The effect of adding silica fume for lightweight concrete brick in terms of strength criteria

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Abstract. Technological developments in the property sector at this time, especially on the walls are lightweight bricks. To find out the extent of the behavior of the characteristics of lightweight bricks, a study of compressive strength and absorption was carried out using materials such as cement, sand, foam agents and silica fume. Research with the addition of silica fume of 5%, 10% and 15% of the weight of cement at the age of 7 days, 14 days and 28 days based on the standard technology planning module of mortar foam material for road construction. Comparison of light brick free compressive strength from normal light brick to lightweight brick with optimum free compressive strength, namely in light brick the addition of silica fume 5%. The results of free compressive strength at the age of 7 days with the addition of silica fume 5% increased by 41% from normal lightweight brick free compressive strength. At the age of 14 days the compressive strength of light-free bricks with the addition of silica fume 5% increased by 57% from normal light bricks and at 28 days increased 41%. The lowest absorption occurs on the use of silica fume 5% with a value of 36%.

1. Introduction
The development of technology in the property sector is now increasing rapidly, both in terms of design and materials used. Walls are a fundamental part of every building, be it a house or a building, the materials used always progress from year to year, for example in bricks [1]. The work of the wall used to be inseparable from the use of bricks, as the times of the thinkers have produced many innovations such as lightweight bricks [2]. In this study, lightweight bricks use a mixture of Portland Cement, sand, foam agents and water (1:20) intending to determine the compressive strength and absorption of water (absorption) and evaluate the effect of adding silica fume using variations of 5%, 10% and 15% of cement weight to compressive strength.

2. Materials and Methods

2.1. Materials
The material used in the manufacture of lightweight concrete in the form of Portland Cement, water, fine aggregate, foam agent and silica fume.

2.1.1. Portland Cement (PC). Portland cement is the most widely used construction material in concrete work, Portland cement is defined as a hydraulic cement produced by grinding a clinker
consisting of hydraulic calcium silicate, which generally contains one or more forms of calcium sulfate as Additional ingredients are ground together with the main ingredients [3].

2.1.2. Water. Water is very influential in making concrete, because water will react with cement which will become an aggregate binding paste. The quantity of water used will affect all the properties of concrete, while the quality of water will affect the hardening and durability of the concrete [4].

2.1.3. Fine aggregate. Fine aggregate or natural sand is the result of natural disintegration of rocks or sand produced by the stone breaking industry. Fine aggregate is material which passes filter No. 8 (2.36 mm). Aggregates can increase mixture stability by locking (interlocking). In addition fine aggregate also fills the space between the grains, this material can consist of broken grains of stone or natural sand or a mixture of both [5].

2.1.4. Foam agent. Foam agent is a material made from a concentrated solution of a surfactant material, which if you want to use must be dissolved with water. One ingredient that contains surfactants is Detergent (CH3 (CH2) 15OSO3-Na+). Foam agent is a chemical mixture derived from a mixture of natural ingredients and artificial materials. Foam agent with natural material in the form of the protein has a density of 80 grams/litre, while artificial material is a synthetic material which has a density of 40 grams/litre [6]. Foam agents can be made by mixing chemicals that are as developers, as well as chemicals making soap foam on the soap [7]. Foam developer material on soap usually uses texapon material. Texapon is a chemical that has the function of removing fat and impurities or substances that have surfactant properties. texapon is very well known in the industry making materials for hygiene such as dishwashing liquid, hand washing liquid, shampoo and so forth. Texapon is an artificial surfactant that can be used as a basic ingredient in the manufacture of liquid soap, shampoo and toothpaste. Texapon will act with water and will produce foam. Texapon is also called sodium lauryl sulfate (C12H25SO4Na). Foam agents in the manufacture of lightweight brick made from texapon must be mixed again with sikacim material so that it is easy to bind with concrete mortar materials and speed up the process of hardening concrete, with a ratio of Texapon (1.5 L): Water (40 L) and Sikacim (0.05%): Texapon + Air (100%) [8].

2.1.5. Silica fume. According to the standard "Specification for Silica Fume for Use in Hydraulic Cement Concrete and Mortar" (ASTM.C.1240.1995: 637-642) [9]. The use of silica fume in concrete mixes is intended to produce concrete with high compressive strength [10]. High strength concrete is used, for example, for structural columns or shear walls, precast or pre-stressed concrete and several other uses [11].

2.2. Methods

2.2.1. Unconfined compression strength test. Free compressive strength is the maximum load achieved at 15% axial strain (SNI 36838-2012) or 20% axial strain. Free compressive strength is the ratio between the load and the area expressed in Mpa or Kg/cm² [12]. Light brick free compressive strength value is obtained by testing the Unconfined Compression Strength Test which is generally used to get the free compressive strength value on the ground but can also be used on light brick. To get the results of light brick compressive strength which is done by testing the Unconfined Compression Strength Test, a correction factor of 0.5 is needed, which aims to convert the dial reading results in mm to kg.

Determination of compressive strength can be done using compressive test equipment and cylindrical test specimens with test procedures at 28 days (MPa or kg/cm2) calculated using the following formula SNI 1974-2011 [13]:

\[ \text{Compressive Strength (MPa)} = \frac{F}{A} \times 10^3 \]
\[ Fc' = \frac{P}{A} \]  

- \( Fc' \) = concrete compressive strength (MPa)  
- \( P \) = maximum compressive force (N)  
- \( A \) = test material cross-sectional area (mm\(^2\))

2.2.2. 28-day Absorption Testing. Before testing the value of light brick absorption, first light brick is weighed before and after soaking for 24 hours. Calculation of the value of the absorption of light bricks that have been treated for a specified time with a different method [14]:

\[ Absorption = \frac{B}{A} x 100\% \]

- \( A \) = Weight of dry test specimens (kg)  
- \( B \) = Weight of test specimens after immersion (kg)

3. Results and discussions

3.1. Aggregate test results

Before being used to make test specimens, the material and material must first be examined for its characteristics. The results of the initial inspection of the aggregate are presented in the table below.

| Aggregate characteristics     | Test results   |
|-------------------------------|---------------|
| Sieve Analysis                | 2.8 %         |
| Volume weight                 | 1.486 kg/m\(^3\) and 1.680 kg/m\(^3\) |
| Water content                 | 3.91 %        |
| Absorption                    | 3.11%         |
| Specific gravity              |               |
| a. Bulk density               | 2.68          |
| b. Dry specific gravity       | 2.48          |
| c. Pseudo Specific Gravity    | 2.60          |
| Sludge levels                 | 3.33 %        |

3.2. Job mix design

This study refers to the mix design of the Mortar-foam Light Weight Hoarding Technology Planning Module for the Construction of the 2014 Pusjatan Road to the normal lightweight brick composition [15]. The addition of silica fume to the mix design is intended to increase the compressive strength and reduce the use of cement.

Light brick planning uses a cement water factor of 0.5, the percentage ratio of sand: foam agent ratio of 20%: 80% and variations in the addition of silica fume taken are 5%, 10% and 15% of the weight of cement. The composition of the need for a light brick mixture for 1 m\(^3\) can be seen in the following Table 2.
Table 2. Lightweight brick composition for 1 m³.

| Material       | Normal Concrete (kg) | Silica Fume Blend Variation |
|----------------|----------------------|-----------------------------|
|                |                      | 5%  | 10%  | 15%  |
| Water          | 300                  | 285 | 270  | 255  |
| Cement         | 150                  | 150 | 150  | 150  |
| Fine aggregate | 385                  | 385 | 385  | 385  |
| Foam agent     | 45                   | 45  | 45   | 45   |
| Silica fume    | -                    | 15  | 30   | 45   |

3.2.1. Unconfined compression strength test. In general, light brick free compressive strength from the tables and graphs above at 7, 14 and 28 days is known by adding silica fume to the light brick mixture, it will increase the value of light brick free compressive strength and optimum compressive strength on the addition of silica fume by 5% but along with the increase in silica fume, the compressive strength of the free brick light decreases.

![Figure 1. Free compressive strength comparison graph.](image)

Based on Figure 1, it can be seen that the ratio of light brick free compressive strength to the age of light brick has increased. Light brick free compressive strength is very influential on the percentage of the addition of silica fume whereas the percentage increase in the addition of silica fume, the free compressive strength will decrease.

Comparison of light brick free compressive strength from normal light brick to light brick with optimum free compressive strength that is light brick with the addition of silica fume 5%. Based on the Figure 1 free compressive strength at the age of 7 days with the addition of silica fume 5% has increased by 41% from the compressive strength of normal light brick. At the age of 14 days the compressive strength of light-free bricks with the addition of silica fume 5% increased by 57% from normal light bricks and at the age of 28 days an increase of 41%.

3.3. Absorption testing

Lightweight brick absorption test was carried out at 28 days. The results of the concrete absorption test results can be seen in the results in Table 3.
Table 3. Lightweight brick absorption test age 28 days.

| Code Test Objects | Dimension | Volume (cm³) | Sample Weight SSD Conditions (gr) | Weight of Sample Dry Condition (gr) | Absorption (%) | Average Absorption (%) |
|-------------------|-----------|--------------|-----------------------------------|-----------------------------------|----------------|------------------------|
| BRN-A             | Cube 5x5x5| 25           | 139.25                            | 100.27                            | 39             | 33.67                  |
| BRN-B             | Cube 5x5x5| 25           | 141.06                            | 108.60                            | 30             |                        |
| BRN-C             | Cube 5x5x5| 25           | 146.17                            | 102.81                            | 32             |                        |
| BRSF-5% A        | Cube 5x5x5| 25           | 142.21                            | 103.62                            | 37             |                        |
| BRSF-5% B        | Cube 5x5x5| 25           | 132.68                            | 97.32                             | 36             |                        |
| BRSF-5% C        | Cube 5x5x5| 25           | 136.93                            | 101.65                            | 35             |                        |
| BRSF-10% A       | Cube 5x5x5| 25           | 136.85                            | 96.21                             | 42             |                        |
| BRSF-10% B       | Cube 5x5x5| 25           | 144.43                            | 107.71                            | 34             | 36.67                  |
| BRSF-10% C       | Cube 5x5x5| 25           | 138.82                            | 103.36                            | 34             |                        |
| BRSF-15% A       | Cube 5x5x5| 25           | 143.54                            | 103.37                            | 39             |                        |
| BRSF-15% B       | Cube 5x5x5| 25           | 137.23                            | 100.24                            | 37             | 37.3                   |
| BRSF-15% C       | Cube 5x5x5| 25           | 134.63                            | 98.93                             | 36             |                        |

Figure 2. Graph of 28 day absorption test results.

Absorption Testing is done by testing 3 cube samples, then the value is averaged with various variations of the mixture. In the graphic image can be seen absorption (absorption) increased, according to the increase in the percentage of silica fume although not too significant. Normal light brick absorption value is 33.67%, silica fume 5% is 36%, silica fume 10% is 36.67% and silica fume 15% is 37.3%.

4. Conclusion

Based on data analysis and discussion in this study, the lightweight brick-free compressive strength for the mixture of silica fume 5%, 10%, 15% at 0.765 MPa, 0.629 MPa and 0.473 MPa. The optimum free compressive strength of light brick with a mixture of silica fume is obtained by adding a variation of silica fume of 5% of the amount of cement used. Free compressive strength with the addition of silica fume 5% at the age of 7 and 14 days has increased by 41% and 57%, while the age of 28 days has decreased by 41% of normal light brick. Absorption value in light brick increases with increasing percentage of silica fume mixture. The value of light brick absorption with a mixture of silica fume 0%, 5%, 10% and 15% respectively were 33.67%, 36%, 36.67% and 37%.
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