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Effect of Foaming Agent Dosage on Workability, Compressive Strength & Density of Lightweight Foam Concrete

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Abstract: An experimental program was designed to investigate the influence of a foaming agent on the fresh and hardened properties of concrete, with the objective of developing a lightweight concrete while assessing its effectiveness in achieving acceptable strength. The study involved the preparation and testing of three concrete mixes with varying dosages of foaming agent, alongside one conventional mix used as a control. For each mix, concrete cubes were cast and cured under standard conditions, and compressive strength tests were conducted at an age of 14 days. The foaming agent was incorporated at dosages of 0.2%, 0.4%, and 0.6% by weight of mixing water. The performance of the modified mixes was evaluated by comparing the test results with those of the control mix, which contained no foaming agent. The experimental results indicated that the addition of the foaming agent had a significant effect on both fresh and hardened concrete. In the fresh state, workability improved progressively with increasing dosage of the foaming agent, due to the air-entraining effect that enhanced flow ability. In the hardened state, however, the compressive strength and unit weight decreased as the proportion of foaming agent increased. This reduction is attributed to the higher volume of entrained air voids, which lower the effective load-bearing area within the concrete matrix.

Keywords: *Concrete, Foam Concrete, Workability, Compressive Strength.*

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I. INTRODUCTION

Foam concrete is a lightweight concrete manufactured by incorporating air voids into the mortar matrix using an appropriate foaming agent. [1], [2]. Foamed concrete extends earlier efforts aimed at enhancing the mechanical performance of cement-based materials by minimizing microstructural inhomogeneity, as seen in Densified Small Particle (DSP) concretes. Its distinctive feature is the use of a full range of aggregate sizes within the mix, which promotes maximum self-compaction. [10]

II. LITERATURE REVIEW

These studies provided comprehensive reviews of foam concrete constituents, production methods, and properties including compressive strength, shrinkage, thermal conductivity, and fire resistance, with emphasis on the role of pozzolanic materials in enhancing performance. They highlighted its wide applications in sustainable construction, void filling, tunnelling, and road engineering, noting that long-term durability and standardization of mix design procedures still require further investigation. [3], [4], [5], These studies focused on producing foam concrete blocks using OPC Grade 53 cement with fine sand and a foaming agent, comparing their performance against normal and pervious concrete in terms of compressive strength, flexural strength, and density. Results confirmed that foam concrete is a sustainable and lightweight alternative suitable for non-structural elements, though it does not reach the mechanical strength of conventional concrete. [6], [7]. These two studies examined the effect of varying binder compositions — either through a ternary system of cement, fly ash, and slag, or by incorporating local materials such as kaolin and red sand on the density and strength of foam concrete. Both concluded that controlling the foam-to-mix ratio and achieving a uniform pore distribution are the decisive factors in attaining the desired mechanical properties. [8], [9]. Concrete is a versatile building material traditionally composed of cement, water, and aggregates, valued for its durability and cost-effectiveness. Lightweight foamed concrete emerged a century ago through pioneering projects in Scandinavia, utilizing alkaline slurries and entrained gases to create specialized precast structures. [10] This study evaluates foam

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concrete with fly-ash as an efficient, insulating alternative to normal concrete for tropical building applications. Results indicate that incorporating 20% fly-ash alongside varying foam agent percentages significantly enhances sound absorption and thermal conductivity while maintaining structural integrity. [11] This article reviews the evolving properties of foam concrete, emphasizing its advantages in lightness, thermal insulation, and durability while detailing the impact of various raw materials on its microstructure. It highlights current advancements and identifies critical research gaps, specifically the need for further investigation into fiber reinforcement and acoustic performance. [10]

III. EXPERIMENTAL STUDY

This study was carried out in few stage. on the initial stage, all the material and equipment's needed must be gathered or check for availability. Then the concrete mixes according to the predefined proportions. Concrete samples were tested through concrete tests such as cube test. Finally, the results obtained were analyzed to draw out conclusion.

High performance concrete was designed by using BSI curing method. Trail control mixes for 28 days with using foam Additive in concrete with different dosages 0.2%, 0.4% and 0.6% respectively from Water content. The results of laboratory experiments were analyzed and discussed to investigate the foam additive on workability of fresh concrete and compressive strength of hardened

➢ *Material Used:*

- Cement: The cement used was Ordinary Portland cement (45Grade) conforming to BS12:1996 [13], the test result in table 1

Table 1 Results of Cement Tests

Type of testing	Results of testing	Ref.BS12:1996
Standard of cement paste	36%	W/C not less than 26% And not more than 33%
Initial setting time	150 min	Not less than 60 min
Final setting time	3 hours 05 min (185 min)x	Not more than 10 hours
Fineness of cement	1%	Not more than 10%
Soundness of cement	2mm	Not more than 10mm
Compressive strength (28) days (standard)	48 N/mm^2	$\geq$42.5N/mm^2 $\leq$62.5 N/mm^2

- Fine Aggregate: The sand used for experimental program was locally procured. The fine aggregates were tested as per British Standard Specification BSI: 882-1997 [14]. The specific gravity of sand was found to be 2.75.

- Coarse Aggregate: The natural broken stone (coarse aggregate) used for the study was of 20mm size maximum. It is conforming BSI: 882-1997 [15]. It was retrieved from a local quarry. The shape and quality of aggregate was uniform throughout the project work and the specific gravity was found to be 2.61. Table 1 shows the results of tests of impurities, specific gravity and water absorption of coarse and fine aggregates.

Table 2 Properties of Aggregates

Experiment name	Fine aggregate	Coarse aggregate
Impurities	% 2.5	-
Specific gravity	2.75	2.60
Water bsorption	0.70%	0.49%

- Water: The used water from Khartoum city water distribution system
- Foam: picked from Aynaa company for ready mix concrete in Khartoum, Sudan (Figure 1.0). And the technical properties tabulated in table 3.0 according to BS 5075

Table 3 Technical Properties @ 25^0c

Color	Brownish liquid
Freezing point	≈ 00C
Specific gravity	1.02 ± 0.02
Chloride content	Nil

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Fig 1 Foam Material

➢ *Mix Design Method*

BSI curing method of mix design was used for mix design for concrete cubes test concrete specimens with various percentages of Foam agent were prepared the details of various mix proportions for different ratios of foam at 14 days.

The aggregate dry density used was 1209*kg/m*^{3,} and the maximum aggregate size use in all mixes was 20*mm*. using standard cubes molds (150*150*150) *mm*, 3 cubes representing each ratio, were casted and tested at age 14 *days*.

➢ *Components of mix materials:*

- Concrete Mixes Design: The concrete mix to resist compression design (25*N/mm*^{2}) The quantities of materials for all the mixtures as illustrated table3: Mix design: (density of 2435 *kg / m*^{3}).

Table 4 The Amounts of the Mixture of Design

Mix Materials	**Weight(*kg/m*^{3})**
Cement content	380
Fine aggregate content	651
Coarse aggregate content	1209
Water content	195

Cube Area = 150×150 = 22.5 ×10^3 *mm*^{2}

Cube Volume = 150×150×150 =3.375 ×10^6 *mm*^{3}.

The result of these experiments have been shown in tables 4 to 7.

IV. RESULTS OF EXPERIMENTS OF FRESH AND HARDENED CONCRETE

The results of hardened concrete tests conducted by adding different ratios of foam material, result for 0.2%, 0.4% and 0.6 are shown in tables 5 to 9 and depicted graphically in Figures 2 to 6.

Table 5 Results of Compressive Strength Tests of the Control Mix Using (0.0 % of Foam Agent)

Cube No	**Age**	**Area of cube *mm*^{2}**	**Failure Load (*kN*)**	**Strength (*N/mm*^{2})**	**Average strength (*N/mm*^{2})**
1	14*day*	22500	743	33	34
2			765	34	
3			787.5	35	

Table 6 Results of Compressive Strength Tests of the Control Mix Using (0.2 % of Foam Agent)

Cube No	**Age**	**Area of cube *mm*^{2}**	**Failure Load (*kN*)**	**Strength (*N/mm*^{2})**	**Average strength (*N/mm*^{2})**
1	*14day*	22500	830	27	28
2			702	28	
3			830	30	

Table 7 Results of Compressive Strength Tests of the Control Mix Using (0.4 % of Foam Agent)

Cube No	**Age**	**Area of cube *mm*^{2}**	**Failure Load (*kN*)**	**Strength (*N/mm*^{2})**	**Average strength (*N/mm*^{2})**
1	*14day*	22500	1114	27	26
2			1037	25	
3			1046	27	

Table 8 Results of Compressive Strength Tests of the Control Mix Using (0.6 % of Foam Agent)

Cube No	**Age**	**Area of cube *mm²***	**Failure Load (*kN*)**	**Strength (*N/mm²*)**	**Average strength (*N/mm²*)**
1	*14day*	22500	960	26	25
2			943	25	
3			866	25	

Table 9 Average for Results of Compressive Strength and slump Tests using (% of Foam Agent)

Weight	**Slump (*mm*)**	**Compressive Strength (*N/mm²*)**	**Ratios of foam**
2500	25	34	00
2000	100	28	0.2
1900	175	26	0.4
1850	190	25	0.6

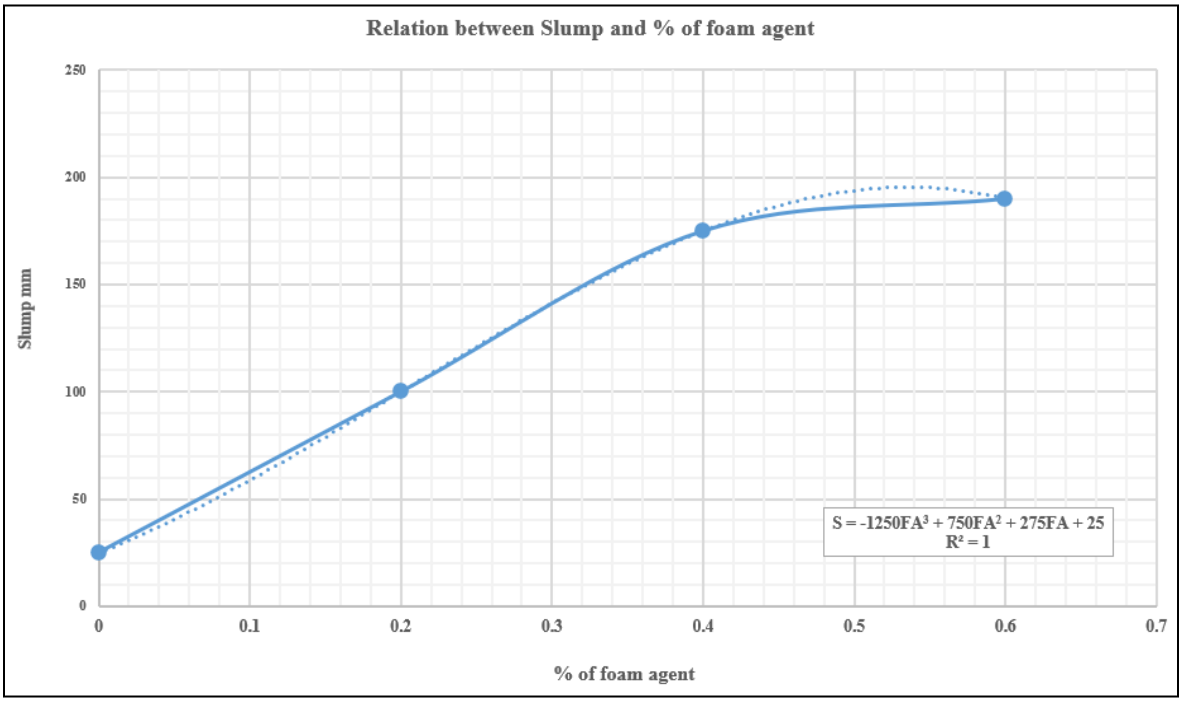

Fig 2 Relation Between Slump and % of Foam Agent

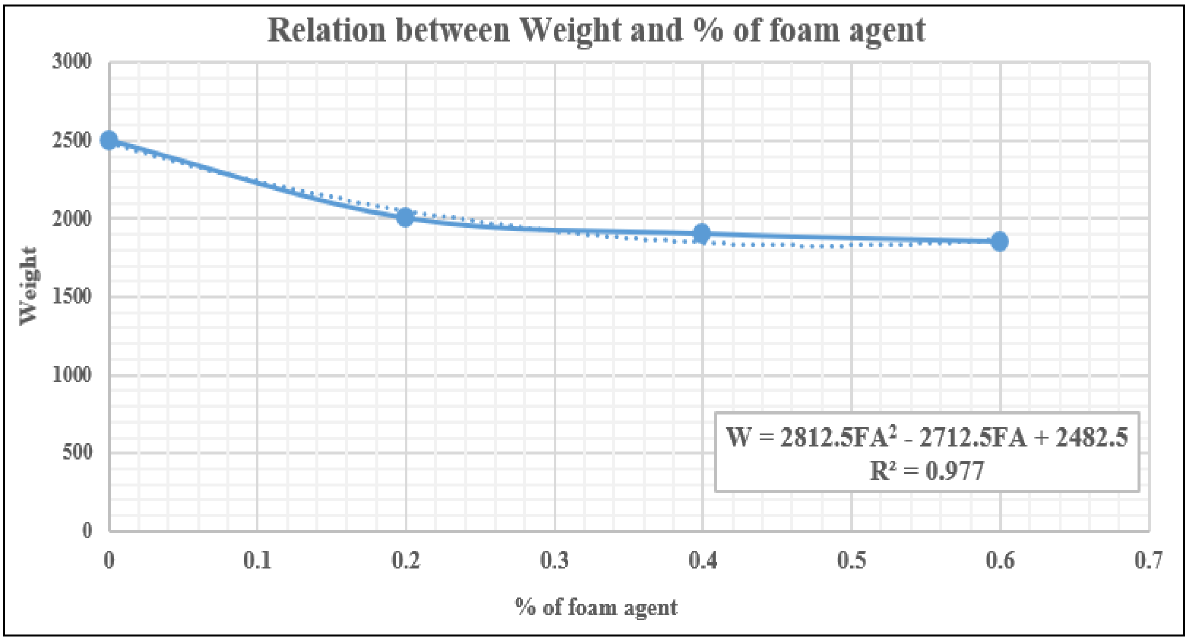

Fig 3 Relation Between Weight and % of Foam Agent

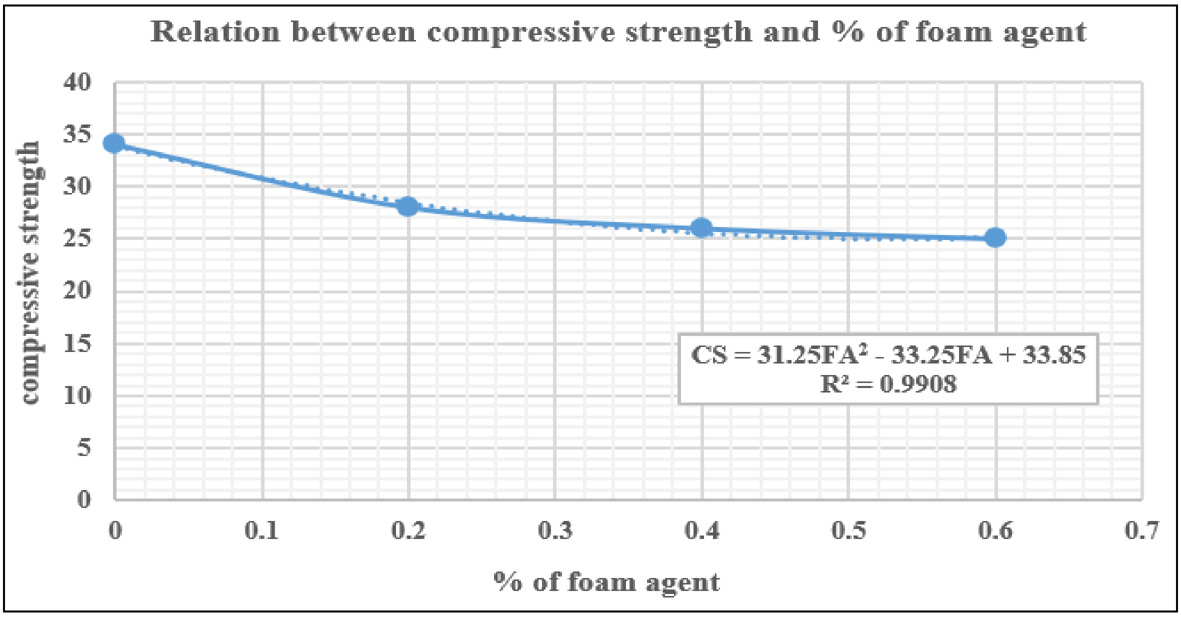

Fig 4 Relation Between Compressive Strength and % of Foam Agent

V. DISCUSSION OF THE RESULTS

➢ *The Results Obtained from the Different Tests are Summarized and Discussed as Following:*

- Fresh Concrete: Table 8 and figure 2 presented that the slump increased with increasing the amount of foam material. and the following equation was obtained:

$S = -1250FA^3 + 750\ FA^2 + 275\ FA + 25$…………………(1)

$R^2 = 1$

Where S: Slump and FA: % of foam agent

- Hardened Concrete: Tables 8 and Figures 3 and 4 showed the results of average Compressive strength of concrete decreased with increasing amounts of foam to the ratio more than 0.2 at 14 days and also showed the weight of concrete decreased with increasing the foam. and the following equations were obtained:

$W = 2812.5FA^2 - 2712.5FA + 2482.5$……………………..(2)

$R^2 = 0.977$

$CS = 31.25FA^2 - 33.25FA + 33.85$………………………..(3)

$R^2 = 0.9908$

Where W: Weight, CS: Compressive strength of concrete and FA: % of foam agent

VI. CONCLUSION AND RECOMMENDATION

In this study, foam was used as an additive to investigate its effect on concrete through the measurement of workability for fresh concrete and compressive strength for hardened concrete at 28 days. Based on the results, it can be concluded that:

- Workability: The incorporation of foam agent consistently improved the workability of the concrete mixes. As the dosage increased from 0.2% to 0.6% by weight of water, the slump value increased due to the lubricating effect of the entrained air bubbles, which reduced internal friction between aggregates.
- Compressive Strength: The compressive strength at 14 days decreased with increasing foam content. This is attributed to the higher volume of air voids introduced into the matrix, which reduces the effective load-bearing area and creates stress concentration points. For instance, the mix with 0.6% foam showed a strength reduction of approximately 45–55% compared to the control mix.
- Density: A noticeable reduction in dry density was observed as the foam dosage increased, confirming the production of lightweight concrete. The density dropped from about 2400 kg/m³ for the control mix to 1700–1900 kg/m³ for the mixes with higher foam content.

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