"Sustainable Concrete Solutions: The Role of Iron Ore Tailings And Glass Fiber In Enhancing Strength"

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Abstract- *This study explores the utilization of iron ore tailings as a sustainable alternative to conventional sand in concrete production, targeting an M25 grade for the concrete mix. We conducted systematic experiments to assess various proportions of iron ore tailings—specifically 10%, 15%, 20%, 25%, and 30%—as a partial replacement for sand, aiming to identify the optimal level that effectively balances workability and mechanical strength. The results indicated a specific ratio that maximized the performance of the concrete mix. Building on this foundation, we incorporated glass fiber into the concrete matrix, substituting a portion of the fine aggregate at varying dosages (0.5%, 0.75%, 1.0%, 1.5%, and 2.0%) to enhance tensile and flexural strengths. The findings highlight the potential of integrating iron ore tailings and glass fiber in developing environmentally friendly concrete solutions and promoting sustainable construction practices.*

Keywords- Iron ore tailings, Glass fiber, Sand replacement, Concrete

I. INTRODUCTION

The rising demand for sustainable building materials has led researchers to explore the use of industrial waste products, such as iron ore tailings, in concrete to enhance its properties and minimize environmental impact. As a by-product of iron extraction, iron ore tailings are produced in large quantities and present significant environmental challenges. Utilizing these tailings as a partial replacement for natural sand not only reduces waste but also decreases reliance on finite resources. Additionally, incorporating glass fibers as a substitute for coarse aggregates enhances the tensile and flexural strengths of concrete, improving its resistance to cracking and overall durability. This combination of iron ore tailings and glass fibers offers an innovative approach to developing high-performance, eco-friendly materials that support sustainable construction and effective waste management practices.

Iron ore tailings are the residual materials generated after extracting iron from its ore, comprising fine particles and minerals that remain once the iron is separated during the mining process. Often stored or discarded in significant quantities, these tailings can lead to environmental issues such as soil degradation and water pollution. To address these challenges, researchers are investigating the potential of using iron ore tailings as a replacement for natural sand in concrete. This approach not only reduces waste and decreases dependence on natural resources but also fosters the creation of sustainable and durable building materials. The specific texture and composition of iron ore tailings can vary based on the mining methods employed. Furthermore, glass fibers, made up of fine strands, enhance the tensile strength and flexibility of concrete, reinforcing it and lowering the risk of cracking. When mixed into concrete, glass fibers boost durability, reduce shrinkage, and improve both tensile and flexural strength. Additionally, glass fiber-reinforced concrete (GFRC) exhibits greater resistance to environmental stressors, including temperature variations and moisture, making it suitable for a wide range of infrastructure applications. Its lightweight nature and durability further enhance its role in sustainable construction practices.

Literature Review

Ramos et al. (2024) [1] conducted a systematic review and scenario analysis to explore the feasibility of using iron ore tailings (IOT) as a substitute for traditional construction materials. Their findings indicate that IOT can be effectively integrated into various construction products, including concrete, mortar, bricks, and blocks, with replacement rates varying from 5% to 100%. The study highlighted that the compressive strength of materials made with IOT consistently met or surpassed the values of conventional materials, thus satisfying the established standards for the evaluated products. This research emphasizes the potential of IOT as a sustainable construction material, contributing to waste reduction and resource conservation.

In a separate study, Owolabi et al. (2023) [2] investigated the use of iron tailings sourced from Itakpe mines as fine aggregate substitutes in concrete. Their results showed that concrete containing 50% iron tailings met workability criteria, with compressive strength increasing from 10.1 N/mm² to 15.3 N/mm² as the replacement level rose. Additionally, flexural strength improved from 15 N/mm² to

16.9 N/mm². The high pH and alkalinity of the curing water suggested that these tailings did not negatively impact durability, permitting up to 75% replacement without detrimental effects on mechanical properties. These findings indicate that utilizing iron tailings can effectively enhance concrete performance while addressing environmental challenges related to waste management.

Arbili et al. (2022) [3] provided a detailed review of concrete incorporating IOT and glass fibers, focusing on their fresh properties, mechanical performance, and durability across different curing stages. The research found that while IOT improved mechanical strength and durability, it also led to a reduction in flowability. Specifically, a 20% substitution of IOT resulted in a 14% increase in compressive strength compared to standard concrete, with up to 40% substitution maintaining sufficient flowability and compaction. However, exceeding this range could compromise both strength and durability due to reduced fluidity. The optimal content of IOT was identified as being between 30% and 40%, suggesting a need for further investigation in this area.

The role of glass fibers in concrete has also been the focus of extensive research. Kene et al. (2012) [11] explored fiber-reinforced concrete (FRC) with various fibers, including glass fibers, and demonstrated significant improvements in compressive, tensile, flexural, and impact strengths. Their study confirmed the beneficial effects of incorporating glass fibers at 0.25% by weight of cement on the mechanical properties of M20 grade concrete. Furthermore, Shakor et al. (2011) [13] conducted comparative tests on concrete with and without glass fibers, showcasing the advantages of Glass Fiber Reinforced Concrete (GFRC) as a feasible alternative construction material. Additionally, Chandramouli et al. (2010) [14] found that the use of alkali-resistant glass fibers resulted in considerable enhancements in compressive strength (20%-25%) and flexural strength (15%-20%) across various concrete grades. These studies collectively highlight the efficacy of integrating glass fibers into concrete to improve its mechanical properties.

Jayasimha et al. (2022) [4] evaluated the use of IOT as a fine aggregate substitute in concrete, incorporating glass fibers, and compared its performance to conventional concrete. The research involved preparing concrete mixes with varying IOT replacement levels, followed by tests to assess workability, compressive and tensile strengths, and durability. The findings indicated that IOT met Zone II requirements per IS: 383–2016, with improved workability and strength observed with up to 40% IOT replacement. Although higher replacement levels led to increased water absorption and weight loss due to acid and chemical exposure, the overall impact on durability remained minimal. This study reinforces the viability of IOT and glass fibers as sustainable alternatives in concrete, emphasizing their potential for promoting sustainability and cost efficiency.

Zhao et al. (2021) [5] presented a comprehensive overview of the characteristics of iron ore tailings and their influence on the workability, mechanical properties, and durability of concrete. The study noted that, despite its low pozzolanic activity, making it unsuitable as a direct cement substitute without activation, advancements in ore beneficiation technology have enhanced the usability of IOT. The research concluded that with appropriate replacement levels, IOT can provide satisfactory workability and mechanical properties, further contributing to sustainable concrete applications.

Overall, this literature review highlights the significant potential of iron ore tailings and glass fibers as sustainable alternatives to conventional construction materials in concrete production. As research progresses, it becomes increasingly evident that IOT not only aids in waste reduction but also supports the creation of high-performance, environmentally friendly building materials.

The optimal replacement level of iron ore tailings as fine aggregate in concrete generally falls between 10% and 30%, improving both workability and mechanical properties without significantly affecting strength. Specifically, a 10% to 15% replacement enhances workability, while a 20% to 25% range is often optimal for achieving maximum compressive strength and sustainability benefits. Although replacing up to 30% may slightly lower strength, it can enhance resistance to environmental factors. For glass fiber, the recommended replacement is between 0.5% and 2% by weight, which boosts tensile strength and crack resistance, with the best results typically seen at 1% to 2%. Therefore, we will use 10-30% iron ore tailings and 0.5-2% glass fiber in our concrete formulation.

Experimental Setup

Based on our literature review, we have chosen to replace fine aggregate with iron ore tailings at various levels: 10%, 15%, 20%, 25%, and 30%. Once we identify the optimal percentage from these replacements, we will introduce glass fiber as a fine aggregate substitute at 0.5%, 0.75%, 1%, 1.5%, and 2%. This systematic approach enables us to assess the combined impact of both materials on concrete properties. In total, we formulated 11 mixes, with the first 6 prepared initially and the remaining 5 created after determining the optimal dose of iron ore tailings. The Table 1outlines the trial mixes of the specimens, which were tested after 7 and 28 days.

Table 1 Trial mixes of mix design

Trial mix	7 days	28 days	Total
T1 (Nominal mix)	3	3	6
T2 (10 % IOT)	3	3	6
T3 (15 % IOT)	3	3	6
T4 (20 % IOT)	3	3	6
T5 (25 % IOT)	3	3	6
T6 (30 % IOT)	3	3	6
T7 (IOT+0.5% GF)	3	3	6
T8 (IOT+0.75% GF)	3	3	6
T9 (IOT+1.0% GF)	3	3	6
T10 (IOT+1.5% GF)	3	3	6
T11 (IOT+2.0% GF)	3	3	6

The trial mixes were designed following the guidelines outlined in IS 10262:2019 to ensure consistency and reliability in our experimental process [1]. We aimed to achieve an optimal balance of workability and mechanical properties by systematically varying the percentages of iron ore tailings and glass fiber for M25 grade of concrete.Table 2 shows the mix design of different mixes

Table 2 mix design of the specimens

Trial Mix	Cement (kg/m^3)	FA (kg/m3)	CA (kg/m3)	Water (kg/m3)	IOT (kg/m3)	GF (kg/m3)
T1 (Nominal mix)	320	876.50	1198.79	151.75	0	0
T2 (10 % IOT)	320	788.85	1198.79	151.75	87.21	0
T3 (15 % IOT)	320	745.028	1198.79	151.75	130.82	0
T4 (20 % IOT)	320	701.20	1198.79	151.75	174.42	0
T5 (25 % IOT)	320	657.37	1198.79	151.75	218.03	0
T6 (30 % IOT)	320	613.55	1198.79	151.75	261.64	0
T7 (IOT+0.5 % GF)	320	699.59	1198.79	151.75	174.42	1.6
T8 (IOT+0.75% GF)	320	698.79	1198.79	151.75	174.42	2.4
T9 (IOT+1.0 % GF)	320	697.98	1198.79	151.75	174.42	3.2
T10 (IOT+1.5 % GF)	320	697.18	1198.79	151.75	174.42	4.0
T11 (IOT+2.0 % GF)	320	696.38	1198.79	151.75	174.42	4.8

A total of 132 specimens were prepared for this study to evaluate the mechanical properties of concrete incorporating iron ore tailings and glass fiber. Each of the 11 concrete mixes consisted of 6 specimens, with 3 designated for testing at 7 days and 3 at 28 days to assess the compressive strength. Similarly, an additional 66 specimens were tested for flexural strength. This systematic approach enabled a thorough analysis of the effects of iron ore tailings and glass fiber on the mechanical properties of the concrete.

Discussion of the findings:

Compressive and flexural test were conducted in this study. Table 3presents the compressive strength test results after 7 and 28 days with iron ore, demonstrating that a 20% replacement is optimal. Similarly, Table *4*displays the flexural test results with iron ore, while Table 5shows the results for all these tests using the optimal 20% iron ore replacement combined with different percentages of glass fiber.

Table 3 Compressive strength with iron ore

Iron ore %	7 days strength (Mpa)	28 days strength (Mpa)
10	18.5	32
15	19	32.1
20	19.2	33
25	18.6	31.3
30	18	31

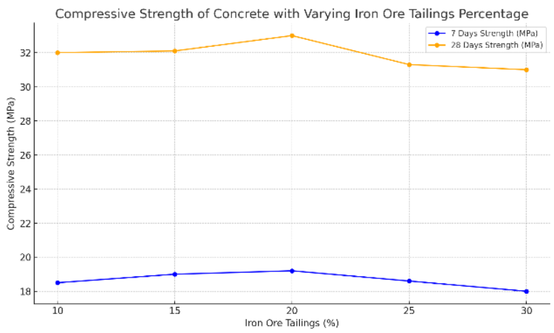

Figure 1 Compressive strength test results with iron ore

Table 4 Flexural test results with iron ore

Iron ore %	Flexural strength 7 days (Mpa)	
10	2.3	3.8
15	2.31	3.86
20	2.33	3.98
25	2.31	3.89
30	2.3	3.88

Table 5 Strength with Glass fiber

Glass Fiber Replacement (%)	**Compressive Strength (MPa)**		**Flexural Strength (MPa)**	
	7 days	28 days		7 days
0.5%	19.04	32.01	0.5%	19.04
0.75%	19.00	32.8	0.75%	19.00
1.0%	19.09	32.95	1.0%	19.09
1.5%	19.02	33.01	1.5%	19.02
2.0%	19.00	33.02	2.0%	19.00

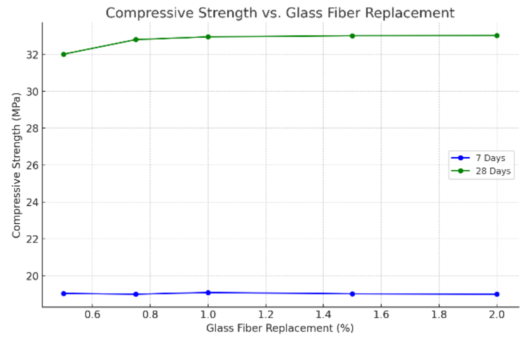

Figure 2 Compressive strength with glass fiber

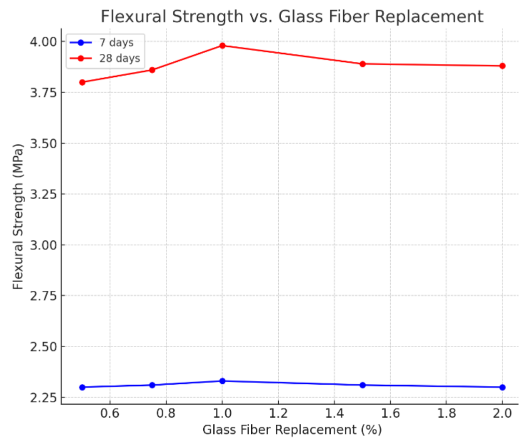

Figure 3 Flexural strength with glass fiber

The study revealed that substituting 20% of fine sand with iron ore tailings in concrete maximized compressive strength, improving its load-bearing capacity while having minimal impact on flexural and tensile strengths, likely due to the denser structure provided by the tailings. Additionally, adding glass fiber at a 1% concentration enhanced durability and crack resistance. This combination demonstrates that using iron ore tailings and glass fiber can sustainably improve concrete's performance and mechanical properties without compromising structural stability.

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