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Performance Evaluation of Eco-friendly Paver Blocks with Replacement of River Sand by Waste Foundry Sand, Fly Ash and Waste Tyre Rubber Crumbs

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CHAPTER 1 INTRODUCTION

1.1 General

Waste Foundry Sand (WFS) is a byproduct generated by the metal casting industry, where high-quality silica sand is used to create molds for shaping molten metals into various parts and products. As foundries repeatedly use this sand during the casting process, it gradually becomes unsuitable for further use due to contamination from binders, metals, and other additives. This spent sand is classified as waste and is often disposed of in landfills, posing significant environmental and economic challenges.

The disposal of WFS contributes to the depletion of landfill space, while the potential leaching of harmful substances, such as heavy metals and chemical additives, into the soil and groundwater raises concerns about its environmental impact. At the same time, the foundry industry faces mounting pressure to minimize waste and reduce raw material consumption, leading to increased interest in sustainable management strategies for WFS.

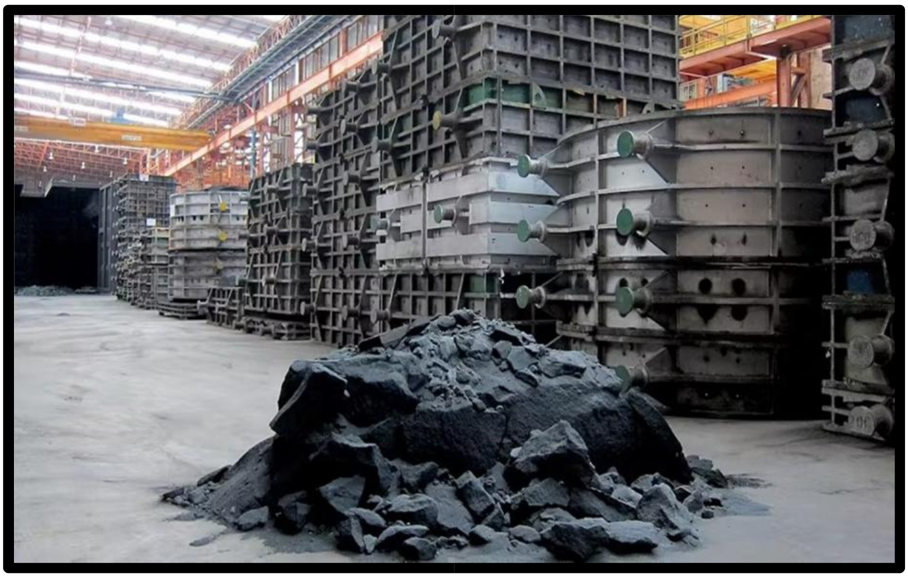


Fig. 1: Waste Foudry Sand

The use of Waste Foundry Sand (WFS) in construction has garnered increasing attention due to its potential to address both environmental concerns and resource shortages.Traditionally, WFS has been disposed of in landfills, leading to significant environmental and economic costs. However, its physical and chemical properties make it a promising candidate for reuse in various construction applications, offering a sustainable solution for managing this industrial waste.

1.2 Composition and Properties of WFS

Understanding the global scale of Waste Foundry Sand (WFS) generation helps contextualize its potential reuse in construction applications.The production of WFS in the world is given in the table below. This highlights the significant quantities generated globally, emphasizing the importance of understanding its composition and properties for sustainable utilization.

Table No 1 WFS production in different countries

SrNo	Country	WFS production (Mt)
1	China	48.75
2	India	11.49
3	United States of America	11.30
4	Brazil	3.00
5	South Africa	1.00
6	Spain	1.00
7	Poland	0.70

WFS is composed predominantly of fine silica sand, which is a crucial ingredient in many construction materials. Its fine grain size and mechanical stability make it suitable for blending into a variety of construction materials.

However, the presence of binders and residual chemicals, including clay, carbonaceous materials, and trace metals, may impact its performance and environmental safety. Depending on the type of foundry process used—green sand or chemically bonded sand— the characteristics of WFS can vary. Green sand, which uses bentonite clay and water as binders, is relatively environmentally benign compared to chemically bonded sand, which may contain organic resins, leading to different considerations for reuse.

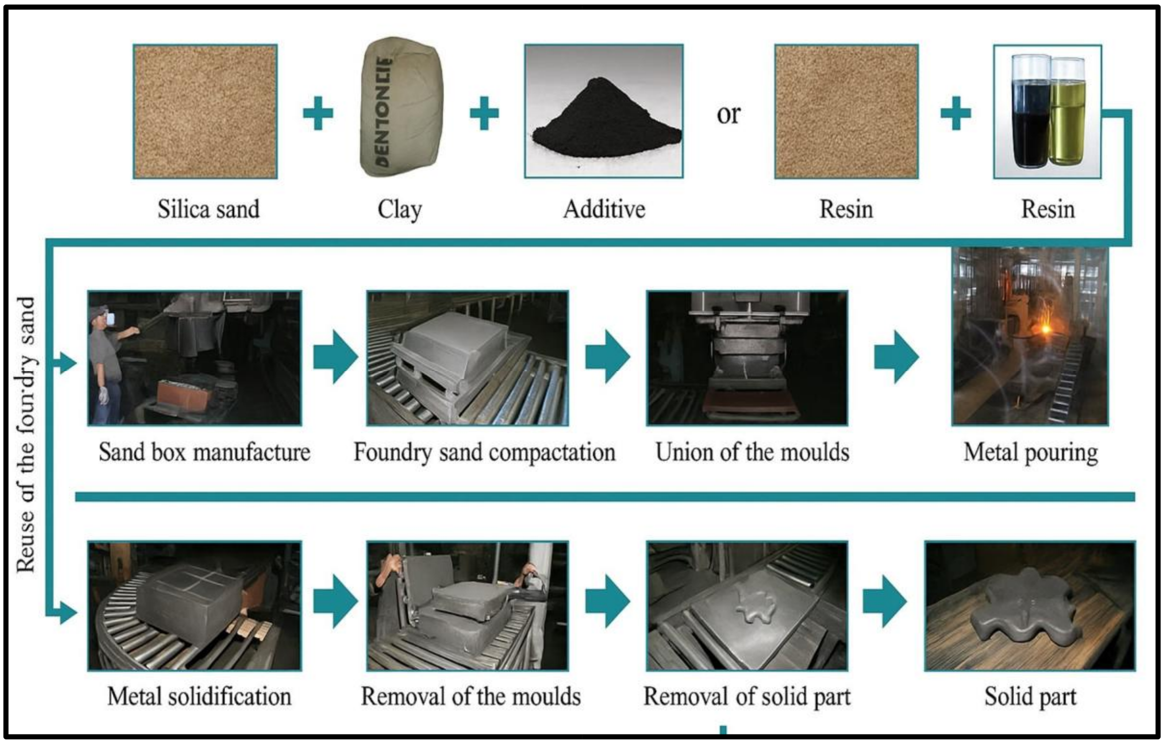
1.2.1 Chemical Oxide Composition of Waste Foundry Sand

Table No 2 Chemical Oxide Composition of WFS

Sr No	Constituent	Value (%)
1	SiO_2	87.91
2	Al_2O_3	4.70
3	Fe_2O_3	0.94
4	CaO	0.14

5	MgO	0.30
6	SO_3	0.09
7	Na_2O	0.19
8	K_2O	0.25
9	TiO_2	0.15

Fig. 2. Metal casting process



1.2.2 Physical Properties of Waste Foundry Sand

Table No 3 Physical Properties of WFS

Sr No	**Characteristic**	**Value**
1	Specific Gravity	2.49
2	Bulk Relative Density	2592 kg/m^3
3	Absorption	0.43%

4	Moisture Content	0.1 – 9.8
5	Clay Lumps and Friable Particles	1 – 42
6	Coefficient of Permeability	$10^{-3} – 10^{-6}$ cm/s
7	Plastic Limit	Non Plastic

1.3 Applications of WFS in Construction Materials

1.3.1 Concrete

One of the most studied applications of WFS is its use as a partial replacement for fine aggregates in concrete production. Fine aggregates, typically natural sand, play a key role in the composition of concrete, contributing to its strength and durability. Research has shown that WFS can replace up to 30% of natural sand in concrete mixes without significantly compromising the material's compressive strength or durability. In fact, in some cases, concrete containing WFS has exhibited enhanced properties, such as improved resistance to sulfate attack and freeze-thaw cycles. This makes WFS a viable option for use in both structural and non-structural concrete applications, such as pavements, blocks, and precast concrete elements.

The use of WFS in concrete not only helps in reducing the demand for natural sand, which is becoming an increasingly scarce resource due to over-exploitation but also offers economic benefits by lowering material costs for concrete manufacturers. Additionally, incorporating WFS into concrete can help divert significant quantities of waste from landfills, reducing the environmental footprint of the construction and foundry industries.

1.3.2 Asphalt Mixtures

Waste Foundry Sand has also been explored as an alternative material in asphalt mixtures, where fine aggregates are needed to fill voids between larger aggregates and to improve the strength and stability of the asphalt pavement. Studies have demonstrated that WFS can be successfully incorporated into hot-mix asphalt.

1.3.3 Geotechnical Applications

WFS has been widely studied for its potential in geotechnical applications, particularly in the construction of embankments, road subgrades, and backfilling operations. Due to its granular nature and relatively stable mechanical properties, WFS can be used as a substitute for natural soils in these applications. Studies have shown that WFS exhibits good compaction characteristics and shear strength, making it suitable for use in various geotechnical projects.

1.3.4 Road Construction

In road construction, WFS can be used as a base or sub-base material, replacing natural soils or aggregates typically used in the lower layers of pavement structures. Its fine grain size and compaction properties help in achieving a stable foundation for the road, while its resistance to deformation under load contributes to the overall durability of the pavement. Additionally, the use of WFS in road construction reduces the demand for natural aggregates, which are often sourced from quarries, contributing to the preservation of natural landscapes.

1.3.5 Landfill Cover and Liner Systems

WFS has also been considered for use in landfill cover systems, where it can act as a barrier layer to minimize the infiltration of water into the landfill, thereby reducing leachate generation. Its low permeability and high compaction density make it an effective material for this purpose.

In some cases, WFS has also been tested as a component in landfill liner systems, where it can help prevent the migration of contaminants into the surrounding environment.

1.4 Significance of Study

The use of Waste Foundry Sand (WFS) in paver block production is significant for promoting sustainability and resource efficiency. By diverting WFS from landfills, it helps reduce environmental impacts and supports a circular economy. Replacing natural aggregates with WFS not only conserves resources but also lowers material costs for manufacturers, enhancing profitability. Research indicates that paver blocks containing WFS exhibit improved mechanical properties and durability, making them suitable for various applications. Additionally, this practice aligns with regulatory initiatives promoting sustainable construction, fostering community engagement in responsible waste management and environmental stewardship. Overall, WFS offers a viable solution for a more sustainable construction industry.

1.5 Aims and Objective:

- To evaluate the physical and mechanical properties of the modified paver blocks, including compressive strength, water absorption

- To improve the split tensile strength and durability of paver blocks by optimizing the mix design with industrial waste materials.

- To reduce production costs and minimize environmental impact by utilizing waste foundry sand, rubber crumbs, and fly ash as sustainable alternatives to natural resources.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

A comprehensive literature review was conducted by analyzing research papers, books, and credible online sources to gain a deeper understanding of the use of waste foundry sand (WFS), rubber crumbs, and fly ash in paver block production. This review examines previous studies on the mechanical properties, durability, and environmental benefits of incorporating industrial waste materials into concrete.

The primary objective of this literature review is to establish a scientific framework for the experimental work, identify key findings from past research, and highlight gaps that this study aims to address. By reviewing existing studies, we aim to validate the feasibility of replacing natural sand with WFS and assess the impact of additional waste materials on strength, cost efficiency, and sustainability.

2.2 Literature Survey

R. M. Sawant (June 2024) investigated the effect of WFS replacement in concrete and found that properties such as compressive strength, water absorption, and porosity varied with different replacement levels. Their findings suggest that up to 25% replacement of fine aggregate with WFS is feasible without significantly affecting strength. However, when the replacement level increased to 35% or more, a decline in compressive strength and workability was observed. The study highlights the need for further research to determine the optimal mix proportions that balance strength and workability.

Gilberto García (May 2024) concluded that incorporating WFS can significantly reduce the environmental impact of natural sand extraction. Their study found that replacing up to 20-30% of fine aggregate with WFS can yield desirable mechanical properties without compromising workability and durability. However, beyond this threshold, there is a noticeable decrease in compressive strength and overall performance. Additionally, full replacement of natural sand with WFS is not recommended for structural concrete due to the significant loss in strength and durability.

Jurgita Malaǐskienė (October 2024) investigated the potential applications of rubber buffing dust and recovered crumb rubber in cement concrete. The study found that incorporating 5-10% rubber waste improved sound absorption and resistance to freeze-thaw cycles but reduced compressive strength and increased water absorption. The authors suggested optimizing the mix design to enhance mechanical properties while maintaining environmental benefits.

Sunday U. Azunna (March 2024) conducted a review on the characteristic properties of crumb rubber concrete. Their research highlighted the potential of rubberized concrete for improving impact resistance, ductility, and sound insulation. However, challenges such as weak bonding with cement and reduced strength were identified. The study emphasized the need for rubber treatment techniques to enhance bonding and overall performance.

Sunit Kumar (May 2023) reviewed the perspectives of using WFS as a partial or full replacement of fine aggregate in concrete. Their study found that a partial replacement level of 20-30% enhances concrete properties, providing a sustainable alternative to natural sand. However, full replacement led to reduced compressive strength and workability, making it unsuitable for structural concrete applications. The authors recommended future research focusing on optimizing WFS usage by incorporating additives or blending it with other recycled materials to improve its performance in concrete mixes.

Kunal Verma & Prof. Mahroof Ahmed (August 2023) conducted a durability study of concrete incorporating WFS and concluded that foundry waste sand can be effectively utilized as a fine aggregate replacement in concrete. The study emphasized that this substitution not only helps conserve natural resources but also addresses waste disposal issues, making it an eco-friendly solution for the construction industry. Additionally, the research suggested further studies on casting paver blocks with 20% and 40% WFS replacement and testing them at different curing ages to better understand the long-term effects of WFS in concrete.

Habib Musa Mohamad (September 2023) conducted a study on developing ecofriendly paver blocks using crumb rubber granules and Eco-Processed Pozzolan (EPP). The study found that incorporating EPP and crumb rubber improved the compressive strength of the blocks by up to 33%, with the highest strength observed when the EPP and rubber content were kept minimal. The results indicate that these materials enhance sustainability while reducing environmental impact, making them a viable alternative for low-cost paving solutions.

Pallavi Rajput (July-August 2022) investigated the use of crumb rubber in interlocking concrete paver blocks. Their research concluded that incorporating rubber waste in paver blocks can improve durability and sustainability while addressing environmental concerns. However, the compressive strength decreased as the rubber content increased, requiring further optimization to balance strength and flexibility for practical applications.

Rohit Soni & Deepak Mathur (June 2020) conducted an experimental study on using commercialized crumb rubber in interlocking concrete paver blocks. Their findings revealed that rubberized concrete pavers exhibited improved flexibility and resistance to cracking. However, as the crumb rubber content increased beyond 20%, there was a significant reduction in compressive strength. The study suggested that a balanced mix design is necessary for optimal performance.

T. Sravani (August 2019) conducted an experimental study on the partial replacement of fine aggregate with WFS in concrete and found that the maximum strength was achieved at a 40% replacement level. The results showed that WFS could be effectively utilized in concrete to enhance compressive strength. However, the study also reported that while the compressive strength was sufficient for reinforced cement concrete (RCC) applications, the split tensile strength was lower than the expected target values, making it unsuitable for plain cement concrete (PCC) applications. This indicates that while WFS can be used in some structural applications, further optimization is required.

Shivradnyi Gaikwad (March 2019) explored the use of waste rubber chips in concrete paver block production. Their study found that rubber inclusion improved skid resistance and impact resistance but reduced compressive strength. The optimal replacement level was identified at 10%, beyond which strength reduction became significant. The study emphasized the need for further research to optimize the mix design for practical construction applications.

Ankit B. Prajapati (May 2019) investigated the economic feasibility and performance of fly ash in cement bricks. Their study found that incorporating fly ash reduces the cost of bricks while improving their strength. The optimal mix with 30% fly ash replacement achieved the best balance between cost, strength, and water absorption. The study emphasized that fly ash utilization in cement bricks supports sustainable construction by repurposing industrial waste.

A. Sofi (October 2018) reviewed the effect of waste tire rubber on the mechanical and durability properties of concrete. The study concluded that rubberized concrete showed reduced compressive and flexural strength compared to conventional concrete. However, up to 10% rubber substitution exhibited better abrasion resistance and water absorption properties. The research recommended using rubberized concrete in non-load-bearing applications such as sound barriers and pavements.

Miloš Šešlija (2016) conducted laboratory testing on fly ash from the Nikola Tesla A power plant. Their study concluded that fly ash possesses good pozzolanic properties and can be used in road structures, provided it is isolated from groundwater and surface water to prevent leaching of harmful chemicals

Jayanta Chakraborty & Sulagno Banerjee (2016) examined the effect of fly ash as a partial replacement for cement in concrete. Their study revealed that compressive strength decreases as the proportion of fly ash increases, with an optimal replacement limit of 45%. Early strength development was slower in fly ash mixes, but long-term strength gain was significant. The study concluded that while fly ash-based concrete is economical and sustainable, it requires longer curing periods to achieve desired strength levels **Table No 4 Materials Previously Used**

Materials Previously Used	**Tests**		
	Compressive Strength	**Water Absorption**	**Split Tensile Strength**
Normal Paver Block	**30+ MPa**	**<5%**	**4+ MPa**
Rubber Crumbs			
5%	**41.02 MPa**	**5.54%**	**3.68 MPa**
10%	**38.13 MPa**	**5.5%**	**3.69 MPa**
15%	**36.45 MPa**	**5.4%**	**3.66 MPa**
Fly Ash in Bricks			
10%	**23.16 MPa**	**4.27%**	–
20%	**23.72 MPa**	**3.72%**	–
30%	**26.01 MPa**	**3.23%**	–
Foundry Sand	–	–	–

2.3 Summary

Recent studies have explored the use of alternative materials such as waste foundry sand (WFS), crumb rubber, and fly ash in concrete and paver blocks to enhance sustainability and reduce environmental impact.

1. Waste Foundry Sand (WFS) in Concrete

Studies on WFS replacement in concrete indicate that partial replacement (20-30%) improves compressive strength while reducing environmental concerns. However, higher replacement levels (above 40%) result in reduced strength and workability.

2. Crumb Rubber in Concrete Pavers

Research on rubber waste in paver blocks highlights its benefits in flexibility, impact resistance, and durability. However, increasing rubber content beyond 20-30% significantly reduces compressive strength. Some studies recommend blending rubber with other materials to optimize mechanical properties.

3. Fly Ash as a Cement Replacement Fly ash has been found to be a cost-effective and sustainable alternative to cement. Studies reveal that 30% fly ash replacement provides an optimal balance of strength, durability, and water absorption. While higher replacement levels (above 40%) reduce early strength, long-term curing enhances mechanical properties. Additionally, fly ash is a viable material for road construction, provided it is properly isolated from groundwater.

CHAPTER 3 METHODOLOGY

3.1 MATERIAL PROPERTIES

3.1.1 Cement

Cement consists of four major compounds Tricalcium Silicate (C_3S), Dicalcium Silicate (C_2S), Tricalcium Aluminates (C_3A) & Tetra calcium Aluminoferrite (C_4AF). Tricalcium Silicate (C_3S) and Dicalcium Silicate (C_2S) are the most important compound responsible for strength. Together they constitute 70 to 80 percent of cement. The average C_3S content in modern cement is about 45 percent and that of C_2S is about 25 percent. During the course of reaction of C_3S and C_2S with water, calcium silicate hydrate (C-S-H) and calcium hydroxide ($Ca(OH)_2$) are formed. Calcium silicate hydrates are the most important products and determines the good properties of concrete. C_3S readily reacts with water and produces more heat of hydration. It is responsible for early strength of concrete. C_2S hydrates rather slowly produces less heat of hydration. It is responsible for later strength of concrete. The C_3A portion of cement hydrates more rapidly, thereby reducing the workability of fresh concrete. Regarding particle size distribution, it may be noted that finer particles hydrate faster than coarser particles and hence contribute more to early age strength concrete; however, at the same time, the faster the rate of hydration may lead to quicker loss of workability due to rapid and large release of heat of hydration.

After reviewing all above requirements, Ordinary Portland Cement (OPC) of 53 grades cement confirming to IS: 12269-1987 is used for this experimental investigation throughout. The cement is tested as per IS: 4031-1988.

Table No 5 Properties of cement

Sr No	**Physical requirement**	**Ultratech OPC53 Grade**	**Is 12629-1989**
1	Specific surface m^2/kg	330	225 min
2	Auto clave (%)	0.6	0.8 max
3	Initial setting time	150	30-60 minutes
4	Final setting time	225	600 minutes

3.1.2 Coarse Aggregate

The nominal maximum size of coarse aggregate should as large as possible within the specified limits but in no case greater than one fourth of the minimum thickness of the member, provided that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and fill the corners of the form. Locally available crushed stone with 20mm size aggregates confirming to IS 383:1970 are used.

3.1.2.1 Tests on Coarse Aggregate

1. Sieve analysis
2. Aggregate impact value
3. Aggregate crushing value
4. Specific Gravity & Water absorption

1. Aggregate Impact Value: (IS 2386-Part IV-1963)

Significance of test: The test is to be considered to be an important test to assess the suitability of aggregates as regards the toughness property.

Table No 6 Allowable limits of aggregates

Sr. No.	**Aggregate impact value (%)**	**Comment**
1	<10	Exceptionally strong
2	10-20	Strong
3	20-30	Satisfactory
4	>35	Weak

2. Aggregate Crushing Value: (IS 2386-Part IV-1963)

Significance of test: The aggregate crushing value is an indirect measure of crushing strength of aggregates. Low aggregate crushing values indicate strong aggregates, as the crushed factor is low.

3. Gravity & Water Absorption:

Significance of test: The specific gravity of aggregate normally used ranges from about 2.5 to 3.0 with an average value of about 2.74. High specific gravity of an aggregate is considered as an indication of high strength. Water absorption of an aggregate is accepted as measure of its porosity. Sometimes this value is even considered as a measure of its resistance to frost action, through this has not been yet confirmed by adequate research. Water absorption value ranges from 0.1% to 2.0% for aggregates. I.R.C has specified the maximum water absorption value as 1.0% for aggregates.To determine the specific gravity of C.A. (20mm) as per IS 2386(part 3)-1963 pycnometer used and the specific gravity of C.A (20mm) 2.8 are shown in Table -3.8.

3.1.3 Water

Water is an important ingredient of concrete as it actively participates in the mix design consideration. It is generally stated in the concrete codes and also in the literature that the water chemically reacts with cement. The strength of cement concrete mainly due to the binding action of the hydrated cement gel i.e., C-H-S gel. The requirement of water should be reduced to that required for chemical reaction of anhydrite cement as the excess water would end up in only formation of undesirable voids (and/or capillaries) in the hardened cement paste in concrete.

As per IS-456:2000 water used for mixing and curing shall be clean and free from injurious amounts of oils, alkalis, salts, sugars, organic materials or other substances that may deleterious to concrete or steel. In the present work, available tap water is used for concreting.

3.1.4 Waste Foundry Sand

Waste Foundry Sand (WFS) is an environmentally friendly material increasingly used in civil engineering applications. It is a byproduct of metal casting processes and can be effectively repurposed as a fine aggregate in concrete and other construction materials. Compared to conventional fine aggregates, WFS offers several unique benefits, including:

- Sustainability: Utilizing WFS helps reduce landfill waste and promotes recycling, contributing to sustainable construction practices.
- Enhanced Strength: WFS can improve the compressive strength of concrete up to certain replacement levels, enhancing the overall durability of the material.
- Cost-Effectiveness: Replacing traditional aggregates with WFS can lead to significant cost savings in construction materials.
- Minimal Environmental Impact: Using WFS minimizes the extraction of natural resources, reducing the carbon footprint of construction projects.
- Compatibility with Various Applications: WFS can be effectively integrated into various construction materials, including paver blocks and bricks, without compromising their physical properties.
- Lightweight Characteristics:WFS can contribute to a reduction in the overall weight of construction materials, potentially lowering transportation and handling costs.
- Thermal Properties: WFS can enhance the thermal insulation properties of concrete, making structures more energy efficient.

3.2 Mix Proportioning & Batching

To study the effect of different waste materials, four types of paver blocks were cast with various mix proportions.

3.2.1 Concrete Mix Design

Table No 7 Concrete Mix Design (Waste Foundry Sand M30)

Material	No. of Specimen	Cement	Course Aggregate	Waste Foundry Sand
WFS (100%)	12	19.575 kg	29.37 kg	14.67 kg

Table No 8 Concrete Mix Design (River Sand M20)

Material	No. of Specimen	Cement	Course Aggregate	River Sand
RS	12	19.575 kg	29.37 kg	14.67 kg

Table No 9 Concrete Mix Design (Waste Tyre Rubber

Crumbs & Waste Fundry Sand M30)

Material	**No. of Specimen**	**Cement**	**Course Aggregate**	**Waste Foundry Sand**	**Weight of RC**
WRT (5%)	12	19.575 kg	29.37 kg	13.95 kg	0.51 kg
WRT (10%)	12	19.575 kg	29.37 kg	13.215 kg	1.005 kg
WRT (15%)	12	19.575 kg	29.37 kg	12.48 kg	1.515 kg

Table No 10 Concrete Mix Design (Flyash as Additional Material M30)

Material	**No. of Specimen**	**Cement**	**Course Aggregate**	**Waste Foundry Sand**	**Weight of Flyash**
FA (10%)	12	19.575 kg	29.37 kg	14.67 kg	1.9575 kg
FA (20%)	12	19.575 kg	29.37 kg	14.67 kg	3.915 kg
FA (30%)	12	19.575 kg	29.37 kg	14.67 kg	5.8725 kg

3.2.2 Batching of Materials

The required quantities of cement, WFS, coarse aggregates, and waste materials were weighed using a digital weighing scale for accuracy. The water-to-cement (w/c) ratio was maintained at 0.45 to 0.50, ensuring proper workability of the mix.

3.3 Mixing Process

1.Dry Mixing:

Cement, waste foundry sand, and coarse aggregates were mixed thoroughly in a concrete mixer or manually on a mixing tray until a uniform color was obtained.

2.Addition of Waste Materials:

For rubber crumbs, uniform distribution was ensured to avoid segregation for fly ash, it was blended well with cement before adding to the mix.

3.Water Addition:

Water was added gradually while mixing continuously to avoid excess moisture and ensure proper consistency.

4.Final Mixing:

The concrete mix was continuously stirred for at least 3–5 minutes until a homogeneous and workable mix was achieved.

3.4 Mould Preparation & Casting

3.4.1 Mould Preparation

Moulds of standard paver block shapes were cleaned thoroughly a thin layer of mould oil or grease was applied to prevent sticking and ease demoulding.

3.4.2 Casting of Paver Blocks

The prepared concrete mix was poured into the moulds in two or more layers. Each layer was compacted manually using a tamping rod or mechanically using a vibrating table to remove air voids after compaction, the surface was leveled using a trowel to ensure uniform thickness.

3.5 Curing Process

The cast paver blocks were left undisturbed in the moulds for 24 hours for initial setting. After 24 hours, the blocks were carefully demoulded and transferred to a water curing tank.Curing was carried out for 7 and 28 days, ensuring full hydration of cement and strength development.

3.6 Testing of Paver Blocks

After curing, the paver blocks were tested for their mechanical properties.

3.6.1 Compressive Strength Test

The blocks were tested in a Universal Testing Machine (UTM) as per IS 15658:2006. Load was applied gradually until failure, and the compressive strength was recorded.

3.6.2 Split Tensile Strength Test

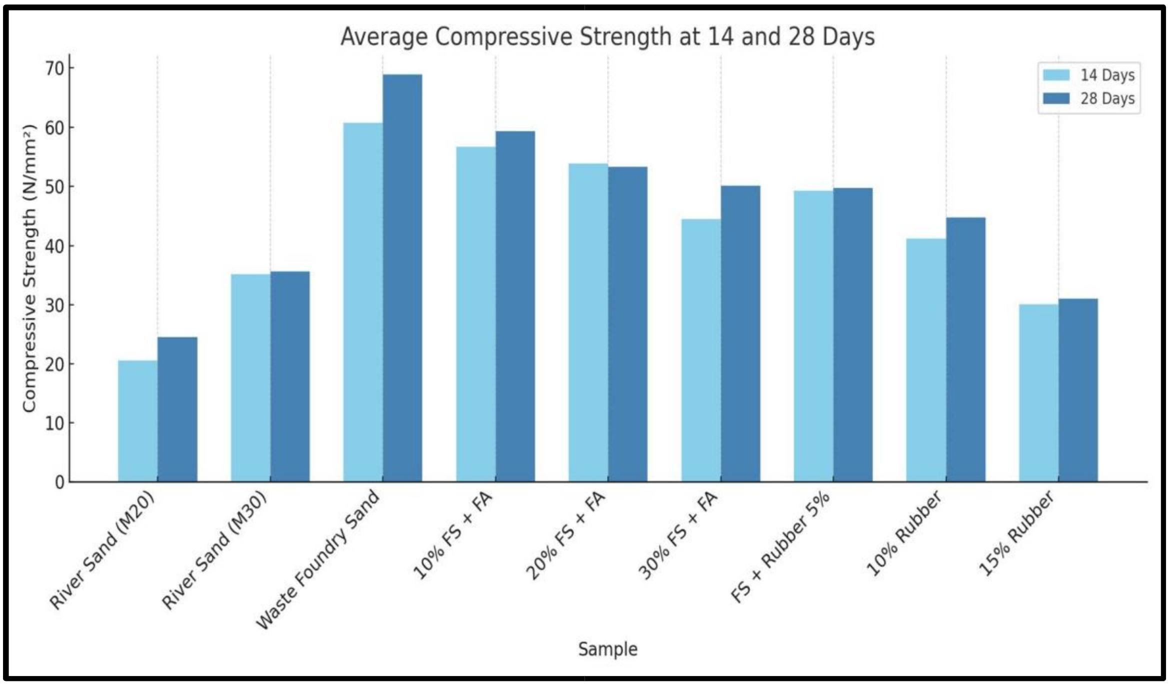
The split tensile strength of the paver blocks was determined using a Universal Testing Machine (UTM) as per IS 15658:2006.
The blocks were placed horizontally between two loading plates, and load was applied gradually until failure.
The split tensile strength was calculated based on the applied load and dimensions of the block.

3.7 Results

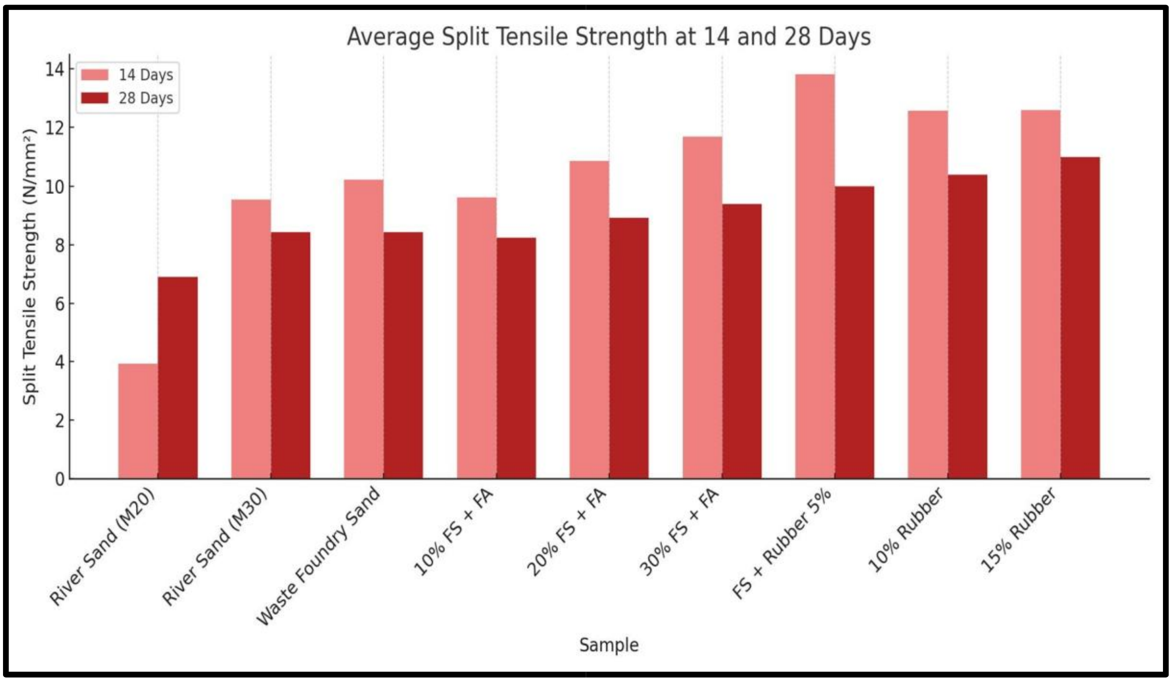
Table No 10 Test Results

NAME OF SPECIMEN	14 days Compressive (N/mm²)	14 days Split Tensile (N/mm)	28 days Compressive (N/mm²)	28 days Split Tensile (N/mm)
River Sand (Market Grade M20)	17.42	4.350	24.72	6.6
	22.68	**3.580**	**25.22**	**7.91**
	21.53	3.87	23.65	6.21
River Sand (M30)	33.23	9.213	35.01	8.33
	36.73	**9.87**	**36.58**	**8.30**
	35.45	9.55	35.35	8.63
Waste Foundry Sand	58.20	10.11	68.31	8.49
	63.47	**10.03**	**69.38**	**8.69**
	60.56	10.53	68.95	8.45
FS + Fly Ash (+10%)	56.27	8.430	58.45	7.7

	57.24	**10.790**	**59.87**	**8.8**
	56.52	9.65	59.54	8.2
WFS+Fly Ash (+20%)	53.16	10.630	52.75	8.88
	54.76	**11.460**	**53.68**	**8.9**
	53.65	10.490	53.49	8.85
WFS+FlyAsh (+30%)	43.51	11.640	49.74	9.06
	45.55	**11.460**	**50.53**	**9.26**
	44.25	11.95	49.95	9.86
WFS(95%) + Rubber Crumbs(5%)	49.08	14.44	47.64	9.95
	49.84	**13.480**	**51.69**	**10.10**
	48.63	13.51	49.85	10.00
WFS(90%) + Rubber Crumbs(10%)	41.31	12.380	45.05	10.19
	41.34	**12.670**	**44.65**	**10.67**
	40.95	12.65	44.54	10.37
WFS(85%) + Rubber Crumbs(15%)	27.55	12.53	30.50	11.24
	31.80	**12.40**	**31.59**	**11.56**
	30.95	12.85	31.04	11.26



Graph No 1. Compressive Strength Results



Graph No 2. Split Tensile Strength Results

CHAPTER 4 CONCLUSION

From the results of the compressive and split tensile strength tests on different concrete mixes, the following conclusions can be drawn:

1. Effect of River Sand (Market Grade M20 & M30)

The M30 mix exhibits significantly higher compressive and tensile strength than the M20 mix at both 14 and 28 days.The 28-day compressive strength of M30 (36.58 N/mm²) is approximately 45% higher than that of M20 (25.22 N/mm²), indicating that M30 provides superior strength development.The tensile strength of M30 is also higher, suggesting better resistance to cracking.

2.Impact of Waste Foundry Sand (WFS)

The use of 100% Waste Foundry Sand significantly enhances both compressive and tensile strength.The highest compressive strength (69.38 N/mm² at 28 days) is observed in the WFS mix, which is almost double that of M20.The tensile strength also improves significantly, indicating better durability.

3.Effect of Fly Ash Replacement (+10%, +20%, +30%)

The addition of fly ash up to 30% results in a decrease in compressive strength compared to 100% WFS.The 10% Fly Ash mix achieves a relatively high strength (59.87 N/mm² at 28 days), but at 30% replacement, strength drops to 50.74 N/mm².However, the split tensile strength increases slightly with increasing fly ash content, indicating improved flexibility and crack resistance.

4.Foundry Sand + Rubber Crumbs (5%)

The incorporation of 5% rubber crumbs leads to a slight decrease in compressive strength (51.64 N/mm² at 28 days) compared to pure foundry sand mixes.However, tensile strength remains high, suggesting that rubber crumbs enhance elasticity and resistance to cracking.

5.Effect of 10% and 15% Replacement

The 10% replacement mix shows a balanced compressive (45.05 N/mm²) and tensile strength (10.19 N/mm²), indicating a stable mix with good mechanical properties.The 15% replacement mix exhibits the lowest compressive strength (30.50 N/mm² at 28 days), which may indicate an excessive replacement level affecting the concrete’s load-bearing capacity.The split tensile strength for 15% replacement is the highest (11.56 N/mm² at 28 days), showing improved flexibility but at the cost of reduced compressive strength.

Final Observations

- Waste Foundry Sand (100%) provides the highest strength, making it an excellent replacement for natural sand.
- Fly Ash (10-20%) maintains strength while improving workability and durability.
- Rubber Crumbs (5%) slightly reduce compressive strength but enhance tensile strength and flexibility.
- Higher Fly Ash content (30%) and 15% Replacement reduce compressive strength, making them less ideal for structural applications.

Recommendation

- For high-strength applications, 100% Waste Foundry Sand or 10% Fly Ash replacement is recommended.
- For structures requiring flexibility and crack resistance, using 5% Rubber Crumbs or higher fly ash content (20-30%) may be beneficial.
- For general construction, M30 with 10-20% foundry sand replacement provides a good balance of strength and durability.

PHOTO GALLERY

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