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Utilization of Waste LDPE as Binder in Concrete Paver Blocks: An Experimental Study

Amrut Mane, Ujwala Gurav, Harish Kittali, Abubakar S N & Dr. Sachin Kulkarni
Department of Civil Engineering, Jain College of Engineering, Belagavi, Karnataka, India
amrutmane@gmail.com, ujwalagurav@gmail.com, harishkittali@gmail.com,
abubakarsn@gmail.com, sachinkjce@gmail.com

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Abstract—

Waste plastic is a growing share of municipal solid waste, and low-density polyethylene (LDPE) is among its largest components. This paper reports an experimental study on concrete paver blocks in which melted LDPE waste is used as the binder in place of cement, with sand as the filler. The specific gravity of the sand, found from two pycnometer trials, averaged 1.89. Three blocks of the mix designated plastic (10% of cement) were tested in compression and failed at 589, 547 and 537 kN, giving compressive strengths of 26.17, 24.30 and 23.86 N/mm² and a mean of 24.77 N/mm². Because the plastic sets on cooling, the blocks need no water curing. The study shows that sand–LDPE blocks can reach compressive strengths in the range of 24–26 N/mm², and it points to the tests still needed before such blocks are recommended for a given traffic category.

Index Terms—paver blocks, LDPE, waste plastic, plastic binder, compressive strength, sustainability.

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I. Introduction

Plastic products are part of everyday life, and their waste is accumulating quickly. About 5.6 million tonnes of plastic waste are generated in India each year, which is roughly 15,342 tonnes per day. Thermoplastics make up about 80% of post-consumer plastic waste. Plastics are largely non-biodegradable and persist for very long periods. A virgin plastic can be recycled only two or three times before heat and pressure degrade it, so recycling alone is not a lasting answer. When the waste is landfilled or burned, it can pollute land, water and air.

Construction uses large volumes of material, which makes it a natural outlet for waste. Waste put into concrete is removed from the waste stream for the long service life of the structure, and it can reduce the extraction of mineral aggregates. The use of waste plastic in construction products, including bricks, blocks and paver blocks, has been studied by several researchers [1]–[5]. Paver blocks are precast interlocking units used for footpaths, parking areas, gardens and road sides. They can be made in many shapes and are laid on a prepared base.

In this work, melted LDPE replaces cement as the binder in paver blocks, and sand acts as the filler. The strength of the blocks comes from the plastic setting on cooling, not from cement hydration.

A. Low-density polyethylene

LDPE is a flexible thermoplastic made from ethylene, with a density of 0.917–0.930 g/cm³ and resin identification code 4. It is widely used in food wrap and shopping bags. It is chemically inactive at room temperature except towards strong oxidising agents and some solvents. It resists moisture, does not conduct electricity and is easy to mould. The LDPE granules used here are 4–5 mm in size, and the supplier data give a temperature resistance of up to 190 °C. As a thermoplastic, LDPE softens on heating and sets again on cooling, which allows it to bind sand particles into a solid block.

II. Objectives of the Project

The objectives of the project are: (i) to use non-biodegradable plastic as a construction material; (ii) to prepare paver blocks with recycled LDPE in different proportions; (iii) to determine the compressive strength of the blocks for a given mix proportion; (iv) to compare the weight of plastic paver blocks with that of normal paver blocks; (v) to evaluate the performance of plastic paver blocks for pavements and other applications; and (vi) to produce cost-effective paver blocks. This paper reports the specific gravity of the sand and the compressive strength of the first mix.

III. Literature Review

Ghude [6] heated plastic waste in an iron pan above 170 °C until it melted into a black liquid, and then mixed in fine and coarse aggregate. The blocks were tested in compression on three samples of the same ratio, with strength taken as load divided by cross-sectional area. The blocks were suited to light-traffic roads and footpaths and cost less than concrete pavers, although their compressive strength was lower.

Panimayam [7] replaced coarse aggregate in M20 concrete with 0%, 2%, 4%, 6%, 8% and 10% waste plastic and tested paver blocks at 7, 14 and 28 days. The strength was comparable to plain cement concrete, and the optimum plastic content was 4%.

Shanmugavalli *et al.* [8] replaced cement with plastic in paver blocks, melting the plastic above 150 °C and mixing it with quarry dust, coarse aggregate and ceramic waste. The blocks showed good heat resistance. Their compressive strength was lower than that of concrete pavers, and they were recommended for gardens, pedestrian paths, cycle ways and non-traffic or light-traffic roads.

Dinesh [9] reported that plastic–sand bricks and paver blocks save cost, remove waste plastic and use far fewer natural resources, and suggested replacing river sand with fly ash or

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quarry dust to cut cost further. Premhar [10] replaced cement with silica fume at 10–40% in paver blocks and found 20% to be optimum, with water absorption below 7%.

IS 15658 [11] specifies precast concrete paving blocks, with strength expressed as 28-day compressive strength determined by the method in its Annex D. The present work uses molten LDPE as the only binder with sand, and reports the specific gravity of the sand and the compressive strength of the blocks.

IV. Casting of Specimens

A. Materials

LDPE waste in granular form (4–5 mm) was used as the binder. Fine sand passing 5 mm was used as the filler. Cement and water, the usual ingredients of a concrete paver, are replaced by the plastic binder in this mix, and the blocks need no water curing. The specific gravity of the sand was determined by the pycnometer method.

B. Specific gravity of sand

The empty pycnometer was weighed (W_1). It was then filled to one-third with sand and weighed (W_2), filled with water with the entrapped air removed and weighed (W_3), and finally filled with water alone and weighed (W_4). The specific gravity is

$$G = (W_2 - W_1) / [(W_2 - W_1) - (W_3 - W_4)] \quad (1)$$

C. Specimen preparation

Fig. 1 shows the process followed. The plastic and sand were mixed in the chosen ratio and heated in a metal pan on a heater fitted with a temperature controller (Fig. 2) until the plastic melted and coated the sand. The hot mix was transferred to the moulds, and the blocks were demoulded and cooled (Fig. 3). Demoulding was immediate and caused no difficulty. The mix is designated plastic (10% of cement) in the test record. Because the plastic binds on cooling, no water curing was done.

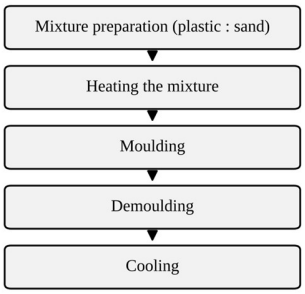


Fig. 1. Process adopted for making the LDPE paver blocks.



Fig. 2. Melting of the plastic–sand mix.



Fig. 3. Moulding, demoulding and cooling of the blocks.

V. Testing of Specimens

Three blocks (FM 1 to FM 3) were tested for compressive strength in a compression testing machine (Fig. 4), following the approach of IS 15658 [11]. Each block was loaded to failure and the failure load was recorded. The compressive strength was calculated as

$$f_c = P / A \quad (2)$$

where P is the failure load (N) and A is the loaded cross-sectional area of the block (mm²). Water absorption was not measured, and no curing was done because the binder is plastic and not cement.



Fig. 4. Compression test of a paver block.

VI. Results and Discussion

A. Specific gravity of sand

Table I gives the pycnometer readings and the specific gravity from (1). Trial 1 gave 1.92 and trial 2 gave 1.86, so the average specific gravity of the sand is 1.89.

TABLE I
SPECIFIC GRAVITY OF SAND

Trial	W1 (kg)	W2 (kg)	W3 (kg)	W4 (kg)	Specific gravity
1	0.659	0.863	1.610	1.512	1.92
2	—	—	—	—	1.86
Average					1.89

B. Compressive strength

Table II gives the results, which are plotted in Fig. 5. The blocks failed at 589, 547 and 537 kN, and the compressive strengths were 26.17, 24.30 and 23.86 N/mm², with a mean of 24.77 N/mm². The three failure loads and strengths correspond to a loaded area of about 22,500 mm². The strongest and weakest blocks differ by 2.31 N/mm², which is 9.3% of the mean. This is a modest scatter for three blocks.

TABLE II
COMPRESSIVE STRENGTH OF PAVER BLOCKS

Mix	Specimen	Failure load (kN)	Strength (N/mm²)	Mean (N/mm²)
Plastic (10% of cement)	FM 1	589	26.17	
	FM 2	547	24.30	24.77

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Mix	Specimen	Failure load (kN)	Strength (N/mm²)	Mean (N/mm²)
	FM 3	537	23.86	

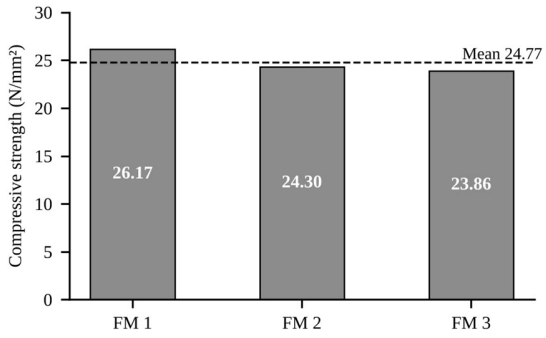


Fig. 5. Compressive strength of the three paver blocks.

A mean strength of 24.77 N/mm² shows that sand bonded only by melted LDPE can carry substantial load without cement. The literature reports that plastic-bound pavers are generally weaker than concrete pavers and suit footpaths, gardens and light-traffic roads [6], [8]. The result here should therefore be checked against the grade requirements of IS 15658 [11] before a traffic category is recommended.

C. Limitations

Only one mix was tested, on three blocks. No cement-bonded control blocks are reported, so the strength cannot be compared with that of a conventional paver, and no strength-gain with age, water absorption, weight comparison or cost analysis is reported. The plastic–sand proportion and heating temperature should be stated for the mix. Benefits such as long life, low maintenance, thermal and sound insulation, and lower cost are cited in the literature [8], [9], but were not tested in this study.

VII. Conclusion

Paver blocks were made with melted LDPE waste as the only binder and sand as the filler. The sand had an average specific gravity of 1.89. Three blocks of the mix plastic (10% of cement) gave compressive strengths of 26.17, 24.30 and 23.86 N/mm², with a mean of 24.77 N/mm². The blocks need no cement and no water curing, and they put non-biodegradable plastic waste to use. Future work should include cement-bonded control blocks, different plastic–sand ratios, strength at different ages, water absorption, weight and cost comparison, and durability and abrasion tests, so that the suitable traffic category for these blocks can be established.

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