

# Use of Waste Foundry Sand in Evaluation of Low-Cost Concrete

Mr. Suraj Raju Kesharwani<sup>1</sup>, Mr. Ishant B. Dahat<sup>2</sup>

<sup>1</sup>Student M. Tech. (Structural Engg.) Dept. of Civil Engineering, G. H. Rasoni University, Amaravati, Maharashtra, India

<sup>2</sup>Assist. Professor Dept. of Civil Engineering, G. H. Rasoni University, Amaravati, Maharashtra, India

<sup>1</sup>[surajkesharwani987@gmail.com](mailto:surajkesharwani987@gmail.com)

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*Abstract— The rapid expansion of urbanization, industrialization, and infrastructure development across the world has resulted in a substantial increase in the consumption of construction materials, particularly natural river sand used as fine aggregate in concrete production. Excessive extraction of river sand has created serious environmental issues such as riverbank erosion, depletion of groundwater resources, destruction of aquatic ecosystems, and ecological imbalance. Simultaneously, foundry industries generate enormous quantities of industrial waste in the form of Waste Foundry Sand (WFS), creating significant disposal, environmental, and economic challenges. Large amounts of WFS are disposed of in landfills every year, occupying valuable land space and increasing waste management costs.*

*Waste Foundry Sand is a high-quality silica-rich by-product obtained from ferrous and non-ferrous metal casting industries after repeated use in moulding and core-making processes. Due to its favorable physical and chemical properties, including high silica content, fine particle size distribution, and good thermal stability, WFS has emerged as a promising alternative material for replacing natural fine aggregate in concrete production.*

*The utilization of Waste Foundry Sand in concrete not only provides an effective solution for industrial waste management but also contributes significantly to sustainable development by conserving natural resources and reducing environmental pollution. Incorporating WFS into concrete promotes the concept of green construction and supports circular economy principles by converting industrial waste into valuable construction materials.*

*This review paper presents a comprehensive evaluation of previous research studies related to the application of Waste Foundry Sand in concrete. The paper critically analyses the influence of WFS on various fresh and hardened properties of concrete, including workability, compressive strength, split tensile strength, flexural strength, durability, water absorption characteristics, and long-term performance. Furthermore, the environmental and economic benefits associated with WFS utilization are discussed in detail.*

*The findings from various studies indicate that the optimum replacement level of natural sand with Waste Foundry Sand generally ranges between 20% and 40%. Within this range, concrete exhibits improved compressive strength, enhanced particle packing density, reduced permeability, and lower water absorption while maintaining acceptable workability characteristics. However, replacement levels beyond the optimum percentage may adversely affect concrete performance due to excess fines and reduced bonding efficiency.*

*Overall, Waste Foundry Sand demonstrates considerable potential for producing low-cost, durable, environmentally sustainable, and high-performance concrete. Its utilization can substantially reduce dependence on natural river sand, minimize industrial waste disposal problems, lower construction costs, and contribute towards sustainable infrastructure development. Future research should focus on long-term durability studies, fiber-reinforced WFS concrete, and large-scale field implementation to fully establish its practical applications in the construction industry.*

**Keywords:** Waste Foundry Sand (WFS), Sustainable Concrete, Green Concrete, Fine Aggregate Replacement, Compressive Strength, Water Absorption, Durability, Circular Economy, Sustainable Construction.

## I. INTRODUCTION

Concrete is one of the most extensively used construction materials worldwide due to its excellent mechanical properties, durability, versatility, ease of availability, and cost-effectiveness. It forms the backbone of modern infrastructure and is widely used in the construction of buildings, bridges, highways, dams, airports, industrial structures, and other civil engineering projects. Concrete is primarily composed of cement, fine aggregate, coarse aggregate, water, and occasionally chemical and mineral admixtures to improve its performance characteristics. Among these constituents, fine aggregate plays a crucial role in influencing the strength, workability, density, permeability, and overall durability of concrete.

In recent decades, rapid urbanization, industrialization, and population growth have significantly increased the demand for construction materials worldwide. The increasing rate of infrastructure development has led to excessive consumption of natural river sand, which is conventionally used as fine aggregate in concrete production. Continuous extraction of river sand from riverbeds has resulted in severe environmental problems and ecological disturbances. Excessive sand mining not only damages river ecosystems but also threatens long-term sustainability by depleting finite natural resources.

The major environmental impacts associated with excessive river sand extraction include:

- Riverbank erosion and instability.
- Lowering of groundwater tables.
- Destruction of aquatic habitats and ecosystems.
- Soil erosion and loss of biodiversity.
- Increased environmental degradation.

- Rising costs due to scarcity of natural sand.

Simultaneously, various industries generate enormous quantities of solid waste materials that pose serious environmental management challenges. Among these industrial wastes, Waste Foundry Sand (WFS) has emerged as a significant by-product generated by ferrous and non-ferrous metal casting industries. Foundry industries utilize high-quality silica sand for preparing moulds and cores used in metal casting operations. After repeated use, the sand gradually loses its binding and thermal properties and is discarded as waste.

Traditionally, Waste Foundry Sand is disposed of in landfills, creating several environmental and economic concerns. Large-scale disposal occupies valuable land resources and increases waste management expenses. In addition, improper disposal may contribute to land pollution and groundwater contamination.

The environmental issues associated with WFS disposal include:

- Land pollution.
- Groundwater contamination.
- Increased landfill requirements.
- Increased disposal and maintenance costs.
- Wastage of reusable industrial resources.

In recent years, researchers have focused on utilizing industrial by-products as alternative construction materials to achieve sustainable development goals. Waste Foundry Sand has attracted considerable attention because of its favorable physical and chemical properties, particularly its high silica content and fine particle size distribution. Its utilization as a partial replacement for natural fine aggregate

in concrete offers a practical solution to both environmental and construction-related challenges.

The incorporation of Waste Foundry Sand in concrete promotes the concept of sustainable construction and circular economy by converting industrial waste into valuable construction resources. It helps conserve natural river sand, reduces environmental pollution, lowers landfill burdens, and decreases the overall cost of concrete production. Numerous studies have demonstrated that optimum replacement levels of WFS can improve concrete properties such as compressive strength, particle packing density, and durability while maintaining acceptable workability.

Therefore, the use of Waste Foundry Sand in concrete production represents an effective approach toward producing low-cost, durable, and environmentally sustainable concrete for future infrastructure development.

## II. MATERIALS USED

The selection of appropriate construction materials plays an important role in determining the strength, durability, workability, and overall performance of concrete. In the present study, conventional concrete ingredients along with Waste Foundry Sand (WFS) were used to produce sustainable and low-cost concrete. The materials used are described below.

### 2.1 Cement

Ordinary Portland Cement (OPC) of 53 Grade was used as the primary binding material throughout the study. OPC 53 Grade was selected due to its high early strength, consistent quality, and widespread availability in the construction industry.

The cement used complied with the provisions of IS 12269. It provides adequate strength development and good bonding between aggregates and cement paste. Cement acts as a hydraulic binder that reacts with water to form a

hardened matrix responsible for the strength and durability of concrete.

The important functions of cement in concrete include:

- Binding fine and coarse aggregates together.
- Providing strength to concrete through hydration reactions.
- Improving durability and impermeability.
- Enhancing structural integrity.

### 2.2 Fine Aggregate

Natural river sand conforming to IS 383 specifications was used as fine aggregate in the study. Fine aggregate occupies approximately 30% to 35% of the concrete volume and significantly influences workability, strength, and durability.

River sand was partially replaced with Waste Foundry Sand at different percentages to evaluate its suitability as an alternative material.

The primary functions of fine aggregate are:

- Filling voids between coarse aggregate particles.
- Improving workability.
- Reducing shrinkage.
- Enhancing concrete density and strength.

### 2.3 Coarse Aggregate

Crushed angular coarse aggregate of 20 mm maximum size was used in the concrete mix. The aggregate was clean, hard, durable, and free from organic impurities.

Coarse aggregate forms the skeleton of concrete and contributes significantly to load-bearing capacity.

The major functions of coarse aggregate include:

- Providing strength and stability.
- Reducing cement consumption.
- Minimizing shrinkage.
- Improving dimensional stability.

- Assisting in uniform mixing.
- Supporting strength development during curing.

*III. PROPERTIES OF WASTE FOUNDRY SAND*

The engineering properties of Waste Foundry Sand determine its suitability for concrete applications. Both physical and chemical properties significantly influence fresh and hardened concrete performance.

**2.4 Waste Foundry Sand (WFS)**

Waste Foundry Sand is an industrial by-product obtained from ferrous and non-ferrous metal casting industries. High-quality silica sand is repeatedly used for mould and core preparation during metal casting operations. After several cycles, the sand loses its desired properties and is discarded.

Instead of disposing of this material in landfills, it can be effectively utilized as a partial replacement for natural fine aggregate in concrete production.

The advantages of utilizing Waste Foundry Sand include:

- Reduction in industrial waste disposal.
- Conservation of natural river sand.
- Reduction in environmental pollution.
- Improvement in concrete density.
- Promotion of sustainable construction practices.

**2.5 Water**

Potable water free from harmful impurities was used for mixing and curing concrete specimens. The water quality complied with IS 456 recommendations.

Water plays a crucial role in the hydration process of cement and directly affects concrete strength and workability.

The functions of water include:

- Initiating cement hydration.
- Providing workability.

**3.1 PHYSICAL PROPERTIES OF WASTE FOUNDRY SAND**

*Table 3.1 Physical Properties of Waste Foundry Sand*

Property	Value
Specific Gravity	2.39–2.55
Bulk Density	2590 kg/m <sup>3</sup>
Water Absorption	0.45%
Moisture Content	0.1–10.1%
Plasticity	Non-plastic
Particle Shape	Sub-angular to spherical

*1) Specific Gravity*

The specific gravity of Waste Foundry Sand ranges from 2.39 to 2.55, which is comparable to natural river sand. This indicates that WFS can effectively replace conventional fine aggregate without significantly affecting concrete density.

*2) Bulk Density*

The bulk density of WFS is approximately 2590 kg/m<sup>3</sup>. Higher bulk density contributes to better compaction and reduced internal voids within concrete.

*3) Water Absorption*

Waste Foundry Sand exhibits relatively low water absorption of about 0.45%, which helps improve durability and reduce permeability.

*4) Moisture Content*

The moisture content ranges between 0.1% and 10.1%, depending upon storage conditions and foundry processes.

Moisture content must be considered during mix design calculations.

5) *Plasticity*

Waste Foundry Sand is non-plastic in nature. Therefore, it does not exhibit undesirable shrinkage characteristics associated with clay-containing materials.

6) *Particle Shape*

The particles are generally sub-angular to spherical in shape, which improves particle packing and produces denser concrete.

3.2 CHEMICAL PROPERTIES OF WASTE FOUNDRY SAND

Table 3.2 Chemical Composition of Waste Foundry Sand

Chemical Constituent Percentage (%)

SiO <sub>2</sub>	87.91
Al <sub>2</sub> O <sub>3</sub>	4.70
Fe <sub>2</sub> O <sub>3</sub>	0.94
CaO	0.14
MgO	0.30
Na <sub>2</sub> O	0.19
K <sub>2</sub> O	0.25
SO <sub>3</sub>	0.09

7) *Silicon Dioxide (SiO<sub>2</sub>)*

Silicon dioxide is the major constituent of Waste Foundry Sand, comprising approximately 87.91% of the total composition. High silica content improves strength, hardness, and durability.

8) *Aluminium Oxide (Al<sub>2</sub>O<sub>3</sub>)*

Aluminium oxide contributes to thermal stability and overall material performance.

9) *Iron Oxide (Fe<sub>2</sub>O<sub>3</sub>)*

Iron oxide is present in small quantities and influences the color and certain mechanical characteristics.

10) *Calcium Oxide (CaO)*

Calcium oxide participates in hydration reactions and contributes marginally to strength development.

11) *Magnesium Oxide (MgO)*

Magnesium oxide is present in very small quantities and generally does not adversely affect concrete performance.

12) *Sodium Oxide (Na<sub>2</sub>O) and Potassium Oxide (K<sub>2</sub>O)*

These alkali compounds are present in minor amounts and should be controlled to minimize the risk of alkali-silica reactions.

13) *Sulphur Trioxide (SO<sub>3</sub>)*

Sulphur trioxide is present in negligible quantities and remains within acceptable limits for concrete applications.

IV. METHODOLOGY

The present study was carried out to evaluate the feasibility of utilizing Waste Foundry Sand (WFS) as a partial replacement for natural fine aggregate in concrete production. The overall methodology consisted of material collection, characterization, mix preparation, specimen casting, curing, and laboratory testing to assess the performance of concrete containing different percentages of Waste Foundry Sand.

Initially, all the required materials, namely Ordinary Portland Cement (OPC), natural river sand, coarse aggregate, Waste Foundry Sand, and potable water, were collected from reliable sources. The physical and chemical properties of each material were determined according to relevant Indian Standard specifications to ensure their suitability for concrete production.

Concrete mixes were prepared by partially replacing natural river sand with Waste Foundry Sand at various percentages while maintaining all other parameters constant. Five different concrete mixtures were prepared for experimental investigation.

The replacement percentages considered in this study were:

- Conventional concrete (0% WFS)
- 20% WFS replacement
- 40% WFS replacement
- 60% WFS replacement
- 80% WFS replacement

After preparing the concrete mix, specimens were cast using standard moulds and compacted properly to eliminate air voids. The specimens were then demoulded after 24 hours and cured in clean water for the specified curing periods.

Fresh concrete tests and hardened concrete tests were subsequently performed to evaluate the effect of Waste Foundry Sand on the overall performance of concrete.

The overall research methodology can be summarized as follows:

1. Collection of materials.
2. Material characterization.
3. Concrete mix design preparation.
4. Partial replacement of natural sand with Waste Foundry Sand.
5. Casting of concrete specimens.
6. Water curing of specimens.
7. Laboratory testing and performance evaluation.
8. Analysis of results.

## V. TESTS CONDUCTED

The performance of Waste Foundry Sand concrete was evaluated by conducting various tests on both fresh and hardened concrete.

### 5.1 Fresh Concrete Tests

#### 1. Slump Test

The slump test was conducted to determine the workability and consistency of fresh concrete mixtures. The test was performed according to standard procedures using a slump cone. The reduction in slump values with increasing WFS content was analyzed to understand the effect of finer particles on concrete workability.

#### 2. Flow Table Test

The flow table test was carried out to evaluate the flow characteristics and cohesiveness of fresh concrete. This test provided information regarding the ability of concrete to spread under vibration and helped assess its suitability for practical construction applications.

### 5.2 Hardened Concrete Tests

#### 1. Compressive Strength Test

The compressive strength test was performed using a Compression Testing Machine (CTM). The specimens were tested after the designated curing period to determine the load-carrying capacity of concrete. Compressive strength is one of the most important parameters used to evaluate concrete quality and structural performance.

#### 2. Water Absorption Test

The water absorption test was conducted to assess the durability characteristics of concrete. Lower water absorption indicates reduced permeability and improved resistance to moisture penetration, thereby enhancing the service life of concrete structures.

## VI. RESULTS AND DISCUSSION

The experimental results indicate that the incorporation of Waste Foundry Sand significantly influences the mechanical and durability properties of concrete.

### 6.1 Compressive Strength Results

Concrete Mix	Compressive Strength (MPa)
Conventional Concrete	26.07

Concrete Mix	Compressive Strength (MPa)
WFS 20%	28.14
WFS 40%	32.00
WFS 60%	25.33
WFS 80%	16.59

The results reveal that compressive strength increased gradually with the increase in Waste Foundry Sand content up to 40% replacement. The maximum compressive strength of 32 MPa was obtained at 40% replacement due to improved particle packing and reduced internal voids.

However, beyond 40% replacement, the compressive strength decreased considerably. Excessive fines and increased surface area demand additional water, adversely affecting the bond between cement paste and aggregates.

Therefore, 40% replacement was identified as the optimum percentage for achieving maximum strength.

### 6.2 Water Absorption Results

Concrete Mix	Water Absorption (%)
Conventional Concrete	4.64
WFS 20%	4.42
WFS 40%	4.10
WFS 60%	3.80
WFS 80%	3.56

The water absorption results indicate a gradual decrease with increasing Waste Foundry Sand content. The finer particles effectively filled the micro-voids within the concrete matrix, producing denser concrete.

Lower water absorption enhances durability by reducing permeability and minimizing moisture penetration into concrete structures.

### VII. RESEARCH GAPS

Based on the literature review and available studies, the following research gaps have been identified:

1. Most studies focus only on short-term mechanical properties, with limited information available on long-term durability.
2. Limited research has been conducted on the application of Waste Foundry Sand in high-strength and high-performance concrete.
3. Very few studies have evaluated the field performance of Waste Foundry Sand concrete under actual service conditions.
4. There is a lack of standardized design guidelines and mix design procedures for WFS concrete.
5. Limited research is available on hybrid concrete systems incorporating Waste Foundry Sand with supplementary cementitious materials.

### VIII. CONCLUSION

The present study demonstrates that Waste Foundry Sand is an effective, economical, and environmentally sustainable alternative to natural river sand in concrete production. The utilization of Waste Foundry Sand not only addresses industrial waste disposal problems but also helps conserve natural resources and reduce environmental degradation caused by excessive river sand mining.

The experimental findings indicate that the optimum replacement percentage generally lies between 20% and 40%, with 40% replacement producing the highest compressive strength. The incorporation of Waste Foundry Sand improves particle packing density, reduces internal voids, and enhances the overall performance of concrete.

Furthermore, water absorption decreases with increasing WFS content, indicating improved durability characteristics. The use of WFS also contributes to reducing landfill burdens and lowering construction costs.

Therefore, Waste Foundry Sand can be successfully utilized for producing sustainable, economical, and environmentally friendly concrete. Its adoption supports circular economy

principles and can significantly contribute to future sustainable infrastructure development.

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