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FORMULATIONS FOR USING ACTIVATED CARBON IN THE PRODUCTION OF CEMENT: A REVIEW

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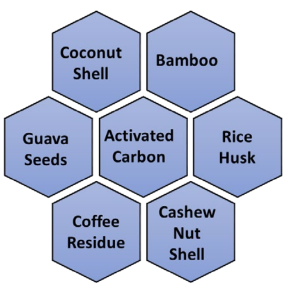
Graphical abstract



Abstract

Activated carbon, distinguished for its exceptional adsorption characteristics, is progressively being investigated for novel applications that extend beyond its conventional functions in the purification of water and air. Within the domain of construction materials, activated carbon has demonstrated encouraging potential in cementitious composites. This paper reviews various applications of activated carbon in cement production and the benefits it brings, including enhanced durability and environmental sustainability. The review covers research articles from 2003 to 2023 indexed in ISI Web of Science and Scopus. Studies indicate that activated carbon is employed in cement composites primarily as an aggregate, additional binder, or additive. As an additional binder, it augments mechanical characteristics including tensile and flexural strength, attributable to its substantial surface area and pore architecture that facilitates enhanced interfacial adhesion with the cement matrix. The inherent porous attributes of activated carbon significantly augment its self-regenerative capabilities through the entrapment and degradation of organic contaminants, thereby extending the longevity of the material. Moreover, fiber-reinforced concrete's chemical endurance has been shown to be improved by activated carbon, which also reduces permeability and shrinkage in lightweight concrete formulations. This comprehensive review further investigates prospective future applications of activated carbon within the realms of cement and concrete technologies.

Keywords: Activated Carbon; cement Formulations; mechanical properties; thermal efficiency; sustainability

1.0 INTRODUCTION

The increased need for creative and ecologically friendly cementitious materials has led to a recent growth in the usage of activated carbon in cement compositions (Althoey et al., 2023). Activated carbon is a versatile material that finds application in energy storage, materials research, and environmental remediation It's a creative way to improve the performance and usefulness of cement-based materials. The most comprehensive summary available covers the quickly evolving topic of activated carbon in cement composites, covering the most recent research, applications, challenges, and possible advancements in the future (Sharma et al., 2022). Cement, one of the construction materials used worldwide, is crucial to economic growth, infrastructural development, and urbanization. Since the process of making cement requires a lot of energy, creates CO2, and depletes natural resources, it inevitably has a negative impact. To address these issues, inventive solutions must be created as well as advanced technology must be included into cementitious materials (Ahmed Ali et al., 2020). Activated carbon has vast surface area, porous structure, and ability to absorb gases, liquids, and dissolved compounds make it a valuable tool for enhancing the properties and functionalities of cement composites. Enhancing the strength, durability, pollutant collection, and multifunctional performance of materials is the aim of incorporating activated carbon into matrices made of cement (Makul, 2020) . In cement composites, activated carbon can be used as an aggregate, extra binder, or additive, as research over the last 20 years has shown. Activated carbon improves interfacial adhesion inside the cement matrix, which improves concrete's mechanical qualities including tensile and flexural strength when used as an extra binder. The durability and lifespan of cement-based products are also increased by its porous character, which aids in self-regenerative properties by allowing the trapping and degradation of organic pollutants. Notably, research has demonstrated that activated carbon can improve chemical resistance in fiber-reinforced formulations, promote permeability, and limit shrinkage in lightweight concrete.

This study offers a thorough analysis of the developments in the use of activated carbon in cement manufacturing, covering studies that were published from 2003 to 2023. The revolutionary potential of activated carbon in addressing major difficulties in cement and concrete technologies is highlighted in this study, which synthesizes findings from top publications indexed in ISI Web of Science and Scopus. Future prospects for using activated carbon to promote high-performance and environmentally friendly building materials are also covered.

2.0 METHODOLOGY

Particularly in cement compounds, activated carbon has experienced a boom in inventive applications in the field of building materials in recent years. There are several benefits to this integration, spanning from increased robustness to ecological sustainability. The successes of these initiatives for sustainability will be addressed in this paper, along with other applications of activated carbon in cement designs. This review includes research publications with keywords like mechanical properties, cement compounds, activated carbon, and sustainable thermal performance that were published between 2003 and 2023 and are included in the Scopus and the International Society of Science indexes. The assessed studies indicate that activated carbon has primarily been used as an addition, aggregate, and extra binder in cement formulations. But other literary works, including books, seminars, editor's letters, review articles, and research articles, that were released before to 2003 were left out. Articles that included any of the following were not accepted: First, activated carbon that has been altered to include organic compounds and nanoparticles for use in electrical conductivity; second, activated carbon that is utilized in water and wastewater treatment; and third, ultrasound-accelerated adsorption on activated carbon.

2.1 Study The Quality Of The Material

A thorough analysis of a few chosen articles was done. In the beginning, the approach was reviewed, if needed, along with the title and abstract. The complete text of pertinent articles was also carefully examined in order to conduct a further review. Last but not least, every article about the several ways that activated carbon can partially replace cement in concrete was categorized based on whether the carbon was used as an aggregate or a binder. 88 articles remained after eliminating all duplicate and irrelevant content, out of the 130 articles that were initially found, as seen in Figure 1. Only studies on the partial replacement of cement (powder or aggregate) with activated carbon and the detection changes in mechanical and thermal properties were allowed to be conducted. Following this screening procedure, 53 papers were retained for additional analysis. Three more articles were carefully evaluated in addition to the original list of articles. A selection of articles has been made. Ultimately, the full-text evaluation of 28 publications was accepted. Figure 2 displays the number of items among the chosen ones that use activated carbon as an aggregate, substitute for cement, or binder.

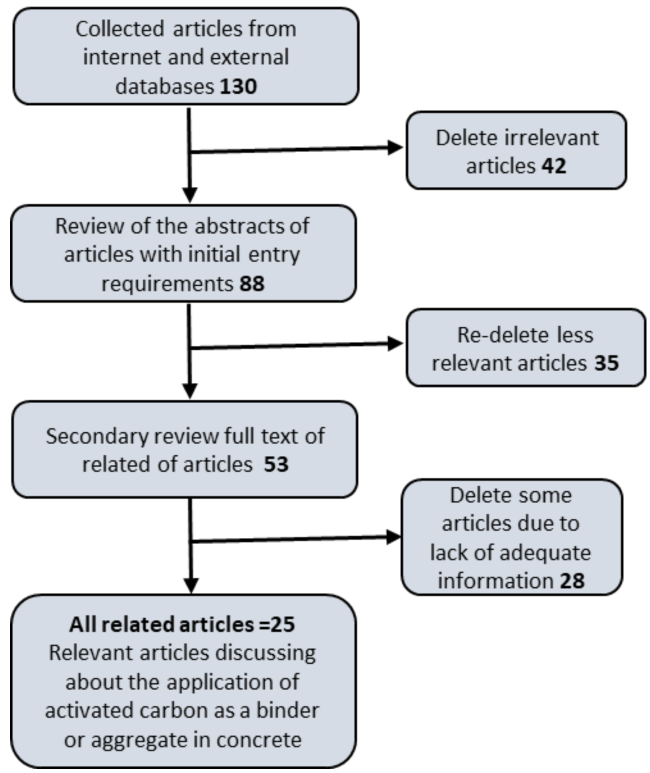


Figure 1 Flow diagram of the search and selection of articles Activated carbon

3.0 RESULTS AND DISCUSSION

Carbonaceous raw resources to create activated carbon, materials like lignite, oilfield pitch, bamboo, husk of coconuts, willow peat moss hardwood, coir fiber, and bamboo are utilized(Gao et al., 2020). Activated carbon can be produced by chemical or physical activation. Tiny, low-volume pores are created during the production of activated charcoal, a form of activated carbon, which improves the outermost area available for chemical processes or absorption(Moses et al., 2019).

3.1. Activated Carbon Synthesis

From Sardar et al. (2021) pointed out that there are three phases involved in making activated carbon: Activation is the process of turning precursors into activated carbon. Postactivation is the process of controlling quality, determining output parameters, and determining the final properties of the activated carbon. Pre-activation is the process of determining the necessary size and quality. The two primary methods for producing AC are chemical and physical processes(Kaminskii, 2020). Physiological treatments involve initially carbonizing the precursors and then activating them in settings that contain nitrogen-based substances (N_2 or NH_3), CO_2, or other inert gases(Krishna et al., 2023). Conversely, when it comes to chemical therapies, the precursors are heated in an inert environment after been first infused with a reagent. In particular, the reactive materials promote the formation and expansion of holes and reticulated formations (Soltani et al., 2015). This is often done with chemical agents such as H_3PO_4, $ZnCl_2$, KOH, NaOH, and H_2SO_4 because they yield high-quality activated carbon(Dimian et al., 2019).

3.2 Methods of Activation

The physical activation process uses hot gases to convert source materials into activated carbons. Air is supplied throughout The technique of burning off the exhaust and creating filtered, graded, and de-dusted activated carbon uses. Paralyzing carbon-containing materials at temperatures 850 degrees Celsius, which is usually in an inert environment such as nitrogen or argon, is the process known as carbonization(Demiral et al., 2011). Furthermore, Temperatures above 250 degrees Celsius, often in the range of 600 to 1200 degrees Celsius, are necessary for activation or oxidation to occur when the charred element or raw material is exposed to oxidizing environments such as steam or oxygen. These procedures yield activated carbon with the ideal properties for a variety of applications (Moses et al., 2019).

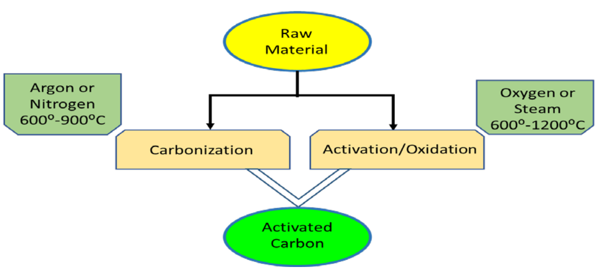


Figure 2 A schematic illustrating the activation of carbon physically (Ganjoo et al., 2023)

Before carbonization, certain chemicals are impregnated into the raw material during chemical activation. These chemicals can be salts, strong bases, or acids. The acid phosphoric (typically at a concentration of 25%) and sodium, potassium, zinc, and calcium hydroxides are typical chemical compositions(Gao et al., 2020). The raw material becomes carbonized during impregnation, typically at temperatures of about 700°C. This process is believed to occur in parallel throughout the carbonization and activation phases. Physical activation takes longer to activate a substance than chemical activation, which requires lower temperatures (Moses et al., 2019).

3.3 Morphological Properties (SEM Analysis)

The figure 3 depicts the microstructural examination of activated carbon, emphasizing its nanoscale particle size distribution and shape. A high magnification view of the activated carbon's surface in image (a) shows a structure that is densely packed with fine features. A closer look at particular areas, as seen in figures (b) and (c), reveals the material's porous nature and particle distribution—two important properties of activated carbon. Specific regions for a more thorough examination of particle sizes and shapes are indicated in image (c). The extracted particles' irregular geometries and size variations, which range from around 55 nm to over 234 nm, are schematically represented in panels (d) and (e). These structural characteristics, which affect the mechanical, thermal, and adsorption properties of activated carbon, are essential to its remarkable adsorption capacity. A thorough microstructural analysis like this offers insightful information for maximizing the performance of activated carbon in cementitious composites and other applications.

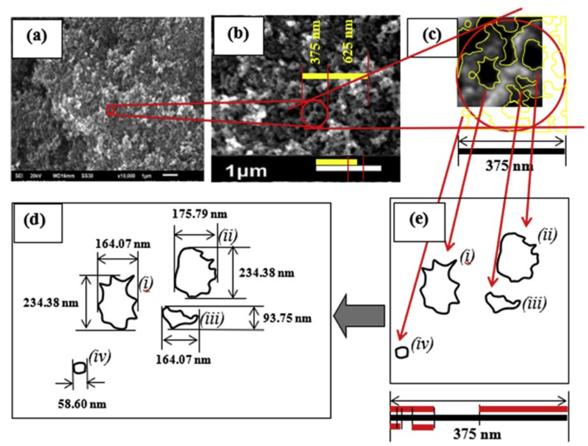


Figure 3 SEM of activated carbon (Wibawa et al., 2020)

3.4 Features of Activated Carbon

A multitude of physicochemical properties of activated carbon are critical to its efficaciousness. It is well renowned for having several uses across a wide range of industries. How something is handled and moved depends on its bulk density, or mass per unit volume (Moses et al., 2019). Furthermore, its ability to ensnare contaminants in its adsorption is highlighted by metrics such as carbon tetra chloride adsorption and iodine adsorption, that demonstrate how well it can filter liquids and gasses (Table 1). Complex pore architectures often maximize the huge surface area, so enabling wide-scale adsorption interactions (Wang et al., 2022). Together, these physical attributes essentially describe how effective and versatile activated carbon is at solving different filtration and purification issues (Ganjoo et al., 2023).

Table 1 - Physical attributes of activated carbon.

Features	Variable range
Dimensions of Particles	0.075mm to 4.75mm(OKPALAEZE, 2022)
Combined Density	0.55+0.05gm/cc(Moses et al., 2019)
Carbon Adsorption Tetra Chloride	19% - 30% (Ganjoo et al., 2023)
Adsorption of Ioden mg/gm	500mg /gm+25 (Moses et al., 2019)
Area of Total Surface (min)	500m^2/gm(Adamu et al., 2023)
Ball Pan Hardness No.	81 – 95 (Thomas et al., 2021)
ph	9 - 10(Justo-Reinoso et al., 2020)
Ash Content	5% Max (Noori et al., 2023)
Moisture	5% Max (Tan et al., 2022)

3.5 Chemical Properties Of Activated Carbon

Special chemical properties are derived from the large surface area and porous structure of activated carbon(Shi et al., 2021). AC have oxide content is comparable to that of regular Portland cement, as Table 2 demonstrates. Silicon dioxide and calcium oxide constitute two significant oxides that are integral components of cement. The surface of activated carbon can attract these materials, changing the material's selectivity and capacity to absorb chemicals. Additionally, they could change The outermost chemistry or participate in catalytic activities, which could affect activated carbon's overall effectiveness in the hydration process (Promdee, 2018).

Table 2 Measurements of the activated carbon XR-F calibration (Promdee, 2018)

Oxide	Low-temperature operation (200°C)	
	Wt .%	(element) ppm
SiO_2	29.4125 (19.6004)	137482.85 (91618.15)
P_2O_5	10.125 (5.2407)	44187.53 (22871.46)
Mo_2O_3	1.4371 (1.0956)	11495.51 (4387.88)
SO_3	0.3475 (2.1794)	1391.74 (17786.08)
Cl_2O	5.0476 (4.2242)	41183.37 (36724.77)
K_2O	16.0551 (7.2079)	133281.41 (59899.81)
CaO	33.8786 (54.2367)	242126.97 (38762.27)
TiO_2	0.6869 (0.4305)	4116.87 (3855.77)
V_2O_5	0.0343 (1.4215)	192.14 (8519.62)
MnO	0.2853 (0.1748)	2209.53 (1353.76)
Fe_2O_3	2.0719 (3.549)	14491.49 (24822.77)
ZnO	0.2366 (0.229)	1901.01 (1839.95)
SrO	0.3816 (0.4105)	3226.77 (3471.15)

Note: values for high temperature operation at 600°C are indicated in brackets.

3.6 Activated Carbon Applications In Cement Compositions

Due to its exceptional porosity, large surface area, and thermal stability, AC has become a significant addition to cement formulations. AC can be used into cement mixtures as a functional component or as an auxiliary binder to improve mechanical and durability properties**.**

3.6.1 Utilizing AC As A Component In Cement Mixtures

To enhance the mechanical and functional performance of cement-based materials, the use of AC in cement mixtures has been thoroughly investigated. When AC is used as an aggregate or mixed component, previous studies have assessed a variety of properties, including as compressive and flexural strength, pH, workability, water absorption, thermal performance, and density, as shown in Table 3. These studies demonstrate AC's ability to alter material behavior across mechanical, chemical, and durability-related parameters, underscoring its complex impact on the cement matrix.

An investigation was conducted into the possibility of substituting coarse aggregate with activated carbon (Chin, Yang, Kong, et al., 2020). The Malaysian agricultural waste known as oil palm kernel shell (OPKS) was transformed into activated carbon by means of the pyrolysis and activation processes. Characterization results showed that because of its porous structure, OPKS activated carbon has a higher water absorption rate and better thermal stability at higher temperatures than OPKS. Using the OPKS concrete mix designs, four distinct mixes of activated carbon concrete were created. Based on experimental results, concrete containing activated carbon from Comparing concrete prepared with and without OPKS, the latter showed inferior functionality, density, splitting tensile strength, compressive strength, and resistance to water penetration. It is possible to consider concrete incorporating OPKS activated carbon to be lightweight, given its compressible strength of up to about 50 MPa. The heat conductivity of the OPKS activated carbon concrete is higher than that of the regular concrete.

Along with permeability, acidity at charge neutrality (pHPZC), surface-associated groups of function, and the specific surface area of acidified and unmodified GAC, the physical behaviors of cement in response to the inclusion of an industrial polycarboxylate a superplasticizer and otherwise unaltered granular activated carbon were compared. Among the reactions that were seen in both the newly formed and hardened stages were the strength of compression, zeta possibility, slump, and setting time. Adding 1% of the fine particles to cement mortar can increase its workability and compressive strength(Justo-Reinoso et al., 2019).

Researchers assessed the impact on porosity and strength of substituting granular activated carbon (GAC) nanoparticles of a comparable size for the fine sand ingredient in cements that are commonly used. Pore structure reactions were studied by means of mercury intrusion porosimetry (MIP), in addition to density and mechanical property changes. When the percentage of replaced sand was 2% or less by mass, GAC addition increased the compressive and tensile strength; in the same range, porosity and critical pore entry width also decreased (<1%). Based on specific sizes and mass substitution ranges, the outcomes suggest the prospective advantages of including lignite GAC into cement-like substances(Justo-Reinoso et al., 2018).

The compressive strength of typical cement mortars was investigated employing activated carbon produced from used coffee grounds in this investigation. The used coffee grounds were gathered, and then the activated carbon reinforcing was made by a physical activation procedure. The percentages of activated carbon and cement were conducted through the integration of the two materials in weight proportions of 0.5%, 1%, 1.5%, 5%, and 10%. The experimental findings indicated that the incorporation of carbon activated up to 1.5% of the total weight significantly enhanced the initial strength of cement mortars. Additionally, it has provided that the formulations containing a moderate Evaluating the quantity of activated carbon (1.5 wt%) with conventional cement without activated carbon, the latter showed inferior strength in compression throughout the curing phase(Na et al., 2021).

Zheng et al. (2017)examined the effects on cement composites of activated carbon incorporating fly ash. According to the study, 20% fly ash cement mortar's compressive strength and microstructure are greatly enhanced by adding 4% mass percentage of activated carbon to the mortar. The substance and calcium silicate hydrate have been found in a microscopy scanning electron microscope image of a few hydrated pastes as examples of hydration products that could be filled in by the activated carbon in the fly ash cement system. InMoses et al. (2019), The effects of activated carbon on certain cement mortar characteristics were studied in an experimental setting. In order to increase a mortar, have compressive and tensile strengths, granular activated carbon was used in place of some of the fine aggregate in this study. Granular activated carbon added at ≤1% by mass was found to reduce the critical pore diameter values and porosity of the material under test.

For use as aggregate in lightweight concrete, paraffin and oil palm kernel shell-derived activated carbon have been used to make phase-changing material. According to Chin, Yang, Kong, et al. (2020), The carbon compound activated by paraffin and OPKS produced residual heats that were identical, registering 57.3 J/g and −57.2 J/g, and solidification and melting temperatures of 31.6 °C and 29.2 °C, respectively, based on the experimental results Furthermore, the blend of paraffin and OPKS-activated carbon demonstrated superior thermal resistance, moderate phase transition temperature, significant latent heat, and superior immunity to thermal deterioration. Concrete combined with OPKS-activated carbon composite and paraffin may also achieve an upper limit of 25 MPa strength at compression after 28 days. An investigation into the thermoregulation capability of panels of concrete with carbon compound activated by petroleum and OPKS revealed that these panels' peak temperatures during the composite PCM were lower.

The substrates employed for ecological protection deteriorate under freeze-thaw conditions, resulting in reductions in their capacity to retain fertilizer and compactness. Therefore, the goal of this study was to improve the antifrost characteristic of vegetative concrete (VC) by using two common forms of activated carbon (AC), wood-based activated carbon (WAC) and coal-based activated carbon (CAC). To ascertain their impact on the mechanical, chemical, biological, and physical characteristics of VC, we examined the effects of five distinct planting soil weight proportions (0.5, 1%, 2%, 4%, and 6%), combined in each type of AC. The control check (CK) was the VC samples that were made without AC. The microbial biomass carbon (MBC) increased to 138.54 $mg \cdot kg^{-1}$ for WAC-6 %-60 from 103.52 $mg \cdot kg^{-1}$ for CK-60, while the leaching loss rate of ammonium nitrogen (NH_4^+–N) dropped to 31.98% for WAC-6 %-60 from 44.87% for CK-60. Additionally, as the percentage of AC blended in the VC grew, the matric suction and water holding capacity first increased and subsequently dropped, with a turning point of roughly 2%. In order to fully utilize the advantages of AC and guarantee that any adverse effects of its use fall within an acceptable range, it is advised that 1% to 2% of the mixture be used, taking into account the findings of prior VC eco-restoration technology studies. Our findings led us to the conclusion that adding AC to VC enhances its appropriateness for use in freeze-thaw situations (Liu et al., 2022).

Table 3 Characteristics of cement formulation (utilizing AC as an aggregate) examined in prior scholarly investigations.

Study	Components analyzed						
	Strength in Compression	Tensile and flexural strength	pH	Working ability	Absorption of water	Temperature performance	Density
(Chin, Yang, Kong, et al., 2020)	√				√	√	√
(Na et al., 2021)	√						
(Justo-Reinoso et al., 2019)	√		√	√			
(Justo-Reinoso et al., 2018)	√	√					√
(Chin, Yang, Paul, et al., 2020)	√					√	
(Zheng et al., 2017)	√	√					
(Liu et al., 2022)	√	√			√		

3.6.2 Adding AC To Cement Formulations As An Extra Binder

Due to its potential to improve structural, durability, and thermal performance, adding AC as an additional binder to cement compositions has been extensively researched. Previous research has examined a variety of material qualities, including as compressive strength, flexural strength, water absorption, heat resistance, and porosity when AC is used as an additional binder, as Table 4 summarizes. Together, our results show that, depending on dosage and material interaction, AC can alter the cement matrix and enhance functional qualities.

Assault by humidity is the main culprit behind most issues with concrete structures. Because of its porosity, open gaps in concrete contain moisture. During the mixing and hydration process, this moisture intrusion happens on prefabricated cement. Vinyl polymer and activated carbon can be added to create what are known as Macro Defect Free (MDF) formulations, which stop moisture intrusion and eliminate this issue. Comparisons were made between the results indicating that specimens with and without activated carbon could tolerate dampness(Chowdhury, 2004).

Mahoutian et al. (2015) examined The qualities of the air gaps in concrete mixed with class F fly ash and activated carbon. Five mixes containing varying amounts of activated carbon and fly ash were investigated in the study. Activated carbon was applied at a mass percentage of fly ash at 0%, 2%, 5%, and 10%. According to the scientists, the addition of activated carbon powder to concrete boosted the material's compressive strength by lowering its air void content. Concrete mixes' strength and air-void properties can be influenced by air-entraining admixtures, fly ash type, water to percentage of binder, and amount of powdered activated carbon. Krou et al.

(2015)demonstrated that applying activated carbon to hydrated cement paste reduces the reactivity of volatile organic compounds in cement plaster. Among the explosive organic compounds are formaldehyde (found in paint, wood goods, and ceiling tiles), (found in tobacco smoke, stored fuels, and automotive exhaust), and toluene (found in paint thinners, bread, coffee, and ripe fruits). Activated carbons could be added as an additive to cement in concrete to improve the quality of the air Banc assurance: A Marketing Perspective. Up to 50 percent of the toluene was adsorbed by powdered activated carbon.

In an experiment,Di Tommaso and Bordonzotti (2016) added activated carbon to concrete; the results showed that this increased the material's performance and durability. The material's flexural strength, compressive strength, and resistance to sulfate attack tested demonstrated maximum values at 0.48%, 1.06%, and 1. There were three distinct activated carbon concentrations used: 0.48%, 1.06%, and 1.43%.

It has been demonstrated that activated carbon reduces the consequences of radioactive substances and the rate at which concrete releases radon Zheng et al. (2017). In the investigation, four distinct kinds of activated carbon were employed. Utilized were activated carbons derived from coal shells, fruit, coconut, and wood waste. The percentages of activated carbon were ten, fifteen, three, five, and one percent of the total. In combinations with 1% to 5% activated carbon, bleeding occurred. When 10% and 15% of the activated carbon was introduced, there was no bleeding. Combinations containing wood, coal, shells of coconut, and the shells observed their exhalation rates drop by 44.3%, 47.1%, 29%, and 19.2%, respectively, when activated carbon was added, according to studies on radon exhalation rates in concrete. The author came to the conclusion that coconut shells' high carbon content significantly lowered the rate of radon emission.

One of the primary objectives of the circular economy is the utilization of industrial waste as an extra cementitious material to create environmentally friendly binders in the future, which will contribute to both socioeconomic advancement and the sustainability of the cement industry This study reports on the effects of significant amounts of waste activated carbon (AC) used in low clinker cements on the properties and structure of the new binders. The study examined the mechanical, chemical, and physical characteristics of combined cement matrices with a pozzolan content of 20%–50% AC. Micro-porosity, heat of moisture, rheology and and shrinkage due to drying were some of these features. Additionally, macro-porosity was assessed using computed tomography. According to the results, the 50% AC binder is appropriate for usage as a low heat cement, and these blended cements satisfy common chemical and rheological parameters. The drying shrinkage was shown to be enhanced by greater AC percentages. Overall porosity increased with increases in the proportion of <100 nm and pore size refinement. With higher replacement ratios, compressive strength decreased. Macroporosity (0.001–0.09 mm3) rose in tandem with the CT findings and as well as the AC focused attention, particularly in the binders that contained 50% of the ingredient (Frias et al., 2018).

Due to its advanced microspore structure, activated carbon powder has the capacity to absorb nitrous oxides, erosionions, and volatile organic compounds, hence increasing the durability and multifunctionality of cement-based products. Research concentrated on the mechanical characteristics, hydration absorption coefficient, and pore architecture of cementitious mortars with fly ash and cement composition of 0.5%, 1.0%, and 2.0% by wight. Both binders with and without FA demonstrated increases in their compression and flexural strength in conjunction with the PAC incorporation ratio. The development of the pore architectures in the cement pastes with and without fly ash was significantly impacted by PAC's alteration of the mortars' water absorption ratio. The general porosity increased in cement pastes without FA but dropped in pastes blended with FA followed an increase in binders' mass from 0.5% to 2.0% for the PAC inclusion rate. PAC demonstrated excellent dispersion into the cured cement pastes in three dimensions and remarkable compatibility with the cement matrix when combined with FA in cement pastes. 3-dimensional imaging indicated that the volume% in the micron-scale pore structures reduced as the amount of PAC incorporated and the degree of fly ash response increased. Perforated aggregate is a helpful component for improving the pore structure and mechanical properties of cement-based products (Wang et al., 2022).

Accordingly, Na et al. (2021), tested how the strength of compression was influenced by activated carbon produced from leftover coffee grounds of standard cement mortars. The activated carbon strengthening was made by gathering used coffee grounds and physically activating them. To construct the activated carbon, cement contains, cement and activated carbon granules were Mixed in weight fractions of 0.5%, 1%, 1.5%, 5%, and 10% respectively. The experiment's results demonstrated that the early strength of cement mortars might be enhanced by adding activated carbon up to 1.5 weight percent. Plus, it was noted that during the curing phase, the composites with less than 1.5 weight percent activated carbon showed superior compressive strength compared to regular cement without activated carbon. The morphological symmetry phenomena that take place on the surfaces of activated carbon granules could be connected to these discoveries(Na et al., 2021).

Table 4 Properties of cement composition studied in previous investigations, with AC added as a supplemental binder

Study	Properties investigate				
	Strength of Compression	Tensile & flexural strength	Absorption of water	Heat	Porosity
(Chowdhury, 2004)			√		√
(Mahoutian et al., 2015)	√				
(Krou et al., 2015)				√	
(Di Tommaso & Bordonzotti, 2016)	√	√			
(Zheng et al., 2017)				√	
(Frias et al., 2018)	√			√	√
(Wang et al., 2022)	√	√			√
(Wang & Aslani, 2021)	√	√			
(Adamu et al., 2023)	√			√	
(Dinesh et al., 2023)	√	√			
(Zhang & Aslani, 2021)	√	√			

4.0 FUTURE RESEARCH DIRECTIONS

a. Investigate approaches to improve the mechanical and thermal properties of cement formulations by utilizing nanostructured activated carbon materials.
b. Assess novel approaches for converting captured carbon dioxide into activated carbon during the manufacturing process, and consider whether cement composites improved with activated carbon might be used as carbon-neutral building materials.
c. Consider about using cement composites with activated carbon into sustainable and intelligent infrastructure systems. For greater the long-term viability and resilience of civil infrastructure, take into account technologies like temperature management systems that adapt to the surroundings, self-sensing structures, and building materials which absorb pollution.
d. For environmental remediation projects including stabilizing soil, reducing air pollution, and cleaning groundwater, consider applying cement composites based on activated carbon.

5.0 CONCLUSIONS

The following inferences could be made in light of the literature review.

a. Activated carbon is used as a binding agents in cement composites to improve their mechanical qualities It resists deformation and cracking because of the significant interfacial interaction The enormous surface area and pore structure enable it to work together with the cement binder.
b. The porous structure of activated carbon makes it an efficient aggregate for collecting and breaking down organic pollutants on material surfaces. since of its self-cleaning property, the composite material lasts longer since contaminants are kept from accumulating and jeopardizing its structural integrity.
c. The molecule's resistance Fiber-reinforced concrete is more resilient to chemical deterioration and has a longer lifespan because activated carbon is added. In lightweight concrete, it also lessens permeability and shrinkage, extending the construction's long-term durability.
d. This study suggests that activated carbon has a promising future. Efforts for research and development focused on further optimizing its use and discovering new applications may enhance the performance and long-lasting nature of cement composites.
e. Since activated carbon is a byproduct from other materials, it may even minimize the negative effects of pollutants on the environment by reducing the need for extra chemical treatments. This is consistent with the broad goals of sustainability in building materials and techniques as well as environmental responsibility.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

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