Investigation on Mechanical Properties of High Strength Light Weight Concrete with Exfoliated Vermiculite and Glass Fiber

Devika Dev S.[1*], Preena Praveen[2]

[1]PG Student, Dept. of Civil Engineering, Sree Narayana Institute of Technology, Adoor, Pathanamthitta, Kerala, India

[2]Assistant Professor, Dept. of Civil Engineering, Sree Narayana Institute of Technology, Adoor, Pathanamthitta, Kerala, India

*Corresponding author's e-mail: devika12904@gmail.com

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ABSTRACT

The concrete type known as high-strength concrete (HSC) has a high level of strength. HSC provides increased strength by the utilization of superplasticizers and silica fume. HSC is found to be very difficult to handle because of its high density. The density of HSC could be lowered with the use of lightweight aggregates. High Strength Light Weight Concrete (HSLWC) includes the behavior of both high-strength concrete and lightweight concrete. The lightweight aggregate used for HSLWC is Exfoliated Vermiculite (EV). It is a byproduct obtained from hydrous phyllosilicate minerals by heating. This provides various applications in the construction industry. This is an environmentally friendly material. Glass fibres will work as a strengthening element in concrete to make it strong and lightweight. The inclusion of glass fibers in HSLWC can raise its mechanical properties. Exfoliated vermiculite and glass fibres are integrated in this study to examine the mechanical characteristics of High Strength Lightweight Concrete (HSLWC).

Keywords: High strength concrete (HSC), High strength lightweight concrete (HSLWC), Exfoliated vermiculite (EV)

1 Introduction

Concrete plays major advances in the field of the construction industry. It is a composite material consisting ofa number of easily accessible constituents such as aggregates, sand, cement, and water. Concrete has been in use for many years as it provides various infrastructural developments. Concrete is a strong and durable building material possessingvarious properties. The evolution of concrete opens up new perspectives in the area of the construction sector. HighStrength Concrete (HSC) is one of the new advancements inconcrete. It can be used to build high-rise structures. HSC is made with commonly used recycled mineral admixtures in the way that fly ash, silica fume, etc. This type of concrete ismore efficient than traditional concrete but it is very difficultto handle because of its higher density. In order to make them lower- density concrete and to make them effortless for handling, lightweight aggregates can be used in HSC. Several lightweight aggregates used in concrete are perlite, pumice, expanded clay, vermiculite, diatomite, etc. Exfoliated vermiculite (EV) is a type of mineral that can be expanded tocreate a lightweight and highly porous material. Fibers are added to concrete to enhance mechanical properties. Glass fibers are added to make concrete stronger and more durable.

The strength and less weight of high-strength lightweight concrete (HSLWC) make it a highly desired type of concrete.The use of exfoliated vermiculite and glass fibers in HSLWC has shown promising results. The lightweight nature of vermiculite reduces the overall weight of concrete while the glass fibers provide improved tensile strength and durability.This combination results in a high-strength, lightweight material that is ideal for use in construction applications where weight is a concern.

Overall, using exfoliated vermiculite and glass fibers in HSLWC can revolutionize the construction industry by providing a stronger and lighter alternative to traditionalconcrete. Further research and development in

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this area willbe necessary to fully understand the properties and applications of this material.

2 Literature Review

2.1 Mohamed Sifan *et al.*, (2023)

The kind and traits of lightweight aggregates (LWA) have a significant impact on the characteristics of light weight high- strength concrete (LWHSC). For generating LWHSC, LWA must have a low density and a high crushing strength. The efficient water binder ratio is lowered by LWAs' reduced water absorption, was the primary factor affecting the workability of LWHSC. Therefore, it is advised to use pre- wetted LWA. More water is absorbed by the gaps in LWA, enhancing internal curing for the creation of high strength. The unification of different fibers extensively upgraded the tensile and flexural strength.

2.2 Lingqi Meng *et al.*, (2023)

This paper discusses lower-density ultra-high strengthconcrete which shows the characteristics of both performanceconcrete and lightweight aggregate. It is essential for the progress of big structures to use lightweight high-strength materials because they can considerably decrease both the dead load and devouring of construction possessions. The reinforced pore structure of inconsequential aggregates mainly affected the strength.

2.3 Ramkumar K.B *et al.*, (2022)

This study combined micro and hooked-end steel fibers to create Self-compacting concrete (SCC) mixtures that improved the mechanical properties and post-breaking behavior of SCC while still meeting the necessary SCC requirements. It was discovered that of all the fibre mixtures, those with a higher proportion of steel fibres improved the lastingness of factual mixes accompanying acceptable SSC traits. This study suggests using different hybrid steel fibers and additional cementitious materials in the SCC because metallic fiber will not hold same amount of water as non- metallic fiber.

2.4 O. Kayali *et al.*, (2003)

High-strength concrete is increasingly being used in the erection of high-rise buildings. In order to produce high- strength lightweight aggregate concrete with efficient structural properties, it will be reinforced with fibers. In this paper, 2 types of fibers are discussed i.e., polypropylene fibers and steel fibers. The integration of steel fibers into lightweight aggregate concrete with high-strength can increase ductility, whereas the inclusion of polypropylene fiber can elevate the value of indirect tensile strength.

3 Materials and Methodology

The components employed in this study comprise cement, silica fume, sand, coarse aggregate, water, superplasticizer, exfoliated vermiculite, and glass fiber. HSLWC can be formulated by ACI mix design. Fine aggregates in HSC are partially replaced bylightweight aggregates to form HSLWC and glass fibers are also added to improve the properties. The specimens were cast and cured at a constant temperature and tested at a specified age. Compressive strength, split tensile strength, and flexural strength were employed to investigate the mechanical properties of HSLWC.

3.1 Materials Used

This study engages common Portland cement of grade53 accompanying relative density of 3.1 and M Sand as fineaggregate accompanying relative density of 2.69. Coarse aggregate of size less than 8mm is used. A finely splitproduct of silicon or ferrosilicon alloys in an electric furnaceis called a silica fume with a specific gravity of 2.23 is used. M sand is partially replaced by exfoliated vermiculite with a specific gravity of 2.79 is used in this study. The polycarboxylate ether-based superplasticizer is used. To enhance the mechanical properties, glass fibers were utilized.It is a unique variety of synthetic fibers made of multiple, incredibly fine glass fibers.12 mm-sized fibers are used in this study.

3.2 Mix Proportion

HSLWC is designed using the ACI technique of mix design (ACI 211.1) with a strength grade of M60. The mix proportion obtained is 1: 1.57: 1.99 by the weight of cement,fine aggregate, and coarse aggregate. Hand mixing is followed to produce the mix. Coarse aggregate and fineaggregate are fundamentally dry assorted for 3 min. Then it is mixed with cement and silica fume added to it. Finally, thewater mixed with a superplasticizer was added to create the mix. Table 1 lists fine aggregates were replaced by 5%, 10%, and 15% with exfoliated vermiculite and the volume fractions of 0.1%, 0.2%, and 0.3% glass fibers were chosen and added to the concrete mixture.

Table 1: *Mix design*

Mix	Replacement of fine aggregate with exfoliated vermiculite	Fiber percentage
Control mix	0%	0%
HSLWC 1	5%	0%
HSLWC 2	10%	0%
HSLWC 3	15%	0%
HSLWC 4	5%	0.1%
HSLWC 5		0.2%
HSLWC 6		0.3%

4 Experimental Methods

4.1 Test on fresh properties

The slump test is one way to gauge the consistency of fresh concrete. It is utilized to ensure that the mixture has received the proper amount of water. Three layers of fresh concrete are poured into the steel slump cone, then set on a strong, impermeable base. The third layer is completed just below the peak of the cone. When the cone is carefully removed, a pile of concrete is left behind that slightly settles or slumps. In this study, the target set for slump flow was 250mm (Figure 1).

Figure 1: *Slump*

4.2 Test on hardened properties

Tests were conducted on the hardened features of the concrete containing compressive strength, tensile stifiness, and flexural strength. 150mm x 150mm x 150mm concrete cubes are cast as the specimen for

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compressive strength. To calculate the split tensile strength, 150 mm x 300mm cylinders were cast. Concrete beams with dimensions of 500 mm×100mm were cast to test flexural strength. Thespecimens were cast and cured for 7, 14, and 28 days.

5 Results And Discussion

5.1 Fresh behavior

The characteristics of lightweight aggregates influence the workability of lightweight concrete. The slump flow test for the concrete flowability is shown in the Table 2. It is found that the addition of vermiculite decreases the workability of concrete. As the vermiculite content decreases the slump gets greater. Vermiculite was dispersed irregularly throughout the matrix and impeded the flow of concrete.

Table 2: *Slump value*

Mix	Slump (mm)
NHSLWC	235
HSLWC 1	197
HSLWC 2	175
HSLWC 3	168

5.2 Compressive strength

The concrete cube specimens are cast and tested on a compression testing machine for determining compressive strength (Figure 2). It is followed as per IS 516-1959.

Figure 2: *Compression testing of cube specimen*

Compared to the compressive strength with the NHSLWC, the compressive strength for all replacements with exfoliated vermiculite decreased. 5% replacement of vermiculite shows greater compressive strength in comparison with 10%, and 15% replacements. Therefore, theoptimum value can be taken as 5%. The compressive strengthwas raised by the inclusion of glass fiber. It is added by 0.1%, 0.2%, and 0.3%. The volume fraction of 0.2% shows increased compressive strength as compared with the addition of 0.1% and 0.3% fiber. Figure 3 shows that among all the mixtures, 5% replacement with exfoliated vermiculite and 0.2% addition of glass fiber i.e., HSLWC 5 yields the highest compressive strength. The graph (Figure 3) displays the trend in compressive strength between concrete replaced with vermiculite and control concrete. The trend also demonstrates the compressive strength of concrete added with glass fiber.

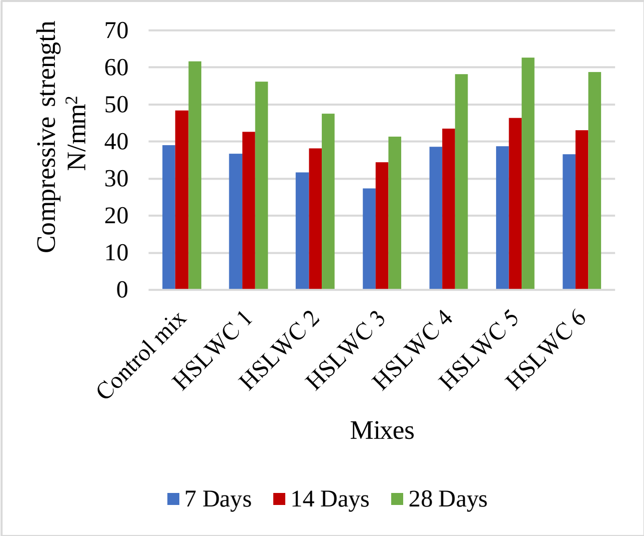

Figure 3: *Comparison of compressive strength between control mix, different percentages of vermiculite mixes, and glass fibers*

5.3 Split tensile strength

The indirect tensile strength of concrete is assessed using the split tensile test. All of the mixtures, as well as the base, and concrete were tested. As per IS 5816:1999, 150 mm x 300 mm cylinders are cast and tested to determine the split tensile strength (Figure 4). The split tensile test verdicts (Figure 5) show that HSLWC 5 has more split stiffness distinguished to different mixes, which may be caused by a difference in how effectively the glass fibers are bonded to the concrete. The specimen with HSLWC 3 mix has lower split tensile strength than the specimens prepared with the other mixes. This is because blends have low ductility, which reduces elongation and causes a quick break when a force is applied.

Figure 4: *Split tensile test*

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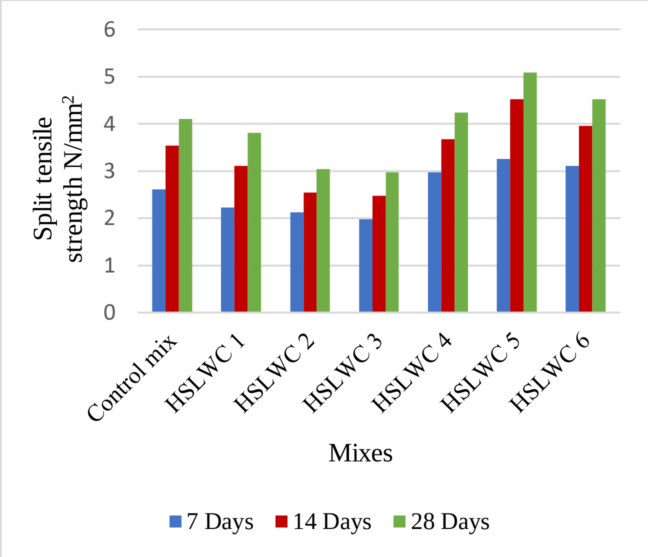

Figure 5: *Contrast of split tensile strength between control mix, different percentages of vermiculite mixes, and glass fibres*

5.4 Flexural strength

The flexural beam was tested in accordance with IS 516- 1959 guidelines (Figure 6). Test samples measuring 500 mm×100mm were utilized. The concrete flexural test is particularly important since it establishes concrete capacity for pure bending. It can be seen from the graph (Figure 7) that HSLWC 5 has greater flexural strength than other combinations. On the other hand, HSLWC 3 exhibits a lower flexural strength. The use of glass fiber enhanced flexural strength.

Figure 6: *Flexural strength test*

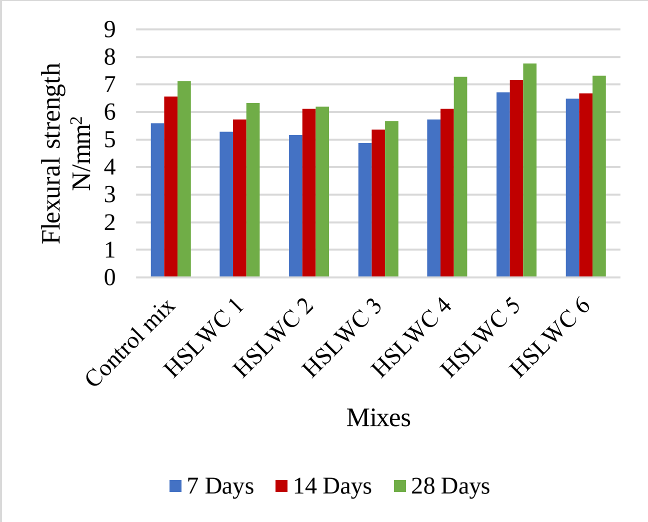

Figure 7: *Contrast of flexural strength between control mix, different percentages of vermiculite, and glass fibers*

6 Conclusions

The current investigation was to determine how the exfoliated vermiculite and glass fiber improved the mechanical characteristics of HSLWC. It was shown that the mechanical characteristics were decreased when fine aggregate was replaced with exfoliated vermiculite whereas the mechanical properties were improved by the use of glassfibers. The following are the findings of this investigation:

- The compressive strength, split stiffness and flexural strength were acquired maximum at 5% substitute with exfoliated vermiculite and 0.2% addition of glass fiber.
- Lowest strength was attained at the 15% replacement with vermiculite.
- Strength decreases by increasing the content of exfoliated vermiculite.
- As the amount of exfoliated vermiculite in concreteincreases, it becomes less workable.

7 Publisher's Note

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References

[1] Mohamed Sifan, Brabha Nagaratnam, Julian Thamboo, Keerthan Poologanathan, Marco Corradi, "Development and prospectives of lightweight high strength concrete using lightweight aggregates" Construction and Building Materials 362 (2023) 129628

[2] Lingqi Meng, Chunxiao Zhang, Jiuqi Wei, Lei Li, Jingbiao Liu, ShiheWang, Yahong Ding, "Mechanical properties and microstructure of ultra-high strength concrete with lightweight aggregates" Case studiesin Construction Materials 18 (2023) e01745

[3] Ramkumar K.B, Kannan Rajkumar P.R, "Impact of hybrid steel fiberson fresh and mechanical properties of Self-compacting concrete" Casestudies in Construction Materials 17 (2022) e01274

[4] O Kayali, M.N Haque, B Zhu, "Some characteristics of high strength fiber reinforced lightweight aggregate concrete" Cement and ConcreteComposites 25 (2003)