Sustainable Paving Blocks from Waste LDPE and Spent Foundry Sand: A Review

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Abstract

Cement-free paver blocks bound with melted waste plastic can turn two problem waste streams, post-consumer plastic and spent foundry sand (SFS), into pedestrian-grade paving, but the evidence is thin and the strength data need verification. This review synthesizes about 30 sources on paver blocks made with alternative aggregates, fibres, industrial by-products and geopolymer binders, and examines one thermoplastic route in detail: waste low-density polyethylene (LDPE) melted as a binder around SFS at a 4:1 sand-to-plastic mass ratio.

Across the literature, partial replacement of cement or aggregate, typically at 15% to 60%, preserves acceptable strength, while complete removal of cement and water curing is rarely attempted. In the LDPE–SFS case reviewed, blocks weighed about 2.90 kg against
4.50 kg for OPC concrete, a reduction of about 35.5%, and carried a lower crushing load (350 against 480, in the units reported). The review flags open issues: inconsistent strength units, leaching, fire and UV behaviour, softening above about 80°C, and the lack of standardised testing. It closes with priorities for scale-up.

Keywords: sustainable construction; low-density polyethylene; spent foundry sand; cementless paver blocks; waste valorization; compressive strength; review

1. Introduction

Urban growth is producing waste faster than cities can absorb it, and construction materials are both a cause and a possible sink [1]. Two streams are especially awkward: non-biodegradable post-consumer plastics such as LDPE, and spent foundry sand from metal casting [6], [30]. Maharashtra currently ranks first in India in plastic waste generation, which makes regional solutions urgent.

Plastic waste. Plastics take roughly 10 to 1,000 years to degrade [6]. Left unmanaged they fill landfills, block storm drains and release microplastics and leachates such as phthalates and Bisphenol A into food chains [30]. Open burning adds dioxins and furans to the air.

Foundry sand. Foundries bind high-grade silica sand with bentonite clay, sea coal or chemical resins to make single-use moulds. After shake-out, large tonnages go to landfill each year, creating groundwater leaching liabilities [15], [30].

Conventional paving inputs. Ordinary Portland Cement (OPC) manufacture accounts for about 8% of anthropogenic CO_2 emissions worldwide [8], [24]. Excessive river sand dredging erodes banks, lowers water tables and damages aquatic ecosystems [23].

A small group of studies tackles these problems together, using waste LDPE as a hot-melt binder and SFS as fine aggregate, which removes cement, water curing and natural sand from the block [21]. This review pursues three objectives:

1. Map how alternative materials have been used in paver blocks.
2. Compare the LDPE–SFS route with conventional OPC concrete on mass, strength and failure behaviour.

3. Identify the gaps that block commercial use.

2. ™cvicw Mcthodology

This is a narrative review of 30 sources: journal and conference papers on paver blocks from 2005 to 2015, plus one US Federal Highway Administration guideline on foundry sand [30]. The sources were grouped by what they substitute (plastic, fibre, industrial by-product, binder) and compared on the properties they report: unit mass, compressive strength, abrasion resistance, water absorption and cost.

One experimental study, the LDPE–SFS paver block work of Gangan and Juvekar [31], is treated as a case study. It supplies the only primary data in this review on a fully cementless, thermally bound block, and Sections 6 to 8 draw on it. Its results are reported as single average values, without specimen counts or variability, so they are indicative, not conclusive.

3. Convcntional Pavcr Blocks and Thcir Footprint

Conventional paver blocks are cement, natural sand and coarse aggregate, compacted and then cured in water. Their strength depends heavily on cement content and water–cement ratio: Ling et al. [4] found that cement contents of 12% to 15% gave compressive strengths of 20 to 42 MPa. Revathi and Selvan [26] reported densities of 1888 to 2202 kg/m³ and water absorption below 7% for precast M40 blocks. Blocks are commonly graded M30 to M40, and the OPC reference blocks in the case study [31] were of this class at a unit mass of about 4.50 kg.

A survey of an industrial paver plant, reported in [31], showed three practical burdens:

- Production relies on multi-stage hydraulic presses, vibration tables and moist-curing tanks, with 28 days of curing.
- Imported machinery often idles because skilled local labour is scarce for maintaining high-pressure pumps and electronic controls.
- These constraints favour a low-tech process that avoids hydraulic equipment and water curing.

The environmental costs sit upstream, in cement (about 8% of global anthropogenic CO_2 [8], [24]) and in river sand extraction [23]. Quality control for finished blocks has also been studied: Brožovský et al. [3] showed that ultrasonic pulse velocity and rebound hammer tests can estimate compressive strength without destroying units.

4. Altcrnativc Matcrials in Pavcr Blocks

Nearly all published work replaces part of the cement or aggregate in a water-cured concrete block; it does not replace the binder itself. The table groups the studies by what is substituted.

Category	Study	Material	Reported finding
Plastic	Raghatate [1]	Shredded plastic bags, 0–1.0%	Compressive strength falls slightly; tensile strength peaks at 0.8%

Plastic	Parihar and Kumavat [2]	Recycled plastic, up to 20% of coarse aggregate	Acceptable integrity; block mass cut by up to 15%
Plastic	Tapkire et al. [6]	PET bottles and PP bags, 20%	Standard mechanical behaviour preserved
Fibre	Kashiyani et al. [11]–[13]	Polypropylene, 0.3–0.4%, top 15 mm	About 40% higher strength; better abrasion resistance; lower absorption
Fibre	Thakur et al. [10]	Nylon fibre with fly ash	13.55% higher strength
Fibre	Tiwari and Joshi [28]	0.3% nylon with 20% fly ash, 80 mm M40	18.86% gain over control
Fibre	Neekhra and Agarwal [25]	0.3% nylon	Better early-age strength
Fibre	Navya and Rao [18], [19]	Coconut and polyester fibre, 0.3–0.4%, top 20 mm	Better flexural capacity
Industrial by-product	Nanda et al. [5]	Stone crusher dust, up to 50% of fine aggregate	56% cost reduction, negligible strength loss
Category	Study	Material	Reported finding
Industrial by-product	Ravikumar et al. [9]	Iron ore tailings	Best strength at 15% replacement
Industrial by-product	Mall et al. [20]	Fly ash, 25%	Optimised M35 blocks
Industrial by-product	Sharma and Kumar [22]	Brick kiln dust, 15%	Used as a partial replacement at 15%
Industrial by-product	Ganjian et al. [24]	ROSA, GGBS and BOS	Up to 60% of OPC replaced
Industrial by-product	Santhosh and Ram [29]	20% cement replaced by fly ash and glass powder	Satisfactory abrasion and absorption
Industrial by-product	Revathi and Selvan [26]	Rice husk ash, M40	Density 1888–2202 kg/m³; absorption below 7%
Industrial by-product	Kalingarani et al. [7]	Fly ash and copper slag	Interlocking blocks produced

Industrial by-product	Santos et al. [14]	Coal combustion waste for sand	Natural fine sand replaced
Industrial by-product	Yeole and Jadhav [16]	Waste steel aggregate	50% higher impact strength
Fine aggregate	Raja and Murugesan [23]	Manufactured sand	43.80 N/mm² strength
Geopolymer	Vaz et al. [8]	Alkali-activated fly ash, no OPC	Early strength within 24 hours at 60°C
Pavement system	Sarkar and Kumar [17]	Interlocking blocks over polyethylene cell confinement	Jointing sand cut deflection by 14%

Three patterns stand out. First, plastics enter concrete as a partial aggregate substitute, usually at about 20%, and the gain is lower mass rather than higher strength [2], [6].
Second, fibres in the top 15 to 20 mm give the most consistent gains in strength and abrasion resistance [11]–[13], [18], [19]. Third, among these studies only the geopolymer route [8] removes OPC entirely, and it still needs alkali activation and heat curing. Reddy and Rao [27] also combined nylon fibre with rice husk ash, extending the fibre approach to a by-product binder.

5. Spcnt Foundry Sand: Propcrtics and Usc in Paving

SFS is a good fit as a fine aggregate because it is mostly silica: the oxide analysis in the case study shows 87.91% SiO_2, with 4.70% Al_2O_3 and a loss on ignition of 5.15% [30]. The residual coating of burnt carbon, bentonite and trace organics is what separates it from clean river sand.

Property	Value	Standard method
Specific gravity	2.39–2.55	ASTM D854 / AASHTO T100
Bulk density	2590 kg/m³ (160 lb/ft³)	ASTM C48 / AASHTO T84
Water absorption	0.45%	ASTM C128
Moisture content	0.1%–10.1%	ASTM D2216
Clay lumps and friable particles	1%–44%	ASTM C142 / AASHTO T112
Permeability	10^{-3} to 10^{-6} cm/s	ASTM D2434 / AASHTO T215
Atterberg limits	Non-plastic	ASTM D4318 / AASHTO T90

Two features matter for plastic binding. Water absorption is low (0.45%), but the wide moisture range (0.1% to 10.1%) and clay-lump range (1% to 44%) show that SFS varies between foundries and batches, so pre-treatment such as drying and screening is worth testing. Its chemistry in full:

Constituent	Content (%)
SiO_2	87.91
Al_2O_3	4.70
Fe_2O_3	0.94
CaO	0.14
MgO	0.30
SO_3	0.09
Na_2O and K_2O	0.44
TiO_2 and P_2O_5	0.15
Loss on ignition (1000°C)	5.15 (range 2.1–12.1)

In conventional concrete, Patel and Pitroda [15], [21] tested SFS as a partial replacement of cement and sand. At 50% replacement, strength held at 23.48 N/mm² while unit cost fell by 20.13%. That result shows SFS is mechanically usable in cement-bound blocks, and the thermoplastic route extends it to a block with no cement at all.

6. Waste LDPE as a Thermoplastic Binder

Feedstock. LDPE is a semi-rigid, highly flexible polymer with branched carbon chains, high chemical resistance, hydrophobic behaviour and a melting range of 110°C to 130°C. The case study [31] drew clean carry bags, stretch films and water sachets from municipal collection centres, commercial packaging and agricultural waste. Plastic was sorted by hand to exclude PVC, PET and polyurethane foam, whose heating can release toxic or high-temperature residues.

Mix design. Trials covered sand-to-plastic mass ratios of 50:50, 60:40, 70:30, 80:20 and 4:1. The 4:1 mix (80% SFS, 20% LDPE) gave the best workability and dense compaction without resin bleeding. Note that 80:20 and 4:1 are the same ratio, so the source lists five labels for four distinct mixes; the trial results themselves are not reported. In this system LDPE only coats and binds the sand, so the mix design is a balance between enough polymer to wet every grain and no excess to bleed out.

Apparatus. Shallow aluminium pans failed: flames reached the plastic and caused combustion, and aluminium's low melting point led to structural failure. A steel drum, 45 cm high and 30 cm in diameter, solved both problems by keeping flame away from the melt and giving room to stir.

Production sequence. The route has no hydraulic press and no curing tank:

1. Heat the drum gently and add sorted LDPE in portions until it melts to a viscous black fluid at about 130°C to 150°C.
2. Add pre-weighed SFS and stir by hand for 15 to 20 minutes, until polymer lumps break up and every grain is coated.
3. Transfer the hot paste with trowels into pre-oiled steel moulds and tamp by hand to expel air.
4. Rock the moulds to loosen the edges, let the block solidify for several minutes, and demould.
5. Air-cool at room temperature for 2 hours.

7. Comparativc Pcrfiormancc

The LDPE–SFS block is about 35.5% lighter than an OPC concrete block but carries a lower crushing load, about 27% lower on the reported figures. Both results come from the case study [31], which compared the blocks against conventional M30/M35 OPC concrete blocks.

Property	OPC concrete block	LDPE–SFS block (4:1)	Difference
Average unit mass	4.50 kg	2.90 kg	About 35.5% lower
Compressive load, as reported	480 N/mm²	350 N/mm²	About 27% lower (derived)
Failure mode	Brittle diagonal shear	Ductile plastic deformation, then crushing	Different

Mass. The weight saving comes mainly from the polymer matrix. LDPE has a specific gravity of about 0.92, against about 2.15 for hydrated Portland cement paste and about
2.65 for natural aggregate [31], while SFS itself, at 2.39 to 2.55 [30], is close to natural sand. Lighter blocks reduce dead load on the sub-base and cut freight costs.

Strength. The paper's own strength figures need care. Strength was measured on a calibrated hydraulic Compression Testing Machine (CTM) with specimens centred between the platens and loaded to failure, but the results are headed "equivalent load scale" and quoted in N/mm². Values of 480 and 350 N/mm² are far above the 20 to 42 MPa
[4] and 43.80 N/mm² [23] reported elsewhere for paver blocks, so they cannot be read as compressive stress. They are most likely failure loads in a different unit. The ratio between the two blocks, about 0.73, may still be meaningful, but absolute strength cannot be checked against pavement-grade requirements until stress is reported from load and loaded area.

Failure behaviour. Concrete blocks fail by brittle diagonal shear. The LDPE composite deforms plastically before crushing, and the semi-flexible matrix absorbs impact and prevents explosive spalling under overload [31]. This ductility is a real advantage in service, and is the one property where the thermoplastic block clearly outperforms concrete.

Suitability. The abstract of [31] describes the blocks as suitable for light-traffic and pedestrian use, while its conclusion limits them to non-traffic pedestrian walkways, cycling tracks, parks and residential compounds. The narrower claim is the safer reading.

8. Environmcntal and Economic Asscssmcnt

The LDPE–SFS block avoids three conventional burdens at once, but no study has yet quantified the net benefit.

Benefits claimed.

- No OPC, so no calcination CO_2 from cement, a sector responsible for about 8% of anthropogenic CO_2 [8], [24].
- No water curing, replacing the 28-day moist-curing tanks of standard plants.
- No river sand, easing dredging damage to banks and water tables [23].

- Diversion of LDPE and SFS from landfill, lowering leaching risk from open dumping [30], [31].

Economics. Cost evidence is indirect. Cement-based blocks with by-product replacement report savings of 56% for stone crusher dust [5] and 20.13% for foundry sand at 50% replacement [15], [21]. Waste LDPE and SFS are low-cost or free feedstocks, and the process needs no hydraulic press, which suits regions with limited maintenance skills. However, the case study [31] gives no cost per block, fuel use or labour time, so the economic case is plausible, not demonstrated.

Trade-offs not yet counted. Melting plastic needs fuel and releases vapours; open burning of plastic emits dioxins and furans [31]. A fair life-cycle comparison must include burner fuel, vapour control and the energy of collecting and sorting plastic, against the avoided cement and sand.

9. Limitations, Challcngcs and ™cscarch Gaps

Previous work has focused on partial replacement of aggregate or cement in water-cured concrete [1]–[29]. Fully cementless, thermally bound blocks made from LDPE and SFS remain underexplored, and the evidence that exists has the following gaps.

Gap	Why it matters
Strength reported as "equivalent load" in N/mm²	Cannot be compared with pavement-grade requirements or other studies
No specimen counts or variability	Single averages hide scatter from hand mixing
Softening above 80°C	Unsuitable for hot industrial settings or uninsulated hot surfaces
Manual mixing and tamping	Density varies if temperature drifts between batches
Gap	Why it matters
Mix trials not reported	The 4:1 optimum cannot be checked against the other ratios
No abrasion, absorption or durability data	These are standard paver properties in [11]–[13], [26], [29]
No leaching, fire or UV data	Safety and service life are unknown
Variable SFS and mixed plastic feedstock	Properties of SFS vary widely [30]; unsorted LDPE may carry additives
No cost or life-cycle data	The sustainability case is not quantified

Two gaps deserve emphasis. The thermal limit is structural: a polyethylene binder softens above 80°C, which sits far below the temperatures that cement-bound blocks tolerate, so surface heating from sun exposure needs testing. And the strength question is one of reporting as much as of material: until failure loads are converted to stress with stated specimen dimensions, the LDPE–SFS block cannot be ranked against the strengths in Section 4.

10. Futurc Scopc and Conclusions

Future scope. Four priorities would move the technology towards commercial use:

1. **Standardised mechanical testing.** Report compressive stress with specimen dimensions and replicate counts, plus abrasion resistance, water absorption and impact behaviour, so results can be compared with the concrete literature.
2. **Fire retardancy and UV stabilization.** Test non-toxic additives such as alumina trihydrate or carbon black to improve fire resistance and slow UV degradation.
3. **Leaching and environmental safety.** Run the Toxicity Characteristic Leaching Procedure (TCLP) to confirm no heavy-metal or organic leaching under acidic rain.
4. **Automated extrusion processing.** Develop closed-loop heating and extrusion machinery with toxic-vapour scrubbers for consistent quality and worker safety at scale.

Conclusions.

1. Published paver block research mostly substitutes part of the cement or aggregate in water-cured concrete. Fibres, industrial by-products and geopolymers each have documented benefits, but few studies remove OPC and water curing together.
2. Waste LDPE melted around SFS at 4:1 by mass is a feasible cementless route, needing only a steel drum, hand tools and no curing [31].
3. The resulting blocks are about 35.5% lighter than OPC concrete blocks (2.90 kg against 4.50 kg) and fail in a ductile way, which lowers handling effort and transport energy.
4. Their crushing load is lower than concrete's, and the reported strength figures cannot yet be read as pavement-grade stress. Use should be limited to non-traffic pedestrian areas until verified.
5. With strength reporting, thermal behaviour, leaching and life-cycle impacts resolved, the approach could cut municipal plastic waste, reuse foundry sand and conserve natural aggregate.

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Note: the source paper named the authors of [2] and [8] differently in its text (Satish and Kumavat; Aaron et al.) than in its reference list. The list entries are used here; please verify them against the original publications.