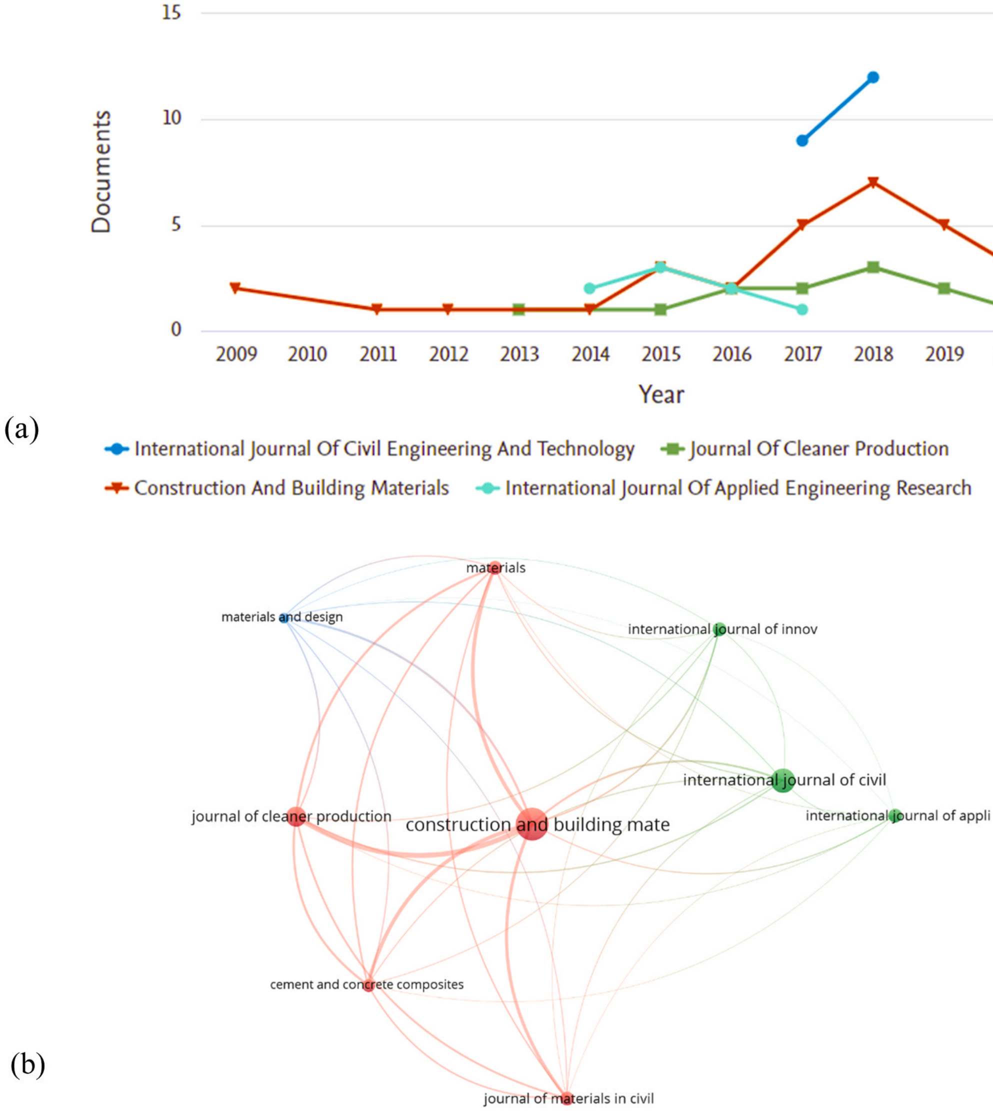


Fig. 5. Relevant publication sources: (a) Annual publication pattern; (b) Scientific mapping.

visualization, indicating a higher density. This finding will aid future writers in selecting keywords that will make it easier to locate published data in a particular domain. The links between bagasse with other keywords have been depicted in Fig. 7(a), and links between concretes and other keywords are shown in Fig. 7(b). The links of bagasse with concrete and pozzolanic materials indicate that it has been used as a pozzolanic material in concrete. Thus, utilizing SBA in CBCs would be a better and sustainable approach.

4.4. Authors mapping

The number of citations a researcher receives indicates their influence in a particular field [80]. In the VOSviewer, the "type of analysis" was set to "co-authorship," while the "unit of analysis" was set to "authors." The minimum number of documents required for an author was maintained at 5, which resulted in 16 of 549 authors meeting the constraints. According to data retrieved from the Scopus database, the top authors in the field of SBA utilization in concrete for sustainable growth with the most documents and citations are listed in Table 3. The average citation count was determined by dividing the total number of citations by each author's total number of publications. Most publications were authored by Bahurudeen A. (14 articles), while the most citations were authored by Cordeiro G.C. (769 citations). It will be difficult to evaluate a researcher's effectiveness independently. The author's rating, on the other hand, will be determined by comparing all variables individually or in combination. When the total number of publications is compared, for example, the top three authors are Bahurudeen A. with 14, Jaturapitakkul C. with 13, and Cordeiro G.C. with 9 publications. Alternatively, if the number of citations is compared, Cordeiro G.C. ranks first with 769, Toledo Filho R.D. ranks second with 743, and Jaturapitakkul C. ranks third with 516 citations. Additionally, when comparing average citations, the author's ranking is as

Table 2
List of top 20 mostly occurred keywords.

S/N	Keyword	Occurrences	Total link strength
1	Bagasse	103	884
2	Compressive strength	99	699
3	Concretes	68	634
4	Bagasse ash	50	252
5	Sugar-cane bagasse	49	460
6	Sugarcane bagasse ash	49	303
7	Portland cement	47	410
8	Concrete	45	334
9	Cements	44	396
10	Fly ash	43	335
11	Durability	42	383
12	Chlorine compounds	33	296
13	Sugar cane	33	285
14	Silica fume	28	213
15	Concrete aggregates	26	273
16	Bagasse ashes	25	214
17	Concrete mixtures	24	208
18	Silica	24	205
19	Water absorption	24	223
20	Cement industry	23	245

(a)

(b)

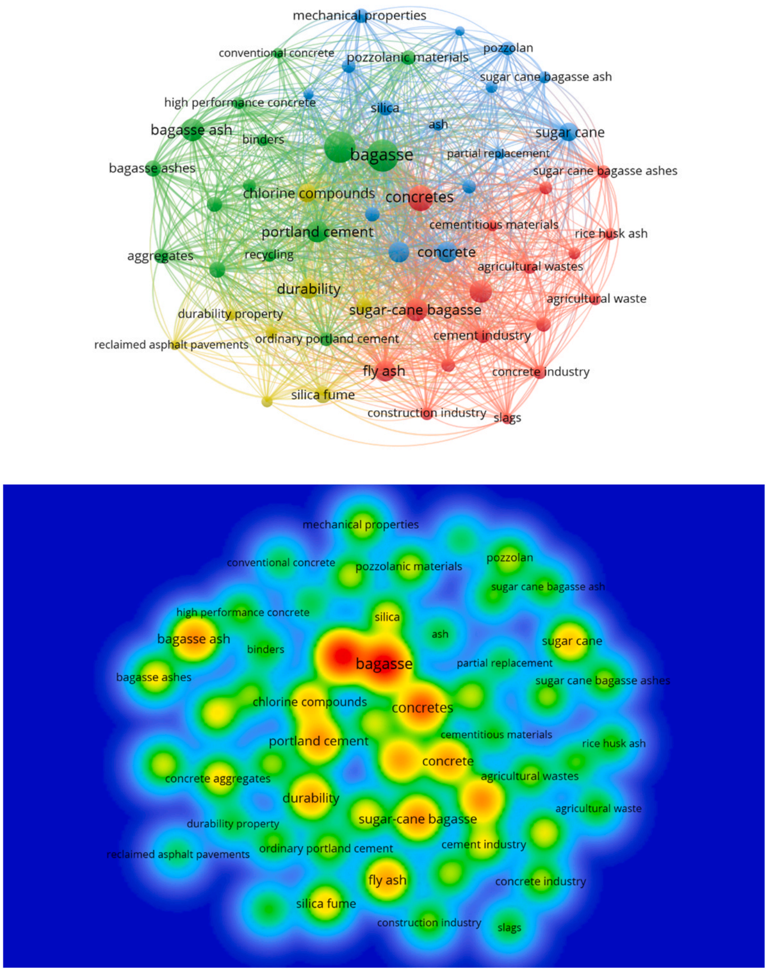
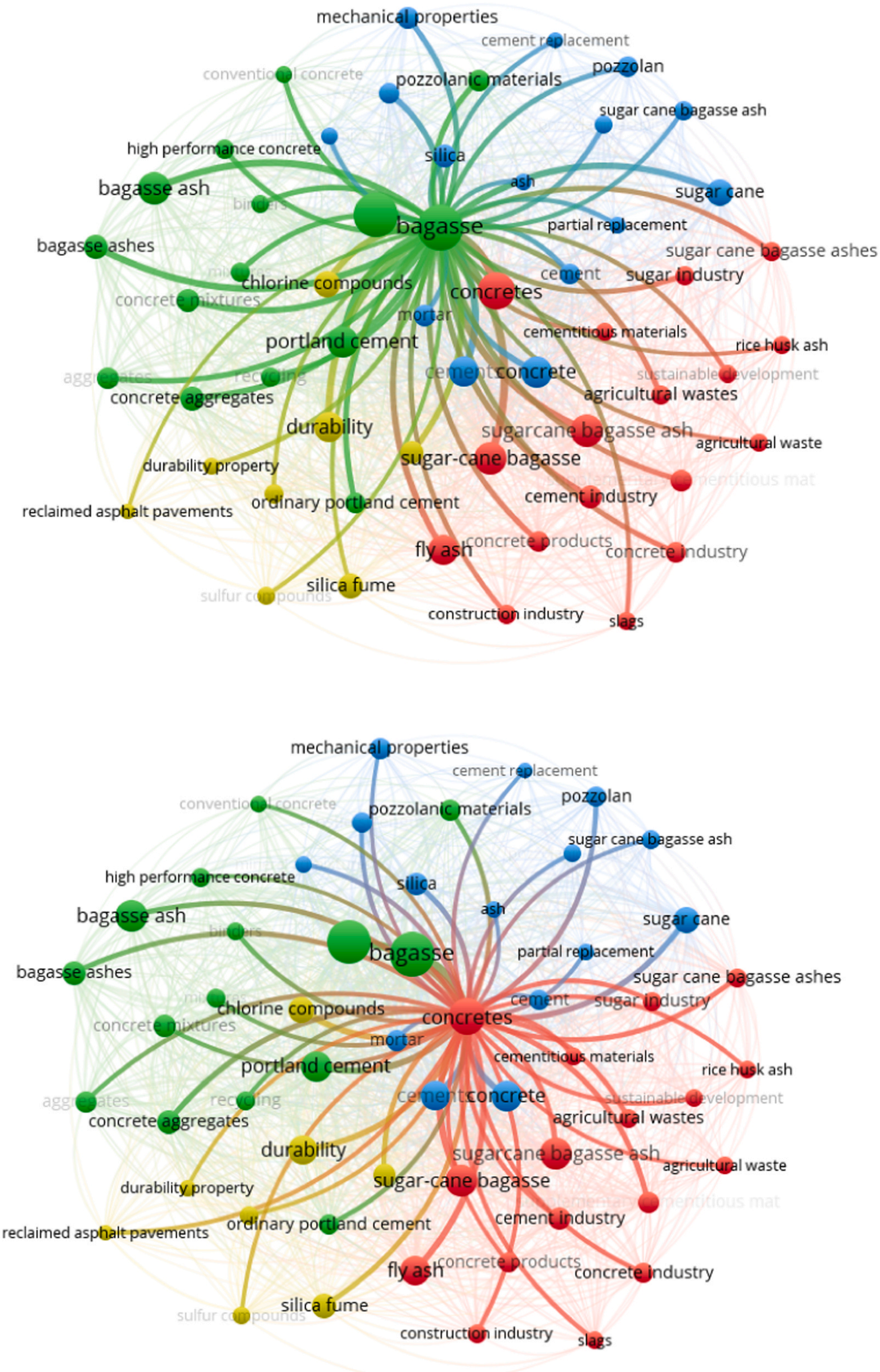


Fig. 6. Scientific mapping of keywords: (a) Visualization of cooccurrence; (b) Visualization of density.



(a)

(b)

Fig. 7. Links of a keyword with others: (a) Bagasse; (b) Concretes.

Table 3
Top authors in the relevant field.

S/N	Author	Documents	Citations	Average citations	total link strength
1	Bahurudeen A.	14	384	27	6
2	Jaturapitakkul C.	13	516	40	14
3	Cordeiro G.C.	9	769	85	12
4	Tangchirapat W.	9	171	19	13
5	Balaji K.V.G.D.	8	15	2	6
6	Chindaprasirt P.	8	175	22	9
7	Santhosh Kumar T.	8	14	2	6
8	Singh S.	8	182	23	0
9	Toledo Filho R.D.	7	743	106	11
10	Santhanam M.	6	373	62	6
11	Aslam F.	5	25	5	5
12	Fairbairn E.M.R.	5	494	99	9
13	Javed M.F.	5	25	5	5
14	Mendoza-Rangel J.M.	5	30	6	0
15	Sales A.	5	207	41	0
16	Sountharajan V.M.	5	3	1	0

follows: Toledo Filho R.D. has 106, Fairbairn E.M.R. has 99, and Cordeiro G.C. has 85 average citations. The visualization of authors with a minimum of five documents and the linkage of the most prominent author is shown in Fig. 8. Only three of the 16 authors have been linked. On the basis of citations in the field of SBA utilization in concrete, it was determined that authors from different regions are not connected to each other.

4.5. Mapping of articles

The number of citations a research article receives reflects its influence on a particular field of study. Articles that receive a large number of citations will be considered landmarks in the research field. The "type of analysis" was set to "bibliographic coupling" and the "unit of analysis" to "document" in the VOSviewer to analyze documents based on citations. The minimum citation count for a document was set at 10, and 82 of the 220 records met these criteria. Table 4 summarizes the top twenty highly cited research articles, their authors, and the year of publication. Ganesan K. [26] received a total of 355 citations for their article titled "Evaluation of bagasse ash as supplementary cementitious material". Cordeiro G.C. [81,82] received 258 and 211 citations, for their respective articles and were ranked in the top three. Fig. 9 illustrates the author's visualization of the articles with the most citations on their respective publications (Fig. 9(a)), the top connected articles (Fig. 9(b)) based on citations, and the density of connected articles ((Fig. 9(c)) in the field of the current study. According to citations, 77 out of 82 documents were connected. This visualization depicts the network of co-citations between the authors who contributed to the study of SBA utilization in concrete for sustainability. The proximity of the articles indicates how closely related they are in terms of citations.

4.6. Mapping of countries

Certain nations have previously made greater contributions than others to the current research domain and continue to do so. The visualization network was created to assist readers in visualizing regions that are serious about sustainable construction. The "type of analysis" was chosen as "bibliographic coupling," and the "unit of analysis" as "countries." The minimum number of documents required by a country was set at five, and 10 of 45 countries met this criterion. Table 5 lists the top most active nations in terms of the number of documents and citations related to the current study area. With 110, 24, and 22 documents, respectively, India, the United States, and China contributed the most documents. Similarly, these countries received the most citations, i.e., 1295, 1055, and 919 respective citations. The total number of documents, citations, and links indicates a country's influence on the evolution of the current research domain. The total link strength reflects the degree to which a country's documents influenced the other countries included in these studies. In comparison to other countries, India had the strongest total link strength (8938), followed by the United States (4965) and Thailand (4531). As a result, it was determined that the aforementioned countries have the greatest influence on the use of SBA in concrete for sustainability. Fig. 10(a) and (b) depict the connectivity and density of countries linked based on citations. The size of the frame reflects a country's contribution to the field of study. Furthermore, the density visualization demonstrates that countries with the highest participation had a higher density. The graphical representation of participating countries will aid future researchers in establishing scientific collaborations, producing joint venture reports, and sharing innovative techniques and ideas.

5. Properties of sugarcane bagasse ash

It is critical to understand the properties of SBA in order to ensure that it functions properly when used in place of cement in CBCs. The hardened properties of CBCs are determined by a variety of factors, including the water-binder ratio (w/b), the chemical composition of the binder, the quality of the filler material, cement type, cement quantity, and quality control measures taken during the concrete production process. SBA's chemical composition has been listed in Table 6. The CaO content of SBA is between

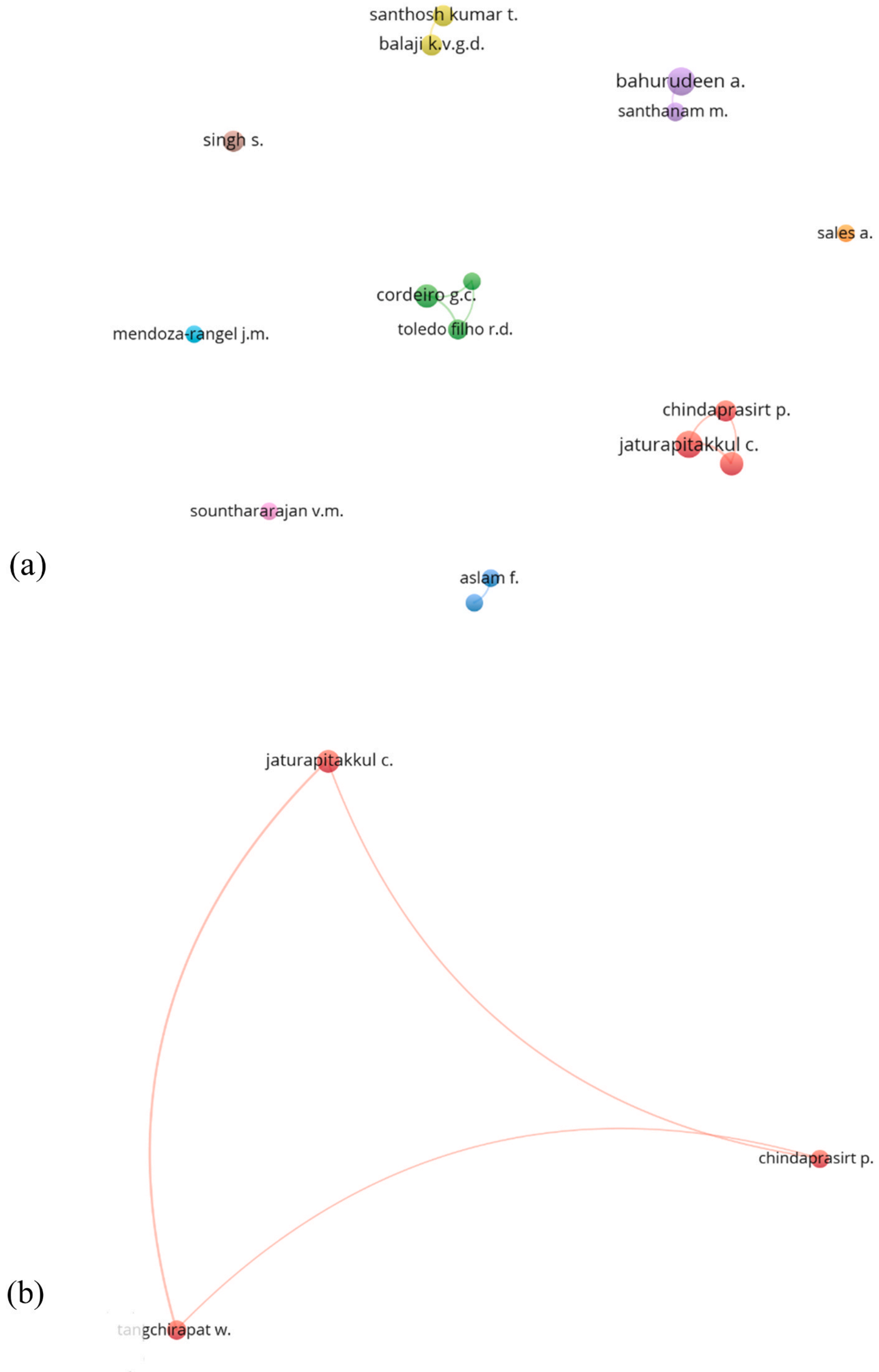


Fig. 8. Co-authorship scientific mapping: (a) Visualization of authors with at least 5 documents; (b) Connected authors.

approximately 1% and 12.6% of the overall composition. According to various research studies, ordinary Portland cement (OPC) comprises a greater concentration of CaO than SBA. The presence of SiO_2 in SBA is used to determine its reactivity. The SiO_2 content is between 57.63% and 78.34%, indicating that SBA contains a high concentration of essential oxides appropriate for a pozzolanic material [83]. According to ASTM C618-08a [84], if the amount of SiO_2, Al_2O_3, and Fe_2O_3 exceed 50% of the total mass, it is categorized as class C pozzolanic material; if the amount exceeds 70%, it is classified as class F pozzolana. Therefore, maximum SBA samples, as listed in Table 6, might be classified as class F pozzolana according to this criterion. If SBA is used in the CBCs manufacturing process, it has the potential to aid in the process of strength development.

Table 4
Top 20 mostly cited documents in the relevant field.

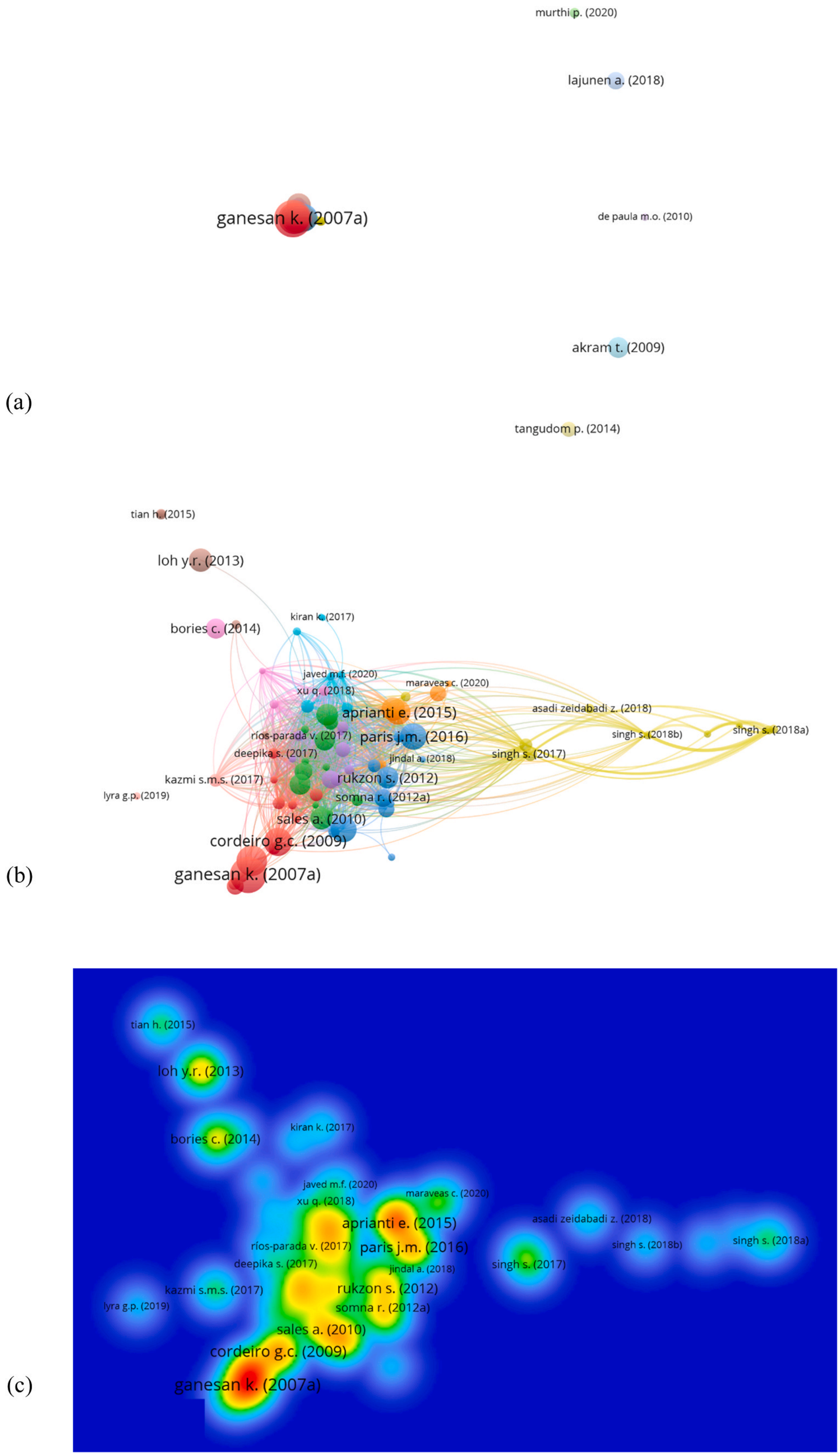
S/N	Document	Title	Citations	Total link strength
1	Ganesan K. (2007)	Evaluation of bagasse ash as supplementary cementitious material	355	64
2	Cordeiro G.C. (2008)	Pozzolanic activity and filler effect of sugar cane bagasse ash in Portland cement and lime mortars	258	48
3	Cordeiro G.C. (2009)	Ultrafine grinding of sugar cane bagasse ash for application as pozzolanic admixture in concrete	211	135
4	Paris J.M. (2016)	A review of waste products utilized as supplements to Portland cement in concrete	190	197
5	Chusilp N. (2009)	Utilization of bagasse ash as a pozzolanic material in concrete	184	117
6	Aprianti E. (2015)	Supplementary cementitious materials origin from agricultural wastes - A review	174	245
7	Aprianti S E. (2017)	A huge number of artificial waste material can be supplementary cementitious material (SCM) for concrete production – a review part II	152	248
8	Loh Y.R. (2013)	Review Sugarcane bagasse - The future composite material: A literature review	147	10
9	Sales A. (2010)	Use of Brazilian sugarcane bagasse ash in concrete as sand replacement	132	66
10	Bahurudeen A. (2015)	Performance evaluation of sugarcane bagasse ash blended cement in concrete	127	170
11	Rukzon S. (2012)	Utilization of bagasse ash in high-strength concrete	126	70
12	Fairbairn E.M.R. (2010)	Cement replacement by sugar cane bagasse ash: CO2 emissions reduction and potential for carbon credits	123	171
13	Bahurudeen A. (2015)	Influence of different processing methods on the pozzolanic performance of sugarcane bagasse ash	107	181
14	Akram T. (2009)	Production of low cost self compacting concrete using bagasse ash	107	0
15	Cordeiro G.C. (2012)	Experimental characterization of binary and ternary blended-cement concretes containing ultrafine residual rice husk and sugar cane bagasse ashes	89	193
16	Somna R. (2012)	Effect of ground fly ash and ground bagasse ash on the durability of recycled aggregate concrete	84	126
17	Sua-Iam G. (2013)	Use of increasing amounts of bagasse ash waste to produce self-compacting concrete by adding limestone powder waste	82	220
18	Amin N.-U. (2011)	Use of bagasse ash in concrete and its impact on the strength and chloride resistivity	77	22
19	Prusty J.K. (2016)	Concrete using agro-waste as fine aggregate for sustainable built environment – A review	73	48
20	Somna R. (2012)	Effect of ground bagasse ash on mechanical and durability properties of recycled aggregate concrete	68	130

The binding and filling materials' physical properties had an effect on the hardened properties of CBCs [96]. The current review focuses on the physical properties of SBA and OPC, including their specific gravity, particle size, shape, color, loose and compacted bulk density, soundness, and specific surface area. These characteristics of OPC are related to those of SBA, which are provided in Table 7. SBA is available in three colors: reddish grey, black, and white. Color variations are related to both the degree of incineration and the structural change of silica in the ash [97]. SBA collected from power plants ranges in color from dark black to light. Dark black shows a greater carbon amount because of inadequate incineration [98], while SBA seems gray at an elevated temperature greater than 800 °C and white when the temperature is above 900 °C [99]. Additionally, prolonged heating is required to convert SBA completely to white ash [100]. Various scholars discovered that the specific gravity of SBA is between 1.78 and 2.88, which is significantly less than the specific gravity of cement (2.9–3.15). This means that when a unit weight of SBA is replaced by cement, a greater volume will result. As a result, the CBC's sample prepared using SBA will have a lower density than those of cement only, and density will further decrease as the amount of SBA in CBCs increases [101]. Additionally, it is believed that pozzolanic materials such as SBA have a lower bulk density than OPC. Because of the decreased density, the volume occupied by an intended mass is increased, and as a result, small voids of the matrix will be filled by these particles, reducing its permeability [102]. According to several researchers, the Blaine specific surface area of OPC is between 309 and 373 m^2/kg, which is significantly less than that of SBA, which is between 514 and 1250 m^2/kg. Because of the high specific surface area of SBA, it requires a greater amount of water, superplasticizing and air entraining admixtures to achieve the same workability as the control mix. While SBA has a finer particle size than cement, its texture is more glassy, similar to that of fly ash particles, which may increase workability [47].

6. Properties of cement-based composites containing sugarcane bagasse ash

6.1. Fresh state properties

Generally, the concrete performance in a fresh state is determined by its workability. Various terms are employed to describe concrete's workability, including mixability, compactability, moldability, and transportability. Fig. 11 depicts the effect of SBA on the slump of fresh mixes, based on literature. The slump test results of Srinivasan and Sathiya [86] revealed that the workability of fresh mix enhanced with the addition of SBA while keeping the w/b constant. At higher content of SBA, the slump value further increased. Priya and Ragupathy [15] examined the effect of SBA on the workability of the fresh mix up to a 25% cement substitution. The results indicated that increasing the amount of SBA improved the slump of the concrete, as indicated in the figure. It was reported that utilization of SBA in concrete decreased the water demand and improved the workability. Subramaniyan and Sivaraja [85] investigated the fresh state properties of concrete containing SBA as SCM in 10%, 20%, 30%, and 40% contents by performing a slump test. The authors demonstrated that the workability of fresh concrete mix increased with the addition of SBA, which was proportional to the



(caption on next page)

Fig. 9. Scientific mapping of articles: (a) Articles with at least 10 citations; (b) Visualization of connected articles; (c) Density visualization of connected articles.

SBA content. The slump of the control mix was 104 mm, while the slump of the mix containing 40% SBA was found to be 153 mm. Rao and Prabath [104] also investigated the effect of SBA on concrete workability. According to the authors, the presence of SBA in concrete resulted in a decrease in workability, depending on the amount of SBA. They stated that the reduction in workability of the fresh mix was caused due to the absorption of water by SBA particles. In another study by Hussein et al. [47], the effect of SBA as SCM used in 5–30% proportions on workability of fresh mix was investigated. They observed an increase in slump values as the SBA content increased. Although SBA has a much finer particle size than cement, its texture is more glassy, similar to that of fly ash particles, resulted in increased workability. Also, the improved workability can be attributed to the SBA's low loss on ignition (LOI) of 1.4%, which indicated that the SBA has been completely burned and the ash contains no carbon. Similar results of increased slump values with SBA addition were noticed by Venkatesh and Rani [49], Mahmud et al. [55], and Patel and Raijiwala [110], as indicated in the figure. Ganesan et al. [26] studied the effect of SBA on the workability of fresh concrete by performing a slump test. Cement was replaced by SBA at 5%, 10%, 15%, 20%, 25%, and 30% proportions and the w/b ratio was kept constant for all mixes. It was found from the test results that with the addition of SBA up to 10%, slump value increase by 17.3% compared to the control mix, while further addition of SBA caused reduction in slump. The slump value dropped by 34.7% at 30% content of SBA. At higher proportions of SBA water demand of the mix increased, resulted in decreased workability. Therefore, it can be concluded that the effect of SBA on workability of fresh mix is inconsistent. The glassy surface texture of SBA mostly enhances the workability, while its high specific surface area tends to reduce the workability.

Most of the past studies reported that the SBA tends to improve the workability of CBCs by increasing compaction factor, as illustrated in Fig. 12. Srinivasan and Sathiya [86] studied the impact of SBA used as SCM on the fresh properties of concrete. Cement was replaced by SBA in 5–25% contents with an increment of 5%. It was found that as the proportion of SBA increased, the compaction factor increased, signifying improved workability. The compaction factor increased from 0.95 to 0.97 (2.1%) with SBA addition. Priya and Ragupathy [15] investigated the use of SBA in concrete as a cement substitute. The results indicated that when compared to the reference mix, the mix with SBA had higher compaction factor values and adequate workability. They observed an increase in compaction factor from 0.88 to 0.96 due to SBA addition, exhibiting a 9.1% improvement than the control mix. Similar results were noticed by Subramaniyan and Sivaraja [85] when SBA was used as SCM in the proportion of 10%, 20%, 30%, and 40%. The compaction factor increased from 0.94 to 0.97, demonstrating improved workability.

6.2. Hardened state properties

6.2.1. Density

The mass of concrete per unit volume is referred to as its density. It is critical in evaluating various properties of concrete, including the estimation of lattice constants for calcium silicate hydrate (C-S-H) phase in hydrated cement, the assessment of porosity, strength, and durability [111]. The impact of SBA as SCM on concrete density has been investigated by several researchers, and the results are illustrated in Fig. 13. Jagadesh et al. [103] investigated the concrete density that contained both natural and processed SBA. Samples of original SBA were obtained from the plant during the boiler cleansing process. While the processed SBA was obtained by grinding the original SBA for 45 min at 300 rpm in a laboratory ball mill. After grinding, the SBA was placed in a furnace set to 400 °C for 4 h. The authors used between 5% and 30% of the original and processed SBA as SCM in concrete. It was noticed that increasing the proportion of original SBA decreased the density of concrete, whereas increasing the proportion of processed SBA, the density of concrete increased up to 20% content and then decreased, as shown in the figure. The authors stated that finer processed SBA particles filled the pore volume of concrete, thereby increasing density. Srinivasan and Sathiya [86] investigated the density of concrete by substituting 5–25% SBA for cement. According to the test results, it was discovered that increasing the amount of SBA reduced the density of concrete. Kumari and Kumar [51] also assessed the density of SBA concrete at w/b of 0.44, 0.45, and 0.46. In their study, they substituted cement for 5%, 10%, 15%, and 20% of SBA. The test results indicated that increasing the SBA percentage decreased the density of concrete. Additionally, one should keep in mind that the concrete density was inversely proportional to the w/b. The results indicated that the concrete density at a w/b of 0.44 was greater than the density at 0.45 and 0.46. The findings of Abdulkadir et al. [92] were similar to those made by previous authors, i.e., that the concrete density decreased when the SBA content was increased.

Hence, it can be concluded that due to the lower bulk density of SBA than cement, the density of composites containing SBA has a lower density than those of cement only. However, the reduced density values are still in the range of normal weight concrete.

6.2.2. Compressive strength

The variation in compressive strength (C-S) with the addition of distinct proportions of SBA has been displayed in Fig. 14. Mostly, incorporation of SBA in lower proportions enhanced the C-S, while a higher amount of SBA negatively impacted the C-S of composites. Srinivasan and Sathiya [86] investigated the effect of using SBA as a cement substitute in concrete. SBA was substituted for 5–25% of the cement weight in their study. The addition of 5% and 10% SBA improved the C-S by about 37.2% and 14.9%, respectively, compared to the reference sample. While an increased amount of SBA degraded the C-S of composites. The reduction in C-S was noted to be around 10.2%, 12.1%, and 17.7% in comparison with the reference sample at 15%, 20%, and 25% SBA content, respectively. The authors reported that 5% SBA was the optimal replacement for M20 grade concrete, 10% SBA concrete had a C-S greater than the reference sample but less than 5% SBA concrete. The improvement in C-S with SBA addition might be attributed to the filler effect due

Table 5
Countries with minimum 5 articles in the relevant study area.

S/N	Country	Documents	Citations	Total link strength
1	India	110	1295	8938
2	Brazil	24	1055	3842
3	Thailand	22	919	4531
4	Pakistan	18	294	4472
5	United States	11	329	4965
6	Malaysia	9	565	2160
7	Mexico	7	76	2719
8	Saudi Arabia	7	44	2659
9	Australia	5	118	1179
10	Spain	5	48	2027

to smaller particle size and pozzolanic reaction due to the presence of amorphous silica in SBA. Priya and Ragupathy [15] used SBA to substitute up to 25% of cement in concrete. C-S tests were conducted on concrete specimens to investigate the influence of different contents of SBA. According to the authors, while 10% was an optimal replacement, concrete with 20% SBA had a C-S greater than the control mix. Only at 25% content of SBA, C-S was less than the control mix. The reason for the C-S reduction at a higher SBA content was that the amount of amorphous silica in the mixture was greater than the amount required to react with the $Ca(OH)_2$ produced during the hydration reaction, thereby reducing the specimen's overall strength. Dhengare et al. [106] examined the effect of using SBA as a cement substitute in M25 and M35 concrete. They replaced 10–30% of cement with SBA passing through a No. 600 sieve. The results indicated that the maximum C-S was obtained by substituting 15% SBA in place of cement in both concrete grades. Whereas, higher amount of SBA reduced the C-S in comparison with the control sample. Kiran and Kishore [107] mixed the concrete with up to 25% SBA. The authors concluded from the test results that 5% SBA was an optimal replacement content. However, concrete with 15% SBA also produced a C-S greater than the reference mix. Ranjith et al. [112] investigated the C-S of concrete utilizing SBA as SCM with 5–25% replacement ratios. It was determined that a maximum of 5% replacement was required to attain adequate C-S. Rao and Prabath [104] produced M25 concrete by partially substituting SBA for cement from 0% to 25% ratios with a 5% increment. The concrete with a 10% SBA replacement provided the highest C-S relative to the reference specimen.

Similarly, Ganesan et al. [26] used SBA to replace 5%, 10%, 15%, 20%, 25%, and 30% cement in concrete. SBA was collected from the mill and then burned for 1 h at a controlled temperature of 650 °C. The carbon content of SBA was reduced from 11.2% to 4.9% as a result of this combustion process. The C-S enhanced by approximately 10.8%, 13.5%, 10.8%, and 5.4% with 5%, 10%, 15%, and 20% SBA content, respectively. However, at 25% and 30% content of SBA, the C-S dropped by 10.8% and 18.9%, respectively, compared to the control sample without SBA. Based on the test results, the authors concluded that 10% SBA content was the optimal amount for M25 concrete and that the concrete with 20% SBA content also had a C-S greater than the reference mix. The increase in C-S could be a result of the higher silica content, specific surface area, fineness, amorphous phase, and degree of reactivity of SBA, as well as the pozzolanic reaction between $Ca(OH)_2$ and reactive silica in SBA, as reported by other researchers [113–117]. Mamatha et al. [23] performed C-S tests on concrete specimens to examine the influence of 5%, 10%, 15%, and 20% nano SBA used as cement replacement. They noticed an improvement in C-S with the increasing amount of SBA. With 5%, 10%, 15%, and 20% nano SBA, the C-S enhanced by around 17.0%, 22.7%, 28.7%, and 32.4%, respectively, relative to the control specimen. The finer particles of nano SBA filled the pores in the matrix, and pozzolanic reaction improved the microstructure of the matrix, thereby enhancing the composites strength. The test results of Inbasekar et al. [46] revealed that up to 10% of SBA content used as SCM improved while higher SBA contents degraded the C-S of concrete. Most of the other studies also reported improvement in C-S when SBA was used as SCM [47,49,52,53,55,91,110,118]. On the other hand, Kumari and Kumar [51] found a reduction in C-S with adding SBA. They replaced cement with 5%, 10%, 15%, and 20% SBA and evaluated the performance of samples. After performing the C-S test, it was noticed that with SBA addition of 5%, 10%, 15%, and 20%, the C-S decreased by about 5%, 9.8%, 16.9%, and 24.9%, respectively, than that of a reference sample. Thus, this study concluded that SBA could enhance the C-S of CBCs when used in lower proportions and decrease the C-S when used in higher proportions. The improvement in C-S of composites might be attributed to the filler effect of SBA finer particles, reducing porosity and pozzolanic properties of SBA due to the presence of reactive silica, resulting in the improved microstructure of composite and ultimately improves the strength properties. The reduction in C-S of composites at higher SBA quantities might be due to the dilution of cement.

6.2.3. Modulus of elasticity

Modulus of elasticity (MOE) is the resistance of a material to elastic deformation in response to the applied force. Additionally, it is a critical parameter for structural design. Fig. 15 shows the MOE values for various concretes containing varying amounts of SBA. Jagadesh et al. [103] conducted a thorough investigation of the MOE of concrete containing both original and processed SBA. Original and processed SBA was used as SCM in concrete in proportions of 5–30% during their investigation. They found a decrease in MOE with original SBA addition at all proportions. The maximum reduction in MOE was 28.4% at an SBA content of 30%. However, MOE mostly increased with processed SBA addition, and the maximum increase was 13.1% higher than the control mix at 10% content of processed

(a)

(b)

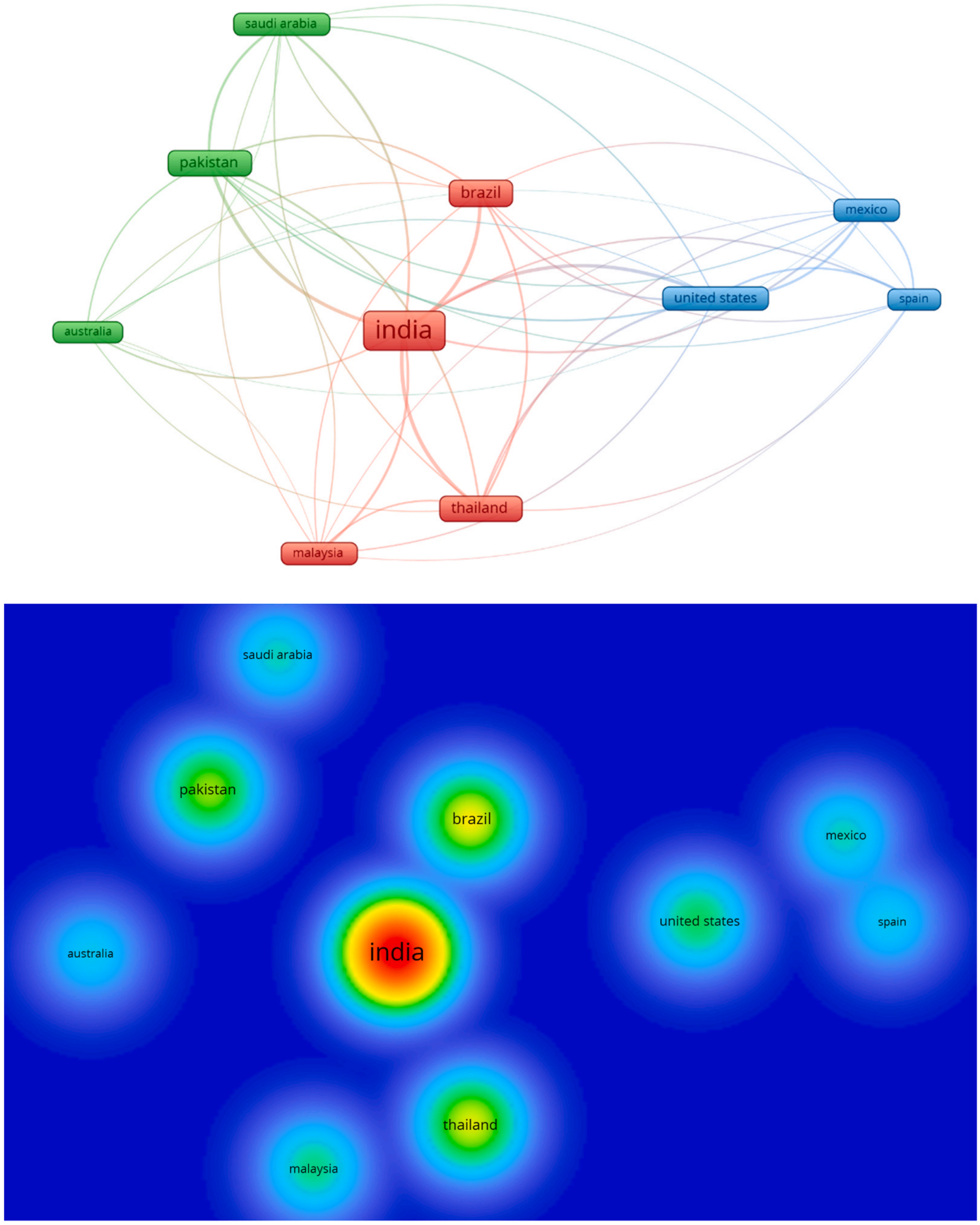


Fig. 10. Scientific mapping of countries: (a) Network visualization; (b) Visualization of density.

SBA. The finer particle size of processed SBA than the original SBA might be a reason for this improvement in MOE. The finer particles of processed SBA benefit the matrix by reducing voids, better pozzolanic reactivity, and enhanced microstructure, resulting in improved properties. Similarly, Priya and Ragupathy [15] examined the influence of various proportions (5–25%) of SBA in place of cement on the MOE of concrete. The experimental results revealed mostly an increase in MOE with SBA addition compared to the reference sample. The highest MOE was achieved at 10% SBA replacement which was 8.5% higher than that of the reference sample. On the other hand, Srinivasan and Sathiya [86] observed a reduction in MOE of concrete containing SBA in different proportions (5–25%). This reduction in MOE was more at higher SBA quantity. In general, the MOE of CBCs containing SBA as cement replacement depends on the particle size of SBA utilized. More the finer particle size SBA used, the higher the MOE will be.

6.2.4. Split-tensile strength

The influence of SBA addition in CBCs on split-tensile strength (S-T-S) has been shown in Fig. 16. The effect of SBA on S-T-S was

Table 6
Chemical composition of sugarcane bagasse ash.

Chemical compound (%)									Ref.
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	N_2O	LOI	
76.67	2.13	3.78	5.59	0.92	–	8.29	0.12	2–5	[85]
78.34	8.55	3.61	2.15	0.83	0.56	3.46	0.12	0.42	[86]
62.43	4.28	6.98	11.80	2.51	1.48	3.53	–	4.73	[53]
64.59	4.38	6.98	11.80	2.51	1.48	3.53	–	4.73	[44]
65.0	4.80	0.90	3.90	–	0.90	2.0	–	10.50	[45]
65.0	3.95	9.17	12.60	0.60	0.10	–	–	9.02	[87]
77.25	6.37	4.21	4.05	2.61	0.11	2.34	1.38	–	[88]
57.63	1.33	1.50	6.14	1.56	3.52	7.33	0.22	21.0	[89]
65.0	3.95	9.17	12.60	0.60	0.10	–	–	9.02	[90]
58.62	19.95	12.25	1.92	2.10	2.07	–	–	1.08	[91]
72.85	1.08	6.96	9.97	6.42	–	6.77	1.97	4.23	[92]
62.10	5.54	5.42	1.0	1.12	–	2.22	0.81	–	[93]
66.89	29.18	–	1.92	0.83	0.56	–	–	0.72	[94]
77.25	6.37	4.21	4.05	2.61	0.11	2.34	1.38	–	[47]
62.43	4.38	6.98	11.80	2.51	1.48	3.53	–	4.73	[95]

Table 7
Physical properties of ordinary Portland cement and sugarcane bagasse ash.

Properties	Sugarcane bagasse ash	Ordinary Portland cement
Color	Reddish grey, black and white	Grey
Size (μm)	0.1–105	22.5–28
Shape	Spherical	–
Loose Bulk density (kg/m^3)	575–578	1160
Compacted Bulk density (kg/m^3)	1200–1561	1560
Specific gravity	1.26–2.88	2.9–3.15
Blaine specific surface area (m^2/kg)	514–1250	309–373
Fineness passing 45 μm (%)	95–97	93
Soundness (mm)	1.21	1–9
References	[17,19,44–46,49,55,103–105]	[19,23,26,49,102,103,105–109]

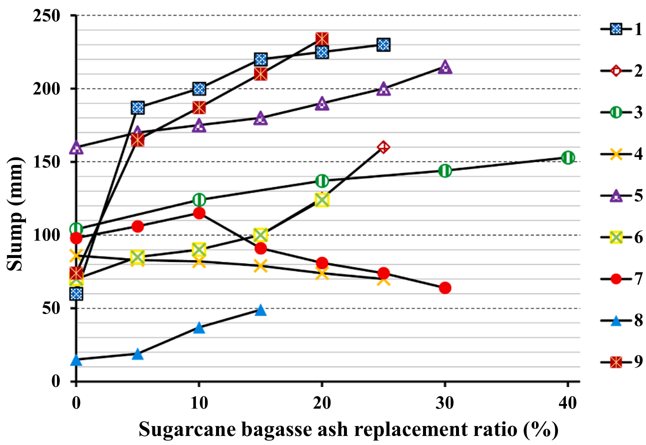


Fig. 11. Effect of sugarcane bagasse ash on slump (1) Srinivasan and Sathiya [86], (2) Priya and Ragupathy [15], (3) Subramaniyan and Sivaraja [85], (4) Rao and Prabath [104], (5) Hussein et al. [47], (6) Venkatesh and Rani [49], (7) Ganesan et al. [26], (8) Mahmud et al. [55], (9) Patel and Raijiwala [110].

found to be similar to that of C-S. Srinivasan and Sathiya [86] investigated the effect of using SBA as SCM in concrete. SBA was used at a rate of 5–25% by cement weight in their study. It was observed that the maximum S-T-S was achieved at a replacement rate of 5% SBA, which was 26.7% higher than the S-T-S of the control mix. The S-T-S with 10% SBA was increased by 6.7% than the control mix. Moreover, the S-T-S was found to be comparable to that of the control mix at 15% SBA content. However, at an increased replacement ratio of 20% and 25%, the S-T-S dropped by 13.3% and 20%, respectively, relative to the control mix. The filler effect and pozzolanic nature of SBA resulted in enhanced S-T-S at a lower replacement ratio. While the reason for the reduction in S-T-S at a higher SBA replacement ratio is that the amount of pozzolanic material in the mix exceeds the amount required to combine with $Ca(OH)_2$ during

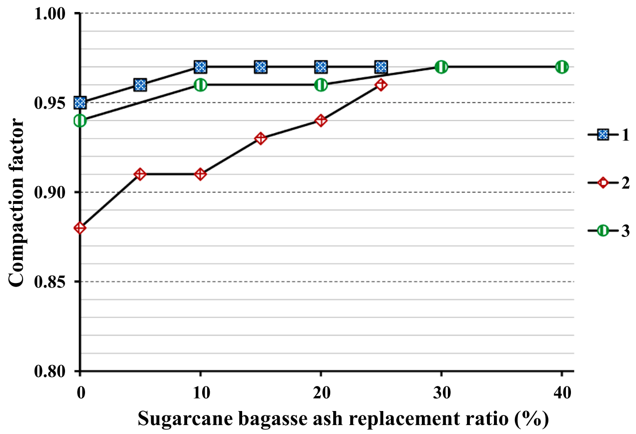


Fig. 12. Effect of sugarcane bagasse ash on compaction factor (1) Srinivasan and Sathiya [86], (2) Priya and Ragupathy [15], (3) Subramaniyan and Sivaraja [85].

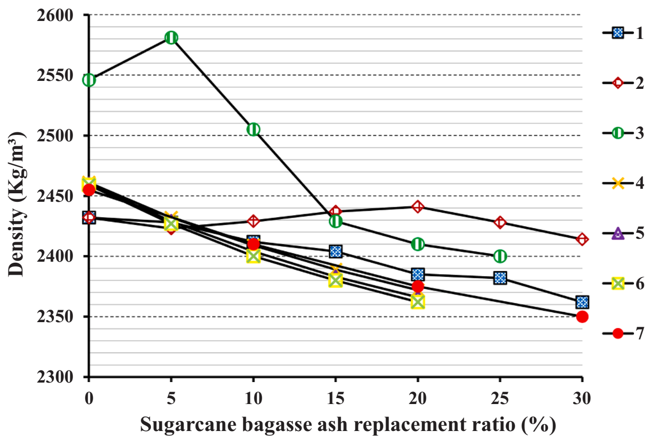


Fig. 13. Effect of sugarcane bagasse ash on density (1) (2) Jagadesh et al. [103] with original and processed SBA, respectively, (3) Srinivasan and Sathiya [86], (4) (5) (6) Kumari and Kumar [51] with w/b: 0.44, 0.45, and 0.46, respectively, (7) Abdulkadir et al. [92].

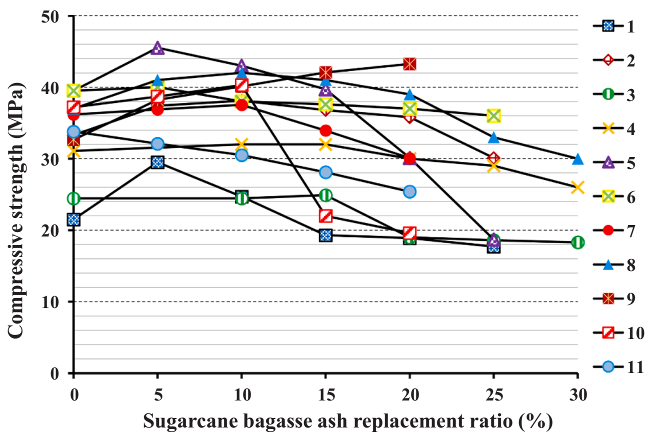


Fig. 14. Effect of sugarcane bagasse ash on compressive strength at 28-days (1) Srinivasan and Sathiya [86], (2) Priya and Ragupathy [15], (3) (4) Dhengare et al. [106] M25 and M35 concrete, respectively, (5) Kiran and Kishore [107], (6) Ranjith et al. [112], (7) Rao and Prabath [104], (8) Ganesan et al. [26], (9) Mamatha et al. [23], (10) Inbasekar et al. [46], (11) Kumari and Kumar [51].

the hydration process, this results in excess silica leaching out and a deficiency in strength because it substitutes part of the binder but does not contribute to strength. Additionally, it is possible that weak zones are caused by defects generated during SBA dispersion. Priya and Ragupathy [15] also used SBA as SCM replacing cement by 5–25%, and evaluated the response of samples in tension. Mostly, improvement in S-T-S was noticed with SBA addition up to 20% content, but at 25% SBA content, the S-T-S of samples was less compared to the reference sample. The highest S-T-S was observed for samples with 10% SBA content.

Similarly, Dhengare et al. [106] explored the impact of SBA as SCM in concrete grades M25 and M35. The S-T-S of M25 concrete was enhanced by 10.7% and 7.1% at SBA replacement levels of 10% and 15%, respectively, relative to the control sample. While at higher replacement levels of SBA, the S-T-S of samples was found to be less than the control sample. Thus, the optimum replacement level of SBA for M25 concrete was 10%. On the other hand, the optimum replacement level for M35 concrete was found to be 15%, resulting in S-T-S improvement by 4.6% that the control sample. The experimental results of Kiran and Kishore [107] indicated that a 5% SBA replacement provided the highest S-T-S. Likewise, Ranjith et al. [112] also agreed that a 5% content of SBA was the optimal amount in normal-weight concrete. In another study by Rao and Prabath [104], the effect of SBA as SCM on S-T-S of concrete was examined. There was improvement observed in S-T-S by adding SBA up to 10% ratio, while S-T-S reduced at higher ratios of SBA. It was reported that a 10% SBA ratio was the optimum quantity, causing a 7.8% increase in S-T-S. Ganesan et al. [26] noticed an increase in S-T-S than the control mix when SBA was used in place of cement up to 20%. However, the optimum SBA content was found to be 15%, resulting in S-T-S improvement by around 10% relative to the control mix. The utilization of more than 20% SBA content caused a reduction in S-T-S relative to the control mix. Mamatha et al. [23] determined that 15% was the optimal replacement level and that concrete containing 20% SBA also had a greater S-T-S than the control mix. An experimental study was performed by Inbasekar et al. [46] to investigate the effect of utilizing SBA in concrete as SCM in replacement levels of 5–20%. The results of the S-T-S test revealed that at 5% and 10% replacement of cement by SBA, the S-T-S increased by approximately 3.1% and 6.3%, respectively. Though most of the researchers found improvement in S-T-S when SBA was utilized as a cement substitute in CBCs, some studies reported the contrary. For example, Kumari and Kumar [51] observed the negative impact on strength properties of concrete with SBA addition. The cement in concrete was partially replaced by 5–20% SBA. It was found that S-T-S of samples containing SBA was less than the reference sample, and this reduction was proportional to the amount of SBA used. It was reported that the drop in S-T-S was around 2.9%, 5.9%, 11.8%, and 17.6% when cement was replaced by SBA at proportions of 5%, 10%, 15%, and 20%, respectively, relative to the reference sample. Hence, this study determined that utilizing SBA in CBCs is favorable at lower replacement levels, while a higher amount of SBA tends to degrade the strength properties of composites. SBA being a finer material fill the voids in the concrete matrix, and being pozzolanic material promotes the growth of hydration products, making improved microstructure and eventually enhances the mechanical performance of composites.

6.2.5. *Flexural strength*

Fig. 17 has been generated based on past studies indicating the effect of SBA addition on flexural strength (F-S) of CBCs. The effect of SBA on F-S was noticed to be similar to the C-S and S-T-S, i.e., F-S increased with SBA addition up to an optimal content and then reduced. Srinivasan and Sathiya [86] explored the impact of SBA when used as SCM in concrete. It was reported that the maximum F-S was achieved by substituting cement for 5% of SBA. Priya and Ragupathy [15] performed the F-S test to study the influence of utilizing SBA in concrete as SCM at replacement levels of 5–25%. They reported improvement in F-S in comparison with the control mix with cement substitution of up to 20% by SBA, while at 25% SBA content, F-S was observed to be less than the control mix. The optimum SBA content giving maximum F-S was 10%. Dhengare et al. [106] conducted an experimental study to determine the optimal amount of SBA to substitute for cement in concrete grades of M25 and M35. Based on F-S test results, the optimum SBA content was noted to be 15% for both concrete grades. In another study by Kiran and Kishore [107], SBA was used in cement's place at 5–25% ratios to determine the F-S variation. It was noted that SBA ratios of 5%, 10%, and 15% increased the F-S by about 12.8%, 5.1%, and 2.6%,

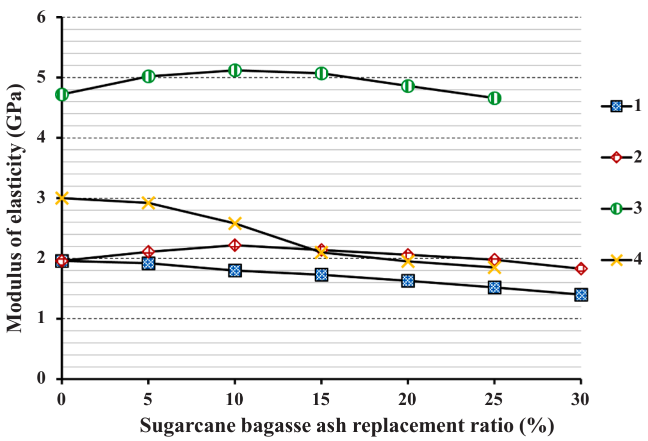


Fig. 15. Effect of sugarcane bagasse ash on the modulus of elasticity (1) Jagadesh et al. [103] with original SBA, (2) Jagadesh et al. [103] with processed SBA, (3) Priya and Ragupathy [15], (4) Srinivasan and Sathiya [86].

respectively, compared to the reference mix. However, a higher replacement ratio of SBA degraded the F-S of concrete. The reduction in F-S compared to the reference mix was noted to be about 25.6 and 48. 7% at SBA ratio of 20% and 25%, respectively. Ranjith et al. [112] also conducted the F-S test and observed the variation in F-S with different percentages (5–25%) of SBA used as SCM in concrete. They noted improvement in F-S at only 5% SBA replacement ratio, relative to the control specimen, while the addition of SBA higher than 5% caused a decrease in F-S. Rao and Prabath [104] evaluated the impact of SBA as a cement substitute in concrete. They concluded in their study that using 10% SBA by cement weight was an optimal replacement ratio having the highest F-S. Therefore, it obvious to say that most of the literature recommended the utilization of SBA as cement replacement in lower percentages. The reasons described above for the variation in C-S and S-T-S are also applicable to the variation in F-S of composites.

6.3. Durability properties

6.3.1. Resistance to chloride penetration

Fig. 18 depicts the influence of various proportions of SBA in CBCs on chloride penetration, as reported in the literature. Ganesan et al. [26] conducted an experiment to determine the resistance of SBA concrete to chloride ion penetration. Cement was substituted by SBA at 5–30% replacement levels. They demonstrated that charges passing through the samples of concrete containing SBA reduced continuously as the SBA percentage increased up to 25%. Although there was an increase at 30% SBA, the value was significantly less than the control mix, as illustrated in the figure. The results indicated that partial substitution of OPC with SBA significantly reduced the chloride penetration. Additionally, it was observed that the overall amount of charge passed decreased by more than 50% when related to the reference sample with 20% SBA content. Amin [119] also made comparable observations, i.e., a continuous reduction in chloride penetration was found up to 25% SBA replacement ratio. Rukzon and Chindaprasirt [45] conducted an experiment to investigate the durability properties of high-strength concrete when 10%, 20%, and 30% SBA was used in place of cement. The results of the tests indicated that the amount of charge passing through the samples containing SBA was significantly less than that passing through the reference sample. Furthermore, it was stated that the reduction in the value of charge passed was more when 30% SBA was substituted. Bahurudeen and Santhanam [120] confirmed previous findings that the value of charge passed through specimens containing SBA was significantly lower than the control specimen. Additionally, they reported that SBA substituted specimens have a lower chloride conductivity index than control specimens, with a drop in conductivity index of about 23%, 48%, and 54% at SBA content of 5%, 10%, and 20%, respectively. In another study by Rukzon and Chindaprasirt [121], it was noticed that replacing OPC with SBA reduced the amount of coulombs, signifying improvement of composite against chloride penetration. This indicated that the electrical charge passed through SBA concrete was less than the charge passed through the control mix. The reduction in chloride penetration with SBA addition might be attributed to the filler effect and pozzolanic action of SBA in the matrix, which made the matrix compact and denser.

6.3.2. Resistance to the acidic environment

An experimental study was conducted by Rambabu and Rama [122] to investigate the resistance of concrete incorporating SBA in HCL and H_2SO_4 solutions. SBA was replaced with cement in proportions of 5–20%. The parameter studied in their research was the C-S variation of completely immersed concrete specimens in 1%, 3%, and 5% HCL and H_2SO_4 solutions after 28, 60, and 90-days of curing. The variation in 28-days C-S of composites cured in different conditions has been shown in Fig. 19. The authors reported that after 28-days of exposure to 1%, 3%, and 5% concentrations of HCL solution, the C-S of control specimens decreased by 20%, 26.5%, and 31.9%, respectively. Also, in 1%, 3%, and 5% H_2SO_4 solution, the C-S loss was 23%, 31.1%, and 34.8%, respectively. C-S of specimen containing 5% SBA exposed to 1%, 3%, and 5% concentrations HCL solution reduced by 17.6%, 22.1%, and 27.9%, respectively, while C-S of specimens exposed to 1%, 3%, and 5% H_2SO_4 solution decreased by 20.6%, 27.5%, and 32.4%, respectively, compared to the

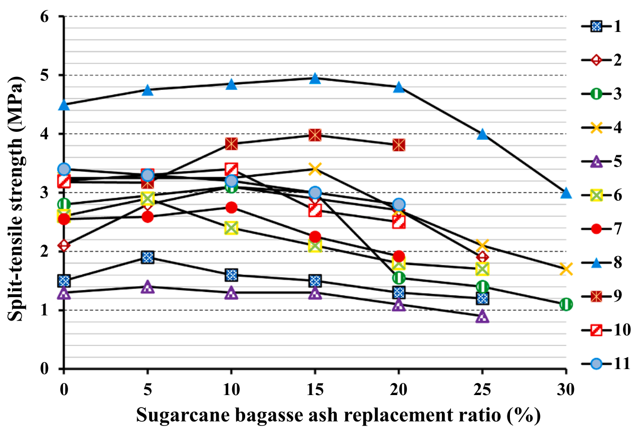


Fig. 16. Effect of sugarcane bagasse ash on split-tensile strength at 28-days (1) Srinivasan and Sathiya [86], (2) Priya and Ragupathy [15], (3) (4) Dhengare et al. [106] with M25 and M35 concrete, respectively, (5) Kiran and Kishore [107], (6) Ranjith et al. [112], (7) Rao and Prabath [104], (8) Ganesan et al. [26], (9) Mamatha et al. [23], (10) Inbasekar et al. [46], (11) Kumari and Kumar [51].

water cured specimen. Additionally, it was noticed that the C-S of the specimens cured in HCL solution was more than that of the H_2SO_4 cured specimen. It was stated that the strength loss associated with SBA replacement was less than that associated with reference specimens in both HCL and H_2SO_4 solutions, as shown in the figure. The better resistance of SBA concrete to an acidic environment can be attributed to the improved microstructure due to the ultra-fine particles of SBA, reducing matrix's porosity, and also to the presence of highly reactive silica in SBA, promoting the growth of hydration products.

Rambabu et al. [123] investigated the effect of SBA as SCM in concrete subjected to a variety of acidic conditions. OPC was replaced by SBA in the proportions of 5%, 6%, 7%, 8%, 9%, and 10%. The findings of the study have been plotted in Fig. 20. The C-S of samples without SBA decreased by around 7.1%, 11.3%, and 15.4% when exposed to 1%, 3%, and 5% HCL solution, respectively, compared to the water-cured sample. With the addition of SBA, the C-S loss was minimized. At 5% SBA content, the C-S of samples exposed to 1%, 3%, and 5% HCL solution was reduced by approximately 8.3%, 12.6%, and 13.4%, respectively, in comparison with the water-cured sample. Similarly, at the SBA proportion of 6% in samples, the C-S loss was observed to be 8.2%, 12.4%, and 14.3% when samples were cured in 1%, 3%, and 5% HCL solution. A similar trend was observed in C-S loss at all replacement levels of SBA, as the figure depicts. The authors concluded from the test results that an SBA content of 6% was the optimal substitute for M35 grade concrete. Several other studies also reported better performance of SBA concrete in an aggressive environment. Gupta et al. [108] investigated the resistance of SBA concrete in Na_2SO_4 solution experimentally. Samples cured in 1%, 3%, and 5% Na_2SO_4 solutions with SBA contents of 5%, 6%, 7%, 8%, 9%, and 10% by mass of cement were examined. It was observed that the addition of SBA to concrete not only protected it from sulphate attack but also enhanced its mechanical strength. Joshaghani [124] conducted an experimental study to determine the effect of SBA as partial replacement of cement on concrete's sulphate resistance. The parameter investigated in their study was the strength reduction of completely submerged concrete specimens in 5% $MgSO_4$ and 5% Na_2SO_4 solutions after 28, 90, 120, 180, and 360 days of curing. The results of the tests indicated that concrete specimens containing up to 25% SBA had a higher C-S than the control specimen, with the maximum C-S noted at a 20% SBA replacement. Additionally, the author demonstrated that weight loss was reduced in all SBA concrete specimens exposed to 5% sulphate, and the specimen comprising 20% SBA had the least weight loss compared to the control specimen. The increased resistance of SBA concrete to acidic environments is related to the enhanced microstructure created by the ultra-fine SBA particles, which reduce matrix porosity, and to the presence of highly reactive silica in SBA, which promotes the formation of hydration products.

7. Discussions on the optimal percentage of sugarcane bagasse ash

Previously, extensive research has been carried out on the utilization of SBA in CBCs, and various properties of the composites have been investigated at different replacement ratios of SBA. Mostly, enhancement in strength properties of composites was observed with SBA incorporation as SCM. However, there observed an optimal percentage of SBA at which the highest strength properties were noted, and beyond that amount, the strength of composites degraded. Researchers from distinct regions reported the optimal percentage replacement ratio of SBA in CBCs based on the strength properties resulted from experimental investigations. These optimal percentages reported in the literature have been compared in the present review. Table 8 shows the results of C-S, S-T-S, and F-S at different SBA contents, their percentage variation compared to the control mix, and the optimal SBA content, as reported in the literature. It was noted that most of the researchers found the optimal replacement ratio of SBA to be 10%, but some observed 5% and 15% SBA as the optimal replacement ratio in CBCs. So, this made clear that optimal SBA content lies in the range of 5–15% by cement mass. The improvement in strength properties of composites caused by SBA up to the optimal amount might be due to the two factors, including filler effect and pozzolanic reaction. The ultra-fine particles of SBA contribute to filling the voids in the matrix, reducing porosity, and improve the performance of the composite with a more compact and denser microstructure. Moreover, SBA contains highly reactive silica in its composition, making it a good pozzolanic material. The pozzolanic reaction between amorphous silica and

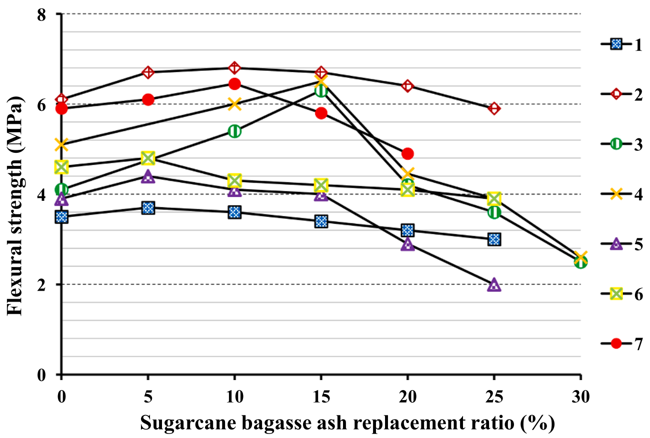


Fig. 17. Effect of sugarcane bagasse ash on flexural strength at 28-days (1) Srinivasan and Sathiya [86], (2) Priya and Ragupathy [15], (3) (4) Dhengare et al. [106] with M25 and M35 concrete, respectively, (5) Kiran and Kishore [107], (6) Ranjith et al. [112], (7) Rao and Prabath [104].

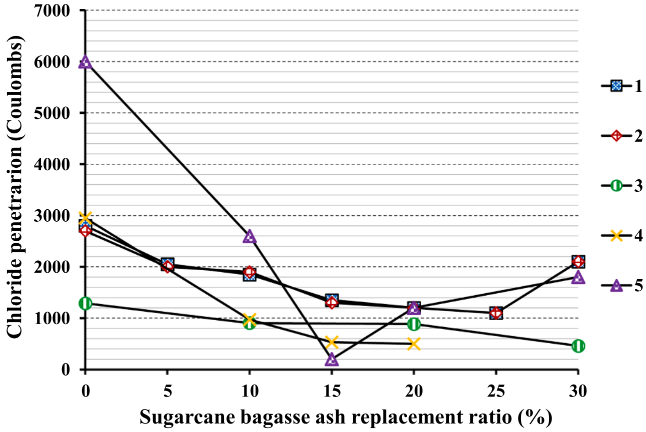


Fig. 18. Effect of sugarcane bagasse ash on chloride penetration (1) Ganesan et al. [26], (2) Amin [119], (3) Rukzon and Chindaprasirt [45], (4) Bahurudeen and Santhanam [120], (5) Rukzon and Chindaprasirt [121].

$Ca(OH)_2$ improves the growth of hydration products, making further improvement in the microstructure and ultimately enhances material strength. While the reason for the reduction in strength properties of composites at higher SBA replacement ratios is that the amount of pozzolanic material in the mix exceeds the amount required to combine with $Ca(OH)_2$, this results in excess silica leaching out and a strength deficiency because it acts as a binder substitute but does not contribute to strength. Additionally, it is possible that weak zones are caused by defects generated during SBA dispersion. Therefore, the utilization of SBA in CBCs as cement replacement is recommended in lower proportions, i.e., 5–15% by mass of cement.

8. Sustainability aspects of utilizing sugarcane bagasse ash in cement-based composites

Following the extraction of sugar from sugarcane, a larger fibrous waste material known as bagasse is left behind. When bagasse is burned in a power plant at a specific temperature for energy production, a large amount of ash known as SBA is produced. There is no valuable use of SBA, and it is usually disposed of in landfills. The problems associated with the disposal of SBA have been depicted in Fig. 21 (a). The dumping of this waste material in landfill areas may cause a dearth of useful areas and produce problems for waste management authorities. Additionally, when SBA contacts with water bodies, it results in contamination of water. Also, being in powder form, SBA can easily mix with air and pollute the atmosphere. Furthermore, SBA might affect the cultivable land if disposed of near agricultural lands. Thus, discarding SBA poses a serious threat to the natural environment and endangers human health. On the other hand, SBA comprises chemical compounds which are suitable for a pozzolanic material. The higher amount of amorphous silica in SBA makes it appropriate to be used as SCM in CBCs. The utilization of SBA in CBCs as partial replacement of cement would be a sustainable approach and may solve the aforementioned problems associated with SBA disposal in landfills. The advantages of SBA utilization in CBCs have been displayed in Fig. 21 (b). The main ingredient of CBCs is cement, but its production consumes a considerable amount of energy, causes natural resources depletion, and CO_2 emission to the environment. Therefore, utilizing SBA in place of cement in CBCs would decrease cement demand and solve these issues by producing sustainable construction materials. Additionally, incorporating SBA results in composites with improved strength properties, as discussed in the above sections, at a lower

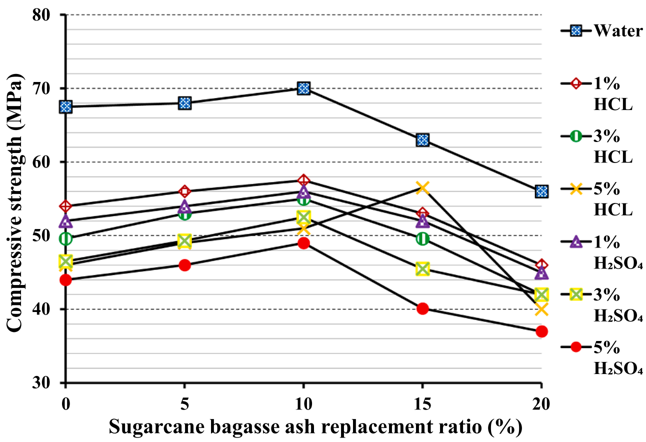


Fig. 19. Effect of sugarcane bagasse ash on 28-days compressive strength at different curing conditions [122].

cost. Moreover, with decreasing quantity of SBA disposal in landfill areas, the waste management problems can be reduced, and the natural environment can be protected.

9. Conclusions

The aim of this study was to carry out a scientometric and traditional manual review on the use of sugarcane bagasse ash (SBA) in cement-based composites (CBCs) as a step towards sustainability in construction. Scientometric analysis was used to determine the relevant study fields, the publication trend of articles, the most influential sources, the co-occurrence of keywords, the most cited articles and authors, and the active countries in the field of SBA utilization in CBCs. Additionally, the sustainable aspects of SBA use in construction materials as secondary cementitious material (SCM) were examined, as well as the effect of SBA on the performance of CBCs in the fresh and hardened state. Furthermore, the durability properties of composites containing SBA were reviewed. Conclusions have been drawn as follows:

- Scientometric analysis of the available data from the Scopus database revealed that Engineering, Materials Science, and Environmental Science accounted for 38.5%, 22.8%, and 10.5% of total documents, respectively, making them the top three areas. From 2007 to 2016, a gradual increase in the number of publications on the use of SBA in concrete was noticed. However, there has been a noticeable increase in the last five years (2016–2021). The top three journals by publication count were found to be Construction and building materials, international journal of civil engineering and technology, and journal of cleaner production with 36, 21, and 16 publications, respectively. The top five most frequently occurring keywords were identified as bagasse, compressive strength, concretes, bagasse ash, and sugarcane bagasse. Additionally, India, Brazil, and Thailand contributed the greatest number of publications to the current study's field of study.
- The presence of a higher amount of amorphous silica in SBA composition making it a good pozzolanic material and suitable to be used as SCM in CBCs. Therefore, it may contribute to sustainability in construction by decreasing cement demand, reducing CO_2 emissions, protecting natural resources, solving waste management problems, and preventing environmental pollution. Hence, a sustainable construction material can be produced by utilizing SBA in CBCs at a lower cost.
- When compared to conventional concrete, concrete containing SBA needed less water to achieve the same workability due to the glassy surface texture of SBA, and the water demand decreased as the SBA percentage replacement increased.
- The density of CBCs reduced with the addition of SBA due to the lower bulk density of SBA than cement. However, the reduced densities of SBA composites lie within the range of normal weight composites. Thus, SBA composites could be used in a variety of applications.
- The strength properties of CBCs improved with SBA addition up to an optimal amount, while further addition of SBA negatively impacted the strength properties. The optimal replacement ratio of SBA in CBCs was in the range of 5–15%. Utilizing the optimal content of SBA enhanced the strength properties of composites.
- The resistance to chloride penetration and acidic environment of CBC specimens could be improved due to the incorporation of SBA as SCM. The resistance offered was proportional to the amount of SBA used.

10. Recommendations for future research

Following a thorough investigation, additional research is essential to determine the behavior of SBA concrete structural members. Future studies may focus on the following:

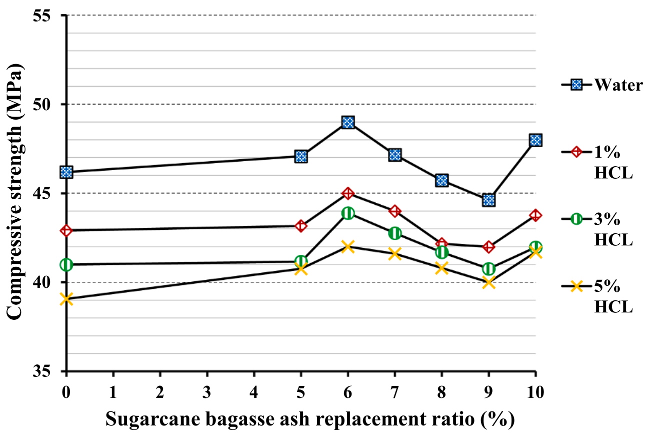


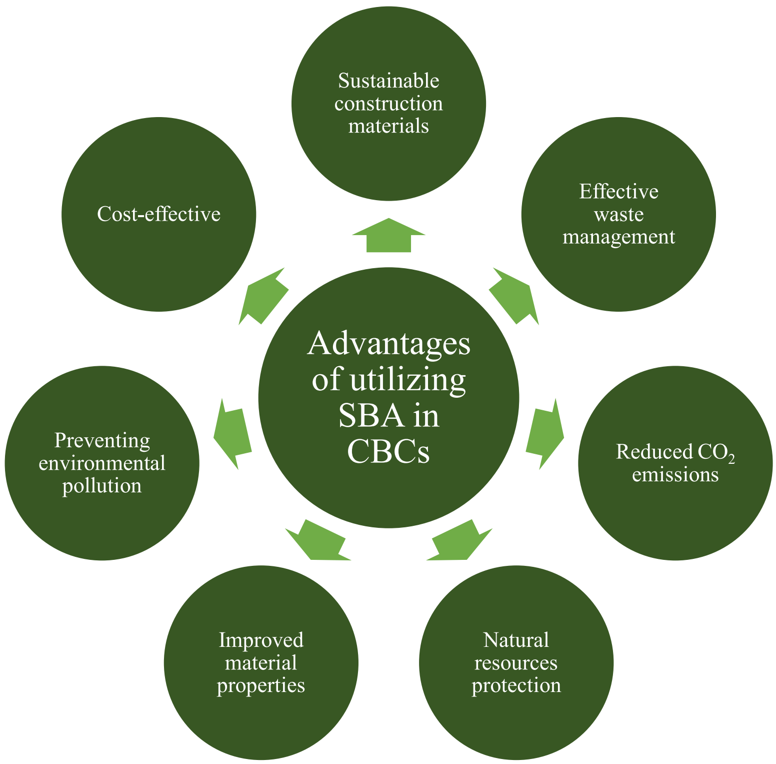
Fig. 20. Effect of sugarcane bagasse ash on 28-days compressive strength at different curing conditions [123].

Table 8
Optimal sugarcane bagasse ash in concrete based on mechanical strength.

Ref.	SBA (%)	C-S (MPa)	C-S variation (%)	S-T-S (MPa)	S-T-S variation (%)	F-S (MPa)	F-S variation (%)	Optimal SBA (%)
[86]	0	21.5		1.5		3.5		5
	5	29.5	+ 37.2	1.9	+ 26.7	3.7	+ 5.7	
	10	24.7	+ 14.9	1.6	+ 6.7	3.6	+ 2.9	
	15	19.3	-10.2	1.5	0.0	3.4	-2.9	
	20	18.9	-12.1	1.3	-13.3	3.2	-8.6	
	25	17.7	-17.7	1.2	-20.0	3	-14.3	
[15]	0	33.3		2.1		6.1		10
	5	37.4	+ 12.3	2.8	33.3	6.7	+ 9.8	
	10	38.1	+ 14.4	3.1	47.6	6.8	+ 11.5	
	15	36.8	+ 10.5	2.9	38.1	6.7	+ 9.8	
	20	35.8	+ 7.5	2.7	28.6	6.4	+ 4.9	
	25	30.1	-9.6	1.9	-9.5	5.9	-3.3	
[106]	0	24.45		2.8		4.1		15
	10	24.45	0.0	3.1	+ 10.7	5.4	+ 31.7	
	15	24.9	+ 1.8	3	+ 7.1	6.3	+ 53.7	
	20	19	-22.3	1.55	-44.6	4.2	+ 2.4	
	25	18.6	-23.9	1.4	-50.0	3.6	-12.2	
	30	18.3	-25.2	1.1	-60.7	2.5	-39.0	
[106]	0	31.1		3.25		5.1		15
	10	32	+ 2.9	3.25	0.0	6	+ 17.6	
	15	32	+ 2.9	3.4	+ 4.6	6.5	+ 27.5	
	20	30	-3.5	2.7	-16.9	4.45	-12.7	
	25	29	-6.8	2.1	-35.4	3.9	-23.5	
	30	26	-16.4	1.7	-47.7	2.6	-49.0	
[107]	0	39.5		1.3		3.9		5
	5	45.5	+ 15.2	1.4	+ 7.7	4.4	+ 12.8	
	10	43	+ 8.9	1.3	0.0	4.1	+ 5.1	
	15	39.7	+ 0.5	1.3	0.0	4	+ 2.6	
	20	30.1	-23.8	1.1	-15.4	2.9	-25.6	
	25	18.7	-52.7	0.9	-30.8	2	-48.7	
[112]	0	39.5		2.6		4.6		5
	5	40	+ 1.3	2.9	+ 11.5	4.8	+ 4.3	
	10	38	-3.8	2.4	-7.7	4.3	-6.5	
	15	37.6	-4.8	2.1	-19.2	4.2	-8.7	
	20	37	-6.3	1.8	-30.8	4.1	-10.9	
	25	36	-8.9	1.7	-34.6	3.9	-15.2	
[104]	0	36.18		2.55		5.9		10
	5	36.89	+ 2.0	2.59	+ 1.6	6.1	+ 3.4	
	10	37.52	+ 3.7	2.75	+ 7.8	6.45	+ 9.3	
	15	33.93	-6.2	2.25	-11.8	5.8	-1.7	
	20	30.07	-16.9	1.92	-24.7	4.9	-16.9	
[26]	0	37		4.5		–	–	10
	5	41	+ 10.8	4.75	+ 5.6	–	–	
	10	42	+ 13.5	4.85	+ 7.8	–	–	
	15	41	+ 10.8	4.95	+ 10.0	–	–	
	20	39	+ 5.4	4.8	+ 6.7	–	–	
	25	33	-10.8	4	-11.1	–	–	
	30	30	-18.9	3	-33.3	–	–	
[23]	0	32.67		3.18		–	–	20
	5	38.23	+ 17.0	3.17	-0.3	–	–	
	10	40.1	+ 22.7	3.83	+ 20.4	–	–	
	15	42.06	+ 28.7	3.98	+ 25.2	–	–	
	20	43.24	+ 32.4	3.81	+ 19.8	–	–	
[46]	0	37.2		3.2		–	–	10
	5	38.7	+ 4.0	3.3	+ 3.1	–	–	
	10	40.3	+ 8.3	3.4	+ 6.3	–	–	
	15	22	-40.9	2.7	-15.6	–	–	
	20	19.6	-47.3	2.5	-21.9	–	–	
[51]	0	33.8		3.4		–	–	–
	5	32.1	-5.0	3.3	-2.9	–	–	
	10	30.5	-9.8	3.2	-5.9	–	–	
	15	28.1	-16.9	3	-11.8	–	–	
	20	25.4	-24.9	2.8	-17.6	–	–	

- The examination of the structural behavior of a material suitable for usage in CBCs will be incomplete without examination of steel-reinforced SBA concrete beams and slabs. The properties such as stiffness, flexural behavior, crack formation, shear properties, and stress-strain behavior are intimated for future research.

(a)



(b)

(caption on next page)

Fig. 21. Sugarcane bagasse ash: (a) Problems with disposal; (b) Advantages of utilization in cement-based composites.

- Currently, considerable research has been conducted on the C-S of SBA composites, but little research has been conducted on the S-T-S and F-S, as well as the development of ratios between C-S, S-T-S, and elastic modulus. As a result, these are suggested for additional and confirmatory studies.
- There is a requirement to evaluate the long-term durability of SBA composites before their practical utilization in construction materials. Additionally, creep, drying shrinkage, bond strength, and elastic modulus are not well defined and recommended for new research.
- There is a dearth of information on the properties and performance of reinforced pre-stressed concrete beams containing SBA when subjected to static loading. It is required to investigate this in greater detail under static and fatigue loading conditions.
- Only a few studies on the utilization of micro and nano SBA in ultra-high-performance concrete are available where future research may focus.
- There is no study conducted on the sorptivity of SBA composites, which can be evaluated in greater detail.
- Numerical/analytical models need to be developed for the calculation of various mechanical properties of CBCs incorporating SBA in different proportions.
- The different chemical compositions of SBA used in CBCs have a distinct influence on their mechanical properties. Therefore, research needs to be conducted to develop a relation between variation in mechanical properties with the chemical composition of SBA.
- It is required to apply computer software tools like the machine learning approach to predict the behavior of CBCs utilizing SBA as partial replacement of cement.
- Most of the past research has been conducted on the utilization of SBA in lower replacement ratios. Future research may focus on the high-volume utilization of SBA in construction materials like geopolymers.
- While significant research has been conducted on the usage of SBA in CBCs, much more work is required to determine the commercial utility of SBA composites in construction.

CRediT authorship contribution statement

W.A.: Conceptualization, Methodology, Investigation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **A.A.:** Data acquisition, Methodology, Formal analysis, Supervision, Writing – review & editing. **K.A.O.:** Funding acquisition, Methodology, Supervision, Writing – review & editing. **F.A.:** Conceptualization, Methodology, Formal analysis, Writing – review & editing. **P.J.:** Data acquisition, Methodology, Formal analysis, Writing – review & editing. **P.Z:** Funding acquisition, Data analysis, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] K.I.M. Ibrahim, Recycled waste glass powder as a partial replacement of cement in concrete containing silica fume and fly ash, Case Stud. Constr. Mater. 15 (2021), e00630.
[2] M. Amiri, F. Hatami, E.M. Golafshani, Evaluating the synergic effect of waste rubber powder and recycled concrete aggregate on mechanical properties and durability of concrete, Case Stud. Constr. Mater. 15 (2021), e00639.
[3] M.Z. Islam, K.M.A. Sohel, K. Al-Jabri, A. Al, Harthy, properties of concrete with ferrochrome slag as a fine aggregate at elevated temperatures, Case Stud. Constr. Mater. 15 (2021), e00599.
[4] S.H. Chu, A.K.H. Kwan, Mixture design of self-levelling ultra-high performance FRC, Constr. Build. Mater. 228 (2019), 116761.
[5] S.H. Chu, H. Ye, L. Huang, L.G. Li, Carbon fiber reinforced geopolymer (FRG) mix design based on liquid film thickness, Constr. Build. Mater. 269 (2021), 121278.
[6] M. Khan, M. Ali, Use of glass and nylon fibers in concrete for controlling early age micro cracking in bridge decks, Constr. Build. Mater. 125 (2016) 800–808.
[7] M.M.D. Seth, B. Kvgd, S. Chilukoti, Influence of PVC waste powder and silica fume on strength and microstructure properties of concrete: an experimental study, Case Stud. Constr. Mater. 15 (2021), e00610.
[8] H.M. Al-Baghdadi, Experimental study on sulfate resistance of concrete with recycled aggregate modified with polyvinyl alcohol (PVA), Case Stud. Constr. Mater. 14 (2021), e00527.
[9] W. Ahmad, S.H. Farooq, M. Usman, M. Khan, A. Ahmad, F. Aslam, R.A. Yousef, H.A. Abduljabbar, M. Sufian, Effect of coconut fiber length and content on properties of high strength concrete, Materials 13 (5) (2020) 1075.
[10] M. Khan, M. Ali, Effectiveness of hair and wave polypropylene fibers for concrete roads, Constr. Build. Mater. 166 (2018) 581–591.
[11] M. Khan, M. Cao, M. Ali, Cracking behaviour and constitutive modelling of hybrid fibre reinforced concrete, J. Build. Eng. 30 (2020), 101272.
[12] M. Khan, M. Cao, C. Xie, M. Ali, Efficiency of basalt fiber length and content on mechanical and microstructural properties of hybrid fiber concrete, Fatigue Fract. Eng. Mater. Struct. (2021).

[13] M. Khan, M. Cao, X. Chaopeng, M. Ali, Experimental and analytical study of hybrid fiber reinforced concrete prepared with basalt fiber under high temperature, Fire Mater. (2021).
[14] P. Hosseini, A. Booshehrian, M. Delkash, S. Ghavami, M.K. Zanjani, Use of nano-SiO 2 to improve microstructure and compressive strength of recycled aggregate concretes. Nanotechnology in Construction 3, Springer, 2009, pp. 215–221.
[15] K.L. Priya, R. Ragupathy, Effect of sugarcane bagasse ash on strength properties of concrete, Int. J. Res. Eng. Technol. 5 (4) (2016) 159–164.
[16] J. Alex, J. Dhanalakshmi, B. Ambedkar, Experimental investigation on rice husk ash as cement replacement on concrete production, Constr. Build. Mater. 127 (2016) 353–362.
[17] O. Akashi, T. Hanaoka, Y. Matsuoka, M. Kainuma, A projection for global CO_2 emissions from the industrial sector through 2030 based on activity level and technology changes, Energy 36 (4) (2011) 1855–1867.
[18] R. Madeleine, Emissions from the Cement Industry, Earth Institute, Columbia University,, Columbia, 2012.
[19] K.V. Teja, P.P. Sai, T. Meena, Investigation on the behaviour of ternary blended concrete with scba and sf, IOP Conference Series: Materials Science and Engineering, IOP Publishing, 2017, p. 032012.
[20] Z. Bayasi, J. Zhou, Properties of silica fume concrete and mortar, Mater. J. 90 (4) (1993) 349–356.
[21] A. Cleetus, R. Shibu, P.M. Sreehari, V.K. Paul, B. Jacob, Analysis and study of the effect of GGBFS on concrete structures, International Research Journal of Engineering and Technology (IRJET), Mar Athanasius College of Engineering, Kerala, India (2018).
[22] E. Özbay, M. Erdemir, H.İ. Durmuş, Utilization and efficiency of ground granulated blast furnace slag on concrete properties–a review, Constr. Build. Mater. 105 (2016) 423–434.
[23] P. Mamatha, D. Narayana, T.N. Kumar, To evaluate the mechanical & durability properties of nano sugarcane bagasse ash in cement concrete, Int. J. Sci. Res. Sci. Technol. 3 (8) (2017) 425–430.
[24] M.C.G. Juenger, R. Snellings, S.A. Bernal, Supplementary cementitious materials: new sources, characterization, and performance insights, Cem. Concr. Res. 122 (2019) 257–273.
[25] K. Li, M. Qin, Q. Gui, Durability properties of structural concretes containing secondary cementitious materials, Green Mater. 7 (1) (2018) 40–51.
[26] K. Ganesan, K. Rajagopal, K. Thangavel, Evaluation of bagasse ash as supplementary cementitious material, Cem. Concr. Compos. 29 (6) (2007) 515–524.
[27] S. Loganayagan, N.C. Mohan, S. Dhivyabharathi, Sugarcane bagasse ash as alternate supplementary cementitious material in concrete, Mater. Today: Proc. 45 (2021) 1004–1007.
[28] M.F.M. Zain, M.N. Islam, F. Mahmud, M. Jamil, Production of rice husk ash for use in concrete as a supplementary cementitious material, Constr. Build. Mater. 25 (2) (2011) 798–805.
[29] L. Tosti, A. van Zomeren, J.R. Pels, A. Damgaard, R.N.J. Comans, Life cycle assessment of the reuse of fly ash from biomass combustion as secondary cementitious material in cement products, J. Clean. Prod. 245 (2020), 118937.
[30] P. Zhang, W. Liao, A. Kumar, Q. Zhang, H. Ma, Characterization of sugarcane bagasse ash as a potential supplementary cementitious material: Comparison with coal combustion fly ash, J. Clean. Prod. 277 (2020), 123834.
[31] Jd.S.A. Neto, M.J.S. de França, N.S. de Amorim Junior, D.V. Ribeiro, Effects of adding sugarcane bagasse ash on the properties and durability of concrete, Constr. Build. Mater. 266 (2021), 120959.
[32] M. Khan, M. Ali, Improvement in concrete behavior with fly ash, silica-fume and coconut fibres, Constr. Build.Mater. 203 (2019) 174–187.
[33] B.A. Tayeh, M. Hadzima-Nyarko, A.M. Zeyad, S.Z. Al-Harazin, Properties and durability of concrete with olive waste ash as a partial cement replacement, Adv. Concr. Constr. 11 (1) (2021) 59–71.
[34] S. Alkheder, Y.T. Obaidat, M. Taamneh, Effect of olive waste (Husk) on behavior of cement paste, Case Stud. Constr. Mater. 5 (2016) 19–25.
[35] E. Arici, E. Çelik, O. Keleştemur, An analysis of the engineering properties of mortars containing corn cob ash and polypropylene fiber using the taguchi and taguchi-based grey relational analysis methods, Case Stud. Constr. Mater. (2021), e00652.
[36] T.F. Awolusi, A.O. Sojobi, D.O. Oguntayo, O.O. Akinkurolere, B.O. Orogbade, Effects of calcined clay, sawdust ash and chemical admixtures on strength and properties of concrete for pavement and flooring applications using taguchi approach, Case Stud. Constr. Mater. 15 (2021), e00568.
[37] M. Adamu, K.O. Ayeni, S.I. Haruna, Y.E.-H. Ibrahim Mansour, S. Haruna, Durability performance of pervious concrete containing rice husk ash and calcium carbide: a response surface methodology approach, Case Stud. Constr. Mater. 14 (2021), e00547.
[38] A. Bicer, The effect of fly ash and pine tree resin on thermo-mechanical properties of concretes with expanded clay aggregates, Case Stud. Constr. Mater. 15 (2021), e00624.
[39] D. Dodoo-Arhin, R.A. Nuamah, B. Agyei-Tuffour, D.O. Obada, A. Yaya, Awaso bauxite red mud-cement based composites: characterisation for pavement applications, Case Stud. Constr. Mater. 7 (2017) 45–55.
[40] K. Viyasun, R. Anuradha, K. Thangapandi, D.S. Kumar, A. Sivakrishna, R. Gobinath, Investigation on performance of red mud based concrete, Mater. Today: Proc. 39 (2021) 796–799.
[41] A.M.T. Bagger, W. Kunther, N.M. Sigvardsen, P.E. Jensen, Screening for key material parameters affecting early-age and mechanical properties of blended cementitious binders with mine tailings, Case Stud. Constr. Mater. 15 (2021), e00608.
[42] H. Ma, H. Zhu, C. Wu, H. Chen, J. Sun, J. Liu, Study on compressive strength and durability of alkali-activated coal gangue-slag concrete and its mechanism, Powder Technol. 368 (2020) 112–124.
[43] D. Shen, K. Liu, C. Wen, Y. Shen, G. Jiang, Early-age cracking resistance of ground granulated blast furnace slag concrete, Constr. Build. Mater. 222 (2019) 278–287.
[44] P.V. Rambabu, K.D. Gupta, G.V. Ramarao, Effect of sulphates (Na2So4) on concrete with sugarcane bagasse ash as a pozzolana, Int. J. Eng. Appl. Sci. 3 (1) (2016), 257749.
[45] S. Rukzon, P. Chindaprasirt, Utilization of bagasse ash in high-strength concrete, Mater. Des. 34 (2012) 45–50.
[46] M. Inbasekar, P. Hariprasath, D. Senthilkumar, Study on potential utilization of sugarcane bagasse ash in steel fiber reinforced concrete, Int. J. Eng. Sci. Res. Technol. (2016).
[47] A.A.E. Hussein, N. Shafiq, M.F. Nuruddin, F.A. Memon, Compressive strength and microstructure of sugar cane bagasse ash concrete, Res. J. Appl. Sci. Eng. Technol. 7 (12) (2014) 2569–2577.
[48] K.S. Sohal, R. Singh, Sustainable Use of Sugarcane Bagasse Ash in Concrete Production, Springer Singapore,, 2021, pp. 397–407.
[49] K.R. Venkatesh, R. Rani, Experimental study on partial replacement of cement with sugaecane bagasse ash in concrete, Int. J. Adv. Eng. Res. Dev. 5 (04) (2018) 778–785.
[50] M.M.N.S. de Soares, D.C.S. Garcia, R.B. Figueiredo, M.T.P. Aguilar, P.R. Cetlin, Comparing the pozzolanic behavior of sugar cane bagasse ash to amorphous and crystalline SiO2, Cem. Concr. Compos. 71 (2016) 20–25.
[51] A. Kumari, S. Kumar, Experimental study on partial replacement of cement by sugaracne bagasse ash, Int. J. Innov. Res. Sci. Eng. Technol. 4 (7) (2015) 2347–6710.
[52] K.V. Ramesh, R. Goutham, S. Kishor, An experimental study on partial replacement of bagasse ash in basalt concrete mix, Int. J. Civil Eng. Technol. ((IJCIET)) 8 (5) (2017) 335–341.
[53] P.O. Modani, M.R. Vyawahare, Utilization of bagasse ash as a partial replacement of fine aggregate in concrete, Procedia Eng. 51 (2013) 25–29.
[54] A. Goyal, A.M. Anwar, H. Kunio, O. Hidehiko, Properties of sugarcane bagasse ash and its potential as cement-pozzolana binder, Twelfth International Colloquium on Structural and Geotechnical Engineering, 2007, pp. 10–12.
[55] M. Safayat, M. Islam, B.A. Rubieyat, M. Hasan, Investigation on the workability and compressive strength of concrete by using bagasse ash from sugar mill, World Sci. News 96 (2018) 191–201.
[56] A. Samariha, A. Khakifirooz, Application of NSSC pulping to sugarcane bagasse, BioResources 6 (3) (2011) 3313–3323.
[57] W. Ahmad, A. Ahmad, K.A. Ostrowski, F. Aslam, P. Joyklad, A scientometric review of waste material utilization in concrete for sustainable construction, Case Stud. Constr. Mater. 15 (2021), e00683.

[58] Y. Xu, J. Zeng, W. Chen, R. Jin, B. Li, Z. Pan, A holistic review of cement composites reinforced with graphene oxide, Constr. Build. Mater. 171 (2018) 291–302.
[59] X. Xiao, M. Skitmore, H. Li, B. Xia, Mapping knowledge in the economic areas of green building using scientometric analysis, Energies 12 (15) (2019) 3011.
[60] O. Mryglod, Y. Holovatch, R. Kenna, Data mining in scientometrics: usage analysis for academic publications, 2018 IEEE Second International Conference on Data Stream Mining & Processing (DSMP), IEEE, 2018, pp. 241–246.
[61] A. Darko, A.P. Chan, X. Huo, D.-G. Owusu-Manu, A scientometric analysis and visualization of global green building research, Build. Environ. 149 (2019) 501–511.
[62] J. Song, H. Zhang, W. Dong, A review of emerging trends in global PPP research: analysis and visualization, Scientometrics 107 (3) (2016) 1111–1147.
[63] M.R. Hosseini, I. Martek, E.K. Zavadskas, A.A. Aibinu, M. Arashpour, N. Chileshe, Critical evaluation of off-site construction research: a scientometric analysis, Autom. Constr. 87 (2018) 235–247.
[64] H. Liao, M. Tang, L. Luo, C. Li, F. Chiclana, X.-J. Zeng, A bibliometric analysis and visualization of medical big data research, Sustainability 10 (1) (2018) 166.
[65] A. Aghaei Chadegani, H. Salehi, M. Yunus, H. Farhadi, M. Fooladi, M. Farhadi, N. Ale Ebrahim, A comparison between two main academic literature collections: Web of Science and Scopus databases, Asian Soc. Sci. 9 (5) (2013) 18–26.
[66] E.M.L. Bergman, Finding citations to social work literature: the relative benefits of using Web of Science, Scopus, or Google Scholar, J. Acad. Librariansh. 38 (6) (2012) 370–379.
[67] L.I. Meho, Using Scopus's CiteScore for assessing the quality of computer science conferences, J. Informetr. 13 (1) (2019) 419–433.
[68] J. Zuo, Z.-Y. Zhao, Green building research–current status and future agenda: a review, Renew. Sustain. Energy Rev. 30 (2014) 271–281.
[69] A. Darko, C. Zhang, A.P. Chan, Drivers for green building: a review of empirical studies, Habitat Int. 60 (2017) 34–49.
[70] W. Ahmad, M. Khan, P. Smarzewski, Effect of short fiber reinforcements on fracture performance of cement-based materials: a systematic review approach, Materials 14 (7) (2021) 1745.
[71] M.P. Markoulli, C.I. Lee, E. Byington, W.A. Felps, Mapping human resource management: reviewing the field and charting future directions, Hum. Resour. Manag. Rev. 27 (3) (2017) 367–396.
[72] A.B. Saka, D.W. Chan, A scientometric review and metasynthesis of building information modelling (BIM) research in Africa, Buildings 9 (4) (2019) 85.
[73] S. Goulden, E. Erell, Y. Garb, D. Pearlmutter, Green building standards as socio-technical actors in municipal environmental policy, Build. Res. Inf. 45 (4) (2017) 414–425.
[74] R. Jin, S. Gao, A. Cheshmehzangi, E. Aboagye-Nimo, A holistic review of off-site construction literature published between 2008 and 2018, J. Clean. Prod. 202 (2018) 1202–1219.
[75] J.Y. Park, Z. Nagy, Comprehensive analysis of the relationship between thermal comfort and building control research-a data-driven literature review, Renew. Sustain. Energy Rev. 82 (2018) 2664–2679.
[76] M. Oraee, M.R. Hosseini, E. Papadonikolaki, R. Palliyaguru, M. Arashpour, Collaboration in BIM-based construction networks: a bibliometric-qualitative literature review, Int. J. Project Manage. 35 (7) (2017) 1288–1301.
[77] N.J. Van Eck, L. Waltman, Software survey: VOSviewer, a computer program for bibliometric mapping, Scientometrics 84 (2) (2010) 523–538.
[78] I.Y. Wuni, G.Q. Shen, R. Osei-Kyei, Scientometric review of global research trends on green buildings in construction journals from 1992 to 2018, Energy Build. 190 (2019) 69–85.
[79] H.-N. Su, P.-C. Lee, Mapping knowledge structure by keyword co-occurrence: a first look at journal papers in technology foresight, Scientometrics 85 (1) (2010) 65–79.
[80] F. Yu, B.E. Hayes, Applying data analytics and visualization to assessing the research impact of the Cancer Cell Biology (CCB) Program at the University of North Carolina at Chapel Hill, J. Sci. Librariansh. 7 (1) (2018) 4.
[81] G.C. Cordeiro, R.D. Toledo Filho, L.M. Tavares, E.M.R. Fairbairn, Pozzolanic activity and filler effect of sugar cane bagasse ash in Portland cement and lime mortars, Cem. Concr. Compos. 30 (5) (2008) 410–418.
[82] G.C. Cordeiro, R.D. Toledo Filho, L.M. Tavares, Ed.M.R. Fairbairn, Ultrafine grinding of sugar cane bagasse ash for application as pozzolanic admixture in concrete, Cem. Concr. Res. 39 (2) (2009) 110–115.
[83] N. Chusilp, C. Jaturapitakkul, K. Kiattikomol, Utilization of bagasse ash as a pozzolanic material in concrete, Constr. Build. Mater. 23 (11) (2009) 3352–3358.
[84] A. C618-08a, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete, ASTM International,, West Conshohocken, PA, 2008.
[85] K.S. Subramaniyan, M. Sivaraja, Assessment of sugarcane bagasse ash concrete on mechanical and durability properties, Adv. Nat. Appl. Sci. 10 (9 SE) (2016) 253–261.
[86] R. Srinivasan, K. Sathiya, Experimental study on bagasse ash in concrete, Int. J. Serv. Learn. Eng. Humanitarian Eng. Soc. Entrepreneurship 5 (2) (2010) 60–66.
[87] S.A. Mangi, N. Jamaluddin, M.H.W. Ibrahim, A.S.M.A. Awal, S. Sohu, N. Ali, Utilization of sugarcane bagasse ash in concrete as partial replacement of cement, IOP Conference Series: Materials Science and Engineering, IOP Publishing, Malaysia, 2017, p. 012001.
[88] N. Shafiq, A.A.E. Hussein, M.F. Nuruddin, H. Al Mattarneh, effects of sugarcane bagasse ash on the properties of concrete, Proceedings of the Institution of Civil Engineers - Engineering Sustainability, Thomas Telford Ltd, 2018, pp. 123–132.
[89] A. Bahurudeen, A.V. Marckson, A. Kishore, M. Santhanam, Development of sugarcane bagasse ash based Portland pozzolana cement and evaluation of compatibility with superplasticizers, Constr. Build. Mater. 68 (2014) 465–475.
[90] M.K. Idris, K. Eldin, E. Yassin, Determination of the effects of bagasse ash on the properties of portland cement, J. Appl. Ind. Sci. 3 (2015) 6–11.
[91] D.B. Patel, H. Lad, S. Priyank, B. Garasia, Experiment study on strength characteristics of concrete using bagasse ash, Int. Res. J. Eng. Technol. ((IRJET)) 5 (5) (2018) 3699–3703.
[92] T.S. Abdulkadir, D.O. Oyejobi, A.A. Lawal, Evaluation of sugarcane bagasse ash as a replacement for cement in concrete works, Acta Tech Corvin. Bull. Eng. 7 (3) (2014) 71.
[93] E. Basika, J. Kigozi, N. Kiggundu, Investigation of sugar cane bagasse ash as a binding material for the construction industry, J. Global Ecol. Environ. 2 (4) (2015) 205–208.
[94] U.R. Kawade, V.R. Rathi, V.D. Girge, Effect of use of bagasse ash on strength of concrete, Int. J. Innov. Res. Sci. Eng. Technol. 2 (7) (2013) 2997–3000.
[95] S.A. Shivakumar, M.N. Karthik, S.I. Sidramappa, Studies on mechanical properties of concrete using Sugarcane Bagasse Ash (Scba), J. Mech. Civil Eng. 5 (3) (2008) 33–37.
[96] M. Aslam, P. Shafigh, M.Z. Jumaat, Oil-palm by-products as lightweight aggregate in concrete mixture: a review, J. Clean. Prod. 126 (2016) 56–73.
[97] K. Ganesan, K. Rajagopal, K. Thangavel, Rice husk ash blended cement: assessment of optimal level of replacement for strength and permeability properties of concrete, Constr. Build. Mater. 22 (8) (2008) 1675–1683.
[98] V.D. Katare, M.V. Madurwar, Experimental characterization of sugarcane biomass ash–a review, Constr. Build. Mater. 152 (2017) 1–15.
[99] A. Bahurudeen, M. Santhanam, Influence of different processing methods on the pozzolanic performance of sugarcane bagasse ash, Cem. Concr. Compos. 56 (2015) 32–45.
[100] R. Embong, N. Shafiq, A. Kusbiantoro, M.F. Nuruddin, Effectiveness of low-concentration acid and solar drying as pre-treatment features for producing pozzolanic sugarcane bagasse ash, J. Clean. Prod. 112 (2016) 953–962.
[101] C. Fapohunda, B. Akinbile, A. Shittu, Structure and properties of mortar and concrete with rice husk ash as partial replacement of ordinary Portland cement–a review, Int. J. Sustain. Built Environ. 6 (2) (2017) 675–692.
[102] N.K. Krishna, S. Sandeep, K.M. MiniStudy on concrete with partial replacement of cement by rice husk ash, IOP Conference Series: Materials Science and Engineering, IOP Publishing, 2016, p. 012109.
[103] P. Jagadesh, A. Ramachandramurthy, R. Murugesan, Evaluation of mechanical properties of sugar cane bagasse ash concrete, Constr. Build. Mater. 176 (2018) 608–617.
[104] M. Rao, N.V.N. Prabath, Green concrete using agro industrial waste (sugarcane bagasse ASH), Int. J. Soft Comput. Eng. 5 (1) (2015) 86–92.

[105] A. Ahmed, O.A.U. Uche, M.T. Abdulwahab, N.U. Amali, Mechanical properties of sugarcane straw waste ash used as binder in concrete production, FUW Trends Sci. Technol. J. 4 (1) (2019) 247–249.
[106] S.W. Dhengare, S.P. Raut, N.V. Bandwal, A. Khangan, Investigation into utilization of sugarcane bagasse ash as supplementary cementitious material in concrete, Int. J. 3 (2015) 109.
[107] K. Kiran, I.S. Kishore, An experimental study on partial replacement of cement with bagasse ash in concrete mix, Int. J. Civil Eng. Technol. 8 (1) (2017) 452–455.
[108] R.B. Gupta, K. Chandraul, M.K. Singh, Experimental study on strength of concrete using sugar cane bagasse ash, Int. Res. J. Eng. Technol. 4 (6) (2017) 2392–2395.
[109] A.A.E. Hussein, N. Shafiq, M.F. NuruddinCompressive strength and interfacial transition zone of sugar cane bagasse ash concrete: a comparison to the established pozzolans, International Conference on Mathematics, Engineering and Industrial Applications, AIP Publishing LLC, 2015, p. 070002.
[110] J.A. Patel, D. Raijiwala, Experimental study on compressive strength of concrete by partially replacement of cement with sugar cane bagasse ash, Int. J. Eng. Res. Appl. 5 (4) (2015).
[111] M.R. Shatat, Hydration behavior and mechanical properties of blended cement containing various amounts of rice husk ash in presence of metakaolin, Arab. J. Chem. 9 (2016) S1869–S1874.
[112] A. Ranjith, J. Sanjith, B.M. Kiran, Experimental investigation on performance of sugarcane bagasse ash concrete in acidic environment, Indexed in Scopus Compendex and Geobase Elsevier, Chemical Abstract Services-USA, Geo-Ref Information Services-USA, List B of Scientific Journals, Poland, Direct. Res. J. 8 (02) (2015) 471–476.
[113] J.F.M. Hernández, B. Middendorf, M. Gehrke, H. Budelmann, Use of wastes of the sugar industry as pozzolana in lime-pozzolana binders: study of the reaction, Cem. Concr. Res. 28 (11) (1998) 1525–1536.
[114] N.B. Singh, V.D. Singh, S. Rai, Hydration of bagasse ash-blended portland cement, Cem. Concr. Res. 30 (9) (2000) 1485–1488.
[115] J.F. Martirena-Hernandez, S. Betancourt-Rodriguez, B. Middendorf, A. Rubio, J. Martinez-Fernandez, J.M. López, R. González-López, Pozzolanic properties of residues of sugar industries (first part), Mater. Constr. 50 (260) (2000) 71–78.
[116] J.F. Martirena-Hernández, S. Betancourt-Rodriguez, B. Middendorf, A. Rubio, L. Martínez-Fernández, I.M. López, R. González-López, Pozzolanic properties of residues of sugar industries (second part), Mater. Constr. 51 (261) (2001) 67–72.
[117] J. Payá, J. Monzó, M.V. Borrachero, L. Díaz-Pinzón, L.M. Ordonez, Sugar-cane bagasse ash (SCBA): studies on its properties for reusing in concrete production, J. Chem. Technol. Biotechnol. Int. Res. Process Environ. Clean Technol. 77 (3) (2002) 321–325.
[118] S.N. Bhargavi, Y.B. Anand, Study on concrete with sugarcane bagasse ash as a partial replacement of cement using HCL solution, Int. J. Sci. Eng. Technol. Res. 5 (16) (2016) 3363–3369.
[119] N.-u Amin, Use of bagasse ash in concrete and its impact on the strength and chloride resistivity, J. Mater. Civil Eng. 23 (5) (2011) 717–720.
[120] A. Bahurudeen, M. Santhanam, Performance evaluation of sugarcane bagasse ash-based cement for durable concrete, 4th International Conference on the Durability of Concrete Structures 24(26) (2014) 275–281.
[121] S. Rukzon, P. Chindaprasirt, Strength, Chloride penetration and corrosion resistance of ternary blends of portland cement self-compacting concrete containing bagasse ash and rice husk-bark ash, Chiang Mai J. Sci. 45 (4) (2018) 1863–1874.
[122] P.V. Rambabu, G.V.R. Rao, Study on sugarcane bagasse ash as a partial replacement of cement in M60 grade concrete exposed to acidic environment, SSRG, Int. J. Civil Eng. 4 (9) (2017).
[123] P.V. Rambabu, G. Aditya, G.V. Ramarao, Effect of acidic environment (HCL) on concrete with sugarcane bagasse ash as pozzolona, Int. J. Eng. Res. Appl. 5 (11) (2015) 59–64.
[124] A. Joshaghani, The evaluation of sugarcane bagasse ash (scba) as supplementary cementitious materials on sulfate resistance of concrete. Concrete and Concrete Structures, 2017, pp. 152–178.