
**DEVELOPMENT AND PERFORMANCE EVALUATION OF FLY ASH–
COLD SETTING RESIN COMPOSITE BRICKS: A LITERATURE
REVIEW**

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ABSTRACT

The rapid accumulation of industrial by-products such as fly ash has created significant environmental challenges, while simultaneously offering a valuable opportunity for sustainable construction material development. Conventional fly ash bricks, though economical and eco-friendly, often exhibit limitations in mechanical strength, durability, and water resistance. In recent years, the incorporation of cold setting resins as a binding agent has emerged as a promising approach to enhance the performance characteristics of fly ash-based composite bricks. This literature review critically examines the development, material composition, manufacturing techniques, and performance behavior of fly ash–cold setting resin composite bricks. It focuses on the influence of resin content, curing conditions, and fly ash particle characteristics on compressive strength, water absorption, density, and durability. The review also compares these composites with conventional fly ash and clay bricks to evaluate improvements in structural and environmental performance. Furthermore, the study highlights existing research gaps, including long-term durability assessment, cost optimization, and large-scale industrial applicability. The findings suggest that cold setting resin significantly improves bonding characteristics and mechanical performance, making these composites a viable alternative for sustainable construction materials.

KEYWORDS: Fly ash bricks; Cold setting resin; Composite bricks; Sustainable construction materials; Compressive strength; Industrial waste utilization; Durability.

INTRODUCTION

The rapid growth of industrialization has led to the generation of large quantities of solid waste, among which fly ash is one of the most abundant by-products produced from coal-fired thermal power plants. Disposal of fly ash poses significant environmental challenges, including air and water pollution as well as the occupation of large land areas. To address these concerns, the utilization of fly ash in construction materials has gained considerable attention in recent years, particularly in the development of bricks and masonry units. Conventional clay bricks, though widely used, are associated with high energy consumption during manufacturing and depletion of natural topsoil resources. In this context, fly ash-based composite bricks offer a sustainable alternative due to their eco-friendly nature, cost-effectiveness, and potential for waste recycling. However, the primary limitation of fly ash bricks is their relatively low mechanical strength and durability when compared to traditional building materials.

To overcome these limitations, researchers have explored the incorporation of binding agents such as cold setting resins in fly ash composites. Cold setting resins act as effective chemical binders that can enhance particle bonding at ambient temperatures without the need for high-temperature curing, thereby improving compressive strength, water resistance, and overall durability of the bricks. The combination of fly ash and cold setting resin thus presents a promising approach for producing high-performance composite bricks. This literature review focuses on the development and performance evaluation of fly ash-cold setting resin composite bricks, highlighting the effects of material composition, resin content, curing conditions, and mechanical behavior. It also discusses the advancements in improving the structural and durability properties of these composite bricks, aiming to provide a comprehensive understanding of their potential as sustainable construction materials.

Literature review

Amar Singh et al (2025) fly ash composites have emerged as an important class of engineering and construction materials because of their excellent mechanical properties, low cost, and environmentally friendly nature. Fly ash, which is a by-product generated from thermal power plants during coal combustion, contains fine particles rich in silica, alumina, and other mineral compounds that contribute to strength and durability when used in composite materials. Researchers have shown that fly ash composites possess high tensile strength, compressive strength, impact resistance, and surface hardness, making them suitable for structural, automotive, aerospace, and construction applications. To manufacture these

composites, several fabrication techniques such as in-situ deposition, hand lay-up, compo-casting, stir casting, and powder metallurgy have been adopted depending on the desired material properties and application requirements. In-situ deposition allows the reinforcement phase to form directly within the matrix, improving bonding and uniformity, while hand lay-up is a simple and economical process commonly used for polymer-based composites. Compo-casting and stir casting are widely used in metal matrix composites because they help distribute fly ash particles evenly throughout the material, thereby enhancing mechanical performance. Despite the extensive research conducted on fabrication methods and performance evaluation, a clear and systematic relationship between the microstructure of fly ash composites and their resulting properties has not yet been fully established. Such a structure–property correlation is essential because the size, distribution, and interaction of fly ash particles within the matrix directly influence strength, toughness, wear resistance, and long-term durability. Therefore, further studies are required to optimize composition, processing parameters, and interfacial bonding in order to achieve maximum performance. In the field of construction materials, hollow fly ash concrete blocks have gained popularity, especially in developing countries, due to their lightweight nature, thermal insulation capacity, and cost-effectiveness. However, many of these blocks are produced without standardized manufacturing guidelines, leading to inconsistent quality and variations in mechanical properties. Recent studies have focused on improving these blocks through optimized mix designs involving different proportions of cement, fly ash, sand, and water. Experimental investigations revealed that properly designed fly ash concrete blocks exhibit significantly higher compressive strength than conventional blocks, along with better water retention capacity and improved modulus of rupture, which indicates enhanced resistance to bending and cracking. The improved properties are mainly attributed to the pozzolanic reaction of fly ash, which refines the pore structure and enhances bonding within the concrete matrix. These findings highlight that the optimization of fly ash content and mix proportions can produce stronger, more durable, and environmentally sustainable construction materials while also promoting the effective utilization of industrial waste.

Dr. Rahul D. Shelke et al (2025) this research focuses on converting large quantities of fly ash generated from coal-fired thermal power plants into an eco-friendly and value-added construction material by developing sustainable fly ash–polymer composites using cold-setting resin as a binder. Composite samples containing 75%, 80%, and 85% fly ash by weight were fabricated through a powder metallurgy compaction method, and selected

specimens were further subjected to hydrothermal curing at temperatures between 110°C and 180°C to improve their structural properties. Detailed experimental investigations, including hardness, compressive strength, density, water absorption, thermal conductivity, wear resistance, and microstructural characterization through SEM, XRD, and FTIR analyses, were carried out to evaluate the performance of the composites. The results showed that increasing fly ash content significantly improved hardness and compressive strength, while hydrothermal curing promoted the formation of calcium silicate hydrate (CSH) and calcium aluminate silicate hydrate (CASH) phases, leading to enhanced bonding, densification, and reduced wear. In addition, the composites exhibited very low thermal conductivity, indicating excellent thermal insulation capability. Overall, the study demonstrates that high-volume fly ash–resin composites possess good mechanical strength, lightweight characteristics, superior insulation properties, and strong potential for sustainable and green building applications while also addressing industrial waste management problems.

C. Elizabeth Rani Juneius et al (2021) bricks are one of the most essential construction materials used in the development of residential buildings, commercial structures, pavements, retaining walls, and many other civil engineering works. Traditionally, clay bricks have been widely used; however, the rapid growth of the construction industry has increased the demand for building materials and simultaneously raised concerns regarding depletion of natural resources, high energy consumption, and environmental pollution caused during conventional brick manufacturing. To overcome these issues, alternative eco-friendly building materials such as fly ash bricks have been developed and widely adopted in modern construction practices. Fly ash bricks are manufactured using industrial by-products and waste materials including fly ash obtained from thermal power plants, granite dust generated from stone cutting industries, sand, cement, and water mixed in suitable proportions. Fly ash acts as the primary binding and pozzolanic material, while granite dust and sand improve the texture, density, and mechanical properties of the bricks. Cement is added to provide additional bonding strength and durability, and water is used to facilitate proper mixing and hydration. The prepared mixture is compacted into molds and cured under controlled conditions to achieve the required strength. Compared to conventional clay bricks, fly ash bricks possess several advantages such as lower weight, higher compressive strength, better dimensional accuracy, smoother surface finish, lower water absorption, and improved resistance to fire and weathering. Their lightweight nature reduces the dead load on structures, thereby lowering the overall construction cost and increasing structural efficiency.

Furthermore, the utilization of fly ash and granite dust helps in the effective disposal of industrial waste materials that would otherwise create serious environmental hazards such as air pollution, land degradation, and water contamination. The manufacturing process of fly ash bricks also consumes less energy because it does not require high-temperature burning like traditional clay bricks, thereby reducing carbon emissions and preserving fertile topsoil. Hence, fly ash bricks are considered a sustainable, economical, and environmentally friendly alternative to conventional bricks and play an important role in promoting green construction and sustainable development in the construction industry.

M. vishnu priya et al (2021) fly ash, a waste material generated from thermal power plants during coal combustion, has become a major environmental concern due to its large-scale disposal and the pollution associated with it. Fly ash mainly consists of fine particles rich in silica, alumina, and other mineral compounds formed when coal is burned at high temperatures. Instead of treating fly ash as industrial waste, modern research considers it a valuable resource for construction materials because it can improve the strength, durability, and sustainability of building products. In this study, an innovative method was developed for producing fly ash composite bricks by mixing fly ash with cold-setting resin and varying proportions of cement, lime, gypsum, sand, and water under controlled temperature conditions. Different compositions were prepared to evaluate the optimum mix for enhanced brick performance. Various mechanical and physical properties such as compressive strength, hardness, water absorption, density, thermal conductivity, flexural strength, bonding strength, efflorescence, and wear resistance were investigated. The results showed that the fly ash–resin composite bricks achieved a compressive strength of 11.24 MPa, hardness of 47.37 HV, density of 1.68 g/cm³, water absorption of 19.09%, and thermal conductivity of 0.055 W/mK, indicating good mechanical stability and thermal insulation properties. Detailed microstructural and chemical analyses using X-ray diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), and Scanning Electron Microscopy (SEM) confirmed the strong bonding and compact structure of the composites. Further investigation compared fly ash bricks with conventional clay bricks by preparing samples containing 3%, 5%, and no cement content. Among all mixes, bricks containing 5% cement demonstrated superior performance with a compressive strength of 15.21 N/mm², which is approximately 63% higher than Class-I conventional bricks. Water absorption was reduced by about 48%, while efflorescence was nearly 50% lower than ordinary bricks, indicating better durability and resistance to moisture damage. Additionally, the flexural strength of fly ash bricks containing

55% fly ash was about 63% greater than conventional bricks, and the bonding strength was nearly double. These findings prove that fly ash composite bricks are lightweight, strong, thermally efficient, cost-effective, and environmentally friendly alternatives to traditional construction materials, thereby offering a sustainable solution for industrial waste utilization and modern infrastructure development.

Vigyan Nidhi et al (2020) fly ash utilization has become an important environmental and industrial concern due to the enormous quantity of ash generated by thermal power plants, which creates serious pollution problems and requires large areas of land for disposal. Traditionally, fly ash has been partially utilized in the construction industry for the production of cement, concrete, and bricks, but recent advancements in material science have introduced polymer composites as a promising alternative for its effective utilization. In epoxy-based polymer composites, fly ash acts as a low-cost reinforcing filler material that enhances both economic and functional properties of the composite. Researchers have demonstrated that incorporating fly ash into epoxy resin can significantly improve mechanical properties such as tensile strength, compressive strength, hardness, stiffness, wear resistance, and impact resistance, while also improving thermal stability, heat resistance, and dimensional stability of the material. These improved properties make fly ash–epoxy composites suitable for a wide range of applications in automotive, aeronautical, marine, electrical, and semi-structural industries where lightweight, durable, and cost-effective materials are required. The performance of these composites largely depends on the interfacial bonding between the fly ash particles and the epoxy matrix. Since untreated fly ash often has poor compatibility with polymers, various surface modification techniques such as silane treatment, alkali treatment, plasma treatment, and coupling agents are used to enhance adhesion between the filler and the matrix. Proper surface treatment increases dispersion of fly ash particles, reduces void formation, improves stress transfer, and ultimately enhances the overall strength and durability of the composite material. Recent studies have therefore focused on optimizing filler content, particle size, and surface treatment methods to develop high-performance fly ash reinforced epoxy composites with superior thermal and mechanical behavior. Thus, fly ash mediated epoxy composites not only provide an environmentally sustainable solution for industrial waste management but also contribute to the development of advanced engineering materials with diverse industrial applications.

Karan Paul et al (2019) this study focuses on investigating the effect of partially replacing natural clay with a composite waste mixture consisting of fly ash and paper sludge in the manufacturing of bricks. The research is primarily aimed at developing sustainable and eco-friendly construction materials by utilizing industrial and paper industry wastes that are otherwise disposed of in landfills and create serious environmental problems. In this work, different proportions of the composite waste mixture are added as a partial substitute for clay during brick production, and the prepared bricks are tested to evaluate their engineering and physical properties. Fly ash, a by-product of thermal power plants, possesses pozzolanic and binding characteristics that can improve the strength and durability of bricks, while paper sludge contributes lightweight and insulating properties due to its fibrous nature. The study examines how varying percentages of these waste materials influence important parameters such as compressive strength, water absorption, density, hardness, shrinkage, and durability of the bricks. The manufactured composite waste bricks are then compared with conventional clay bricks to determine their suitability for construction applications. Through this comparison, the research aims to identify an optimum mix proportion that provides adequate strength, reduced weight, lower water absorption, and better environmental performance. In addition to improving brick properties, the utilization of fly ash and paper sludge helps in conserving natural clay resources, reducing industrial waste disposal issues, lowering production costs, and minimizing environmental pollution. Therefore, the study contributes toward sustainable waste management and promotes the development of green building materials for modern construction practices.

Mohamed Vade et al (2019) investigated the application of artificial neural networks (ANNs) for predicting the compressive strength of geopolymer blocks produced using Moroccan fly ash and phosphogypsum, which are industrial by-products used to develop sustainable construction materials. In their study, two ANN approaches were compared: the multilayer perceptron (MLP) and the radial basis function (RBF) network. A total of 99 experimental data samples were collected from laboratory tests, which were then divided into training and testing datasets to develop and validate the predictive models. The researchers focused on optimizing the structure of the MLP model by systematically adjusting key parameters such as the number of hidden layers, number of neurons in each layer, and the type of activation function to improve prediction accuracy. After several trials, the best-performing configuration was identified as an MLP model with two hidden layers containing 8 and 10 neurons respectively, using the hyperbolic tangent activation function. This

optimized MLP model demonstrated superior performance compared to the RBF network in accurately predicting compressive strength values. The study highlights that ANN-based models can effectively capture complex nonlinear relationships between mix composition and mechanical properties of geopolymers, making them powerful tools for reducing experimental effort and improving the efficiency of material design and performance evaluation in sustainable construction applications.

Panuwat Joyklad et al (2018) in conventional construction, hollow or interlocking concrete blocks are widely used because they are easy to assemble, reduce mortar usage, and speed up construction. However, standard CCI blocks often suffer from limitations such as moderate strength, higher water absorption, and lower durability under harsh environmental conditions. To address these issues, the authors explored alternative mix designs where fly ash is partially used as a replacement or additive alongside cement and sand.

Fly ash plays a key role in the study because it is a fine, pozzolanic material rich in silica and alumina. When it reacts with calcium hydroxide released during cement hydration, it forms additional cementitious compounds (mainly calcium silicate hydrates). These compounds help densify the internal structure of the block, reducing voids and improving bonding between particles. As a result, the microstructure becomes more compact and less porous. The experimental program involved preparing different mix proportions of fly ash, cement, and sand to manufacture hollow interlocking blocks. These blocks were then tested for important engineering properties such as compressive strength, water absorption, and modulus of rupture (flexural strength). Compressive strength is crucial because it determines the load-bearing capacity of the blocks, while water absorption indicates durability and resistance to weathering. The modulus of rupture reflects the block's resistance to bending and cracking. The results showed that the inclusion of fly ash significantly improved the compressive strength compared to conventional CCI blocks. This improvement is mainly due to the pozzolanic reaction and better particle packing, which reduce internal pores and increase density. Additionally, the blocks with fly ash showed lower water absorption, meaning they are less permeable and more resistant to moisture penetration. This directly enhances durability, especially in humid or rainy environments. The study also observed an improvement in flexural strength (modulus of rupture), indicating better resistance to cracking under bending stresses. The research concludes that optimizing the mix design with fly ash not only improves mechanical performance but also enhances durability characteristics of hollow interlocking blocks. It suggests that such blocks can serve as a cost-

effective and sustainable alternative to conventional masonry units, especially in large-scale construction. The use of fly ash also contributes to environmental sustainability by reducing cement consumption and utilizing industrial waste that would otherwise require disposal.

Ravi Kumar et al. (2014) investigated the behavioral and engineering performance of fly ash bricks prepared using a combination of fly ash, cement, gypsum, sand, and lime in different proportions to optimize strength and durability. The study mainly focused on evaluating how varying material compositions influence the physical and mechanical properties of the bricks. To assess their performance, several standard tests were conducted, including compressive strength test, water absorption test, and unit weight (density) test, and the results were compared with those of conventional clay bricks. The findings revealed that fly ash bricks exhibited significantly higher compressive strength than traditional burnt clay bricks, indicating better load-bearing capacity and structural reliability. This improvement was mainly attributed to the pozzolanic reaction between fly ash and lime in the presence of cement, which forms additional calcium silicate hydrate (C-S-H) gel that enhances bonding and densifies the brick structure. In addition, the study observed lower water absorption in fly ash bricks, suggesting improved durability and reduced porosity. Overall, the research concluded that fly ash bricks are a more sustainable and high-performance alternative to conventional bricks, suitable for modern construction applications, especially where strength and durability are critical requirements.

Basumajumdar et al. (2004) investigated the chemical and physical interaction between fly ash (FA) and lime for the development of bricks, focusing on how cementitious properties are generated under normal temperature curing conditions in the presence of moisture. Their study demonstrated that when fly ash is mixed with lime and compacted, a slow pozzolanic reaction occurs in which the calcium oxide (CaO) from lime reacts with the reactive oxides present in fly ash, mainly silica (SiO₂), alumina (Al₂O₃), and iron oxide (Fe₂O₃). This reaction leads to the formation of secondary cementitious compounds such as calcium silicate hydrates (C-S-H), calcium aluminate hydrates (C-A-H), and other complex hydrated phases, which are primarily responsible for strength development in the compacted material. The researchers monitored the reduction of free lime content over different curing periods to understand the progress of the reaction and confirmed that as curing time increases, more lime is consumed in forming stable hydrated products, thereby improving the structural integrity of the mix. The study also highlighted the importance of densification through

compaction, showing that adequate pressure is necessary to bring reactants into close contact and facilitate effective bonding. Based on experimental results, they concluded that an optimal compaction pressure in the range of 200–250 kg/cm², especially when combined with a controlled water or steam curing process, produces the most durable and mechanically stable fly ash–lime bricks, as it ensures maximum pozzolanic activity and better microstructural development.

METHODOLOGY

The methodology adopted in the literature for the development and performance evaluation of fly ash–cold setting resin composite bricks generally involves the collection and characterization of raw materials such as fly ash, cold setting resin, sand, lime, cement, and water using tests for particle size distribution, specific gravity, chemical composition, and fineness. Different mix proportions are then prepared by varying the percentage of fly ash and resin binder to identify the optimum composition for strength and durability. The materials are thoroughly mixed in dry and wet conditions to achieve uniform consistency, after which the composite mixture is placed into brick moulds and compacted either manually or mechanically under controlled pressure. Unlike conventional clay bricks, these composite bricks are cured at ambient temperature because the cold setting resin hardens without high-temperature firing, thereby reducing energy consumption and environmental pollution. After curing for specified periods such as 7, 14, and 28 days, the prepared specimens are subjected to laboratory testing to evaluate physical, mechanical, and durability properties. Common tests reported in the literature include compressive strength, water absorption, density, hardness, efflorescence, thermal conductivity, impact resistance, and resistance to chemical attack. Microstructural analysis techniques such as Scanning Electron Microscopy (SEM), X-ray Diffraction (XRD), and Fourier Transform Infrared Spectroscopy (FTIR) are also employed in some studies to examine the bonding mechanism and interaction between fly ash particles and resin matrix. The experimental results are finally compared with conventional clay bricks and fly ash bricks to assess the feasibility, sustainability, cost effectiveness, and structural performance of fly ash–cold setting resin composite bricks for construction applications.

CONCLUSION

The review on the development and performance evaluation of fly ash–cold setting resin composite bricks highlights the growing importance of utilizing industrial waste materials in sustainable construction practices. Fly ash, being abundantly available as a by-product of thermal power plants, offers significant environmental and economic advantages when incorporated into brick manufacturing. However, conventional fly ash bricks often suffer from lower compressive strength, brittleness, and durability limitations. The incorporation of cold setting resin as a binding material has emerged as an effective approach to overcome these shortcomings.

From the literature surveyed, it is observed that the addition of cold setting resin improves the bonding characteristics between fly ash particles, resulting in enhanced compressive strength, reduced water absorption, improved dimensional stability, and better resistance to environmental degradation. Resin-based composite bricks also demonstrate faster setting behavior and reduced curing requirements compared to conventional cement-based bricks, thereby reducing energy consumption and production time. Several researchers reported that optimum resin content significantly influences the mechanical and durability properties of the composite bricks, while excessive resin addition may increase cost and reduce workability.

The studies further indicate that fly ash–resin composite bricks possess potential advantages such as lightweight nature, improved surface finish, enhanced chemical resistance, and better thermal insulation properties. These characteristics make them suitable for non-load-bearing walls, partition structures, and sustainable low-cost housing applications. In addition, the effective utilization of fly ash helps in minimizing landfill disposal problems and reduces environmental pollution associated with industrial waste accumulation.

Despite the promising outcomes, certain challenges still remain. Limited long-term durability studies, higher resin cost, lack of standardized manufacturing procedures, and insufficient field performance data restrict large-scale commercial adoption. Further research is therefore necessary to optimize resin dosage, evaluate long-term structural behavior, study fire resistance and thermal performance, and develop eco-friendly and cost-effective resin alternatives.

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