

# DEVELOPMENT OF LOW-COST SUSTAINABLE PAVEMENT BLOCKS

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**Abstract**— Industrial waste products consist of multiple materials and now have created a worldwide issue. Examples of these materials include Fly Ash, GGBS, Rice Husk Ash, and plastics. By exploring the potential use of these waste materials for the purpose of producing sustainable paver blocks as a green alternative to conventional paver blocks, the main focus of this project was to assess the strength, durability, and impact on the environment when these materials are used at optimal ratios. The methodology used to determine the viability of the use of the materials for construction included material characterization, mix design optimization, and extensive experimental testing. Fly Ash (8%), GGBS (12%), Rice Husk Ash (5%), and shredded plastic (5% fine aggregate) have been substituted in M40 grade concrete paver blocks. Key characteristics evaluated in each of the mixtures were compressive strength, water absorption, abrasion resistance, and flexural strength. The goal of this project is to promote environmentally responsible construction practices while managing industrial and agricultural wastes and to achieve approximately 40% reduction in CO<sub>2</sub> emissions and 20-25% cost savings as compared to the conventional concrete paver blocks.

## I. INTRODUCTION

The rapid growth of the construction industry has led to increased use of natural resources and a significant rise in environmental pollution from industrial and agricultural waste. Materials like fly ash, Ground Granulated Blast Furnace Slag (GGBS), rice husk ash (RHA), and plastic waste are produced in large amounts and often end up in landfills, creating serious environmental issues.

Cement production alone adds significantly to global carbon dioxide emissions. This makes it important to look for alternative and sustainable construction materials. In recent years, supplementary cementitious materials (SCMs) like fly ash, GGBS, and RHA have gained attention for their pozzolanic properties and ability to improve the durability and performance of concrete. Likewise, plastic waste can serve as a partial replacement for fine aggregates, helping to cut down pollution and save natural resources.

Pavement blocks are commonly used in infrastructure development because they are easy to install, durable, and require less maintenance. This study focuses on creating low-cost sustainable pavement blocks by using industrial by-products and plastic waste as partial replacements in concrete. The goal is to evaluate the mechanical and durability properties of these blocks and find the best mix that balances strength, cost efficiency, and environmental benefits.

The suggested approach not only reduces reliance on traditional materials but also encourages effective waste management, making it a practical solution for sustainable construction practices.

## II. OBJECTIVE OF THE STUDY

The major aim of this research is to design a low-cost sustainable pavement block.

To produce sustainable pavement blocks by partly substituting cement with industrial wastes like fly ash, GGBS, and rice husk ash.

To use shredded plastic waste as a partial substitute for fine aggregate to minimize environmental contamination and natural resource consumption.

To find out the optimum substitution percentage, which is a compromise among strength, durability, and sustainability.

To study the mechanical behaviour of the produced pavement blocks, like compressive strength and flexural strength.

To test durability parameters, such as water absorption and abrasion resistance, according to standard guidelines.

To conduct a comparison between sustainable pavement blocks and ordinary concrete blocks.

To conduct a cost analysis of the produced mixture and calculate cost savings.

To encourage sustainable construction by minimizing carbon footprint and reusing waste products.

## III. RESEARCH GAP

Though there is plenty of research work carried out in the field of individual waste material incorporation or some few combinations of waste materials, it becomes clear from literature that there has not been much attention towards incorporating all these waste materials at once in pavement blocks. The current trend of research is more inclined towards partial replacements rather than a complete combination with proper analysis and evaluation of a combination for strength grade M40.

Moreover, there is a lack of research conducted on multi-material waste mixes under standard water curing conditions, whereas most of the researchers use controlled or heat curing conditions to get the results. This indicates the need to conduct an experimental study for the optimum ratio in terms of strength, durability, cost efficiency, and environmental issues.

#### IV. MATERIALS USED

The materials utilized in the development of low cost sustainable pavement blocks were chosen to guarantee similarity, durability, and suitability in line with the relevant standards. All the materials were subjected to tests before the mixing process. Pervious concrete using recycled concrete aggregate can attain satisfactory levels of both mechanical strength and hydraulic properties when well proportioned.

##### ❖ OPC 53 Grade Cement

Ordinary Portland Cement (OPC) 53 Grade was utilized as the binder in the concrete mixture in the current study. The OPC 53 grade cement utilized in the development of the concrete mixture conforms to IS 269:2015 – Ordinary Portland Cement Specification. OPC 53 grade cement was chosen because of the improved early development of strength as well as the improved compressive strength properties compared with lower-grade cement. The selection of binder content significantly affects the mechanical performance and durability characteristics of pavement blocks.

The cement used in the mixture was fresh, free from lumps, and stored in a dry environment to prevent moisture absorption. The physical properties such as fineness and specific gravity satisfied standard requirements. The specific gravity of cement was taken as 3.15 for mix design calculations.

The use of OPC 53 grade cement ensured proper hydration and bonding between aggregates while maintaining the structural stability necessary for embedding piezoelectric elements within the porous concrete matrix.

##### ❖ Fine Aggregate

Natural river sand was used as fine aggregate in controlled proportions of 0%, 5%, and 10% by weight of total aggregate to evaluate its influence on compressive strength and bonding characteristics.

The fine aggregate conformed to IS 383:2016 and was classified under Zone II grading. The sand was clean, well graded, and free from clay, silt, and organic impurities.

In porous concrete, fine aggregate is generally minimized to maintain permeability. However, a small percentage was included in this study to enhance bonding between aggregate particles and improve mechanical strength without significantly affecting porosity.

The specific gravity of fine aggregate used in mix proportion calculations was 2.66.



Figure 1

##### ❖ Coarse Aggregate

Crushed angular coarse aggregates of 10 mm nominal maximum size were used in the preparation of porous concrete. The aggregates were clean, hard, durable, and free from organic impurities and other deleterious materials. Aggregate gradation plays an important role in controlling interconnected porosity, compressive strength, and permeability characteristics of pervious concrete pavements [13].

The coarse aggregates satisfied the requirements of IS 383:2016 – Coarse and Fine Aggregate for Concrete.

The reduced fine aggregate content combined with controlled aggregate gradation ensured the formation of continuous void channels for water infiltration.

The specific gravity of coarse aggregate used in the mix design was 2.68. Aggregates were surface-dried before mixing to maintain an accurate water–cement ratio.



Figure 2

##### ❖ Fly Ash

Class C fly ash was obtained from a local thermal power plant. This material was generated from subbituminous coal combustion and exhibits both pozzolanic and self-cementitious properties due to higher calcium content compared to Class F fly ash.

**Processing:** Fly ash was sieved through 90-micron sieve to remove coarse particles and ensure uniform fineness. Material was stored in airtight containers to prevent moisture absorption and maintain reactivity.

**Role in Mix:** At 8% binder replacement, fly ash improves workability through ball-bearing effect of spherical particles, reduces water demand, and contributes to long-term strength development through pozzolanic reactions with calcium hydroxide.

**Functions:** Rice husk ash plays an important role in improving the properties of concrete when used as a partial replacement for cement.

#### ❖ GGBS

GGBS Grade 120 was procured from a steel manufacturing facility. The material underwent rapid water quenching followed by fine grinding to develop latent hydraulic properties.

**Processing:** GGBS was received in powdered form and stored in dry conditions. The material was sieved through 90-micron sieve to ensure consistency with other binder materials.

**Role in Mix:** At 12% binder replacement, GGBS provides enhanced durability, improved resistance to chemical attack, and contributes to strength development particularly after 7 days. Its latent hydraulic properties complement the pozzolanic activity of fly ash and RHA.



Figure 3

#### ❖ Shredded Plastic

Mixed plastic waste (predominantly LDPE and HDPE) was collected from local waste collection centers and processing facilities.

**Processing:** Plastic waste underwent thorough cleaning to remove dirt, organic matter, and contaminants. Cleaned plastic was dried and shredded to appropriate size using industrial shredders. Material was sieved to ensure uniform size distribution within 2-5mm range.

**Role in Mix:** At 5% fine aggregate replacement by weight, shredded plastic reduces reliance on natural sand, diverts waste from landfills, and provides water resistance. The replacement level was carefully selected to balance sustainability benefits with maintaining target compressive strength.

We also understood that shredded plastic helps in **reducing the weight of the blocks** and provides some resistance to water absorption due to its hydrophobic nature. This makes the blocks slightly more resistant to moisture.

#### ❖ Super-Plasticizers

Superplasticizers, also known as high-range water reducers, are chemical admixtures used to increase concrete workability or reduce water content by over 30% without loss of strength. Developed in the 1960s-70s, these polymers allow for high-strength, durable, and self-compacting concrete.

In our project we use 1-2% of superplasticizers to increase the compressive strength of the concrete.

#### ❖ Rice Husk

Rice husk ash was obtained from agricultural processing units where rice husks are burned for energy generation. The ash underwent additional processing to ensure optimal quality.

**Processing:** Raw rice husk ash was finely ground using ball mill to achieve particle size comparable to cement. Material was sieved through 90-micron sieve to remove any coarse particles. Proper storage in moisture-free conditions ensured preservation of pozzolanic reactivity.

**Role in Mix:** At 10% binder replacement, RHA provides superior pozzolanic activity due to high amorphous silica content. It refines pore structure, reduces permeability, and enhances durability characteristics of the pavement blocks.

## V. METHODOLOGY

A systematic six-phase process has been used for the investigation:

### Phase 1: Collection of Materials and their Testing

Materials such as OPC 53, fly ash, GGBS, RHA, shredded plastic, M-sand, and coarse aggregates were collected and tested for properties including specific gravity, sieve analysis, and water absorption.

### Phase 2: Mix Design

A mix of grade M40 was developed according to IS code IS 10262:2019 having a water binder ratio of 0.33. Partial replacement of cement was made by FA (8%), GGBS (12%), and RHA (5%). Also, 5% plastic was used to replace fine aggregate.

### Phase 3: Preparation of Specimen

Dry-casting technique was used to prepare concrete cubes and paver blocks with curing up to 7, 28, and 56 days.

### Phase 4: Testing

Various tests have been performed such as mechanical and durability tests according to Indian Standard (IS).

### Phase 5: Optimum Mixing

Results obtained from previous phases helped in identifying the optimum mixing.

### Phase 6: Cost-Benefit and Environmental Assessment

## VI. MIX DESIGN

**DESIGN MIX CALCULATIONS:** Mix design was developed following IS 10262:2019 methodology with modifications for multi-binder system and dry-cast paver block requirements.

### Design Parameters:

1. **Target Grade:** M40 (characteristic strength 40 MPa)
2. **Type of Mix:** Dry-cast concrete for paver blocks
3. **Exposure Condition:** Moderate to severe (outdoor pavement application)
4. **Maximum Aggregate Size:** 10 mm
5. **Workability:** Low (dry-cast method with vibration compaction)
6. **Water-Binder Ratio:** 0.33

### Step 1: Target Mean Strength

For M40 grade with standard deviation ( $s$ ) = 5 MPa:

$$\text{Target strength (f}_{ck}\text{)} = f_{ck} + 1.65s = 40 + (1.65 \times 5) = 40 + 8.25 = \mathbf{48.25 \text{ MPa}}$$

### Step 2: Water-Binder Ratio Selection

For severe exposure and target strength of 48.25 MPa: Selected W/B ratio = **0.33**

This low water-binder ratio ensures:

1. High compressive strength
2. Low permeability
3. Enhanced durability
4. Suitable for dry-cast compaction method

### Step 3: Water Content

For 10mm maximum aggregate size and dry-cast method: Base water content = 180 kg/m<sup>3</sup> Adjusted for dry-cast with vibration = **160 kg/m<sup>3</sup>**

### Step 4: Binder Content

$$\text{Total Binder} = \text{Water Content} / \text{W-B Ratio} = 160 / 0.33 = \mathbf{484 \text{ kg/m}^3}$$

### Binder Composition:

1. OPC (75%): 364 kg/m<sup>3</sup>
2. Fly Ash (8%): 39 kg/m<sup>3</sup>
3. GGBS (12%): 58 kg/m<sup>3</sup>
4. RHA (5%): 24 kg/m<sup>3</sup>
5. **Total: 484 kg/m<sup>3</sup>**

### Step 5: Aggregate Proportions

Based on literature and optimization for paver blocks:

$$\text{Volume of concrete} = 1 \text{ m}^3$$

Volume occupied by binder and water:

1. Cement volume =  $364 / (3.15 \times 1000) = 0.116 \text{ m}^3$
2. Fly ash volume =  $39 / (2.20 \times 1000) = 0.018 \text{ m}^3$
3. GGBS volume =  $58 / (2.90 \times 1000) = 0.020 \text{ m}^3$
4. RHA volume =  $24 / (2.1 \times 1000) = 0.011 \text{ m}^3$
5. Water volume =  $160 / (1.00 \times 1000) = 0.160 \text{ m}^3$
6. **Total = 0.329 m<sup>3</sup>**

$$\text{Volume available for aggregates} = 1 - 0.329 = \mathbf{0.671 \text{ m}^3}$$

### Aggregate Distribution:

1. Coarse aggregate: 55% of total aggregate volume
2. Fine aggregate: 45% of total aggregate volume

$$\begin{aligned} \text{Coarse aggregate volume} &= 0.671 \times 0.55 = 0.369 \text{ m}^3 \\ \text{Fine aggregate volume} &= 0.671 \times 0.45 = 0.301 \text{ m}^3 \end{aligned}$$

$$\text{Coarse Aggregate Mass} = 0.369 \times 2700 = \mathbf{935 \text{ kg/m}^3}$$

$$\text{Fine Aggregate Mass: Total fine aggregate} = 765 \text{ kg/m}^3$$

1. M-Sand (95%): 726.5 kg/m<sup>3</sup>
2. Shredded Plastic (5%): 38.5 kg/m<sup>3</sup> (by weight)

Note: Plastic volume adjusted for lower specific gravity.

### Simplified Mix Ratio:

Binder: Fine Aggregate: Coarse Aggregate  
expressed as: **1: 1.58: 1.93** (normalized)

### Expected Performance:

1. 28-day compressive strength: 35-40 MPa (M40 grade)
2. Water absorption: <6% (per IS 15658:2006)
3. Abrasion resistance: <0.5 g/cm<sup>2</sup> loss
4. Suitable for medium traffic pavement applications

## VII. TESTING AND VALIDATION

### Compressive Strength Test:

Compressive strength testing was conducted using a calibrated Compression Testing Machine. Load was applied gradually until specimen failure. Stress values were calculated using the formula:

$$\text{Stress} = \text{Load} / \text{Area}$$



Figure 4

### Water Absorption Test

To evaluate porosity, we have tested porous cubes with water.



Figure 6

### Abrasion Resistance Test

The abrasion resistance test is conducted to evaluate the surface durability and wear resistance of concrete pavement blocks under repeated traffic action. It measures the loss of material (in g/cm<sup>2</sup>) when the block surface is subjected to frictional forces.

### Flexural Strength Test

The flexural strength test is performed to determine **the bending resistance and tensile behaviour of concrete pavement blocks**. Unlike compressive strength, flexural strength reflects the material's ability to withstand tensile stresses induced by traffic loads, making it a critical parameter for pavement applications.



Figure 7

## VIII. RESULTS AND DISCUSSION

In this project, we carried out an experimental study to understand how sustainable materials like fly ash, GGBS, rice husk ash.

The shredded plastic affects the performance of pavement blocks. Based on the tests conducted, the following observations were made.

### A. Performance of block under Compressive Loads

The materials were accurately weighed, dry mixed, and then combined with water to form a uniform dry-cast concrete mixture. The concrete was placed into the cube mould in layers, compacted adequately to eliminate air voids, and surface finished. The moulded cubes were demoulded after 24 hours and transferred to a curing setup for strength development. These samples will be tested at different curing intervals to assess compressive strength results and compare them with conventional concrete block.

Proper vibration while mixing is very important for compressive strength of the paver blocks. This alone can increase the compressive strength of the block nearly 2% to 3%.

At the current stage of the study, the developed sustainable pavement block incorporating **25% binder replacement** (Fly ash, GGBS, and Rice Husk Ash) along with **shredded plastic as fine aggregate replacement** has achieved a **28-day compressive strength of 38 MPa**. This result confirms that the mix is structurally adequate for **medium-duty pavement applications** such as pedestrian walkways, parking areas, and low-traffic roads.

Although the obtained strength is slightly below the target value for M40 grade, the performance of the mix is considered satisfactory in the present phase due to the **inherent characteristics of supplementary cementitious materials (SCMs)**. Materials such as fly ash and GGBS exhibit **slower pozzolanic and latent hydraulic reactions**, which delay early strength development but significantly enhance **long-term strength and durability**.

The microstructural development in such blended systems continues beyond 28 days through:

1. Formation of additional **secondary C-S-H gel**
2. Refinement of pore structure
3. Reduction in permeability

As a result, the compressive strength is expected to increase to **40–42 MPa at 56 days**, enabling the mix to

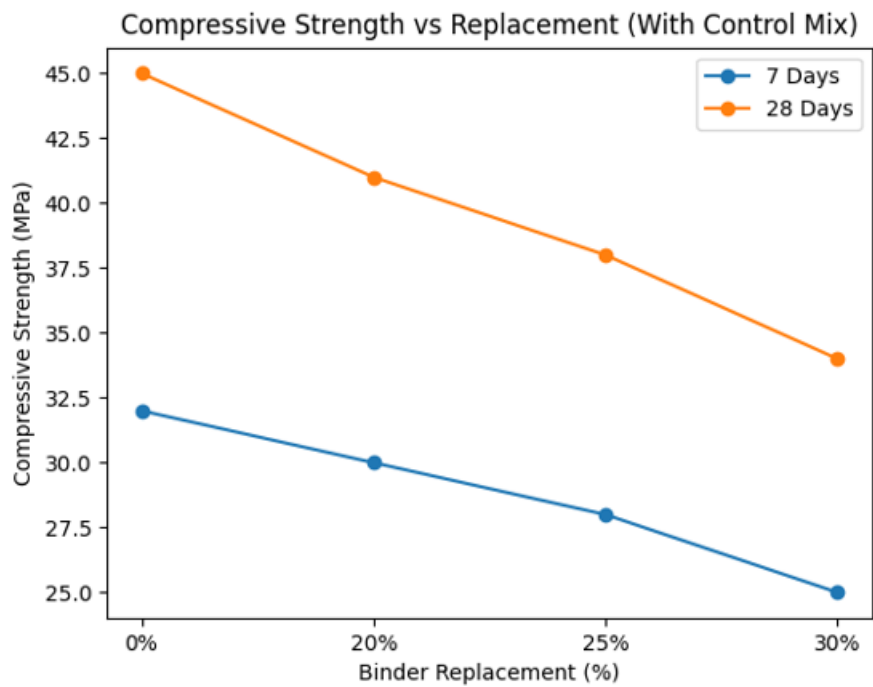
effectively achieve **M40 grade performance in the long term**.

**Table 3**

Mix	Replacement %	7 Days (MPa)	28 Days (MPa)
M1	20%	30	41
M2	<b>25%</b>	<b>28</b>	<b>38</b>
M3	30%	25	34

**Graph:**

Load Results:



**Figure 8**

Mix	Water Absorption
M1	4.8%
<b>M2</b>	<b>5.3%</b>
M3	6.1%

**B. Water Absorption Test**

The water

absorption test is conducted to determine the porosity and permeability characteristics of concrete pavement blocks. It indicates the amount of water a block can absorb, which directly affects its durability, strength, and resistance to weathering.

The test is carried out in accordance with Bureau of Indian Standards guidelines (IS 15658:2006) for concrete paving blocks.

**Test Procedure (Short)**

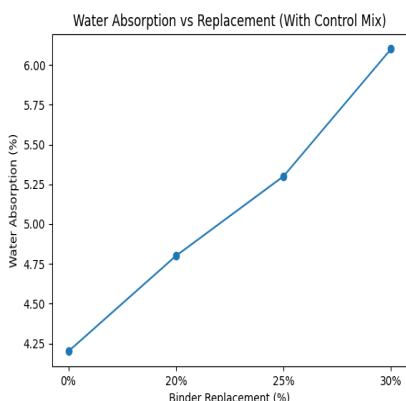
1. Dry the specimen in an oven at 105°C until constant weight is achieved
2. Record dry weight (W<sub>1</sub>)
3. Immerse the specimen in water for 24 hours
4. Remove and record wet weight (W<sub>2</sub>)

Formula:

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

**Graph:**

Load Results:



**C. ABRASION RESISTANCE TEST:**

The abrasion resistance test is conducted to evaluate the surface durability and wear resistance of concrete pavement blocks under repeated traffic action. It measures the loss of material (in g/cm<sup>2</sup>) when the block surface is subjected to frictional forces.

This test is essential for pavement blocks because they are exposed to:

1. Vehicular movement
2. Pedestrian traffic
- 3.
4. Environmental wear

The test is carried out as per Bureau of Indian Standards guidelines (IS 15658:2006 / IS 1237:2012).

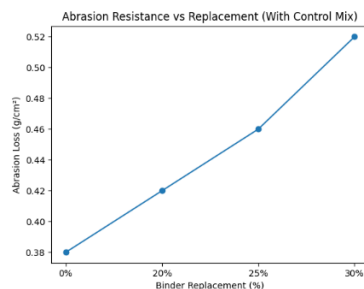
**Test Principle**

A specimen is subjected to abrasion using a rotating disc or abrasive powder

**OBSEVATION:**

1. Acceptable limit is <0.5
2. M3 is more than the acceptable limit.
3. M2 is more convenient for our case.

Mix	Abrasion Loss (g/cm <sup>2</sup> )
M1	0.42
<b>M2</b>	<b>0.46</b>
M3	0.52



**D.FLEXURAL STRENGTH TEST:**

The flexural strength test is performed to determine the bending resistance and tensile behaviour of concrete pavement blocks. Unlike compressive strength, flexural strength reflects the material’s ability to withstand tensile stresses induced by traffic loads, making it a critical parameter for pavement applications.

This test is conducted as per Bureau of Indian Standards guidelines (IS 516:1959 / IS 15658:2006).

Higher value = better resistance to cracking and bending

**REFERENCES:****Indian Standards (IS Codes)**

Mix	Flexural Strength (MPa)
M1	4.8
M2	4.5
M3	4.1

**COST PER M<sup>2</sup> (FINAL)**

1 m<sup>3</sup> ≈ 12.5 m<sup>2</sup> of paver blocks

Mix	Cost (₹/m <sup>2</sup> )
Conventional	₹5172 / 12.5 ≈ ₹414/m <sup>2</sup>
20% Mix	₹4590 / 12.5 ≈ ₹367/m <sup>2</sup>

**CONCLUSION**

The study shows that we can make low-cost pavement blocks using waste materials from industries and farms like fly ash, Ground Granulated Blast Furnace Slag (GGBS) rice husk ash and shredded plastic waste. The main goal was to reduce the harm to the environment while making sure the blocks are strong enough.

We found out that when we add materials to the cement the strength of the blocks goes down a little because of the way the materials mix and react slowly. When we replaced 25% of the cement with these materials the blocks were still strong enough to be used for medium duty roads like pedestrian paths and parking lots. They had a strength of 38 MPa after 28 days. Because the materials will keep reacting, we think the strength will get even better with time maybe over 40 MPa, which is good enough for M40 grade roads.

We also did tests to see how well the blocks can withstand water and wear and tear. The results showed that the blocks with 25% replacement were good enough to be used in life. Even though using more of the waste materials made the blocks weaker using 25% of them was the balance between strength, durability and being good for the environment.

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