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A Review Paper on Experimental Investigation on High Strength Concrete Incorporating M-Sand and Iron Ore Tailing as Partial Fine Aggregate Replacement

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Abstract

The increasing demand for high-strength concrete and the depletion of natural river sand have created a need for sustainable alternative materials in concrete production. This study experimentally investigates the use of manufactured sand (M-sand) and iron ore tailings (IOT) as partial replacements for natural fine aggregate in high-strength concrete. M-sand is used as an alternative to conventional river sand, while iron ore tailings, a waste material generated during iron ore processing, are incorporated to reduce the environmental impact associated with their disposal and to conserve natural resources. Concrete specimens are prepared with different proportions of M-sand and iron ore tailings as partial fine aggregate replacements. The effect of these replacements on the workability, compressive strength, split tensile strength, and flexural strength of high-strength concrete is evaluated. The experimental results are compared with those of conventional concrete to determine the suitability of the proposed materials. The study aims to identify an optimum replacement level that provides satisfactory mechanical performance while promoting sustainable construction practices. The utilization of M-sand and iron ore tailings has the potential to reduce the consumption of natural sand, minimize industrial waste, and contribute to the development of economical and environmentally sustainable high-strength concrete.

Keywords: High-strength concrete, M-sand, Iron ore tailings, Fine aggregate replacement, Sustainable concrete, Sustainable construction.

1. INTRODUCTION

Concrete is one of the most widely used construction materials because of its high compressive strength, durability, availability, and versatility. With the rapid growth of infrastructure and construction activities, the demand for concrete and its constituent materials has increased significantly. Fine aggregate, particularly natural river sand, is an important component of concrete. However, excessive extraction of river sand has resulted in depletion of natural resources, environmental degradation, and ecological disturbances. Therefore, the use of alternative fine aggregate materials has become an important area of research in sustainable construction. Manufactured sand (M-sand) is produced by crushing and processing hard rocks into fine particles and can be used as an alternative to natural river sand. Its use can reduce dependence on natural sand and provide a more controlled source of fine aggregate. However, the properties of M-sand, such as particle



Fig 1.1- Iron ore tailing sand

Iron ore tailings (IOT) are finely divided waste materials generated during the beneficiation and processing of iron ore. Large quantities of tailings are produced by the mining industry and are commonly stored in tailing ponds or disposal areas. Improper management of these materials can create environmental and land-use problems.

The utilization of iron ore tailings as a partial replacement for fine aggregate provides an opportunity to convert an industrial waste material into a useful construction resource.

High-strength concrete requires carefully selected materials and proper mix proportions to achieve the desired mechanical and durability properties.

Incorporating M-sand and iron ore tailings into high-strength concrete can provide both environmental and economic benefits. However, excessive replacement may affect workability and strength due to differences in particle size, shape, surface characteristics, and packing density.

Therefore, this review paper focuses on the existing research related to the incorporation of M-sand and iron ore tailings as partial replacements for fine aggregate in high-strength concrete. The review examines their influence on fresh and hardened concrete properties, identifies suitable replacement levels reported in previous studies, and highlights research gaps for future experimental investigation.

2. OBJECTIVES

1. To review the existing literature on high-strength concrete incorporating M-sand and iron ore tailings as partial fine aggregate replacements.
2. To study the properties of M-sand and iron ore tailings and their suitability as alternative fine aggregate materials.
3. To investigate the effect of M-sand and iron ore tailings on the workability of high-strength concrete.
4. To review their influence on mechanical properties, particularly:
5. To identify suitable replacement percentages of M-sand and iron ore tailings based on findings reported in previous research.

6. To evaluate the environmental benefits of using industrial waste and reducing dependence on natural river sand.
7. To identify research gaps in existing studies related to the combined use of M-sand and iron ore tailings in high-strength concrete.
8. To provide a basis for future experimental investigation and development of sustainable high-strength concrete.

3. LITERATURE REVIEW

3.1. Aboagye(2026)

The authors of this study reviewed the influence of manufactured sand on different concrete properties. The review considered particle shape, grading, fines content and the type of crusher used to produce M-sand. The study reported that the angular particles of M-sand can improve packing and strength but may reduce workability. The effect of fines content and superplasticizer requirements was also discussed. The review provides useful information for selecting M-sand as an alternative to natural river sand.

3.2. Chaitanya(2026)

In this research, M-sand was used as the fine aggregate in sustainable concrete containing fly ash and different levels of silica fume. Compressive, split tensile and flexural strengths were evaluated at different curing ages. SEM, EDS and TGA investigations were used to understand the microstructure of the concrete. Machine-learning models were also applied to predict compressive strength and reduce experimental trials. The study demonstrates the potential of M-sand for producing high-performance sustainable concrete.

3.3. Liu (2026)

In this research, iron ore tailings were converted into noninserted artificial aggregates for use in UHPC. The researchers investigated the effect of different replacement levels on strength and microstructure. Experimental testing was combined with microstructural analysis to understand the strengthening mechanism. The study focused on how the tailings-based aggregate affected the internal structure of UHPC. The results provide useful information for utilizing iron ore tailings in high-performance concrete.

3.4. Pujary(2026):

In this research, iron ore beneficiation plant tailing was investigated as a replacement for natural fine aggregate in concrete. The study examined the suitability of the tailing material for concrete production. Fresh and hardened concrete properties were considered for different replacement levels. The research highlights the possibility of converting a large-volume mining waste into a useful construction material. The study is directly relevant to sustainable fine-aggregate replacement using iron ore tailings.

3.5. Vaidya (2026):

In this research, iron ore tailings were incorporated into structural concrete as an alternative to conventional fine aggregate. The study investigated the relationship between concrete microstructure, strength and durability. The researchers focused on reducing the dependence on natural river sand through waste utilization. Microstructural characteristics were related to the resulting engineering properties of concrete. The work provides recent information for optimizing structural concrete containing iron ore tailings.

3.6.Senthamilselvi (2026):

In this research, iron ore tailings were used to partially replace M-sand in geopolymer concrete. Replacement levels of 0%, 20%, 40% and 60% were investigated for mechanical properties. Concrete specimens and beams were tested to study strength, durability and flexural behaviour. The study reported that the 40% replacement mixture showed favourable strength characteristics. This paper is particularly relevant because it directly combines M-sand and iron ore tailings in a concrete system.

3.7. Chen (2026)

In this research, iron ore tailings sand was used to replace river sand in cast-in-situ concrete. The study investigated concrete exposed to combined sulphate and magnesium attack. Mechanical properties and degradation behaviour were examined under aggressive environmental conditions.

3.8. Aboagye, Gosselin and Wilson (2026)

The authors of this study reviewed the influence of manufactured sand (M-sand) on the fresh and hardened properties of concrete. The review examined important characteristics of M-sand, including particle shape, surface texture, grading, crusher type and fines content. The study reported that the angular shape and rough surface of M-sand can improve particle packing and contribute to compressive strength, but may reduce workability. The authors found that appropriate fines content can improve strength and durability, while excessive fines can increase water demand and the requirement for superplasticizer. The review also discussed M-sand applications in self-compacting concrete and ultra-high-performance concrete. The study highlights the need for suitable mix-design methods and standards for wider use of manufactured sand as a replacement for natural sand.

3.9.Fang (2025)

The authors of this study reviewed the physical and mineral characteristics of iron ore tailings sand. The review compared IOT sand with natural sand and discussed its suitability as a fine aggregate. Workability, compressive strength, tensile strength, flexural strength and elastic modulus were discussed. The study also reviewed drying shrinkage and durability properties of IOT concrete. The authors identified future research needs for large-scale application of IOT sand in concrete.

3.10. Huang (2025)

In this research, iron ore tailings sand was incorporated into ultra-high-performance concrete using different binders. The study compared ordinary Portland cement-based UHPC with alkali-activated binder UHPC. Strength, durability and sustainability characteristics were investigated. The researchers also evaluated the effect of IOT sand on freeze-thaw and sulphate resistance. The study demonstrates the potential of IOT sand in high-performance and sustainable UHPC systems.

3.11. Chen (2025)

In this research, the influence of iron tailings sand content on concrete workability was studied. Mechanical properties and cyclic compressive behaviour were also investigated. The study found that increasing IOT sand content can reduce slump and affect water absorption. The cyclic compression response was evaluated to understand the structural behaviour of the

concrete. The results are useful for determining suitable IOT replacement levels in concrete mixtures.

3.12. Wang – (2025)

In this research, iron ore tailings were used as fine aggregate and cementitious material in recycled concrete. The study investigated the influence of tailings on mechanical performance and microstructure. The researchers observed that suitable amounts of tailings could improve concrete strength. Excessive tailings increased microcracks and unreacted particles in the concrete matrix. Microstructural analysis was used to explain the relationship between tailings content and concrete performance.

3.13. Fang et al. (2025)

The authors of this study the characteristics and utilization of iron ore tailings sand (IOTS) as a replacement for natural sand in concrete. The review discussed the physical properties, mineral composition and differences between iron ore tailings sand and natural sand. The study examined the effects of IOTS on concrete mix proportion, workability, mechanical properties, drying shrinkage and durability. The authors also reviewed experimental, theoretical and numerical studies on the structural performance of concrete containing iron ore tailings sand. The review indicated that properly treated IOTS can partially or completely replace natural sand and can contribute to sustainable concrete production. The study identified future research needs for improving the large-scale application of IOTS in concrete and structural members.

3.14. Shi, J, Pan, W., Kang – (2024)

In this research, iron tailings powder and iron tailings sand were incorporated into UHPC. Iron tailings powder was used to replace part of the cement, while iron tailings sand replaced quartz sand. Mechanical strength, flexural toughness and durability were investigated. SEM, MIP and heat-of-hydration tests were used to study the microstructure and hydration behaviour. The study determined suitable contents of iron tailings materials for developing sustainable UHPC.

3.15. Shi et al (2024)

In this research, iron ore tailings were used as aggregate in ultra-high-performance geopolymer concrete. The effects of IOT on flowability and compressive strength were investigated. Microstructural characterization was carried out to explain the mechanism responsible for strength development. The study showed that suitable utilization of IOT can improve the strength of UHP geopolymer concrete. The research provides an alternative method for recycling iron ore tailings into high-performance construction materials.

3.16. Luan – (2024)

In this research, recycled concrete powder and iron ore tailings sand were incorporated into UHPC. The study investigated mechanical properties and environmental performance of the modified UHPC. Iron ore tailings sand was used as a replacement for natural sand. The research also considered the environmental benefits associated with waste utilization. The study reported a UHPC mixture using recycled concrete powder and IOT sand with favourable overall performance.

3.17. Li(2024)

In this research, iron ore tailings were used as fine aggregate in carbon-fibre cement-based materials. The study investigated compressive strength, sulphate freeze-thaw resistance and piezoresistive behaviour. Microstructural and pore-distribution characteristics were also examined. The combination of IOT and carbon fibre was studied for self-sensing cementitious materials. The research demonstrates that IOT can be used in advanced cement-based materials exposed to aggressive environments.

3.18. Zhu (2024)

The study examined the influence of IOT sand on the properties of lightweight cement-based material. The research investigated the relationship between tailings characteristics and concrete performance. The use of iron tailings provided a method for recycling mining waste in construction materials. The study is useful for understanding the wider application of IOT sand beyond conventional concrete.

3.19. Zhang(2023)

Utilization of Iron Ore Tailings with High Volume in Green Concrete. In this research, iron ore tailings were used at high volume in green concrete. IOTs were incorporated as supplementary cementitious material and aggregate. The study investigated compressive strength, transport properties, pore structure and the interfacial transition zone. The research demonstrated that IOT-based materials can contribute to sustainable high-performance concrete. The study is important for developing concrete with reduced dependence on natural resources.

3.20. SeifElDin(2023)

In this research, iron ore tailings were used as fine aggregate in UHPC at 30% and 40% replacement levels. Steel, basalt, polypropylene and glass fibres were incorporated in different combinations.

Compressive, tensile and impact-related performance was investigated. SEM analysis was used to study the microstructure of the developed concrete. The study demonstrates the possibility of combining IOT with fibre reinforcement for high-performance concrete.

3.21. Liu(2023)

In this research, iron ore tailings were used as aggregates in engineered cementitious composites. Compressive strength, flexural strength, deformation and tensile-related properties were investigated. The study aimed to replace conventional fine aggregate with industrial waste. The researchers examined the effect of IOT on the mechanical and deformation behaviour of ECC. The results demonstrate the potential of IOT for producing more sustainable high-performance composites.

3.22. Singh and Chandaliya (2023)

The authors of this study reviewed the use of manufactured sand (M-sand) as a sustainable replacement for natural sand in conventional concrete. The review examined the effects of M-sand on important properties such as workability, compressive strength and durability of concrete.

The study discussed how M-sand is produced by crushing and screening rocks such as granite or basalt. The authors reported that M-sand can provide performance comparable to, and in some cases better than, natural sand when properly graded and proportioned. The use of M-sand can reduce dependence on river sand and help minimize the environmental problems

associated with excessive sand extraction. The study concluded that M-sand has significant potential as a sustainable fine aggregate for concrete production.

3.23. Li(2023)

In this research, iron tailings were incorporated into concrete to develop a more sustainable construction material . The study investigated the preparation method and engineering properties of the resulting green concrete . The research focused on utilizing industrial solid waste and reducing consumption of natural resources . Strength and material characteristics were evaluated for different mixtures. The study supports the application of iron tailings in environmentally friendly concrete production.

3.24. Liu – 2023

In this research, the mechanical performance of iron tailings concrete was investigated under environmental exposure . The concrete was subjected to dry–wet cycles and negative-temperature conditions .Changes in mechanical properties and internal damage were examined. The study provides information about the behaviour of IOT concrete under repeated environmental actions. Such durability information is important when considering IOT concrete for long-term structural applications.

3.25. Huang – (2023)

In this research, high-sulphur iron ore tailings were utilized in cement mortar. The study investigated the influence of tailing content and curing temperature on material performance. The research considered the challenges associated with using high-sulphur mining waste in cement-based materials .Different curing conditions were examined to understand their influence on the mortar. The study contributes to the safe and effective utilization of difficult iron ore tailings materials.

3.26. Jayasimha – (2022)

In this research, iron ore tailings were used as a partial replacement for fine aggregate in high-strength concrete. The study focused on compressive strength and durability characteristics. Different replacement percentages were investigated to identify a suitable IOT content. The research demonstrated that IOT can be considered for high-strength concrete when an appropriate replacement level is selected. This paper is highly relevant to the proposed research on high-strength concrete containing IOT.

3.27. Arbili(2022)

The authors of this study reviewed research concerning the utilization of iron ore tailings as fine aggregate. Fresh concrete properties, mechanical properties and durability characteristics were considered. The study discussed the environmental problems associated with accumulation of iron ore tailings. It also examined the potential benefits of replacing natural fine aggregate with IOT. The review supports the development of sustainable concrete using industrial waste materials.

3.28. SelvaGanesh(2022)

The authors of this study reviewed manufactured sand and recycled aggregate as alternatives to conventional concrete materials. The review highlighted the environmental problems associated with excessive river-sand extraction. Different properties of concrete containing M-sand were discussed. The study emphasized the potential of M-sand for reducing dependence on natural river sand. This research is useful for the M-sand component of the proposed study.

3.29. Zheng (2022)

In this research, iron ore tailings were used as fine aggregate in mixed-fibre-reinforced concrete. The study investigated carbonation resistance and pore structure. The researchers examined how IOT and fibre reinforcement affected the internal structure of concrete. The relationship between pore characteristics and durability was also considered. The study provides useful information about long-term durability of concrete containing IOT.

3.30. Zhu2022

In this research, iron-tailing sand was incorporated into recycled aggregate concrete. The study focused on the behaviour of the concrete under high-temperature exposure. Changes in concrete performance after heating were investigated. The research combines two sustainable materials recycled aggregate and iron-tailing sand. The results are useful for understanding the thermal performance of sustainable concrete containing IOT.

3.31. Zhou(2022)

In this research, iron tailings sand was incorporated into concrete beams to study fire resistance. The behaviour of the beams under high-temperature exposure was investigated. Changes in mechanical performance and damage characteristics were examined. The study extended IOT research from material-level properties to structural members. It provides useful information for assessing the application of iron-tailings concrete in structural construction.

3.32. Karthikeyan(2021)

In this research, dumped iron ore tailings were used as partial replacement of fine aggregate. IOT replacement levels of 0%, 20%, 30% and 40% were investigated. Steel fibre and hybrid steel-basalt fibre were used to improve tensile and flexural performance. Compression, flexure, durability, and porosity tests were performed. The study demonstrates the possibility of combining IOT with fibre reinforcement to improve concrete performance.

3.33. Zhao(2021)

The authors of this study reviewed the characteristics of iron ore tailings and their application in concrete. Workability, mechanical properties and durability of IOT concrete were compared with conventional concrete. The study discussed the influence of IOT characteristics on concrete performance. Relationships between different mechanical properties were also examined. The review concluded that suitable IOT replacement can provide satisfactory concrete performance and sustainability benefits.

3.34. Zhang2021

The authors of this study reviewed the cementitious activity and utilization methods of iron ore tailings. Different activation methods for improving the reactivity of IOT were discussed. The paper examined applications of IOT in cementitious materials, bricks and concrete. The environmental and resource-saving benefits of large-scale IOT utilization were highlighted. The authors also identified the need for further research on long-term durability and environmental performance.

3.35. Bezerra(2021)

In this research, iron-rich ore tailings were studied as a partial replacement for cement. Both dry and sludge forms of iron-rich tailings were investigated. The researchers examined rheology, hydration and compressive strength. The results indicated that IOT can influence

hydration through a nucleation effect. The research provides useful background for understanding the physical and chemical behaviour of iron-rich tailings in cementitious systems.

3.36. Chinnappa(2020)

In this research, iron ore tailings were investigated as fine aggregate in concrete. The study evaluated the influence of IOT replacement on concrete strength. Experimental results were combined with statistical evaluation to understand the significance of different parameters. The research demonstrated the potential of IOT to reduce the use of conventional natural fine aggregate. The paper provides a useful foundation for studying IOT-based sustainable concrete.

3.37. Oritola(2020)

In this research, the physical and engineering characteristics of iron ore tailings were investigated. The properties of IOT were compared with those required for conventional fine aggregate.

Microscopic and material characterization techniques were used to understand the particle characteristics. The study considered the suitability of IOT for concrete production. The research provides important basic material data before using IOT as a fine-aggregate replacement.

3.38. Zhang(2020)

In this research, iron ore tailings were used to replace manufactured sand in UHPC mortar. Replacement levels of 0%, 20%, 40%, 60%, 80% and 100% were investigated. Compressive strength and permeability were evaluated together with SEM and MIP analysis. The study reported favourable strength performance at suitable IOT replacement and improved impermeability. This is one of the most directly relevant papers because it specifically combines IOT with manufactured sand in UHPC.

3.39. Cheng(2020)

In this research, siliceous iron tailings were incorporated into concrete to study durability performance. study investigated how iron tailings affect the long-term behaviour of concrete. Research considered the suitability of siliceous tailings as a construction material. Durability characteristics were examined in addition to normal concrete performance. The study provides supporting evidence for using iron tailings as an alternative concrete material.

3.40. Chinnappa and Karra (2020)

In this research, the authors investigated the use of iron ore tailings (IOT) as a partial replacement for fine aggregate in concrete. The study also incorporated Alccofine as a cement replacement and evaluated the combined effect of IOT and Alccofine on concrete properties. The results showed that workability decreased as the IOT Alccofine content increased. The study reported compressive strengths of up to 70 MPa for the investigated mixtures, while flexural and split tensile strengths also increased with increasing IOT–Alccofine content within the studied range. Statistical regression models were developed to predict the mechanical properties of concrete containing IOT and Alccofine. The research demonstrated the potential of IOT as a fine aggregate in high-strength concrete while also supporting the utilization of mining waste in sustainable construction.

4. CONCLUSION

After studying these Reviews, We concluded that the utilization of M-sand and iron ore tailings as partial replacements for natural fine aggregate has significant potential in the production of sustainable high-strength concrete. M-sand can effectively reduce the dependence on natural river sand, while iron ore tailings provide a useful application for an industrial waste material that would otherwise require disposal. The incorporation of these materials can influence the workability, compressive strength, split tensile strength, and flexural strength of concrete. The performance depends strongly on the replacement percentage, particle size, grading, and physical and chemical characteristics of the materials. Appropriate replacement levels can provide satisfactory mechanical properties, whereas excessive replacement may adversely affect workability and strength. Overall, the combined utilization of M-sand and iron ore tailings can contribute to natural resource conservation, industrial waste management, and sustainable construction. Further experimental studies are required to determine the optimum combination and replacement percentage for high-strength concrete and to evaluate long-term durability properties. The findings of future research can help establish practical guidelines for the wider use of these alternative materials in concrete construction.

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