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Effect of Corn Cob Ash on Fresh and Mechanical Properties of Concrete: A Systematic Literature Review

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ABSTRACT

In this research review, the effect of corn cob ash (CAA) as a cement replica- is figured out critically on fresh as well mechanical properties of concrete. These review integrates outcomes on workability, compressive strength, and flexural strength of CAA mixed concrete, while taking structured inspection of peer evaluated probing published between 2009 and 2023. The review comes out with the fact that although CAA blended concrete exhibits pozzolanic aptitude yet particle size and replacement level effects accordingly on fresh and mechanical properties. Requisite replacement levels generally fall within range of 5% to 15% but higher levels often result in reduction of strength. This paper pins downs notable research interval in long term strength analysis along with conformity of CAA manufacturing protocols, while recommending upcoming research directives for the utilization of this sustainable agricultural waste in concrete manufacturing.

Keywords: CCA; Cement Replacement; Concrete; Workability; Mechanical Properties.

Introduction

The significant consumed construction material globally is concrete after water with annual mass production of more than 4 billion cubic meters. Concrete production units emit about 7% of global CO_2 waste mainly from clinker calcinations

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accompanied by fossil fuel burning (Bheel et al. 2024a, 2024b). While global cement urge is estimated to rise up to 20% by 2050, the production units incur significant pressure to eliminate or reduce carbon emission through replacement binder and SCMs (Ige et al. 2025).

To replace alternatively conventional SCMs including fly ash and ground granulated blast furnace slag, agricultural biomass ashes-ABAs have become remarkable sustainable replacement materials (Bheel et al. 2024c, 2024d). Out of them, corn cob ash-widely available waste, has great capability for appreciation in cement blended materials. Worldwide corn generation creates large amount of corn cobs as waste products which contribute to air pollution and harmful greenhouse emissions when they are burnt in open field (Bheel et al. 2021; Bheel and Adesina 2021). Environmental pollution can be mitigated by controlled incineration of corn cobs which would generate ash having pozzolanic properties highly usable for partial cement replica.

Corn cob ash is incinerated in controlled burning of corn cobs at temperatures going from 500% to 800% C. The combusting temperature, duration and agricultural source have significant impact on the chemical configuration of CAA. Research shows that CAA has remarkable quantity of silica, aluminium oxide, and iron oxide having pozzolanic particles conforming ASTM C618-22 needs for natural pozzalanic. CCA has yielded "inconsistent findings" when contrasted with different ABAs like rice husk ash and sugarcane bagasse ash, according to studies conducted by Mirzaei et al. (2025), which categorized it as an "agricultural processed waste" ashes. The variation highlights the necessity of doing a thorough analysis of processing factors and how they affect concrete's CCA outcome.

Methodology

Search Strategy and Selection Criteria

In order to find appropriate material, our review used a methodical methodology. Several scholarly databases, such as Google Scholar, Scopus, and Web of Science, were searched applying the following keyword combinations: "corn cob ash," "corn cob ash concrete," "agricultural waste ash," "supplementary cementitious material," and "sustainable concrete." Only English-language peer-reviewed journal articles, conference proceedings, and review papers released between 2009 and 2025 were included in the procedure of searching.

Inclusion conditions essential studies to:

Investigate corn cob ash as a partial cement replacement in concrete or mortar

Report quantitative data on fresh and/or mechanical properties

Provide clear methodology regarding CCA preparation and concrete mix design

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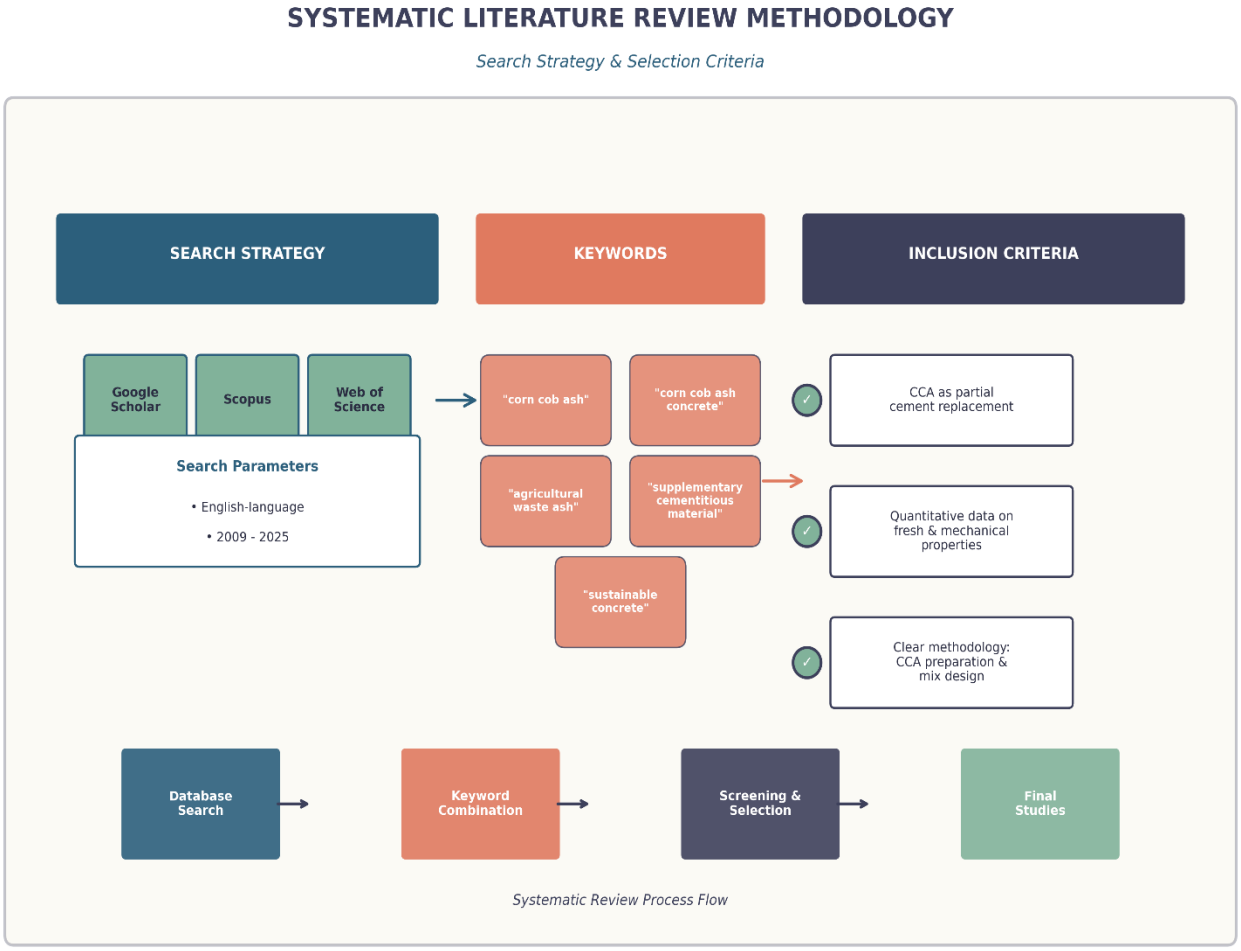


Figure 1: Search Strategy and Selection Criteria for CCA

Data Extraction and Analysis

The temperature and time of CCA formation, substitution concentrations, water-to-binder ratio, curing circumstances, and assessed characteristics were among the important data taken from particular investigations. In order to provide a full evaluation of CCA efficiency, the evaluation provided priority to studies that provided thorough measurement of both hardened and fresh concrete parameters.

Results and Discussion of Prior Studies

Effects of CCA on Workability of Fresh Concrete

Workability is one of most important freshly mixed characteristics that affects concrete preparation, compactness, and finishing. It is greatly impacted by the addition of CCA via a number of processes:

Water Demand and Slump: Research continuously shows that including CCA increases water usage. In comparison to control mixes, Adesanya and Raheem (2009) found that concrete blends with 10% CCA substitution needed 8–12% more water to

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achieve a consistent slump. The following factors are responsible for this rise in water requirements:
CCA components have a larger specific surface area than cement.
Increased internal friction due to porous, uneven particle shape.
Absorption of water mixed by cellular ash formations and carbon that has not burned.

Slump Loss: According to investigate, concrete combined with CCA loses slump more quickly over time. According to Abubakar et al. (2016), composite with 15% CCA substitution reduced slump by 15–25% more in the initial sixty minutes than the control mix. The increased ability to absorb water of CCA and possible particle agglomeration are associated with this faster slump loss.

Viscosity and Cohesion: CCA inclusion increases concrete cohesiveness and decreases bleeding, especially at substitution ranges of 5–10%, according to Ahmad et al. (2023). By filling in the spaces between cement components, the tiny CCA substances enhance the packing of particles and lessen the possibility for segregation. Additionally, Table 1 displays the results of fresh property investigations carried out by different scholars.

Table 1: Summary of Workability Studies on CCA Concrete

Study	CCA Replacement (%)	W/B Ratio	Slump (mm)	Workability Assessment
Adesanya & Raheem (2009)	0 (Control)	0.55	75	Medium
	5	0.55	65	Medium
	10	0.55	50	Low-Medium
	15	0.55	35	Low
Abubakar et al. (2016)	0 (Control)	0.50	80	Medium
	10	0.50	60	Medium
	20	0.50	40	Low
	30	0.50	20	Very Low
Memon et al. (2019)	0 (Control)	0.45	90	High
	5	0.45	75	Medium-High
	10	0.45	60	Medium

Effect of CCA on Compressive Strength (CS) of Concrete
The mechanical attribute of CCA concrete that has been studied frequently is its CS. CS growth and CCA substitution have complicated, dosage-dependent connections, according to the research. Table 2 lists the results of the different investigators. The CS of CCA-based concrete is constantly less than that of control concrete throughout the initial periods. This decrease in strength is ascribed to:
Dilution influence: Initial hydration growth of products is limited by a lower cement concentration.
Slow pozzolanic response: To initiate pozzolanic processes, CCA needs $Ca(OH)_2$ from hydration of cement, that happens gradually over a long period.

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Water competition: There may be less water available for cement hydration because to CCA grains' significant water consumption.

Table 2: Compressive Strength Development in CCA Concrete

Study	CCA (%)	7-day Strength (% of Control)	28-day Strength (% of Control)	90-day Strength (% of Control)
Adesanya & Raheem (2009)	5	92	98	105
	10	85	95	102
	15	78	88	95
Abubakar et al. (2016)	10	88	96	103
	20	75	85	92
	30	62	72	78
Oriola et al. (2023)	5	94	101	108
	10	89	97	104
	15	82	91	98
Șerbănoiu et al. (2022)	5	90	99	106
	10	84	94	101
	15	76	87	94

Long-Term Strength Growth: The information shows a reliable pattern of strength improvement after 28 days composites combined with CCA. At optimal replacement levels (5–10%), many studies report strength exceeding control concrete at 56–90 days due to progressive pozzolanic reactions. The secondary C-S-H formation from CCA-silica reacting with calcium hydroxide contributes to denser microstructure and enhanced long-term strength.

Optimal Replacement Levels: Based on systematic analysis, the optimal CCA replacement level for compressive strength ranges from 5% to 10%. At these levels, 28-day strength typically achieves 95–101% of control concrete strength, with significant improvement at later ages. Replacement levels exceeding 15% generally result in unacceptable strength reduction (>10% below control) even at extended curing periods.

Effect of CCA on Flexural Strength (FS)

Research conducted on flexural strength show that the resistance to bending of structural concrete is impacted by the addition of CCA. Identical to CS, FS and CCA percentage have a correlation that peaks at 5–10% substitution. More porosity and poorer ITZ between aggregates and cement might be the cause of the decrease in FS at greater substitute levels. Researchers' findings about the impact of CCA on concrete's FS are compiled in Table 3.

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Table 3: Flexural Strength of CCA Concrete

Study	CCA (%)	28-day Flexural Strength (MPa)	% of Control
Abubakar et al. (2016)	0	4.85	100
	10	4.62	95
	20	4.12	85
	30	3.58	74
Ikponmwosa & Salau (2015)	0	5.20	100
	5	5.15	99
	10	4.89	94
	15	4.42	85

Comparison with Other Agricultural Biomass Ashes

A thorough systematic evaluation of 35 agricultural residues wastes was carried up by Mirzaei et al. (2025), which offers crucial background for CCA efficacy. According to their investigation, CCA produced "inconsistent findings" when compared to other well-known Agricultural Biomass Ashes, as Table 4 illustrates.

In contrast to silica-rich ashes like RHA, the aforementioned comparison shows that although CCA has pozzolanic properties, its outcome is less reliable and ideal at smaller substitution dosages. Stricter control over the starting point and manufacturing processes is necessary for dependable results, as seen by the variation in CCA performance among experiments.

Table 4: Comparative Performance of Selected Agricultural Biomass Ashes

Ash Type	Pozzolanic Oxide Content (%)	Optimal Replacement (%)	Compressive Strength Performance	Reliability
Rice Husk Ash (RHA)	85–95	30	Excellent (often exceeds control)	High
Sugarcane Bagasse Ash (SCBA)	70–80	20	Good to Excellent	High
Wheat Straw Ash (WSA)	60–75	20	Good	Moderate-High
Corn Cob Ash (CCA)	58–72	10–15	Moderate to Good	Moderate
Sawdust Ash	45–65	5–10	Poor to Moderate	Low
Coconut Shell Ash	50–70	10–15	Moderate	Moderate

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Conclusions

The impact of maize cob ash on the characteristics of concrete is thoroughly examined in this comprehensive overview of the literature. Important findings consist of:

CCA integration decreases workability and raises water consumption; at substitution thresholds of 10–15%, slump decrease is 15–35%.

In order to achieve 95–100% of the desired concrete strength after 28 days with a notable long-term strength enhancement, the ideal CCA substitution amounts fall between 5% and 10%. Strength decrease is typically undesirable for applications in construction at greater levels of substitution (>15%).

According to CS, flexural strength performs best at 5–10% substitution and gradually decreases at greater levels.

In comparison to silica-rich substitutes like rice husk ash, CCA exhibits intermediate pozzolanic properties and lower optimum levels of substitution amongst agricultural residue particles. The fact that prior systematic evaluations classified it as yielding "inconsistent findings" highlights the necessity of better-quality control.

For the development of environmentally friendly concrete, corn cob ash is a feasible, if minor, additional cementitious element. A thoughtful evaluation regarding processing settings, cautious substitution levels, and reasonable performance expectations are necessary for its appropriate deployment. CCA and related agricultural waste products will become more significant as the building sector moves closer to zero emissions, so long as investigation keeps addressing existing constraints and establishing dependable, standardized use processes.

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