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Experimental Investigation on Strength Variation of Steel-Fibre-Reinforced Concrete Paver Blocks Using an Economical Stainless-Steel-Coated Mould

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Abstract—Concrete paver blocks are among the most widely adopted flexible pavement surfaces, yet their production cost is governed largely by the service life of the mould used for casting. Plastic and rubber moulds, although economical, fail after a limited number of repetitions because of wear, dimensional distortion and edge chipping, whereas solid steel moulds are durable but prohibitively expensive for small and medium manufacturers. This study investigates a combined strategy in which a conventional paver mould is made economical by internally coating it with a 1.6 mm stainless-steel (SS) plate conforming to IS 15658:2006, and the block itself is reinforced with crimped steel fibres at 0.5% by volume in an M30 concrete mix. A total of thirty-two blocks were cast and tested for water absorption, compressive strength, abrasion resistance and tensile strength, and the results were benchmarked against conventional blocks produced from uncoated moulds. The SS coating increased mould repetitions substantially without any measurable loss of dimensional accuracy, while the steel-fibre blocks showed a 0.83% reduction in water absorption, a 4.06 N/mm^2 gain in compressive strength, a 0.56 MPa gain in tensile strength and improved post-cracking behaviour. A cost analysis confirms that the combined modification is achieved at almost no additional recurring cost, making the approach attractive for sustainable, low-cost pavement production.

Index Terms—Abrasion Resistance, Concrete Paver Block, Compressive Strength, IS 15658:2006, Mould Coating, Steel Fibre, Sustainable Pavement, Tensile Strength

I. INTRODUCTION

Interlocking concrete paver blocks have emerged as one of the most popular flexible surface treatments for exterior pavements, combining visual appeal, ease of maintenance and the capacity to carry heavy vehicular loads. When adequately interlocked, a well-designed paver pavement can perform satisfactorily for around twenty years and is available in a wide range of shapes, colours and patterns, which makes it suitable for walkways, driveways, parking lots, industrial floors and landscaping applications. The quality and economy of paver block production, however, depend critically on the mould used for casting, since the mould controls the dimensional accuracy, surface finish and number of blocks that can be produced before it is discarded.

Moulds in the Indian market are predominantly manufactured from plastic, rubber or steel. Plastic moulds are the cheapest, typically priced around Rs. 125 per piece, but they cannot be reused many times because of rapid wear, surface abrasion and distortion of the corners; this frequent replacement raises the effective cost per block. Rubber moulds offer an intermediate service life at about Rs. 500 per piece, while solid steel moulds, although capable of a very large number of repetitions, cost around Rs. 8,500 per piece and are therefore uneconomical for small-scale and medium-scale producers. A practical need therefore exists for a mould that combines the affordability of plastic with a service life closer to that of steel.
The common shapes and types of paver block moulds are illustrated in Fig. 1.

Fig. 1. Common shapes and types of paver block moulds.

A. Problem Statement

The unit cost of a concrete paver block remains high because of the low repetition count of the mould, and blocks cast from worn moulds tend to break under overload, occasionally leading to premature pavement failure and associated safety hazards, as shown in Fig. 2. There is thus a twin problem: the mould must be made more durable and economical, and the block itself must be made stronger so that it resists the loads it carries during service.

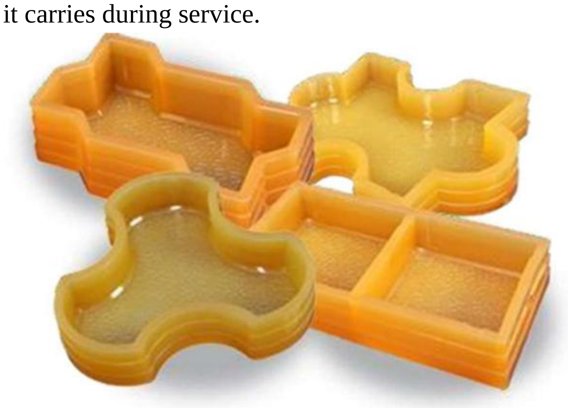

Fig. 2. A damaged paver block showing edge failure and cracking.

B. Aim and Objectives

The present work aims to study the variation in strength of paver blocks produced from an economical, stainless-steel-coated mould and to quantify the effect of reinforcing the block with crimped steel fibres.

The specific objectives are:

- To study the variety of moulds available in the industry for the manufacture of paver blocks;
- To develop and coat a mould with a 1.6 mm stainless-steel plate so that its internal dimensions conform to is 15658:2006;
- To cast and test paver blocks with and without steel fibres for various proportions and combinations; and
- To carry out a cost analysis comparing the proposed mould and fibre-reinforced block with conventional practice.

II. LITERATURE REVIEW

A considerable body of work has examined the use of discrete fibres and of improved mould materials to enhance paver block performance. This section summarises the most relevant studies and identifies the gap that the present work attempts to address.

Arube et al. [1] analysed the effect of steel fibres on concrete paving blocks and reported that, although the fibre addition improved certain mechanical properties, the basic mechanical behaviour of the samples was not adversely affected, and the best mix gave acceptable skid resistance. Kandekar et al. [2] observed that the compressive strength of fibre-reinforced paving blocks rose from 68.70 MPa to 86.80 MPa as the steel fibre content increased from 0.50% to 2.50%, while the abrasion loss decreased from 861.11 mm^3 to 708.33 mm^3, with optimum performance around 0.50-1.50% fibre by mass.

Shaikh [3] compared polypropylene, steel and hybrid fibres and found that a hybrid combination of 0.4% polypropylene and 0.6% steel fibre yielded a compressive strength of about 47.2 MPa, although such hybrid blocks were roughly 18% more expensive than ordinary blocks. Patil and Shelke [4] reported that additions of 0.3% and 0.4% polypropylene fibre improved abrasion resistance and flexural strength at 28 days, and that waste steel aggregates could raise the impact strength of paver blocks by up to 50%. Shah et al. [5] noted a modest 2.7-5% increase in compressive strength and a 42% increase in flexural strength at 0.5% recycled tyre steel fibre content.

Ananthi [6] studied polypropylene fibres in concrete paver blocks and reported maximum compressive strength at 0.15% fibre, with water absorption increasing up to 0.25% fibre. Balendran et al. [7]

examined steel fibres in normal and lightweight high-strength concrete with compressive strengths of 90-115 MPa at 1% fibre by volume, noting that a low fibre volume significantly increases splitting tensile strength and modulus of rupture with little effect on compressive strength. Zhang et al. [8] reviewed concrete reinforced with recycled steel fibres from waste tyres and concluded that such fibres can reinforce concrete and, in some applications, replace industrial steel fibres.

Jaral and Firdous [9] reviewed steel-fibre-reinforced concrete pavements and reported slight increases in compressive and split tensile strength and a clearer increase in flexural strength. Xu and Shi [10] established correlations among the mechanical properties of steel-fibre-reinforced concrete for water/binder ratios of 0.25-0.5, aspect ratios of 55-80 and volume fractions of 0.5-2.0%. Lu and Hsu [11] found that steel-fibre reinforcement only marginally increased the uniaxial compressive strength of high-strength concrete but notably improved its post-peak deformation capacity. Pitroda [12] demonstrated that innovative additions of polypropylene fibre in interlocking paver blocks can marginally improve compressive strength.

Research Gap

The reviewed literature concentrates almost exclusively on the fibre or the concrete mix, and treats the mould as a fixed, unchangeable input. None of the studies addresses the combined effect of (i) an economical, stainless-steel-coated mould that extends service life while retaining IS 15658:2006 dimensional tolerances, and (ii) steel-fibre reinforcement of the cast block, evaluated jointly through the same set of physical tests and a cost analysis. The present work fills this gap by treating the mould and the block together as an integrated, low-cost production system.

III. METHODOLOGY

The experimental programme was carried out in two coordinated phases. In the first phase, a conventional paver mould was internally coated with a 1.6 mm stainless-steel (SS) plate to extend its service life without altering the block geometry. In the second phase, paver blocks were cast in the coated mould from an M30 concrete mix with and without crimped steel fibres, and the two sets were compared through standard tests.

A. Materials and Steel Fibres

Ordinary Portland Cement of grade OPC-53 (UltraTech) was used as the binder. The coarse aggregate was a 6 mm downgraded fraction and the fine aggregate was crushed sand; their relevant properties are listed in Table I. Crimped steel fibres, purchased at approximately Rs. 210 per kilogram, were used as the discrete reinforcement. The crimped steel fibres used in this study are shown in Fig. 3. Steel fibres are short, discrete lengths of steel with a length-to-diameter ratio in the range of 20 to 100; their hooked or crimped profile mechanically anchors them within the cement matrix, which improves tensile strength, crack resistance, toughness and impact and fatigue resistance. The crimped geometry was selected because its undulations provide better interlocking with the surrounding mortar than straight fibres, and the resulting bridging action across cracks delays their propagation under load.

Fig. 3. Crimped steel fibres used as reinforcement in the paver blocks.

Table I. Properties of Aggregates Used in the Mix

Property	6 mm Aggregate	Natural Sand	Crushed Sand
Specific gravity	2.845	-	2.710
Water absorption (%)	1.70	-	2.76

B. Mould Coating

A standard paver mould was selected as the base and its internal faces were lined with a 1.6 mm stainless-steel plate. The SS lining was chosen because it is hard, smooth and corrosion resistant, so that the mould can withstand repeated stripping and cleaning without the edge chipping and dimensional drift suffered by plastic moulds. The conventional mould before coating and the stainless-steel-coated mould are shown in Fig. 4. After coating, the mould dimensions were re-measured and confirmed to lie within the tolerances prescribed by IS 15658:2006, which specifies a minimum block thickness of 50 mm and a maximum of 120 mm with standard thicknesses of 60, 80, 100 and 120 mm. The dimensional comparison before and after coating is given in Table II. The coated moulds were supplied to the production unit in September 2022, and the number of repetitions achieved was monitored as a measure of the mould economy.

Fig. 4. Conventional mould (left) and stainless-steel-coated mould (right).

Table II. Comparison of Mould Dimensions Before and After Coating

Dimension	Before coating	After coating	IS 15658 tolerances
Width (mm)	125	122	Within limit
Length (mm)	250	247	Within limit
Thickness (mm)	60	57	Within limit

C. Mix Design

The concrete mix was designed for an M30 grade using OPC-53 cement. The mix proportions, expressed both per cubic metre and per 50 kg bag of cement, are summarised in Table III. The mix gave a concrete density of 2410 kg/m^3, and the proportions by weight were approximately 1.03: 1.20: 3.49 (cement: 6 mm aggregate: crushed sand) with a free water content of 0.47 by weight of cement.

Table III. Mix Design Details for the M30 Paver Block

Ingredient	Per m^3 (kg)	Per 50 kg bag (kg)	Ratio by weight
Cement (OPC-53)	400	50.00	1.03
Coarse aggregate, 6 mm	467	58.38	1.20
Fine aggregate, crushed sand	1360	170.00	3.49
Free water (litres)	182.75	22.84	0.47

Note: Concrete density = 2410 kg/m^3.

Based on the volume calculations and the guidance of the relevant IS codes and the literature reviewed, the fibre dosage was fixed at 0.5% by volume of concrete, which corresponded to a total of about 470 g of crimped steel fibres per batch of fifteen blocks. This dosage was selected because it lies in the lower part of the optimum range (0.5-1.5%) reported by Kandekar et al. [2] and is sufficient to produce crack-bridging without the workability and balling problems associated with higher fibre contents.

D. Casting Procedure

Sixteen conventional blocks and sixteen steel-fibre blocks, a total of thirty-two blocks, were cast for the comparison.

The procedure adopted for casting was as follows:

- The required quantity of crimped steel fibres was weighed and kept ready for the fibre batches;
- The dry ingredients were dry-mixed, and the steel fibres were scattered gradually to ensure uniform dispersion and to avoid fibre balling;
- The coated moulds were filled with the fresh mix, compacted on the vibrating table and levelled to the top of the mould;
- The blocks were demoulded after a 24-hour recovery period, and the moulds were inspected for wear; and

- The blocks were cured under standard conditions and then tested in accordance with the relevant IS codes.

Table 2 Recommended Dimensions and Tolerance for Paver Blocks

(*Clauses* 6.2.2.1, 6.2.2.2, 6.2.3 *and* 9.1.2)

Sl No.	Dimension	Measurement Method, Ref to	Recommended Values	Tolerance Limit for Paver Block: Thickness < 100 mm	Tolerance Limit for Paver Block: Thickness ≥ 100 mm
(1)	(2)	(3)	(4)	(5)	(6)
i)	Width, W	Annex B	To be specified by manufacturer	± 2 mm	± 3 mm
ii)	Length, L	Annex B	To be specified by manufacturer	± 2 mm	± 3 mm
iii)	Thickness, T	Annex B	50 to 120 mm	± 3 mm	± 4 mm
iv)	Aspect ratio (L/T)	Annex B	Maximum : 4.0	+ 0.2	+ 0.2
v)	Arris/chamfer	Annex B	Minimum: 5 mm Maximum : 7 mm	± 1 mm	± 1 mm
vi)	Thickness of wearing layer	6.2.3	Minimum : 6 mm	+ 2 mm	+ 2 mm
vii)	Plan area, A_{SP}	Annex B	Maximum : 0.03 m²	+ 0.001m²	+ 0.001m²
viii)	Wearing face area, A_{SW}	Annex B	Minimum 75 percent of Plan Area	− 1 percent	− 1 percent
ix)	Squareness	Annex B	Nil	± 2 mm	± 3 mm

Fig. 5. Casting of paver blocks in the stainless-steel-coated mould.

E. Testing Standards

The cast blocks were tested for water absorption, compressive strength, abrasion resistance and tensile strength following the procedures laid down in IS 15658:2006 and the associated test codes. Compressive strength was determined at 3, 7, 14 and 28 days on companion cube specimens to track the strength-gain curve of the mix, and the hardened block tests were carried out at 28 days.

IV. RESULTS AND DISCUSSION

The results are presented in three parts: the strength-gain behaviour of the trial mix, the comparative performance of the conventional and steel-fibre blocks, and the economic outcome of the mould modification. Throughout the testing, the coated moulds showed no visible wear or dimensional change, confirming that the SS lining achieved the intended extension of service life.

A. Strength Gain of the Trial Mix

The compressive strength of the trial mix cubes, measured at four ages, is given in Table IV. The strength increased progressively from 22.62 N/mm^2 at 3 days to 40.12 N/mm^2 at 28 days, reflecting the normal hydration of the OPC-53 binder and confirming that the mix satisfied the M30 target at 28 days.

Table IV. Compressive Strength of Trial Mix Cubes

Age	Compressive strength (N/mm^2)
3 days	22.62
7 days	30.33
14 days	35.66
28 days	40.12

B. Comparison of Conventional and Steel-Fibre Blocks

The 28-day test results for the conventional blocks and the blocks containing 0.5% crimped steel fibre are compared in Table V. The addition of steel fibre reduced the water absorption from 5.43% to 4.60% (a drop of 0.83 percentage points), increased the compressive strength from 44.77 to 48.83 N/mm^2 (a gain of 4.06 N/mm^2) and increased the tensile strength from 4.35 to 4.91 MPa (a gain of 0.56 MPa). The abrasion value, expressed as the volume of material lost, increased from 17160 mm^3 to 19997 mm^3; a higher volume loss indicates lower abrasion resistance, so this parameter warrants attention and is discussed below.

Table V. Comparison of Conventional and Steel-Fibre Paver Blocks

Test	Conventional block	Steel-fibre block	Change
Water absorption (%)	5.43	4.60	-0.83
Compressive strength (N/mm^2)	44.77	48.83	+4.06
Abrasion loss (mm^3)	17160	19997	+2837
Tensile strength (MPa)	4.35	4.91	+0.56

C. Discussion

The reduction in water absorption is consistent with the crack-bridging action of the fibres, which reduces the interconnected capillary network in the surface zone and therefore the permeability of the block; a lower water absorption is generally associated with better frost and durability resistance in service. The gain in compressive strength, although modest in percentage terms, is significant for a paver block because it directly raises the load class to which the block can be assigned under IS 15658:2006, and the accompanying gain in tensile strength indicates improved resistance to the flexural and impact stresses that cause edge spalling and mid-span cracking in service.

The increase in abrasion loss observed for the fibre blocks is attributed to the presence of fibres close to the wearing surface: where a fibre lies just below the surface, the surrounding mortar can be loosened more easily under abrasive action, producing a slightly higher volume loss in the standard test. This effect is, however, accompanied by a much-improved post-cracking behaviour, since the fibres hold the matrix together after the first crack and prevent the catastrophic fracture that is typical of plain concrete pavers. Optimising the fibre content and the finishing technique is therefore expected to recover the abrasion performance while retaining the strength and toughness gains.

Fig. 6. Paver block specimens after compressive strength test.

D. Cost Analysis

A cost analysis was carried out to evaluate the economic benefit of the combined modification. The manufacturing cost of a batch of sixteen blocks was about Rs. 3,000, giving a unit block cost of roughly Rs. 188. A conventional rubber mould costs about Rs. 250, whereas the stainless-steel-coated mould developed in this work costs about Rs. 300, and the steel fibre added per block costs only about Rs. 40 per kilogram and is negligible on a per-block basis. Because the coated mould achieves a far larger number of repetitions than the plastic or rubber mould, the additional one-time cost is recovered quickly, and the strength and durability gains are obtained at almost no additional recurring expenditure.

Table VI. Cost Comparison of Mould Options

Item	Approx. cost (Rs.)	Repetition range
Plastic mould (per piece)	125	365-547
Rubber mould (per piece)	500	1095-1460
Solid steel mould (per piece)	8,500	Very high
Proposed SS-coated mould	300	Significantly increased
Steel fibre (per kg)	40-210	-

V. CONCLUSION

An experimental study was carried out to improve both the economy of paver block moulds and the strength of the blocks themselves. Based on the test results and the cost analysis, the following conclusions are drawn:

- The conventional moulds used in the industry are inexpensive but fail early because of wear, which raises the effective cost per block;
- Internally coating the mould with a 1.6 mm stainless-steel plate produced a mould whose post-coating dimensions remained within the tolerances of is 15658:2006 while substantially increasing the number of usable repetitions;
- The addition of 0.5% crimped steel fibre by volume to an m30 paver block reduced the water absorption by 0.83 percentage points, indicating improved moisture and durability resistance;
- The compressive strength of the blocks increased by 4.06 n/mm^2 and the tensile strength by 0.56 mpa, confirming a higher load-bearing capacity and better resistance to cracking and impact;
- The abrasion loss increased by 2837 mm^3, an effect attributed to fibres close to the wearing surface and addressable through finishing and dosage optimization.

- The cost analysis shows that the combined mould and fibre modification is achieved at almost no additional recurring cost, making the proposed system attractive for sustainable, low-cost paver production.

Overall, the results demonstrate that an economical, stainless-steel-coated mould combined with steel-fibre reinforcement can deliver paver blocks of higher strength and durability than conventional blocks, while keeping the production cost low.

VI. FUTURE SCOPE

- Optimise the steel fibre dosage between 0.5% and 1.5% to maximise strength while minimising the abrasion loss;
- Investigate the use of recycled tyre steel fibres as a sustainable, low-cost alternative to industrial crimped fibres;
- Conduct long-term durability tests, including freeze-thaw and sulphate resistance, on blocks cast in the coated mould;
- Study the effect of fibre orientation and surface finishing on the abrasion resistance of the wearing face;
- Carry out large-scale field trials to validate the repetition count of the coated mould under continuous industrial production;
- Extend the cost analysis to a full life-cycle assessment that includes the environmental benefit of reduced mould replacement.

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