

Utilization of Agro-Industrial Waste for Sustainable Brick Production

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Abstract — This study explores the feasibility of manufacturing eco-friendly bricks using dairy sludge as a primary raw material, supplemented with construction waste and fly ash as admixtures. Dairy sludge, a by-product of milk processing industries, presents significant environmental disposal challenges due to its high organic and moisture content. When appropriately treated and combined with pozzolanic materials like fly ash and inert construction debris, it can be transformed into a viable brick-making component. The experimental methodology involved varying the proportions of dairy sludge, fly ash, and construction waste to assess the optimal mix for compressive strength, water absorption, durability, and thermal conductivity. Preliminary results indicate that bricks produced from this composite mix demonstrate satisfactory mechanical and thermal properties comparable to conventional clay bricks, while significantly reducing carbon emissions and resource depletion and also pave the way for cost-effective and eco-conscious construction practices.

Keywords: Eco-friendly Bricks, Dairy Sludge, Fly Ash, Construction Waste, Sustainable Construction Materials, Compressive Strength, Thermal Conductivity, Waste Utilization

I. INTRODUCTION

A. Dairy Industries:

The dairy industry encompasses a broad range of processes, beginning with the milk yield of milk and extending through to the final distribution of various dairy products to consumers. Once collected, the raw milk is transported to dairy processing plants, where it undergoes a series of treatments, including pasteurization, homogenization, and fermentation, to fabricate an array of dairy products such as cheese, yogurt, butter, and ice cream. Each product may involve specific processes; for example, cheese-making includes curdling and aging, while yogurt production requires bacterial fermentation. After processing, these dairy products are packaged and stored under controlled conditions to maintain their freshness and safety. Throughout this entire process, the industry is increasingly focusing on environmental sustainability and animal welfare, reflecting the evolving values and expectations of modern consumers.

1) Effect of dairy sludge on environmental:

- Nutrient Runoff: Dairy sludge often contains high levels of nutrients, particularly nitrogen and phosphorus. If improperly managed, these nutrients can seep into water bodies, leading to eutrophication, which may trigger harmful algal blooms and create dead zones in aquatic ecosystems.
- Contaminant Leaching: Dairy sludge may contain organic and inorganic contaminants, such as pathogens, heavy metals, and chemical residues. If these are not properly handled, they can seep into ground water or

surface water, contaminating water supplies and harming aquatic life.

- Pathogen: Untreated or improperly treated sludge may cultivate pathogens that could be hazardous if they come into contact with soil, plants, or humans. This can pose a risk to agricultural productivity and human health.
 - Odor Emission: Dairy sludge can emit unpleasant odours. This is particularly an issue if the sludge is stored or applied to land without proper treatment.
- 2) *Uses of dairy sludge:*
- Soil Amendment and Fertilizer: Dairy sludge is rich in organic matter and nutrients, making it a valuable soil amendment. It can be used to improve soil structure, increase organic content, and provide nutrients for crops.
 - Composting: Dairy sludge can be mixed with other organic wastes to create compost. This process stabilizes the organic matter and produces a nutrient-rich material that can be used to enhance soil fertility.
 - Energy Generation: Dairy sludge can be used in anaerobic digestion to produce biogas, a renewable energy source. The biogas generated can be used for electricity generation or as a fuel.
 - Water Treatment: Dairy sludge contains organic matter that can be used in water treatment processes, particularly in the removal of heavy metals and other contaminants from wastewater.
 - Land Reclamation: Dairy sludge can be used in land reclamation projects to restore degraded lands by adding organic matter and nutrients to the soil, improving its fertility and structure.
 - Biochar Production: Dairy sludge can be converted into biochar through pyrolysis. Biochar is a stable form of carbon that can be used as a soil amendment to improve soil health and sequester carbon.

B. Construction Waste:

By repurposing waste materials, such as demolition debris and leftover construction materials, into brick production. This approach not only diminishes the environmental impact of waste disposal but also imp diverting waste from landfills and conserving the natural resources used in brick production. These construction waste-infused clay bricks retain the essential properties of traditional bricks, such as strength and durability, while supporting the circular economy by diverting waste from landfills and conserving the natural resources used in brick production. This approach is in line with contemporary sustainability objectives, promoting eco-friendly construction materials for the future.

- Concrete and Masonry Waste: Includes broken concrete, bricks, tiles, and stones, often generated during demolition or renovation of structures.
- Mixed Debris: A fusion of different types of construction waste, often found in demolition projects where materials are not segregated.

The significance of converting waste into useful materials, particularly in the context of environmental protection and sustainable development. This technique not only supports in waste management but also reduces. The environmental impact linked to traditional brick manufacturing, which relies heavily on non-renewable resources and involves high energy consumption.

Construction and demolition waste includes materials rendered unusable from repair, demolition, and construction activities, constituting 30% of waste in the EU and 40% of municipal solid waste. This waste primarily comprises mineral materials like concrete, bricks, and tiles, along with metals, glass, wood, gypsum, and hazardous substances. Recycling rates vary from 10% to 90% across EU member states, with concrete being the largest component. Despite significant recycling efforts, 35% of this waste is landfilled, and up to 54% may end up in illegal dumps. The construction industry is a major environmental burden, contributing 30% of resource extraction, 25% of waste, and notable CO₂ emissions.

1) Uses of Construction Waste in Clay Brick

- Resource Efficiency: Recycling construction waste, like demolition debris, diverts waste from landfills and reduces the need for virgin materials, promoting sustainability.
- Enhanced Brick Properties: Crushed concrete or masonry can boost brick strength. Waste materials can add structural stability and longevity to bricks.
- Cost Reduction: Waste materials can cut production costs. Reduces disposal costs and provides a cheaper raw material alternative.
- Environmental Benefits: Recycling waste into bricks decreases landfill use. Reduces resource demand and energy consumption.
- Innovative Material Development: Incorporating various waste types can create bricks with unique properties, such as better fire resistance or acoustic performance.

C. Fly Ash:

The main goal of this project is to utilize fly ash waste in construction without compromising its properties, thereby mitigating environmental pollution. In India, approximately annually, 75 million tons of fly ash are generated, yet only about 5% is utilized. This underutilization highlights the necessity to encourage the utilization of fly ash, as its disposal presents a serious environmental issue.

The efficient application of fly ash in construction materials has garnered attention from technologists and government bodies. India has around 75 thermal power plants, and the quality of fly ash generated varies significantly between them, often requiring further processing to ensure consistency for use in construction materials. Historically, fly ash produced from burning coal was emitted into the atmosphere with flue gases, leading to environmental and health issues that led to regulations reducing emissions to less than 1%. Despite these measures, over 65% of the fly ash generated worldwide is still disposed of in landfills and ash ponds.

Coal combustion products, such as fly ash (FA.) and bottom ash (BA), have been increasingly explored as substitutes for clay in brick production.

The incorporation of Fly Ash (FA) and Bagasse Ash (BA) into bricks has shown promising results, with these materials potentially enhancing the physical, mechanical, and durability properties of bricks to levels comparable to those of traditional clay-based bricks. Despite this potential, existing research has not extensively explored the combined use of Fly Ash (FA) and Bagasse Ash (BA) in brick manufacturing. To fill this research gap, the current study examines the innovative concept of replacing clay in bricks with a blend of Fly Ash (FA) and Bagasse Ash (BA), aiming to create a more sustainable and effective approach to brick production.

Fly ash is sorted based on its chemical composition and physical attributes, which largely depend on the type of coal burned in power plants. The most widely used classification system is founded on the American Society for Testing and Materials (ASTM) standards, particularly ASTM C618, which categorizes fly ash into two main types: Class F and Class C.

1) Advantages of fly ash (FA)

- Improved Workability: Fly ash particles are spherical and fine, which can enhance the workability of concrete mixes, making them easier to pour and finish.
- Increased Strength and Durability: When utilized as a partial substitute for cement in concrete, fly ash can contribute to higher long-term strength and durability. It also improves resistance to cracking, scaling, and alkali-silica reaction (ASR).
- Reduced Permeability: Fly ash can decrease the permeability of concrete, which renders the structure more resistant to water and chemical ingress, enhancing its durability in harsh environments.
- Environmental Benefits: Incorporating fly ash in construction decreases the need for cement, which plays a major role to CO₂ emissions. Additionally, it helps in recycling waste material that would otherwise require disposal.
- Cost Savings: Fly ash is often less expensive than Portland cement, leading to cost savings in concrete production, especially in large-scale projects.
- Reduced Heat of Hydration: The use of Fly Ash (FA) lowers the heat generated during the hydration process of cement, which reduces the risk of thermal cracking in large concrete structures.
- Improved Sustainability: Utilizing fly ash contributes to sustainable construction practices by reducing the reliance on natural resources and minimizing landfill waste.

2) Disadvantages of fly ash (FA)

- Variability in Quality: The qualities of fly ash can differ derived from the origin of the coal and the burning process. This variability can affect the consistency and predictability of concrete performance.
- Slower Strength Gain: Concrete including fly ash may develop strength more slowly, particularly in

the early stages. This can be a disadvantage in projects where early strength is critical.

- Increased Setting Time: Fly ash can increase the setting time of concrete, which may require adjustments in construction schedules.
- Prospective for Reduced Air Entrainment: The application of fly ash (FA) can influence the air-entrainment process in concrete, potentially leading to lower freeze-thaw resistance in colder climates.
- Potential for High Carbon Content: Fly ash with high unburned carbon content (high LOI) can negatively impact the functionality of concrete, especially regarding workability, water demand, and the effectiveness of air-entraining agents.

3) Uses of fly ash in clay brick

- Improved Brick Properties: Fly ash can increase the compressive strength of clay bricks, making them more durable and resistant to stress. The fine particles of fly ash improve the plasticity and workability of the clay mix, facilitating easier brick formation and handling.
- Cost Reduction: Using fly ash as a partial replacement for clay can reduce the cost of raw materials, leading to cost savings in brick production. Fly ash is often less expensive than virgin clay, providing an economical alternative for brick manufacturers.
- Environmental Benefits: Incorporating fly ash into clay bricks helps recycle a by-product that would otherwise contribute to landfill waste, supporting environmental sustainability. Using fly ash can reduce the demand for raw clay, which decreases the energy and emissions associated with clay extraction and processing.
- Enhanced Durability: Fly ash can improve the resistance of bricks to weathering, erosion, and chemical attack, enhancing their longevity and performance in various environmental conditions.
- Improved Thermal Insulation: Fly ash can contribute to better thermal insulation properties of bricks, making buildings more energy-efficient by reducing heat transfer.
- Development of Specialty Bricks: Fly ash can be used to create bricks with unique characteristics, such as lighter weight, improved fire resistance, or enhanced acoustic properties.

II. GENERAL EXPLANATION

This project focuses on creating eco-friendly bricks by using waste materials that are usually thrown away and cause pollution. Instead of using traditional clay, the bricks are made using a mixture of:

- Dairy sludge – a waste product has nutrients and organic matter from milk processing industries but is difficult to manage in large quantities
- Construction waste – leftover material like broken concrete or bricks from demolition sites
- Fly ash – a fine powder that comes from burning coal in power plants

By combining these three materials in the right proportions, we can make bricks that are:

Strong and durable, Water-resistant, Thermally efficient (good at keeping buildings cool or warm), Low-cost and sustainable

A. Working procedure:

- 1) The dairy sludge is first treated and dried to reduce moisture and smell.
- 2) It is then mixed with crushed construction waste and fly ash.
- 3) The mixture is moulded into brick shapes and dried or fired, depending on the process.
- 4) The final bricks are tested for strength, water absorption, and other properties.

Benefits:

- Reduces pollution from dairy and construction industries
- Saves natural resources like clay and topsoil
- Lowers carbon emissions compared to traditional bricks
- Promotes recycling and waste management
- Provides a cost-effective building material

III. MATERIAL AND METHODOLOGY:

This chapter explores the properties of the material, the methods for calculating mix proportions in various earlier clay mixtures, and the parametric analyses of those mixtures. Materials: clay, dairy sludge, construction waste, fly ash and water.

- Clay: A mixture of clay and soil was provided by a brick factory in the Vijayapur city, Karnataka, India. The mixture of clay was sieved in laboratory to obtain particle size of 0.5 mm. This was utilized in preparation of mix proportion likes (5%, 10%, and 15%) with additives.



Fig. 3.1: clay

- Dairy Sludge: A dairy sludge was provided by the Vijayapura & Bagalkot District Co-operative Milk Producers' Societies' Union Ltd., Vijayapura Dairy, Bhutanal, Vijayapura – 586103. The mixture of clay and dairy sludge sieved in laboratory to obtain Particle size of 0.5 mm. This was utilized in preparation of mix proportion likes (5%, 10%, and 15%) with additives.



Fig. 3.2: Dairy Dry Sludge.

- Construction Waste: Construction waste, or construction and demolition (C&D) waste, comprises materials from building, renovating, repairing, and demolishing structures like buildings, roads, and bridges.

In the classification of inert materials like concrete, bricks, asphalt, glass, and ceramics, I have focused on recycling broken bricks from demolition. Reuse bricks helps minimize landfill waste, conserve resources, and support sustainable construction practices.



Fig. 3.3: Construction Waste.

- Fly Ash: Fly Ash provided by Parekh Infra in the Vijayapura, Karnataka, India 586103. Burning harder, old anthracite and bituminous coal typically generates Class F fly ash. Utilizing fly ash as a partial alternative to clay typically leads. Improved Work ability, fly ash being a fine particulate, enhances the workability of the clay mixture, making it easier to mould and shape the bricks during production.



Fig. 3.4: Class Fly Ash.

- Portable Water: Water is added to clay to accomplish the right consistency for moulding. It improve the plasticity of the clay, making it easier to shape into bricks, portable water available from the campus lab was used, supporting IS 3025.



Fig. 3.5: Portable Water.

- Clay Brick Mould: A clay brick mould is a device or a tool employed in the manufacture of clay bricks, a mixture of clay and soil was provided by a brick factory in the Vijayapura city, Karnataka, India. Which are among the oldest and most widely used building materials. The mould shapes and sizes the clay into uniform bricks before they are dried and fired. Here's an overview of clay brick moulds and their use in brick making. Mould size (230×110×80mm).



Fig. 3.6: Clay Brick Mould.

IV. METHODOLOGY

The methodology outlined in this study provides a comprehensive approach to understanding traditional clay brick manufacturing. The practice of manual moulding, controlled drying, and firing processes ensures the fabrication of high-quality bricks.

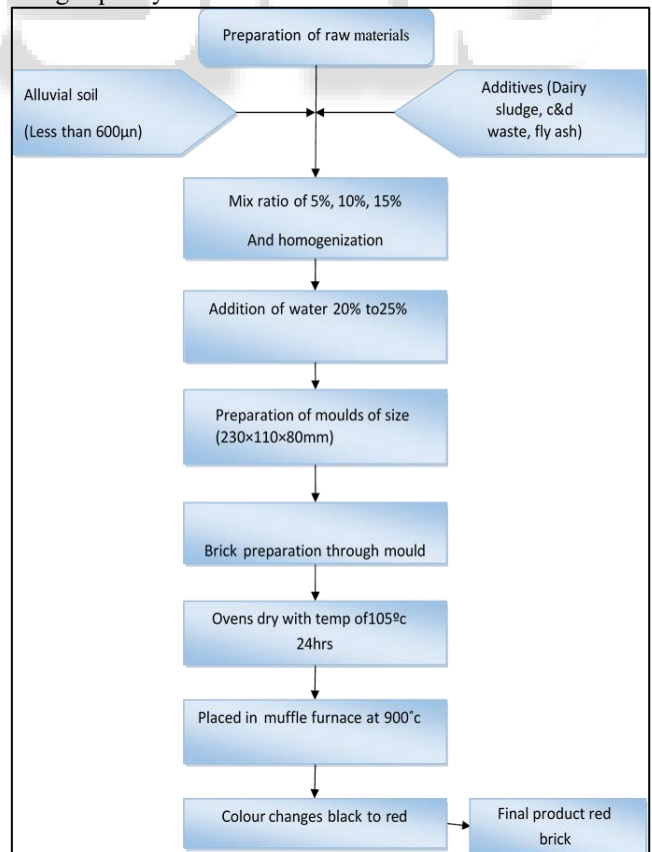


Fig. 3.7: Flow chart of Brick Making Process

V. EXPECTED PROJECT OUTCOMES

- Bricks made with large fractions of waste or by-products (dairy sludge, fly ash, construction waste) instead of conventional clay and/or firing.
- Use of admixtures to improve strength, durability, reduce environmental footprint.
- Possibly curing methods like ambient curing, or geopolymers, or hydraulic pressing rather than high-temperature kiln firing.

Key parameters / performance metrics

Property Typical target / range for usable bricks

- Compressive strength ~ 3-25 MPa depending on intended use (non-loadbearing / partition / wall / structural)
- Density / Dry density depends on porosity; maybe ~ 1400-2000 kg/m³ if fairly compact, lower if light weight bricks
- Water absorption / porosity Low absorption desirable, e.g. less than ~ 20-25% by weight for moderate exposure; tighter bricks for exterior walls
- Thermal conductivity Lower is better; fly-ash, porous components tend to reduce conductivity — good for insulation
- Durability Resistance to weather, freeze-thaw cycles (if applicable), cycles of wetting/drying, sulphate/chloride attack if in marine or industrial environment
- Shrinkage / cracking Minimal; after curing, avoid big cracks; control of organic content is important
- SEM Analysis Focused electron beam to scan a sample's surface, providing high-resolution images of its texture, composition, and topography at the nanometre scale.
- Leach ability / environmental safety especially from sludge — heavy metals, organics — immobilization is important so no harmful leaching.

REFERENCES

- [1] D. Simon, C. P. Battistessa, D. C. Arduzzo, S. Gass, and A. Cristoba, "Valorization of sludge from the effluent treatment of the dairy industry as clay substitutes in building bricks," *Construction and Building Materials*, vol. 286, 2021. Available: <https://doi.org/10.1016/j.conbuildmat.2021.124955>.
- [2] M. A. I. Juel, A. Mizan, and T. Ahmed, "Sustainable use of tannery sludge in brick manufacturing in Bangladesh," *Waste Management*, vol. 69, pp. 1-11, 2016. Available: <http://dx.doi.org/10.1016/j.wasman.2016.12.041>
- [3] M. Dubale, M. V. Vasić, G. Goel, A. Kalamdhad, and B. Laishram, "The recycling of demolition roof tile waste as a resource in the manufacturing of fired bricks: A scale-up to the industry," *Construction and Building Materials*, vol. 381, 2024. Available: <https://doi.org/10.1016/j.conbuildmat.2023.134727>.
- [4] G. S. dos Reis, B. G. Cazacliu, A. Cothenet, P. Poullain, M. Wilhelm, C. H. Sampaio, E. C. Lima, W. Ambros, and J.-M. Torrenti, "Fabrication, microstructure, and properties of fired clay bricks using construction and demolition waste sludge as the main additive," *Journal of Cleaner Production*, vol. 255, 2020. Available Word Document- 1.docx.
- [5] S. Elavarasan, A. K. Priya, and V. K. Kumar, "Manufacturing fired clay brick using fly ash and M Sand," *Materials Today: Proceedings*, vol. 33, pp. 4018-4023, 2020. Word Document- 1.docx
- [6] M. Sutcu, E. Erdogmus, O. Gencel, A. Gholampour, E. Atan, and T. Ozbakkaloglu, "Recycling of bottom ash and fly ash wastes in eco-friendly clay brick production," *Journal of Cleaner Production*, vol. 233, pp. 753-764, 2019. Available: <https://doi.org/10.1016/j.jclepro.2019.06.017>.
- [7] S. K. Singh, S. Kulkarni, V. Kumar, and P. Vashistha, "Sustainable utilization of deinking paper mill sludge for the manufacture of building bricks," *Journal of Cleaner Production*, vol. 199, pp. 386-393, 2018.
- [8] M. Contreras, S. R. Teixeira, M. C. Lucas, L. C. N. Lima, D. S. L. Cardoso, G. A. C. da Silva, G. C. Gregório, A. E. de Souza, and A. dos Santos, "Recycling of construction and demolition waste for producing new construction material (Brazil case-study)," *Construction and Building Materials*, vol. 123, pp. 15-19, 2016. Available: <http://dx.doi.org/10.1016/j.conbuildmat.2016.07.044>.
- [9] L. Xu, G. Wei, W. Tao, and Y. Nanru, "Study on fired bricks with replacing clay by fly ash in high volume ratio," *Construction and Building Materials*, vol. 19, pp. 243-247, 2004.
- [10] C. Rodríguez, C. Parra, G. Casado, I. Minano, F. Albaladejo, and F. Benito, "The incorporation of construction and demolition wastes as recycled mixed aggregates in non- structural concrete precast pieces," *Journal of Cleaner Production*, vol. 119, pp. 47-52, 2016. Word Document- 1.docx
- [11] S. Abbas, M. A. Saleem, S. M. S. Kazmi, and M. J. Munir, "Production of sustainable clay bricks using waste fly ash: Mechanical and durability properties," *Journal of Cleaner Production*, vol. 135, pp. 1237-1244, 2016. Available: <https://doi.org/10.1016/j.jclepro.2016.07.047>.
- [12] S. M. S. Kazmi, M. J. Munir, I. Patnaikuni, Y. Wu, and U. Fawad, "Thermal performance enhancement of eco-friendly bricks incorporating agro-wastes," *Energy and Buildings*, vol. 158, pp. 1117-1129, 2017. Word Document- 1.docx
- [13] C. Bories, L. Aouba, E. Vedrenne, and G. Vilarem, "Fired clay bricks using agricultural biomass wastes: Study and characterization," *Construction and Building Materials*, vol. 91, pp. 158-163, 2015. <https://doi.org/10.1016/j.conbuildmat.2015.05.002>.
- [14] A. L. Murmu and A. Patel, "Towards sustainable bricks production: An overview," *Journal of Environmental Management*, vol. 191, pp. 177-189, 2017. Word Document- 1.docx
- [15] E. Asensio, C. Medina, M. Frías, and M. I. Sánchez de Rojas, "Fired clay-based construction and demolition waste as pozzolanic addition in cements. Design of new eco- efficient cements," *Construction and Building Materials*, vol. 233, pp. 118-125, 2020. Word Document- 1.docx

- [16] M. Menegaki and D. Damigos, "A review on current situation and challenges of construction and demolition waste management," *Journal of Cleaner Production*, vol. 182, pp. 8-14, 2018. Word Document- 1.docx
- [17] Z. Wu, A. T. W. Yu, L. Shen, and G. Liu, "Quantifying construction and demolition waste: An analytical review," *Waste Management*, vol. 34, pp. 1683-1692, 2014. <https://doi.org/10.1016/j.wasman.2014.05.01>
- [18] IS-1077, Common Burnt Clay Building Bricks – Specification, Bur. Indian Standard, 2007.
- [19] ASTM C62–17 Standard Specification for Building Brick (Solid Masonry Units Made from Clay or Shale), (2023)

