The Innovation of Interlock Bricks with A Mixture of Bagasse Ash Without Combustion

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Abstract. Nowadays, the wall building material is dominated by clay brick and the process requires combustion. Therefore, the need for the development of interlock brick to introduce wall material that is easy to install, strong, without combustion and environmentally friendly. The shape design of interlock brick is made with Modified Tanzanian Interlock Brick (MTIB). Interlock brick size is 25.1 x 12.6 x 7.8 cm. The method of brick making with the experiments of various variations of the mixture to know the product specifications of suction, absorption, salt content and compressive strength with a quality target of grade 50 kg/cm² that qualified SNI 15-2094-2000. The result was an MTIB that meet the requirements of SNI in a mixture with a ratio of 2 Clay: 3 Sand: 3.5 Portland Cement: 1.5 Bagasse Ash. Specifications of MTIB product obtained results compressive strength of 63.78 kg/cm², absorption of 19%, the salt content of 4.14%, volume weight of 1.549 g/cm³ and a specific gravity of 1.81 and water suction power of 57.34 g/dm²/minute. MTIB innovations made from the waste of bagasse ash and without combustion process could be utilized for efficient civil building construction, fast, economical, and environmentally friendly compared with other brick materials.

1. Introduction

1.1. Background

The rapid development of buildings, fences, and housing in Indonesia have made the need for wall material increasing. At present, the wall building material is dominated by bricks made from clay and the drying process requires combustion. Generally, blocks need plaster and precision in the field. In line with these needs, materials that are easy to install, strong and environmentally friendly are in desperate need. Therefore, it is necessary to develop interlock bricks to introduce wall materials that are easy to install, strong and environmentally friendly. In the case of developing interlock bricks, this time avoids the combustion process by adding a mixture of cement. The goal is to become an interlocking brick that is environmentally friendly and maintain good survival for the next generation. Brick making is generally very dependent on clay which must be extracted as raw material from the brick. But gradually these raw materials will run out or be subject to excavation restrictions because they damage the environment.
Therefore, the need to reduce clay raw materials with other materials to minimize the use of clay in the manufacture of interlock bricks. One of them is by adding silica-containing materials that are like cement if they react with water. Bagasse ash is one of the wastes which consists of inorganic salts and is rich in silica (Si). This waste is challenging to dispose of because the function of bagasse ash is less useful for plantations or agriculture, even by some farmers consider bagasse ash as a destroyer of soil fertility [12].

According to previous research, silica will react with cement and water to form calcium silicate hydrate which functions as an adhesive [19]. Another study related to the study of bricks with additive material of bagasse ash or the like in research [1], [2], [3], [5], [7], and [20]. Based on the above, a study was conducted on the innovation of interlock bricks with a mixture of bagasse ash using clay as a base material mixed with added material in the form of cement to avoid the process of combustion, sand, water and printed using a hydraulic machine, like as the previous research with using interlock brick such as [4], [6], [8], [9], [10] and [13]. By using these materials and tools, it is hoped that interlock bricks are easily installed, environmentally friendly and achieve SNI standard compressive strength.

1.2. Research Objectives
The research objective is to find out the novelty of interlock bricks from bagasse ash without the combustion process.

2. Theoretical Basis

2.1 Brick
Bricks are part of the building used to make a building, and materials are useful for making bricks originating from the ground with or without a mixture of other materials which are then burned at high temperatures so they cannot be destroyed again if soaked in water [5]. The definition of brick according to the Red Brick as Building Material NI-10 [11], is a building element for the construction of buildings and made from the soil with or without a mixture of other materials, burned high enough, so that it cannot be destroyed again if soaked in water. A light red brick is a red brick whose weight is less than 1.2 kg/dm³. While hollow red brick is red brick with a total cross-sectional area of more than 25% of its cross-sectional area.

According to SNI 03-0349-1989 Concrete Bricks for Couples Walls, concrete bricks are a type of brick-shaped building made from the main ingredients of Portland cement, water, and aggregates used for wall pairs. The original brick is divided into solid concrete bricks and hollow concrete bricks. Solid concrete brick is brick that has a solid cross-section of 75% or more of the total cross-sectional area and has a solid volume of more than 75% of the entire brick volume while perforated concrete brick is a brick which has a cross-sectional area of more than 25% over the cross-sectional area and more hole volume of a 25% total volume limit [14].

2.2 Brick Quality Requirements
In this study using SNI 15-2094-2000 because interlock brick is a transformation of solid or perforated red brick with a maximum volume of 15%, while the size of interlock brick hole with MTIB form is 5.72% [17]. Bricks for wall pairs must meet the following quality requirements:

2.2.1 Visibility. The solid red brick for the wall pair must be a long rectangular prism, have elbow ribs, flat planes and do not show cracks.

2.2.2 Compressive Strength. The magnitude of the average compressive strength and the variation coefficients allowed for solid red bricks for wall pairs are by Table 1 and can be calculated using the following Equation 1:

\[ \tau = \frac{P}{A} \]  

With, \( \tau \) is the average compressive strength (kg/cm²), \( P \) is the maximum load (kg), \( A \) is the area size press (cm²)
According to SNI 15-2094-2000 which discusses solid red brick for wall pairs, bricks for wall pairs according to the lowest compressive strength are divided into 3 (three) classes, likes Table 1.

| Classes | Minimum average compressive strength of 30 bricks tested kg/cm² (MPa) | The coefficient of variation of the average compressive strength under test (%) |
|---------|---------------------------------------------------------------------|--------------------------------------------------------------------------------|
| 50      | 50 (5)                                                              | 22                                                                            |
| 100     | 100 (10)                                                            | 15                                                                            |
| 150     | 150 (15)                                                            | 14                                                                            |

The coefficient of variation is the statistical parameter that is most widely used to determine the amount of variability in a sample. The magnitude of the figure is estimated through price s; the price of s is not absolute but varies from sample to sample; the coefficient of variation can be determined by Equation 2 [7]. As for the standard coefficient of variation can be seen in Table 1.

\[ v = \frac{S_d}{\bar{x}} \times 100\% \]  

With, \( v \) is the coefficient of variation, \( S_d \) is the standard deviation of the compressive strength (kg/cm²), and \( \bar{x} \) is the average compressive strength (kg/cm²).

2.2.3 Volume Weight. The volume weight is the weight of the unit volume to determine the weight of the contents [17]. Calculation of volume weight can be calculated using Equation 3 as follows:

\[ VW = \frac{W}{V} \]  

With, \( VW \) is the volume weight (kg/cm³), \( W \) is the weight of brick (kg), and \( V \) is the volume of brick (cm³).

2.2.4 Salinity. The Salinity which is soluble salts can cause structural damage "efflorescence" on the surface of the brick are magnesium sulfate (MgSO₄), sodium sulfate (NaSO₄), potassium sulfate (KSO₄), with a total salt content maximum of 1.0% [17]. In SNI 10-1978:6 subchapters 6.2.5, the salinity standards for bricks are as follows:

- It is not dangerous if less than 50% of the brick surface is covered by a thin layer of white due to the crystallization of dissolved salts.
- There is a possibility of harm if 50% or more of the brick surface is covered by a thick white layer due to the crystallization of soluble salts, but the parts of the brick surface do not become powder or detach.
- Harm if more than 50% of the brick surface is covered by a thick white layer because the crystallization of soluble salts and the parts of the brick surface become powdered or released.

The salt content test aims to determine the amount of salt contained in bricks. If in the process of installing salt there is a salt content, weathering will occur due to dissolved salts and will result in a bad bond between the brick and the mixture. Testing of salinity can be calculated using Equation 4 as follows [18]:

\[ Salinity = \frac{F_{salt}}{F_{brick}} \times 100\% \]  

With, Salinity is a salt content (%), \( F_{salt} \) is the extent of salt fields attached to bricks (cm²), and \( F_{brick} \) is the extensive brick (cm²).

2.2.5 Water Absorption. Water absorption is the ability of bricks to absorb the percentage of water weight. The testing of water absorption is an essential factor because it is one of the properties of bricks which dramatically affects the strength of brickwork. Water absorption on the brick must be controlled to prevent a lot of water loss from the mixture being used and to avoid cracking during plastering. Determining water absorption is used in Equation 5 [17]. If the absorption of water is less than 20%, the brick is considered good.
With, WA is the water absorption (%), A is the dry weight of brick (fixed) in kg, and B is the weight of brick after soaking for 24 hours (kg).

2.2.6 Power of Suction Brick. The testing of suction power to the brick aims to measure the amount of suction power on the interlocking brick. Suction power dramatically influences the strength and quality of the brick pairing work. Different suction power will cause differential voltage and cracks. Therefore, it is important to equalize the suction power before installation. The suction power of bricks can be calculated using Equation 6 [17].

\[ \omega = \frac{B-A}{F} \]  

with, \( \omega \) is the power of suction brick (g/dm\(^2\)/minute), A is the dry oven weight of brick (g), B is the weight of the brick after soaking per minute (g), and F is the brick base area which is related to water (dm\(^2\)/minute).

2.2.7 Specific Gravity of Brick. Specific gravity is the ratio between the weight of the volume unit of a material to the weight of the contents of the same volume at the specified temperature. The specific gravity of the brick can be calculated using Equation 7 as follows [15]:

\[ \gamma = \frac{W_{\text{sat}}}{W_{\text{sat}}-W} \]  

with, \( \gamma \) is the specific gravity of brick, \( W_{\text{sat}} \) is the saturated weight of brick (g), W is the saturated weight of brick in water (g).

3. Methodology

3.1. Experimental Techniques

This research is quantitative through an experimental approach, in the form of non-combustion brick testing with the addition of bagasse. The parameters sought in this study were compressive strength, specific gravity, volume weight, salt content, suction power, and absorption. By regarding the effect of bagasse ash as additional material for brick making without combustion [20]. So this research will start from the testing of materials characteristics, design of specimens, manufacture of samples, maintenance of samples to testing. The test object is made in the form of a Modified Tanzanian Interlock Brick (MTIB) brick size of 250 x 125 x 75 mm and with a mixture of bagasse additives.

In making bricks, the clay used must be clean of the 4.75 mm sieve and not too plastic dirt. In order not to cause high dry strength properties that affect the results of brick drying interlock. Therefore, before the process of making interlocking, it is necessary to do a 4.75 mm sieve and atterberg boundary testing of clay. The sand used in making interlock is a local sand brick originating from sand mines, Kalipuro district, Banyuwangi Regency. In making interlock bricks, sand is used to reduce shrinkage and facilitate drying.

Supplementary material in the manufacture of interlock bricks is bagasse ash from waste from the Company of Glenmore Sugar Industry like Figure 1. Bagasse ash must be clean of garbage and sieved with no. 200 to obtain a grain size equivalent to cement. With fine particle granules, the hydration will be faster because the hydration starts from the surface of the grain.
3.2. Instrument
Manual hydraulic interlock brick molding machine used to print a mixture of materials that have been mixed to form a 250 x 125 x 75 mm interlock brick. In the use of a manual hydraulic interlock brick molding machine, a mold will be made in the form of the expected MTIB mold like Figure 3. In Figure 2 there is a picture of a manual hydraulic interlock brick molding machine.

3.3. Mix Design of Interlock Brick
After the tools and materials were prepared, then the next step is to do the mix composition design of interlock brick design. For the mix composition design, the interlock brick design was measured by using a volume comparison of materials with several trial-and-error alternative mix designs to determine right proportions and achieve quality with the SNI standard compressive strength.

The best composition ever tested with a mixture of 2 Clay: 3 Sand: 3 Portland Cement: 2 Calcium: 2 Bagasse ash produces a quality of 40.49 kg/cm². For the composition is assumed total is 12 times the volume of the patch (2 kg) can produce 15-20 interlock bricks. If using dye material to add its artistic material, can use cement dye with a composition of 5 ounces per 24 kg. As for alkaline resin material is quite 3 or sufficiently adjusted to the composition. The alkali function is to make the soil pH not too acidic, so bonded cement to be strong and solid, increasing the color density, and harden. Example comparison for 1 m³ red brick: 150 kg Cement: 450 kg Fine sand: 900 kg red soil + (2 kg alkali red brick dissolved 50 lt water), all dry ingredients are stirring in a dry state. For my Preliminary testing, if the composition without Ash with ratio 3 Clay: 4 Sand: 2 Cement: 3 Calcium have a quality of 33.73 kg/cm², and then without clay with ratio 4 Sand: 3 Cement: 3 Calcium: 2 Bagasse ash has a quality of 53.15 kg/cm².

The conclusions of my study, the comparison of the volume of bagasse ash with cement must be more cement to obtain good compressive strength on the interlocking brick. Based on the composition of previous studies regarding interlock bricks, the mix design of brick interlock design with a comparison of 2 clay: 3 sand: 3 Portland Cement: 2 bagasse ash without calcium, this is based on development and research. The specimen to be made in 30 pieces with the form of MTIB.
3.4. Making Interlock Brick
Simion Hosea Kintingu made an important modification to repair the interlocking brick to fit the requirements of the Tanzanian people. The size of the bricks is 300 x 150 x 100 mm, similar to the size of Thailand and Bamba type. However, it does not cover the lack of brick Tanzanian Interlock Brick system, the stability of the wall during construction in the vertical direction can not be covered properly. So it requires mortar and reinforcement to achieve its maximum strength [10].

The form of interlock brick that will be made is an interlocking brick in the form of Modified Tanzanian Interlock Brick (MTIB) which is a modified form of Thai brick with Tanzanian with a size of 250 x 125 x 75 mm shown in Figure 3. The Modified Tanzanian Interlock Brick (MTIB) has the advantage of a pyramid locking system with a hole in the middle. This form was considered better because the force excitation transformation can be distributed evenly in the horizontal direction. In its application in the field, it does not require people who have special skills (anyone can install it correctly and quickly) because the installation is almost similar to the Lego kids game.

![Figure 3. Modified Tanzanian Interlock Brick](image)

4. Results and Discussion

4.1. Testing of Atterberg Limits for Clay Soils
The average moisture content at the liquid limit (LL) is 35.19%, plastic limit (PL) is 29.67%, and for index plasticity (PI) value is the difference in the liquid limit at the plastic limit of 5.52 %. In testing the atterberg boundary which is a soil sample taken from one of the conventional red brick entrepreneurs Banyuwangi Regency can be graphed in Figure 4.

![Figure 4. Atterberg Limits for Clay Soils](image)

4.2. Testing of Specific Gravity for Fine Aggregate
From the results of testing the specific gravity for fine aggregate (sand), it was found that the average density of sand was 2.33 grams. This result was not included in standard density according to ASTM
C128-78, which is 2.5-2.7 grams. So that the sand material cannot be used in the process of brick making because it can affect the quality of bricks so it should replace with sand material that has better quality.

4.3. Testing of Sieve Analysis for Fine Aggregate
From the results of sand filter analysis, it was found that the sand had a fine aggregate modulus of 3.563%, while the required fineness modulus of the granules is 1.50-3.80%. Based on the current requirements, the test results can be stated for this sand will produce a good mixture if used for interlock brick mixture.

4.4. Making Interlock Brick Test Materials
The test object is made in the form of MTIB brick. To molding bricks in the form of MTIB, a press with a hydraulic press of about 6 tons was used. By the planned mix, in this study used three types of mixtures measured by volume comparisons were as follows:

1. 2 Clay: 3 Sand: 2.5 Portland Cement: 2.5 Bagasse Ash
2. 2 Clay: 3 Sand: 3 Portland Cement: 2 Bagasse Ash
3. 2 Clay: 3 Sand: 3.5 Portland Cement: 1.5 Bagasse Ash

In the process of making interlock brick specimens, the materials needed are clay, sand, portland cement, and bagasse ash. With enough water added until the mixture is saturated and can be grasped (not runny). Figure 5 shows the test object in the form of MTIB. After the interlocking brick is molded, it is allowed to dry at room temperature. After drying, the interlocking brick is ready to be tested according to the age of the test.

Figure 5. Drying of Interlock Brick Test Objects

4.5. Testing of Interlock Brick Salt Content
Figure 6 shows the highest salt content found in mixture 1, and the lowest is found in mixture 3. It shows that the percentage of salt content in interlock brick specimens is influenced by the amount of bagasse ash added. The more bagasse ash added the higher the content of the salt in the interlocking brick. Similarly, the opposite.

Figure 6. Salt Content of Interlock Brick With Bagasse Ash Mixture

4.6. Testing of Interlock Brick Suction Power
Of the three mixed variations tested, none met the SNI 15-2094-2000 standard because the value produced from each specimen was >20 g /dm²/minute. It could be concluded that the amount of suction power on the interlocking brick is influenced by the amount of addition of bagasse on the brick composition. The more addition of bagasse, the higher the suction power. Vice versa, if the addition of bagasse ash is less, the suction power will be smaller.

4.7. Testing of Interlock Brick Absorption

In Figure 7, it can be seen that mixture 1 has the highest absorption and mixture 3 has the lowest absorption of all mixed variations. Therefore, it can be concluded that the amount of water absorption on the interlocking brick is influenced by the addition of bagasse ash to the composition applied. The more bagasse ash added, the higher the absorption capacity produced. Vice versa, the less bagasse ash is added, the smaller the absorption power generated by the interlocking brick will be.

![Figure 7. Average Absorption of Interlock Brick](image)

4.8. Testing of Interlock Brick Specific Gravity

In Figure 8, it can be seen that the addition of bagasse ash affects the specific gravity produced by interlock bricks. The more bagasse ash added, the smaller the particular severity produced. If the less bagasse ash is combined, the higher the value of the specific gravity produced.

![Figure 8. Average Specific Gravity of Interlock Brick](image)

4.9. Testing of Interlock Brick Volume Weight

In Figure 9, shows that the volume weight of the interlocking brick is influenced by how much bagasse ash was added to the interlock brick composition. The more addition of bagasse then the weight of the amount produced will be lighter. Vice versa, if the addition of bagasse ash is less, the weight of the resulting volume will be more substantial.
4.10. **Testing of Interlock Brick Compressive Strength**

In Figure 10, it can be seen that the addition of bagasse ash is very influential on the compressive strength of the interlocking brick. The more bagasse ash added, the smaller the compressive strength produced by the interlocking brick. Vice versa, the less bagasse ash is added, the higher the compressive strength of the interlocking brick. The results of the compressive strength of interlock bricks with a mixture of bagasse ash have the highest compressive strength in variations of mixture 3 that is 2 Clay: 3 Sand: 3.5 Portland Cement: 1.5 Bagasse Ash, with an average compressive strength of 63.78 kg/cm² and entered in class 50 in accordance with SNI 15 - 2094 - 2000.

4.11. **Recapitulation of Test Results**

From the results of all tests carried out on traditional bricks and interlock bricks with bagasse ash mixture with three mixed variations, it can be seen the results of the test analysis in Table 2.

**Table 2. Recapitulation of Test Results for Conventional Bricks and Interlock Bricks with Bagasse Ash Mixes**

| No. | Type of Testing   | Unit            | SNI Standard | Conventional Bricks | Interlock Brick |
|-----|-------------------|-----------------|--------------|---------------------|-----------------|
| 1   | Salinity          | %               | <50          | 0                   | 16.14 5.05 4.14 |
| 2   | Suction power     | g/dm²/mentit    | Max. 20      | 139.06              | 58.75 57.34 57.34 |
| 3   | Absorption        | %               | Max. 20      | 36                  | 20 20 19 |
| 4   | Specific gravity  | -               | 1.66         | 1.74 1.76 1.81      |
| 5   | Volume weight     | g/cm³           | 1.11         | 1.511 1.537 1.543   |
| 6   | Compressive strength | kg/cm²  | Min. 50      | 12.11               | 30.26 47.28 63.78 |

4.12. **Advantages of Modified Tanzanian Interlock Brick (MTIB)**

The advantages of interlock bricks are the Modified Tanzanian Interlock Brick as follows:

1. The simple placement of connections between interlock brick cavities.
2. The composition of interlock bricks made from a mixture of bagasse ash waste which is environmentally friendly.
3. This interlock brick is environmentally friendly because it does not go through the combustion process.
4. In the implementation of the field, interlock bricks are faster than conventional bricks because they are mutually binding.

![Modified Tanzanian Interlock Brick](image)

Figure 11. Modified Tanzanian Interlock Brick

5. Conclusions
In adding bagasse ash to the composition of the interlocking brick without combustion process with the Modified Tanzanian Interlock Brick (MTIB) form, it dramatically affects the quality of the interlocking brick. The best composition is in mixture 3, which is a ratio of 2 Clay: 3 Sand: 3.5 Portland Cement: 1.5 Bagasse Ash. The specifications are the weight until 3332 - 3426 g with a salt content of 4.14% which will continue to increase if bagasse ash is added more and more, water suction power of 57.34 g/dm²/minute, absorption of 19%, specific gravity of 1.81, volume weight of 1.549 g/cm³ and a compressive strength of 63.78 kg/cm² fulfills class 50 quality. If more bagasse ash is added, it will further reduce the compressive strength of the interlocking brick.

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