



OPEN ACCESS INTERNATIONAL JOURNAL OF SCIENCE & ENGINEERING

Experimental Investigation on Paver Blocks Using By-Products and Waste Materials

Akash S¹, Aswin A², Abinesh R³, Feno Franglin J P⁴, Sony. P⁵

^{1,2,3,4,5}Department of Civil Engineering, Stella Mary's College of Engineering, Aruthenganvilai, Kanyakumari, Tamil Nadu, India, Anna University, Chennai 600025

Abstract: The paver block is one of the most widely used flexible surface-treatment options for exterior pavement applications, valued for its aesthetics, durability, ease of maintenance and replacement, and skid resistance. This study investigates the feasibility of manufacturing Type-C paver blocks — with all faces curved or corrugated so that adjoining units interlock along their vertical faces — by partially replacing conventional aggregates with industrial by-products and waste materials. Fine aggregate was partially replaced with copper slag (0, 10, 20, 30, 40 and 50 %), while coarse aggregate was partially replaced with coconut shell (10, 15 and 20 %) and crumb rubber (10, 15 and 20 %), individually and in combination, in M20-grade concrete. The physical properties of all constituent materials — specific gravity, fineness modulus and water absorption — were characterised, and mixes were proportioned as per IS 10262:2009. Paver block specimens (250 mm × 125 mm × 60 mm) were cast, cured and tested for compressive strength at 7, 14 and 28 days. The results indicate that a 20 % replacement of fine aggregate with copper slag combined with coconut shell as coarse aggregate produced the highest 28-day compressive strength among the mixes studied, exceeding the target strength of the control mix. The study demonstrates that copper slag, coconut shell and crumb rubber can be effectively utilised in paver-block manufacture, reducing natural-resource depletion and offering a sustainable route for the disposal of industrial and agricultural waste.

Key words: Paver block, copper slag, coconut shell, crumb rubber, compressive strength, waste materials, sustainable construction.

I. Introduction

Paver blocks are a form of pre-cast concrete unit used primarily for outdoor flooring and road construction rather than for load-bearing walls. They provide a flexible pavement surface that is easy to maintain, highly durable and pleasant to walk on, and they are available in a variety of shapes, patterns and colours, making them suitable for both functional and aesthetic applications on local roads, footpaths and the exterior areas of buildings [1].

The construction industry is one of the largest consumers of natural aggregate, and the continued extraction of river sand and quarried stone raises concerns about resource depletion and environmental degradation. At the same time, industrial and agricultural sectors generate large volumes of by-products — such as copper slag, coconut shell and scrap-tyre crumb rubber — that are frequently disposed of as landfill. Utilising these materials as partial replacements for conventional aggregate in paver-block production offers a route to conserve natural resources while providing a productive outlet for waste streams, in line with the broader goal of sustainable construction.

The objectives of this work are to (i) manufacture paver blocks utilising by-products and waste materials, (ii) partially replace fine aggregate with copper slag and coarse aggregate with coconut shell and crumb rubber, (iii) compare the compressive strength obtained for each replacement level to identify the optimum proportion, and

(iv) cast the final paver block using the optimum combination identified from the experimental investigation.

II. Literature Review

Lailesh et al. [2] studied the production of paving blocks using fine and coarse waste glass. At a 20 % fine-glass (FG) replacement level, compressive strength, flexural strength, splitting tensile strength and abrasion resistance improved by 69 %, 90 %, 47 % and 15 %, respectively, relative to the control sample.

Koganti et al. [3] investigated cement-concrete paving blocks incorporating quarry dust, glass powder and ceramic dust. Quarry dust could be replaced up to 40 % with an economic benefit of about 10 %, while glass powder and ceramic dust were limited to 20 % replacement before strength declined; coal dust was found unsuitable as a fine-aggregate substitute.

Soni et al. [4] examined granulated copper slag as a sand replacement (0–50 %) and reported no significant leaching of copper or iron, with both compressive and split-tensile strength increasing with slag content.

Singh [5] reviewed the use of coconut shell as a partial replacement for coarse aggregate, noting its ready availability and favourable mechanical properties for concrete and road-construction applications.

Parmar et al. [6] used crumb rubber as a partial coarse-aggregate replacement and found that increasing rubber content reduced

compressive and flexural strength while improving workability, offering environmental and cost benefits for non-structural applications.

Naganur et al. [7] reported that copper slag as a fine-aggregate replacement improved workability, with 40–50 % substitution giving strength comparable to the control mix; strength declined beyond 50 %.

Ambrish et al. [8] investigated copper slag replacement of fine aggregate at 10, 15 and 20 % in M25 concrete and observed increased strength and durability with slag addition.

Ramesh et al. [9] replaced coarse aggregate with 5–10 % coconut shell in M20 concrete, producing lightweight, cost-effective concrete evaluated at 7 and 28 days.

Yasin et al. [10] partially replaced natural aggregate with shredded rubber and found that higher rubber content significantly reduced compressive, tensile and flexural strength, recommending its use only in non-structural elements such as pavements and partition walls.

Kanojia et al. [11] reported that at 40 % coconut-shell replacement of coarse aggregate, 7-day compressive strength fell by 62.6 % while the 28-day reduction was only 21.5 %, with concrete density reduced by 7.47 %.

Collectively, the reviewed literature indicates that copper slag, coconut shell and crumb rubber can each be incorporated into concrete at moderate replacement levels without unacceptable strength loss, and in several cases with a strength gain, motivating the combined investigation undertaken in this study.

III. Materials and Methodology

The properties of concrete, both fresh and hardened, depend largely on the properties of its constituent materials. Laboratory characterisation tests were therefore carried out on each material, followed by mix design and casting of paver-block specimens. The overall methodology is summarised in Fig. 1.

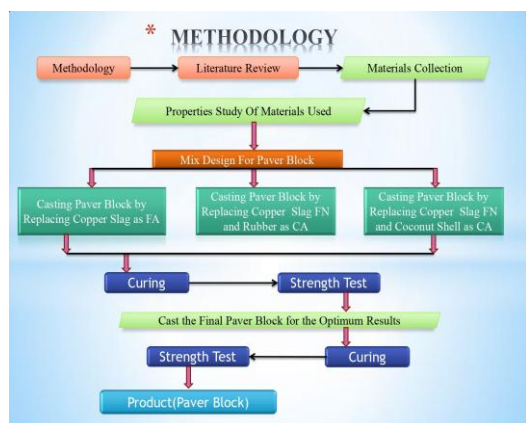


Figure 1. Methodology adopted for the experimental investigation.

3.1 Fine Aggregate

Manufactured sand (M-Sand), produced by crushing hard granite stone with a particle size below 4.75 mm, was used as fine aggregate. M-Sand offers a controlled gradation, is free of clay and silt impurities, and reduces dependence on river-sand extraction.

Its specific gravity, determined using a pycnometer as per IS 2386:1963, was 2.575, and the fineness modulus obtained from sieve analysis was 4.24.

3.2 Copper Slag

Copper slag, a by-product of the copper-smelting process, was obtained from Sterlite Copper (Vedanta Limited), Thoothukudi, Tamil Nadu — a facility with an annual production capacity of 400,000 metric tonnes of copper. Globally, only 15–20 % of the copper slag generated is currently reused, making it an attractive candidate for partial replacement of fine aggregate. The specific gravity of the copper slag, determined by the pycnometer method, was 2.6, with a fineness modulus of 3.8.

3.3 Coarse Aggregate

Crushed granite coarse aggregate of nominal size 20 mm was used. Aggregate typically occupies 60–80 % of the volume of concrete and governs its dimensional stability, stiffness and abrasion resistance. The specific gravity of the coarse aggregate was 2.74, the fineness modulus from sieve analysis was 7.88, and the water absorption was 0.5 %.

3.4 Coconut Shell

Coconut shell, an agricultural waste material, was used as a partial replacement for coarse aggregate. Its suitability arises from its high strength and modulus, high lignin content that improves weathering resistance, low cellulose content that limits moisture absorption relative to other agricultural residues, and its non-biodegradable nature. The specific gravity of the coconut shell used was 2.75 and its water absorption was 2.0 %.

3.5 Crumb Rubber

Crumb rubber, recovered from scrap automotive and truck tyres by removing steel and tyre cord and mechanically reducing the residual material to a granular form, was used as a further partial replacement for coarse aggregate. The specific gravity of the crumb rubber was 1.5 and its water absorption was 0 %.

3.6 Material Properties Summary

Table 1 summarises the physical properties determined for each material.

Table 1: Physical properties of constituent materials.

Material	Specific Gravity	Fineness Modulus	Water Absorption (%)
Fine aggregate (M-Sand)	2.575	4.24	—
Copper slag	2.60	3.80	—
Coarse aggregate	2.74	7.88	0.5
Coconut shell	2.75	—	2.0
Crumb rubber	1.50	—	0.0

3.7 Mix Design

Mix proportioning was carried out for M20-grade concrete in accordance with IS 10262:2009, using PPC 53-grade cement, a maximum water–cement ratio of 0.50 and a target slump of 50 mm.

The assumed standard deviation was 4 N/mm², giving a target mean strength of 26.6 N/mm². The resulting base mix required 378.18 kg/m³ of cement, 732.19 kg/m³ of fine aggregate, 1127.52 kg/m³ of coarse aggregate and 186 kg/m³ of water. Copper slag was substituted for fine aggregate at 0, 10, 20, 30, 40 and 50 % by mass; coconut shell was substituted for coarse aggregate at 10, 15 and 20 %; and crumb rubber was substituted for coarse aggregate at 10, 15 and 20 %, both independently and in combination with a fixed 20 % copper-slag replacement. Table II presents representative mix proportions.

Table 2: Mix proportions for M20-grade paver block with copper-slag (CS) replacement of fine aggregate.

Mix	Cement (kg/m ³)	Copper Slag (kg/m ³)	Fine Agg. (kg/m ³)	Coarse Agg. (kg/m ³)	Water (kg/m ³)
M0 (0 % CS)	378.18	0	732.19	1127.52	186
M1 (10 % CS)	378.18	73.21	658.19	1127.52	186
M2 (20 % CS)	378.18	146.40	585.75	1127.52	186
M3 (30 % CS)	378.18	219.65	512.53	1127.52	186
M4 (40 % CS)	378.18	292.88	439.31	1127.52	186
M5 (50 % CS)	378.18	366.10	366.10	1127.52	186

3.8 Specimen Preparation and Curing

Paver-block specimens of size 250 mm × 125 mm × 60 mm were cast in zig-zag steel/cast-iron moulds. Dry constituents were mixed for a minimum of 10 minutes until a uniform colour was achieved, after which water was added. The mix was placed in the mould in layers approximately 5 cm deep and each layer was compacted with no fewer than 25 tamping strokes. Specimens were finished smooth with a trowel, stored in moist air for 24 hours, demoulded, and then cured in clean fresh water until the age of testing (7, 14 or 28 days).

3.9 Compressive Strength Test

Compressive strength was determined in accordance with IS 516:1959. Cured specimens were removed from the curing tank, the bearing surfaces of the testing machine were wiped clean, and the specimen was centred between the plates.



Figure 2. Compressive strength testing of a paver-block specimen.

Load was applied without shock at a rate of 15 ± 3 N/mm²/min until failure, and the maximum load sustained was recorded. Compressive strength was calculated as the maximum load divided by the plan area of the specimen. The test set-up is shown in Fig. 2.

IV. Results and Discussion

The 28-day compressive strength of the various paver-block mixes is summarised in Tables III–V. Each reported value is the average of three specimens tested at the given replacement level.

4.1 Effect of Copper Slag Replacement

Table 3 presents the compressive strength of paver blocks with fine aggregate replaced by copper slag at 0–50 %. Strength increased from 25.26 N/mm² at 0 % replacement to a maximum of 31.2 N/mm² at 20 % replacement — an improvement of about 23 % over the control mix — before declining at higher replacement levels, falling to 24.2 N/mm² at 50 % replacement. This trend indicates that 20 % is the optimum copper-slag replacement level for fine aggregate, consistent with the improved packing and particle-size distribution reported for moderate slag contents in the literature.

Table 3: 28-day compressive strength — copper slag as partial replacement of fine aggregate.

Copper Slag (%)	Strength Trials (N/mm ²)	Average Strength (N/mm ²)
0	24.0, 26.8, 25.0	25.26
10	29.0, 30.1, 29.4	29.70
20	30.0, 32.4, 31.2	31.20
30	28.0, 28.5, 28.0	28.16
40	25.0, 23.8, 28.9	25.90
50	23.8, 24.9, 23.9	24.20

4.2 Effect of Copper Slag with Crumb Rubber

With fine aggregate fixed at 20 % copper-slag replacement, coarse aggregate was further replaced with crumb rubber at 10, 15 and 20 % (Table 4). Strength peaked at 28.2 N/mm² for 15 % crumb-rubber replacement before falling to 24.5 N/mm² at 20 %, reflecting the lower stiffness and weaker bonding of rubber particles within the cement matrix at higher dosages, consistent with prior studies on rubberised concrete.

Table 4: 28-day compressive strength — 20 % copper slag with crumb rubber replacement of coarse aggregate.

Crumb Rubber (%)	Strength Trials (N/mm ²)	Average Strength (N/mm ²)
10	24.8, 27.5, 25.6	25.90
15	27.6, 29.5, 27.5	28.20
20	23.6, 25.7, 24.3	24.50

4.3 Effect of Copper Slag with Coconut Shell

With fine aggregate again fixed at 20 % copper-slag replacement, coarse aggregate was replaced with coconut shell at 10, 20 and 30 % (Table V). This combination gave the highest strengths recorded in the study, peaking at 35.7 N/mm² for 20 % coconut-shell

replacement — an increase of over 40 % relative to the plain control mix — before declining to 32.5 N/mm² at 30 % replacement. The superior performance of the copper-slag/coconut-shell combination is attributed to the favourable interlocking of the coconut-shell particles with the cement matrix and the pozzolanic contribution of the fine copper-slag fraction.

Table 5: 28-day compressive strength — 20 % copper slag with coconut shell replacement of coarse aggregate

Coconut Shell (%)	Strength Trials (N/mm ²)	Average Strength (N/mm ²)
10	33.5, 35.7, 34.3	34.50
20	35.4, 35.8, 35.7	35.70
30	31.5, 33.6, 32.4	32.50

4.4 Discussion

Across all three series, the compressive strength followed a rise-then-fall trend typical of aggregate-replacement studies: an initial improvement in packing density and interfacial bonding at moderate replacement levels, followed by a decline as the replacement material's lower stiffness (crumb rubber) or altered particle geometry (coconut shell, high slag content) begins to dominate. The combination of 20 % copper slag with 20 % coconut shell gave the best overall performance among the mixes tested, exceeding the target mean strength of 26.6 N/mm² by a wide margin and confirming the suitability of copper slag and coconut shell as sustainable substitutes for conventional paver-block aggregate.

V. Conclusion

- Copper slag can effectively replace fine aggregate in paver-block concrete up to an optimum level of 20 %, beyond which compressive strength declines.
- Coconut shell, used as a partial coarse-aggregate replacement alongside 20 % copper slag, produced the highest 28-day compressive strength (35.7 N/mm²) among all mixes investigated, at a 20 % replacement level.
- Crumb rubber can partially replace coarse aggregate up to 15 % without significant strength loss, offering improved workability and a sustainable outlet for scrap-tyre waste, though further increases reduce strength.
- The combined use of copper slag, coconut shell and crumb rubber in paver-block manufacture reduces dependence on natural fine and coarse aggregate, supporting resource conservation and the beneficial reuse of industrial and agricultural waste streams.
- Based on the compressive-strength results, a mix comprising 20 % copper slag as fine-aggregate replacement together with 20 % coconut shell as coarse-aggregate replacement is recommended as the optimum combination for casting the final paver-block product.

VI. References

- [1] S. K. Paver Block Studies Group (compiled from project literature review), "General overview of flexible

pavement applications of paver blocks," Project Report, Stella Mary's College of Engineering, 2023.

- [2] Lailesh et al., "Producing paving blocks using fine and coarse waste glass," 2021.
- [3] S. P. Koganti et al., "Manufacturing of cement concrete paving blocks and precast hard products using industrial by-products," 2017.
- [4] M. M. Soni et al., "Potential use of granulated copper slag as a replacement for sand in concrete mixes," 2018.
- [5] I. Singh et al., "Utilization of coconut shell as a partial replacement of coarse aggregate," 2020.
- [6] A. Parmar et al., "Use of crumb rubber as a partial replacement of coarse aggregate," 2015.
- [7] J. Naganur et al., "Effect of copper slag as a partial replacement of fine aggregate," 2014.
- [8] Ambrish et al., "Partial replacement of copper slag as fine aggregate," 2015.
- [9] A. Ramesh et al., "Usage of coconut shell as the partial replacement for coarse aggregate," 2018.
- [10] A. Yasin et al., "Partial replacement of natural aggregates with shredded rubber aggregates," 2012.
- [11] Kanojia et al., "Performance of coconut shell as coarse aggregate in concrete," 2017.
- [12] S. Gupta et al., "Partial replacement of fly ash, marble dust and crushed concrete aggregate in concrete mixture," ISSN 1006-6748, vol. 27, no. 7, pp. 328–336, 2021.
- [13] R. Joshi et al., "Effect on compressive strength of concrete by partial replacement of cement with fly ash," Int. J. Eng. Res. Appl., vol. 4, no. 2, 2017.
- [14] Z. S. Adnan et al., "Performance of rice husk ash as a material for partial cement replacement in concrete," iCITES 2020, vol. 48, pt. 4, pp. 842–848, 2022.
- [15] U. Sharma et al., "Comparative study on the effect of industrial by-products as a replacement of cement in concrete," Int. Conf. Mater. Process. Charact., vol. 44, pt. 1, pp. 45–51, 2021.
- [16] Z. Hamid and S. Rafiq, "An experimental study on behavior of wood ash in concrete as partial replacement of cement," ICMSD 2020, vol. 46, pt. 9, pp. 3426–3429, 2022.
- [17] R. A. Naibaho et al., "Utilization of bagasse ash to reduce the use of cement in brick making," JRPP, vol. 3, no. 4, pp. 537–541, 2015.
- [18] R. Srinivasan and K. Sathiyar, "Experimental study on bagasse ash in concrete," Int. J. Serv. Learn. Eng., vol. 5, no. 2, pp. 60–66, 2010.
- [19] V. Priyadarshini et al., "Enhancement of mechanical properties of bagasse ash based hollow concrete blocks using silica fumes as admixtures," Civil Environ. Res., vol. 7, no. 5, pp. 78–83, 2015.

- [20] A. M. Neville, Properties of Concrete, 5th ed. Pearson Education, 2011.
- [21] B. S. Mohammed, K. M. A. Hossain, J. T. E. Swee, G. Wong, and M. Abdullahi, "Properties of crumb rubber hollow concrete block," 2012.