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Optimizing the performance and Evalating Mechanical Properties of Paving Blocks by Incorporating Local Waste Plastic

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***Abstract*—The research aims to contribute to sustainable construction practices by investigating the utilization of locally available waste plastics in the development of paving blocks. The study involves the selection of suitable waste plastics, focusing on types prevalent in the local environment, such as LDPE type of plastic. Through proper experimentation, different proportions of waste plastics are incorporated into the paving block mix to strike a balance between enhancing mechanical properties and maintaining cost-effectiveness. Mechanical properties like compression, are rigorously tested to assess the overall performance of the plastic waste-based paving blocks. Additionally, the durability of the blocks is evaluated by subjecting them to environmental stressors such as water exposure and temperature variations. A comprehensive cost-benefit analysis was studied to compare the production costs of plastic waste-based paving blocks with traditional materials, considering factors such as material acquisition, processing, and manufacturing. Furthermore, an environmental impact assessment is undertaken to quantify the potential benefits in terms of reduced plastic pollution. Community involvement plays a crucial role in this study, with engagement activities aimed at understanding and incorporating local perspectives on the use of waste plastics in construction materials. The outcomes of this research will provide valuable insights into the feasibility and practicality of incorporating waste plastics in paving blocks, offering a sustainable alternative to traditional construction materials.**

***Keywords*— Paving Block; LDPE; Plastic Waste; cement; Concrete; Compressive Strength.**

I. INTRODUCTION

The increasing prevalence of plastic waste has become a global environmental concern, with significant implications for ecosystems, human health, and the overall well-being of the planet. Plastics, due to their non-biodegradable nature, persist in the environment for extended periods, leading to pollution of land, water bodies, and air. The management of plastic waste has thus emerged as a critical challenge, necessitating innovative and sustainable solutions.

The construction industry, being a major consumer of resources, plays a substantial role in environmental degradation. Traditional construction materials contribute to resource depletion and environmental pollution, prompting a pressing need for alternative, eco-friendly materials. Concurrently, there is a growing interest in repurposing waste materials for construction to mitigate the environmental impact of both the plastic crisis and the construction sector.

This study is grounded in the intersection of these two critical issues, aiming to address the environmental challenges posed by plastic waste while contributing to the development of sustainable construction practices. Specifically, the focus is on exploring the feasibility of incorporating locally available waste plastics into paving blocks. Paving blocks are widely used in various construction applications, and their production from recycled plastics holds the promise of not only reducing plastic pollution but also providing a cost-effective and environmentally responsible alternative to traditional paving materials. The research seeks to optimize the performance and cost-effectiveness of paving blocks by systematically studying the mechanical properties, durability, and economic viability of incorporating waste plastics. By doing so, the study aims to contribute valuable insights that bridge the gap between environmental conservation and sustainable construction, offering a practical and eco-conscious solution to the challenges posed by plastic waste in the context of the construction industry.

A. Preliminary Investigation

Concrete paver blocks were first introduced in Holland in the fifties as replacement of paver bricks which had become scarce due to the post-war building construction boom. These blocks were rectangular in shape and had more or less the same size as the bricks. During the past five decades, the block shape has steadily evolved from non-interlocking to partially interlocking to fully interlocking to multiply interlocking shapes. Consequently, the pavements in which non-interlocking blocks are used are designated as 'Concrete Block Pavement (CBP)' or non-interlocking CBP, and those in which partially, fully or multiply interlocking blocks are used are designated as 'Interlocking Concrete Block Pavement (ICBP)'.

CBP/ICBP consists of a surface layer of small-element, solid un-reinforced pre-cast concrete paver blocks laid on a thin, compacted bedding material which is constructed over a properly profiled base course and is bounded by edge restraints/kerb stones, The block joints are filled using suitable fine material. A properly designed and constructed CBP/ ICBP gives excellent performance when applied at locations where conventional systems have lower service life due to a number of geological, traffic, environmental and operational constraints. Many number of such applications for light, medium, heavy and very .heavy traffic conditions are currently in practice around the world.

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II. STUDY OF RELEVANT IS CODES AND SPECIFICATION IS CODE: - IS 15658: 2006

Name: - PRECAST CONCRETE BLOCKS FOR PAVING

This standard specifies constituent materials, products requirements and test methods for solid, un-reinforced pre-cast cement concrete paver blocks and complimentary products used for light, medium, heavy and very heavy traffic paving applications and other applications.

A. Following IS Code Specification Check out: -

IS 15658: 2006 covers Precast Concrete Blocks for Paving with the following requirements:

i) Grade Designation: M-30, M-35, M-40, M-50 and M-55.

ii) Dimensions: The thickness of the blocks shall be not less than 50 mm and not more than 120 mm and shall also meet the thickness requirement specified under Table 1 of IS 15658: 2006. When agreed to between manufacturer and purchaser, Blocks of thickness more than 120 mm may also be manufactured. Length and Width: To be specified by the manufacturer.

iii) Blocks can be manufactured in one layer or two layers.

iv) Considering the above, Precast Concrete Blocks for Paving are categorized into the following groups based on Grade Designation:

	GROUP I	GROUP II
GRADE DESIGNATION	M-30, M-35, M-40	M-50, M-55

B. List of Test Equipment: -

Sr. No.	Tests used in with Clause Reference	Test Equipment
1.	Aggregates (clause 4.2)	Test sieves for aggregate testing
2.	Dimensions, tolerance and thickness of wearing layer (clause 6.2.2, 6.2.3)	- Steel calipers - Steel rules / Vernier caliper -Weighing balance - Sheets of thin cardboard of uniform thickness - Sharp pencil - Sharp scissors - Odd leg marking gauge - Engineers square or profiled template - Feeler gauge
3.	Water absorption (clause 6.2.4)	- Weighing balance - Drying air oven
4.	Compressive strength (clause 6.2.5)	- Compression testing machine with bearing blocks and plates (rate of loading 15 ± 3 N/mm2 min)
5.	Abrasion resistance (clause 6.2.6)	- Abrasion testing machine - Hot air oven - Weighing balance - Standard abrasive powder - Grinding disk with defined load - Stop watch
6.	Tensile splitting strength (clause 6.2.7)	- Testing machine with rigid bearers of radius 75 ± 5 mm - Packing piece thickness 4 ± 1 mm & width 15 ± 1 mm - Water bath capable to maintain temperature 27 ± 2° C
7.	Flexural strength /breaking load (clause 6.2.8)	- Testing apparatus with rollers of diameter 25 - 40 mm. - Loading machine with rate 6 kN/min

C. Terminology

i) Actual Dimension — Measured dimensions of a paver block.
ii) Arris — Part of a block where two faces meet which can be bevelled, rounded, chamfered, or splayed, as shown in Fig.
iii) Aspect Ratio — The ratio of length to thickness of a paver block.
iv) Backing Layer — Layer of concrete on the lower face of a two-layer paver block, made of material same as or different from that used in the wearing layer of the block.
v) Bed Face — That surface of a paver block which, when paved, comes in direct contact with the bedding material.
vi) Chamfer — Bevelled arris, as shown in Fig.
vii) Chased Side Face — The side face of a paver block, having a recessed profile, as shown in Fig.
viii) Colour — Appearance of a paver block due to pigment used in concrete, other than natural cement colour.

D. Waste Plastic Analysis (Local Domestic Waste)

- Waste plastic type: PET (Polyethylene Terephthalate) bottles, HDPE (High-Density Polyethylene) containers, LDPE (Low-Density Polyethylene) plastic bags, and PVC (Polyvinyl Chloride) pipes.
- A) Analysis methods: Visual inspection, density test, burn test, scratch test, and solubility test.
- PET bottles: Based on the density test, float/sink observation, burn test, and scratch test, the sample is most likely PET. It floats, burns with a blue flame and no smoke, melts readily, and scratches easily.
- HDPE containers: The density test, float/sink observation, and burn test suggest HDPE. It floats, burns with a yellow flame and black smoke, melts and drips, and scratches moderately.
- LDPE plastic bags: Similar to PET, the density, float/sink behavior, and burn characteristics suggest LDPE. It floats, burns with a blue flame and black smoke, melts and drips, and scratches easily.
- PVC pipes: The high density, sinking behavior, and burn characteristics along with solubility in acetone point towards PVC. It sinks, burns with a yellow flame and black smoke, chars, leaves residue, and scratches with difficulty.
- The analysis indicates the presence of PET, HDPE, LDPE, and PVC in the local domestic waste plastic.
- Plastic Waste used in a paver block was collected from the surrounding locality then with help shedding machine crushed plastic is used. Low density polyethylene (LDPE) plastic is used, it includes plastic bags, shampoo packets, oil bottles.

III. MIX DESIGN OPTIMIZATION

This research investigated the feasibility of incorporating local waste plastics into paving blocks to enhance sustainability and reduce environmental impact. The aim was to develop a cost-effective paving block mix with suitable performance characteristics complying with the standards of IS 15658: 2006 Precast Concrete Blocks for Paving.

A. Materials:

- Cement: Ordinary Portland Cement (OPC) 53 grade conforming to IS 269: 1989.
- Fine aggregate: Natural sand conforming to IS 383: 1970.
- Coarse aggregate: Crushed stone with a maximum size of 10 mm.
- Waste plastic: Locally available waste plastics (LDPE) shredded to a size of 2-5 mm.
- Water: Potable water free from impurities.
- Plasticizer: Superplasticizer conforming to IS 9103: 1999, if required.

B. Mix Design Procedure

Preliminary Mix Design:
The preliminary mix design was based on the recommendations of IS 15658: 2006 and previous research on incorporating plastic waste in concrete. The following proportions were used as a starting point:
Cement: Fine aggregate: Coarse aggregate = 1: 2: 3 (by weight)
Water/cement ratio = 0.45
The waste plastic content was varied from 5% to 15% by weight of cement, and the mix proportions were adjusted to maintain adequate workability.

C. Trial Mixes

Three trial mixes are going to be prepared with varying waste plastic contents:

Mix ID	Waste Plastic Content (%)
Mix 1	5%
Mix 2	10%
Mix 3	15%

D. Casting and Curing

Paving block specimens will be cast from each trial mix using molds conforming to the desired shape and size (as per IS 15658: 2006). The specimens will be vibrated to ensure proper compaction and then cured for 7 and 28 days under standard conditions.

E. Testing

Compressive Strength: Compressive strength tests conducted on the paving block specimens at 7 and 28 days as per IS 15658: 2006. The average compressive strength of each mix will be calculated and compared with the minimum required strength for the chosen paving block grade.
The apparent compressive strength of individual specimen calculated by dividing the maximum load (in N) by the plan area (in mm2). The corrected compressive strength calculated by multiplying the apparent compressive strength by the appropriate correction factor from IS code given. The strength is expressed to the nearest 0.1 N/mm^2.

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IV. PROPERTIES OF MATERIALS

A. Cement:

In this work, Ordinary Portland cement (OPC) of Altratech (53 grade) brand obtained from a single batches was used. The physical properties of OPC as determined are given in following table. The cement satisfies the requirement of IS: 8112-1989. The specific gravity was 3.15 and fineness was 2800 cm2/g.

The cement grade 53 is known for its rich quality and is highly durable. Hence it is used for constructing bigger structures like building foundations, bridges, tall buildings, and structures designed to withstand heavy pressure. With a good distribution network this cement is available most abundantly.

B. Plastic waste (LDPE)

Plastic Waste used in a paver block was collected from the surrounding locality, then with help shedding machine crushed plastic is used. Low density polyethylene (LDPE) plastic is used which is indicated by resin number 4. It includes plastic bags, shampoo packets, oil bottles.

Sr. No.	Particulars	Value
1.	Melting point	150°
2.	Thermal co efficient of expansion	100-200X10^-6
3.	Density	0.910-0.940
4.	Tensile Strength	0.20-0.40 (N/mm^2)

C. Aggregate:

Locally available coarse aggregate were used in this work. Aggregates passing through 12mm sieve and retained on 10mm sieve were sieved and tested as per Indian standard specification IS: 383-1970.

a) Fine Aggregate (sand) - In this project we are using (Natural Sand) Fine aggregate resulting from the natural disintegration of rock and which has been deposited by streams or glacial agencies. The river sand was used as natural river sand.

b) Coarse Aggregates- Coarse aggregate are the crushed stone used for making concrete. The commercial stone is quarried, crushed and graded. Much of the crushed stone used is granite, limestone and trap rock. Crushed angular granite metal of 10 mm size from a local source was used as coarse aggregate. The specific gravity of 2.6 and fineness modulus 6.05 was used. Size of aggregates used Aggregates passing through 12.5 mm size sieve and retained on 10 mm size sieve are used. Specific Gravity of aggregates used were 2.884

D. Water:

The water used for mixing and curing of concrete should be free from harmful materials and objectionable strain on surface. A part of mixing water is utilized in the hydration of cement and the remaining water serves as lubricant between the fine and course aggregates and make concrete workable. Generally minimum 0.3 to 0. 8 w/c ratios are required for hydration.

V. RESULT

A. Results:

Compressive strength for paver blocks Plastic paver blocks of size 215X115X6mm were casted. The maximum load at failure reading was taken and the average compressive strength is calculated using the following equation.

Compressive strength (N/mm2) = (Ultimate load in N / Area of cross section (mm2))

Proportion name	Plastic Waste	Compressive Strength (N/mm2)
PB1	0%	12.67
PB2	0%	13.89
PB3	0%	13.70
	Avg.	13.42

TABLE I. COMPRESSIVE TESTING RESULT FOR ORDINARY PAVING BLOCKS

Proportion name	Plastic Waste	Compressive Strength (N/mm2)
PB T1 A	5%	12.17
PB T1 B	5%	13.50
PB T1 C	5%	13.43
	Avg.	13.03

TABLE II. COMPRESSION STRENGTH RESULT FOR BLOCK TYPE I

Proportion name	Plastic Waste	Compressive Strength (N/mm2)
PB T2 A	10%	10.34
PB T2 B	10%	11.21
PB T2 C	10%	9.67
	Avg.	10.40

TABLE III. COMPRESSION STRENGTH RESULT FOR BLOCK TYPE II

Proportion name	Plastic Waste	Compressive Strength (N/mm2)
PB T3 A	15%	7.45
PB T3 B	15%	8.67
PB T3 C	15%	8.89
	Avg.	8.34

TABLE IV. COMPRESSION STRENGTH RESULT FOR BLOCK TYPE III

VI. CONCLUSION

This paper gives the detail survey of the work carried out in paver block made with the help of plastic. Paver block made by composite materials, has a medium compressive strength. The main constituents of paver block are cementing concrete.

- The utilization of waste plastic in production of paver block has productive way of disposal of plastic waste.
- The cost of paver block is reduced when compared to that of concrete paver block.
- Paver block made using plastic waste, quarry dust, coarse aggregate and ceramic waste have shown better result.
- It also shows good heat resistance.
- Though the compressive strength is low when compared to the concrete paver block it can be used in gardens, pedestrian path and cycle way etc.
- It can be used in Non-traffic and light traffic road.
- The plastic paver block have low water absorption property."

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