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# Study of Compressive Strength of Cellular Lightweight Concrete (CLC) Bricks Using Empty Palm Fruit Bunch Ash (EPFBA) as an Additive

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**Abstract:** The rapid advancement of scientific knowledge in the construction field has spurred research on Cellular Lightweight Concrete (CLC) bricks by incorporating Empty Palm Fruit Bunch Ash (EPFBA). This study focuses on CLC bricks with the addition of EPFBA at 1%, 1.5%, and 2% of the cement weight, which are then compared with CLC bricks without EPFBA. These bricks undergo compressive strength testing at 7,14, and 28 days following the testing method specified in SNI 8640-2018. The specimen curing process is conducted at room temperature for three consecutive days, with thrice daily watering. The compressive strength test results at 28 days indicate that CLC bricks without EPFBA yield 2.11 MPa, CLC bricks with the addition of 1% EPFBA yield 1.06 MPa, CLC bricks with the addition of 1.5% EPFBA yield 1.95 MPa, and CLC bricks with the addition of 2% EPFBA yield 2.33 MPa. In conclusion, the addition of EPFBA to CLC bricks at 28 days enhances the compressive strength of CLC bricks.

**Keywords:** *CLC brick; EPFB; Compressive strength*

## 1. Introduction

Lightweight bricks offer several advantages, including ease of casting, lighter weight, a smooth surface, precise shape, and increased construction efficiency. In their application, there are two common types of lightweight bricks used, namely Autoclaved Aerated Concrete (AAC) and CLC. CLC bricks are made by infusing foam into the mortar mixture, while AAC bricks rely on a chemical reaction to create air bubbles.

Research in the field of material and material engineering has led to various innovations aimed at enhancing the quality of lightweight bricks. One particular innovation under scrutiny in this research is the utilization of EPFBA as an additional material. EPFBA, which is a solid waste from Palm Oil Companies, is formed through the incineration of Empty Fruit Bunches (EFB) which occurs in a burning furnace. EFBs are first dried, then incinerated at high temperatures to transform them into ash.

The utilization of EPFBA represents an innovative step in managing the abundant oil palm resources in Kampar Regency. As of 2021, Kampar Regency boasts approximately 226,169 hectares of oil palm plantations, producing roughly 2,868,627 tons of palm oil (Kanadia and

Nugraha, 2022). Empty palm fruit bunches account for 23% of the fresh fruit bunch weight, containing 36.81% cellulose, 27.01% hemicellulose, and 15.07% lignin (Falah and Nelza, 2019).

Up until now, Empty palm fruit bunches have primarily been utilized as organic fertilizer (Iskandar, 2023). It is hoped that incorporating EPFBA into CLC brick production will result in improvements to their characteristics. This study focuses on CLC bricks due to their simpler production process compared to AAC bricks. Therefore, it is expected that the addition of EPFBA will have a positive impact on the quality of CLC bricks produced.

## 2. Literature Review

### 2.1 Relevant Research

This research is built upon previous studies, enriching the existing theories. The following are the relevant studies that serve as references:

- Syapawi et al. (2022) conducted a study where they replaced up to 15% of limestone with the CLC lightweight brick production method. The results indicated an increase in compressive strength of CLC lightweight bricks with the substitution of limestone.
- Noprian et al. (2021) investigated the influence of substituting rice husk ash and Foam Agent (FA) on the density, compressive strength, and water absorption of lightweight bricks. The findings revealed that the substitution of rice husk ash increased water absorption while decreasing the compressive strength and density of the lightweight bricks.
- Tondok and Mastor (2019) evaluated the impact of limestone ash up to 20% on the density and compressive strength of lightweight bricks. The results showed an increase in density and a decrease in compressive strength of the lightweight bricks.

In summary, the studies under review have offered valuable insights into the properties of lightweight bricks when using different substitutions and additives. Syapawi et al. (2022) showed the potential for improving compressive strength by replacing limestone, while Noprian et al. (2021) highlighted the trade-offs between increased water absorption, reduced compressive strength, and density when substituting rice husk ash and using FA. Tondok and Mastor (2019) emphasized the positive impact of limestone ash on density but noted a decrease in compressive strength. The choice of substitution or additive should align with specific project requirements and quality standards. Further research in this field can contribute to the development of lightweight bricks with enhanced performance characteristics, suitable for diverse construction applications.

Based on relevant research, there are similarities with the research conducted by the author, which involves CLC lightweight bricks using FA. However, it is important to note that a research study should not replicate existing work entirely. To enhance the originality of this study, the following distinctions have been established:

- This research incorporates EPFBA as an additional material with percentages of 1%, 1.5%, and 2% of the cement weight.
- Testing and sample measurements adhere to methods regulated by the National Standardization Agency, commonly referred to as SNI (Standard Nasional Indonesia). The test specimens were determined in accordance with SNI 8640-2018, which measures 15 x 20 x 60 cm.
- Testing the characteristics of fine aggregates follows the latest SNI standards, including density testing (SNI 1970-2016), moisture content testing (SNI 8319-2016), and organic content testing (SNI 2816-2014).

### 2.2 Category and Characteristics of Lightweight Bricks

SNI 8640-2018 distinguishes lightweight bricks based on weight categories as shown in the following table:

**Table 1.** Lightweight Brick Weight Categories

| Weight Categories Based on Dry Oven Weight ($kg/m^3$) | Structural Bricks | | Non-structural Bricks | |
|---|---|---|---|---|
| | Outdoor | Indoor | Outdoor | Indoor |
| 500 | - | - | 400 – 600 | 400 – 600 |
| 700 | - | 600 – 800 | 600 – 800 | 600 – 800 |
| 900 | 800 – 1,000 | 800 – 1,000 | 800 – 1,000 | 800 – 1,000 |
| 1,100 | 1,000 – 1,200 | 1,000 – 1,200 | 1,000 – 1,200 | 1,000 – 1,200 |
| 1,300 | 1,200 – 1,400 | 1,200 – 1,400 | 1,200 – 1,400 | 1,200 – 1,400 |

Source: SNI 8640-2018

Based on the function and condition of lightweight bricks, they must meet the following requirements:

**Table 2.** Physical Requirements of Lightweight Bricks

| Physical Requirements | Unit | Structural Bricks | | Non-structural Bricks | |
|---|---|---|---|---|---|
| | | Outdoor | Indoor | Outdoor | Indoor |
| Class | - | IA | IB | IIA | IIB |
| Average Compressive Strength, Min. | MPa | 6.0 | 4.0 | 2.0 | 2.0 |
| Individual Compressive Strength, Min. | MPa | 5.4 | 3.6 | 1.8 | 1.8 |
| Water Absorption, Max. | % | 25 | - | 25 | - |
| Thickness, Min. | mm | 98 | 98 | 98 | 73 |
| Drying Shrinkage, Max. | % | 0.2 | 0.2 | 0.2 | 0.2 |

Source: SNI 8640-2018

## 2.3 Constituents of CLC Bricks

The raw materials used in this study consist of cement, sand, EPFBA, and FA. Typically, lightweight bricks are composed of two main components, namely the binder and the filler. Cement and water serve as the binding materials, with cement binding the fine aggregates when hydrated by water, while aggregates like sand and other fillers provide the brick's structure. The FA is an additional component used to increase volume and reduce the brick's mass, hence the term lightweight bricks. Additionally, EPFBA is employed as an additional variable, functioning as an additional filler material for lightweight bricks and strengthening their structure.

### 2.3.1 Portland Cement

SNI 15-2049-2004 explains that Portland Cement is a type of cement characterized by its binding properties, originating from the final grinding of cement clinker, especially calcium silicate, which exhibits hydraulic properties. It is ground together with additives in the form of one or more types of calcium sulfate compounds and may include other additional substances.

**Fig 1.** Cement

### 2.3.2 Fine Aggregates

According to SNI 03-6861.1-2002, the criteria for sand suitable for mixing are as follows:

- The maximum clay content on the sand's surface should not exceed 5%. If it exceeds this limit, a washing process must be conducted before use.
- Fine aggregates should not contain excessive organic matter (living substances) and should be verified through the Abrams-Harder color test using a 3% NaOH solution, with a standard not exceeding number 3.
- The fineness modulus should range from 1.5 to 3.8 and must fall into one of the gradation zones, which include zones 1, 2, 3, and 4.

**Fig 2**. Fine Aggregates

### 2.3.3 Foam Agent (FA)

FA, or Foaming Agent, is an adhesive solution derived from a surfactant substance that, when used, must first be dissolved in water, forming a colloidal solution. Synthetic surfactants used in FA can be classified based on their hydrophilic properties concerning the parts of the molecule that dissolve in water as follows:

- Anionic surfactants, which produce approximately 70% of the foam.
- Cationic surfactants, which produce foam with a percentage of less than 5% and possess positive hydrophilicity.
- Non-Ionic (Polar) surfactants generate 25% neutral foam. It is also known that reducing the electrical charge provides higher adaptability in lightweight concrete mixtures.
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**Fig 3.** Foam Agent

### 2.3.4 Empty Palm Fruit Bunch Ash (EPFBA) as Admixture

SNI 7656-2012 explains that additives are substances, whether in powder or liquid form, added to a concrete mixture during mixing in specific quantities to alter certain properties. These additives serve the purpose of modifying these properties to make them suitable for particular applications, cost-effective, or for other purposes such as cost savings.

**Fig 4.** Empty Palm Fruit Bunch Ash

EPFBA contains approximately 35-40% potassium oxide ($K_2O$), 7% diphosphorus pentoxide ($P_2O_5$), 9% calcium (Ca), and 3% magnesium oxide (MgO) with a pH of 9.9. The contents of EPFBA indicate its potential use as an additive to enhance the quality of lightweight bricks. This is because EPFBA contains silica and calcium oxide compounds, which play a significant role in the formation of the lightweight brick structure.

### 2.3.5 Water

Water is a vital element in concrete production, even though it is inexpensive. It must be pure, free from impurities and chemicals that could affect concrete quality. Adhering to specified water requirements is crucial. The water used for treating or immersing the concrete can be the same as that used in the mixture, as long as it doesn't contain residues or chemicals that could harm the concrete's integrity.

## 3. Method

Lightweight bricks incorporate fine aggregate that passes through a 4.80 mm sieve. The fine aggregate must not exceed 5% sludge content and should be free from organic matter. Dry conditions are essential when using sand. The EPFBA, which is in granular form, is preferred for its better integration with the lightweight brick mixture. The mixing process involves initially blending the sand and cement materials, incorporating the EPFBA, and then adding water and the foam agent. The composition of materials is determined based on property test results, which are compiled into a job mix formula (JMF). Once the mixture is thoroughly mixed, it should be weighed before placement in the mold, and if the density meets the requirements, it can be poured into the mold.

The manufacturing of CLC bricks is conducted using specialized equipment suitable for the field, in addition to standardized testing of the prepared job mix

(a) mold (b) Mixer (c) Compression Machine (d) Foam Machine

**Fig 5.** CLC Brick Equipment

The light brick mold was opened after 24 hours and a curing process was carried out by wrapping the test object in plastic for 14 and 28 days. The curing process is carried out to maintain the water content in the test object and then compressive strength testing is carried out at the age of 7 days, 14 days and 28 days.

Compressive strength testing was carried out to determine the effect of using empty bunch ash on the compressive strength of lightweight bricks. Apart from that, it is also to find out the optimal variation in using empty bunch ash in light brick mortar. The test results can be used as a solution for using lightweight additives to obtain optimal compressive strength results.

## 4. Result and Discussion

The compressive strength of lightweight bricks was assessed at 7, 14, and 28 days after the initial mixture was poured into the mold. Each test involved four lightweight brick samples, measuring 150 mm in length, 150 mm in width, and 150 mm in height, following the guidelines of SNI 8640-2018. The results of the tests for each composition and sample ages (7, 14, and 28 days) are presented in Table 3. In comparison to the 0% EPFBA composition, which represents the standard lightweight brick, it is evident that the 2% EPFBA composition exhibits the highest compressive strength, followed by the 1.5% EPFBA composition, while the 1% EPFBA composition shows the lowest compressive strength. The subsequent graph provides a summary of the compressive strength test outcomes.

**Table 3.** Compressive Test Result

| No. | Variations in EPFBA Addition | Compressive Strength Values Based on Testing Age (MPa) | | |
|---|---|---|---|---|
| | | 7 Days | 14 Days | 28 Days |
| 1 | 0% | 1.72 | 1.78 | 2.11 |
| 2 | 1% | 0.33 | 0.78 | 1.06 |
| 3 | 1.5% | 1.00 | 1.06 | 1.95 |
| 4 | 2% | 1.72 | 1.95 | 2.33 |

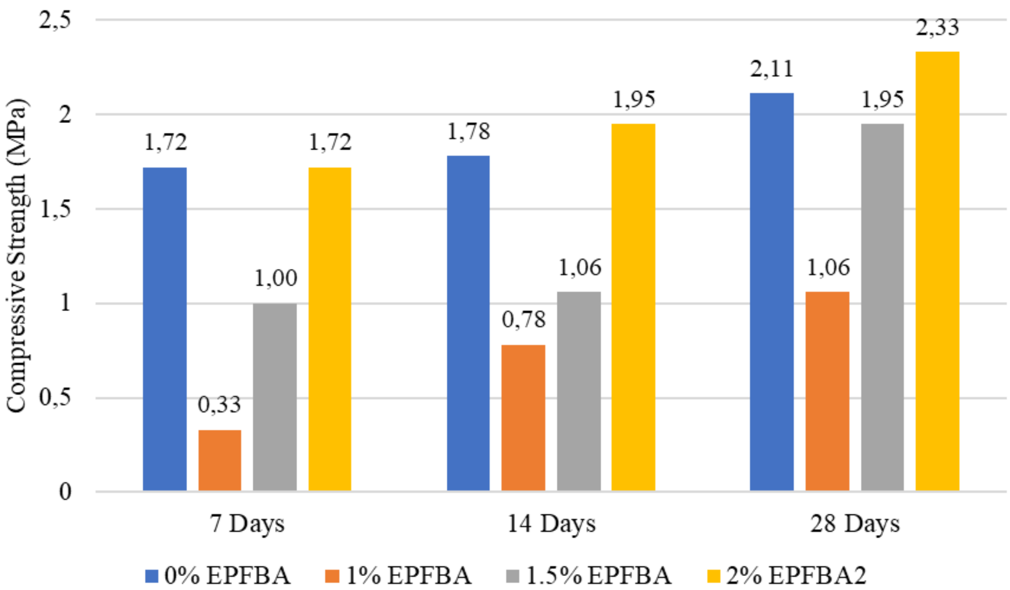


**Fig 6.** Diagram of Compressive Test Result

Fig. 6 displays the compressive strength values of lightweight bricks at 7 days. At a 0% EPFBA addition, the compressive strength is 1.72 MPa, while a 1% addition results in 0.33 MPa, 1.5% addition yields 1 MPa, and 2% addition provides 1.72 MPa. After 14 days, a 0% EPFBA addition produces a compressive strength of 1.78 MPa, 1% addition results in 0.78 MPa, 1.5% addition leads to 1.06 MPa, and 2% addition achieves 1.95 MPa. After 28 days, a 0% EPFBA addition shows a compressive strength of 2.11 MPa, 1% addition results in 1.06 MPa, 1.5% addition yields 1.95 MPa, and 2% addition results in 2.33 MPa.

The composition of the lightweight brick mixture that exhibits the most significant increase in compressive strength with a 2% EPFBA addition at test ages of 7, 14, and 28 days is 1.72 MPa, 1.95 MPa, and 2.33 MPa, respectively. These results are in accordance with the testing standards outlined in SNI 8640-2018. Notably, only the 1.5% EPFBA addition, tested for 28 days, demonstrated a water absorption rate of 25.03%, meeting the required standards for lightweight bricks. However, it did not meet the specified targets for other physical requirements of lightweight bricks.

## 5. Conclusion and Recommendation

The conclusion of the study results indicates that the compressive strength of lightweight bricks varies depending on the percentage of EPFBA addition. At 7 days, the addition of 0% and 1% EPFBA resulted in low compressive strength, 1.72 MPa and 0.33 MPa, respectively. However, the addition of 1.5% and 2% resulted in better compressive strength, 1 MPa and 1.72 MPa, respectively. At 14 days, the 0% and 1% EPFBA additions still showed low compressive strength, with values of 1.78 MPa and 0.78 MPa, respectively. The addition of 1.5% led to an increase in compressive strength to 1.06 MPa, and the addition of 2% yielded the highest compressive strength at 1.95 MPa. At 28 days, the 0% EPFBA addition had the highest compressive strength at 2.11 MPa. The addition of 1% and 1.5% still showed low compressive strength, at 1.06 MPa and 1.95 MPa, respectively. However, the addition of 2% resulted in the highest compressive strength at 2.33 MPa. The decrease in compressive strength for the 1% and 1.5% additions at 7 and 14 days is attributed to other factors during the specimen manufacturing or curing process.

Based on the research conclusion, there are recommendations that can be suggested for further investigation regarding the factors that influence compressive strength during the early curing period when using 1% and 1.5% EPFBA additions to optimize the curing process and minimize adverse effects.

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