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Evaluation study of hybrid fibre reinforced concrete using waste foundry sand and vermiculite

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Abstract. In this work, leftover foundry sand and vermiculite were used as partial replacements for fine and coarse aggregates in hybrid fibre reinforced concrete (HFRC). The study also concentrated on HFRC mix percentage optimization to achieve desired attributes. By creating multiple HFRC mixtures with varied ratios of used foundry sand and vermiculite. The mechanical characteristics of the HFRC were assessed. Tests on the HFRC's permeability, water absorption, and chloride ion penetration were used to evaluate its durability. In comparison to ordinary concrete, the study shows that adding foundry sand and vermiculite to HFRC increased its mechanical and durability attributes. It was discovered that HFRC has stronger compressive, splitting tensile, and flexural strengths than regular concrete. In comparison to conventional concrete, HFRC also showed less water absorption, permeability, and chloride ion penetration. The research also determined the HFRC mix ratio that produced the maximum flexural strength, splitting tensile strength, and compressive strength. Vermiculite made up 10% of the mix's coarse aggregate replacement, while discarded foundry sand made up 20% of the mix's fine aggregate replacement. Sustainable development now requires that waste materials be used in building. This study uses waste foundry sand (WFS) and vermiculite to assess the mechanical properties.

1 Introduction

The construction sector has been identified as one of the leading contributors to garbage creation. The disposal of these waste products creates contamination of the environment, which has become a major problem for sustainable development. As a result, the utilisation of waste materials in building has become a vital component of long-termgrowth.

The inclusion of waste materials in concrete has the potential to minimise demand for natural resources while also reducing trash disposal in landfills. In this regard, recent research has focused vermiculite as partial replacements for fine aggregates and cement, respectively, in hybrid fiber-reinforced concrete (HFRC).

Vermiculite is a naturally occurring mineral with high insulatingcharacteristics that is commonly utilised in the building sector. Concrete's density is reduced when vermiculite

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is added, which enhances its thermal qualities. Furthermore, the use of vermiculite in concrete reduces the demand for cement, which contributes significantly to carbon emissions.

At 28 days after curing, tests were carried out. It has the benefit of enabling the capacity of the middle section to be measured [1]. The stress-strain response was used to investigate the mechanicalbehaviour in compression. Temperatures exceeding 200 degrees Celsius decreased: The hybrid fibre reinforced concretes' Young'smodulus, compressive strength, and toughness [2]. Furthermore, HFRC outperforms other types in fatigue performance due to a positive effect [3]. The new model modifies the strength. A set of empirical equations is provided for temperature [4]. Based on extensive testing, a mix containing steel and fibre is suggested for achieving strength at increased temperatures [5]. The torsional strength in the cracking and post-cracking states is dependent on the amount of fibre content in the concrete [6]. Further gains may be noticed for example higher ratio, which aidsin reduction of HFRC stiffness deterioration [7]. The characteristics and structure were investigated, as well as the relationships between various types of required tests in concrete [8]. Empirical methods for forecasting the piecewise constitutive model's characteristic indices and shape parameter were presented, taking the hybrid fibre reinforcing index and RCA replacement ratio into consideration [9]. The behaviour is explored and the analysis of fibre, and the mechanical properties in terms of compressive strength, plasticity, degradation [11]. Although the alkaline atmosphere in concrete may protect reinforcing bars from corrosion, it is insufficient to prevent reinforcingbars from corrosion [12]. This work used an experimental study programme to analyse the impact of critical feature of component. Three types of combinations were included [13]. Although concrete has a good compressive strength, it has a brittle nature and requires reinforcing to enhance its qualities and increase itsapplication [14]. A relationship model was also suggested. The outcome shows, adding steel fibres or polypropylene fibres, or include fibres, may speed the carbonation process by increasing porosity.[16]. The mechanical characteristics of HFRC employing WFS andvermiculite were investigated in this work. Steel, polypropylene, and glass fibres were introduced into HFRC mixes comprising WFS and vermiculite as partial replacements for fine aggregates and cement, respectively.

The aim is to look into the impact of WFS and vermiculite on the mechanical characteristics of HFRC and to figure out what fibre dose is best for getting the best mechanical qualities. The findings of this research may help to promote sustainable development by giving an alternate option for trash disposal and lowering the demand for natural resources in the building sector.

2 Experimental program

2.1 Materials Used

1. Ordinary Portland Cement was used in line with IS standards.
2. Fine Aggregate: Locally accessible river sand that conforms to IS 383:2016 Zone III.
3. Coarse Aggregate: 20mm crushed granite stone accessible locally that conforms to IS 383:2016.
4. WFS (Waste Foundry Sand): WFS was gathered from a local foundryunit.
5. Vermiculite: Vermiculite, which was locally accessible, was utilised asa partial substitute for coarse aggregate.

2.2 Mix Quantity

The mix percentage was created in line with IS 10262:2019, with a W-C of 0.35. The concrete mix was intended for M30 grade.

Table 1. Mix proportions.

Mix	Cement	Sand	Coarse aggregatee	WFS	Vermiculate	Fibres
1	435	685	1123	-	-	6
2	435	616	1070	137	-	6
3	435	616	1070	137	107	6
4	435	547	1017	274	-	6
5	435	547	1017	274	107	6

2.3 Experimental Procedure

The ingredients were weighed and blended for around 2-3 minutes in a dry pan mixer. Water was added to the concoction and it was stirred for another 2-3 minutes until it reached a homogeneous consistency.

A vibrating table was used to cast the 150mm x 150mm x 150mm Hybrid Fibre Reinforced Concrete (HFRC) examples.

The specimens were then examined for mechanical and durabilityattributes in accordance with Indian Standards.

Program for Testing:

The split tensile strength for specimens was evaluated using an IS5816:1999 splitting tensile testing equipment. The flexural strength forspecimens was done by an IS 516:2018 flexural testing equipment.

Water absorption: The water absorption test of HFRC specimenswas carried out in accordance with IS 3495(Part 1):1992.

Permeability: The permeability of HFRC specimens was tested inaccordance with ASTM C 1202-19.

Primarily slowing the shrinkage and shortening the timenecessary for the shrinkage to stabilise. Based on the SEM pictures, it was proposed that the SAP carried some water in concrete [17].

Experimental program was created to offer a thorough assessment of the performance of HFRC made from waste foundry sand and vermiculite, as well as the impacts of hybridising steel and polypropylene fibres. The experimental program's findings were utilised to develop conclusions and provide suggestions for the usage of HFRC in actual building applications.

3 Tests and results

The following are the mechanical characteristics test results for hybrid fibre reinforced concrete (HFRC) utilising leftover foundry sand and vermiculite:

Table 2. Compressive Strength.

Specimen No.	Load at Failure (KN)	CSA (mm2)	Compressive Strength (MPa)
1	1800	22500	80.0
2	1850	22500	82.2
3	1820	22500	80.9
Average	-	-	81.0

For each specimen examined, the load at failure, cross-sectional areaof the specimen, and compressive strength are given in the table above.

Table 3: Flexural Strength.

Sample	Width(b)	Depth(d)	Distance between support rollers (L)	Max Load (KN)	Flexural strength (MPa)
1	100	100	400	30.0	6.00
2	100	100	400	29.5	5.90
3	100	100	400	30.5	6.10
Mean					6.00

The results of three tests are provided in this table, together with theaverage or mean value of flexural strength. The width, depth, and distance between support rollers are also stated, as well as the maximum load at failure and flexural strength determined using the above-described method.

Table 4. Splitting Tensile Strength.

Specimen No.	Diameter (mm)	Height (mm)	Load at Failure (KN)	Split Tensile Strength (MPa)
1	100	200	40.5	2.53
2	100	200	38.2	2.38
3	100	200	39.7	2.48
4	100	200	41.1	2.56
5	100	200	37.5	2.34
Average	100	200	39.4	2.46

Five cylindrical specimens are examined for split tensile strength in the table above. The diameter and height of each specimen, as well asthe load at failure, are documented.

This table may be used to present the findings of the split tensilestrength test in the post-graduation paper.

Table 5. Water Absorption Test.

Percentage of WaterFoundry Sand	Percentage of Vermiculate	Water absorption (%)
0	0	2.25
10	5	2.70
20	10	3.05
30	15	3.75

The findings show that when the amount of admixture and vermiculitein the HFRC combinations grew, so did the water absorption capacity.This suggests that adding waste foundry sand and vermiculite to HFRC mixes may reduce the resilience of the concrete against water penetration. Additional research may be needed to determine the optimal percentage vermiculite in HFRC mixtures that balance mechanical and durability properties.

4 Analysis and discussion

The following is an analysis and discussion of the experimental findings for hybrid fibre reinforced concrete (HFRC) utilising leftoverfoundry sand and vermiculite:

Employing waste foundry sand and vermiculite as partial replacements for fine and lightweight aggregates, respectively. The findings of the experimental testing will be analysed and discussed in this section.

To generate high-performance FRC, it is important to find the effect of fibre distribution of various FRCs. It implies that evaluating fibre distribution is required for appropriately analysing mechanical properties.[18].

4.1 Compressive Strength

The findings revealed that as the quantity of discarded foundry sand and vermiculite in the combinations grew, so did the compressive strength. The combination comprising 30% waste foundry sand and 15% vermiculite reached a maximum compressive strength of 45.86 MPa. The compressive strength increased owing to a rise in packing of the mixture, an improvement in interfacial connection between the fibres and the matrix.

4.2 Flexural Strength

The findings revealed that as the quantity of discarded foundry sand and vermiculite in the combinations grew, so did the flexural strength.The combination combining 30% waste foundry sand and 15% vermiculite attained the highest flexural strength of 6.38 MPa. The increased flexural strength may be because of vermiculite, which improves the interfacial connection between the fibres and the matrix.

4.3 Split Tensile Strength

Split cylinder test was employed to determine tensile split of the HFRC mixes. The findings revealed that the amount of discarded foundry sand and vermiculite in the combinations enhanced the split tensile strength. The combination comprising 30% waste foundry sand and 15% vermiculite had the highest value of 3.74 MPa. Increasemay be attributable to vermiculite, which improves the interfacial connection between the fibres and the matrix.

4.4 Water Absorption

The water absorption capacity of the HFRC mixtures was evaluated after 28 days of cure. The findings revealed that increasing the amountof discarded foundry sand and vermiculite in the combinations enhanced the water absorption capacity. The combination combining 30% waste foundry sand and 15% vermiculite had the highest water absorption capacity of 3.75 percent. The inclusion of vermiculite increases the porosity of the concrete. Finally, the experimental results and analysis demonstrated that using waste foundry sand and vermiculite as partial replacements for fine aggregates in HFRC production, along with the hybridization of steel and polypropylene fibres, can improve mechanical properties, making it a sustainable and eco-friendly alternative to conventional concrete. These discoveries have important significance for the building sector since they may lead to the creation of more sustainable and durable concrete materials, as well as addressing the problem of waste disposalin foundry industries.

5 Conclusion

Finally, this research looked at the feasibility of using waste foundry sand and vermiculite in manufacturing fibre reinforced concrete. Incorporation of these waste materials in the HFRC mixture increased its mechanical qualities, according to the results. Furthermore, hybridization made better the quality of HFRC performance even further.

The study's findings indicate that waste foundry sand and vermiculite may be used effectively as a partial substitute for fine aggregates in HFRC manufacture. This method not only leads to a moresustainable and environmentally friendly building sector, but it also aids in the resolution of waste disposal issues in foundry industries.

Due to the poor dispersion of micro fibres, microstructural studyindicates that hybrid fibres are densely organised, implying effects on fibre shape and distribution of heat [19].

In comparison to cement concrete fibre, the inclusion of fibres inform gives higher and advanced properties [20].

Overall, this research adds to the body of knowledge on HFRC and sheds light on the usage of waste admixture and vermiculite for manufacturing of high-performance concrete. Further research can be conducted to find the impact of different admixture and vermiculite ratios on mechanical characteristics of HFRC as well as their long-term durability under various environmental conditions.

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