EVALUATION OF FOAM CONCRETE PROPERTIES USING XANTHAN GUM (XG) AND DIVERSE SURFACTANT COMBINATIONS

GUGULOTH SUMAN[1], Dr. B. NARESH[2]

[1]M. Tech Student, Department of Civil Engineering, Jb institute of engineering and technology, Hyderabad, Telangana 500075

[2]Assistant Professor, Department of Civil Engineering, Jb institute of engineering and technology, Hyderabad, Telangana 500075

Abstract *The impact of Xanthan Gum (XG) and various surfactant combinations on the characteristics of foam concrete is examined in this research. Different combinations of three surfactants were utilized with different XG dosages: Sodium Lauryl Sulfate (SLS), Nonylphenol Ethoxylate (NPE), and Cocamido propyl Betaine (CAPB). Foam characteristics (initial density, viscosity, and stability), fresh state characteristics (fresh density and flow time), and hardened state qualities (compressive strength, split tensile strength, and water absorption) were the primary areas of experimental investigation.*

The foam stability and mechanical performance were shown to be greatly affected by surfactant combinations. At lower XG concentrations, the SLS+CAPB combination performed the best, whereas at higher XG levels, the NPE+CAPB combination excelled. While increasing the XG concentration made the foam more stable, it also made it thicker. Optimal results were achieved with modest XG levels, and the water-to-solid (W/S) ratio had a significant impact on both fresh density and flow time. Lower concentrations of XG had little effect on mechanical performance, while 0.2% XG increased both compressive and split tensile strengths. The reduction in water absorption that occurred with XG doses ranging from 0.1% to 0.2% suggests that the pore structure was improved and the porosity was reduced. Applications in lightweight construction and insulating materials may benefit from the study's significant insights into the appropriate usage of surfactant mixtures and XG to enhance the qualities of foam concrete.

Keywords Foam concrete, surfactants, Sodium Lauryl Sulfate (SLS), Nonylphenol Ethoxylate (NPE), Cocamidopropyl Betaine (CAPB), Xanthan gum, lightweight concrete, foam stability, workability, Compressive strength.

1. INTRODUCTION

The self-compacting nature of foam concrete makes mechanical vibration unnecessary during installation. Cemex, water, and a stable foam are the main ingredients. The foam is created using a foaming agent, which evenly distributes air holes throughout the material. The ratio of foam to slurry determines the density of foam concrete, which usually falls between 300 and 1600 kg/m³. You may add sand, powdered fuel ash (PFA), quarry dust, or limestone dust to make it even better [1,2].

Both pre-foaming and mixed foaming are the two primary methods for producing foam concrete. Both approaches include adding table foam to a cementitious slurry in order to get the desired density and characteristics [3]. A number of considerations, including project requirements, available equipment, and desired level of product consistency, go into deciding on a manufacturing technique.

Advantage of foam concrete

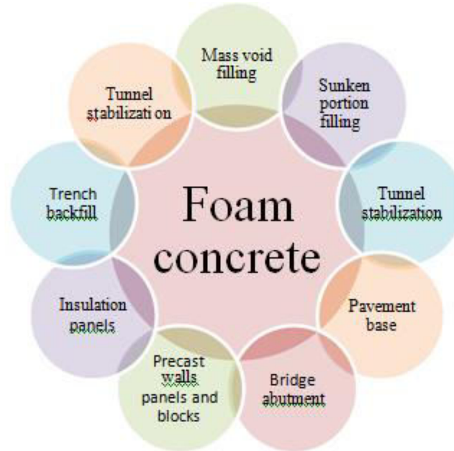
The main benefits of foam concrete are as follows:

1. Having a compressive strength of 0.2-18 N/mm² and a low density of 350-1600 kg/m³, it is perfect for lightweight construction.

2. Pumping and void filling without compaction are made easier by its high fluidity and self-leveling qualities.
3. Superior fire protection—a 15-centimeter wall keeps flames at bay for more than seven hours.
4. Exceptional acoustic and thermal insulation due to low thermal conductivity [4] .
5. The capacity to withstand high temperature changes guarantees long-term endurance.
6. Hypoallergenic, non-decomposing, insect-, rodent-, and fungal-resistant.
7. Time and money saved by a decrease in foundation costs, the ability to build on unstable soils, and quick execution.

Applications of foam concrete

1. Floor and wall insulation, fireproof dividers, and acoustic and thermal insulation are all applications for this material.
2. Utilized for filling in tunnels, repairing sewers, and voids in subterranean places; also used to fill in abandoned fuel tanks.
3. Used in subway and tube infill to decommission obsolete infrastructure economically.
4. Lightweight foundations may be used to lessen the chances of settling in locations with poor soil.
5. Part of modular and industrialized building systems' pre-cast blocks and panels.
6. Lightweight sub-base filler used in road construction to avoid settling and in airport aircraft arrestor systems.



Applications of foam concrete

2. LITERATURE REVIEWS

Higher concentrations of sodium lauryl sulfate (SLS) increased pore homogeneity in foamed cement based on hydrogen peroxide, but they drastically decreased compressive strength owing to the excessive creation of air voids, according to research by Hamza et al. After creating a protein-based foaming agent using human hair residue, Zhang et al. found that SLS had the greatest foaming performance and that α-sodium alpha-alkenyl sulfonate (AOS) gave the most stable foam. In their study on lightweight cellular concrete (LWCC), Theenathayalan et al. discovered that fly ash was the most effective foam stabilizer, while sodium lauryl ether sulfate (SLES) offered better foam stability. SLS was therefore chosen as the preferred foam stabilizer [5]. Furthermore, their research showed that aerosol-based foam applications were superior to traditional foam-based approaches for structural applications due to better compressive strength (16.8 MPa).

The use of surfactants greatly enhances the mechanical characteristics, bubble production, and foam retention. Anionic surfactants alone led to bigger holes and poor foam stability, according to research by Kashani et al., who studied foam concrete with both ionic and non-ionic surfactants. The significance of surfactant selection was highlighted when a mixture of anionic SDS and non-ionic Triton X-100 enhanced foam stability and increased compressive strength by 25%. In their study on 3D-printable foam concrete, Boddepalli et al. found that surfactants with a viscosity greater than 5 MPa greatly enhanced foam stability, decreasing foam drainage and boosting extrudability. As a result, these surfactants are perfect for use in additive manufacturing [6].

In their subsequent study, Theenathayalan et al. assessed several surfactants, such as SLS, CTAB, and SDBS. Their research shown that when compared to CTAB and SDBS, SLS produced the most stable air cells of micron size, with superior compressive strength and durability [7] .

Objectives of the study

1. To assess the efficacy of foam produced with three distinct surfactants: Nonylphenol Ethoxylate (NPE), Sodium Lauryl Sulfate (SLS), and Cocamidopropyl Betaine (CAPB).
2. To investigate foam concrete's characteristics in their uncured form.
3. Conduct compressive strength and split tensile tests on foam concrete to learn more about its mechanical characteristics.
4. Evaluate the durability and porosity of foam concrete by analyzing its water absorption properties.
5. Fifthly, to evaluate the effect of various surfactant mixtures on the overall functionality of foam concrete.

3. MATERIALS USED

3.1 Cement

Ordinary Portland Cement (OPC) of 53grade, readily available in the local market, was used in this study. Specific gravity of 3.15

3.2 Sand

The maximum size of sand used can be 5mm. Use of finer sands up to 2mm with amount passing through 600 micron sieve range from 60 to 95%.

3.3 Water

Water was a key component in both foam generation and the casting process for making the mix.

3.4 Foam

Foam is generated when a solution of water and a foaming agent is driven into a mixing chamber by compressed air through a series of restrictions.

Manufacturing of foam

1. First, the foaming agent (CAPB, SLS, or NPE) was mixed with a certain amount of water to produce a uniform solution.

2. Compressed air at a pressure of 5.2 kPa was introduced to the foaming solution and a foam generator in order to push the solution beyond its limits and create foam.
3. After collecting the foam, it was ready for testing and possible application in making foam concrete [8].
4. The Initial Foam Density Test was used to determine the density of the freshly made foam. After that, the Foam Stability Test was used to determine how sturdy it was.

Foam generator

Tests to be conducted on foam concrete

The following are the major tests to be conducted on foam concrete

1. Initial foam density
2. Foam stability test
3. Viscosity test

Procedure for foam concrete preparation

The required concentration of surfactant was applied to create the foam. Concurrently, the cementitious slurry was prepared by mixing cement with water and additives such Xanthan gum. As can be seen in the table below, four different water-to-solid (W/S) ratios were used to produce the mixtures [9].

Mix proportions of four different W/S ratios

W/S Ratio	For 10litres of foam concrete			
	Cement(in kg)	Sand(in kg)	Foam(in g)	Water(in kg)
0.17	5.12	10.25	48	2.56
0.20	5.0	10.0	48	3.0
0.25	4.8	9.6	48	3.6
0.30	4.61	9.23	48	4.1

The foam was gradually added to the slurry while it was being regularly mixed to ensure even distribution.
For each combination, ten cubes measuring 50 mm x 50 mm x 50 mm and two cylinders with 10 cm diameter × 20 cm height were cast. To ensure proper compacting and to release any air bubbles that may have been retained, the molds were gently tapped [10, 11].
After a little trowel or steel scale smoothing, the surface was left undisturbed for the first setting. After demolding, the samples were cured in water for 25 days, and then they were cured in an oven for 3 days.

Casting of cube sand cylinders

Curing of foam concrete samples

Taking wet weight of the sample

Placing the samples for oven drying

4. EXPERIMENTAL STUDY

Compressive strength of concrete

1. The concrete cube specimens, measuring 50 mm x 50 mm x 50 mm, were carefully removed from the mold after the curing period to ensure they were undamaged.
2. In order to ensure that the strain would be spread uniformly, the cubes were cleaned, leveled, and polished prior to testing.
3. Finally, the third step was to ensure that each concrete cube's flat surface was receiving the load from the compression testing apparatus.
4. Using the compression testing equipment, the concrete cube was exposed to a constant-rate, steadily growing force until it shattered.
5. The specimen's compressive strength was determined by noting the maximum load at which it collapsed.

Cube under compression in UTM

Split tensile Strength

1. A compression test was performed on the specimen by positioning it horizontally in a device that exerts a tension along the axis of the cylinder.
2. A steel plate or another smooth loading cap was applied to both ends of the cylinder to ensure that the weight was distributed equally. Both the specimen and the loading plates were almost the same diameter.
3. A constant compressive force, typically 0.2 MPa/min, was applied until the specimen broke or separated. Avoiding sudden shock loading was achieved by gradually applying the load.
4. The specimen was recorded as collapsing at the maximum load (P), which was the utmost force applied to the concrete cylinder prior to splitting.

Split tensile test of cylinders

Water absorption test

Finding the average amount of water that the cubes absorbed was as simple as dividing the average dry mass by the average wet mass, and then noting the result to the nearest 0.05 kg (0.1 lb). To get the average amount of water absorbed, we divided the total amount of water by the density of water, which is given in kilograms per cubic meter [12].

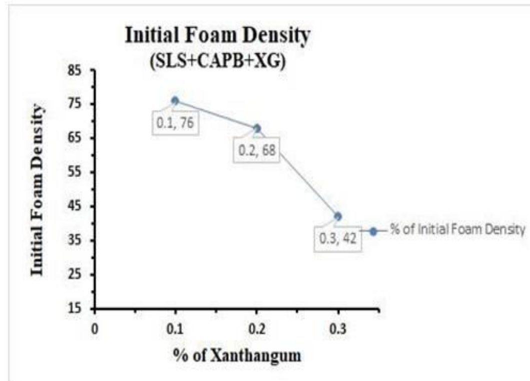
The water absorption was calculated using the equation: Absorption, % by volume =100

*(v w) / (v c) .

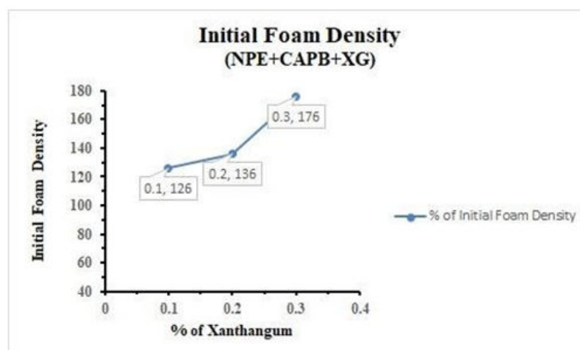
5. EXPERIMENTAL RESULTS

The findings and analysis of the experimental investigation are presented in this chapter. The study examined foam properties including initial density, viscosity, and stability. The flow duration and density of foam concrete in its fresh form were also assessed.

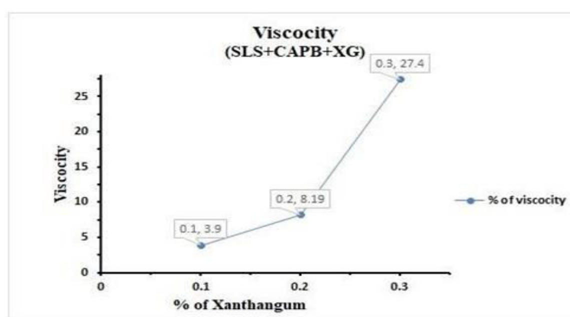
Mechanical properties were evaluated by testing the foam concrete samples for water absorption and compressive and split tensile strengths. To facilitate comparison and analysis of the effects of different surfactant combinations and xanthan gum on the performance of foam concrete, the collected data has been presented systematically using graphs [13, 14].



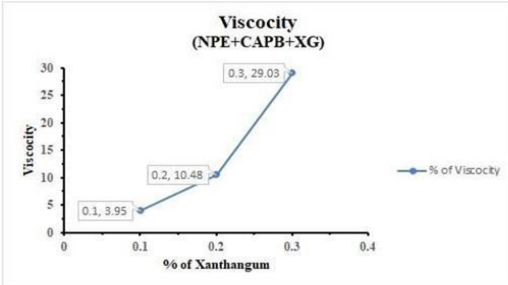
Percentage of xanthun gum Vs Initial foam density graph



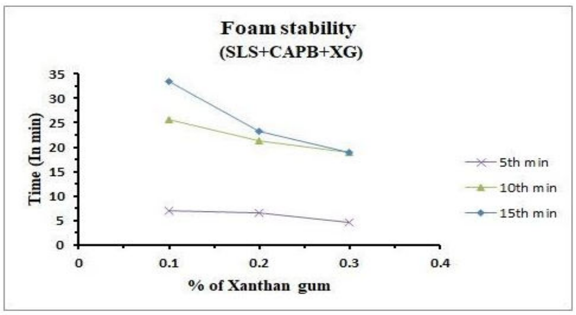
Percentage of xanthun gum Vs Initial foam density graph



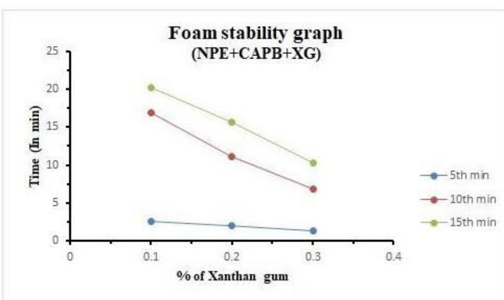
Percentage of xanthun gum Vs Viscocity graph



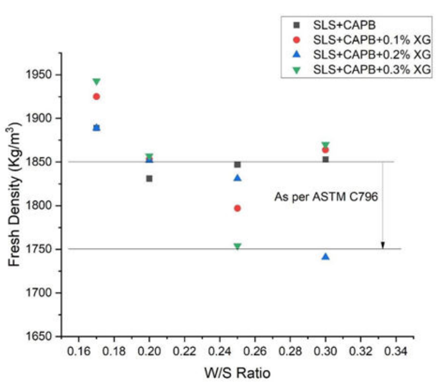
Percentage of xanthun gum Vs Viscocity graph



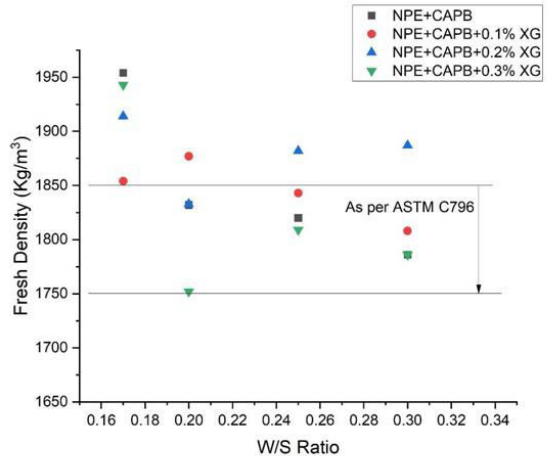
Percentage of xanthun gum Vs Foam stability graph



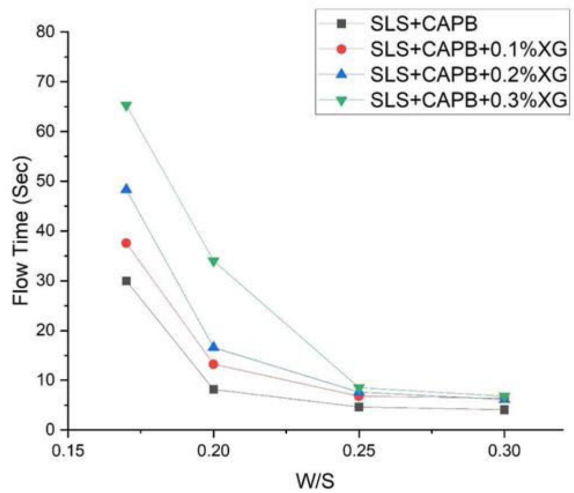
Percentage of xanthun gum Vs Foam stability graph



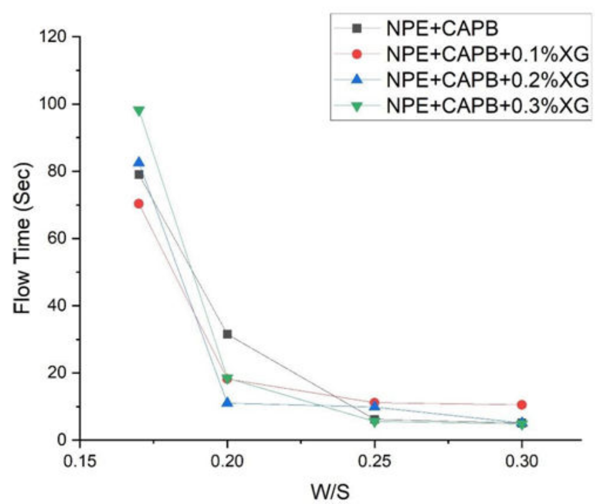
W/S Ratio Vs Fresh density graph



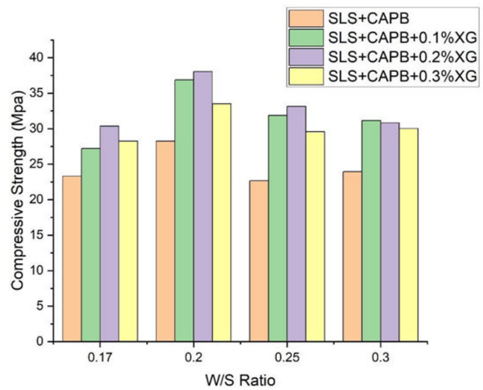
W/S Ratio Vs Fresh density graph



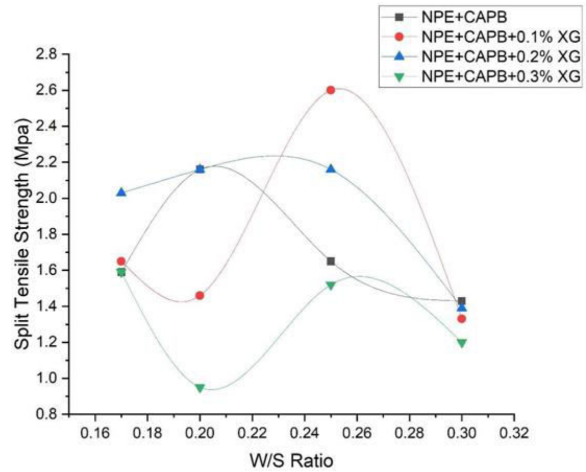
W/S Ratio Vs Flow Time graph



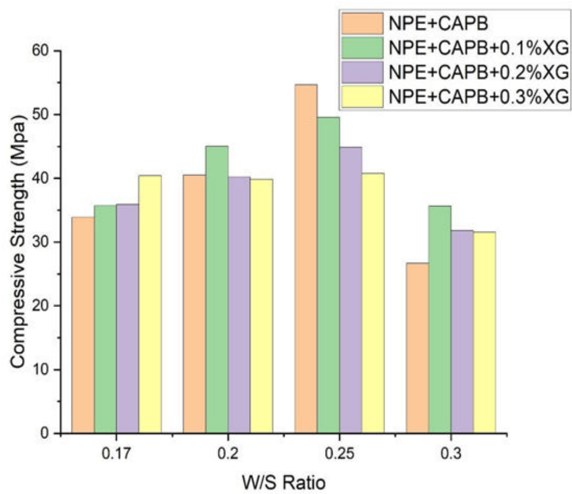
W/S Ratio Vs Flow Time graph



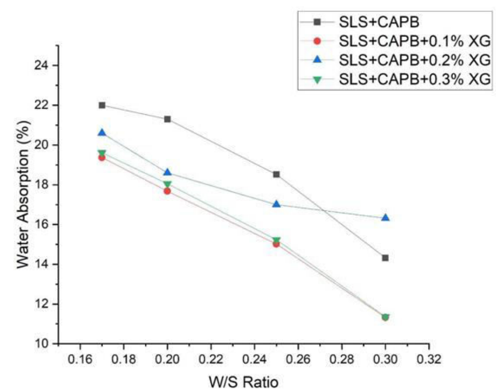
W/S Ratio Vs Compressive Strength graph



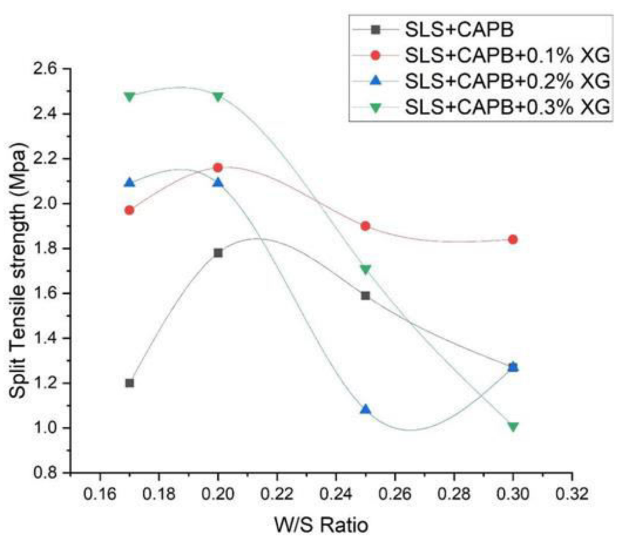
W/S Ratio Vs Split Tensile Strength graph



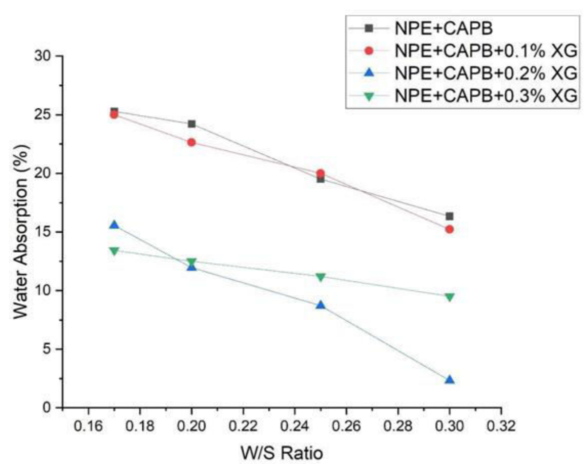
W/S Ratio Vs Compressive Strength graph



W/S Ratio Vs Water Absorption graph



W/S Ratio Vs Split Tensile Strength graph



W/S Ratio Vs Water Absorption graph

6. SCONCLUSIONS

1. Initial foam density decreased with increasing Xanthan Gum (XG) for SLS and CAPB, enhancing air incorporation, while foam density increased with XG for NPE and CAPB, improving bubble stabilization. Viscosity also rose with higher XG content, leading to better foam stability.

2. Fresh density decreased with higher W/S ratios and XG content, promoting uniform air distribution. Flow time increased with XG due to its thickening effect, especially at lower W/S ratios, affecting workability.

3. Compressive strength reduced with increasing W/S ratios but improved significantly with 0.2%XG.Split tensile strength peaked at W/S ratios around 0.25,with higher XG (0.3%) maintaining foam structure effectively.

4. Water absorption decreased with higher W/S ratios and XG content, reducing porosity. The most effective reduction in water absorption was observed with 0.1% to 0.2% XG.

5. 0.2% XG provided the best balance of compressive strength, tensile strength, and low water absorption. SLS+CAPB excelled in foam stability and mechanical strength at lower XG levels, while NPE+CAPB performed better at higher XG dosages.

Future research could explore long-term durability and micro structural properties of foam concrete with these surfactant combinations and stabilizers.

REFERENCES

1. This information is from Ayyanar and Masthan Ali (2024). Utilizing machine learning approaches, we analyzed the compressive strength of sustainable fiber reinforced foamed concrete. No. 11, Issue 3,5701 of Materials Research Express. doi: 10.1088/2053-1591/ad2db7
2. Zhang et al. (2024). Research by Du, Han, Feng, and Yang. A composite protein foaming agent derived from human hair remnant was developed and its performance was studied. Scientific Reports, 16(6608). The link to the article is https://doi.org/10.3390/su16156608.
3. Thirdly, in 2018, Hajimohammadi, A., Ngo, T., and Mendis, P. For use in foam concrete, increasing the durability of pre-made foams. Composites Made of Cement and Concrete. The publication's DOI is 10.1016/j.cemconcomp.2017.12.014.
4. A study conducted by Theenathayalan, Venkatesan, and Jeyasubramanian in 2024. Sodium lauryl sulfate-based foam/aerosol with flyash stabilized lightweight cellular concrete for structural applications: an experimental examination. Academic Plaza. DOI: 10.21203/rs.3.rs-4256993/v1.
5. In 2025, Theenathayalan and Vincent published a paper. Research on the microstructural properties and strength of

lightweight concrete impregnated with air cells. Publication: 29(4), 693-714, European Journal of Civil and Environmental Engineering. Doi: 10.1080/19648189.2024.2414211 CITE THIS POST

6. The authors of the cited work are Qiu et al. (2022) and Zhang et al. (2022). Investigation of the efficacy of a novel composite foaming agent in the production of foamed concrete by experimental means. Article number 7217479 from the journal Advances in Materials Science and Engineering. URL: https://doi.org/10.1155/2022/7217479
7. Huang, X., Fu, Y., Wang, L., & Li, Y. (1950). Review of current research and best practices on foam concrete. Volume 6153602 of the Journal of Advanced Materials Research and Engineering. This link will take you to the publication: https://doi.org/10.1155/2020/6153602. A
8. Saba, J., Palma Calabokis, O., and Baldovino, J. D. J. A. (2024). A bibliographical and bibliometric study of four cementing agents for soil stabilization, with an experimental emphasis on xanthan gum, and a subsequent confirmation of the results by testing. The journal Sustainability, 16(5363) months ago. http://doi.org/10.3390/su16135363. 9.
9. The publication's DOI is 10.3390/polym16060740. Wu, C. (year 2024). Investigations on the process and flexural mechanical characteristics of environmentally friendly coir fiber foamed concrete (CFFC). Paper number: 14(17105) in the Scientific Reports series. 10—Boddepalli, U., Gandhi, I. S. R., and Panda, B. (2023). https://doi.org/10.1038/s41598-024-67137-z.
10. Dependence of surfactant properties on the stability of printed foam concrete in three dimensions. The link to the article is https://doi.org/10.1007/s11709-023-0964
11. In a study conducted by Rakam, Sahu, and Pillalamarri in the year 2024. The most recent findings and developments in the manufacturing of foam concrete with mineral additives are summarized in this survey. You can access the article at this link: https://doi.org/10.1007/s41062-024-01760-7.
12. Wang, F., Jin, W., Chu, H., Xi, X., Zhang, F., & Wu, J. (2023). Research on the combined effects of xanthan gum and sodium methylsiliconate on the water stability and mechanical strength of phosphogypsum road aggregates. DOI: 10.3390/ma16206766
13. Muhammad I. Khan, S. Sufian, R. Shamsuddin, M. Farooq, and N. Saafie (2024). Trinary compound of phosphoric acid geopolymer, sodium lauryl sulfate, and calcium alginate for synergistic methylene blue adsorption. The link to the article is https://doi.org/10.1007/s11356-024-33573-7.
14. Naavya and Hathiram (2024). P. How polyvinyl alcohol and carboxy methylcellulose affect the stability of foam concrete forms for better performance.