Workability and Compressive Strength Development of Banana Leaf Ash Based Concrete

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ABSTRACT

Objective: To evaluate the effect of banana leaf ash (BLA), used as a partial replacement for ordinary Portland cement at 0-30% by weight in 5% increments, on the workability and compressive strength of concrete at 1, 3, 7 and 28 days of curing, and to identify a practical BLA replacement level for low-strength construction applications.

Research Method: Dry banana leaves collected from the Nawabshah area of Sindh were burnt and sieved to produce BLA. Standard 100 x 100 x 100 mm concrete cubes were cast at seven BLA dosage levels (0%, 5%, 10%, 15%, 20%, 25% and 30% by weight of binder), with mix proportions, aggregates and the water-binder ratio held constant across all batches. Slump was measured immediately after mixing, and compressive strength was determined using a universal testing machine after 1, 3, 7 and 28 days of water curing.

Findings: Both workability and compressive strength decreased consistently as BLA content increased. Slump fell from 49 mm (control) to 7 mm at 30% BLA, an 86% reduction, with the rate of loss accelerating sharply beyond 15% BLA. Twenty-eight-day compressive strength fell from 29.9 MPa (control) to 14.5 MPa at 30% BLA (a 51.5% reduction), while at 10% BLA the 28-day strength loss was limited to about 9%. These trends are consistent with recent BLA studies (Islam et al., 2024; Aanu et al., 2025) that likewise report a dilution-driven strength penalty at comparable dosages.

Originality: While fly ash, rice husk ash and sugarcane bagasse ash are well characterised as cement replacements, banana leaf ash remains comparatively under-studied. This is among the first investigations to evaluate BLA concrete across a full 0-30% dosage range at four curing ages using locally sourced agricultural waste from Sindh, Pakistan, providing a regionally grounded dataset in support of agro-waste valorisation in construction.

Keywords: Banana leaf ash; supplementary cementitious material; workability; compressive strength; agricultural waste; sustainable concrete

1. INTRODUCTION

Concrete derives its name from the Latin concretus, meaning “compacted” or “condensed” — the passive participle of concrescere, formed from com- (“together”) and crescere (“to grow”) (Fouad & Copham, 1998). It is widely regarded as the most durable and heavily used construction material in the world, with current global consumption estimated at 10 to 15 billion tonnes per year (Heimann, 2010). Three properties explain its dominance: freshly mixed concrete has a plastic consistency that allows it to be cast into virtually any shape; it resists water without damage to the matrix, unlike timber or steel, making it well suited to water-retaining and water-conveying structures; and it is readily available in most parts of the world using largely local raw materials (Heimann, 2010).

Concrete is a composite material made of cement, fine aggregate, coarse aggregate and water, with or without chemical admixtures and supplementary cementitious materials such as fly ash, silica fume and slag. It hardens through hydration — the chemical reaction between cement and water that binds the aggregates into a solid, stone-like mass (Fouad & Copham, 1998). It is used in pavements, pipes, roads, block walls and foundations, and its ingredient proportions can be varied to tailor strength, density, and chemical or thermal resistance to a given application.

Alongside good durability and fire resistance, concrete continues to gain strength for years after casting provided sufficient moisture is available for continued hydration, though most of its design strength is attained by 28 days. It resists compression well but has comparatively low tensile capacity, which is why it is usually reinforced with steel in structural applications. Because of shrinkage, thermal movement and sustained loading, some degree of cracking is essentially unavoidable in concrete structures (Fouad & Copham, 1998).

Producing concrete without regard to sustainable materials and methods is increasingly the exception rather than the rule. Cement manufacture is energy-intensive and a significant source of greenhouse gas emissions, while the growing volume of industrial and agro-industrial waste has made land for its disposal scarce; improper disposal or open burning of this waste creates additional health and environmental hazards. Waste management has put extra burden on project (Memon et al. 2023). These pressures have pushed researchers toward using such wastes as construction materials in their own right. Pakistan, as a major agricultural economy, generates substantial banana-plantation waste every year, particularly in Sindh province, yet this waste sees very little productive reuse. This study was undertaken to evaluate banana leaves collected from local plantations in Nawabshah, converted to ash by burning, as a supplementary cementitious material in concrete — specifically assessing the workability of banana-leaf-ash (BLA) concrete and the effect of BLA on compressive strength at different curing ages.

2. LITERATURE REVIEW

2.1 COMPONENTS OF CONCRETE

Concrete is essentially a combination of four ingredients: cement (binder), fine aggregate (void filler), coarse aggregate (the main volume-occupying component), and water (the agent that hydrates the binder). Portland cement is the most common form of cement worldwide and the primary binding component of concrete, mortar, stucco and most non-specialty grouts. It is a fine powder produced by grinding Portland cement clinker (typically more than 90% of the mix) together with a small proportion of calcium sulphate and other minor constituents, as permitted under European standard EN 197-1 (Bell, 2006). The clinker itself is a hydraulic material composed of calcium silicates ($3CaO \cdot SiO2$ and $2CaO \cdot SiO2$), which together make up at least two-thirds of its mass, along with aluminium- and iron-bearing phases; the CaO:SiO2 ratio is not below 2.0, and MgO content is limited to a maximum of 5.0% by mass (Bell, 2006).

Fine aggregate particles pass a 4.75 mm sieve and are retained on a 0.15 mm sieve. Sand, crushed stone, ash or cinder, and surkhi (Yeoh, 2010) are the materials most commonly used as fine aggregate, and are typically sourced either from the natural disintegration of rock transported by glaciers and streams, or from the crushing of stone and gravel. Grading plays a significant role in producing good concrete; Table 1 shows the grading requirements typically specified for fine aggregate.

Table 1: Grading requirement for fine aggregate

Sieve size	Zone 1	Zone 2	Zone 3	Zone 4	ASTM C33-78
9.5 mm (3/8 in)	100	100	100	100	100

4.75 mm (3/16 in)	90-100	90-100	90-100	95-100	95-100
2.36 mm (#8)	60-95	75-100	85-100	95-100	80-100
1.18 mm (#16)	30-70	55-90	75-100	90-100	50-85
600 μm (#30)	15-34	35-59	60-79	80-100	25-60
300 μm (#50)	5-20	8-30	12-40	15-50	10-30
150 μm (#100)	0-10	0-10	0-10	0-15	2-10

Coarse aggregate consists of natural stone — crushed, uncrushed, or a blend of the two — and must be hard, strong, durable and free of clay coatings, organic matter and other deleterious material. Particles are generally larger than 4.75 mm (3/16 in), typically ranging from 9.5 to 37.5 mm (3/8 to 1.5 in) (AASHTO, 2007). Well-graded, angular crushed aggregate is generally preferred for strong, durable concrete, since angular particles with rough surface texture interlock and reduce the risk of segregation. Mixing water must be free of organic matter, oils and harmful impurities; water fit for drinking is generally considered suitable for use in concrete.

2.2 BANANA LEAF ASH AND COMPARABLE POZZOLANS IN CONCRETE

Numerous researchers have investigated the fresh and hardened properties of concrete incorporating recycled material i.e. used material with spefic process (Shaikh et al. 2023) and supplementary cementitious materials. Reddy and Reddy (2012) examined high-performance concrete (HPC) in which cement was replaced with fly ash, silica fume and metakaolin, using an M60 mix design and 90-day curing in 5% HCl, NaOH, MgSO4 and Na2SO4 solutions; they found that supplementary cementing materials improved durability while reducing the heat of hydration, and that replacing cement with fly ash reduced strength by between 1.92% and 12.64% depending on the replacement level. Wagan et. al. (2022) studied use of rice husk ash in the concrete to assess its effect on strength.

Rao et al. (2012) studied the durability of metakaolin-blended concrete (grade M20) exposed to H2SO4 and HCl, using steel fibres at aspect ratios of 60 and volume fractions of 0%, 0.5%, 1.0% and 1.5%. They found that fibre reinforcement combined with a 10% cement replacement reduced mass loss and increased compressive strength relative to plain concrete in acidic exposure. Murthi and Kumar (2008) investigated the acid resistance of ternary blended concrete (20% fly ash plus 8% silica fume by weight) against plain and binary blended concrete, reporting mass losses of 19.6% and 16.1% in plain OPC samples after 28 and 90 days in sulphuric and hydrochloric acid, respectively, and concluding that the ternary blend performed best.

Al-Tamimi and Sonebi (2003) evaluated self-compacting concrete (SCC) immersed in 1% HCl and 1% H2SO4 and found it outperformed conventional concrete, taking 18 weeks to reach 10% mass loss compared with 6 weeks for conventional concrete. Reddy (2012) examined fly-ash and silica-fume blended cement exposed to varying chloride-ion concentrations and reported a 2-19% reduction in compressive strength at 28 and 90 days. Beulah and Prahallada (2012) studied metakaolin-blended HPC exposed to 5% HCl for 30, 60 and 90 days and found that residual compressive strength decreased progressively with immersion time as the effective water-binder ratio increased.

Otuoze et al. (2012) characterised sugarcane bagasse ash (SCBA), produced by burning bagasse at 600-700°C, and found a combined SiO2 + Al2O3 + Fe2O3 content of 74.44%, meeting the threshold commonly used to classify a pozzolan. Using a 1:2:4 mix with OPC replaced at 0-30%, they found that reinforced concrete with dense aggregate performed best at around 10% SCBA replacement, while mass concrete could tolerate 15-35% SCBA, beyond which reduced bond strength became limiting —

a pattern broadly consistent with the dosage-dependent strength loss reported for BLA in the present study. More broadly, agricultural, industrial and mineral by-products such as PFA, POFA, rice husk ash and ground granulated blast-furnace slag are now well established as pozzolanic cement replacements that can improve both the economics and, in many cases, the durability of concrete (Park & Tia, 2004; Nurdeen et al., 2012; Lian & Zhuge, 2010; Yusuf et al., 2014; Hesami et al., 2014).

2.3 RECENT ADVANCES IN BANANA LEAF ASH CONCRETE (2023-2025)

Research specifically on banana leaf ash has expanded considerably since 2023. Islam et al. (2024) examined BLA as a pozzolanic cement replacement at levels up to 30% by weight — closely mirroring the dosage range adopted in the present study — and reported a progressive decline in mechanical strength alongside microstructural (SEM/XRD) evidence of reduced calcium-silicate-hydrate formation at higher replacement levels, attributing much of the loss to a dilution effect rather than an absence of pozzolanic activity. Aanu et al. (2025) reported a similar compressive-strength trend while additionally finding improved chloride-ion resistance in BLA-blended mixes, suggesting that BLA may offer durability benefits in chloride-exposed environments even where strength is reduced.

Stel'makh et al. (2024) modified the particle size and activation process of banana leaf ash prior to blending, and achieved smaller strength penalties than are typically reported for untreated ash, indicating that further processing — fine grinding or thermal activation — is a promising route to mitigating the strength loss observed with as-burnt BLA. Most recently, Olaiya et al. (2025) published a dedicated review of BLA in concrete, concluding that while the material is a technically viable pozzolan, the literature remains fragmented across differing burning temperatures, particle sizes and test protocols, which limits direct comparability between studies.

Limited literature remains available on BLA sourced and tested under Pakistani conditions specifically. The banana plantations of Sindh province are a significant and largely untapped source of agricultural waste, and this study was undertaken to assess the workability and age-dependent compressive strength of concrete made with BLA sourced from the local plantations of Nawabshah, using a systematic dosage range (0-30%, in 5% increments) and four curing ages (1, 3, 7 and 28 days) consistent with, and directly comparable to, the recent international literature summarised above.

3. METHODOLOGY

The hardened performance of concrete is governed by its ingredients and their properties, mix proportions, production method, and curing regime and age; each of these was therefore addressed carefully before testing began. Weight-based mix proportions were used throughout, with BLA substituted for OPC at dosage levels of 0%, 5%, 10%, 15%, 20%, 25% and 30% by weight of binder. Mix proportions, aggregate type and source, and the water-binder ratio were held constant across all batches so that the observed effects could be attributed to the BLA substitution alone. Table 2 summarises the batches cast and tested.

Table 2: Details of the batches of specimens cast and tested

S#	Batch	Dosage of BLA
1	B-1	0%
2	B-2	5%
3	B-3	10%
4	B-4	15%
5	B-5	20%

6	B-6	25%
7	B-7	30%

Standard 100 mm x 100 mm x 100 mm cubes were cast for each batch and cured in water for 1, 3, 7 and 28 days. At each age, two properties were assessed: workability and compressive strength. Workability describes the ease with which fresh concrete can be placed and compacted with minimal segregation; it is closely linked to the quantity of internal work needed to achieve full compaction, and the workability required varies with the application — a narrow, congested section requires a more flowable mix than a large, open pour.

4. RESULTS AND DISCUSSIONS

4.1 WORKABILITY OF BANANA LEAF ASH CONCRETE

Workability was assessed using the slump cone test; a photograph of the test being conducted is shown in Figure 1, and the measured slump values are presented in Table 3 and Figure 4.

Figure 1: Measuring the workability of a fresh BLA concrete specimen using the slump cone test

Table 3: Workability at different BLA replacement levels

Batch	BLA (%)	Average Slump (mm)
1	0%	49
2	5%	43
3	10%	34
4	15%	22
5	20%	10
6	25%	9
7	30%	7

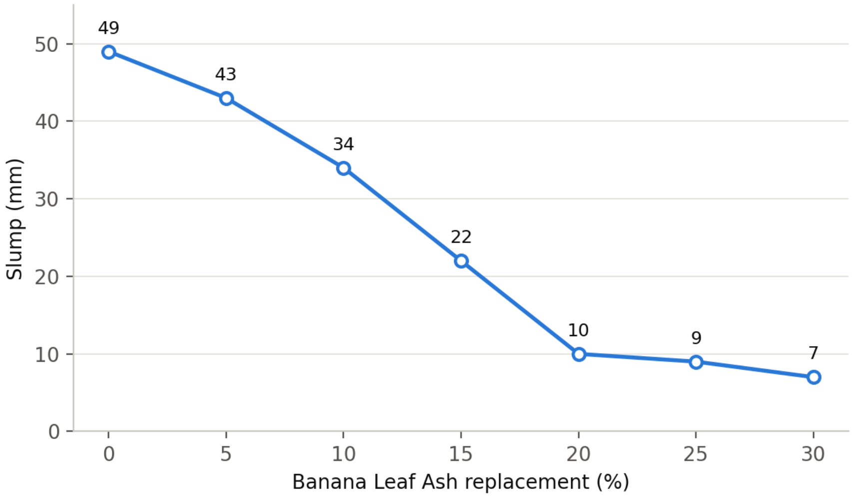

Figure 4: Effect of BLA replacement on the workability of concrete

Table 3 and Figure 4 show that partially substituting cement with BLA reduces workability at every dosage tested. The slump falls from 49 mm for the control mix to 7 mm at 30% BLA — an 86% reduction. The rate of slump loss is not uniform across the dosage range: between 0% and 15% BLA the slump falls by 27 mm (49 to 22 mm), a loss of roughly 2 mm per percentage point of replacement, whereas beyond 15% BLA the slump collapses to single digits and the rate of loss accelerates sharply before levelling off close to zero flow. This behaviour is consistent with the high loss-on-ignition and porous, angular particle morphology typically reported for uncontrolled agricultural ashes, which increases the water demand of the paste for a given consistency. It implies that where BLA is used at dosages above about 15%, an appropriate water-reducing admixture or plasticiser will generally be required to maintain workable concrete, and that BLA dosage should be selected with the required workability class in mind rather than on strength considerations alone.

4.2 EFFECT OF BANANA LEAF ASH ON COMPRESSIVE STRENGTH

Compressive strength was determined at 1, 3, 7 and 28 days for all seven BLA dosages using a universal testing machine (UTM), as shown in Figures 2 and 3. Tables 4 to 7 report the average compressive strength at each age, together with the percentage change relative to the BLA-free control mix at the same age; Table 8 compares strength development across all four ages, and Figure 5 plots the full strength-dosage-age dataset.

Figure 2: Specimen under compression testing

Figure 3: Specimen being weighed prior to testing

Table 4: Compressive strength at 1-day curing

Batch	BLA (%)	Average Compressive Strength (MPa)	% Change vs. Control (0% BLA)
1	0%	18.0	-
2	5%	16.2	-10.00
3	10%	14.6	-18.89
4	15%	11.3	-37.22
5	20%	8.0	-55.56
6	25%	7.2	-60.00
7	30%	6.1	-66.11

Table 5: Compressive strength at 3-day curing

Batch	BLA (%)	Average Compressive Strength (MPa)	% Change vs. Control (0% BLA)
1	0%	24.9	-
2	5%	23.9	-4.02
3	10%	21.9	-12.05
4	15%	15.5	-37.75
5	20%	12.4	-50.20
6	25%	10.8	-56.63
7	30%	8.1	-67.47

Table 6: Compressive strength at 7-day curing

Batch	BLA (%)	Average Compressive Strength (MPa)	% Change vs. Control (0% BLA)
1	0%	26.2	-
2	5%	25.2	-3.82
3	10%	23.2	-11.45
4	15%	16.8	-35.88
5	20%	13.7	-47.71
6	25%	12.1	-53.82
7	30%	9.4	-64.12

Table 7: Compressive strength at 28-day curing

Batch	BLA (%)	Average Compressive Strength (MPa)	% Change vs. Control (0% BLA)
1	0%	29.9	-
2	5%	29.1	-2.68
3	10%	27.2	-9.03
4	15%	20.2	-32.44
5	20%	16.4	-45.15
6	25%	15.9	-46.82
7	30%	14.5	-51.51

Note: the percentage-change values above are recalculated directly from the average strengths reported in each table, relative to the control mix at the same curing age.

From Tables 4-7, compressive strength decreases with increasing BLA content at every curing age, and the reduction becomes markedly steeper once replacement exceeds 15%. Table 8 compares strength development at all four ages for each dosage, expressing the 1-, 3- and 7-day strengths as a percentage of the corresponding 28-day strength.

Table 8: Compressive strength development across curing ages

Batch	BLA (%)	1-Day MPa	1-Day (% of 28d)	3-Day MPa	3-Day (% of 28d)	7-Day MPa	7-Day (% of 28d)	28-Day MPa
1	0%	18.0	60.3	24.9	83.2	26.2	87.5	29.9
2	5%	16.2	55.7	23.9	82.2	25.2	86.7	29.1
3	10%	14.6	53.7	21.9	80.5	23.2	85.3	27.2
4	15%	11.3	55.9	15.5	76.7	16.8	83.2	20.2
5	20%	8.0	48.8	12.4	75.6	13.7	83.5	16.4
6	25%	7.2	45.3	10.8	67.9	12.1	76.1	15.9
7	30%	6.1	42.1	8.1	55.9	9.4	64.8	14.5

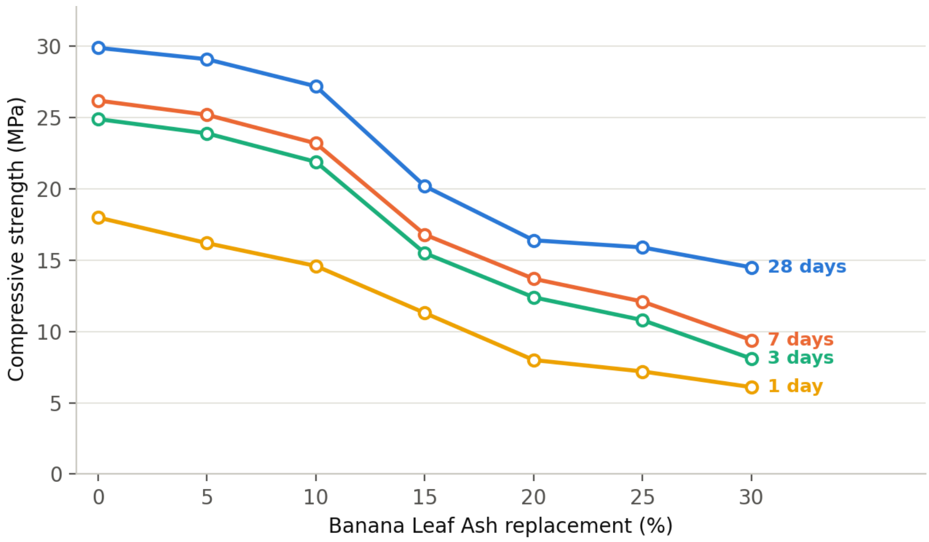

Figure 5: Compressive strength development of BLA concrete at different curing ages

For the control mix, strength reaches about 60% of its 28-day value after 1 day, 83% after 3 days and 88% after 7 days — a maturity progression typical of ordinary

Portland cement concrete. Table 8 shows that this relative maturity pattern is broadly preserved up to about 15% BLA, but becomes noticeably slower at 25% and 30% BLA, where only 42-45% of the 28-day strength is reached at 1 day and 56-65% at 7 days. This indicates that high BLA dosages not only reduce the ultimate strength attainable but also slow the rate of early strength gain, consistent with a dilution effect combined with slower pozzolanic reaction — the same mechanism proposed by Islam et al. (2024) on the basis of microstructural evidence.

Beyond 10% BLA, the reduction in 28-day compressive strength accelerates sharply (from -9.03% at 10% to -32.44% at 15%), mirroring the pattern already observed for workability in Section 4.1. Applying a working threshold of no more than about 10% strength loss at 28 days for general low-strength applications, 10% BLA is the highest dosage in this study that stays within that threshold, while 15% BLA may still be acceptable specifically for non-structural or mass-concrete applications where a substantially larger strength reduction (and reduced workability) can be tolerated in exchange for a greater proportion of cement replaced. This is consistent with the dosage ranges reported for other agricultural ashes, where reinforced concrete with dense aggregate typically tolerates lower replacement levels (around 10%) than mass or plain concrete (15-30%) (Otuoze et al., 2012).

5. CONCLUSIONS

The following conclusions are drawn from this experimental study of the workability and compressive strength of banana leaf ash (BLA) concrete:

- Banana leaf ash alters both the workability and compressive strength of concrete when used as a partial cement replacement, with the effect becoming pronounced beyond about 15% BLA.

- Workability decreases progressively with increasing BLA content. Slump falls from a maximum of 49 mm for ordinary concrete to a minimum of 7 mm at 30% BLA, an 86% reduction; an appropriate plasticiser or water-reducing admixture is recommended where BLA is used above about 15% replacement, to maintain adequate workability.

- Average compressive strength follows a similar declining trend to workability, decreasing at all ages and dosage levels tested, though the proportional reduction is generally smaller than that observed for workability.

- The maximum 28-day strength achieved was 29.9 MPa for the control mix, falling to 14.5 MPa at 30% BLA — a 51.5% reduction. At 5% BLA replacement, 28-day strength decreased by about 2.7%, followed by reductions of about 9.0% and 32.4% at 10% and 15% BLA, respectively.

- Applying a working threshold of roughly 10% loss in 28-day compressive strength as acceptable for general low-strength applications, 10% BLA is recommended as the optimum cement replacement level, offering a meaningful reduction in cement demand with limited strength penalty and a manageable loss of workability. A 15% BLA dosage may still be considered for non-structural or mass-concrete applications where a larger strength reduction is acceptable, but it should not be treated as an equivalent "optimum" without the admixture adjustment discussed above.

- Limitations: this study did not characterise the chemical composition, particle size distribution or specific gravity of the BLA used, and does not report the number of replicate specimens tested or a measure of scatter (e.g., standard deviation) around the reported averages. Future work should include oxide/XRF analysis of the ash, a stated replicate count with reported variability, and microstructural evidence (e.g., SEM/XRD, following the approach of Islam et al., 2024) to confirm the dilution-versus-reactivity mechanism proposed here.

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REFERENCES

Aanu, A., Imran, M. A., & Lateef, J. (2025). Investigating the influence of banana leaf ash on the compressive strength and chloride resistance of concrete. American Journal of Civil Engineering and Constructions, 1(2), 1-12. https://doi.org/10.54536/ajcec.v1i1.5010

Al-Tamimi, A. K., & Sonebi, M. (2003). Assessment of self-compacting concrete immersed in acidic solutions. Journal of Materials in Civil Engineering, 15(4), 354-357.

American Association of State Highway and Transportation Officials (AASHTO). (2007). Guidelines for concrete mixtures containing supplementary cementitious materials to enhance durability of bridge decks. Transportation Research Board, National Research Council.

Bell, K. (2006). Timber bridges. NTNU, Norway.

Beulah, M., & Prahallada, M. C. (2012). Effect of replacement of cement by metakaolin on the properties of high performance concrete subjected to hydrochloric acid attack. International Journal of Engineering Research and Applications, 2(6), 33-38.

Fouad, F. H., & Copham, C. A. (1998). Evaluation of concrete containing fly ash with high carbon content and/or small amounts of wood. Department of Civil Engineering, University of Alabama at Birmingham.

Heimann, R. B. (2010). Classic and advanced ceramics. Wiley-VCH.

Hesami, S., Ahmadi, S., & Nematzadeh, M. (2014). Effects of rice husk ash and fiber on mechanical properties of pervious concrete pavement. Construction and Building Materials, 53, 680-691.

Islam, M. H., Law, D. W., Gunasekara, C., Sobuz, M. H. R., Rahman, M. N., Habib, M. A., & Sabbir, A. K. (2024). Assessing the influence of banana leaf ash as pozzolanic material for the production of green concrete: A mechanical and microstructural evaluation. Materials, 17(3), 720. https://doi.org/10.3390/ma17030720

Lian, C., & Zhuge, Y. (2010). Optimum mix design of enhanced permeable concrete — an experimental investigation. Construction and Building Materials, 24(12), 2664-2671.

Memon, M. A., Memon, A. H., Memon, Z. A., Khahro, S. H., & Memon, A. Q. (2026). Optimizing Nylon Fibers and Supplementary Cementitious Materials for High-Strength Self-Compacting Concrete. Civil Engineering Journal, 12(7), 2681–2698. https://doi.org/10.28991/CEJ-2026-012-07-03

Memon, M. A., Memon, N. A., Memon, B. A., Memon, A. H., & Memon, A. Q. (2023). Workability and mechanical behavior of steel fiber reinforced self-compacting concrete with supplementary cementitious materials. Composite Interfaces, 30(7), 729-748.

Murthi, P., & Kumar, V. S. (2008). Studies on acid resistance of ternary blended concrete. Asian Journal of Civil Engineering, 9(5), 487-496.

Nurdeen, M. A., Johari, M. A., & Hashim, S. F. (2012). Flexural performance of green engineered cementitious composites containing high volume of palm oil fuel ash. Construction and Building Materials, 37, 518-525.

Olaiya, B. C., Lawan, M. M., Olonade, K. A., & Abubakar, S. A. (2025). Banana leaf ash as sustainable alternative raw material for the production of concrete: A review. Discover Materials, 5(1), 100. https://doi.org/10.1007/s43939-025-00296-6

Otuoze, H. S., Amartey, Y. D., Sada, B. H., Ahmed, H. A., Sanni, M. I., & Suleiman, M. A. (2012). Characterization of sugar cane bagasse ash and ordinary Portland cement blends in concrete. Proceedings of the 4th West Africa Built Environment Research (WABER) Conference, Abuja, Nigeria, 1231-1237.

Park, S. B., & Tia, M. (2004). An experimental study on the water-purification properties of porous concrete. Cement and Concrete Research, 34(2), 177-184.

Rao, D. P. S., Sravana, P., Rahim, Z. A., & Sekhar, T. S. (2012). Durability studies on steel fiber reinforced metakaolin blended concrete. AKGEC International Journal of Technology, 3(1), 38-43.

Reddy, B. M. (2012). Effect of hydrochloric acid on blended cement and silica fume blended cement and their concretes. International Journal of Science and Technology, 1(9).

Reddy, M. V. S., & Reddy, I. V. R. (2012). Studies on durability characteristics of high performance concrete. International Journal of Advanced Scientific and Technical Research, 6(2).

Shaikh, I., Memon, B. A., Memon, M. A., Oad, M., & Memon, A. H. (2023). Effect of steel fibers on compressive strength of recycled aggregate concrete. Journal of Applied Engineering Sciences, 13(1), 123-130.

Stel'makh, S. A., Shcherban', E. M., Beskopylny, A. N., Chernilnik, A., & Elshaeva, D. (2024). Eco-friendly concrete with improved properties and structure, modified with banana leaf ash. Journal of Composites Science, 8(10), 421. https://doi.org/10.3390/jcs8100421

Wagan, I. H., Memon, A. H., Memon, N. A., Memon, F. T., & Lashari, M. H. (2022). Rice husk ash (RHA) based concrete: workability and compressive strength with different dosages and curing ages. Journal of Applied Engineering Sciences, 12(1), 113-120.

Yeoh, E. C. (2010). Behaviour and design of timber-concrete composite floor system. University of Canterbury.

Yusuf, M. O., Johari, M. A., Ahmad, Z. A., & Maslehuddin, M. (2014). Strength and microstructure of alkali-activated binary blended binder containing palm oil fuel ash and ground blast furnace slag. Construction and Building Materials, 52, 504-510.