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Experimental Analysis of Mechanical Properties of Fiber Reinforced Cenosphere Lightweight Concrete with Higher Temperature Effect

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Abstract:
The aim of this research is to explore the impact of polypropylene fibers and glass fibers on the mechanical characteristics of lightweight concrete when subjected to elevated temperatures. Different fiber ratios ranging from 0.25% & 0.50% by volume of concrete were tested to evaluate their impact on various concrete mixtures. Cenosphere is lightweight material as used with cement as bonding material. Pumice aggregate, which is known for its lightweight properties, was utilized as the coarse aggregate. The study aimed to explore various characteristics of lightweight concrete such as slump value, unit weight, and compressive, tensile, and flexural strength. The concrete samples were subjected to different temperatures ranging from 200°C to 400°C for two hours. The findings revealed that the addition of glass fibers improved the tensile strength of the concrete and enhanced the compressive and flexural strength of the lightweight concrete. However, the incorporation of polypropylene fibers resulted in more cracks and pore formation in the concrete. Additionally, the compressive and flexural strength of the concrete decreased with an increase in temperature up to 400°C.

Keywords: Cenosphere, lightweight aggregate, glass fibers, polypropylene fibers, compressive strength and concrete.

1. Introduction

A distinct kind of concrete, known as lightweight aggregate concrete or cellular concrete, is referred to as lightweight concrete due to its significantly lower weight than conventional concrete. (Alwesabi et al., 2020), (Xu et al., 2020). This material finds extensive use in construction projects that require weight reduction, such as high-rise buildings, bridges, and precast elements. (Amin & Tayeh, 2020), (Li & Ma, 2020). Lightweight concrete is distinguished by its use of lightweight aggregates such as expanded clay, shale, slate, or volcanic materials. (Niu et al., 2020), (Asim et al., 2020).

The properties of lightweight concrete include a reduced density, with the density typically falling within a certain range 800 to 2000 kg/m³, the density of this concrete is notably less than that of regular concrete. (around 2400 kg/m³) (Yuan & Jia, 2021), (Düğenci et al., 2015), (Su et al., 2014). The decreased density leads to a significant decrease in the weight of the structure, which is beneficial for tall buildings and structures where weight is an important factor. (Niu et al., 2019), (Niaki et al., 2018). Compared to traditional concrete, lightweight concrete has superior thermal insulation properties.(Yang et al., 2021), (Rajamanickam et al., 2019). Maintaining a stable internal temperature is easier with lower thermal conductivity, resulting in increased energy efficiency and reduced heating or cooling expenses (Sabapathy et al., 2021), (Yang et al., 2021). Lightweight concrete has improved fire-resistant properties compared to traditional concrete due to its lower density and the use of lightweight aggregates. (Affan & Ali, 2022), (Thanaraj et al., 2019), (He et al., 2020). This product enhances the amount of time during which it can resist fire, giving occupants more time to evacuate and emergency responders more time to act during fire incidents (Mydin et al., 2015), (Feng et al., 2020). When using lightweight concrete, you can expect less shrinkage and creep, which are crucial for preventing cracks and ensuring the structure's durability in the long run. (Taghipoor & Sadeghian, 2022), (Jiang et al., 2014). Although lightweight concrete has a lower density, it is still easy to work with and can be placed and finished during construction with ease.(Zhou et al., 2020), (Müller et al., 2019).

2. Experimental Study

For this research, conventional Portland cement was utilized with cenosphere (10%) and tested following the guidelines of IS 4031. To regulate microstructure, interfacial migration (ITZ), early mechanical strength, and durability, silica fume was added as an extra mineral to the concrete. In this study, natural pumice was utilized as the light coarse aggregate. Various tests based on IS 2386:1963 were conducted on the coarse aggregate.the specific gravity of all material shown in below Table 1.

Sr. No.	Materials	Specific Gravity
01	Cement	3.15
02	Cenosphere	0.85
03	Fine Aggregate	2.59
04	Coarse Aggregate	2.66
05	Pumice Aggregate	0.95
06	Silica Fume	2.4
07	Polypropylene Fiber	0.9
08	Glass Fibers	2.60

To enhance the quality of concrete, a modified polycarboxylate aqueous solution called Viscocrete-20 HE is added to create a high-performance superplasticizer concrete mix. This superplasticizer is ideal for concrete mixes that require early strength, reduced water resistance, and great flow properties. The mix proportions for lightweight concrete can be found in Table 2.

Table 2: Mix Proportion for Lightweight Concrete for 1m^3

Mix ID	Water (Lit)	Cement (Kg)	Cenosphere (Kg)	Polypropylene Fiber (Kg)	Glass Fibers (Kg)	Silica Fume (Kg)	Superplasticizer (Lit)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	Pumice Aggregate (Kg)
M1	170	384.75	42.75	0	0	57.71	3.85	712.67	390.04	724.36
M2	170	384.75	42.75	2.25	0	57.71	3.85	712.67	390.04	724.36
M3	170	384.75	42.75	4.5	0	57.71	3.85	712.67	390.04	724.36
M4	170	384.75	42.75	0	6.5	57.71	3.85	712.67	390.04	724.36
M5	170	384.75	42.75	0	13	57.71	3.85	712.67	390.04	724.36

M1 mix is the concrete without any fibers, M2 mix is the concrete with 0.25% Polypropylene fibers, M3 mix is concrete with 0.50% Polypropylene fibers, M4 mix is the concrete with 0.25% Glass fibers & M5 mix is the concrete with 0.50% Glass fibers.

The experiment tested five different concrete mixes, two of which contained Polypropylene fibers, two contained Glass Fibers, and one was a control mix. The fibers were added in two ratios of 0.25% and 0.50% concrete by volume. Additionally, 15% silica fume was added to the mixture based on the cement content. The concrete aggregate was made up of a combination of natural coarse aggregate and pumice aggregate at rates of 35% and 65%, respectively. Pumice aggregate was used in both saturated and dry surface conditions. The ratio of fine aggregate to coarse aggregate was 40:60, and a high efficiency water reducing agent was added at a rate of 1% of the cement, equivalent to 384.75 kg/m3.

3. Results

The purpose of this study is to assess the new and hardened characteristics of lightweight aggregate concrete. A range of tests have been performed to assess key concrete properties, including compressive strength, flexural strength, and splitting tensile strength. Through this research, we aim to gain insight into the mechanical properties and durability of lightweight concrete when subjected to different conditions and loads. By examining the strength of various concrete types at different levels, this study aims to enhance our understanding of concrete performance and its potential utilization in construction, real estate, and engineering. The outcomes of this study will promote a deeper comprehension of lightweight aggregate behavior and its applicability to a variety of applications, ultimately supporting sustainable construction.

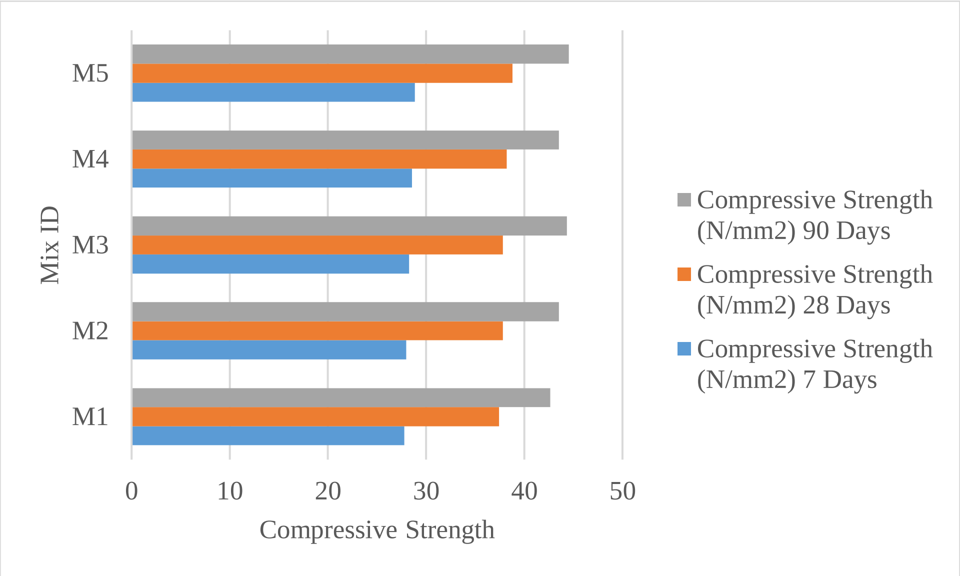

Fig.1: Compressive strength of the concrete

The study assessed the compressive strength of various concrete mixtures and found that the M2 mixture, which contained 0.25% polypropylene fiber, demonstrated the highest compressive strength. It was observed that incorporating polypropylene fibers into the concrete matrix had a beneficial impact on the compressive strength of the concrete, leading to enhanced performance.

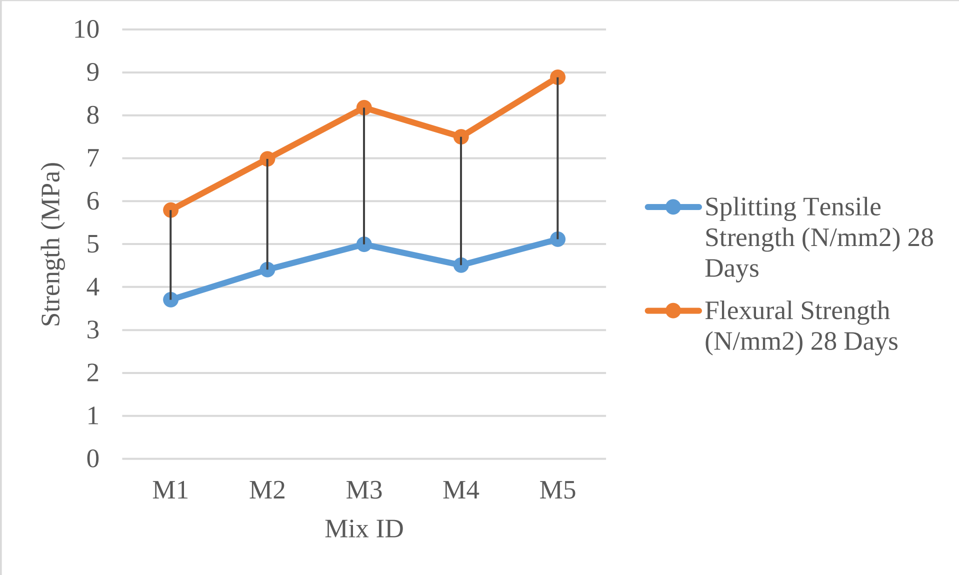

Fig.2: Splitting tensile strength and Flexural strength of the concrete

Through research, a thorough analysis was conducted on the splitting tensile strength and flexural strength of lightweight aggregate concrete. Experimentation was done with various combinations, each with different amounts of glass fiber. Among the different types of concrete, the M5 blend containing 0.50% glass fiber volume demonstrated the highest levels of both tensile strength and flexural strength.

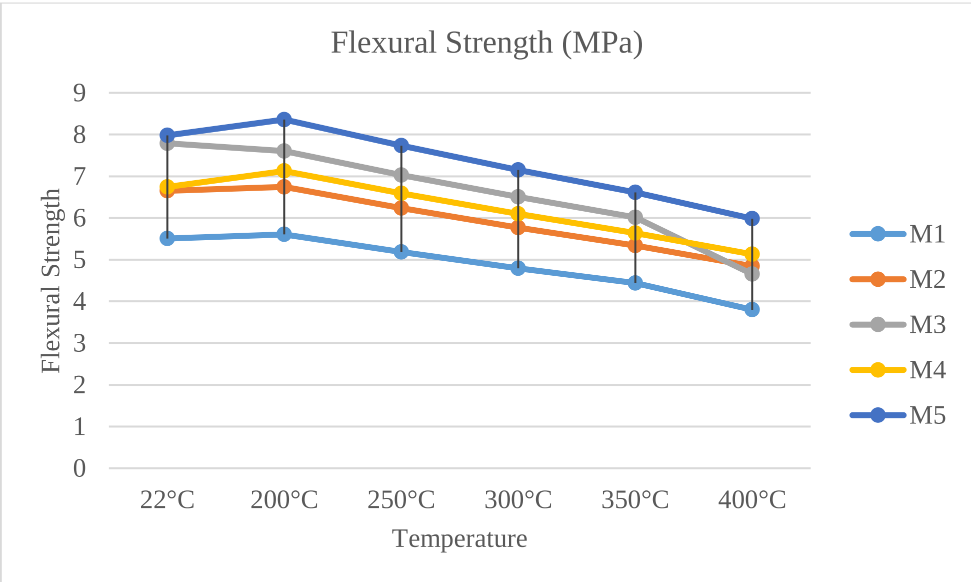

Fig.3: Effect of Temperature on Flexural strength

Research has focused on investigating the flexural strength of materials of different sizes. The results show that the flexural strength reaches its maximum value at 200°C. However, as the temperature rises to 400°C, the flexural strength gradually decreases. This finding indicates that there is an optimum temperature (about 200°C) at which the material has the highest flexural strength. Beyond that, the flexural strength begins to decrease as the temperature continues to increase. Understanding the temperature behavior of these materials is especially important for their use in areas where they can burn during their lifetime.

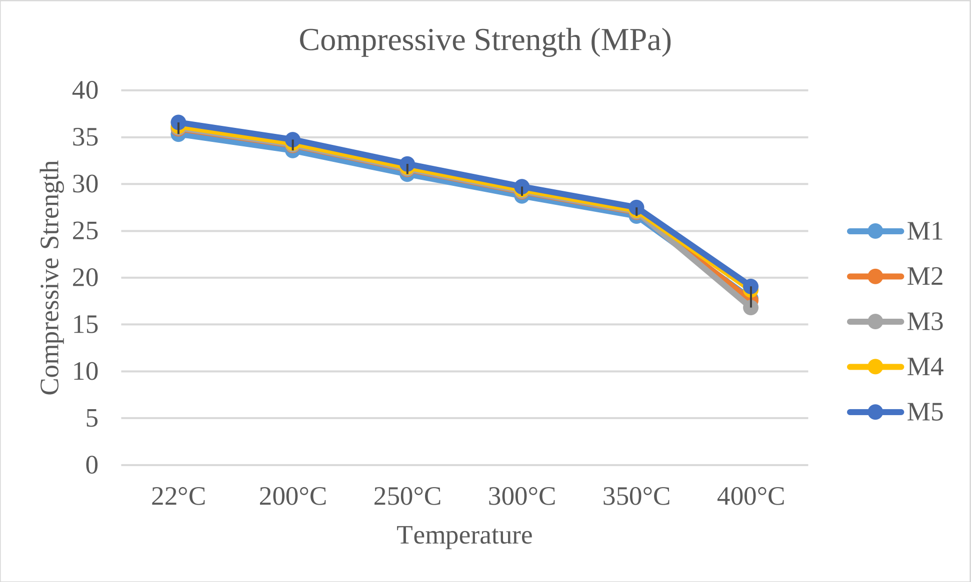

Fig.4: Effect of Temperature on Compressive strength

In this study, the compressive strength of concrete samples was analyzed at temperatures ranging from 22°C to 400°C. The results indicated that the highest strength was observed at 22°C, but the strength significantly reduced when the temperature reached 400°C. This suggests that changes in ambient temperature influence the properties of concrete, affecting its ability to withstand stress.

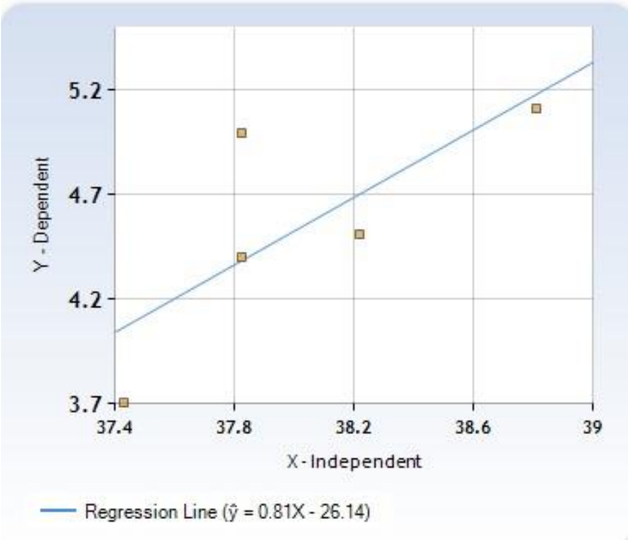

Fig.5 Regression analysis for compressive strength (X-axis) and Splitting Tensile strength (Y-axis)

Based on regression analysis, there appears to be a correlation between compressive strength and splitting tensile strength, with a positive relationship between the two variables. While the correlation is not absolute, the scatterplot data points suggest a general pattern of increasing tensile strength as the compressive strength increases.

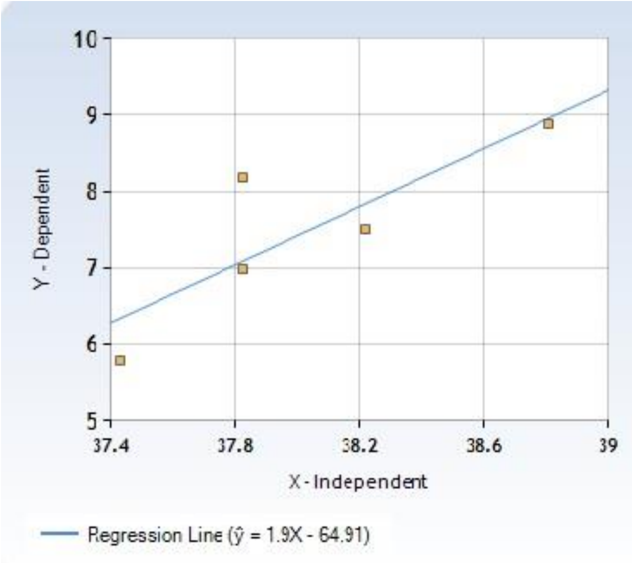

Fig.6: Regression analysis for compressive strength (X-axis) and Flexural strength (Y-axis)

A study was conducted using regression analysis to explore the correlation between compressive strength (X-axis) and flexural strength (Y-axis) in concrete samples. The findings revealed a strong connection between these two vital properties of concrete. The analysis demonstrated that as the compressive strength increases, the flexural strength of the material also increases. This relationship implies that an increase in compressive strength will lead to a corresponding increase in flexural strength.

4. Conclusions

To sum up, this study conducted regression analysis to explore how compressive strength and flexural strength of concrete samples are related. The findings showed that there is a positive correlation between the two properties, which means that higher compressive strength results in higher flexural strength of the material. Furthermore, the research also investigated the impact of temperature on the compressive and flexural strength of concrete, highlighting the crucial role of temperature in influencing these mechanical properties. Understanding these relationships is essential to optimize the design and performance of concrete structures in various environments and applications. Further research in this field could lead to better concrete formulations and construction practices for enhanced durability and safety.

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