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Stone dust as replacement for fine aggregate in cellular lightweight concrete (CLC): Volume weight and compressive strength

PAREA R. RANGAN[1,a*], M. TUMPU[2,b], Y. SUNARNO[1,c] and MANSYUR[3,d]

[1]Civil Engineering Department, Faculty of Engineering, Christian University of Indonesia, Toraja, Indonesia

[2]Disaster Management Study Program, The Graduate School, Hasanuddin University, Makassar, Indonesia

[3]Civil Engineering Department, Faculty of Engineering, SembilanBelas November University, Kolaka, Indonesia

[a]pareausanrangan68@gmail.com, [b]tumpumiswar@gmail.com, [c]yohanssunarno@gmail.com, [d]mansyurusn14@gmail.com

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Abstract. A type of lightweight concrete called cellular lightweight concrete (CLC) has a lower volume weight than ordinary concrete and is made of cement, sand, water, and a foaming agent. In this investigation, CLC lightweight concrete was utilized as a lightweight brick. The purpose of this study was to ascertain how the compressive strength and volume weight of CLC lightweight bricks would change if stone dust were used in place of fine aggregate. Making lightweight bricks with stone dust substitutions of 0%, 50%, and 100% of the weight of the fine aggregate was the experimental process used in this study. The compressive strength and volume weight of the lightweight bricks that had been cured for 3, 7, 14, and 28 days were then measured. Because stone dust has a good binding capacity, the results showed that using it as a fine aggregate replacement in a mixture of lightweight bricks increased the compressive strength; the highest compressive strength value was obtained at a substitution of 100% stone dust at 28 days, which was 24.62 kg/cm^2. The volume weight of a mixture of lightweight bricks increased by 0.66 gr/cm^3 when stone dust was used in place of fine aggregate. In place of 50% stone dust, the volume weight value increased by 2% to 0.67 gr/cm^3, and by 4% to 0.68 gr/cm^3 for 100% stone dust. Due to its volume weight range of 0.6-1.8 gr/cm^3, this lightweight brick can still be designated as lightweight concrete.

Introduction

A porous brick that is lighter in density than regular brick is said to be lightweight. Cellular lightweight concrete (CLC) is one of various forms of lightweight bricks available on the market [1-3]. In general, Portland cement, fine aggregate, water, and a foam agent were combined to make CLC lightweight bricks [4-6]. By adding foam to a concrete mortar mixture without generating a chemical reaction, CLC lightweight bricks are created. Air bubbles were kept stable during rapid mixing using a foaming agent. Both natural and artificial materials can be used to generate foam agents [7–9].

The CLC lightweight brick business had to grapple with the problem of how to boost the compressive strength of CLC lightweight bricks because the strength produced was still quite low while maintaining the density value, keeping the bricks light. As a result, both in terms of the mixed materials and the composition of the mixture employed in the manufacturing process, new developments in the production of CLC lightweight bricks continue to be developed. lightweight CLC bricks Lesovik et al., 2020 [10], who did experimental study on the use of silica sand as a substitute for fine aggregate to improve the performance of foam concrete, carried out some of these investigations. It was shown that the compressive strength and indirect tensile strength of foam concrete could be maximized by utilizing silica sand and adding calcium. White dirt was found to boost the compressive strength of lightweight bricks in a study by Amran et al. (2015 [11], which looked at the experimental examination of the compressive strength and water absorption of CLC with that material as an aggregate.

Figure 1. *Cellular Lightweight Concrete (CLC)*

It was vital to find other options by utilizing the abundant natural resources since as development expanded, so did the demand for fundamental building construction materials. For instance, stone dust from the waste processing of coarse aggregate, which granules pass through perforated sieve by 4.75 mm and kept sieved by 0.075 mm, can be utilized as a light-weight brick-making material in Toraja, South Sulawesi Province.

On the other hand, the local population exclusively utilized stone dust for straightforward building tasks like printing stone and other such tasks. The stone dust employed in this study was created utilizing a used stone crusher in Buakayu, Bonggakaradeng District, Toraja. The findings of a study by A. Haris Ratih in 2016 [12] that looked at how using stone ash affected the compressive strength of concrete of the K-350 quality indicated that the stone ash-containing mixture could have an impact on the compressive strength of concrete.

The compressive strength decreased with the amount of stone ash utilized, but the 350 kg/cm^2 limit could still be reached. A combination containing 40% stone ash had the highest average compressive strength. In this study, it is envisaged that the usage of stone dust can be employed as a substitute for fine aggregate in the composition of lightweight bricks and can enhance the quality of lightweight bricks with targeted compressive strength.

Materials and Methodology

Lightweight Brick Physical Requirement

The Indonesian National Standard (SNI) requirement has not been found to address the viability of lightweight bricks. Based on this, SNI 03-3449-2002 [13] was utilized as a criteria to be employed for lightweight bricks regarding concrete bricks for masonry walls [14]. The lightweight brick reference C will be used to determine the physical requirements for the feasibility of concrete bricks.

Table 1. Lightweight brick physical requirement [14]

Physical requirement	Unit	Lightweight brick quality level			
		I	II	III	IV
Minimum average of compressive strength	kg/cm^2	100	70	40	25
Bruto compressive strength of specimen	kg/cm^2	90	65	35	21
Minimum average of water absorption	%	25	35	-	-

Stone Dust
Stone dust was an artificial aggregate-based building material (minerals or fillers with a particle size generally less than 0.075 mm, which is a by-product or processed crushed stone used in stone crushers). Stone ash was sharp and gray in color, with a fine-grained texture. It has pozzolanic components, is tough and long-lasting (it contains silica and alumina compounds that are not cementitious, but their smooth form when mixed with water can turn into a solid mass).

Stone dust's water content, volume weight in a loose state, volume weight in a solid state, and sludge content were all examined for their physical properties. The results were 3.1%, 1.3, 1.5, and 2.4%, respectively. 2.3, 2.4, 2.5, and 4.2%, respectively, were the results of the bulk specific gravity, saturated surface dry specific gravity, apparent specific gravity, and water absorption.

Fine Aggregate
River sand, the fine aggregate employed in this study, had water content values of 4.2%, 1.2, 1.4, and 3.4%, respectively, as well as volume weights in loose, solid, and sludge conditions. 2.4, 2.5, 2.7, and 4.6%, respectively, were the results of the bulk specific gravity, saturated surface dry specific gravity, apparent specific gravity, and water absorption.

Foam Agent
Foam agent is one of the foam agents made from hydrolyzed protein-based ingredients. Natural ingredients in the form of proteins with a density of 80 grams per liter can be used as foam agent-forming substances. In order to generate lightweight concrete, this foam ingredient had to stabilize air bubbles during quick mixing.

Research Design
Making lightweight bricks with stone dust substitutions of 0%, 50%, and 100% of the weight of the sand was the experimental procedure employed in this investigation. We examined lightweight bricks to determine their compressive strength and volume weight value after curing them for 3, 7, 14, and 28 days. Table 2 lists each of the 36 test objects that were used in this investigation.

Table 2. The number of test object

Age (Day)	Normal lightweight briks	Subtitusion of stone dust	
		50%	100%
3	3	3	3
7	3	3	3
14	3	3	3
28	3	3	3
Σ	12	12	12
Total	36		

Results and Discussion

Volume Weight of CLC Lightweight Bricks
Figure 2 displays the volume weight calculations for standard CLC lightweight bricks and CLC lightweight bricks with 50% and 100% substitutes of stone dust. As can be seen, the typical CLC lightweight bricks had an average volume weight of 0.75 grams per cubic centimeter at 3 days, 0.75 gram/cm^3, at 7 days, 0.75 gram/cm^3, at 14 days, 0.72 gram/cm^3 and 0.66 gram/cm^3 at 28 days. The average volume weight of lightweight bricks with CLC substitution of 50% stone dust at the age of 3 days was 0.81 gram/cm^3, at the age of 7 days it was 0.77 gram/cm^3, at the age of 14 days it was 0.76 gram/cm^3, and at the age of 28 days it was 0.67 gram/cm^3. The average volume weight of CLC lightweight substitution of 100% stone dust at the age of 3 days was 0.83 gram/cm^3, at the

age of 7 days it was 0.78 gram/cm^3, at the age of 14 days it was 0.77 gram/cm^3, and at the age of 28 days it was 0.68 gram/cm^3.

The results show that all the specimens were lightweight concrete in accordance with SNI 03:2847:2013, namely the volume weight for lightweight concrete is 650–1840 kg/m^3, while the volume weight of foam concrete produced is an average of 770 kg/m^3 [15]. Foam usage had a significant impact on the weight and volume of foam concrete. The foam concrete became lighter and had a decreased compressive strength as more foam was added.

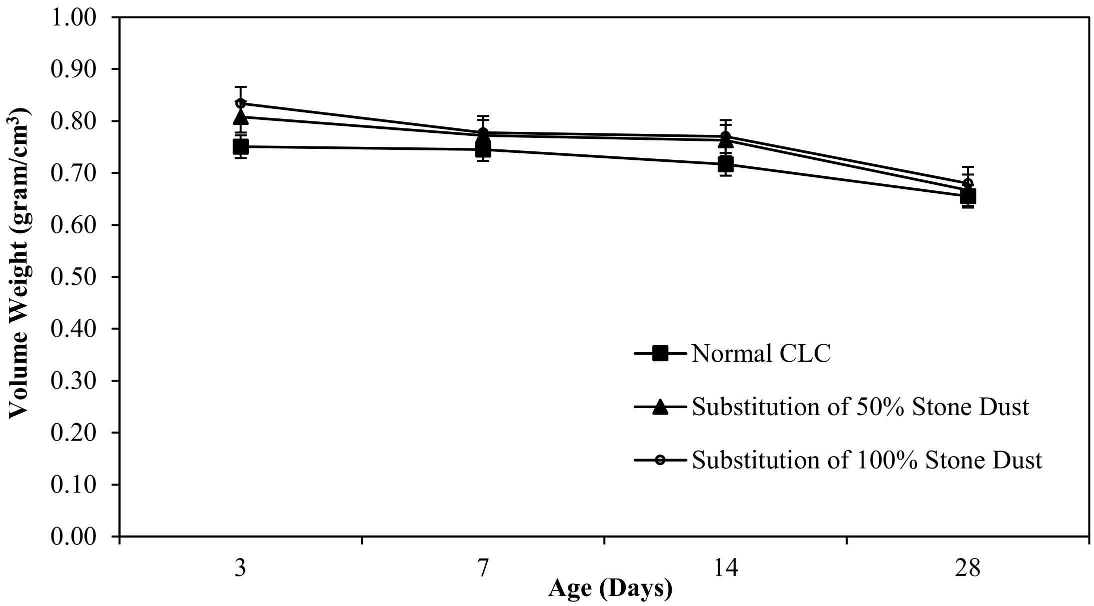

Figure 2*. Volume weight of Cellular Lightweight Concrete (CLC)*

Compressive Strength of CLC Lightweight Bricks

Figure 3 displays the outcomes of the lightweight bricks' compressive strength test at ages 3, 7, 14, and 28 days. As can be shown, the typical CLC lightweight bricks had an average compressive strength of 8.54 kg/cm^2 at three days, 13.44 kg/cm^2 at seven days, 21.90 kg/cm^2 at fourteen days, and 22.66 kg/cm^2 at twenty-eight days. Lightweight bricks with a CLC substitution of 50% stone dust had an average compressive strength of 9.67 kg/cm^2 after three days, 13.60 kg/cm^2 after seven days, 22.21 kg/cm^2 after fourteen days, and 23.26 kg/cm^2 after 28 days. At the ages of 3, 7, 14, and 28, the compressive strength of lightweight bricks with 100% stone dust CLC substitution was, on average, 10.12 kg/cm^2, 15.11 kg/cm^2, 23.42 kg/cm^2, and 24.62 kg/cm^2.

All mixes' compressive strengths rose as the specimens aged, which is consistent with the behavior of concrete made with Portland cement. As the material aged, the compressive strength of foam concrete kept rising. The stabilization of the bubbles that had developed as a result of the response of composite portland cement when mixing foam into concrete led to the rise in compressive strength, which subsequently persisted with the hydration process lasting until the age of 28 days. The compressive strength of foam concrete can be impacted by the addition of foam to the mixture [16,17].

The amount of load that the lightweight bricks can support depends on the amount of foam added to the lightweight concrete mixture. According to the test results, the amount of foam agent added to the foam concrete mixture significantly affected the load that the lightweight bricks could support. It is evident from the resulting load value that as the volume of foam utilized rose, the load value that the lightweight bricks could support declined. In all combinations of lightweight concrete, the presence of gas results in the development of a deflection value that contrasts with a considerable difference; frequently, this physical attribute is utilized to identify the zone of gas accumulation [18-21].

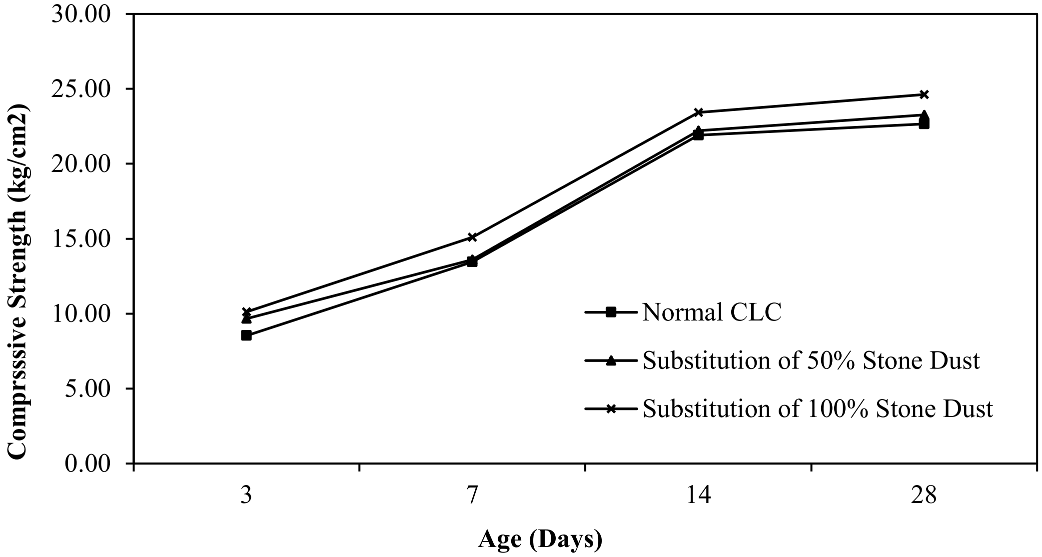

Figure 3. *Compressive strength of Cellular Lightweight Concrete (CLC)*

Conclusion

It was possible to combine PCC cement, sand, and stone dust to create a mortar that, when combined with foam, produced lightweight concrete that demonstrated good compaction. The rise in the compressive strength of lightweight concrete bricks from the age of 3 to 28 days demonstrates that the good compatibility of all the ingredients employed allows the hardening of the concrete to proceed smoothly during the binding process.

The volume weight of cellular lightweight concrete (CLC) increased by 0.66 gram/cm^3 over time when stone dust was used as a fine aggregate replacement. In place of 50% stone dust, the volume weight value increased by 2% to 0.67 gram/cm^3, and by 4% to 0.68 gram/cm^3 for 100% stone dust. Due to its volume weight range of 0.600 to 1,800 gram/cm^3, this light brick can still be referred to as being light.

Because stone dust has strong bonding power, it can be used as a fine aggregate replacement in cellular lightweight concrete (CLC) mixtures to boost compressive strength. The highest compressive strength value is obtained by substituting 100% stone dust aged for 28 days at 24,62 kg/cm2, which is in accordance with Indonesian requirements for lightweight concrete bricks for infilled walls. However, due to the influence of foam agents, which cause pores in lightweight bricks, the compressive strength does not meet the requirements to be used as wall pairs.

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