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Behaviour of Fiber Reinforced Olivine Sand Concrete

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Abstract

This study investigates the behaviour of fiber-reinforced olivine sand concrete (FROSC), focusing on its mechanical properties, workability, and durability. Olivine sand, a naturally occurring mineral with carbon sequestration potential, is used as a fine aggregate replacement, while steel fibers (5% by cement weight) are incorporated to enhance tensile and compressive strengths. The experimental program utilized M30 grade concrete, assessing compressive strength, split tensile strength, water absorption, and Sorptivity. Results indicate that while olivine sand concrete alone achieves slightly lower compressive strength (26.76 MPa) than the target (30 MPa), the addition of steel fibers increases it to 30 MPa, meeting design specifications. The study highlights the eco-friendly potential of olivine sand and steel fibers in sustainable concrete production.

Keywords: Fiber-reinforced concrete, Olivine sand, Steel fibers, Compressive strength, Split tensile strength, Workability, Durability, Carbon sequestration, Sustainable construction.

1. Introduction

Concrete remains the second most utilized material globally after water, driven by the rapid growth of the construction industry. Cement, a key component, is produced in massive quantities (approximately 298 million tons annually), with production expected to rise. However, cement manufacturing relies heavily on limestone, a depleting resource, and emits significant CO_2 due to high energy demands. This necessitates sustainable alternatives. Olivine sand, a silicate mineral with carbon absorption capabilities, and steel fibers, often recycled, offer promising solutions. This study explores the behaviour of fiber-reinforced olivine sand concrete (FROSC), aiming to reduce environmental impact while enhancing mechanical properties

2. Literature Review

Several studies have explored fiber-reinforced concrete and the role of olivine sand in improving mechanical properties. Research highlights the beneficial impact of steel fibers on tensile strength, crack resistance, and flexural performance. Additionally, olivine sand's potential for carbon sequestration and enhanced durability has been established.

2.1 Summary of Literature

- **Mechanical Properties of Steel Fibrous Concrete**: Investigates tensile strength improvements due to steel fibers.
- **Fibrous Concrete with Waste Materials**: Examines waste-based fibers and their impact on strength.
- **Nano-Silica in Concrete**: Highlights olivine-based nano-silica for enhancing concrete properties.
- **Geo-Polymer Concrete with Olivine Sand**: Evaluates varying olivine sand proportions.
- **Effect of Steel Fibers on Concrete Strength**: Reviews previous research on fiber reinforcement in concrete.

3. Materials

3.1 Cement: Used as the primary binding agent, M53-grade cement is selected for its high strength.

3.2 Olivine Sand: Olivine sand is chosen due to its superior heat absorption, low thermal expansion, and high refractoriness. Its composition primarily includes forsterite (Mg_2SiO_4) and fayalite (Fe_2SiO_4).

Figure 1: Olivine Sand

3.3 Coarse Aggregate: Crushed stone of 20mm size is utilized, ensuring optimal mechanical properties.

3.4 Water: Clean potable water is used for mixing and curing.

3.5 Steel Fiber: Steel fibers, with an aspect ratio of 20-100, are incorporated to enhance ductility and tensile strength.

Figure 2: Steel Fibers

4. Methodology

4.1 Experimental Procedure

- Procurement and testing of raw materials.
- Mix design as per IS 10262:2019.
- Casting and curing of specimens.
- Strength and durability testing.

4.2 Mix Design

- Cement: 457 kg/m³
- Water: 192 kg/m³
- Olivine sand: 577 kg/m³
- Coarse aggregate: 1157 kg/m³
- Steel fibers: 5% of cement weight
- Water-cement ratio: 0.42

4.3 Testing Methods

- **Workability:** Slump test
- **Compressive Strength:** 150mm x 150mm cubes tested at 7 and 28 days
- **Split Tensile Strength:** 150mm x 300mm cylinders tested at 28 days
- **Durability Tests:** Water absorption and Sorptivity analysis

5. Results and Discussion

5.1 Workability

- Slump value without steel fibers: 3mm
- Slump value with steel fibers: 2mm
- Observation: Steel fibers reduce workability due to increased internal friction

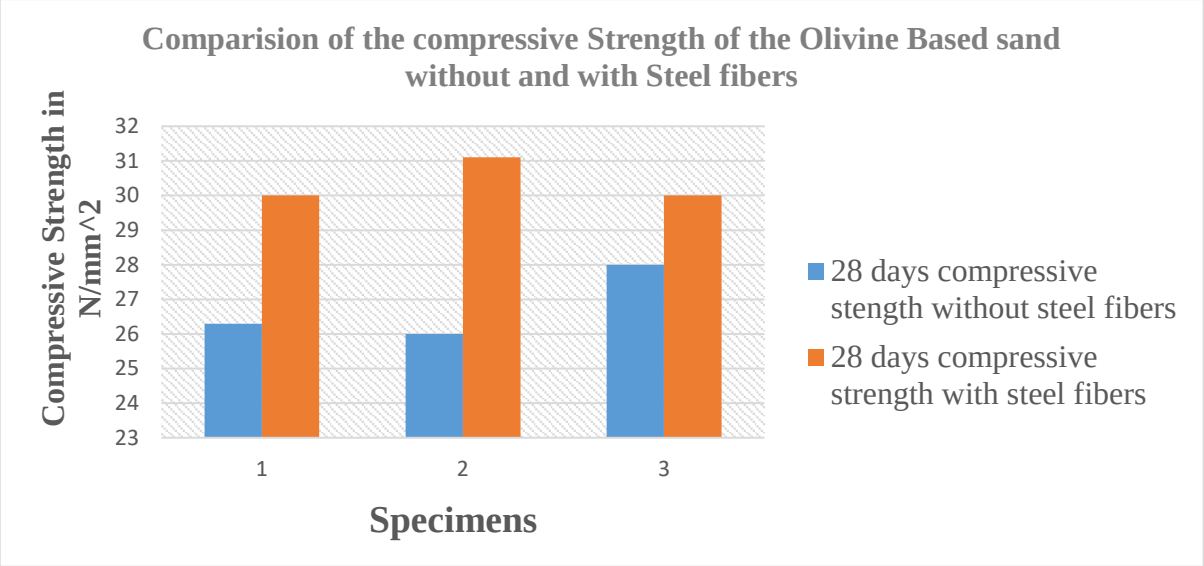
5.2 Compressive Strength

Compression testing machine was used to determine the compressive strength of 150mmX150mm specimens after 7 days and 28 days of curing for olivine sand based concrete with and without steel fibres.

According to the mix design, the 28 days compressive strength of the olivine based concrete should be 30 N/mm^2, from the graph it can be seen that the strength achieved in the concrete by complete replacement of fine aggregate by olivine sand is less than the target strength. This could be due to the influence of chemical composition of the olivine sand. In order to increase the strength of the olivine sand based concrete 5% steel fibers.

Table 1: Compressive strength olivine sand based concrete

Condition	7 Days (MPa)	28 Days (MPa)
Without Steel Fibers	17.7	26.76
With Steel Fibers	20.13	30



Graph 1: Comparison of olivine sand based concrete with and without steel fibers

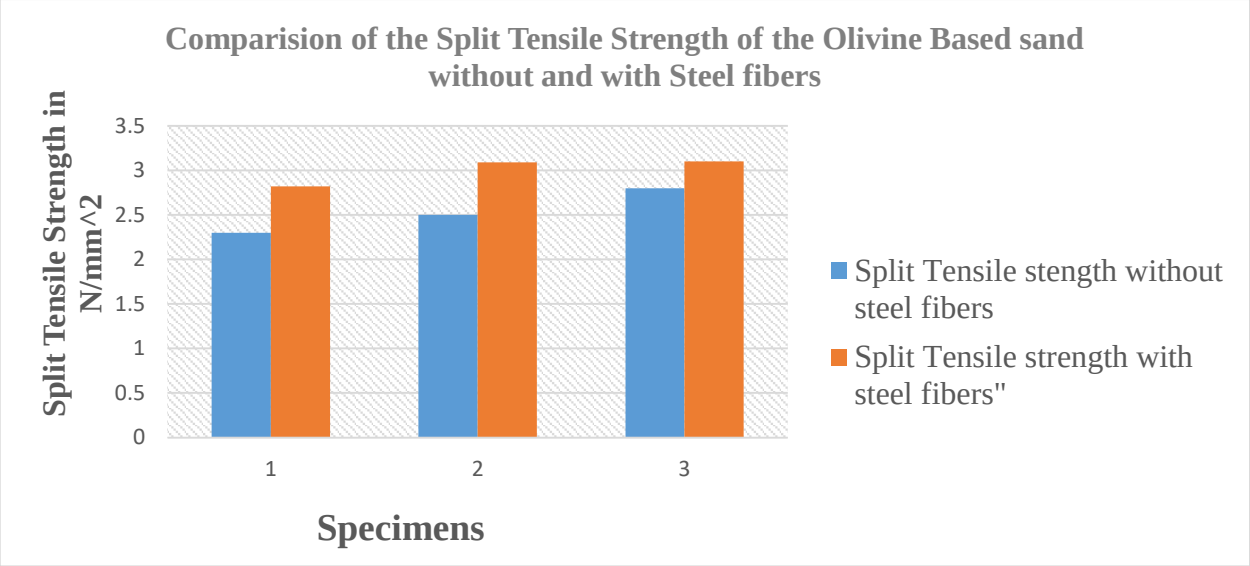
From the table 1 and graph 1 it is observed that 28 days average compressive strength of the olivine based concrete with the steel fibers is 30 MPa. Which is higher than the compressive strength of the olivine based concrete without steel fibers and it is satisfying with the target strength as per mix design.

5.3 Split Tensile Strength

The Universal testing equipment was used to assess the split tensile strength of a specimen measuring 150mm x 300mm. The split tensile strength of cylinder without adding steel fibers as shown in table 2.

Table 2: Split tensile strength of cylinder

Condition	28 Days (MPa)
Without Steel Fibers	2.5
With Steel Fibers	3.0



Graph 2: Comparison of split tensile strength of cylinders with and without steel fibers

From the table 5.11 & graph 5.4 it can be witnessed that the split tensile strength of the olivine based concrete with steel fibers is slightly increases as that of the concrete without steel fibers. The average split tensile strength of the olivine sand based concrete with steel fibers is 3MPa.

5.4 Durability Analysis

5.4.1 Water absorption test

The water absorption of Cubes is tested after 28 days of curing. The results are tabulated in below table 3

Table 3: Water absorption test of Cubes

SL NO.	Dry weight (W1) Grams	Wt. Of specimen after Immersing In Water (W2) Grams	Water Absorption (%)
1	9.5	9.6	1.17
2	8.65	8.8	1.73
3	7.65	7.7	1.16

From the table 3 it is observed that the initial absorption values (at 30min) of the specimens were less than the recommendations given by the concrete society. Based on the above results of the water absorption test concrete specimens casted using the olivine sand having lower absorption rates.

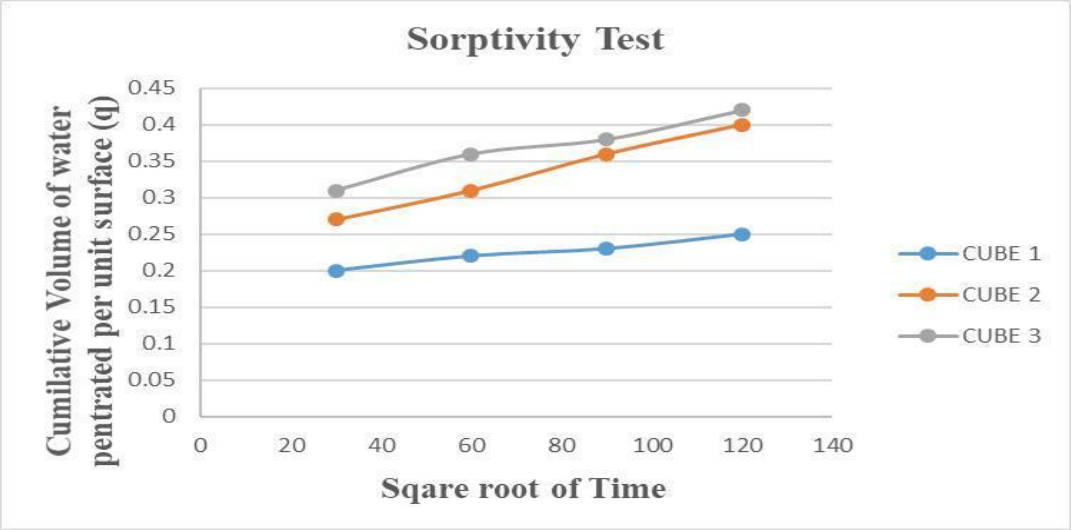
5.4.2 Sorptivity test

Sorptivity refers to the rate at which water percolates through the pores of concrete due to capillary action. ASTM C 642-82 was used to conduct the test.

Table 4: Sorptivity test results

No.	Initial weight (kg)	Weight gained after 30min (kg)	Weight gained after 60min (kg)	Weight gained after 90min (kg)	Weight gained after 120min (kg)	Sorptivity values 10-5 mm/min-0.5	Average Sorptivity
A	9.05	9.10	9.15	9.20	9.25	8.1	11.16
B	8.10	8.16	8.23	8.31	8.40	12.1	
C	8.75	8.82	8.90	8.98	9.08	13.3	

From the table 4 it is clear that the Sorptivity value of olivine sand based concrete is 11.16 mm/h$^{0.5}$ and it indicates that the durability of olivine based concrete is good.



Graph 3: Sorptivity test results of different interval of time

The cumulative volume of water that has penetrated per unit surface of exposure 'q' is plotted against the square root of time of exposure. The resulting graph could be approximated by straight line. The slope of this straight line is measure of moment of water through the capillary pores and is called Sorptivity.

Conclusions

Based on the results of the present study, the following significant conclusions may be drawn:

- Olivine sand is a naturally occurring mineral with carbon-sequestration properties, making it an eco- friendly alternative to traditional aggregates in concrete.
- The use of olivine sand in concrete, reduces dependency on depleting river or quarry sand.

- Steel fibres, often produced from recycled materials, reduce the need for additional reinforcement like steel bars, leading to resource savings.
- Workability of the olivine sand based concrete is good, true slump is archived.
- The addition of steel fibres decreases workability because of increased internal friction.
- Compressive Strength of the Olivine sand concrete slightly lower than target compressive strength, this may be due to reaction between olive sand and cement matrix.
- Average Compressive Strength of the Olivine sand concrete is 26.76 MPa
- The addition of 5% of steel fibres increases the Compressive Strength of the Olivine sand based concrete
- Average Compressive Strength of the Olivine sand based concrete with steel fibres is 30MPa
- The inclusion of steel fibres by 5% significantly improves split tensile strength of the olivine sand based concrete.
- Average Split tensile Strength of the Olivine sand based concrete with and without steel fibres is 3MPa & 2.5 MPa respectively.
- Durability studies on Olivine sand based concrete shows that concrete quality is good.

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