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Experimental Investigation on Cellular Light Weight Concrete

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ABSTRACT: In recent years, various advanced technologies have been introduced in concrete production, including Cellular Lightweight Concrete (CLC), which has gained significant attention. CLC offers numerous advantages over conventional concrete, making it a promising innovation in the construction industry. fly ash-based CLC an environmentally friendly and sustainable material with low energy requirements. The foaming agent Marjanol, a Protein based concrete foaming agent is used for experimentation purpose. To enhance the strength of the concrete green fibers are added in the foaming agent was implemented to enhance the strength of the foam concrete. 0.15%, 0.2%, and 0.3% of the total mix was used by volume to get the maximum strength. After 28 days of proper curing, the foam concrete achieves 99.62% of its compressive strength. The maximum compressive strength recorded was 21.1 MPa, with the peak load-bearing capacity reaching 3.49 kN at approximately 5% foam content. The maximum flexural strength of the foam concrete was observed to be 2.5 MPa.

KEYWORDS: Cellular Lightweight Concrete (CLC), Fly ash, Foaming Agent, Silica fume.

I. INTRODUCTION

Due to the focus on sustainable development and the need to reduce energy use and CO_2 emissions, there is a growing demand for lightweight concrete, aerated concrete, and lightweight foam concrete [1]. Cellular Lightweight Concrete (CLC) is a type of lightweight concrete made at normal temperatures, just like regular concrete [2]. CLC contains tiny, uniform air pockets created using foaming agents or gas-producing chemicals. In India, CLC is especially useful for low-rise buildings and for partition walls in multi-storey structures due to its light weight and good thermal properties [3]. These lightweight forms contain a higher volume of air-filled cells, which act as barriers to heat transfer, making the material an excellent choice for insulating roofs, floors, and walls [4]. This reduces the need for additional insulation materials and helps maintain comfortable indoor temperatures, especially in hot climates [5]. As the density increases, CLC becomes stronger and more suitable for load-bearing elements, such as wall panels, blocks, and even precast components. Higher density variants (closer to 1,800 kg/m³) are used where greater strength is required without sacrificing the benefits of lighter weight compared to conventional concrete [6]. In addition to its adjustable density, CLC offers several practical and environmental advantages [7]. The foam liquid's primary function is to introduce air bubbles into the cement-based mixture, making the concrete lightweight. The foam itself is generated separately using a foam generator, where a foaming agent is diluted with water to produce the foam. Foam concrete gets lighter as more foam is added, meaning the more foam in the mix, the lower the density the lower the resulting density of the concrete [8]. Cellular Lightweight Concrete is a new material made by adding foam to a cement-based mix. This concrete can be produced in a range of densities, from as light as 300 kg/m3 to as heavy as 1850 kg/m3, making it suitable for various uses, from lightweight non-structural elements to stronger structural components, depending on the required strength and weight. The combination of fly ash and foam in CLC results in a material that is both lightweight and durable.

This research paper insights that the application of foam concrete is more sustainable option compared to traditional concrete. The stability of Foam increases with increase in foaming agent percentage and percentage drainage minimizes with time.





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II. LITERATURE SURVEY

Foam concrete is often used in high-rise buildings for both load-bearing and non-load-bearing purposes, as well as in other applications [9]. The water-cement ratio affects the material's porosity, dry density, and strength [10]. The water-cement ratio has a strong impact on the internal structure and overall quality of the foam concrete [11]. The best water-cement ratios for mix designs with target densities of 400, 500, 600, 700, and 800 kg/m³ are 0.58, 0.54, 0.56, 0.55, and 0.53, respectively [12]. The foam itself is generated separately using a foam generator, where a foaming agent is diluted with water to produce the foam. Foam concrete gets lighter as more foam is added, meaning the more foam in the mix, the lower the density the lower the resulting density of the concrete [13]. Foam Concrete is a type of cement-based mortar that consists of cement, water, and foam created using a foaming agent [14]. The foam generator functions by mixing the foaming agent (typically a surfactant) with water to create a stable foam. This foam is then incorporated into the cement slurry, where the bubbles get trapped within the mixture, forming an air-void structure. The size and distribution of these bubbles depend on factors such as the foam concentration, mixing time, and the properties of the foam agent. Smaller bubbles result in higher density and enhanced strength, while larger bubbles contribute to lighter, less dense concrete with better insulation properties [15-16].

III. METHODOLOGY

53-grade Ordinary Portland Cement, fly ash, with a specific gravity of 2.25, Silica fume, 70 15 with a specific gravity of 2.12, The foaming agent Marjanol Protein Based Concrete Foaming Agent Liquid procured from M/S Marjan Industries, New Delhi, India. Chemical constituents of concrete Foaming are 1. Sodium Lauryl Sulphate 2. Sodium Lauryl Ether Sulphate 3. Alpha Olefin Sulphonate 4. Sodium Lauryl Ether Sulphate 5. Coco Amido Propyl Betain etc. The study uses 53-grade Ordinary Portland Cement as per IS 12269-1987 standards and potable water conforming to IS 456:2000. Fly ash, with a specific gravity of 2.25, is procured from the local vendor MIDC, Ahilyanagar, Maharashtra, India. Silica fume, with a specific gravity of 2.12, is obtained from MIDC, Ahilynagar, Maharashtra, India. The foaming agent is a protein-based standard, derived through the hydrolysis of animal proteins such as keratin from sources like horn meal, hooves, fish scales, and casein from cattle and pigs. Fig 1, shows the Flow chart of general working process of foam concrete preparation.



Fig 1. Flow chart of general working process of foam concrete preparation





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IV. EXPERIMENTAL RESULTS

To understand the behaviour of lightweight concrete, standard testing procedures will be conducted to evaluate its material and structural properties. These tests also examined how the properties varied based on different mix designs and compositions. The proposed control mix proportion was 1: 1.5: 0.45 by weight of cement, sand, and water with consideration of foam. Table 1 represents mix design. Fig. 2. Result of age vs. compressive strength with control and silica fume mix. 3-Day Strength: The mixture without silica demonstrated a marginally higher early strength, recording approximately 3.2 MPa, compared to the silica-containing batch, which showed around 2.8 MPa. By the seventh day, the trend reversed the silica-enhanced mix exhibited improved strength characteristics, rising to roughly 3.5 MPa. In contrast, the control mix experienced a slight decline, settling near 2.9 MPa. At 28 days, the silica mix exhibited a marked improvement in compressive performance, reaching close to 4.9 MPa.

Table 1. Composition of the mixtures for target density 1150 kg/m³

Mixture No.	Required Density in (kg/m ³)	w/c	C (kg)	S (kg)	W (kg)	Added water (Lit)	Silica Fume
1	1150	0.45	18.88	28.32	8.5	0	0
2	1150	0.45	18.88	28.32	8.5	0.5	10%
3	1150	0.45	18.88	28.32	8.5	0.75	15%



Fig. 2. Result of age vs. compressive strength with control and silica fume mix

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Fig 3a-3e shows the formation of foam and mix preparation, cube casting, its drying and test.

Fig 3.a. Foam formation by adding foaming agent Fig 3.b. Foam concrete mix preparation

Fig 3c. Casting of Foam specimen Fig 3c. natural drying of specimen

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Fig. 3e. Testing of CLC Sample

The compressive strength of foamed concrete is influenced by a variety of interrelated factors, each playing a critical role in determining the material's mechanical performance. Among the most significant of these are the density of the mix, the type and proportion of cement used, the water-to-cement (w/c) ratio, the nature of the foaming agent or surfactant, and the curing conditions applied during the hardening process. A higher density generally leads to increased strength due to the reduced presence of air voids. Similarly, the selection and dosage of cement impact the formation and bonding of hydration products, while an optimal w/c ratio ensures sufficient workability without compromising strength. The average compressive strength of foamed concrete was 21.1 N/mm2 at 28 days.

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Table 2. Compressive strength of foam concrete

Compressive strength of foam concrete						
7 days	14 days	28 days				
11.0	17.4	21.1				
8.0	20.5	20.0				
10.0	17.6	21.0				
7.6	11.5	19				

The split tensile test of foam concrete is carried out to measure its tensile strength, which refers to the material's ability to resist forces that try to pull it apart. This property is crucial for structural applications, where tension forces can affect the safety and durability of a structure. During the test, cylindrical samples of foam concrete are prepared and cured. The test is typically performed after 7, 14, and 28 days of curing to observe how the tensile strength develops over time. Fig 4. Represents split tensile strength of foam concrete. The maximum strength achieved is 3.49 KN for foam content percentage around 5%, as the more foam added voids are going to increases rapidly due to which strength of concrete going to reduced.

Fig. 4. split tensile test

Flexural strength of foam concrete refers to its ability to resist bending stress without breaking. This property is particularly important in structural elements such as slabs, beams, and pavements, where the concrete is subjected to bending or flexing forces. To determine flexural strength, a standard test called the modulus of rupture test is performed, usually using a beam specimen (commonly 100 mm \times 100 mm \times 500 mm). The beam is placed on two supports and loaded in the middle (or third-point loading) until it breaks. The maximum load applied before failure is used to calculate the flexural strength. Like other strength tests, this one is conducted after 7th, 14th, and 28th days of curing to monitor how the material gains strength over time. The maximum Flexural strength of foam concrete was found to be 2.5 MPa.

V. CONCLUSION

- The stability of Foam increases with increase in foaming agent percentage and percentage drainage minimizes with time. The maturity strength of LCC matrix after 28 days attains 99.62% compressive strength with proper curing of specimens.
- An experimental result shows consistency with the maturity concept of compressive strength for a period of 28 days.
- Low density form requires more foam, which can make it harder to stabilize the mixture. For low density higher the water absorption and durability are found to be moderate.
- The maximum compressive strength found to be 21.1 MPa. The maximum strength achieved is 3.49 KN for foam content percentage around 5%.
- The maximum Flexural strength of foam concrete was found to be 2.5 MPa

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