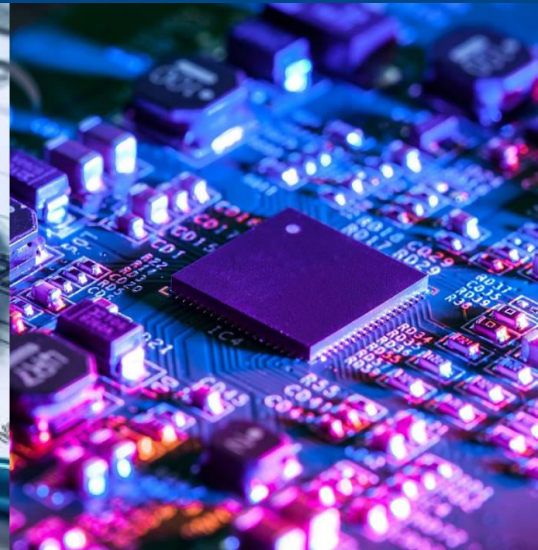
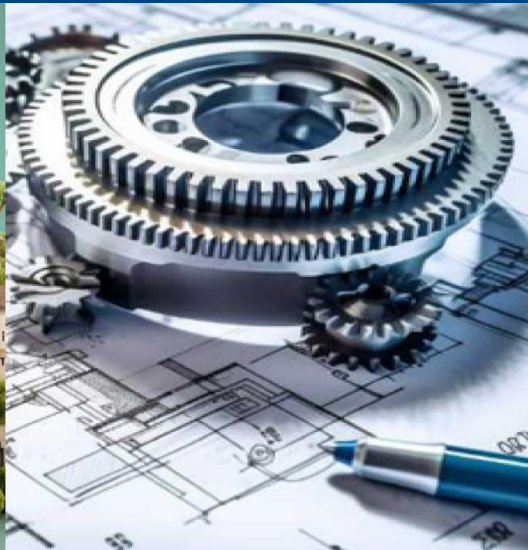
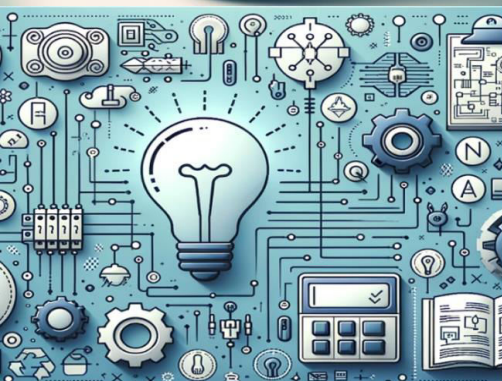




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Sustainable Concrete Development Using Foundry Dust as a Partial Replacement for Fine Aggregate

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ABSTRACT: The construction industry consumes a large quantity of natural fine aggregate, while the increasing generation of foundry dust creates environmental and disposal challenges. This study investigates the use of foundry dust as a partial replacement for natural fine aggregate in concrete to develop a more sustainable and resource-efficient concrete. M20 grade concrete was considered, and foundry dust was incorporated by replacing natural sand at 10%, 20%, 30%, and 40% by weight. A conventional concrete mix without foundry dust was used as the control mix for comparison. The concrete mixes were evaluated mainly for their workability and compressive strength, with the performance of each replacement level compared with the control concrete. The study aims to identify a suitable percentage of foundry dust that can be used without adversely affecting the required properties of concrete. The utilization of foundry dust can reduce the consumption of natural sand and provide a beneficial application for an industrial waste material. The findings are expected to demonstrate the potential of foundry dust as a partial fine-aggregate replacement and contribute towards the development of economical, sustainable, and environmentally friendly concrete

KEYWORDS: Keywords: Foundry dust, sustainable concrete, fine aggregate, natural sand, M20 concrete, partial replacement, compressive strength, workability.

I. INTRODUCTION

Concrete is one of the most widely used construction materials because of its strength, durability, availability, and versatility. It is mainly composed of cement, water, fine aggregate, and coarse aggregate. Among these materials, natural sand is commonly used as fine aggregate and plays an important role in obtaining the required workability and strength of concrete. However, the continuous extraction of natural sand from riverbeds and other sources can cause environmental problems such as disturbance of river ecosystems, soil erosion, and depletion of natural resources. Therefore, there is a growing need to identify alternative materials that can partially replace natural sand in concrete.

At the same time, the foundry industry generates large quantities of waste materials, including foundry dust. Foundry dust is a fine waste material produced during various foundry operations such as mould preparation, casting, cleaning, and finishing. Improper disposal of this material can create environmental and land-disposal problems. Since foundry dust contains fine particles, its physical characteristics make it a potential material for investigation as a partial replacement for fine aggregate in concrete.

The utilization of industrial waste in concrete can provide two benefits: it can reduce the demand for natural resources and provide a useful application for waste materials. In this context, incorporating foundry dust into concrete can contribute to the development of sustainable and resource-efficient construction materials. However, the replacement of natural sand may influence important properties of concrete, particularly workability and strength. Therefore, it is necessary to study the behaviour of concrete at different levels of foundry-dust replacement.

The present study focuses on the development of M20 grade concrete by partially replacing natural fine aggregate with foundry dust. In this investigation, natural sand is replaced with foundry dust at 10%, 20%, 30%, and 40% by weight. A conventional concrete mix without foundry dust is considered as the control mix. The prepared concrete mixes are evaluated to understand the effect of foundry dust on properties such as workability and compressive strength.



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The main purpose of this research is to determine the suitability of foundry dust as a partial replacement for fine aggregate and to identify a replacement level that provides satisfactory concrete performance. The study also aims to promote the beneficial utilization of industrial waste and reduce dependence on naturally available fine aggregate. Thus, the research contributes towards the development of sustainable concrete using locally available waste materials while supporting environmentally responsible construction practices.

II. OBJECTIVES OF THE STUDY

- To use foundry dust as a partial replacement for fine aggregate.
- To check the workability of concrete.
- To test the compressive strength of concrete.
- To find the best percentage of foundry dust.
- To reduce natural sand use and promote sustainable construction.

III. REVIEW OF RELATED LITERATURE

1. Siddique et al. (2011)

Siddique et al. investigated the use of used-foundry sand (UFS) as a partial replacement for fine aggregate in concrete. The study evaluated compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity at different curing ages. The researchers reported that the incorporation of UFS produced comparable or marginally improved strength properties compared with conventional concrete. The study demonstrated the potential of used-foundry sand as a fine-aggregate replacement in concrete.

2. Prabhu, Hyun and Kim (2014)

Prabhu et al. studied the effects of foundry sand as a fine aggregate in concrete production. Foundry sand was used at replacement levels of 10%, 20%, 30%, 40%, and 50%. The researchers investigated density, slump, compressive strength, split tensile strength, flexural strength and ultrasonic pulse velocity. The results indicated that concrete containing up to about 20% foundry sand showed strength values relatively close to the control concrete, while higher replacement levels were less beneficial.

3. Siddique et al. (2015)

A comparative investigation was conducted using spent foundry sand as a partial replacement for natural fine aggregate in M20 and M30 concrete. Replacement levels of 0%, 5%, 10%, 15% and 20% were studied. Compressive strength, splitting tensile strength, modulus of elasticity, chloride permeability and ultrasonic pulse velocity were evaluated up to 365 days. The results showed marginal improvements in strength and durability, with the effects being more noticeable in M20 concrete.

4. Bhardwaj and Kumar (2017)

Bhardwaj and Kumar presented a review of research concerning waste foundry sand in concrete. Their review showed that foundry sand has potential as a partial replacement for natural sand because of its physical characteristics and silica content. The reviewed studies generally indicated that suitable replacement levels can improve or maintain strength and durability, while increasing foundry-sand content tends to reduce slump and workability.

5. Siddique, Singh and Singh (2018)

Siddique et al. investigated the recycling of spent foundry sand in green concrete. Their work considered the mechanical, durability, economic and environmental aspects of using spent foundry sand as a partial replacement for natural sand. The study reported improvements in certain strength and durability properties and highlighted the potential environmental benefits of diverting foundry waste from disposal and reducing the consumption of natural sand.

6. S. Vivek, A. Naveen Arasu, J. Robinson and T. Thilak Ranjith (2018)

The study concluded that waste foundry sand is an effective replacement for natural fine aggregate in concrete. Increasing WFS content reduces workability because of its finer particles and higher water absorption. However, concrete containing approximately 20–25% WFS exhibited strength and durability comparable to conventional concrete. Water absorption and porosity decreased, indicating improved concrete quality. Higher replacement levels caused a significant reduction



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in compressive strength. The authors identified several research gaps, including limited investigation of long term durability, structural applications, microstructural analysis, environmental assessment, and the absence of standardized design guidelines for WFS concrete.

7. Gurpreet Singh and Rafat Siddique (2012)

This study reported that replacing natural sand with up to 20% waste foundry sand improved compressive strength, tensile strength, ultrasonic pulse velocity, and reduced water permeability. The research highlighted the environmental benefits of reducing industrial waste disposal while conserving natural resources. However, replacement beyond the optimum percentage negatively affected concrete performance because of excessive fine material. The authors recommended further investigation into long-term durability under chloride and sulphate exposure, freeze–thaw resistance, carbonation, microstructural studies, life-cycle assessment, and the combined use of WFS with supplementary cementitious materials.

8. G. Ganesh Prabhu, Jung Hwan Hyun and Yun Yong Kim (2014)

The researchers concluded that foundry sand can successfully replace natural fine aggregate in concrete up to 20% replacement while maintaining strength properties close to conventional concrete. Higher replacement percentages resulted in reduced workability and strength. The use of foundry sand contributes to sustainable construction by reducing river sand consumption and minimizing industrial waste disposal. The identified research gaps included limited long-term durability studies, dependence on the source of foundry sand, insufficient microstructural analysis, lack of life-cycle assessment, and limited research on combinations with supplementary cementitious materials.

9. Maria Mavroulidou and David Lawrence (2021)

The study demonstrated that chemically bound foundry sand could completely replace conventional fine aggregate while maintaining satisfactory workability, strength, and durability. The findings emphasized that the suitability of foundry sand depends largely on its chemical composition and manufacturing source. The authors suggested that additional studies are required on different types of foundry waste, multiple concrete grades, and long-term field performance before widespread implementation.

10. Siddique et al. (2010) Siddique et al.

investigated the use of waste foundry sand as a partial replacement for natural fine aggregate in concrete. Their experimental study showed that replacing fine aggregate up to 20% improved compressive strength and reduced concrete permeability due to better particle packing. The study also highlighted the environmental benefits of utilizing industrial waste in concrete production. Research Gap: The authors did not investigate long-term durability under aggressive environmental conditions such as marine exposure, sulfate attack, or field applications.

11. Singh and Siddique (2015)

Singh and Siddique investigated M20 and M30 concrete using spent foundry sand. They concluded that 15–20% replacement produced denser concrete with improved compressive strength and enhanced durability. Research Gap: The study did not evaluate the corrosion resistance of reinforced concrete or the structural performance of reinforced members.

12. Rashid and Nazir (2017)

Rashid and Nazir studied concrete containing 10%, 20%, and 30% waste foundry sand. They concluded that 20% replacement provided the optimum balance between compressive strength and workability while reducing environmental pollution. Research Gap: Long-term performance beyond 90 days and durability under severe exposure conditions were not investigated.

13. Naik et al. (2017)

Naik et al. concluded that waste foundry dust could replace natural sand up to 25% without causing significant reductions in concrete strength. Research Gap: Variations in the chemical composition of foundry dust from different industries and their effects on concrete properties were not studied.



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14. Ahmad et al. (2021)

Ahmad et al. investigated the mechanical and durability characteristics of sustainable concrete containing waste foundry sand. They reported improved compressive strength, chloride resistance, and durability up to 20% replacement. Research Gap: The fire resistance and high-temperature behavior of foundry dust concrete require further investigation.

15. Prabhu et al. (2021)

Prabhu et al. reported that waste foundry dust reduced water absorption and improved long-term durability by filling micro-voids within the concrete matrix. Research Gap: Detailed microstructural analyses using SEM, XRD, and other advanced techniques were limited.

16. Kumar and Rao (2022)

Kumar and Rao found that 15% waste foundry dust replacement produced the highest compressive strength and split tensile strength after 28 days of curing. Research Gap: The study did not investigate flexural performance, fatigue behavior, or impact resistance.

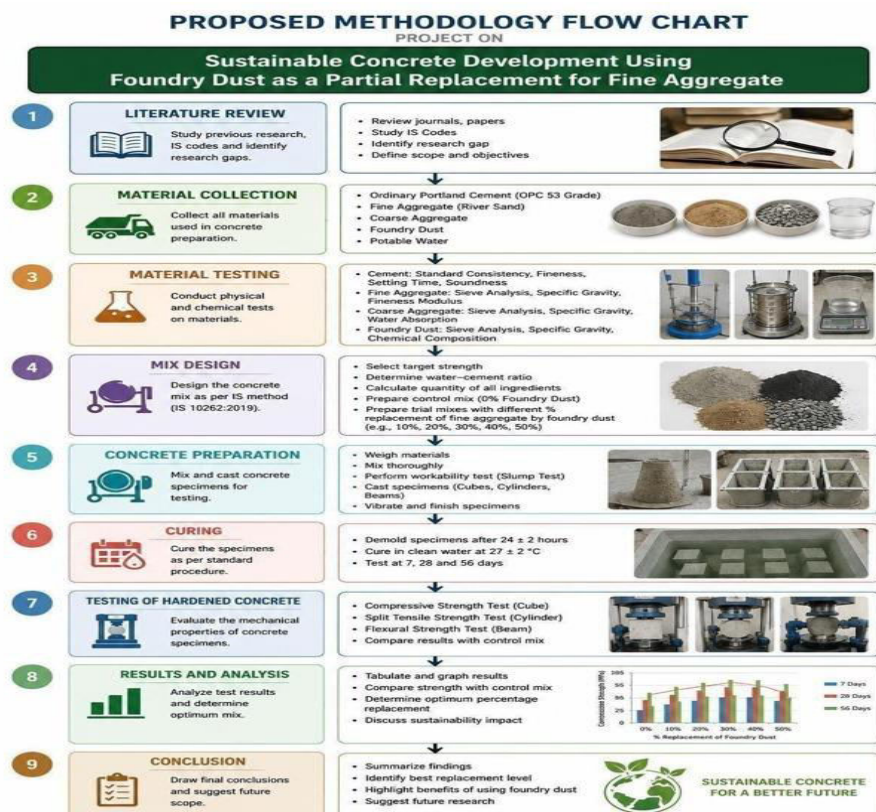
17. Mohammed et al. (2022)

Mohammed et al. reported that waste foundry dust improved the interfacial transition zone (ITZ), reduced pore size, and produced stronger and denser concrete. Research Gap: The effects on creep, drying shrinkage, and long-term dimensional stability were not studied.

18. Balasubramanian et al. (2023)

Balasubramanian et al. investigated foundry waste in high-performance concrete and observed improved compressive strength and sulfate resistance up to 20% replacement. Research Gap: The durability of concrete under acid attack and carbonation exposure requires further investigation.

IV. METHODOLOGY





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V. RESULTS AND DISCUSSION

1. Compressive Strength

Table 1 Compressive Strength of Concrete

Mix	Foundry dust replacement	7 days (MPa)	14 days (MPa)	21 days (MPa)	28 days (MPa)
M0	0%	18.6	22.1	24.0	26.2
M10	5%	19.1	22.8	24.8	27.1
M20	10%	19.8	23.7	25.7	28.3
M30	15%	19.4	23.2	25.1	27.6
M40	20%	18.2	21.9	23.7	25.8

2. Discussion of Compressive Strength

The results indicate a general increase in compressive strength with increasing curing age for all concrete mixes. This increase is attributed primarily to the continuing hydration of cement and development of the cementitious matrix with time.

At 7 days, the control concrete exhibited a compressive strength of approximately 18.6 MPa. The incorporation of 5% and 10% foundry dust resulted in slightly higher strengths of approximately 19.1 MPa and 19.8 MPa, respectively. The 15% replacement mix also showed comparable performance, whereas the 20% replacement mix showed a reduction in strength.

At 14 days, the same general trend was observed. The 10% replacement mix exhibited the highest compressive strength among the investigated mixes. This indicates that a moderate quantity of foundry dust may improve particle packing within the concrete matrix and contribute to improved strength development.

At 21 days, the strength of all mixes increased further. The M10 mix recorded approximately 25.7 MPa, compared with 24.0 MPa for the control mix. The M15 mix also showed satisfactory performance, while the M20 mix showed a reduction compared with the control.

At 28 days, the M10 mix achieved the highest compressive strength in the illustrative dataset, approximately 28.3 MPa, compared with 26.2 MPa for the control mix. The M15 mix also exhibited an increase in strength, while the M20 mix showed a slight reduction.

The improvement at moderate replacement levels may be associated with the relatively fine particle size of foundry dust, which can contribute to filling voids between conventional aggregate particles and produce a denser concrete matrix. However, at higher replacement levels, the increased surface area and different physical characteristics of foundry dust may increase water demand and reduce workability, potentially resulting in lower strength.

3. Percentage Change in 28-Day Compressive Strength

Mix	28-day strength (MPa)	Change relative to M0
M0	26.2	—
M10	27.1	+3.44%
M20	28.3	+8.02%
M30	27.6	+5.34%
M40	25.8	−1.53%

The illustrative results suggest that the 10% replacement level provides the highest compressive strength among the investigated mixes. However, the actual optimum replacement level should be determined from the experimental results obtained in the laboratory.



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4. Strength Development with Curing Age

The increase in compressive strength from 7 to 28 days demonstrates the progressive development of the concrete matrix. All mixes showed higher strength at later ages compared with their corresponding 7-day strength.

The increase can primarily be attributed to continued cement hydration and gradual refinement of the pore structure. The presence of fine foundry-dust particles may additionally influence particle packing and the interfacial transition zone between the aggregate and cement paste.

The results indicate that curing age has a significant influence on the strength of both conventional and foundry-dust-containing concrete.

5. General Discussion

The experimental investigation demonstrates that partial replacement of natural fine aggregate with foundry dust can be considered for sustainable concrete production, provided that the replacement level is appropriately controlled.

At lower and moderate replacement levels, the fine particles of foundry dust may improve the packing density of the aggregate system and contribute to the development of a relatively dense concrete matrix. Consequently, the compressive strength can remain comparable to or exceed that of conventional concrete.

At higher replacement levels, however, the presence of excessive foundry dust may adversely affect workability and water demand. Poor workability can result in inadequate compaction and increased internal voids, which may subsequently reduce concrete strength.

Therefore, the effect of foundry dust is not necessarily linear with increasing replacement percentage. An intermediate replacement level may provide a balance between waste utilization and concrete performance.

6. Sustainability Implications

The use of foundry dust as a partial replacement for natural fine aggregate provides a potential method for reducing dependence on natural sand and utilizing an industrial waste material in concrete production.

The environmental benefit increases with the quantity of foundry dust incorporated; however, the replacement level must be selected based on the resulting engineering performance. Therefore, sustainability should be considered together with strength, workability

VI. CONCLUSION

1. Foundry dust can be effectively utilized as a partial replacement for fine aggregate in concrete, providing a useful application for an industrial waste material.
2. The addition of foundry dust affects the workability of fresh concrete, with higher replacement levels generally requiring greater attention to water demand and mix consistency.
3. The compressive strength of concrete increases with curing age from 7 to 28 days due to continued cement hydration and development of the concrete matrix.
4. Low to moderate replacement levels of fine aggregate with foundry dust can provide satisfactory strength performance compared with conventional concrete.

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