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Replacement of M-Sand by Waste Foundry Sand in Concrete Blocks

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***Abstract*: The disposal of waste foundry sand (WFS) in landfills is a widespread issue, prompting the metal casting industry to explore reusing WFS. Concrete production offers a promising avenue for utilizing WFS as a substitute for M sand, potentially benefiting both the environment and construction costs. This project focuses on analyzing the physical properties of WFS, formulating concrete mixes for M25 grade concrete per IS 456:2000 standards and evaluating mechanical properties like compressive and split tensile strength. The aim is to determine the ideal formulation for concrete mixture by assessing the performance at different replacement levels of WFS (0%, 25%, 50%, 75%, and 100%). The experiment sourced materials from various locations, including cement, waste foundry sand, fine aggregate, coarse aggregate, and water. To assess the impact of replacing M sand with WFS on OPC mix properties, several laboratory tests were conducted. These tests encompassed particle size distribution analysis for fine aggregate, aggregate impact value assessment, workability testing, as well as evaluations of compressive strength, split tensile strength, flexural strength, and durability. The project aims to address the challenge of WFS disposal by exploring its potential as a substitute for M sand in concrete production, with the goal of optimizing mix designs and enhancing mechanical properties across different replacement levels.**

***Keywords*: Waste Foundry Sand (WFS), Compressive strength, Split tensile strength, Flexural strength.**

1. Introduction

Concrete blocks serve as a robust foundation in construction, enhancing structural stability and integrity. Their diverse sizes and shapes offer design flexibility, making them adaptable for various construction needs. Cost-effectiveness compared to alternative materials makes concrete blocks a pragmatic choice for both residential and commercial projects. Their durability, resistance to weathering, pests, and fire ensures longevity in building structures. Hollow concrete blocks provide natural insulation, aiding energy efficiency by regulating temperatures and reducing reliance on additional insulation materials. They offer design versatility, either as an industrial feature or adorned with various finishes to suit architectural aesthetics. Concrete blocks are typically composed of ordinary Portland cement, fine aggregate, coarse aggregate, and water.

In this project, we investigate the viability of substituting M sand with waste foundry sand in concrete block manufacturing. Waste foundry sand, a byproduct of metal casting, becomes available once it's no longer suitable for mold casting. Efforts to find environmentally sustainable solutions for its management and reuse have led to exploring its potential in construction materials like concrete. Comprising silica sand, clay, and additives used in casting, waste foundry sand varies in particle size, influencing its applicability across industries, including construction. Considerations for residual metals and impurities from the casting process are essential for environmental and safety compliance.

The makeup of discharged waste foundry sand can impart varying degrees of permeability, which may be advantageous for specific uses like soil enhancement. Its residual thermal properties make it suitable for applications requiring resistance to high temperatures. However, it's crucial to thoroughly evaluate the engineering characteristics of waste foundry sand, particularly when contemplating its use as a substitute in construction materials such as concrete. Assessing its properties ensures suitability for intended applications and informs decisions regarding its incorporation into various projects.

Utilizing waste foundry sand as a substitute for M sand in concrete blocks presents opportunities for both economic savings and environmental conservation. By repurposing waste foundry sand, we mitigate the environmental burden associated with its disposal, contributing to sustainable practices. However, it's imperative to assess the engineering characteristics of the concrete, such as ability to withstand compression, durability, and workability, when integrating waste foundry sand. Comprehensive testing and analysis are vital to guarantee that the replacement maintains or enhances the performance of the concrete blocks. Achieving success in integrating waste foundry sand necessitates a balanced approach that considers technical considerations alongside broader environmental implications.

A. Objectives

The objective of the study as follows,

1) To find the suitability of utilizing waste foundry sand as a substitute for fine aggregate in concrete.
2) To determine the optimum replacement value of M-Sand employing waste foundry sand for developing a workable mix.

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3) To assess the mechanical and durability characteristics of concrete mix with waste foundry sand.

2. Methodology

1) The experimental study commenced with problem identification and the selection of appropriate materials.
2) Workability tests, including slump cone and compaction factor tests, were conducted to assess material behavior.
3) Casting and curing procedures were implemented to prepare specimens for mechanical testing.
4) Mechanical tests, such as compressive strength, flexural strength, split tensile test, and water absorption test, were performed to evaluate material properties.

3. Materials

A. Fine Aggregates

Both M sand and WFS serve as fine aggregates in construction materials. M sand, short for Manufactured Sand, is produced by crushing rocks, quarry stones, or larger aggregates into smaller particles. It offers an alternative to river sand and is favored in construction for its uniform particle size and shape. Free from impurities, M sand boasts consistent quality, making it well-suited for use in concrete, mortar, and various construction applications. In contrast, waste foundry sand typically comprises fine grains of sand, clay, and other materials used in mold creation for casting metal parts. Generated in significant quantities by foundries, waste foundry sand is often recycled multiple times before disposal.

B. Material Testing

All tests are executed as per the IS 456:2000.

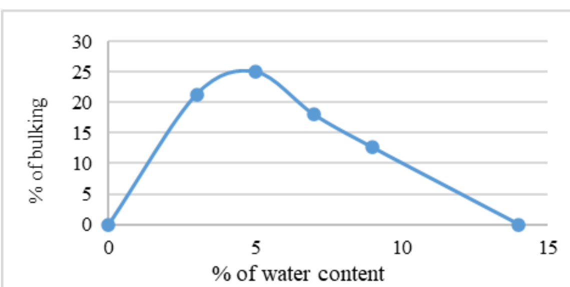

Fig. 1. Bulking of M Sand

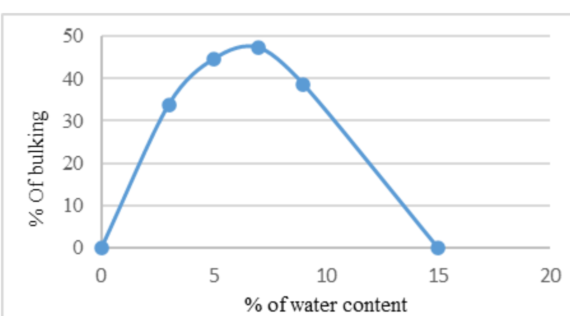

Fig. 2. Bulking of WFS

Table 1
Bulking

Fine Aggregate	% of bulking occurred	% of water content at maximum bulking	% of water content when bulking is zero
M Sand	25	5	14
WFS	47.26	7	15

Table 2
Sieve analysis

Properties	M Sand	WFS
Fineness modulus	2.9	1.87
Effective size, D_{10}	0.48mm	0.23mm
Uniformity coefficient, D_{60}/D_{10}	2.11	1.95

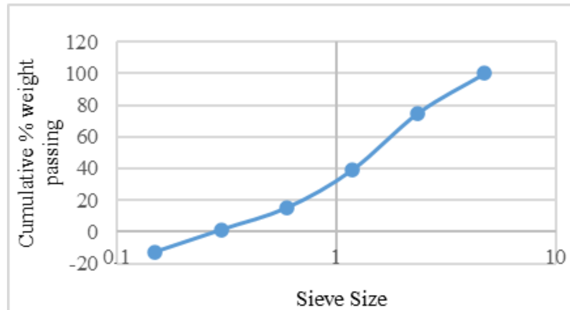

Fig. 3. Particle size distribution of M Sand

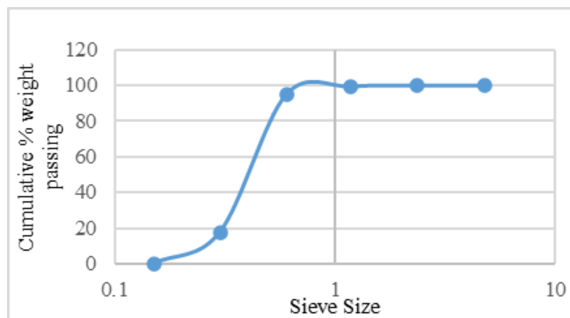

Fig. 4. Particle size distribution of WFS

4. Mix Design

The M25 concrete mix designed with a ratio of 1:1:2 according to IS 456:2000 standards were successfully employed in our construction project, ensuring the targeted robustness and resilience of the concrete blocks.

Table 3

Materials	M Sand replaced with WFS (kg/m^3)					Total Weight (kg/m^3)
	Control mix	M25F	M50F	M75F	M100F	
Cement	27.9	27.9	27.9	27.9	27.9	139.5
CA	69.6	69.6	69.6	69.9	69.6	348
M sand	31.6	23.7	15.8	7.92	0	79.02
WFS	0	7.92	15.8	23.7	31.6	79.02
Water	12.7	12.7	12.7	12.7	12.7	63.5

5. Workability Test

A. Slump Test

In accordance with IS 456:2000 standards, the malleability of concrete is evaluated by measuring the slump at each batch of mixing using a slump cone apparatus. The slump test provides a quantitative measure of the consistency and fluidity of the concrete mix, indicating its ability to be placed, compacted, and shaped effectively on-site.

B. Compaction factor test

The compaction factor test assesses the concretes workability by measuring the degree of compaction achieved through a standardized procedure, aiding in assessing the ease of concrete placement and ensuring optimal performance in construction applications.

6. Compressive Strength Test

The compressive strength results at 7 days highlight that the M25F mix outperformed the control mix, while the M100F mix exhibited the lowest strength, indicating that higher cement content doesn't always result in higher early strength. At 28Days, the M50F mix showed the highest compressive strength, surpassing the control mix, while the M100F mix had the lowest strength, suggesting higher cement replacement levels may hinder long-term strength development. Overall, while the M25F and M50F mixes showed promising results, higher replacement levels in the M75F and M100F mixes resulted in lower strengths when compared to the standard mix, indicating varied impacts on long-term strength properties.

Table 4

Specimen type	**Compressive strength test of 7days, N/mm^2**			**Mean, N/mm^2**
Control mix	28.66	24	28.22	26.96
M25F	30.22	28	32.66	30.29
M50F	26.88	19.77	22.22	22.95
M75F	23.77	22.88	25.55	24.06
M100F	18.88	19.77	18.22	18.22

Table 5

Specimen type	**Compressive strength test of 28day, N/mm^2**			**Mean**
Control mix	40	37.55	40	39.18
M25F	38.6	39.33	42.21	40.05
M50F	42.22	41.12	41.30	41.55
M75F	29.33	30.43	32	30.59
M100F	27.54	27.33	28.26	27.84

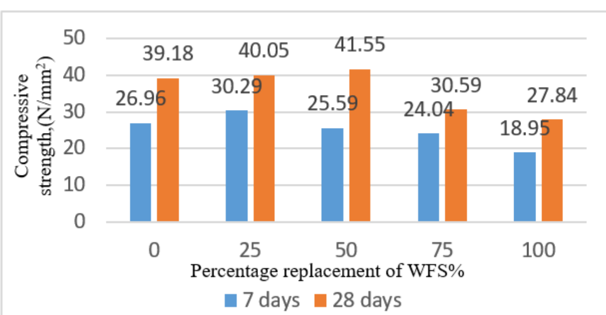

Fig. 5. Graph of 7 & 28days compressive strength

7. Split Tensile Strength Test

The 28-day split tensile strength results reinforce the findings on flexural strength, showcasing the performance of concrete mixes incorporating various proportions of WFS as a substitute for fine aggregate. Across the mixes, M25F, M50F, and M100F displayed higher split tensile strengths than the control mix, with M75F exhibiting the highest strength overall. This consistent trend of strength enhancement with increasing WFS replacement levels underscores the comparability of the various replacement levels with the control mix, affirming the viability of incorporating WFS as a sustainable alternative in concrete production.

Table 6

Specimen type	**Split tensile strength, T (N/mm^2)**			**Mean split tensile strength (N/mm^2)**
Control mix	2.12	2.05	2.19	2.12
M 25 F	2.26	2.33	2.68	2.42
M 50 F	2.54	2.61	2.68	2.61
M 75 F	2.97	3.04	2.82	2.94
M 100 F	2.90	2.82	2.75	2.82

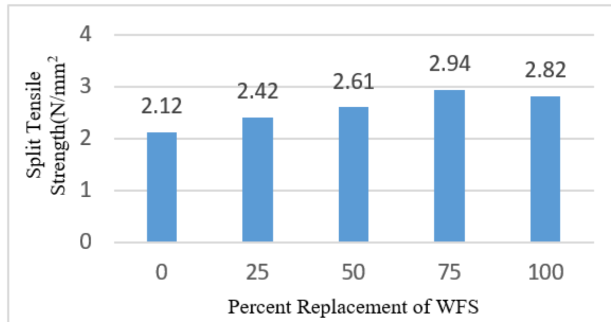

Fig. 6. Graph of 28day split tensile strength

8. Flexural Strength Test

The 28-day flexural strength results offer valuable insights into concrete mixes incorporating varying percentages of WFS as a substitute for fine aggregate. Among the mixes, M25F and M50F exhibited superior flexural strengths compared to the standard mix, with M50F showing the highest strength overall. These findings underscore the importance of a balanced approach to fine aggregate replacement with WFS for achieving optimal concrete performance.

Table 7

Specimen type	**Flexural strength, f_b (N/mm^2)**			**Mean flexural strength (N/mm^2)**
Control mix	5.7	6.5	6.2	6.15
M 25 F	10.26	10.29	10.51	10.35
M 50 F	9.98	10.58	10.56	10.90
M 75 F	10.16	10.56	11.34	10.68
M 100 F	8.1	8.13	8.56	8.26

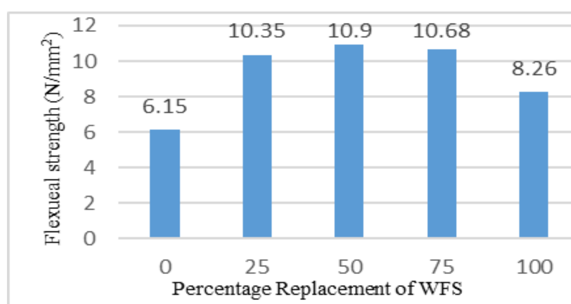

Fig. 7. Graph of 28day flexural strength test

9. Water Absorption

A. 28Days Water absorption of Cube

The water absorption values of the 28-day cubes for different concrete mixes with varying percentages of WFS replacements were analyzed and compared to the standard mix. The control mix exhibited a water absorption rate of 1.01%, while the M25F mix showed a slightly higher value of 1.05%. Interestingly, both the M50F and M75F mixes displayed the similar water absorption characteristics of 1.32%, indicating a consistent performance with increasing waste foundry sand content. The M100F mix, with the highest percentage replacement of WFS, demonstrated a water absorption rate of 1.37%. Overall, it can be concluded that the various percentage replacements of WFS in concrete mixes are akin to the control mix in terms of water absorption. This suggests that incorporating WFS as a partial replacement for conventional aggregates can be a viable and sustainable option without compromising the quality and durability of the concrete. Further research and testing could provide more insights into the long-term performance and environmental benefits of incorporating waste foundry sand into concrete production.

Table 8

Specimen type	Water Absorption, %			Mean
Control mix	1.05	0.99	0.99	1.01
M 25 F	0.93	0.91	1.32	1.05
M 50 F	1.28	1.47	1.32	1.32
M 75 F	1.36	1.28	1.33	1.32
M 100 F	1.34	1.48	1.29	1.37

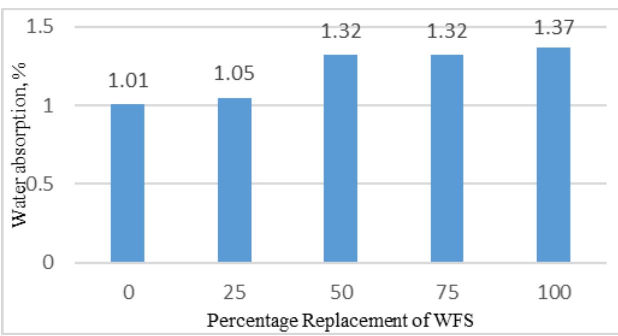

Fig. 8. Graph of 28days water absorption of cube

B. *28Days Water absorption of Cylinder*

The water absorption values obtained from the 28-day cylinders for different concrete mixes with varying percentages of WFS replacements provide valuable insights into the performance of these mixes. The results indicate that as the percentage of waste foundry sand replacement increases, there is a gradual elevated water absorption level. However, despite these incremental increases, all the mixes, including M25F, M50F, M75F, and M100F, remained within a relatively close range compared to the standard mix. This suggests that the various percentage replacements of WFS in concrete mixes are indeed comparable to the control mix in terms of water absorption. The consistent performance of the mixes with waste foundry sand replacements indicates that integrating waste foundry sand as a partial substitute for conventional aggregates does not significantly compromise the water absorption properties of the concrete.

Table 9

Specimen Type	Water Absorption, %			Mean
Control mix	0.96	0.70	0.61	0.75
M 25 F	0.78	0.97	0.69	0.81
M 50 F	0.69	0.86	0.96	0.83
M 75 F	0.95	0.99	1.12	1.02
M 100 F	0.99	1.1	1.01	1.03

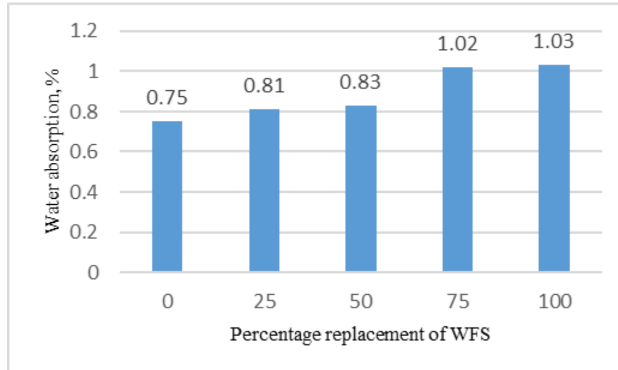

Fig. 9. Graph of 28days water absorption of cylinder

C. *28Days Water Absorption of Beam*

The outcome indicates that the water absorption rates for M25F, M50F, M75F, and M100F are within a relatively close range compared to the standard mix, with only slight incremental increases as the percentage of WFS replacement increases. The results suggest that the inclusion of WFS in concrete mixes can maintain comparable water absorption characteristics to conventional concrete, high lighting its potential for enhancing the overall quality and longevity of concrete structures while promoting sustainability in construction practices. Additional research and testing could provide further confirmation and detailed insights into the benefits of utilizing WFS in concrete production.

Table 10

Specimen type	Water absorption, %			Mean
Control mix	0.71	0.55	0.63	0.63
M 25 F	0.56	0.70	0.65	0.63
M 50 F	0.69	0.65	0.64	0.66
M 75 F	0.71	0.69	0.70	0.7
M 100 F	0.73	0.74	0.76	0.71

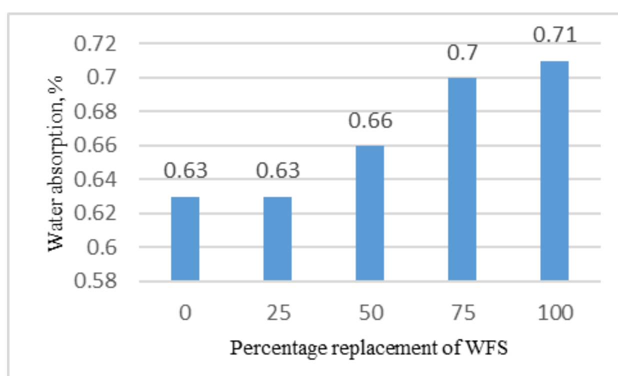

Fig. 10. 28days water absorption of beam

10. Conclusion

The project findings indicate that the concrete mix with a slump value of 162 mm and a compaction factor of 0.962 offers optimal workability and ease of compaction. Moreover, the M25F mix exhibited the highest compressive strength at 7 days, surpassing the control mix. However, at 28 days, while the M25F and M50F mixes showed promising results, higher replacement levels (M75F and M100F) displayed lower strengths, suggesting a limit to the benefits of increased replacement. Additionally, in flexural and split tensile strength tests at 28 days, mixes with higher replacement levels generally showed slightly lower strengths compared to the standard mix. However, all mixes, including those with WFS replacements, demonstrated comparable water absorption rates to the standard mix, implying the feasibility of using WFS as a sustainable alternative without compromising concrete quality and durability.

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