Study on Performance of Lightweight Concrete Bricks with a ratio of Sand and Cement Composition

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Study on performance of lightweight concrete bricks with a ratio of sand and cement composition

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Abstract. Cellular Lightweight Concrete (CLC) brick is a material composition for wall building made of Portland cement, water, and fine aggregate blended with a foaming agent. The weight of the brick is light due to the air cavities formed in the CLC brick. The number composition of sand and cement in the CLC brick could improve the strength of the bricks. Thus, it is essential to find out the sand and cement consumption in order to improve the rate of brick strength. The study aims to improve the strength of the CLC bricks with the different composition of the material and to find out the index properties of the CLC bricks with the variable component of the materials. The study used an experimental work in the material laboratory with two variations of the material composition. The first variation is mixing concrete for the ratio of cement and sand of 1:2, while the second variation is mixing concrete for cement and sand ratio of 2:3. The wet density of the CLC brick is about 800-900kg/m^3, and the average compressive strength test was conducted at ages 3, 7, 14, and 28 days for each test. Three identical specimens were prepared for each test. The study resulted in the 28-day strength of the CLC brick with a mass ratio of cement to sand 1:2 of 0.52 MPa, and the strength of the CLC brick with a mass ratio of cement to sand 2:3 was 0.68 MPa. The first variation was lower by 24.5% than the second variation in terms of strength. The higher cement consumption used into the mixed can make porosity of the specimen decrease, and then the strength of the specimen will improve.

1. Introduction

One effort to reduce the density of concrete is to make a stable cavity in the concrete mixture. Concrete cavities can be produced through gas or air bubbles. Therefore, this concrete mixture is called foam concrete. Commonly, foam concrete does not contain coarse aggregate, but only contains material with very light materials, such as water, and foam. Therefore, it can be considered relatively homogeneous when compared to conventional concrete.

The index properties of foam concrete, such as density, depend on the microstructure and mixture composition, and the treatment of the specimen. The principle of making Cellular Lightweight Concrete (CLC) is to make micro air cavities by adding foam in the mortar mass to reduce the weight value of the volume [1]. The main advantage of CLC brick concrete is that the material is lightweight and easily found on the site, enabling economic cost savings. Meanwhile, the disadvantage of foam concrete is its porosity, which tends to reduce the strength of the material.

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The composition of cement and sand has an essential role in increasing the strength of light brick. However, lower density of the concrete gives lower compressive strength of CLC brick. Therefore, it is necessary to know the index properties and percentage of the portion of cement and sand to get the optimal strength in the mixing concrete.

The weight of the brick is light due to the air cavities formed in the CLC brick. The relative composition of sand and cement in the CLC brick could improve the strength of the bricks. So it is essential to find out the sand and cement consumption in order to improve the rate of the brick strength. The study aims to improve the strength of CLC bricks with different composition of the material and to find the index properties of the CLC bricks with the variable material components.

2. Theoretical background

The simple method for obtaining the optimal foam concrete strength is by making variations in the composition of the mixture of cement, sand, and foam. The right percentage of the foam concrete mixture can increase the compressive strength of the CLC. However, the results of compressive tests must meet the requirements of the National Standard of Indonesia (SNI) 03-0349-1989, as shown in table 1. Meanwhile, the shape and texture of the CLC brick are shown in figure 1.

Table 1. Physical requirements of concrete bricks [2]

Physical Requirement	Unit	Brick quality level solid concrete				Brick quality level hollow concrete			
		I	II	III	IV	I	II	III	IV
Average of Compressive strength	kg/cm^2	100	70	40	25	70	50	35	20
Individual Compressive strength	kg/cm^2	90	65	35	21	65	45	30	17

Figure 1. The Cellular Lightweight Concrete (CLC) brick and the texture of CLC brick.

The study of foam concrete by [3] defined the composition of cement and sand as a 1:2 ratio. This is the composition of the material most often used for foam concrete. As, based on the density of concrete, the CLC brick concrete has a lighter volume weight than conventional concrete bricks, the CLC bricks are, therefore more suitable to be used as non-structural elements, such as walls in multi-storey buildings. Thus, the load received by structural elements can reduce the total mass of the structure, which causes the load to be smaller and makes the design lighter.

The CLC bricks can be made using local material, Woro sand and Kwarsa sand, such as was done by [4]. The study carried out a compressive strength test, and tensile strength test of the CLC bricks

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and the results of denoted mixing concrete using the Kwarsa sand gave a compressive strength of 4.02 MPa at 28 days after casting, while the Woro sand gave compressive strength of 3 MPa.

Based on the chemical composition of CLC brick, [5] stated that hydrated lime produces $Ca(OH)_2$, which will result in a higher volume of free lime. The presence of free lime can lead to the development of volume at the time of binding (setting time), which, ultimately, results in cracking and damage to cement paste and hardened concrete. Also, the presence of $Ca(OH)_2$ can cause weakening of the adherence to the concrete filler elements. The organic content in fine aggregates must also be measured. Too much organic in fine aggregates causes a loss in the quality of CLC brick [6]. On the other hand, [7] presented an experimental study on the optimum amount of polypropylene fibers which can be used in lightweight high-strength concrete. The study aimed to prevent spalling when exposed to hydrocarbon fire, taking into consideration the characteristics of the lightweight aggregate, the water-to-cement ratio (*W/C*) of the mixtures, and the length and thickness of the fibers.

Cellular Lightweight Concrete is a brick that has a density lighter than a brick in general. Lightweight brick has the primary raw material consisting of silica sand, lime, cement, water, plus foaming agent material, which is then treated with water vapor pressure. Unlike ordinary bricks, light brick weight can be adjusted as needed. In general, light brick density ranges from 600 to 1600kg/m^3 [8]. Based on [9], the advantage of using lightweight brick is that water absorbed by the pore when making lightweight bricks will provide additional water used for curing from inside the brick.

A foaming agent is a concentrated solution of a surfactant material, which, when used, must be first dissolved in water [10]. Meanwhile, Sikament NN is a superplasticizer with a large amount of water-reducing and accelerating concrete hardening. The use of Sikament NN is to reduce water in the concrete having an initial higher strength. The strength will increase by 40% when achieving water reduction of 20% for the compressive strength of concrete at 28 days. Sikament NN can be used at a dose of 0.3% to 2.3% of the weight of cement, depending on the compressive strength to be planned [6]. Other researchers, such as [11], mentioned that the influence of filler like fly ash and the particle size of the sand caused an improvement in the strength of foam concrete and replacement of sand with fly ash resulted in higher strength. The filler with a finer texture resulted in a higher ratio of strength to density. On the other hand, [3] reported that the compressive strength of foamed concrete with Synthetic Surfactants (SS) is 11% and 43% higher than that of foamed concrete with Animal glue Surfactants (AS) and Plant Surfactants (PS), respectively.

The compressive strength test is one of the performances of lightweight brick to be measured. Compressive strength is the ability of lightweight brick to resist compressive forces in each unit of light brick surface area. Theoretically, light brick compressive strength is influenced by the strength of its components, namely cement paste, cavity volume, aggregate, and interface (interface relationship) between cement paste with aggregate [12]. The compression test procedure followed the Indonesian National Standard (SNI) 03-1974-1990 [13].

The CLC bricks specimen of size 600mm x 200mm x 100mm were cast in laboratory using the two variations composition. The portland composite cement type 1 was used in this study. The compressive strength test of the bricks was done at the age of brick 3,7,14, and 28 days. Before testing, the specimen keep in open area with room temperature.

The compressive strength value can be calculated by the formula:

$$f'_c = P/A \tag{1}$$

where :

f'_c = compressive strength (MPa)

P = compressive load (N)

A = cross-sectional area of light brick specimen (mm^2)

3. Research methodology

This research used two different compositions of cement and sand ratio of mass. The first composition is called Variation 1, with a ratio of cement and sand of 1:2, and the second composition is called

Variation 2, with the ratio of cement and sand as 2 : 3. The variable composition of the CLC bricks is presented in table 2. The research tested 24 specimens to obtain strength and density of lightweight brick. The mass ratio of the foaming agent and water was 1:30. The CLC paste was made with a mass ratio of cement to water of 0.5. The material consisted of cement, sand, water, and foam agent, while the leading equipment used in this research included foam generator with a capacity of 200 liters per minute and a compression testing machine with capacity of 100kN.

Table 2. Plan for mortar mixture.

Specimen Code	Material			
	Cement (kg)	Sand (kg)	w/c ratio	Sikamen (ml)
Variation (1)	100	200	0.5	200
Variation (2)	100	150	0.5	200

The compression strength test of lightweight bricks was conducted using the loading frame when the CLC bricks were at the age of 3, 7, 14, and 28 days. The specimen was placed on the loading frame with a horizontal position. Figure 2 shows the specimen placed in the test tool.

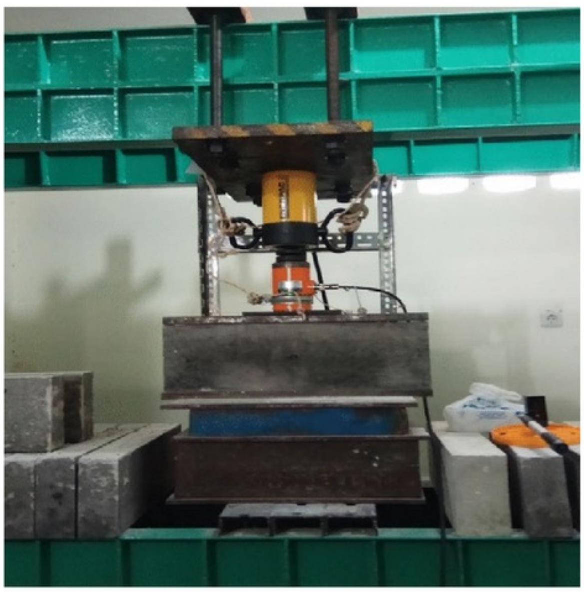

Figure 2. Specimen of the lightweight bricks at age 3 days.

The test equipment was operated until the maximum load was obtained when the specimen failed. The value of lightweight brick compressive strength was recorded using data logger. The complete instrumentation picture is shown in figure 3.

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Figure 3. Instrumentation setting out.

4. Result and discussion

The testing result of the characteristics and compression strength of the lightweight concrete brick was carried out at the material and construction laboratory. All the characteristics of the lightweight brick material testing in this study were carried out according to the National Standard of Indonesia procedures. The physical properties of fine-aggregate are shown in table 3. The mud rate of the fine aggregate is 4.87% and the apparent specific gravity of the fine aggregate is 2.65. The results of sieve analysis on fine aggregates indicated that fine aggregates were in specification No. 4 based on SNI 03-2828-2000 [14], which states that fine aggregates are fine grading. The fine modulus value provides an indicator that the level of fine aggregate is contained in the mortar. Too much fine aggregate causes a thin layer of fine aggregate and the cement to rise to the surface.

Table 3. Fine Aggregate Characteristic.

No	Testing item	Result	Standard Range
1	Mud rate (%)	4.87	< 5
2	Specific Gravity		
	a. Apparent Specific Gravity	2.65	2.58-2.83
	b. Bulk Specific Gravity on Dry	2.28	2.58-2.83
	c. Bulk Specific Gravity on SSD	2.40	2.58-2.83
	d. Absorption (%)	5.49	2.0 – 7.0
3	Water content (%)	3.73	3 – 5
4	Volume weight (gr/cm^3)		
	a. Solid condition	1787.77	1400-1900
	b. Dry condition	1297.74	1400-1900
5	Rate of Organic	No. 2	Max No. 3
6	Fine-Modulus	2.04	1.5-3.8

Based on table 3, the result of the fine-aggregate testing indicated the level of mud on the fine aggregates using in this study met condition according to ASTM C-33-74 [15], and the fine aggregates included a medium sand category with fineness modulus of 2.04. The effect of variation composition

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contents on the compressive strength of CLC brick is presented in figure 4 and table 4. The mix with Variation 2 with higher cement content shows higher compressive strength than Variation 1 at the age of 3, 7, 14, and 28 days. The research resulted in the different composition effects on the physical and mechanical properties of CLC brick, including the density and compressive strength.

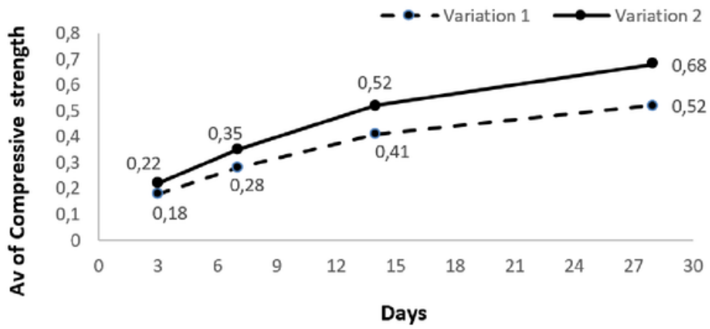

Figure 4. Compressive strength of the CLC brick.

Table 4. The compressive strength with the variation of composition cement and sand.

Var No.	Cemen: Sand	Sample No.	Compressive Strength (MPa)							
			3 days		7 days		14 days		28 days	
				Avr		Avr		Avr		
1	1 : 2	1	0.18		0.30		0.44		0.51	
		2	0.19	0.18	0.26	0.28	0.40	0.41	0.53	0.52
		3	0.17		0.29		0.40		0.52	
2	2 : 3	1	0.23		0.35		0.50		0.66	
		2	0.23	0.22	0.34	0.35	0.54	0.52	0.69	0.68
		3	0.20		0.36		0.51		0.70	

The use of sand consumptions in 1 m^3 of mixing concrete in Variation 1 and Variation 2 was 200kg and 150kg, respectively, with the amount of cement consumption 100kg for both variations. Thus, the use of cement consumption in Variation 2 is more than Variation 1 in 1m^3 of mixing concrete. The study evidences the average density of foam concrete at the age of 28 days, as shown in table 5. Variation 2 shows a higher density value compared to Variation 1. The condition shows that more use of cement in Variation 2 has caused an increase in mixed density of the mixing foam concrete. This condition causes the increasing of compressive strength in 28 days between Variation 1 and Variation 2 is about 24.5%.

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Table 5. The density of the variation of composition cement and sand.

Variation No.	Density (kg/m^3)
1	841
2	894

Experimental work shows specimens for Variation 1 and Variation 2 at age 3 days collapsing on the bottom of CLC brick surface and large cracks occurring along the foam concrete surface. Meanwhile, specimens at age 28 days showed longitudinal collapse at the bottom. The cracked texture arises along the light brick surface. The colours of specimen for age 3 days look wet rather than specimen at 28 days as shown in figure 5. Meanwhile, figure 6 indicates the specimen age 28 days is brighter and look drier rather than age 3 days. The condition shows that lightweight concrete age 28 days is sufficient to receive loading, as shown in figure 6.

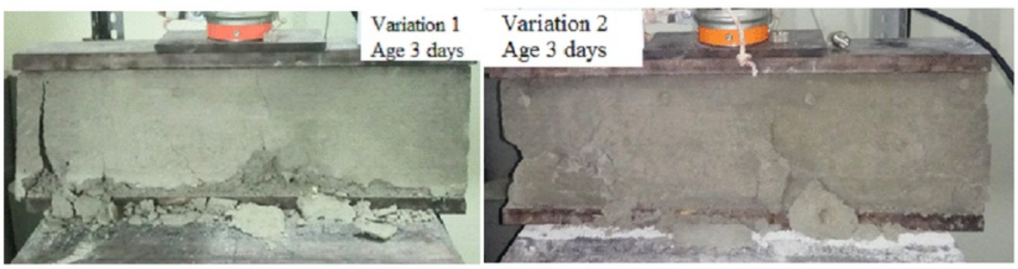

Figure 5. The compressive test on specimen age 3 days.

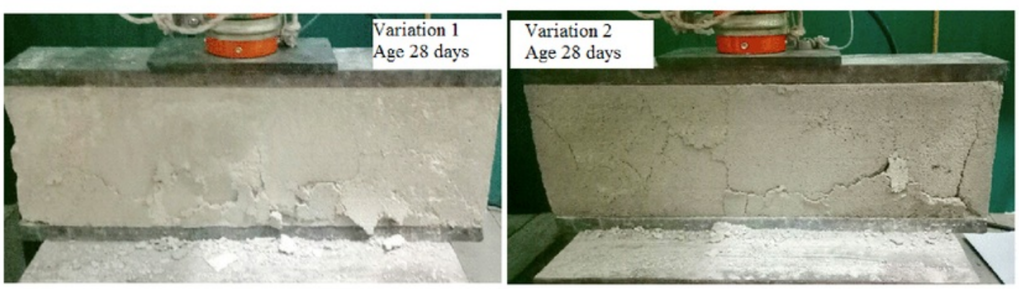

Figure 6. The compressive test on specimen age 28 days.

The strength of Variation 2 is higher than Variation 1. However, the increase in strength produced is not significant because of small additions (low strength). Given the results of this study are similar to studies reported in the literature, such as [12] and [3], reducing the size of sand particles can, therefore, lead to the increased strength of foam concrete. The replacement of sand with materials such as fly ash could conduct higher strength, and fine aggregate fillers could produce higher strength and density ratios as well. For further research, the addition of fly ash in both mixed variations in this study needs to be developed in order to obtain a significant lightweight concrete strength.

5. Conclusion

The conclusions generated from this study based on the material characteristics and parameters used are:

1. The higher density gives the higher compression for index properties of CLC brick.
2. The increase in cement content of the mix results in increased strength for compressive strength,
3. The increasing of compressive strength in 28 days between Variation 1 and Variation 2 is about 24.5%.

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