

Effect of Utilization of Waste Plastic with Black Cotton Soil on Bricks

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Abstract - Rapid urbanization and increasing plastic waste generation have become major environmental concerns worldwide. Simultaneously, conventional brick manufacturing consumes large quantities of natural clay, causing depletion of natural resources and environmental degradation. This study investigates the feasibility of manufacturing eco-friendly bricks using waste plastic and black cotton soil as alternative materials. Different proportions of waste plastic were incorporated into black cotton soil along with fly ash and water to produce sustainable bricks. The mechanical and physical properties such as compressive strength, water absorption, durability, hardness, and cost effectiveness were evaluated. The results indicate that incorporating waste plastic significantly reduces water absorption while improving durability and reducing production cost. The proposed bricks provide an environmentally sustainable alternative for non-load-bearing construction applications and contribute toward effective plastic waste management.

Keywords: Waste plastic, Black cotton soil, Sustainable bricks, Compressive strength, Water absorption, Fly ash, Eco-friendly construction.

I. INTRODUCTION

The construction industry is one of the fastest-growing sectors worldwide and plays a crucial role in the economic development of every nation. However, this rapid growth has resulted in excessive consumption of natural resources and increased environmental degradation. Among various construction materials, bricks are one of the oldest, most widely used, and essential building components utilized in residential, commercial, industrial, and infrastructural projects. Conventional burnt clay bricks have been used for centuries because of their durability, availability, and satisfactory engineering properties. However, their manufacturing process requires enormous quantities of fertile topsoil and significant energy consumption during kiln firing.

The large-scale extraction of fertile clay soil for brick manufacturing has become a serious environmental concern. Continuous removal of topsoil reduces agricultural productivity, accelerates land degradation, and disturbs the ecological balance. Furthermore, traditional brick kilns consume substantial amounts of coal and other fossil fuels, leading to the emission of greenhouse gases such as carbon dioxide (CO₂), sulfur dioxide (SO₂), and particulate matter that contribute to global warming and air pollution. Therefore, there is an urgent need to develop sustainable alternatives that

can reduce dependency on conventional raw materials while maintaining acceptable engineering performance.

Simultaneously, plastic waste management has emerged as one of the most significant environmental challenges of the twenty-first century. Due to rapid urbanization, industrialization, population growth, and changing lifestyles, plastic consumption has increased dramatically across the globe. Plastic materials have become indispensable in daily life because they are lightweight, inexpensive, durable, water-resistant, and easy to manufacture. They are extensively used in packaging, household products, agriculture, healthcare, transportation, and construction industries.

Despite these advantages, plastic poses a serious threat to the environment after disposal. Plastic is a non-biodegradable material that can remain in the environment for hundreds of years without decomposition. Improper disposal of plastic waste results in soil pollution, water contamination, drainage blockage, and severe damage to terrestrial and aquatic ecosystems. Open burning of plastic waste releases toxic gases, including dioxins and furans, which are harmful to human health and the environment. In developing countries like India, the increasing accumulation of plastic waste has become a major challenge for municipal solid waste management systems.

India is one of the largest producers and consumers of plastic products in the world. The enormous quantity of plastic waste generated annually has created serious environmental and public health concerns. Conventional waste management methods such as landfilling and incineration are becoming increasingly unsustainable due to limited land availability, rising disposal costs, and adverse environmental impacts. Therefore, researchers and engineers are actively exploring innovative methods to recycle and reuse plastic waste in various construction applications.

Another material that has gained attention in sustainable construction is black cotton soil. Black cotton soil is widely distributed across several Indian states, including Maharashtra, Karnataka, Gujarat, Tamil Nadu, Madhya Pradesh, Andhra Pradesh, and parts of Telangana. This soil is rich in montmorillonite minerals, which exhibit high swelling and shrinkage characteristics due to variations in moisture content. Because of these properties, black cotton soil is generally considered problematic for conventional construction activities.

However, despite its limitations, black cotton soil is abundantly available and inexpensive. With suitable stabilization techniques and the addition of supplementary materials, its engineering properties can be significantly improved. Utilizing black cotton soil in brick manufacturing can reduce dependence on conventional clay and provide a productive use for locally available materials.

The production of bricks using waste plastic and black cotton soil can also provide several additional benefits, including reduced production costs, lower water absorption, improved durability, lightweight construction materials, and enhanced environmental sustainability. Such bricks can be particularly beneficial for low-cost housing projects and affordable infrastructure development in developing countries.

Therefore, the present study focuses on investigating the feasibility of manufacturing sustainable bricks using waste plastic and black cotton soil. The study aims to evaluate their physical and mechanical properties, including compressive strength, water absorption, durability, and overall performance, to determine their suitability as an alternative construction material. This approach supports the principles of sustainable development, waste minimization, circular economy, and environmentally responsible construction practices for future generations.

II. OBJECTIVES OF THE STUDY

The objectives of the present study are:

1. To manufacture bricks using black cotton soil, waste plastic, fly ash, and water.
2. To determine optimum proportions through trial mixes.
3. To evaluate compressive strength.
4. To determine water absorption characteristics.
5. To study physical properties and durability.
6. To evaluate cost effectiveness.
7. To develop sustainable construction materials.

III. RESEARCH GAP

The following research gaps are identified:

1. Very limited studies utilize black cotton soil in brick manufacturing.
2. Limited optimization studies for plastic percentages.
3. Few studies investigate long-term durability.
4. Limited field implementation studies.
5. Lack of standardized design guidelines.
6. Limited life-cycle assessment studies.

IV. METHODOLOGY

A. MATERIALS USED

4.1 Black Cotton Soil

Black cotton soil was used as the primary base material for the preparation of sustainable bricks. The soil sample was collected from Shevati village in Amravati district, Maharashtra. Black cotton soil is extensively available in central and southern regions of India and is characterized by its high swelling and shrinkage behavior due to the presence of expansive clay minerals.

The soil possesses a fine-grained texture, high plasticity, and excellent moisture retention capacity. The major mineral present in black cotton soil is montmorillonite, which is responsible for its expansion during wet conditions and shrinkage during dry conditions. Although these characteristics make the soil problematic for conventional construction activities, proper stabilization and blending with suitable additives can significantly improve its engineering properties.

The important constituents present in black cotton soil include lime, magnesium, iron, and alumina, which contribute to its binding properties and overall strength development.

1) *Physical Properties of Black Cotton Soil*

Property	Description
Colour	Black to blackish-grey
Particle Size	Very fine particles
Texture	Fine-grained soil
Plasticity	High
Moisture Holding Capacity	Very high

2) *Chemical Composition of Black Cotton Soil*

- Montmorillonite clay mineral
- Lime (CaO)
- Magnesium (Mg)
- Iron (Fe)
- Alumina (Al₂O₃)

The use of black cotton soil in brick manufacturing helps reduce the consumption of fertile agricultural clay and provides an economical alternative raw material for sustainable construction practices.

4.2 *Fly Ash*

Fly ash was used as a supplementary cementitious material in this study. The fly ash was collected from the thermal power plant located in Amravati district. Fly ash is a by-product generated during the combustion of pulverized coal in thermal power plants.

It consists of very fine spherical particles rich in silica and alumina, which contribute to pozzolanic reactions during the brick manufacturing process. The incorporation of fly ash improves workability, increases durability, and reduces the overall production cost of bricks. In addition, its utilization minimizes environmental pollution associated with fly ash disposal.

3) *Physical Properties of Fly Ash*

Property	Value
Specific Gravity	2.62
Fineness	83%

4) *Chemical Composition of Fly Ash*

Component	Percentage (%)
SiO ₂	35 – 39

Component	Percentage (%)
Fe ₂ O ₃	0.5 – 2
Al ₂ O ₃	20 – 33
CaO	5 – 16
MgO	1 – 5.5
SO ₃	0.5 – 1.5

Fly ash also contributes to reducing carbon emissions by partially replacing conventional materials used in brick production.

4.3 *Waste Plastic*

Waste plastic was collected from the Municipal Corporation Solid Waste Management Department of Amravati city. The collected plastic waste was segregated, washed thoroughly with clean water, dried, and processed before use.

Plastic waste management has become a major environmental issue due to the enormous quantity of plastic generated daily. Since plastic is non-biodegradable and remains in the environment for several hundred years, its reuse in construction materials provides an effective and sustainable disposal solution.

In this study, plastic materials having thickness greater than 25 microns were selected because they possess better heat resistance and structural stability during brick manufacturing. The selected plastic was shredded into small pieces and converted into powder form to ensure uniform mixing with other materials.

5) *Types of Plastic Used*

- Polyethylene Terephthalate (PET)
- High Density Polyethylene (HDPE)
- Low Density Polyethylene (LDPE)
- Polypropylene (PP)

6) *Properties of Waste Plastic*

Property	Obtained Value	Standard Value
Initial Setting Time	32 min	30 min
Final Setting Time	580 min	600 min
Fineness	96%	≥ 90%
Specific Gravity	3.14	3.10–3.15
Standard Consistency	34%	30–35%

7) *Plastic Percentage Used*

Different proportions of waste plastic were used to determine the optimum composition.

Sample	Waste Plastic Content
B1	5%
B2	15%
B3	25%
B4	50%

4.4 Water

Water is an essential ingredient in the brick manufacturing process. It facilitates proper mixing, improves workability, and aids in achieving adequate bonding among the constituent materials.

Clean potable water free from impurities such as oil, acids, alkalis, organic matter, and suspended particles was used throughout the study. Generally, water suitable for drinking purposes is considered appropriate for brick manufacturing. Adequate water content is important because excess water may lead to excessive shrinkage and cracking during drying, whereas insufficient water may result in poor bonding and inadequate compaction.

V. METHODOLOGY

The experimental methodology adopted in this study consisted of a systematic sequence of operations beginning with material collection and ending with performance evaluation of the manufactured bricks.

The overall process involved the following stages:

1. Collection of materials
2. Soil preparation
3. Mixing
4. Moulding
5. Drying
6. Firing
7. Testing

5.1 Collection of Materials

The raw materials used in the study, namely black cotton soil, fly ash, waste plastic, and water, were collected from their respective sources.

- Black cotton soil was collected from Shevati village, Amravati.
- Fly ash was collected from a thermal power plant in Amravati.
- Waste plastic was collected from the municipal solid waste disposal department.

- Clean potable water was arranged for mixing purposes.

All materials were properly cleaned and stored before use.

5.2 Soil Preparation

The collected black cotton soil was first dried and sieved to remove unwanted materials such as stones, roots, pebbles, and other impurities.

The soil was then processed to obtain a homogeneous fine-grained material suitable for brick production.

Tempering was carried out by adding water and allowing the mixture to stabilize for approximately 5 to 7 days to improve workability.

5.3 Mixing

The required quantities of black cotton soil, fly ash, and waste plastic powder were mixed thoroughly.

Uniform mixing was essential to ensure proper distribution of all constituents throughout the brick body.

The addition of fly ash helped improve strength and reduce cracking during drying and firing.

The processed waste plastic acted as a filler material and enhanced water resistance.

5.4 Moulding

The prepared mixture was poured into rectangular moulds of dimensions:

190 mm × 90 mm × 90 mm

The moulds were slightly larger to account for shrinkage during drying and firing.

A frog of 10–20 mm depth was provided on one face of the brick.

After compaction, excess material was removed to obtain uniform dimensions.

5.5 Drying

The freshly moulded bricks were placed in open air for drying. Drying removes excess moisture and prevents cracking during firing.

The drying period varied according to weather conditions:

- Summer: 8–10 days
- Winter: 15–20 days

Proper drying is essential to avoid deformation and shrinkage cracks.

5.6 Firing

After drying, the bricks were arranged systematically inside a clamp kiln.

The firing process consisted of three stages:

1) 1. Pre-heating Stage

Removal of residual moisture.

2) 2. Firing Stage

High temperatures promote vitrification and strength development.

3) 3. Cooling Stage

Gradual cooling prevents thermal cracking.

The complete firing process required:

- Summer: 20–25 days
- Winter: 40–45 days

VI. TEST PERFORMED

Various laboratory tests were conducted to evaluate the performance of the manufactured bricks.

6.1 Compressive Strength Test

The compressive strength test was conducted using a Universal Testing Machine (UTM).

The brick specimen was placed between the loading plates, and compressive load was gradually applied until failure occurred.

The compressive strength was calculated using:

Compressive Strength = $\frac{\text{Maximum Load}}{\text{Cross-sectional Area}}$
Compressive Strength = $\frac{\text{Maximum Load}}{\text{Cross-sectional Area}}$

The test indicates the load-bearing capacity of the bricks.

6.2 Water Absorption Test

The test was conducted according to **IS 3495 (Part II): 1992**.

1) Procedure:

1. Dry the brick and record its weight.
2. Immerse it in water for 24 hours.
3. Remove and wipe excess water.
4. Record the wet weight.

The percentage water absorption is calculated as:

Water Absorption (%) = $\frac{W_2 - W_1}{W_1} \times 100$
Water Absorption (%) = $\frac{W_2 - W_1}{W_1} \times 100$

Where:

W_1 = Dry weight

W_2 = Wet weight

Lower water absorption indicates better quality bricks.

6.3 Efflorescence Test

This test determines the presence of soluble salts.

Procedure:

- Immerse the brick in water for 24 hours.

- Dry it under shade.
- Observe the white deposits formed on the surface.

Lower efflorescence indicates superior quality.

6.4 Fire Resistance Test

This test evaluates the ability of bricks to withstand elevated temperatures without significant deterioration.

It determines their suitability for fire-prone environments.

6.5 Hardness Test

The hardness test was performed by scratching the brick surface using a steel rod.

Good quality bricks should:

- Resist scratches.
- Maintain surface integrity.
- Not disintegrate easily.
- Possess adequate wear resistance.

These tests collectively determine the suitability of the developed sustainable bricks for practical construction applications.

VII. CONCLUSION

The present study evaluated the structural performance of RCC underpass bridge systems subjected to vehicular and seismic loading conditions.

The following conclusions were drawn:

1. Box bridge configurations showed superior seismic performance compared to pier bridges.
2. The box bridge exhibited approximately 9.44% lower displacement under earthquake loading.
3. Base shear increased with increase in span length due to higher structural mass.
4. Shorter span bridges possessed higher stiffness but experienced greater acceleration and stress concentration.
5. The 10 m span bridge demonstrated the most balanced structural behaviour with minimum displacement and stable dynamic response.
6. All bridge models remained structurally safe under the considered loading conditions.
7. Moderate-span RCC box-type underpass bridges are recommended for seismic-prone regions because of their improved rigidity and structural efficiency.

VIII. FUTURE SCOPE

The following areas may be considered for future research:

- Nonlinear dynamic analysis under real earthquake records.
- Detailed soil–structure interaction analysis.
- Use of prestressed concrete and composite materials.
- Experimental validation using shake table testing.
- Fatigue and durability assessment under repeated loading.

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