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Feasibility Study on the Use of Iron Ore Tailing and Glass Fiber as Fine Aggregates in the Concrete

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ABSTRACT:

Because there is less natural sand available and it is becoming more expensive, this study attempts to determine whether iron ore tailings and glass fibres may be used in place of fine aggregates in concrete. As a means to use waste materials in concrete, lower the cost of the material, and provide inexpensive building materials, this study will help to provide the observations and results that will allow an optimal percentage of usage of iron ore tailings and glass fibres to be seen. It also indirectly aids in reducing environmental issues brought on by various waste materials released into the environment, including iron ore tailings. Here, iron ore tailings and glass fibres are used in various percentages—0%, 5%, 7%, 10%, 12%, and 14%—in place of the fine aggregates. They undergo a variety of laboratory tests, including workability, flexural, and compressive strength tests. The findings give an ideal replacement proportion at which failure probability rises. Every test is conducted in accordance with the IS code, and it takes 28 days to complete

1. Introduction

Global building activities depend heavily on concrete, a composite material made of cement, fine and coarse aggregate, water, and possible admixtures. The increase in demand for building materials, such as natural river sand, sourced from different sources, has resulted in higher standards and expenses, which have an effect on the environment. Estimates of the yearly global aggregate use or extraction vary from 32 to 50 billion tons, with sand being a vital component. Construction-related increases in demand have an impact on the environment on a variety of industries, including tourism, fishing, insurance, and more. Sand extraction from seabed, lakes, riverbeds, and pits has a variety of negative effects. Due to river or coastal erosion, it causes land loss, lowers the water table, reduces the amount of sediment available, intensifies and increases the frequency of floods, aggravates droughts, increases greenhouse gas emissions, and endangers the survival of certain species. Concern over the effects of sand mining on the environment is growing as construction activities increase. Industrial waste production has increased in tandem with the growing demand for natural resources and rising living standards. Therefore, turning waste materials into secondary resources through recycling makes sense as a way to loosen environmental regulations and advance sustainability. Notably, the concrete industry has taken in millions of tons of industrial waste, some of which include dangerous elements. China is a major player in the iron and steel sector, and during the past three decades, its fast-economic growth has resulted in the creation of a significant volume of industrial waste. Cement production benefits greatly from the use of slag and other leftovers, yet hazardous waste such as iron ore tailings is routinely disposed of with regular garbage, endangering the environment. In 2008, China's 0.6 billion tons of yearly iron ore tailings discharged were recycled into new resources at a rate of just 7%, highlighting the need for more sustainable waste management techniques. In order to lessen the negative environmental effects of naturally extracting river sand, this work intends to clarify earlier studies on the addition of iron ore and glass fiber to concrete. Since iron ore is known to have negative consequences on the environment, water supplies, and public health, work has been done to find

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workable alternatives. The assessment looks at the proportions and ratios of iron ore to concrete, discusses the benefits of adding glass fiber, and determines the best replacement percentages to cut costs and environmental effect. The characteristics of these concrete substitutes are assessed using a variety of tests, such as tensile strength tests, flexural testing, compression tests, and evaluations of their durability and workability.In conclusion, a research of the industry's procedures is required to address environmental problems due to the growing demand for building materials, especially natural river sand. A step toward sustainability is the use of industrial wastes as substitute resources in the creation of concrete, such as iron ore and glass fiber. This analysis emphasizes how crucial it is to optimize replacement percentages and carry out in-depth property appraisals in order to open the door for economically and environmentally responsible alternatives in the building sector

2. Objectives

The objective of this research is to find out the feasibility of the use of iron ore tailings with glass fiber. as here in this research both the materials used are waste material which somehow causes a bad environmental impact and pollutes the environment.

Also, this research helped us to find a feasible environment-friendly material that can be used in the place of fine aggregates as the amount of natural sand is decreasing day by day which is ultimately rising the price of the fine aggregates and also causing several bad impacts in the environment, on structures made near by the coastal areas, aquatic or marine animals.

Along with that, it helps us to find out the percentage at which both waste products can be used so that we can use them without compromising the other properties of the concrete and the materials can be used effectively.

3. Materials and Methods

3.1 Iron Ore Tailings

The iron ore that may be extracted from rocks and minerals profitably in order to make metallic iron. The common types of iron ore include magnetite (Fe_3O_4, 72.4% Fe), hematite (Fe_2O_3, 69.9% Fe), geothite (FeO (OH), 62.9% Fe), limonite (FeO (OH).n(H_2O), 55% Fe), and siderite ($FeCO_3$, 48.2% Fe). One of Nigeria's most frequent metallic resources, according to reports, is iron ore. It is distributed across the northwest, north central, southwest, and southeast parts of the nation. There are more than thirty states with deposits of iron ore, with an estimated one billion tons of reserves—800 million tons of proved reserves and 500 million tons of probable reserves—located in Enugu, Niger, Zamfara, Kaduna, Oyo, and Anambra.

An estimated 200 million metric tonnes of iron ore reserves, with an average iron ore composition of 36%, are located near National Iron Ore Mining Company (NIOMCO), Itakpe in Kogi state. The iron ore needs to be beneficiated at a rate of eight (8) million tonnes per year by NIOMCO in order to supply 2.15 million tons of 63% to 64% grade concentrate of iron (Fe) annually to Ajaokuta Steel Company Nigerian Limited and 68% Fe concentrate as pellet feed for the direct reduction plant at Aladja, Nigeria. Iron ore concentrate beneficiation produces a form of solid waste known as powdered iron ore tailings, or IOTs. Large amounts of tailings are obtained as waste products of the beneficiated iron ore at the expected rate of production, and the predicted stripping ratio (waste/ore ratio) of the deposit would amount to about 28 million tons.

3.2 Some highlighted points regarding the iron ore tailings:

- Iron ore tailings are an industrial solid waste that is generated during the iron ore beneficiation process. This type of trash has quickly amassed as a result of the global increase in demand for steel, iron, and related sectors.
- Because of the increased demand for iron, lower iron-content iron ores are mined, which increases the amount of tailings produced.
- With an anticipated iron ore content of 1.5 billion tons in 2019, the world's useable iron ore production was almost 2.5 billion tons, with Australia, Brazil, China, and India leading the way.
- According to reports, the output of IOT in western Australia is anticipated to reach 632 million tons annually, with one ton of iron ore produced yielding an average of two tons of IOT.
- Brazil is anticipated to produce 0.4 tons of tailings for every ton of beneficiated iron ore, and the country produces 260–275 million tons of IOT annually.

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- In India, tailings generation accounts for between 10–25% of the total iron ore mining production, with an estimated 20 million tons of IOT produced annually.
- Due to China's fast-growing iron and steel sectors over the past three decades, the country has collected 5 billion tons of IOT as of 2015, and it releases over 600 million tons of IOT annually.

3.3 Properties of Iron Ore Tailings

- Iron ore tailings have specific properties based on various studies.
- Iron ore tailings used in studies contain approximately 14.54% iron and 54.41% SiO_2, with main ferrous metal minerals like magnetite and pyrite.
- These tailings exhibit good grindability, better than that of GBFS (Ground Granulated Blast Furnace Slag).
- The main components of iron tailings' chemical makeup are oxides of silicon, calcium, and aluminum, accounting for more than half of the overall content.
- Iron tailings are frequently used in concrete production as a fine aggregate replacement for river sand, taking advantage of their large specific surface area, small particle size, and possible pozzolanic activity.
- Studies have explored the stabilization of iron ore tailings with alkali-activated binders, achieving strength values up to 6.59 MPa after 28 days of curing at 40 °C.
- The world reserves of iron ore are around 170 billion tons, with over 2.4 billion tons processed in 2019, mainly by Australia and Brazil.
- Iron ore tailings are generated globally at a rate of 1.4 billion tons per year, with Brazil alone producing around 260–275 million tons annually.
- Techniques like chemical stabilization are being investigated to reduce risks associated with mining tailings and potentially monetize these materials.

These properties highlight the potential for utilizing iron ore tailings in various applications, especially in the construction industry, due to their unique characteristics and composition.

Table 1: Chemical properties of iron ore tailings.

S.no	Chemical properties	Percentage %
1.	Moisture	0.1487
2.	Total organic carbon	0.6442
3.	Total organic matter	0.7598
4.	Fe_2O_3	0.2312
5.	Copper	0.0061
6.	Zinc	0.0018
7.	Nickel	0.0013
8.	Sodium	0.0051
9.	Sodium oxide	61.4771
10.	Calcium oxide	11.8924
11.	Potassium	0.0012
12.	Magnesium oxide	4.1640
13.	Chromium	0.0017
14.	Cadmium	1.65E-06
15.	Magnesium	0.0025
16.	Aluminum oxide	20.6630

Table 1 displays the chemical characteristics of IOT from earlier research. The primary constituents of iron ore tailings are essentially the same as those of natural sand, and their high silica content suggests that they may be utilized in the preparation of concrete.

Table 2: Physical properties of iron ore tailings

S.No	Property	Value
1.	Fines (clay & silt) %	6.50

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2.	Sand content (%)	69.50
3.	Gravel content (%)	24
4.	Specific gravity	2.65
5.	Minimum dry density (kg/m3)	1685
6.	Maximum dry density(kg/m3)	1860
7.	Effective grain size, D10 mm	0.13
8.	D60 (mm)	2.67
9.	D30 (mm)	0.70
10.	Coefficient of uniformity, Cu	20.54
11.	Coefficient of curvature, Cc	1.41

Table 2 lists some of the physical characteristics of IOT that have been employed in several studies conducted in various places. There is a range of 2.34 to 3.49 specific gravities. The typical range of specific gravities for aggregates used in construction is 2.5 to 3.0, with an average of 2.68. Their specific gravity shows that some IOTs are heavier than typical river sand. With the exception of iron ore tailings from Perenjori, West Australia, IOT satisfies the criteria that the fineness modulus not be larger than 3.2. Sand with a fineness modulus of more than 3.2 is often not used to make acceptable concrete. Tailings from iron ore are produced based on its kind, geology, and technique of treatment.

3.4 Glass fiber

- It's a material with excellent corrosion resistance, lightweight, and sound, electrical, and thermal insulation qualities.
- it is much cheaper and significantly less brittle when used in composites.
- Glass fibers have various properties that make them valuable materials in different industries. Some key properties of glass fibers include:
- **Mechanical Strength**: Glass fibers exhibit high tensile strength, making them suitable for applications where strength and durability are essential.
- **Thermal Insulation**: Glass fibers trap air within them, providing good thermal insulation properties with a low thermal conductivity.
- **Chemical Resistance**: Glass fibers are resistant to chemical attacks, enhancing their durability in harsh environments.
- **Manufacturability**: Glass fibers can be manufactured into continuous filaments of various diameters, allowing for flexibility in applications.
- **Density**: Glass fibers have a relatively low density, contributing to their lightweight nature.
- **Elongation**: Glass fibers can undergo more elongation before breaking compared to materials like carbon fiber.
- **Composition**: Glass fibers are primarily made of silica (SiO_2) and other compounds like aluminum hydroxide, sodium carbonate, and borax, influencing their properties and performance in different applications.

These properties collectively make glass fibers versatile materials used in various industries, including construction, marine, and aerospace, due to their strength, insulation capabilities, and resistance to environmental factors.

4. Methodology

Here, we tested the concrete using a variety of methods

to ascertain its diverse outcomes. Some of the tests included workability, flexural, and compressive strength testing. Additionally, these tests helped us to know that at what proportion of glass fiber and iron ore tailings should be added to concrete in place of fine aggregates

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to provide the best possible outcomes in terms of workability, flexural strength, and compressive strength.

In order to compare the strength and other parameters with the other samples that contained glass fibers and iron ore tailings, a total six samples of M25 Grade with the same water content of 40% (0.4) were prepared for testing. The samples prepared were as follows at 0% replacement, 5% IOT with 5% Glass fiber, 7% IOT with 7% glass fiber, 10% IOT with 10% Glass fiber, 12% IOT with 12% Glass fiber, and 14% IOT with 14% Glass fiber. Both materials are added at equal percentages as a replacement for fine aggregate.

The concrete prepared was of grade M25 with the water content taken as 40% and the testing was done in 28 days by following the standard procedure mentioned in the IS code.

Table 4.1 Samples Calculation

S.no	% replaced	C (kg)	FA (kg)	CA (kg)	W (L)	IOT (kg)	GF (kg)
1	0%(IOT) + 0% (GF)	7.5	7.5	15	3	-	-
2	5%(IOT) + 5% (GF)	7.5	6.75	15	3	0.375	0.375
3	7% (IOT)+ 7% (GF)	7.5	6.45	15	3	0.525	0.525
4	10% (IOT) + 10% (GF)	7.5	6	15	3	0.75	0.75
5	12 % (IOT) + 12% (GF)	7.5	5.7	15	3	0.9	0.9
6	14% (IOT) + 14% (GF)	7.5	5.4	15	3	1.05	1.05

C-Cement, FA-Fine Aggregate, CA-Coarse Aggregate, W-Water, IOT-Iron Ore Tailing & GF-Glass Fibre

5. Effect of iron ore tailings and glass fiber on M25 grade of concrete content.

5.1 Compressive strength

Compressive **strength test**, a mechanical test measuring the maximum amount of compressive load a material can bear before fracturing. It was observed that on increasing the amount of iron ore tailings and glass fiber

Table 5.1.1 Compressive strength at 0% replacement.

S.no	Grade	No. of days	Compressive strength
1.	M25	28 days	29.78 N/mm^2
2.	M25	28 days	28.04 N/mm^2
3.	M25	28 days	29.25 N/mm^2
Average strength = 29.25 N/mm^2			

Table 5.1.2 Compressive strength at the replacement of fine aggregates with 5% iron ore tailings and 5% glass fibres

S.no	Grade	No. of days	Compressive strength
1.	M25	28 days	29.80 N/mm^2
2.	M25	28 days	27.65 N/mm^2
3.	M25	28 days	28.60 N/mm^2
Average strength = 28.68 N/mm^2 (passed)			

Table 5.1.3 Compressive strength at the replacement of FA with 7% IOT and 7% glass fiber

S.no	Grade	No. of days	Compressive strength
1.	M25	28 days	28.50N/mm^2
2.	M25	28 days	28.00 N/mm^2
3.	M25	28 days	27.85 N/mm^2
Average strength = 28.11 N/mm^2 (passed)			

Table 5.1.4 Compressive strength at the replacement of FA with 10% IOT and 10% glass fiber

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S.no	Grade	No. of days	Compressive strength
1.	M25	28 days	26.50 N/mm^2
2.	M25	28 days	28.80 N/mm^2
3.	M25	28 days	27.50 N/mm^2
Average strength = 26.93 N/mm^2 (passed)			

Table 5.1.5 Compressive strength at the replacement of FA with 12% IOT and 12% glass fiber

S.no	Grade	No. of days	Compressive strength
1.	M25	28 days	25.50 N/mm^2
2.	M25	28 days	24.85 N/mm^2
3.	M25	28 days	25.70 N/mm^2
Average strength = 25.35 N/mm^2 (passed)			

Table 5.1.6 Compressive strength at the replacement of FA with 14% IOT and 14% glass fiber

S.no	Grade	No. of days	Compressive strength
1.	M25	28 days	23.50N/mm^2
2.	M25	28 days	24.50 N/mm^2
3.	M25	28 days	23.75 N/mm^2
Average strength = 23.92 N/mm^2 (failed)			

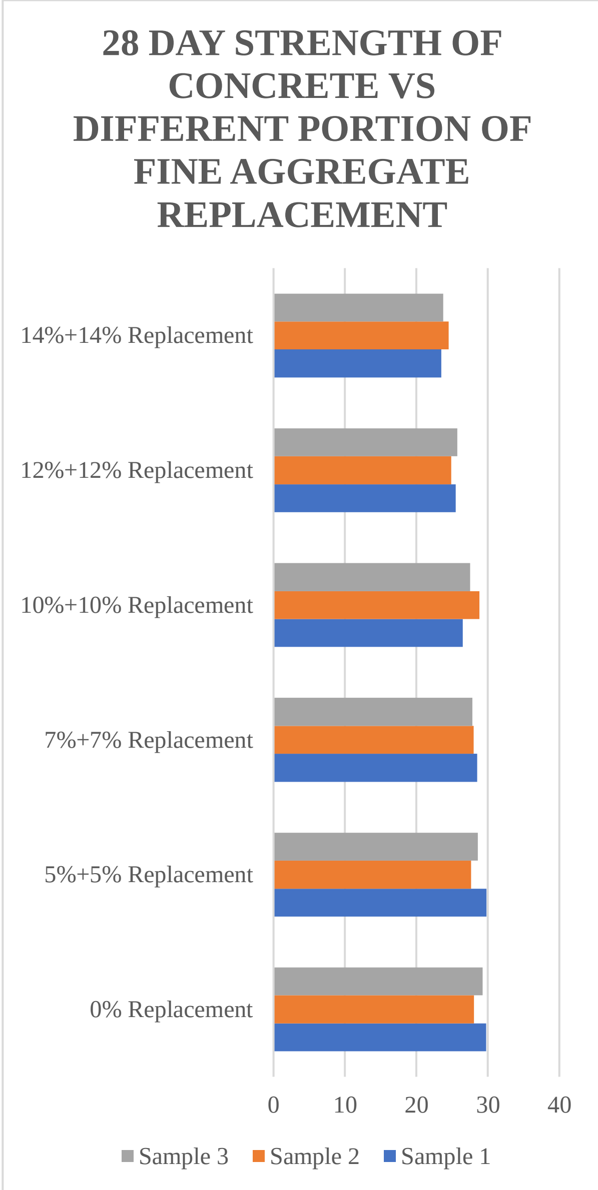

Figure 1: 28 days strength of concrete vs different portions of fine aggregate replacement

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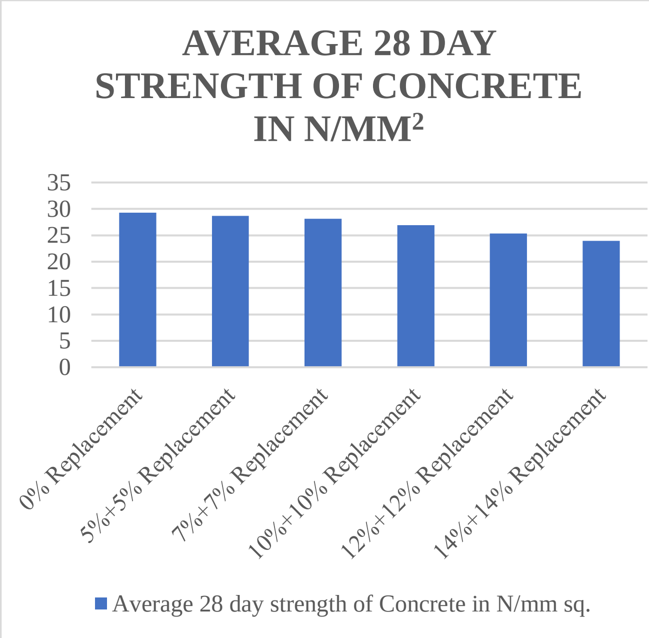

Figure 2: Average 28 days strength of concrete in N/mm^2

So, here as we can see on replacing the fine aggregate with 14% IOT and 14% glass fibres the sample failed, here we can say only replacement till 12% is permitted as per compressive strength criteria

Figure 3: TESTING OF SPECIMEN

5.2 Flexural strength test

Flexural testing is used to determine the flex or bending properties of a material. Sometimes referred to as a transverse beam test, it involves placing a sample between two points or supports and initiating a load using a third point or with two points which are respectively call 3-Point Bend and 4-Point Bend testing. It can also be defined as the material's ability to resist under deformation under load.

Table 5.2.1 Flexural strength at different percentages of IOT and Glass fiber

S.no	% replaced	Grade	No. of days	Flexural strength test (N/mm^2)
1.	0%	M25	28 days	3.01 (Passed)
2.	5% IOT + 5% GF	M25	28 days	3.65 (Passed)
3.	7% IOT + 7% GF	M25	28 days	3.227 (Passed)
4.	10% IOT + 10% GF	M25	28 days	3.16 (Passed)
5.	12% IOT + 12% GF	M25	28 days	3.13 (Passed)
6.	14% IOT + 14% GF	M25	28 days	2.99 (Fail)

Figure 4: Flexural strength test on specimen

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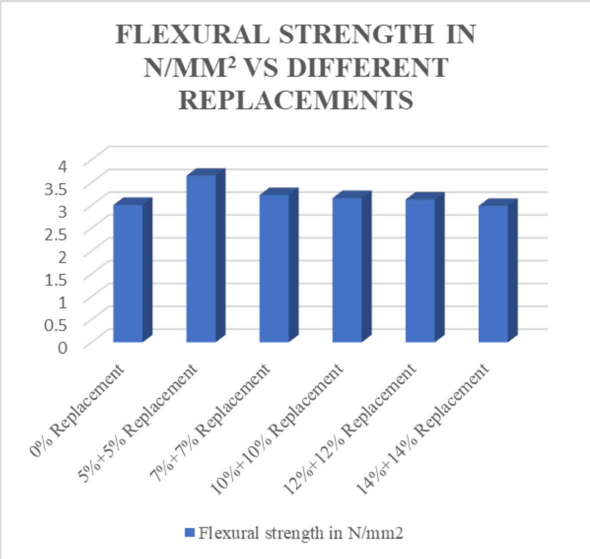

Figure 5: flexural strength in N/mm² vs different percentages of replacement

So here we can see on replacing the fine aggregate with different percentages of iron ore tailings and glass fiber we can observe that at first the flexural strength is increasing but on replacing the fine aggregate more than 12% a decrement in the flexural strength can be seen due to which the replacement is permitted till 12% only.

5.3 Workability

The phrase "workability of concrete" refers to the general and subjective ability of freshly mixed concrete to be combined, spread, compacted, and finished with the least amount of homogeneity loss.

Table 5.3.1 Workability at different percentages of IOT and Glass fiber

S.no	% Replace	Grade	Slump value
1.	0%	M25	80mm
2.	5% IOT + 5% GF	M25	48mm
3.	7% IOT + 7% GF	M25	35mm
4.	10% IOT + 10% GF	M25	20mm
5.	12% IOT + 12% GF	M25	10mm
6.	14% IOT + 14% GF	M25	7mm

So here as we can see that on increasing the amount of iron ore tailings and glass fibres it was observed that the workability of the concrete is reducing so there is no boundation for the workability criteria.

The reason for the decrement in the workability could be owing to the fineness and large specific surface area of the IOT, which necessitates a substantial amount of water to wet all the particles in the mix also with several studies it was found that on while adding IOT to the mix flowability of concrete decreases and water demand increases

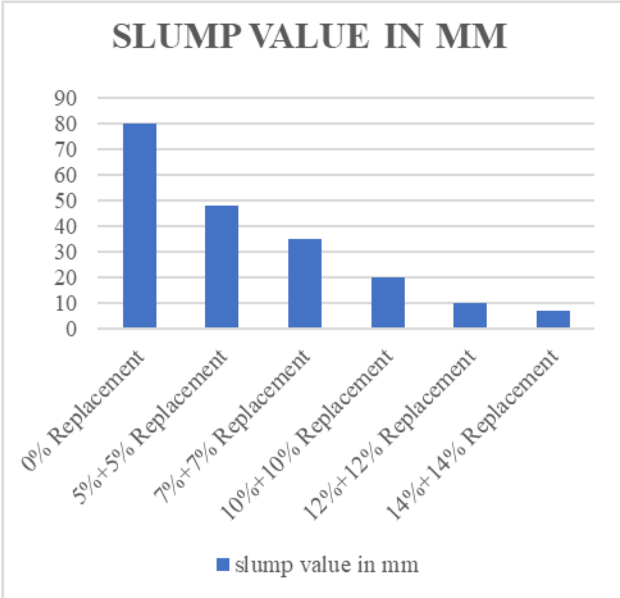

Figure 6: Slump value of concrete at different percentages of IOT and Glass fiber in place of Fine aggregates

6. Conclusion

In this research three parameters were measured on a nominal mix grade of M25 by the laboratory tests and the results obtained are as follows:

1. On the addition of iron ore tailings and glass fiber as a replacement of fine sand the compressive strength obtained for M25 grade of concrete at 28 days are 29.25 N/mm² at 0% replacement, 28.68 N/mm² at 5% replacement, 28.11 N/mm2 at 7% replacement, 26.93 N/mm² at 10% replacement, 25.35 N/mm2 at 12% replacement which are all passed as per the criteria but

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the strength obtained at 14% replacement is 23.92 N/mm^2 which does not fulfil the criteria and considered as a failed sample.

2. The flexural strength of the concrete is increased when iron ore tailings and glass fibres are added. The flexural strength obtained at 0% replacement is 3.01 N/mm^2, at 5% replacement 3.65 N/mm^2, at 7% replacement 3.227 N/mm2, at 10% replacement 3.16 N/mm^2, at 12% replacement 3.13 N/mm^2 and at 14% replacement 2.99 N/mm^2. All the samples passed the acceptance criteria after the testing at 28 days but the sample contains 14% IOT and glass fiber failed.

3. The workability of the concrete has been reduced with the addition of the iron ore tailings and glass fiber. the results obtained at 0% replacement is 80mm, at 5% replacement 48mm, at 7% replacement 35mm, at 10% replacement 20mm, at 12% replacement 10mm and at 14% found 7mm.

4. From the above results we can conclude that iron ore tailings can be used with glass fiber in the place of fine aggregates but only up to 12% if we want the overall performance of the concrete to be good.

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