International Journal of Allied Research in Engineering and Technology (IJARET)
Volume.13, Number 7; July -2022;
ISSN: 2836-5631| Impact Factor: 5.52
https://zapjournals.com/Journals/index.php/ijaret
Published By: Zendo Academic Publishing

A COMPARATIVE STUDY OF FOAM AGENT AND CLAM SHELL POWDER IMPACT ON CONCRETE COMPRESSIVE STRENGTH AND ABSORBENCY

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Article Info

Keywords: concrete, lightweight concrete, foam concrete, foam agent, strength, density, absorption rate, pozzolan, clam shell waste, eco-friendly construction..

Abstract

Concrete is a versatile construction material composed of Portland cement or other hydraulic cement, fine aggregate, coarse aggregate, and water, optionally with additives, that forms a solid mass. It is classified based on its strength (f'c) and density (c), with three categories each. Low-strength concrete possesses f'c < 20 MPa, medium-strength concrete with f'c = 21 MPa - 40 MPa, and high-strength concrete with f'c > 41 MPa. Similarly, concrete is categorized by density as lightweight (< 1,900 kg/m³), normal weight (2,200 kg/m³ - 2,500 kg/m³), and heavy weight (> 2,500 kg/m³). Various studies have explored lightweight concrete to achieve low density while maintaining sufficient strength.

Among the lightweight concrete types, foam concrete stands out due to its unique production process involving gas bubbles or air in cement mortar, forming numerous air pores within the concrete. Foam agents play a crucial role in this process, affecting the absorption rate of the concrete. These agents can be categorized into three types: polymer foam agent, protein foam agent, and surface-active agent.

Foam concrete typically exhibits lower compressive strength compared to normal concrete. To improve its physical and mechanical properties, researchers have explored the incorporation of materials containing pozzolanic properties. One such material is clam shell waste, abundant in coastal areas like North Aceh, where shellfish habitats contribute to clam shell waste production.

In this study, we investigate the utilization of clam shell waste as a natural pozzolan in foam concrete. Our research aims to understand the impact of clam shell waste on the density, strength, and absorption rate of foam concrete. By incorporating this waste material, we seek to enhance the overall performance of foam

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concrete, providing an eco-friendly alternative for construction applications.

1. Introduction

Concrete is a mixture of Portland cement or other hydraulic cement, fine aggregate, coarse aggregate, and water, with or without additives, that form a solid mass [1].Concrete is generallys categorized based on its strength (f'_c) and density ($_c$). Based on the strength, the concrete divided into 3 categories namely low strength concrete where fc' < 20 MPa, medium strength concrete where fc' = 21 MPa – 40 MPa, and high strength concrete where fc' > 41 Mpa [2], [3], [4]. Meanwhile, [5] categorized the concrete into low-strength concretes in range of [0.7 MPa–2.0 MPa], moderate-strength concretes in range of [7 MPa –14 MPa] and structural concretes in range of [17 MPa – 63 MPa].

Based on the density, concrete is divided into 3 categorizes namely lightweight concrete with a unit weight of < 1,900 kg/m^3, normal weight concrete with a unit weight of 2,200 kg/m^3 - 2,500 kg/m^3 and heavy weight concrete with a unit weight of > 2,500 kg/m^3 [1]. Meanwhile, according to the [6], the lightweight concrete should be in range of 320 kg/m^3 to 1920 kg/m^3.

The research on lightweight concrete is keep increasing to find the concrete material with low density but still can maintain the strength of concrete [5], [7], [8]. One of the lightweight concrete is foam concrete which is a mixture of cement, water, aggregate and foam agent. The lightweight foam concrete is produced by making gas bubbles or air in cement mortar so that there will be many air pores formed in the concrete [9]. In addition, the use of foam aagentswill affect the absorption rate of the concrete [9]. Foam agent is a chemical material which is frequently used in the manufacturing of lightweight foam concrete [10], [11], [12]. Foam agents can be classified into 3 types, namely polymer foam agent, protein foam agent and surface-active agent [13].

Foam concrete has a relatively low compressive strength compared to normal concrete. The addition of materials containing pozzolan can improve the physical and mechanical properties of foam concrete [14]. One of the materials which contains the pozzolan is clam shell which contains lime (CaO), alumina and silica compounds. In addition, North Aceh is a coastal area which is a habitat for the shellfish, and this will lead to the producing of clam shell waste. Hence, in this study, the use of the clam shell waste as the nature pozzolan in the foam concrete is investigated to study its influence on the density, strength, and absorption rate on the foam concrete.

2. Literature Review

According to[15], the size of air bubbles (foam) in foam concrete is very small approximately about 0.1~1.0 mm and uniformly dispersed in the concrete. Generally, there are 2 basic methods to produce gas/air bubbles in foam.

a. The first method is called gas concrete, where the process is through injecting a chemical reaction in the form of gas/air into a wet mortar and it will produce gas/air bubbles in large quantities. A frequently used method is to add aluminum powder to the mixture.
b. The second method is called foamed concrete, where a foaming agent is added to the concrete mixture. Foaming agent is one of the foam-making materials that usually comes from hydrolyzed protein-based materials or soap resins. The function of the foaming agent is to quickly stabilize the air bubbles during mixing. The foam agents can be both natural and artificial materials. Foam agent with natural ingredients in the form of protein may has a density of 80 grams/liter, while artificial materials in the form of synthetics may have a density of 40 grams/liter.

Meanwhile, the clam shells are hard and contain lime, silica, manganese oxide, alumina, and others to improve the quality of concrete. The clam shell is treated to produce powder like using a los angeles machine and filtered with an appropriate sieve so that the clam shell powder is obtained in the same size as the fine aggregate. The type of clam shells used in this study are a type of blood mussel (anadara granosa). Based on [16], the chemical content of clam shells is CaO (66.7%); SiO (7.88%); Fe_2O_3 (0.03); MgO (22.28); and Al_2O_3

(1.25). According to [17], mixed design is a combination of composite materials. The characteristics and properties of the material will affect the result of the design. The design of concrete mixtures is intended to determine the composition or proportion of the constituent materials of concrete. The proportion of the mixture of concrete constituent materials is determined through a concrete mix design. This is done so that the proportions of the materials can meet the technical and economic requirements.

3. Methods

3.1. Materil Properties

Various testing shall be conducted prior to the mix design of the concrete to ensure the concrete is mixed properly. The testing included the determination of moisture content, absorption rate, density, organic content and sieve analysis of aggregate and clam shell powder.

3.2. Mix Design

This study used five concrete-forming materials, namely Portland cement, fine aggregate, water, foam agent and clam shell powder. The proportion of concrete mixture was carried out based on previous research conducted [18]. In this study, nine variations of concrete were used to investigate the effects of mixing foam agent and clam shells in the concrete on the density, compressive strength, and absorption of concrete. After conducting a trial using the proportion of the initial material in accordance with the research [18] the results of the material proportion are shown in Table 1.

Table 1: Proportions of Material For Each Variation of Concrete

No.	Variation	Water (Kg)	Cement (Kg)	Sand (Kg)	Clam Shells (Kg)	Foam Agent (Kg)	Number of specimens
1	BN	2.8	5.6	8.4	0	0	3
2	BF5	2.3	4.6	6.9	0	0.115	3
3	BF10	2	4	6	0	0.2	3
4	BF15	1.85	3.7	5.55	0	0.277	3
5	BF20	1.4	2.8	4.2	0	0.28	3
6	BF5Ck	2.3	4.6	6.55	0.35	0.115	3
7	BF10Ck	2	4	5.7	0.3	0.2	3
8	BF15Ck	1.85	3.7	5.27	0.28	0.277	3
9	BF20Ck	1.4	2.8	3.99	0.21	0.28	3
			Total				27

Where:

BN : Normal Concrete

BF5 : Concrete with 5% foam agent

BF10 : Concrete with 10% foam agent

BF15 : Concrete with 15% foam agent

BF20 : Concrete with 20% foam agent

BF5CK : Concrete with 5% foam agent and 5% clam shell

BF10CK : Concrete with 10% foam agent and 5% clam shell

BF15CK : Concrete with 15% foam agent and 5% clam shell

BF20CK : Concrete with 20% foam agent and 5% clam shell

3.3. Density of Concrete

The density of concrete is determined immediately after the specimen is opened from the formwork. Based on its weight, the density is then determined by the Equation 1.

$$\gamma = \frac{W}{V} \tag{1}$$

Where:

□ = Density of foam concrete (kg/m³)

W = Weight of foam concrete (kg) V = Volume of concrete foam (m³) **3.4. Water Absorption**

The water absorption test is carried out to determine the amount of absorption in foam concrete. The testing is done after the specimen is soaked for 28 days in the water. Immediately after the specimen is taken out from the water and the specimen is ensured in dry surface condition, the specimen is weighted, and the value is recorded for the purpose of density calculation. Immediately after that, the specimen is put in the oven at a temperature of 110^0 C for 24 hours[19]. The process is continued with the measurement of the weight of the dried specimen. The absorbency of water can be determined using the Equation 2.

$$Wa = \frac{Ws - Wd}{Wd} x\ 100\% \tag{2}$$

Where:

Wa = water absorption (%)

Ws = Saturated weight of specimen (gr)

Wd = Dry weight of specimen (gr) **3.5. Compressive Strength Testing of Concrete**

Concrete compressive strength is a function of axial force and the cross-sectional area of the concrete specimen. Compressive strength testing of concrete is carried out at the age of 28 days of the specimens. The surface of specimens shall be prepared in flat surface to receive the axial force and it is then placed between two loading plates. The load is applied slowly until the specimen fails or cracks. The compressive strength of concrete is determined using the Equation 3.

$$f'c = \frac{F}{A} \tag{3}$$

Where:

f'c = Compressive strength (N/mm²) F = Maximum compressive load (N)

A= Cross-sectional area of the specimen (mm²)

4. Results and Discussion

4.1. Properties of aggregate and clam shell powder

Based on the testing, the dry density, wet density, moisture content, and absorption rate of fine aggregate were 2.590 gr/cm^3, 2.532 gr/cm^3, 10.132 %, and 2.285%, respectively. Meanwhile, the average density and moisture content of clam shells were 2.758 gr/cm^3 and 0.824%, respectively. In addition, the proportion of water in the concrete mixture has been adjusted in respect to the moisture content of the materials.

4.2. Density of Concrete

The density of concrete is determined at the age of specimen of 28 days, and it is measured in the dray condition. The result shows that the adding of clam shell in the foam concrete reduced the density of the foam concrete. The lowest density of the foam concrete was 1387.12 kg/m^3 which was obtained at 20% variation of foam agent and 5% of clam shell. The value is much lower compared to the density without clam shell at the same content of foam agent where the value was 1549.42 kg/m^3. Meanwhile, compared to the normal concrete the density of the foam concrete with and without clam shells was reduced by 34.55% and 26.89%, respectively. The results of the foam concrete density for all variations of the specimen are shown in Table 2 and Fig. 1.

Table 2: Density of Concrete Volume

No	Variations	Weight of Specimen (kg)			Average weight (kg)	Density of specimen (kg/m³)
		Specimen I	Specimen II	Specimen III		
1	BN	11.23	11.07	11.41	11.23	2119.37
2	BF5	11.11	10.80	11.00	10.97	2070.3
3	BF10	10.53	10.30	10.45	10.42	1966.50
4	BF15	9.05	9.15	8.91	9.03	1704.17
5	BF20	8.32	8.22	8.10	8.21	1549.42
6	BF5CK	10.81	10.81	10.64	10.75	2028.78
7	BF10CK	9.60	9.75	9.63	9.66	1823.07
8	BF15Ck	8.64	8.90	8.74	8.96	1690.96
9	BF20Ck	7.35	7.47	7.23	7.35	1387.12

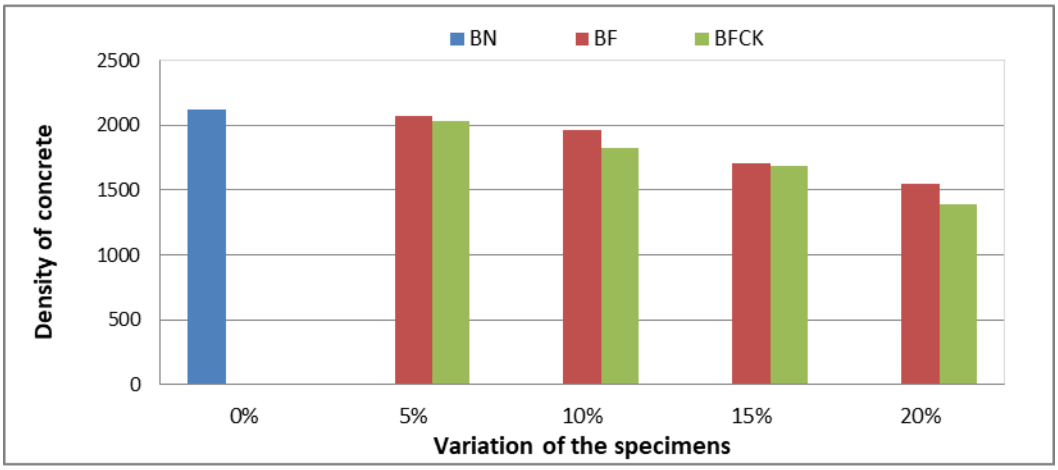

Fig. 1. The relationship between the variation of the specimen and its respective density

4.3. Compressive Strength of Concrete

The result shows that the compressive strength of the foam concrete by adding the clam shell is slightly reduced compared to the foam concrete without clam shells. The reduction of the strength was obtained at the variation of 20% where the strength of foam concrete with clam shell was 5.51 MPa which was lower compared to 6.85 MPa obtained from foam concrete without clam shell. The result agreed with the study conducted [20] where they noticed that the lowest value of the foam concrete can be as low as 4.3 MPa. The detail of the compressive strength of the concrete is presented in Table 3 and Fig. 2 below:

Table 3. Compressive Strength of Concrete

No	Variations	Compressive Strength (MPa)	Average compressive

strength (MPa)

		Specimen I	Specimen II	Specimen III	
1	BN	27.12	27.18	27.80	27.36
2	BF5	24.29	22.53	22.40	23.08
3	BF10	15.06	14.78	14.89	14.91
4	BF15	7.70	7.76	7.59	7.68
5	BF20	7.02	6.79	6.74	6.85
6	BF5CK	16.48	16.65	16.53	16.55
7	BF10CK	10.70	10.59	10.59	10.63
8	BF15Ck	6.57	6.74	5.40	6.57
9	BF20Ck	5.44	5.49	5.61	5.51

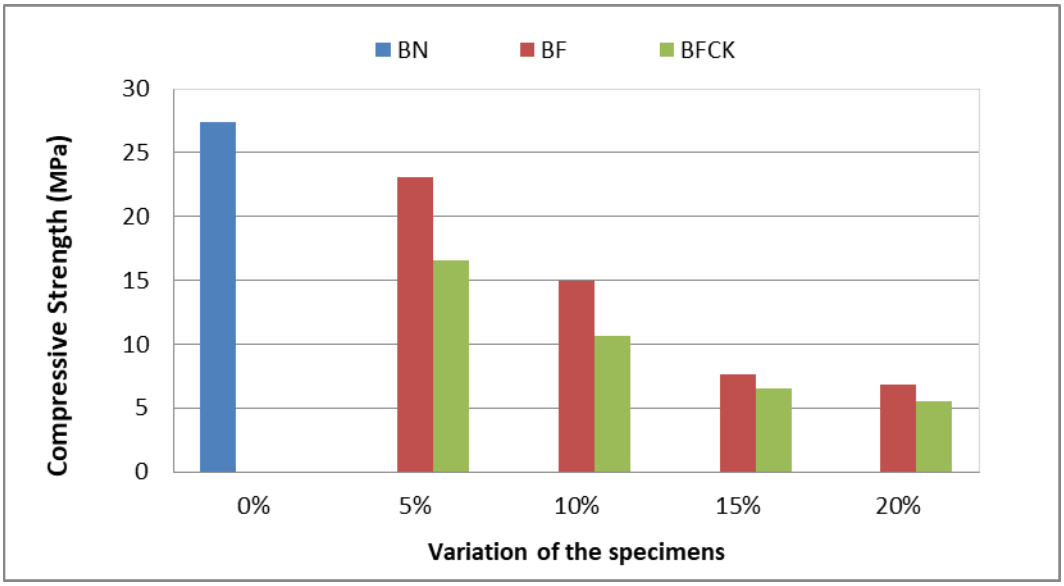

Fig. 2. Compressive strength of concrete

4.4. Water absorption capacity of foam concrete

This result shows the amount of absorption in *foam concrete* at the age of 28 days of the specimens. The highest absorption rate of the concrete is obtained from foam concrete contained 15% of foam agent and 5 % of clam shell. Meanwhile, at the variation of 5% foam agent and 5% of clam shell, the absorption rate is almost similar to the normal concrete. In addition, the adding of clam shell in the foam concrete seems to increase the absorption rate. The details of the absorption rate for all variations of the concrete are shown in Table 4 and Fig. 3.

Table 4. Absorption rate of concrete

No.	**Variations**	**Absorbency (%)** Specimen I	Specimen II	Specimen III	**Average absorbency (%)**	**Absorbency increment (%)**
1	BN	1.61	1.52	1.53	1.55	0
2	BF5	1.68	1.42	1.55	1.55	0
3	BF10	1.32	1.93	1.54	1.60	3.00
4	BF15	1.57	1.67	1.53	1.59	2.58
5	BF20	1.58	1.64	1.67	1.63	5.15
6	BF5CK	1.61	1.72	1.62	1.65	4.09
7	BF10CK	1.8	1.51	1.52	1.61	3.66

8	BF15Ck	1.53	1.74	1.68	1.65	6.45
9	BF20Ck	1.64	1.7	1.53	1.62	4.73

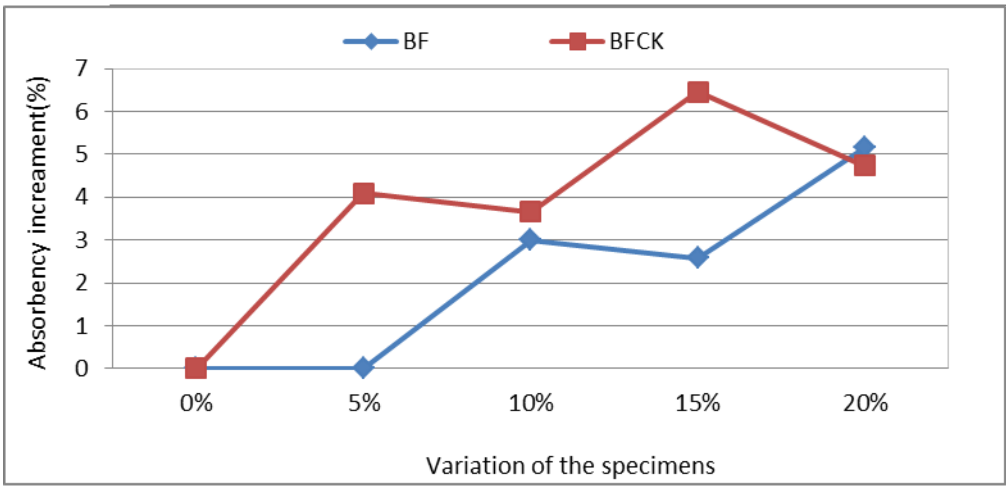

Fig. 3. Absorption rate of concrete for all variations

5. Conclusion

Based on the results, it was concluded that the density of the foam concrete is much lower compared to the normal concrete. In addition, adding clam shell in the foam concrete significantly reduced the density where the highest reduction was obtained at the combination of form agent 20% and 5% of clam shell. However, as the percentage of form agent increased, the compressive strength of concrete decreased and the adding of clam shell did not improve the strength of concrete. The adding of clam shell in foam concrete seems does not improve the absorption rate of the foam concrete. However, the more detailed study by varying the foam agent and clam shell with small scale increment shall be studied in further research to investigate the optimum combination of the two material by considering reduction of density and maintaining the compressive strength.

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