IJREI

International Journal of Research in Engineering and Innovation (IJREI)

journal home page: http://www.ijrei.com

ISSN (Online): 2456-6934

International Journal of Research in Engineering and Innovation Vol-8, Issue-3 ISSN: 2456-6934

ORIGINAL ARTICLE

To study the mechanical and durability characteristics of concrete utilizing waste foundry sand

Himanshu Sahni, Noorul Bashar

Department of Civil Engineering, Vivekananda College of Technology and Management, AKTU, Aligarh, Uttar Pradesh, India

Article Information

Received: 21 January 2024
Revised: 09 March 2024
Accepted: 28 April 2024
Available online: 02 May 2024

Keywords:

Concrete
Sustainability
Compressive strength
Split tensile strength
Flexural strength.

Abstract

Currently, the availability of high-quality natural river sand is scarce, requiring transportation over long distances, and its rapid depletion is a significant concern. In this project, the focus lies on assessing the behavior of concrete by partially replacing natural sand with waste foundry sand. The experimental investigation primarily examines the mechanical and durability, split tensile strength, Ultrasonic Pulse Velocity Test, flexural strength, and permeability of concrete. This evaluation involves replacing natural river sand with varying percentages (0%, 10%, 20%, 30%, 40%) of waste foundry sand by weight. Tests are conducted on cubes and beams to analyze the mechanical properties and durability characteristics of concrete with waste foundry sand compared to concrete with natural sand as fine aggregate. The study includes assessments of splitting tensile strength and flexural strength at different ages (7, 28, 56, and 90 days). Results indicate a decrease in workability as the percentage of waste foundry sand in the mix increases.

1. Introduction

Foundries typically recycle and reuse this sand extensively within their operations. However, once the sand reaches a point where it can no longer be effectively reused, it is termed waste foundry sand. Due to the diminishing availability of landfill space and the escalating costs associated with disposal, finding alternative uses for waste materials and byproducts has become an increasingly attractive option. In India, approximately 2 million tons of waste foundry sand are generated annually, with the United States disposing of 6–10 million tons each year. The automotive industry and its components are significant contributors to the generation of foundry sand. Foundries typically procure high-quality, specialized silica sands for their molding and casting processes. These sands are of higher quality compared to natural sands used in construction fill sites. Therefore, finding alternative uses for waste foundry sand can not only reduce disposal costs but also contribute to environmental sustainability by minimizing the need for landfill space and reducing the overall environmental impact of foundry operations. As landfill space becomes increasingly scarce, landfill disposal costs are rising due to additional charges for transportation and landfill operations. While the volume of excess foundry sand for disposal can be reduced by reclaiming a greater percentage of the sand before disposal, new sands are still needed to compensate for shakeout losses and degraded sand. Maintaining a good binding system and ensuring casting quality require the removal of degraded sand from the casting process. A comprehensive solution to this issue involves the valuable reuse of foundry byproducts.
The AFS Grain Fineness Number (AFS GFN), an industry parameter indicating the average grain size, ranges between 40 – 90 for most waste foundry sands, compared to around 40 for regular fine aggregate. Additionally, foundry sand exhibits

Corresponding author: Himanshu Saini
Email Address: himanshu.sahni.nitw@gmail.com
https://doi.org/10.36037/IJREI.2024.8303.

uniform equidimensional sub-angular aggregate properties. These inherent physical properties enhance the flow consistency of CLSM, and when incorporated into CLSM mixes, the reuse of foundry sand offers significant environmental and economic benefits. The rising costs and environmental impacts associated with mining virgin sand for CLSM, asphalt, and concrete are driving the need for the reuse of natural resources.

2. Materials and methods

2.1 Materials Used

According to the IREDA-CII Report 2004, India has around 10,000 foundry units, including both registered and unregistered ones. Considering that 4550 units are registered, the estimated number of unregistered units is approximately 5450 units. Experts in the foundry sector estimate that there are around 1500 unregistered foundry units scattered across the country.

Figure 1: Waste Foundry Sand

Figure 2: Disposal of Waste Foundry Sand

This disparity in the number of unregistered units is mainly due to the fact that the 5450 units include various micro and small units engaged in castings. In contrast, the data for the 1500 units only includes foundry units involved in grey iron casting using conventional furnaces and excludes those units that are very small-scale and use crucibles for metal melting. Additionally, some foundry units have closed down due to non-compliance with government pollution standards, such as those in Howrah, Agra, and surrounding areas. Foundries in India produce most of these units are clustered together, with cluster sizes ranging from 30 to 500 units. The export of castings from India, both sanitary and industrial combined, has seen steady growth year after year, increasing from Rs. 1,404 crores in 2001-02 to Rs. 2,997 crores in 2005-06, almost doubling in five years.

Table 1: Country V/S Foundry Production: Scenario Of World

Country	2009		2010		2011	
	Million tones	Rank	Million tones	Rank	Million tones	Rank
China	35.3	1	39.6	1	41.26	1
US	7.40	2	8.24	3	10.01	2
Japan	4.40	4	4.76	5	5.74	4
India	7.40	3	9.05	2	9.99	3
Germany	3.90	5	4.79	4	5.46	5
Brazil	2.30	7	3.24	7	3.34	7
Italy	1.67	9	1.97	9	2.21	9
France	1.74	10	1.96	10	2.04	10
Korea	2.10	8	2.23	8	2.34	8
Russia	4.20	6	4.20	6	4.3	6

2.2 Preparation of specimens

Conducted a study on the fresh and hardened properties of concrete incorporating waste foundry sand as a replacement for fine aggregate. In their research, regular concrete sand was replaced with 25% and 35% of waste foundry sand and clean foundry sand by weight. The results revealed that the concrete mixture containing 25% of waste foundry sand exhibited an increase in certain properties by 10% compared to the mixture containing 35% of waste foundry sand. However, it was observed that the compressive strength of the control mix was approximately 20-30% higher than the mixes containing waste foundry sands.

2.3 Cement

Cement plays a crucial role in concrete mixes, serving to bind sand and stone together while filling voids to create a compact mass. Despite comprising only about 20% of the mix volume, cement is the active binding medium and the sole ingredient under scientific control. Any variation in its quantity can impact the compressive strength of the concrete. In this investigation, Ordinary Portland Cement (OPC) Grade 43 BANGUR was used for all mixes. Various tests were conducted, and the results are tabulated in Table 2.

2.4 Aggregates

Aggregates, whether coarse or fine, provide bulk to the concrete, while fine aggregates play a crucial role in producing a workable and uniform concrete mix. Additionally promoting plasticity in the mix and preventing segregation during transportation. Since aggregates make up about 75% of concrete's volume, their influence on concrete performance is significant, with their properties playing a crucial role in determining overall performance.

Table 2: Properties of Cement

Characteristics	Experimental values	Recommended values
Specific Gravity	31.5	26– 33%
Initial setting Time	42(min)	30 min (Minimum)
Final Setting Time	450(min)	600 min (Maximum)
Specific Gravity	3.00	3-3.25
Compressive strength (MPa) 3-days 7-days 28-day	 23.2 (MPa) 34.6(MPa) 42.3(MPa)	 23 (MPa) 33 (MPa) 43 (MPa)
Soundness, Le Chatelier's test	5.5 mm	10 mm (Maximum)
Loss on Ignition	3.94%	5% (Maximum)

2.5 Fine Aggregate

In accordance with IS: 383-2016, fine aggregate, often referred to as sand size aggregate, is defined as material that passes through a 4.75mm IS sieve. For the present study, locally sourced river bed sand was utilized. A total sample weight of 2000 g was taken, and the results of the sieve analysis of the fine aggregate are presented in Table 3.

Table 3: Sieve Analysis of Fine Aggregate

Sieve Size (mm)	Weight Retained (gm.)	Cumulative wt retained (gm.)	% Cumulative wt retained (gm.)
4.75	18	18	0.9
2.36	43	61	3.05
1.18	267	328	16.4
0.6	540	868	43.4
0.3	982	1850	92.5
0.15	115	1965	97.8
Pan	35	2000	100

Fineness Modulus =Sum of cumulative weight retained /100
Fineness Modulus =354.05/100 =3.54
Hence as per IS 383-2016, fine aggregate lies to Grading Zone II

3. Experimental Methodology

Various types of tests such as compressive strength, tensile strength, flexural strength and permeability are conducted on the concrete cube of size 150mm x 150mm x 150mm and beam of size 100mm x 100mm x 500mm.

3.1 Compressive Strength

The compressive strength of concrete is a fundamental property that determines its ability to withstand compressive stresses, which are prevalent in most structural applications. While concrete may be employed to resist tensile or shear stresses in specific cases, the compressive strength often serves as an indicator of these properties. Thus, the concrete-making characteristics of various mix ingredients are commonly evaluated based on their compressive strength. Laboratory determination of compressive strength typically involves testing cubes or cylinders using a compression testing machine.

Figure 3: Compression testing machine

Figure 4: Tested Specimen

3.2 Tensile Strength

The tensile strength of concrete is approximately 10% of its compressive strength. Tensile splitting strength tests of concrete block specimens were determined as per IS: 5816-1999.After curing of 28 days the specimens were tested for tensile strength using a calibrated compression testing machine of 1000 KN capacity.

3.3 Flexural Strength

It's typically determined by loading concrete beams measuring 100 x 100 x 500mm. The flexural strength is expressed in megapascals (MPa) and is determined according to standard test methods such as IS: 516-1959, which typically employs third-point loading. However, the exact correlation can vary for different materials and mix designs, and is typically established through laboratory testing.

4. Results and discussion

4.1 Strength

The present experimental work involved casting concrete cubes with dimensions of 150mm x 150mm x 150mm, incorporating six different percentages of Waste Foundry Sand. Additionally, standard size beams measuring 100mm x 100mm x 500mm were cast for determining compressive, split tensile, and flexural strength. Slump test is conducted to determine the workability of concrete at constant w/c ratio of 0.4 and the variation of slump has been shown in Fig. 5.

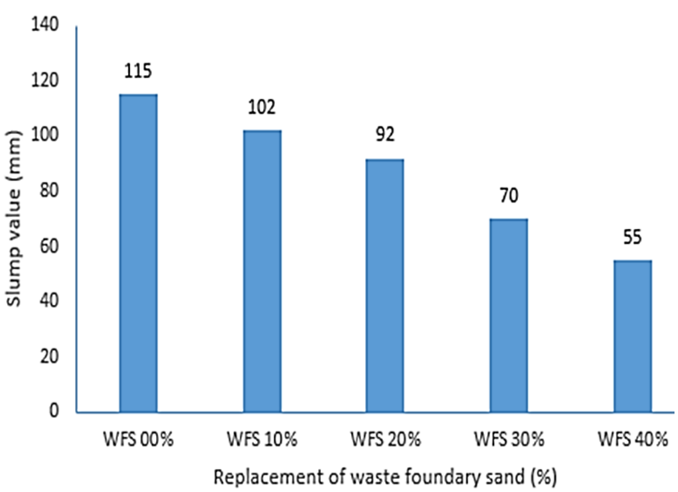

Figure 5: Variation of slump (mm)

The reduction in workability observed with increasing percentages of waste foundry sand in concrete can be attributed to its finer particle size compared to regular sand, leading to higher cohesion in the mix. As the foundry sand content rises, the mix tends to become stiffer and less workable, possibly due to void filling action. This increased stiffness results in a harsh and sticky mix. Moreover, the finer particles of foundry sand necessitate higher water demand compared to regular sand. It seems like you've provided a summary of the experimental setup and the data collected for compressive strength testing of concrete cube specimens with varying percentages of waste foundry sand (WFS) replacement. The specimens were tested at different ages (7 days, 28 days, 56 days, and 90 days), and the average compressive strength values for each replacement level. The replacement levels include 0%, 10%, 20%, 30%, and 40% of fine aggregate with waste foundry sand, labeled as WFS 00%, WFS 10%, WFS 20%, WFS 30%, and WFS 40% respectively. This comparative study aims to assess how the percentage of WFS replacement affects the compressive strength of concrete over time.

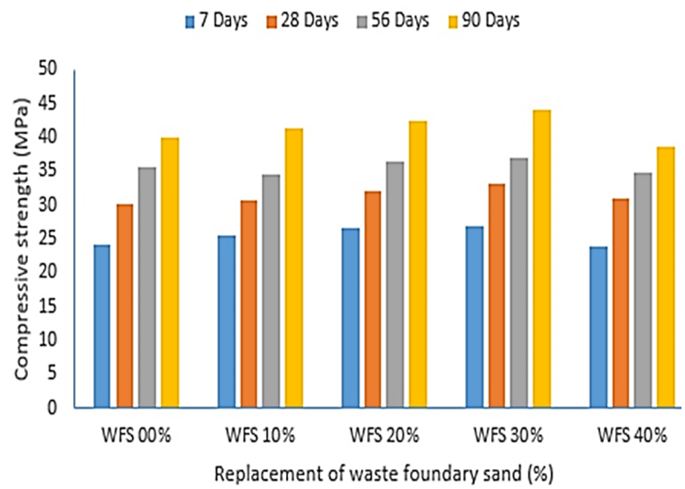

Figure 6: Comparison of compressive strength

The test was carried out according to IS: 5816-1970(10). In this test, compressive line loads were applied along a vertical symmetrical plane, which causes splitting of the specimen. The average values of 3 specimens for each category at the ages of 7 days, 28days 56 days and 91 days revealed in Fig. 7. The flexural strength tests were conducted on beam specimens measuring 100mm x 100mm x 500mm, following the guidelines outlined in IS: 516-1959(8). These specimens were subjected to two-point loading, and the average values of three specimens for each category at 28 days, 56 days, and 91 days are presented in Fig. 8. Additionally, the load vs. deflection curves for WFS00%, WFS10%, WFS20%, and WFS30% are provided on the subsequent pages.

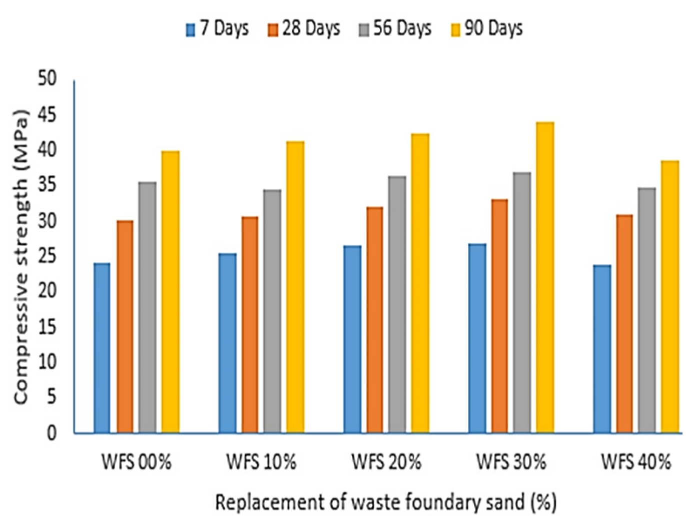

Figure 7: Comparison of Tensile strength

Table 4: Flexural Strength

S. No	Mix. No.	Flexural Strength (MPa)			
		7 Days	28 Days	56 Days	91Days
1	WFS00%	2.97	3.74	4.04	4.13
2	WFS10%	3.02	3.82	4.14	4.26
3	WFS20%	3.23	4.12	4.24	4.38
4	WFS30%	3.46	4.2	4.4	4.46
5	WFS40%	2.81	3.55	3.59	3.73

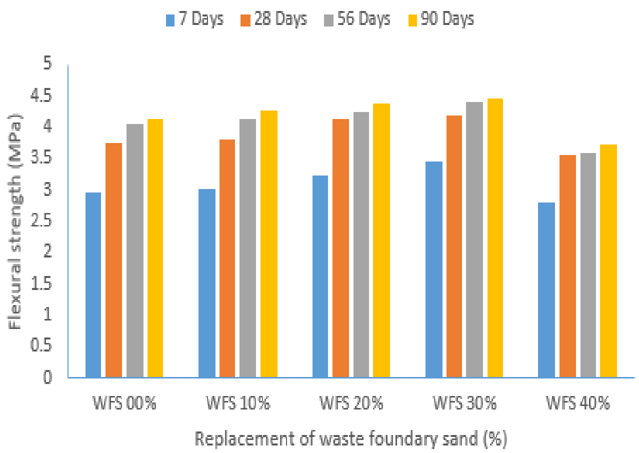

Figure 8: Comparison of flexural strength

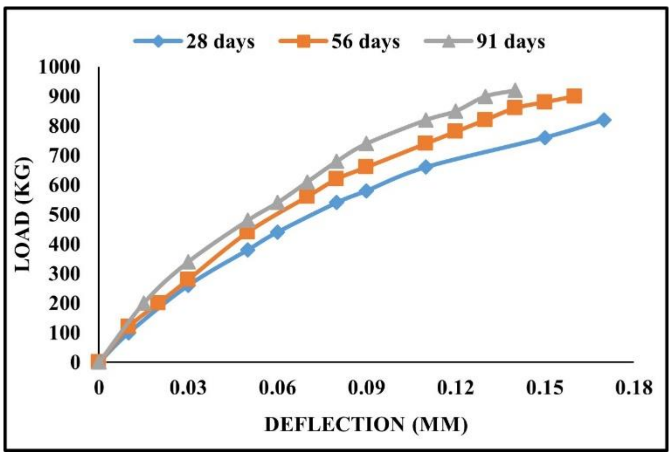

Figure 9: Load vs. Deflection curve for WFS00%

5. Microstructure Analysis

The application of transmission and scanning electron microscopy (SEM) techniques has enabled the detailed examination of concrete's microstructure, revealing its heterogeneous and complex nature. The microstructure of concrete, particularly the calcium-silica-hydrate (C-S-H) phase, plays a crucial role in determining its mechanical behavior. Factors such as particle size, shape, distribution, concentration, orientation, topology, composition, and pore structure influence the mechanical properties of C-S-H phases. WFS30%) are depicted, offering visual evidence of how the microstructure changes with the inclusion of waste foundry sand. respectively. The SEM image at 15 KX magnifications (Fig. 4.15) reveals the formation of C-S-H gel at

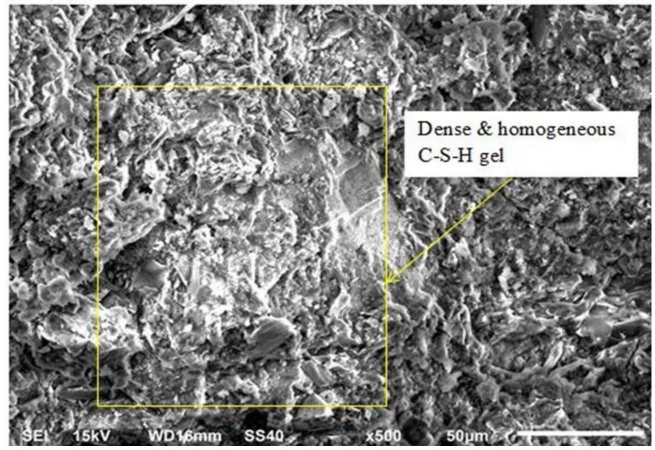

Figure 10: SEM image of WFS30%

6. Conclusions

On the basis of the experimental investigation undertaken, following conclusions are drawn:

1. Workability is decreased with the increase of foundry sand content. This may be due to the void filling action of the waste foundry sand as it is finer than the fine aggregate, which gives a high cohesion to the mix.
2. Compressive strength, split tensile strength and flexural strength of concrete specimens increased, with the increase in fine aggregate replacement by foundry sand, providing maximum strength at 30% replacement, and beyond that, the strength parameters showed a decline in their respective values.
3. The increase in compressive strength ranged from 2% to 7% depending on the percentage of waste foundry sand (WFS) and the age of testing. In comparison, the increase in splitting tensile strength varied between 6.5% and 14.5%, while for flexural strength, it ranged from 8% to 13%.
4. The increase in strength parameters may be due to the fineness of the foundry sand. The foundry sand fineness is higher than fine aggregate and reduces the porous nature in concrete thereby increasing density and strength.
5. Ultrasonic Pulse velocity increases up to 30% replacement of waste Foundry Sand. Above 30% Ultrasonic Pulse Velocity decreases.
6. The permeability of concrete containing waste foundry sand decreases up to a 30% partial replacement. This reduction occurs because the fineness of the foundry sand, which is higher than that of the fine aggregate, reduces the porous nature of the concrete, thereby decreasing its permeability.
7. The replacement of natural sand with used foundry sand up to 30% is desirable for several reasons. Firstly, it is cost-effective, as it allows for the reuse of waste material that would otherwise be disposed of, reducing the need for virgin fine aggregate.

References

[1] Abichou T, Benson C. Database on Beneficial Reuse of Foundry Byproducts, Recycled Materials in Geotechnical Applications Geotech. ASCE, Spec.Publ. 79, 1992, 210 – 223.
[2] BIS: 10262-1982. Recommended guidelines for concrete mix design, Bureau of Indian Standards, New Delhi, India
[3] BIS: 1199-1959. Indian standard methods of sampling and analysis of concrete, Bureau of Indian Standards, New Delhi, India
[4] BIS: 3085 –1965, "Method of test for Permeability of Cement Mortar and Concrete" Bureau of Indian Standards, New Delhi, India
[5] BIS: 383-1970. Specifications for coarse and fine aggregates from natural sources for concrete, Bureau of Indian Standards, New Delhi, India
[6] BIS: 516-1959. Indian standard code of practice – methods of test for strength of concrete, Bureau of Indian Standards, New Delhi, India
[7] BIS: 5816-1999. Splitting tensile strength of concrete – test method, Bureau of Indian standards. New Delhi, India
[8] Eknath P. Salokhe D., "Application of foundry waste sand in the manufacture of concrete", IOSR-JMCE, ISSN: 2278-1684, 2005, 43-48.
[9] Fiore S, Zanetti MC. Foundry wastes reuse and recycling in concrete production.American Journal of Environmental Sciences3(3): 2007; 135–42.
[10] Guney, Yucel S, Yasin D; Yalcin M; TuncanA. Re-usage of waste foundry sand in high-strength concrete. Waste Management, Vol. 30, 2010, 1705–1713
[11] Johnny B, Taher L, Ellie F, "Utilization of recycled and waste materials in various construction applications", American Journal of Environmental Science, 9 (1), 2013, 14-24,
[12] IREDA-CII Report 2004
[13] Khatib JM, Ellis DJ. Mechanical properties of concrete containing foundry sand. ACI Special Publication;(SP-200). 2001. 733–48
[14] Kumbhar P, Usharani S. "Experimental study of mechanical properties of concrete blended with used foundry sand", Global Journal Engineering and Applied Sciences, ISSN 2249-2631, 2011, 122-126,
[15] Naik R and Singh S S, Permeability of Flowable Slurry Materials Containing Foundry Sand and Fly Ash, Journal of Geotechnical and Geoenvironmental Engineering-ASCE, 123(5), 1997, 446-452.
[16] Naik TR, Kraus RN, Chun YM, Ramme WB, Singh SS. Properties of field manufactured cast-concrete products utilizing recycled materials. J Mater Civil Eng 15(4):2003; 400–7.
[17] Naik TR, Viral M, Dhaval M, Mathew P., "Utilization of used foundry sand in concrete", Journal of Materials in Civil Engineering, Vol. 6, 1994, 516-520,
[18] Park C; Kim B; Yu Y. The regeneration of waste foundry sand and residue stabilization using coal refuse. Journal of Hazardous Materials, vol. 203– 204, 2012, 176– 182.
[19] Reddi L, Rieck P, Schwab G.Stabilization of Phenolics in Foundry Sand Using Cementations Materials, Journals of Hazardous Materials, 45, 1995, 89-106.

Cite this article as Himanshu Sahni, Noorul Bashar, To study the mechanical and durability characteristics of concrete utilizing waste foundry sand, International Journal of Research in Engineering and Innovation Vol-8, Issue-3 (2024), 114-119. *https://doi.org/10.36037/IJREI.2024.8303*.