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Vaishali F. Hadge, & Mr. Laxmikant C. Tibude. (2026). Development and Performance Evaluation of Eco-Friendly Bricks Using Fly Ash, Coconut Shell, and Coconut Fiber. *International Journal of Multidisciplinary Academic Studies and Research (IJMASR)*, 1(4), 71–80. <https://doi.org/10.5281/zenodo.20144398>

Article Info

Received: 6th April 2026, Accepted: 10th April 2026, Published: 13th April 2026.

Development and Performance Evaluation of Eco-Friendly Bricks Using Fly Ash, Coconut Shell, and Coconut Fiber

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Abstract- The fast growth of construction work in India and all over the world has increased the demand for building materials like bricks, cement, sand, and aggregates. Due to this, natural resources such as soil, sand, and stone are being used excessively. Traditional clay bricks are made by using top fertile soil and burning them in kilns, which causes air pollution and increases carbon emissions. At the same time, large amounts of industrial waste and agricultural waste are generated every year, and their proper disposal has become a serious issue. Therefore, it is very important to find new construction materials that are eco-friendly, cost-effective, and sustainable. In this study, an attempt has been made to use waste materials like fly ash, coconut shell, and coconut fiber for making eco-friendly bricks. Fly ash is a waste material produced from thermal power plants. It has good binding properties and can be used as a replacement for cement or soil in brick making. Using fly ash helps in reducing pollution and also makes use of waste material effectively. Coconut shell and coconut fiber are agricultural wastes that are easily available in India. Coconut shell is hard and strong, so it can be used as a lightweight aggregate in bricks. It helps in reducing the weight of bricks and improves thermal insulation, which means it can keep buildings cooler. Coconut fiber is a natural fiber taken from coconut husk. It has good tensile strength and flexibility. It acts like reinforcement in bricks and helps in reducing cracks and improving durability. In this study, coconut fiber is added in different percentages like 5%, 10%, and 15% of the total volume of bricks to check its effect on strength and performance. The bricks are prepared by mixing fly ash, coconut shell, coconut fiber, sand, and cement properly. After casting, the bricks are cured for a specific period. The prepared bricks are tested in the laboratory for different properties. These tests include compressive strength, water absorption, efflorescence, and hardness. The results show that adding coconut fiber improves crack resistance and flexibility of bricks. Coconut shell reduces the weight of bricks and improves insulation properties.

Keywords: Eco-Friendly Bricks, Fly Ash, Coconut Shell, Coconut Fiber, Sustainable Construction, Waste Utilization, Lightweight Bricks.

I. INTRODUCTION

The construction industry plays a very important role in the economic development of any country. In India, due to rapid urbanization, population growth, and infrastructure development, the demand for construction materials has increased very rapidly. Materials like bricks, cement, sand, and aggregates are used in large quantities. Among these, bricks are one of the most commonly used materials for building construction. Traditionally, bricks are made from clay, which is obtained from fertile agricultural land. The process of manufacturing clay bricks involves digging soil, moulding, drying, and burning in kilns at high temperatures. This process consumes a large amount of energy and releases harmful gases like carbon dioxide (CO₂), sulphur dioxide (SO₂), and other pollutants into the atmosphere. As a result, it causes environmental problems such as air pollution, global warming, and depletion of fertile soil. In recent years, there has been a growing concern about environmental protection and sustainable development.

Sustainable construction focuses on reducing the use of natural resources, minimizing waste, and using eco-friendly materials. One of the best ways to achieve this is by using industrial and agricultural waste materials in construction. Fly ash is one such industrial waste material produced from thermal power plants. It is available in large quantities and poses disposal problems. If not properly managed, fly ash can cause air and water pollution. However, it has good cementitious properties and can be used as a binding material in construction. Similarly, coconut shell and coconut fiber are agricultural waste materials generated in large amounts in India. Coconut shell is a hard material that can be used as a lightweight aggregate, while coconut fiber has good tensile strength and can be used as reinforcement material. These materials are generally discarded as waste, causing environmental issues. By combining fly ash, coconut shell, and coconut fiber, eco-friendly bricks can be developed. These bricks are lightweight, cost-effective, and environmentally friendly. They also help in reducing waste and conserving natural resources. Therefore, this study focuses on the development and performance evaluation of eco-friendly bricks using these materials.

II. METHODOLOGY

Materials Used:

In this study, eco-friendly bricks are developed by using a combination of industrial and agricultural waste materials along with conventional construction materials. The selection of materials is based on availability, cost-effectiveness, & their engineering properties.

The following materials are used for the preparation of bricks:

1. Cement

Cement is used as a binding material in the brick mix. Ordinary Portland Cement (OPC) is used in this study due to its good binding properties and availability. It helps in holding all the materials together and provides strength to the bricks.

Properties of Cement:

1. Good binding capacity
2. High compressive strength
3. Quick setting and hardening

2. Fly Ash

Fly ash is the main material used in this study. It is a fine powder obtained from thermal power plants and acts as a pozzolanic material. It reacts with calcium hydroxide to form cementitious compounds, thereby improving strength and durability.

Properties of Fly Ash:

1. Fine particle size
2. Pozzolanic nature
3. Improves workability
4. Reduces heat of hydration

3. Coconut Shell

Coconut shell is used as a lightweight aggregate in the brick mix. It is collected, cleaned, dried, and crushed into small sizes before use. It helps in reducing the weight of bricks and improving thermal insulation.

Properties of Coconut Shell:

1. Low density
2. High hardness
3. Good durability
4. Eco-friendly

4. Coconut Fiber

Coconut fiber is used as a reinforcing material. It is extracted from coconut husk, cleaned, and cut into small lengths before mixing. It improves crack resistance and toughness of the bricks.

Properties of Coconut Fiber:

1. High tensile strength
2. Flexible and ductile
3. Lightweight
4. Biodegradable

5. Fine Aggregate (M-Sand)

Manufactured sand (M-Sand) is used as fine aggregate. It helps in improving the workability and filling the voids in the mix. It also contributes to the strength of bricks.

Properties of M-Sand:

1. Uniform particle size
2. Good bonding with cement
3. Easily available

6. Water

Clean and potable water is used for mixing and curing of bricks. Water plays an important role in hydration of cement and development of strength.

Mix Design:

The mix design is one of the most important steps in the preparation of eco-friendly bricks. It involves selecting suitable proportions of materials such as fly ash, cement, M-sand, coconut shell, and coconut fiber to achieve the required strength, durability, and workability. In this study, fly ash is used as the main binding material, while cement is added in a smaller proportion to improve bonding and strength. Coconut shell is used as a lightweight aggregate, and coconut fiber is added as reinforcement material in different percentages.

Basis of Mix Design:

The mix design is prepared based on the following considerations:

1. Availability of materials
2. Required strength of bricks
3. Workability of mix
4. Reduction in weight
5. Optimum use of waste materials

Mix Proportions:

In this study, three different mixes are prepared by varying the percentage of coconut fiber while keeping another materials constant.

Table 3.1: Mix Proportions of Eco-Friendly Bricks

Mix ID	Fly Ash (%)	Cement (%)	M-Sand (%)	Coconut Shell (%)	Coconut Fiber (%)	Total (%)
M1	55	10	20	10	5	100
M2	50	10	20	10	10	100
M3	45	10	20	10	15	100

In the present study, the total mix proportion was maintained at 100% for all brick samples. The percentage of coconut fiber was varied as 5%, 10%, and 15% for Mix M1, M2, and M3 respectively, while the percentages of cement, M-sand, and coconut shell were kept constant. The fly ash content was adjusted accordingly to maintain the overall mix proportion at 100%.



Figure 3.1: Collection of raw materials used for eco-friendly brick preparation

III. RESULTS AND DISCUSSION

Compressive Strength Test:

The compressive strength test is conducted to determine the load carrying capacity of bricks. The test is performed after curing periods of 7, 14, and 28 days.

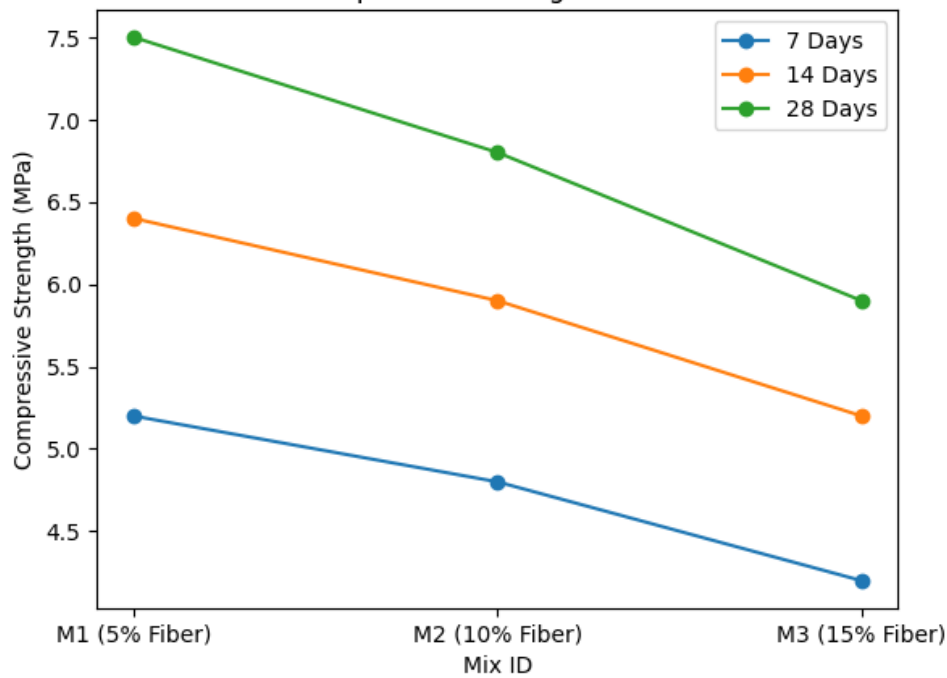
Table 4.1: Compressive Strength Results

Mix ID	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
M1 (5% Fiber)	5.2	6.4	7.5
M2 (10% Fiber)	4.8	5.9	6.8
M3 (15% Fiber)	4.2	5.2	5.9

Observation:

- Strength increases with curing period
- M1 shows highest strength
- Increase in fiber reduces compressive strength due to voids

Compressive Strength Results



Graph 4.1: Compressive Strength Variation

Water Absorption Test:

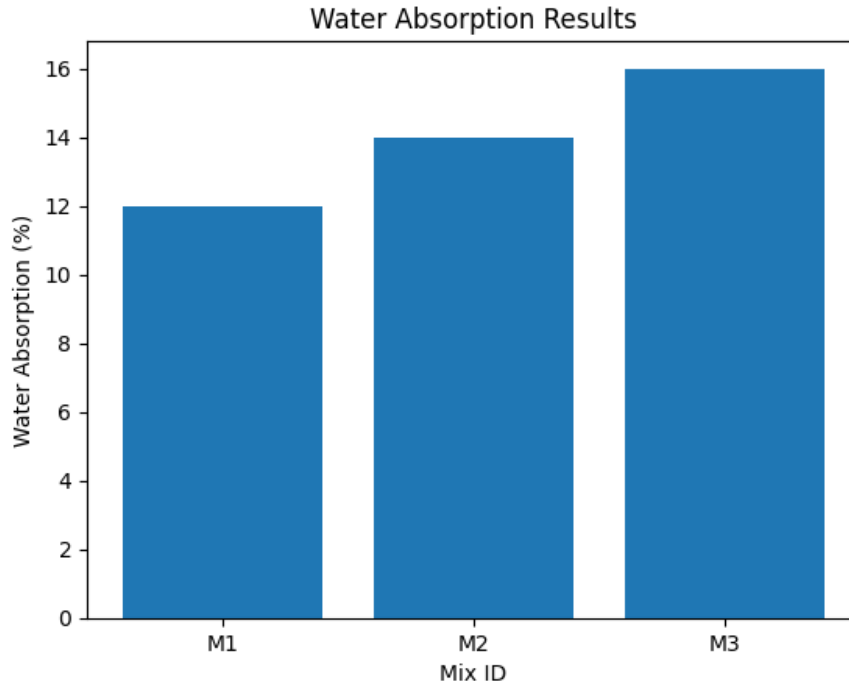
Water absorption test is conducted to determine the porosity and durability of bricks.

Table 4.2: Water Absorption Results

Mix ID	Water Absorption (%)
M1	12%
M2	14%
M3	16%

Observation:

- Water absorption increases with fiber content
- M1 shows lowest absorption (better durability)
- Higher fiber creates more voids



Graph 4.2: Water Absorption Comparison

Efflorescence Test:

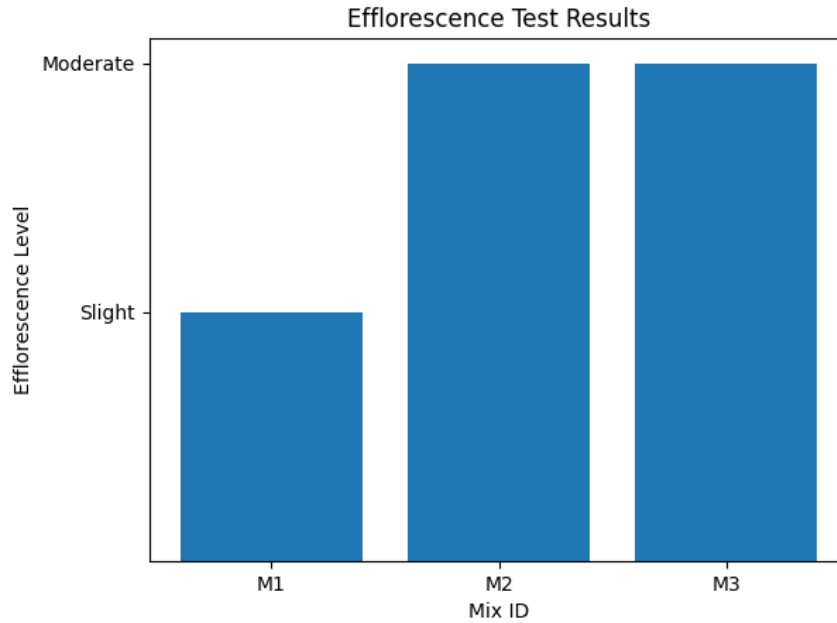
Efflorescence test is conducted to check the presence of soluble salts on brick surface.

Table 4.3: Efflorescence Results

Mix ID	Observation
M1	Slight
M2	Moderate
M3	Moderate

Observation:

- M1 shows least efflorescence
- Higher fiber mixes show more salt deposition



Graph 4.3: Efflorescence Test

Hardness Test:

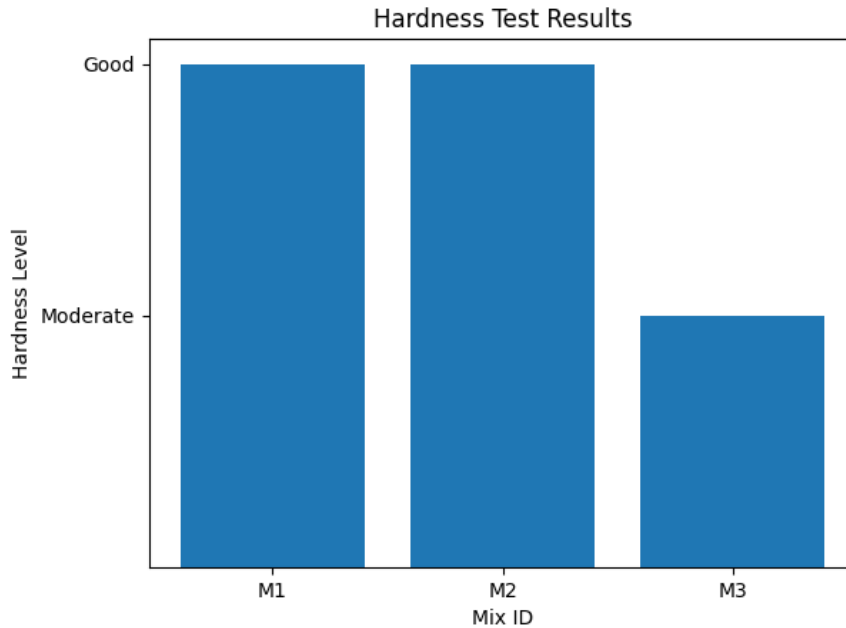
Hardness test is conducted by scratching the brick surface.

Table 4.4: Hardness Test Results

Mix ID	Result
M1	Good
M2	Good
M3	Moderate

Observation:

- M1 and M2 show good hardness
- M3 shows slight reduction due to higher fiber



Graph 4.4: Hardness Test

Discussion of Results:

The experimental investigation carried out in this study provides a clear understanding of the behavior and performance of eco-friendly bricks prepared using fly ash, coconut shell, and coconut fiber. Various tests such as compressive strength, water absorption, efflorescence, and hardness were conducted, and the results obtained from these tests have been analyzed in detail to evaluate the suitability of these bricks for construction purposes.

From the compressive strength test results, it is observed that the strength of bricks increases with the increase in curing period, which indicates proper hydration of cement and pozzolanic reaction of fly ash. However, when comparing different mixes, it is clearly seen that the compressive strength decreases as the percentage of coconut fiber increases. The mix M1, containing 5% coconut fiber, shows the highest compressive strength, followed by M2 (10% fiber), and the lowest strength is observed in M3 (15% fiber). This reduction in strength with higher fiber content is mainly due to the increase in voids and reduction in bonding between particles. Coconut fiber, being a natural and flexible material, does not bond as strongly as cementitious materials, and excessive fiber leads to poor compaction and weak internal structure.

At the same time, the inclusion of coconut fiber provides significant advantages in terms of crack resistance and ductility. It acts as a reinforcing material within the brick matrix and helps in bridging micro-cracks that develop during drying and loading. This improves the toughness and flexibility of bricks, making them less brittle compared to conventional bricks. Therefore, while higher fiber content reduces compressive strength, it enhances the overall durability by preventing sudden failure and crack propagation.

The use of coconut shell as a partial replacement for aggregate has shown positive results in reducing the weight of bricks. Due to its low density, coconut shell helps in producing lightweight bricks, which reduces the dead load on structures. This is particularly beneficial in multi-storey buildings and areas with weak soil conditions.

In addition, coconut shell provides good thermal insulation properties, which can help in maintaining indoor temperature and reducing energy consumption for cooling. Thus, coconut shell contributes to both structural and environmental benefits.

The water absorption test results indicate that water absorption increases with the increase in coconut fiber content. Mix M1 shows the lowest water absorption, while M3 shows the highest. This is because higher fiber content creates more pores and voids within the brick structure, allowing more water to enter. Higher water absorption may reduce durability and resistance to weathering. Therefore, controlling fiber content is necessary to maintain acceptable limits of water absorption.

Efflorescence test results show that the bricks exhibit slight to moderate efflorescence, which is within permissible limits. The presence of soluble salts is minimal and does not significantly affect the quality or appearance of bricks. Hardness test results indicate that bricks with lower and moderate fiber content (M1 and M2) have good surface strength, while M3 shows a slight reduction due to higher fiber content affecting surface bonding. Overall, the experimental results clearly show that there is a trade-off between strength and ductility when coconut fiber is added. While fiber improves crack resistance and flexibility, excessive addition reduces compressive strength and increases water absorption.

Based on the comparative analysis of all properties, it can be concluded that the optimum mix lies between M1 and M2 (5% to 10% coconut fiber). These mixes provide a good balance between strength, durability, weight reduction, and crack resistance. M1 is more suitable where higher strength is required, while M2 can be used where moderate strength and improved ductility are needed.

From the experimental results, the following conclusions can be drawn:

1. Compressive strength decreases with increase in fiber content
2. Coconut fiber improves crack resistance but reduces strength at higher percentages
3. Coconut shell reduces weight and improves insulation
4. Water absorption increases with fiber content
5. Optimum mix is M1 or M2 (5–10% fiber)

CONCLUSION

The present study focused on the development and performance evaluation of eco-friendly bricks using fly ash, coconut shell, and coconut fiber as alternative materials to conventional clay bricks. From the experimental investigation, it can be concluded that the use of industrial and agricultural waste materials in brick manufacturing is not only feasible but also beneficial from environmental, economic, and technical points of view.

The results obtained from various tests such as compressive strength, water absorption, efflorescence, and hardness clearly indicate that eco-friendly bricks can be successfully produced with satisfactory performance. The compressive strength of bricks was found to increase with curing period, which shows proper hydration and strength development. Among the different mixes, the bricks with lower fiber content (M1 – 5% fiber) showed higher compressive strength, while higher fiber content (M3 – 15%) resulted in reduced strength due to increased voids and poor bonding. Water absorption test results revealed that absorption increases with increase in coconut fiber content, indicating higher porosity in bricks with more fiber. Efflorescence test results showed slight to moderate salt formation, which is within acceptable limits. Hardness test results indicated that bricks with lower and moderate fiber content have good surface strength.

The addition of coconut fiber improved crack resistance, flexibility, and toughness of the bricks, while coconut shell helped in reducing the weight and improving thermal insulation properties. However, excessive use of fiber negatively affected compressive strength and durability. From the overall analysis, it can be concluded that the optimum mix lies between 5% to 10% coconut fiber, which provides a good balance between strength, durability, and weight reduction. The study proves that eco-friendly bricks can be used as an alternative to conventional bricks, especially in non-load-bearing structures, and contribute to sustainable construction practices.

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