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Article

Study of the Characteristics of CLC (Cellular Lightweight Concrete) with the Addition of Rice Husk Ash

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A B S T R A C T

This study aims to analyze the effect of adding rice husk ash on the compressive strength of Cellular Lightweight Concrete (CLC) blocks. The research background is based on the need for building materials that are lightweight, environmentally friendly, and possess adequate mechanical strength. Rice husk ash is used as an additive material due to its high silica content and its potential to enhance the bonding between particles in the lightweight concrete matrix. The research method employed is an experimental method with variations in the addition of rice husk ash of 0%, 2.5%, 5%, and 10% by weight of cement. The test specimens were cube-shaped and were tested at the ages of 7, 14, and 28 days in accordance with SNI 8640-2018. The results indicate that the compressive strength increases with both the concrete age and the percentage of rice husk ash addition up to an optimum limit. At the age of 28 days, the highest compressive strength was obtained at the 10% rice husk ash variation, reaching 3.63 MPa, while the 5% variation produced a compressive strength of 3.33 MPa. Compared to lightweight blocks without the addition of rice husk ash, all variations exhibited a significant increase in compressive strength. Based on these results, it can be concluded that the addition of rice husk ash up to 10% is effective in improving the compressive strength of CLC lightweight blocks and meets the requirements for non-structural lightweight blocks.

1. Introduction

The development of science and technology has experienced a significant increase from year to year, including in the field of building construction. One of the important components in construction is walls, in which bricks remain the most widely used material. The high demand for bricks has encouraged the emergence of innovations in construction materials, one of which is lightweight brick. Lightweight brick is a concrete-based material that has characteristics of high strength, resistance to water and fire, and good durability. Its manufacturing process is carried out by creating air bubbles within the cement paste, forming a cellular structure that results in a lighter brick weight (Aidi et al., 2022).

In general, lightweight bricks used in wall construction are divided into two types, namely Autoclaved Aerated Concrete (AAC) and Cellular Lightweight Concrete (CLC). Both types of bricks apply the same principle, which is introducing air bubbles into the mortar to reduce the material's density. Although they use similar basic materials, such as cement, sand, and lime, the main difference lies in their production methods. The quality and strength of lightweight bricks are strongly influenced by the composition of their constituent materials and the production process, including the proportions of cement, water, sand, and foaming agent used (Aidi et al., 2022)

CLC lightweight bricks have the advantage of lower density compared to conventional bricks. The raw materials of CLC lightweight bricks consist of silica sand, cement, water, and an expanding agent that are processed using steam pressure. The density of CLC lightweight bricks can be adjusted according to construction requirements, with a density range between 400 and 1,800 kg/m³ (Subagiono et al., 2021). In their application as wall materials, lightweight bricks must meet established quality standards, one of which refers to SNI 8640-2018; therefore, material modification efforts are required to improve their quality.

One form of modification that can be carried out is the addition of organic or inorganic materials that are abundant but have not been optimally utilized. Rice husk is an agricultural waste produced in very large quantities, particularly in Kampar Regency, with annual rice production reaching 36,823.04 tons and generating approximately 11,046.91 tons of rice husk. Rice husk is a by-product of the rice milling process that is often not optimally utilized and can even cause environmental problems. According to Budirahardjo et al. (2014), rice milling generally produces about 20–30% husk, 8–12% bran, and 50–63.5% milled rice (Septiawan & Setiawan, 2022).

Rice husk has great potential to be utilized as an additive material in the production of lightweight bricks because it has pozzolanic properties and a very high silica content, which is approximately 85–90% (Antoni, 2007; Arif Fatwa et al., 2022). Rice husk ash produced from complete combustion is characterized by its white color and contains nanosilica capable of filling pores in lightweight concrete. Several previous studies have shown that the addition of rice husk ash has the potential to improve the quality of lightweight bricks, particularly in terms of water absorption and mechanical strength, because active silica is able to enhance the bonding between particles in the concrete matrix (Aidi et al., 2022;Taufieq, 2024).

Nevertheless, research on the effect of variations in the percentage of rice husk ash addition on the compressive strength and density of CLC lightweight bricks still needs to be further investigated, particularly with reference to the SNI 8640-2018 standard and testing at different concrete ages. Therefore, this study aims to examine the effect of adding rice husk ash at levels of 2.5%, 5%, and 10% by weight of cement on the compressive strength and density of CLC lightweight bricks. The results of this study are expected to provide a scientific contribution to the development of environmentally friendly construction materials, as well as to serve as an alternative for the sustainable utilization of agricultural waste in the construction sector.

2. Literature Review

2.1 Definition and Characteristics of CLC Lightweight Blocks

Lightweight blocks were first developed in Sweden in 1923 as an alternative building material and were later further developed by Joseph Hebel in Germany in 1943. In Indonesia, lightweight blocks began to be recognized in 1995 following the establishment of PT Hebel Indonesia in East Karawang, West Java (Beno et al., 2022). This development indicates that lightweight blocks are construction materials that continue to undergo innovation to meet the demands of modern buildings that require structural efficiency and ease of implementation.

According to SNI 03-2847 (2019), lightweight concrete is concrete that uses lightweight aggregates with a concrete density not exceeding 1,840 kg/m³. Subagiono et al., (2021) citing Efendi et al. (2019), state that CLC lightweight blocks generally have low strength ranging from 0.5 to 2.0 MPa. These lightweight blocks are composed of silica sand, cement, water, and foaming agents, which are processed using steam pressure, with a density that can be adjusted between 400 and 1,800 kg/m³.

Lightweight blocks have various advantages compared to red bricks and concrete blocks, including being more cost- and time-efficient, easy to install, heat resistant, resistant to water seepage, soundproof, and lightweight so they do not impose excessive loads on the substructure of buildings (Suryanita, 2020). Therefore, lightweight blocks are highly suitable for application in high-rise buildings and in areas with soft soil conditions.

Based on (Badan Standardisasi Nasional, 2018), bata ringan *CLC* merupakan batako yang dibuat CLC lightweight blocks are concrete blocks produced by adding foam water in the form of preformed foam using a foam machine and mixing it with mortar under high pressure (Badan Standardisasi Nasional, 2018). This standard also specifies the physical requirements of lightweight blocks, including average compressive strength, individual compressive strength, water absorption, minimum thickness, and drying shrinkage, which serve as references in this study (SNI-8640, 2018).

2.2 Constituent Materials of Lightweight Bricks

Cellular Lightweight Concrete (CLC) lightweight bricks are composed of several main materials, namely cement, fine aggregate (sand), water, a foam agent, and additives. The cement commonly used is Portland cement, which is a hydraulic binder produced from the grinding of cement clinker containing calcium silicates and supplemented with calcium sulfate compounds as well as other permitted additives (SNI 2049-2015). The fine aggregate consists of natural sand with a maximum particle size of 5.0 mm and must meet certain requirements, including sharp and hard particles, a maximum mud content of 5%, freedom from excessive organic materials, a fineness modulus of 2.2–3.2, and a well-graded particle distribution. (Syapawi et al., 2022). The foam agent is a surfactant solution dissolved in water to generate and maintain air bubbles within the mixture, thereby forming a porous structure; based on hydrophilic properties, surfactants are classified into anionic, cationic, and non-ionic types, in which non-ionic surfactants produce more stable foam and are neutral in lightweight brick mixtures (Syapawi et al., 2022).

In addition, additives or admixtures are materials other than cement, water, and aggregates that are added to modify the properties of concrete or mortar (Badan Standardisasi Nasional, 2012), either in the form of chemical or mineral substances that function to improve concrete performance (Suryanita, 2020). The combination of these materials gives CLC lightweight bricks advantages such as low weight, ease of cutting and nailing, high insulation capacity, and resistance to fire (Suryanita, 2020).

2.3 Rice Husk Ash

Rice husk ash is the result of the combustion of rice husks and is rich in silica (SiO_2). The combustion process removes organic substances and produces a natural pozzolanic material that is capable of reacting with water and lime to form an insoluble solid mass (Diwa et al., 2022). Heat treatment affects the level of pozzolanic activity and the fineness of the ash, so that rice husk ash has the potential to improve the quality of concrete or lightweight bricks.

2.4 Aggregate Testing

Aggregate testing is conducted to ensure material quality and includes specific gravity testing in accordance with SNI 1970-2016 (Badan Standardisasi Nasional, 2016), sieve analysis based on SNI 03-1968-1990 (Badan Standardisasi Nasional, 1990), mud content examination referring to SNI 4428-1997 (Badan Standardisasi Nasional, 1997), and organic content testing in accordance with SNI 2816-2014 (Badan Standardisasi Nasional, 2014). All of these tests aim to ensure that the aggregates meet the technical requirements for lightweight brick mixtures.

2.5 Mix Design, Curing, and Testing

The mix design of lightweight bricks was conducted to determine the material composition based on the module issued by the Ministry of Public Works (Suryanita, 2020). he curing process was carried out using the water curing method to ensure optimal cement hydration. Testing of bulk density, water absorption, and compressive strength of the lightweight bricks referred to (SNI-8640, 2018), so that the research results can be compared in a standardized and objective manner.

2.6 Relevant Research and Research Novelty

Various previous studies have examined the use of additive materials in CLC lightweight bricks, including limestone substitution (Syapawi et al., 2022), the use of rice husk ash and other waste materials in lightweight concrete (Arumningsih et al., 2023), the addition of ATKKS (Kaswara, 2023), red brick powder (Wahdah et al., 2024), as well as the combination of rice husk ash and lime as a cement replacement (Diwa et al., 2022).

Based on these studies, the novelty of this research lies in the use of rice husk ash as an additive material in CLC-type lightweight bricks, with specific percentage variations and testing of compressive strength and bulk density based on SNI 8640-2018. Therefore, this study is expected to provide a scientific contribution to the development of environmentally friendly lightweight bricks based on agricultural waste.

3. Research Methodology

3.1 Reserch Design

This study employs an experimental design aimed at analyzing the effect of the addition of rice husk ash on the physical and mechanical properties of Cellular Lightweight Concrete (CLC) blocks. The independent variable in this study is the variation in the percentage of rice husk ash addition, namely 2.5%, 5%, and 10%, while the dependent variables include compressive strength. The research was conducted at the Integrated Engineering Laboratory of Universitas Pahlawan Tuanku Tambusai.

3.2 Research Object

The object of this study consists of CLC lightweight concrete specimens made from a mixture of Portland cement produced by PT Semen Padang, sand from PT Usaha Jaya Kontraktor (UJK), water, foam agent, and rice husk ash. The specimens were cast in the form of blocks measuring 15 × 20 × 60 cm and cubes in accordance with the testing requirements. Testing was carried out at curing ages of 7, 14, and 28 days.

3.3 Research Instruments

The research instruments used include laboratory equipment and testing standards referring to the Indonesian National Standards (SNI). The examination of the specific gravity of fine aggregates refers to SNI 1970-2016, sieve analysis refers to SNI 03-1968-1990, mud content refers to SNI 03-4428-1997, and organic content refers to SNI 2816-2014. Testing of density, water absorption, and compressive strength of lightweight concrete blocks refers to SNI 8640-2018. The main equipment used includes a hydraulic compression testing machine, scales, an oven, a caliper, a pycnometer, sieves, and specimen molds.

3.4 Research Procedure

The research procedure begins with the collection of primary and secondary data. The research stages include the examination of constituent materials of the lightweight concrete blocks, mixing of materials according to the planned proportions, casting of specimens, demolding, and curing of the lightweight concrete blocks using the water curing method. After the curing process is completed, tests on density, water absorption, and compressive strength of the lightweight concrete blocks are conducted at the specified ages. All stages of the research are carried out systematically to obtain accurate and accountable data.

3.5 Data Analysis Technique

Data analysis is conducted using a quantitative descriptive approach based on the results of laboratory testing. The obtained data are grouped according to the research variables and presented in the form of tables and graphs to facilitate interpretation. The analysis focuses on testing compressive strength of rice husk ash addition and the effect of rice husk ash addition on the quality of CLC lightweight concrete blocks.

4. Results and Discussion

4.1 Compressive Strength Test Results

The compressive strength testing of lightweight bricks was conducted in accordance with SNI 8640-2018 (Badan Standardisasi Nasional, 2018). The tests were carried out at curing ages of 7, 14, and 28 days with variations in the addition of rice husk ash of 0%, 2.5%, 5%, and 10% by weight of cement. Each variation was tested using three cubic specimens with dimensions of 150 × 150 × 150 mm. The results of the compressive strength testing of the lightweight bricks are presented in Table 1.

Table 1. Recapitulation of Compressive Strength Test Results of CLC Lightweigh

No	Variation	Compressive Strength			Unit
		7	14	28	
1	0%	0,30	0,90	2,59	mpa
2	2,50%	0,31	1,48	2,59	mpa
3	5%	0,77	1,63	3,33	mpa
4	10%	0,84	2,00	3,63	mpa

Based on Table 1, it can be observed that the compressive strength values of the lightweight bricks increased with the increasing testing age for all variations of rice husk ash addition. This increase in compressive strength indicates that the cement hydration process occurs gradually and becomes more optimal at longer concrete ages.

To facilitate the interpretation of the results, the recapitulation of compressive strength values is presented in graphical form in Figure 1.

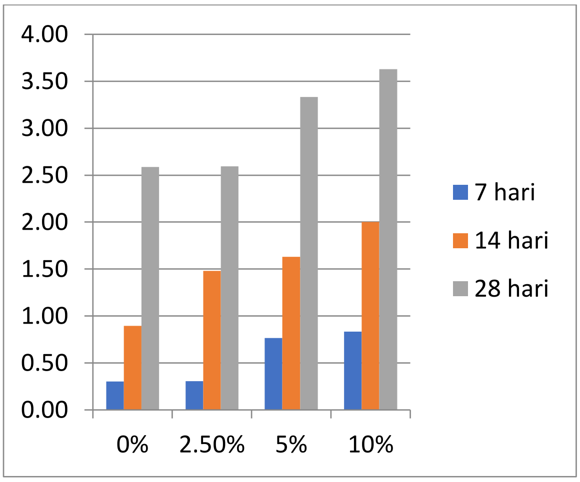

Figure 2. Graph of Recapitulation of Test Results

4.2 Testing of Rice Husk Ash on the Compressive Strength of CLC Lightweight Bricks

The test results show that the addition of rice husk ash has a positive effect on the compressive strength of CLC lightweight bricks. At the age of 7 days, the lightweight bricks with a 10% rice husk ash variation produced the highest compressive strength of 0.84 MPa, while the variation without rice husk ash (0%) showed the lowest compressive strength value of 0.30 MPa. This indicates that rice husk ash begins to play a role in improving the bonding between particles from the early age of the concrete.

Figure 1. Compressive Strength Test Using Hydraulic Loading

At the age of 14 days, the increase in Compressive strength became more significant. Highest among tested variations with 10% rice husk ash addition reached a compressive strength of 2.00 MPa, which was higher than the 5% variation at 1.63 MPa and the 2.5% variation at 1.48 MPa. This condition indicates that the silica content in rice husk ash contributes to pozzolanic reactions that strengthen the matrix structure of lightweight concrete as the curing age increases.

At the age of 28 days, the lightweight bricks with 10% rice husk ash addition produced the highest compressive strength of 3.63 MPa, followed by the 5% variation at 3.33 MPa. Meanwhile, the lightweight bricks without rice husk ash addition and the 2.5% variation showed the same compressive strength value of 2.59

MPa. These results indicate that a higher percentage of rice husk ash, up to a certain limit, is able to significantly increase the compressive strength of lightweight bricks.

The increase in compressive strength is in line with the objective of this study, which is to analyze the effect of rice husk ash addition on the compressive strength of CLC lightweight bricks. Mechanically, rice husk ash functions as a pozzolanic additive that can fill micro-pores and improve the internal structure of lightweight concrete, thereby increasing compressive strength. The results of this study also support the use of rice husk ash as an alternative additive material that has the potential to improve the quality of non-structural lightweight bricks while utilizing agricultural waste in a more environmentally friendly manner.

5. Conclusion

Based on the results of the study, it can be concluded that the addition of rice husk ash has a positive effect on the compressive strength of Cellular Lightweight Concrete (CLC) lightweight bricks. The compressive strength values increased with increasing curing age and the percentage of rice husk ash, with the best results obtained at the 10% variation, which produced the highest compressive strength of 3.63 MPa at the age of 28 days. This increase indicates that rice husk ash acts as a pozzolanic material capable of improving the internal structure of lightweight concrete by filling micro-pores, thereby enhancing the compressive strength of lightweight bricks and having the potential to be utilized as an environmentally friendly additive material for non-structural lightweight bricks.

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