



Influence of Foaming Agent Type on The Behavior of Foamed Concrete

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KEY WORDS

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ABSTRACT

In this work the desired aim is to study the effect of two various sorts of a foaming agents on the properties of foamed concrete to obtain high quality with a target density is nearly 1600 kg/m³. The standard samples were designed by employing two types of foam agent (FA), the first one is commercially named (EABSSOC foam agent, FA) while the second is the foam of detergent liquid (D) which known (Fairy). The results showed that the FA sample records the lower bulk density compared to the other types. The perfect mix which involved 1wt.% of (D) had higher values of the compressive strength 20.25MPa, 16.32MPa of the curing in water and air respectively and flexural strength (F.S) values were 6.89MPa, 4.47MPa of the cured samples in (air, water) for various durations (7, 14 and 28) days compared to the samples that contained 1 and 0.8wt. % of FA. The obtained compressive strengths were 5.1MPa, 4.3MPa while the flexural strengths were 2.74MPa, 2.9MPa for the samples contained 1wt. % foam agent (FA) after the curing into water and air at the same duration. It is obvious that the addition of foam to the cement mortar paste imparts great characteristics as lightweight with flowability. These properties and others make it suitable for some applications, for example, a decrease of the dead load from the structure, thermal and acoustic insulating and use it in non-structural sections such as a wall.

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1. INTRODUCTION

Foam concrete (FC) is comparatively a popular material having cementitious characteristics, integrated with entrained foam into the cement-based mortar which can be fabricated in different densities ranging from 300 kg/m³ to 1600 kg/m³. It is very well may be viewed as generally homogeneous when contrasted with normal concrete, as it doesn't contain coarse aggregate phase [1]. Foamed concrete properties depend on the microstructure and composition, which are affected by the type of foam used. Foam concrete is like fluid, porous concrete recognized with lightweight,

manufactured by mixing the cement mortar with separately manufacture techniques which include pre-foaming and then curing [2, 3]. The foaming agent has a greater fundamental effect on foam concrete. The foaming agents included in the mixture water create a discrete air voids cavity that becomes consolidated into the cement mortar. Foamed concrete features are basically reliant upon the nature of the foaming agent [4]. The second type is detergent foam is a category of chemical compounds that are used for cleaning because of their dual hydrophobic and hydrophilic characteristics. Due to its chemical structure and reactivity, a detergent can bind to an oily stain, detergent foam can be added to cement to reinforce and guarantee the longevity of concrete [5]. Dish detergent foam adds tiny air bubbles to the cement mixture which is called air entrainment. After curing, these bubbles become small pockets of air in the concrete. These voids permit the concrete to breathe thus preventing cracking as the concrete expands and contracts in fluctuating weather conditions. Thereafter foam concrete is lightweight due to reducing the density of concrete [6]. The density of foamed concrete is lower than ordinary concrete about 50%-80% and the density of foam concrete is determined by the ratio of foam to slurry or cement paste and densities [7]. Foam concrete is a reasonable application in numerous fields of civil and construction engineering for its possession distinctive features including density decrease, reduced thermal conductivity, acoustic insulation, high flowability, the self-compactness of concrete, given the ease of the producer and its relative cost [8, 9].

Akram and his coworkers [10] studied the foam concrete designed by the mix prepared in two categories. The designs of the control mix were represented with a formula (60C40S0.4FA) while the designs of the detergent mix were represented with the formula (60C40S0.4D). Regarding the controlling mixture contain 0.4FA which means the foam agent percent (FA), 60C and 40S represent the cement amount and sands within the mixture correspondingly which found as the perfect mixture designing in comparison with the controlling one. The results determined the compressive strength for 28 days of different control and detergent mixing designs. The 28-days compressive strength is greater than that concerning the controlling mixtures. This behavior can be attributed to increasing the strength in the controlling mixtures with a slow rate in comparison with the detergent mixtures. This study explained how the equally spread of bubbles of FA can be accountable for the relatively high strength of the reference mixtures design comparing with the detergent mixture design of twenty-eight days.

Nassar and Memon [11] prepared foam concrete samples of the eight control mixes were produced by using a foaming agent, and eight corresponding mixes were produced by incorporating locally manufactured detergent as a foaming agent. The difference in the amount of cement, sand, and in all mixes the dosage of foam agent and detergent (D) was constant at 0.3 and 0.5 replacement weight percent of the cement in these mixes. The samples were produced and tested for density, compressive strength. The results showed that the as-placed density of control mixes was relatively higher than that density of the detergent mixes, it occurs more air-entertainment in case of detergent mixes. While the as-placed density for control mixes ranged from 0.89 to 1.05 g/cm³, the as-placed density of the detergent mixes, varied over a range of 0.80 to 0.96 g/cm³. The results showed the compressive strength at seven and twenty-eight days while the detergent mix design has a higher at 7days compressive strengths than that of control mix designs. However, in age time 28 days were strength higher in the case of control mixes.

This research aims to produce foamed concrete by using two types of foam (foam agent, detergent) and study the influence of added foaming types on the foamed concrete properties comparing with reference concrete (R) such as bulk density, compressive strength, flexural strength and clarify the homogenization process for foam concrete samples through SEM micrographs.

2. EXPERIMENTAL PARTS

1. Materials

A. Cement

Ordinary Portland cement (Type 1) manufactured by (BAZian) factory which commercially named (Krasta) was used during is the work. Cement utilized conformed to Iraqi Standards No.5 (1984) [12].

B. Sand

Sand was utilized through this research recognize as (Al- Ekhaider). The sieve analysis of fine aggregates is tabulated in Table I. The general characteristics of fine aggregates are conforming to Iraqi Standards Limits (I.Q.S) No.45 (1984) [13].

TABLE I: Sieve analysis results of sand

Sieve size (mm)	Cumulative passing %	Limited of I.Q.S No.45/1984, zone (4)
10	100	100
4.75	95	90-100
2.36	86	85-100
1.18	77	75-100
0.6	59	60-79
0.3	30	12-40
0.15	13	0-10

C. Foam agent

The quality of foam is important to the stability of foam concrete, affects the strength, and hardening of the final product. Foam agent with commercial code (EABSSOC) was used in this work conforming to ASTM C869[14], it used in this work with two ratios 1, 0.8wt.% of cement weight. Table II illustrates some important properties of an EABSSOC foaming agent (FA).

TABLE II: Important properties of the used foaming agent (FA)

Characterization	Description
Appearance	Translucent liquid
Specific gravity	1.02
Water Solubility	Infinite
Dosage rate	0.3-0.6 liters per m ³ of foamed concrete produced
pH	6.7 in solution

D. Detergent Foam

Detergent type (Fairy) was used in this research which commercial is available as a green liquid, it was used with percentage 1wt.% of cement weight. Liquid detergent also a plasticizer of the concrete that makes it easier to work and produce foam concrete. This is due to the presence of an air-entrainment agent. Where the pH of the detergent diluted with water rings 6-7. This detergent was diluted with water to obtain white foam but a less dense foam agent.

E. Water

Tap water was used for the mixing process and preparation of samples and then curing, of each concrete mix during this work.

II. Preparation steps of samples

A. Mixing process of samples

The foam concrete was prepared according to ASTM C796-97[15] the preparation process was carried out in three stages and the materials ratios are shown in Table III.

Step (no.1): was included preparing the foamed concrete (FC). The dry materials (cement: sand) ratio (1:2) were mixed for two minutes, then two-thirds of water were added to the dry materials and the mixing was continued for two minutes.

Step (no.2): the residual water was added to each type of foaming agent then the mixture was mixed by hand for 4 minutes, but for detergent foam, the mixture was blended by the electrical machine for 8 minutes to become dense foam but it is still less density compared to the foam agent, this method is called pre-foaming process.

Step (no.3): each type of the prepared foams was added to the wet materials mixture (cement, sand, and water) and mixed for two minutes and then obtaining a homogeneous foamed mortar.

TABLE III: Mix proportions of materials percentage with target density 1600 kg/m³ foamed concrete mixes

Mix type	C/S Ratio	W/C Ratio	Foam Agent (FA) (%)	Detergent (D) (%)	Target density/cm ³
R	1:2	0.50	-	-	1600
FA	1:2	0.45	1	-	1600
FA	1:2	0.45	0.8	-	1600
D	1:2	0.45	-	1	1600

R: Reference concrete, FA: foam agent, D: detergent.

B. Molding, casting and Curing

Prior to the molding process, all the molds were oiled cautiously to ready for the foam mortar casting. The prepared samples were cast with 3 layers, all layers were compacted by using plastic rod subsequently, the samples were left wet for curing at laboratory temperatures for 24 hours to become hardened, then removed from the molds after the expiration at 24 hours and curing in plastic containers containing pine water at period age included seven, fourteen and twenty-eight days.

III. The performed Tests

A. Bulk density test (B.D)

Bulk density tests were specified conforming to the ASTM C109 standards [16]. Sample with dimensions (50×50×50 mm) was utilized of the bulk density test with curing in water and air at periods (3,7,14 and finally 28) days. This bulk density value was calculated by dividing the sample mass by the cubic sample volume. It can be calculated by applying the equation [17]:

$$\rho = m / V \quad (1)$$

where: ρ : Bulk density of the sample, m : sample mass, V : sample volume.

B. Compressive strength test (C.S)

(50×50×50mm) cubic samples were compressed under compression load conforming to ASTM C109 [16]. This test was carried out by using a machine (model 065-10019/B) with a load capacity of (250000N). The compressive strength (C. S) of the sample was specified from the maximum load applied on the sample during the testing process to realize the complete failure divided by the average of a cross-sectional area of the cubic sample. It can be calculated by following the equation [17]:

$$C.S = F / A \quad (2)$$

Where; C.S: Compressive Strength (MPa), F: Force applied on the sample (Newton (N)), A: sample cross-sectional area (mm²).

C. Flexural Strength test (F.S)

Prism samples with dimensions (B×D×L= 40×40×160mm) were subjected to a 3-points flexural test according to ASTM C 348-02[18] specifications. A(CONTROLS) was used in this test pattern (065-10019/B) machine of (250000N) load capacity value. The prism was subjected to center –point loading (three-point test). Flexural strength value (F.S) can be determined by applying the following equation:

$$F.S = (3 PL) \div [2b \times (d^2)] \quad (3)$$

where: F.S: Flexural Strength (MPa); P: applied load on the sample (N); L: The span between two-point (mm); b: width of prism sample (mm); d: thickness of prism sample (mm).

D. Scanning Electron Microscope Test (SEM)

Scanning electron microscope (SEM), was used to study the surface microstructure of samples, the magnification estimated SEM about (2500×). The sample was prepared through the first step by the drying process in an oven while in the second step, the samples were coated with the flash material diluted with water) and therefore the sample surface was prepared to be ready for the test, hence samples were photographed by a Scanning electron microscope.

3. RESULTS AND DISCUSSIONS

I. Bulk Density

The bulk density of foam concrete samples compares with reference concrete which has been subjected to (water, air) at 3,7,14, and 28 days as shown in [Figure (1 a, b)]. Results showed that the bulk density, reduced with the increasing of foam agent (FA) ratio to (1wt.%) and recorded 1.85g/cm^3 and 1.51g/cm^3 after 28 days from (water, air) curing respectively because the increasing of foam agent played an effective role in the reduction of the bulk density of foam concrete but when 0.8wt.% FA was added to the mortar, the bulk density was increased to 2.02g/cm^3 , 1.75g/cm^3 for the two curing routes respectively. This behavior agrees with previous studies [19]. After addition 1wt.% detergent foam into the mortar instead of foam agent, it is noticed that the bulk density increases to 1.97g/cm^3 in water curing and 1.74g/cm^3 in air curing.

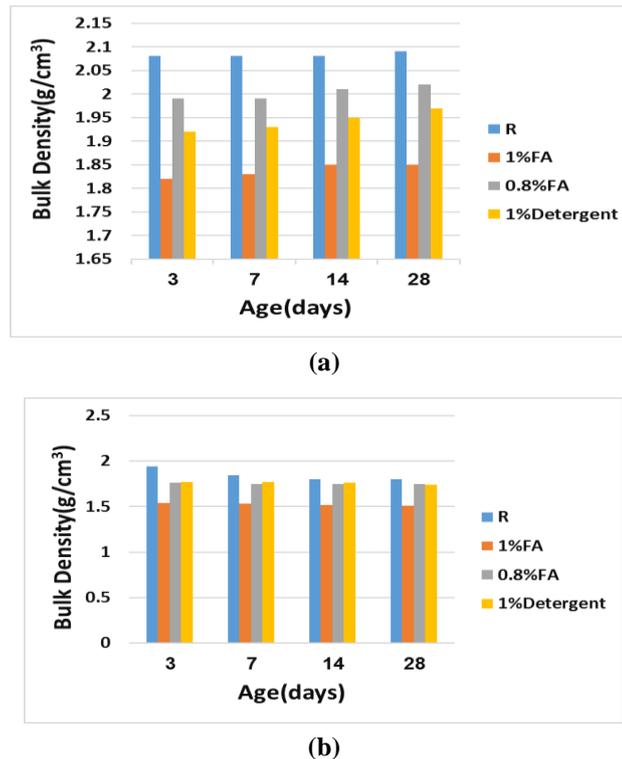
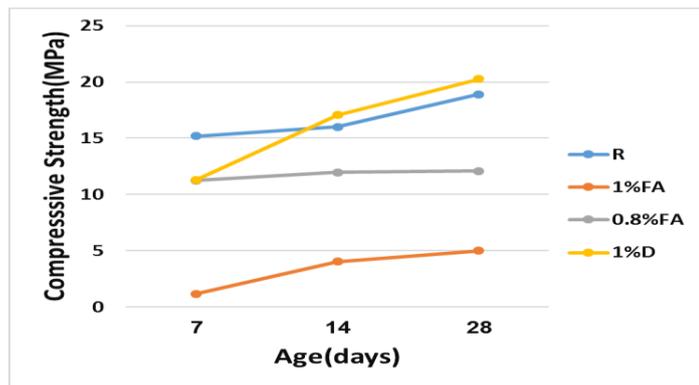


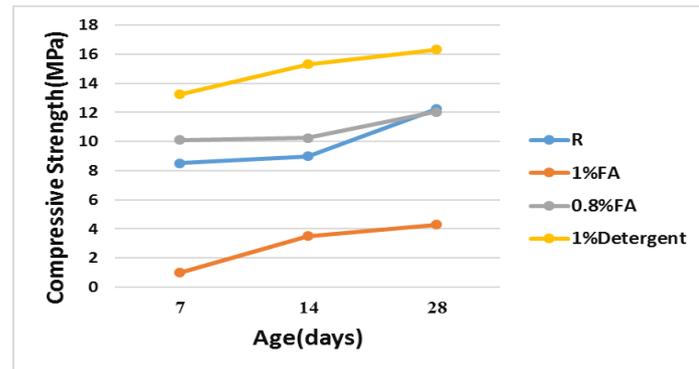
Figure 1: Role of foaming agent type on (bulk density-age) relation of foamed concrete (FC) compared to (R) subjected for 3,7,14,28 days in a) water, b) air.

II. Compressive strength (C.S)

Compressive strength was tested for the foam concrete compared to the reference concrete (R) is demonstrated in [Figure (2a, b)]. The results illustrate that the compressive strength value was decreased after adding (FA), it is well noticed that the lowest value is in the range (5.1MPa) of the sample cured into the water and (4.3MPa) of the sample cured in the air after adding 1wt.%FA while reducing FA to 0.8wt.% the compressive strength reached a value to (12.08MPa, 12.05MPa) for water and air curing at 28 days. It was instituted that the compressive strength (C.S) was acquired some increase with the two processes at (7,14,28) days. The use of 1wt.% D in mortar gives higher compressive strength compared to foam agent (FA) with the various curing process at (7,14 and 28) days, the compressive strength values were equated to (20.25MPa) (16.32MPa) at 28 days respectively. The compressive strength increasing with increase the time of immersion in water for 28 days because the sample will be retaining the moisture which is important for the hydration process and the lower porosity results from the greater degree of cement hydration without any loss of the concrete cubes moisture, therefore the concrete samples could have high compressive strength. Although it has a good value in terms of compressive strength, it's an effect of negative on the density. The results of this test give us an idea about the importance of creating a state of balance between the characteristics of density and compression and reaching the optimal properties of foamed concrete. This result agrees with a previous study by Waheed et al [20].



(a)

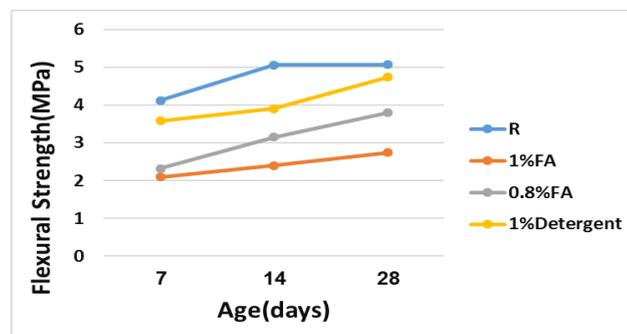


(b)

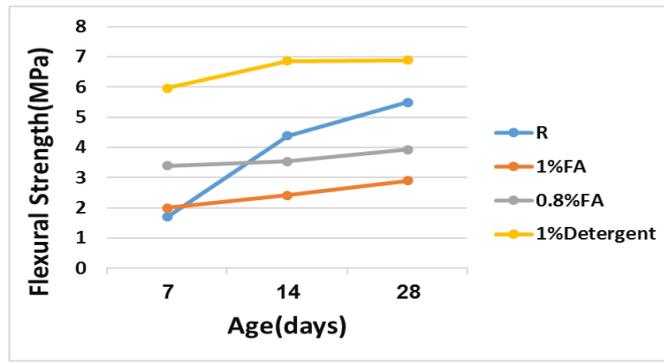
Figure 2: Effectiveness of foaming agent types (FA and D) on the compressive strength of foamed concrete comparing with (R) after the curing in: a) water; b) air for 7; 14 and 28 days.

III. Flexural Strength (F.S)

The flexural strength test results are given in [Figure (3 a, b)]. This test showed that the value of the flexural strength (F.S) was increased when reducing the proportion of foam agent that added to the mixes compared with reference concrete. It is observed that the higher value of (F.S) is (4.03MPa) at (0.8wt.%) of (FA). The values were higher when the samples were cured in the air contrasted with those cured in water. This result agrees with a previous study by Funso et. al [21]. After adding 1wt.% D into a mortar, the flexural strength value was 6.89MPa for the sample cured in the air which is higher than that cured in water. It can be observed that the values of flexural strength for air-cured samples are higher than those immersed in water. This because the molecules of water could be penetrating into the foamed concrete pores and cavities make it easily crack and fail. These values of the flexural strength are higher after adding the detergent foam than that of sample contained foam agent (FA), this may be due to the good physical adhesion and bonding nature between the detergent foam and the constituents of mortar. This good bonding of the interlayers of mortar reflects positively on the flexural strength value and other properties.



(a)

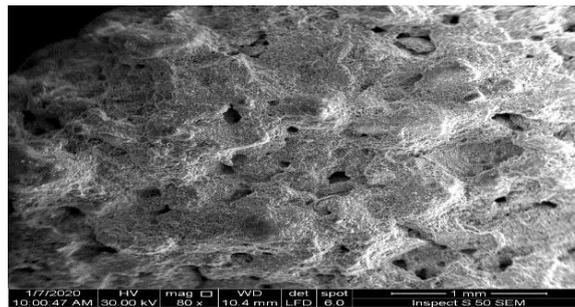


(b)

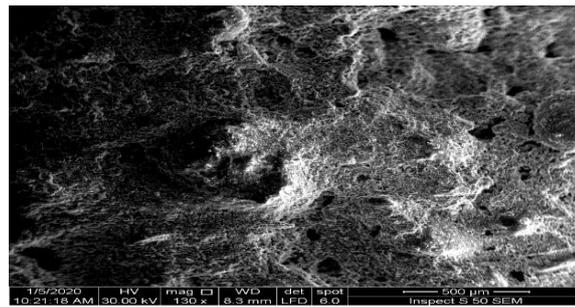
Figure 3: (Flexural Strength-Age) behavior of foamed concrete prepared by using two types of foaming agents comparing with (R) after curing in: a) water, b) air for 7,14,28 days.

IV. Scanning Electron microscope (SEM)

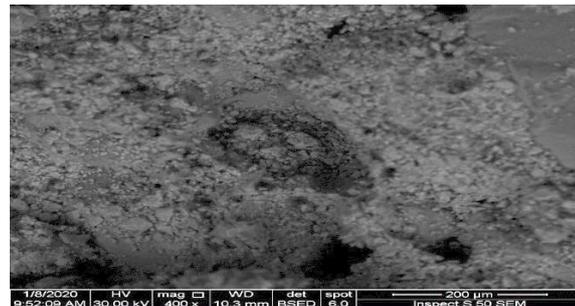
The micrographs of the scanning electron microscope of foamed concrete that contains 1,0.8wt% FA are shown in Figure (4 a, b). After comparing the two images, it can be observed that the distribution and size of the pores were increased when the foam agent content was increased from 0.8 to 1wt.%. The microstructure was varied after using 1wt.% of (D) to the mortar instead of 1wt.% of FA as shown in Figure (4c). It can be concluded that the difference in the microstructure had affected directly the properties of foamed concrete. In general, the micrographs give a good indication of the prepared foamed concrete where there are no separation or clear defects between the constituents, and the nature of bonding is good to make the concrete behaves as the material with one phase.



a- 1%FA



b- 0.8%FA



c-1%D

Figure 4: Scanning electron micrographs of foam concrete with different foaming agent type.

4. CONCLUSIONS

The results of this experiment inserted a good idea to use two types of a foaming agent to produce foam concrete with lower density compared to the reference concrete. As result, according to tests that have been done, the amount and type of foam used to influence the performance of foamed concrete. It is found that the ratio (1wt. %) of foam agent has the lowest bulk density compared to other samples, but using (1wt.%) of detergent gives the optimum values of compressive and flexural strengths in water and air curing in 7,14,28days. It is clear that the microstructure of the prepared concrete affected its properties, but it gives us a good impression of the nature of the bonding of the components of that concrete and there are no separation or internal defects.

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