Journal of Science Engineering Technology and Management Science
Volume 02, Issue 06, June 2025 ISSN: 3049-0952
www.jsetms.com DOI:10.63590/jsetms.2025.v02.i06.pp79-86

THE ROLE OF RECYCLED MATERIALS AND SUPPLEMENTARY BINDERS IN SUSTAINABLE CONCRETE

Hitesh Kumar[1], Dr Deepak Verma[2]
[1] Student, M.Tech Structural Engineering, U.I.E.T, M.D.U, Rohtak
[2.] Assistant Professor, Department of Civil Engineering, U.I.E.T, M.D.U, Rohtak
hk.kumar202000@gmail.com

To Cite this Article

Hitesh Kumar , Dr Deepak Verma, "The Role Of Recycled Materials And Supplementary Binders In Sustainable Concrete, Vol. 02, Issue 06, June 2025, pp:06-09, DOI: http://doi.org/10.63590/jsetms.2025.v02.i06.pp79-86

Submitted: 01-04-2025 Accepted: 10-05-2025 Published: 31-05-2025

Abstract: *The increasing demand for sustainable construction materials has catalyzed intensive research into environmentally responsible alternatives to traditional concrete. This literature review explores innovative strategies for incorporating industrial and construction waste materials including fly ash (FA), recycled aggregates (RA), bottom ash, polymer fibers, and various geopolymeric binders into concrete to enhance both mechanical performance and ecological sustainability. Across diverse methodologies, researchers have evaluated the effects of materials such as treated wastewater (TWW), recycled concrete aggregates (RCA), coal bottom ash (CBA), and supplementary cementitious materials (SCMs) like ground granulated blast furnace slag (GGBS) and silica fume (SF) on concrete's fresh and hardened properties, durability, and resistance to environmental degradation. Notably, the integration of fly ash across multiple studies has consistently demonstrated improvements in durability, strength development over extended curing periods, and reductions in environmental footprint particularly when combined with fiber reinforcement or alkaline activation for geopolymer applications. Collectively, these findings underscore the feasibility of transitioning toward a circular construction economy by utilizing sustainable concrete technologies without compromising structural integrity, offering a roadmap for future eco friendly building practices.*

Keywords: *Sustainable concrete, recycled aggregates, fly ash, geopolymer concrete, supplementary cementitious materials*

1 INTRODUCTION

The construction industry remains one of the largest global consumers of natural resources and a significant contributor to greenhouse gas emissions, primarily due to the extensive use of ordinary Portland cement (OPC) and virgin aggregates. As the environmental impact of traditional construction practices becomes increasingly apparent, sustainable alternatives in concrete production are garnering substantial attention. A major focus has been placed on reducing the carbon footprint of cementitious materials and conserving non renewable resources through the incorporation of recycled, industrial, and waste derived materials. These efforts align with broader goals of a circular economy, wherein waste streams are repurposed to create high performance, low impact construction materials.

A wide body of recent literature demonstrates various approaches to sustainable concrete development, particularly through the use of fly ash (FA), ground granulated blast furnace slag (GGBS), recycled concrete aggregate (RCA), coal bottom ash (CBA), and treated wastewater (TWW). These materials are employed either as partial replacements for cement, fine or coarse aggregates, or as components in alkali activated binders. Their integration not only diverts waste from landfills but also reduces the need for energy intensive virgin materials. Fly ash, in particular, has been a cornerstone of sustainable concrete formulations due to its pozzolanic activity, availability, and capacity to improve long term durability. The chart illustrates the utilization of industrial waste, with major uses in land disposal (20%), soil works (13%), and construction materials like bricks, cement, and panels (each around 11–12%). Minor applications include roofing, aggregates, and high value materials.

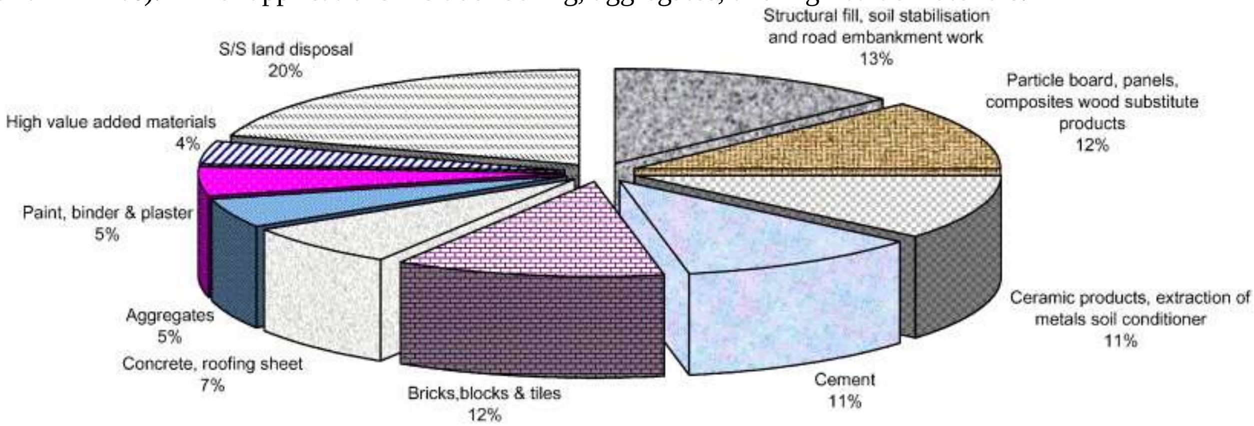

Figure 1: Future Potentials for solid waste recycling and utilization

Table 1: Different Types of Waste Materials and Their Uses

Waste Material	Source	Common Uses
Fly Ash (FA)	Thermal power plants	Cement replacement, geopolymer concrete, bricks, blocks, soil stabilization
Ground Granulated Blast Furnace Slag (GGBS)	Steel manufacturing	Cement replacement, concrete, high performance concrete mixes
Recycled Concrete Aggregate (RCA)	Demolished concrete structures	Coarse aggregate in new concrete, road base, embankments
Red Mud	Aluminium industry (Bayer process)	Bricks, tiles, soil conditioner, stabilization agent
Coal Bottom Ash (CBA)	Thermal power plants	Fine aggregate replacement, filler in concrete
Waste Glass	Household/industrial waste	Sand replacement in concrete, decorative concrete, bricks
Ceramic Waste	Construction/demolition waste	Aggregate replacement, tiles, decorative applications
Rubber (e.g., tire waste)	Used vehicle tires	Asphalt modification, impact absorbing floors, playgrounds
Plastic Waste	Household/packaging industry	Fiber reinforcement, lightweight bricks, paving blocks
Demolition Waste (mixed)	Construction sites	Fill material, recycled aggregates, road base
Silica Fume	Silicon and ferrosilicon production	High performance concrete, pozzolanic material
Rice Husk Ash (RHA)	Agro waste (rice milling)	Cement replacement, pozzolanic additive
Wood Ash	Biomass fuel combustion	Cement replacement, soil stabilization
Municipal Solid Waste Incineration Ash (MSWI Ash)	Urban waste	Cement substitute, filler material (after treatment)
Eggshell Powder	Food/agricultural waste	Partial cement replacement, calcium rich additive

Used Cooking Oil (UCO)	Household/food industry waste	Workability enhancer in concrete, admixture in eco mortar

This table presents various types of waste materials sourced from industrial, agricultural, and domestic activities, along with their common applications in construction. Materials like fly ash, GGBS, and RCA are widely used as replacements for cement and aggregates, while others such as red mud, plastic waste, and eggshell powder contribute to specialized uses like bricks, soil conditioning, or admixtures. These sustainable alternatives not only enhance concrete properties but also support waste reduction and circular economy practices in the construction industry.

2 LITERATURE SUMMARY

Sustainable construction practices are increasingly shifting toward utilizing industrial by products, recycled aggregates, and alternative binders to develop environmentally friendly concrete composites. A key focus in recent literature has been the incorporation of recycled concrete aggregate (RCA) and treated wastewater (TWW) in cementitious systems. In a notable study, Abdelrahman Abushanab et al. (2023) assessed the bond strength between corroded steel reinforcement and recycled aggregate concrete (RAC) incorporating TWW, RCA, and fly ash (FA). Their results showed a reduction in bond strength due to the use of TWW (30%) and RCA (18%) owing to increased porosity and microstructural changes. However, fly ash improved the bond behavior and mitigated corrosion related deterioration, especially at higher corrosion levels. This highlights FA’s potential in enhancing durability in corrosive environments, even when sustainable water and aggregates are used. The integration of geopolymer technology and polymer fibers for lightweight concrete was advanced by Adem Ahıskalı et al. (2024). Their work on one part foam geopolymer concrete, developed using fly ash activated by sodium metasilicate and reinforced with polypropylene (PP) fibers, demonstrated significant improvements in thermal resistance, density, and compressive strength. The replacement of limestone with industrial slag aggregates further enhanced both fresh and hardened properties. The addition of 1% PP fiber and 50% slag resulted in the optimum mix for structural and durability performance, confirming the potential of this system for sustainable lightweight construction applications. A significant body of work has explored hybrid recycled aggregate systems. Amardeep Meena et al. (2024) examined high volume fly ash self compacting concrete (HVFA SCC) using coal bottom ash (CBA) and RCA. Their optimal blend 20% CBA and 25% RCA enhanced compressive, flexural, and tensile strengths over long-term curing due to pozzolanic reactions. However, excessive RCA content negatively affected fresh properties. Their findings emphasized the importance of proportion control to balance sustainability and workability. Expanding on RCA applications, Asad Elmagarhe et al. (2024) investigated porous asphalt mixtures (PAMs) containing RCA and FA, showing improved tensile strength and Marshall stability at 30% RCA inclusion. Although RCA improved moisture resistance, it could not fully eliminate water damage due to its high absorption rate. Despite this, PAMs maintained excellent permeability, making them suitable for drainage layers in pavement structures. In terms of waste incorporation in brick and masonry materials, Aswin Kumar Krishnan et al. (2024) reviewed the use of fly ash and other industrial wastes in clay and concrete bricks. Their findings from 170 studies concluded that FA enhances mechanical performance and sustainability, particularly under optimized curing and water to cement ratios. However, excessively high w/c ratios could weaken performance, and thermal firing raised environmental concerns due to energy demands. B.R. Andharia et al. (2023) contributed by developing high volume fly ash concrete (HVFAC) incorporating RCA and dredged marine sand (DMS). Their best performing mix (50% FA, 10% DMS) achieved 30–34 MPa strength and exhibited superior resistance to sulfate and chloride attacks, making it suitable for marine applications. The partial inclusion of DMS improved strength and enhanced durability while demonstrating good resource conservation. The design and simplification of geopolymer concrete (GPC) using recycled aggregates was addressed by Banoth Gopalakrishna and Pasla Dinakar (2024). They proposed a new mix design method for 100% recycled aggregate GPC using fly ash and alkaline activators. Compressive strengths ranged from 14 to 35 MPa, and the mixes demonstrated excellent chloride resistance, validating their use in coastal structures. Their extended study with GGBS inclusion (Gopalakrishna et al., 2024) further enhanced early age strength and corrosion resistance, showing that GGBS Fly Ash synergy offers both durability and reduced environmental footprint. In the realm of high performance recycled aggregate concrete (HMRAC), Chengyuan Wang et al. (2024) used 50% RCA combined with micro powders (10% silica fume, 15% slag, and 5% fly ash).

Their orthogonal experimental design revealed a 29.5% strength improvement and a 21.9% carbon reduction, establishing HMRAC as both structurally and environmentally superior.

The synergistic reuse of waste materials was exemplified by Chun Ran Wu (2025), who used red mud (RM), RCA, and circulating fluidized bed (CFB) fly ash to create a sustainable concrete (SCRC). RM mitigated the adverse effects of fly ash and enhanced segregation resistance. Despite the economic drawbacks of higher superplasticizer demand, the concrete offered excellent heavy metal immobilization and environmental safety. Nanotechnology enhanced mixes were explored by Ghasan Fahim Huseien et al. (2023) through the addition of bio-based graphene oxide nanoplatelets (BGWNPs) to high volume FA concrete. Their study reported major gains in bond strength and durability, with substantial reductions in CO_2 emissions and binder costs. The integration of 6% BGWNPs yielded the best mechanical outcomes. Thermal and sulfate resistant foam concrete was produced by I.G.M. Ozkan et al. (2024) using pine cone powder (PCP), fly ash, and GGBS. Their optimized mix (50% PCP and 100% GGBS) exhibited strong thermal insulation and compressive strength of 12.48 MPa, suitable for energy efficient non-structural applications. To combat hazardous waste accumulation, Jinwang Mao et al. (2024) recycled municipal solid waste incineration fly ash (MSWIFA) into ultra high-performance concrete (UHPC), achieving over 110 MPa strength. The study emphasized heavy metal immobilization and sustainability, with MSWIFA based mixes demonstrating reduced environmental contamination.

M. Alharthai et al. (2024) examined concrete containing recycled aggregates, FA, and polypropylene fibers (PPF). They found that while RA lowered strength, FA and PPF offset these effects, improving compressive strength and ultrasonic pulse velocity (UPV), leading to better internal uniformity. Machine learning's role in sustainable mix optimization was explored by Maedeh Hosseinzadeh et al. (2023), who used models like Random Forest and XGBoost to predict mechanical properties of FARAC. Their web-based tool allows users to input mix variables and receive real time strength predictions, promoting sustainable design with minimal trial testing. A follow up study in 2024 applied multiscale modeling and Mori Tanaka theory to predict elastic properties, demonstrating a 25% reduction in modulus with full RCA use and validating the effectiveness of advanced predictive modeling. Mohammed Abed et al. (2022) adopted a multi criteria decision making (MCDM) approach to optimize self compacting concrete (SCC) with RA and FA. They found that 50% RA and 15% FA significantly reduced costs (up to 23.9%) while improving strength and reducing chloride penetration. This framework effectively balanced environmental, economic, and technical aspects. Muhammad Murtaza et al. (2024) incorporated FA, cement kiln dust (CKD), and recycled concrete powder (RCP) in SCC. They concluded that FA and CKD improved workability and compressive strength, while coal gangue powder (CGP) decreased performance. Microstructural analysis confirmed densification via pozzolanic reactions. N. Binte Shahid et al. (2025) addressed recycled brick aggregate concrete (RBAC) by adding silica fume and nylon fibers. The combined additives improved mechanical and durability performance, offsetting the inherent weaknesses of porous brick aggregates. In terms of artificial aggregates, Pengfei Ren et al. (2024) utilized incineration bottom ash (IBA), fly ash, and GGBS to produce artificial aggregates with excellent strength and low ASR expansion. However, leaching tests indicated concerns about heavy metal contamination, necessitating further environmental evaluation.

Pingheng Zeng et al. (2025) studied the long-term effects of sulfate erosion and sustained loading on FA concrete. Their proposed models for compressive strength and elastic modulus performed better than existing ones, confirming the viability of high FA replacements under harsh conditions. Rudra Pratap Singh et al. (2023) and Rudra Singh et al. (2024) extensively evaluated geopolymer concretes made with FA, GGBS, SF, and RCA. They achieved high mechanical performance (e.g., 52.15 MPa compressive strength) and excellent durability against acid and sulfate attacks, with the GPC MG15 mix showing the best all around performance. S. Gao et al. (2025) introduced a novel treatment combining fly ash cement slurry and CO_2 mineralization to improve coal gangue aggregates (CGA). The modified aggregates improved strength, durability, and CO_2 capture, providing both structural and environmental advantages.

Samina Hameed et al. (2024) used expanded polystyrene (EPS), used cooking oil (UCO), and coconut fibers to develop lightweight RBAC. While strength slightly decreased due to EPS, durability and thermal insulation were improved, supporting their use in sustainable masonry applications. Shahzadi Irum et al. (2024) focused on geopolymer concrete using RCA and RFA with FA and GGBS. Their findings showed that high temperature curing significantly enhanced strength and durability, especially in fully recycled aggregate mixes. Water absorption increased with RCA but remained within acceptable limits. Somanshi Aggarwal et al. (2024) demonstrated the effectiveness of machine learning (Bagging Regressor and XGBoost) in predicting SCC strength with fly ash and RCA. Their GUI tool enables accurate prediction of compressive strength, offering a user friendly and resource efficient mix design solution. Uma Shankar Biswal and Pasla Dinakar (2021) proposed a two-stage mixing approach and DIN based methodology for RAC mix design. Their strategy improved particle packing and reduced porosity, especially when GGBS replaced 50% of OPC, enhancing both fresh and hardened concrete performance.

Xiongzhou Yuan et al. (2023) studied high strength geopolymer concrete using eggshell powder (ESP) and rice husk ash (RHA) to replace FA. At 20% ESP, the composite showed optimal strength and chloride resistance. Heat curing was critical for mechanical development and microstructural densification. Xuan Dao et al. (2024) treated RCA from various parent concrete grades with cement–fly ash slurry. Soaking for up to 72 hours improved physical and structural properties, reduced water absorption by 30%, and enhanced aggregate bonding paving the way for high quality recycled concrete. Yulin Patrisia et al. (2024) integrated pond ash and recycled glass sand into concrete bricks, achieving strength over 29 MPa with superior thermal insulation and fire resistance. While slightly lower in strength than conventional bricks, they met construction standards and improved sustainability metrics. Zuowei Liu et al. (2023) performed a life cycle assessment (LCA) on biomineralized FA RCA concrete. Their findings revealed that biomineralization reduced environmental impact significantly, although chemically treated RCA had higher associated energy costs. The study supports balancing sustainability and mechanical gains.

3 FUTURE SCOPE

As global environmental concerns intensify, the demand for sustainable construction materials will only continue to rise. While current research has demonstrated promising results using industrial by products, recycled aggregates, and geopolymer binders in concrete, several opportunities remain for future exploration to optimize performance, scalability, and environmental impact. Firstly, the large scale industrial implementation of sustainable concrete technologies needs further investigation. Many laboratory scale studies have shown potential, but real-world challenges such as raw material variability, transportation logistics, and quality control in on site applications must be addressed. Pilot projects and demonstration buildings using fully recycled aggregate geopolymer concrete (RAGPC), lightweight recycled concrete, or foam geopolymer systems can bridge this gap between research and practice. Secondly, standardization of testing protocols and long-term performance evaluations are essential. Current studies often vary in testing conditions, making direct comparisons difficult. The development of international guidelines for characterizing concrete made with recycled and alternative materials would ensure consistency and facilitate wider adoption.

Advanced modeling techniques, such as machine learning, multiscale modeling, and finite element simulations, should be further leveraged to predict long term behavior, optimize mix designs, and forecast structural reliability under diverse loading and environmental conditions. Integration of artificial intelligence (AI) driven platforms with practical mix design tools will empower engineers and researchers to design concrete mixes based on performance requirements with minimal trial and error. From a material perspective, the search for novel activators and eco friendly additives is another promising avenue. Current alkali activated systems often rely on chemicals such as sodium hydroxide and sodium silicate, which may present safety and cost issues. Future work should focus on developing low cost, low toxicity, and bio based alkaline activators to further reduce the environmental burden. Additionally, the exploration of region-specific waste materials such as palm oil fuel ash, agricultural residues, or demolition dust can localize sustainable practices. These materials should be incorporated into circular economy models, promoting both waste reduction and socio-economic development. Finally, life cycle assessment (LCA), embodied energy analysis, and carbon footprint evaluations must become integral to concrete research. Future studies should not only optimize mechanical performance but also quantify and minimize the environmental costs, aiming for net zero or carbon negative concrete formulations. In conclusion, the future of sustainable concrete research lies in multidisciplinary integration merging material science, environmental engineering, digital modeling, and policy frameworks to make eco friendly construction mainstream, efficient, and globally scalable.

4 CONCLUSION

The reviewed literature underscores a transformative shift in the concrete industry toward sustainability through the adoption of recycled aggregates, industrial by products, and alternative binder systems. Fly ash, ground granulated blast furnace slag (GGBS), recycled concrete aggregates (RCA), red mud, silica fume, and a wide array of novel waste materials have been successfully employed to improve the mechanical, durability, and environmental properties of concrete.

One of the key insights across multiple studies is the role of fly ash not only as a performance enhancer but also as a crucial agent in reducing cement consumption and associated carbon emissions. When combined with RCA or activated in geopolymer systems, fly ash significantly improves strength retention, sulfate and chloride resistance, and long-term durability. Similarly, geopolymer concrete (GPC) formulations using alkali activated FA and GGBS have shown exceptional mechanical performance and corrosion resistance, making them a viable alternative to traditional Portland cement-based concretes. Machine learning and advanced modeling approaches have also emerged as valuable tools for optimizing mix designs and predicting performance, offering efficient paths to tailor sustainable concrete to specific applications. Overall, this review confirms that the convergence of sustainable material utilization, performance-based design, and environmental awareness is no longer optional but essential for the future of construction. The integration of recycled and industrial waste materials when scientifically validated and strategically applied can produce concrete that meets modern engineering demands while significantly contributing to a greener built environment.

References

- Abed, M. et al. (2022) 'Performance keys on self-compacting concrete using recycled aggregate with fly ash by multi-criteria analysis', Journal of Cleaner Production, 378(August), p. 134398. Available at: https://doi.org/10.1016/j.jclepro.2022.134398.
- Abushanab, A. and Alnahhal, W. (2023) 'Bond strength of corroded reinforced recycled aggregate concrete with treated wastewater and fly ash', Journal of Building Engineering, 79(September 2023), p. 107778. Available at: https://doi.org/10.1016/j.jobe.2023.107778.
- Aggarwal, S. et al. (2024) 'A novel data-driven machine learning techniques to predict compressive strength of fly ash and recycled coarse aggregates based self-compacting concrete', Materials Today Communications, 39(February), p. 109294. Available at: https://doi.org/10.1016/j.mtcomm.2024.109294.
- Ahıskalı, A. et al. (2024) 'Mechanical and durability properties of polymer fiber reinforced one-part foam geopolymer concrete: A sustainable strategy for the recycling of waste steel slag aggregate and fly ash', Construction and Building Materials, 440(May). Available at: https://doi.org/10.1016/j.conbuildmat.2024.137492.
- Alamri, M. et al. (2024) 'Enhancing the engineering characteristics of sustainable recycled aggregate concrete using fly ash, metakaolin and silica fume', Heliyon, 10(7), p. e29014. Available at: https://doi.org/10.1016/j.heliyon.2024.e29014.
- Alharthai, M. et al. (2024) 'The enhancement of engineering characteristics in recycled aggregates concrete combined effect of fly ash, silica fume and PP fiber', Alexandria Engineering Journal, 95(December 2023), pp. 363–375. Available at: https://doi.org/10.1016/j.aej.2024.03.084.
- Andharia, B.R. et al. (2023) 'Sustainable high volume fly ash concrete with recycled C&D waste and dredged marine sand', Materials Today: Proceedings [Preprint], (xxxx). Available at: https://doi.org/10.1016/j.matpr.2023.04.313.
- Binte Shahid, N., Mutsuddy, R. and Islam, S.R. (2025) 'Synergistic impact of supplementary cementitious materials (silica fume and fly ash) and nylon fiber on properties of recycled brick aggregate concrete', Case Studies in Construction Materials, 22(March), p. e04484. Available at: https://doi.org/10.1016/j.cscm.2025.e04484.
- Biswal, U.S. and Dinakar, P. (2021) 'A mix design procedure for fly ash and ground granulated blast furnace slag based treated recycled aggregate concrete', Cleaner Engineering and Technology, 5, p. 100314. Available at: https://doi.org/10.1016/j.clet.2021.100314.

- Cao, J., Zou, Z. and Zeng, P. (2025) ‘Mechanical properties of fly ash concrete after the coupling effects of sustained load and sulphate erosion’, Construction and Building Materials, 460(January), p. 139866. Available at: https://doi.org/10.1016/j.conbuildmat.2025.139866.
- Dao, X.H. et al. (2024) ‘Effect of the strength grade of parent concrete on the performance of recycled aggregate treated by cement-fly ash slurry under prolonged soaking duration’, Construction and Building Materials, 411(December 2023), p. 134528. Available at: https://doi.org/10.1016/j.conbuildmat.2023.134528.
- Gao, W.-C. et al. (2023) ‘Shrinkage model for concrete incorporating coal gangue coarse and fine aggregates’, Journal of Building Engineering, 80. Available at: https://doi.org/10.1016/j.jobe.2023.107865.
- Gopalakrishna, B. and Dinakar, P. (2024a) ‘An innovative approach to fly ash-based geopolymer concrete mix design: Utilizing 100 % recycled aggregates’, Structures, 66(June), p. 106819. Available at: https://doi.org/10.1016/j.istruc.2024.106819.
- Gopalakrishna, B. and Dinakar, P. (2024b) ‘The evaluation of the life cycle and corrosion properties of recycled aggregate geopolymer concrete incorporating fly ash and GGBS’, Journal of Building Engineering, 94(March), p. 109977. Available at: https://doi.org/10.1016/j.jobe.2024.109977.
- Hameed, S. et al. (2025) ‘Investigating lightweight recycled brick aggregate concrete incorporating EPS beads: Application to masonry units’, Results in Engineering, 25(January), p. 104019. Available at: https://doi.org/10.1016/j.rineng.2025.104019.
- Hosseinzadeh, M., Dehestani, M. and Hosseinzadeh, A. (2023) ‘Prediction of mechanical properties of recycled aggregate fly ash concrete employing machine learning algorithms’, Journal of Building Engineering, 76(March), p. 107006. Available at: https://doi.org/10.1016/j.jobe.2023.107006.
- Huseien, G.F. et al. (2024) ‘Evaluation of high-volume fly-ash cementitious binders incorporating nanosilica as eco-friendly sustainable concrete repair materials’, Construction and Building Materials, 447(December 2023). Available at: https://doi.org/10.1016/j.conbuildmat.2024.138022.
- Irum, S. and Shabbir, F. (2024) ‘Performance of fly ash/GGBFS based geopolymer concrete with recycled fine and coarse aggregates at hot and ambient curing’, Journal of Building Engineering, 95(June), p. 110148. Available at: https://doi.org/10.1016/j.jobe.2024.110148.
- Krishnan, A.K. et al. (2024) ‘A transition towards circular economy with the utilisation of recycled fly ash and waste materials in clay, concrete and fly ash bricks: A review’, Journal of Building Engineering, 98(October), p. 111210. Available at: https://doi.org/10.1016/j.jobe.2024.111210.
- Liu, Z. et al. (2023) ‘Exploring the sustainability of concrete with fly ash, recycled coarse aggregate and biomineralisation method by life cycle assessment’, Journal of Cleaner Production, 406(November 2022), p. 137077. Available at: https://doi.org/10.1016/j.jclepro.2023.137077.
- Mao, J. et al. (2024) ‘Innovative dual-benefit recycling and sustainable management of municipal solid waste incineration fly ash via ultra-high-performance concrete’, Science of the Total Environment, 957(October), p. 177852. Available at: https://doi.org/10.1016/j.scitotenv.2024.177852.
- Meena, A., Singh, N. and Singh, S.P. (2023) ‘High-volume fly ash Self Consolidating Concrete with coal bottom ash and recycled concrete aggregates: Fresh, mechanical and microstructural properties’, Journal of Building Engineering, 63(PA), p. 105447. Available at: https://doi.org/10.1016/j.jobe.2022.105447.
- Murtaza, M. et al. (2024) ‘Durability of high strength self-compacting concrete with fly ash , coal gangue powder, cement kiln dust, and recycled concrete powder’, 449(September). Available at: https://doi.org/10.1016/j.conbuildmat.2024.138345.
- Patrisia, Y. et al. (2024) ‘Optimizing engineering potential in sustainable structural concrete brick utilizing pond ash and unwashed recycled glass sand integration’, Case Studies in Construction Materials, 21(October), p. e03816. Available at: https://doi.org/10.1016/j.cscm.2024.e03816.
- Ren, P., Mehdizadeh, H. and Ling, T.C. (2024) ‘Performance investigation of the artificial aggregate by integrally recycling incineration bottom ash and fly ash’, Cement and Concrete Composites, 152(May), p. 105678. Available at: https://doi.org/10.1016/j.cemconcomp.2024.105678.
- Singh, R.P. et al. (2024) ‘Durability assessment of fly ash, GGBS, and silica fume based geopolymer concrete with recycled aggregates against acid and sulfate attack’, Journal of Building Engineering,

82(September 2023), p. 108354. Available at: https://doi.org/10.1016/j.jobe.2023.108354.

- Wang, C. et al. (2023) 'Orthogonal experimental design for compressive strength of recycled coarse aggregate concrete with silica fume-slag-fly ash hybrid micro-powders', Construction and Building Materials, 408(October), p. 133669. Available at: https://doi.org/10.1016/j.conbuildmat.2023.133669.
- Wu, C.R. et al. (2025) 'Synergistic reuse of red mud and circulating fluidised bed fly ash in self-compacting recycled concrete', Construction and Building Materials, 470(230), p. 140533. Available at: https://doi.org/10.1016/j.conbuildmat.2025.140533.
- Yuan, X. et al. (2024) 'Evaluation of the performance of high-strength geopolymer concrete prepared with recycled coarse aggregate containing eggshell powder and rice husk ash cured at different curing regimes', Construction and Building Materials, 434(May), p. 136722. Available at: https://doi.org/10.1016/j.conbuildmat.2024.136722.
- Yucesan, M. et al. (2024) 'Evaluating sustainability of urban mobility of Asian cities: An integrated approach of interval type-2 fuzzy best-worst method and MULTIMOORA', Engineering Applications of Artificial Intelligence, 127. Available at: https://doi.org/10.1016/j.engappai.2023.107266.