Preparation and Mechanical Properties of Pressed Straw Concrete Brick

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Abstract. Rice straws have been widely used as wall filler material in China, Australia, and United States, by spinning them into hays with an approximate dimension of 40 cm of height, 40 cm of thickness and 60 cm of width, using a machine. Then, the hays are placed into a wall frame until they fill it completely. After that, the wall frame is covered with wire mesh and plastered. In this research, rice straws are to be used as concrete brick fillers, by pressing the straws into hays and then putting them into the concrete brick mold along with mortar. The objective of this research is to investigate the mechanical properties of concrete brick, namely: compressive strength, specific gravity, and water absorption power. This research used experimental research method. It was conducted by using concrete bricks which had 400 cm of width, 200 cm of height, and 100 cm of thickness, made from rice straws, cement, sand, and water as the test sample. The straws were each made different by their volume. The mortars used in this research were made from cement, sand, and water, with the ratio of 1:7:0.5. The concrete bricks were made by pressing straws mixed with glue into hays, and then cut by determined variations of volume. The variations of hays volume were 0 m³, 0.000625 m³, 0.00075 m³, 0.000875 m³, 0.00125 m³, 0.0015 m³, 0.00175 m³, 0.001875 m³, 0.00225 m³, and 0.002625 m³. There were 3 samples for each volumes of hays. The result shows that the straw concrete bricks reached the maximum compressive strength of 1.92 MPa, specific gravity of 1,702 kg/m³, and water absorption level of 3.9 %. Based on the provided measurements of products in the Standar Nasional Indonesia (Indonesian product standardization), the concrete bricks produced attained the prescribed standard quality.

1. Introduction
The research on wall made of rice straws, commonly called as straw bale, is necessary to be developed, since the use of straws as mixed material of lightweight concrete will create an eco-architecture building.

The facts should be noted that buildings are the largest energy user, starting from construction, construction material, building operation, and building maintenance to building demolition. If a life cycle analysis of a building is conducted, the building’s impacts on the environment will be shown. The overall costs of unsustainable architecture are, therefore, greater than the sustainable one, so that following on the line of eco-architecture will save cost in longer term.[1-3]
This wall of straws is developed in countries such as China, United States, and Australia. The building wall is made by spinning rice straws into hays with an approximate length of 30-60 cm. Then, the hays are placed into a wall frame and then covered with wire mesh to strengthen it. It is then plastered with mortar.

The renewal in this research is the creation of a lighter block of hay material than ordinary brick. This brick Straw including material that the temperature is higher then suitable when used for cold areas and also for the insulation of the room soundproof. Because the weight of the structure is reduced, the workload will also be smaller so that the structure is expected to be safer and very suitable for housing in earthquake prone areas. Implementation on building materials especially for wall-shaped brick is more environmentally friendly than clay brick. Straw as a material brick is an environmentally friendly material so that this paper match to construction materials conference topic.

Straws contain silica so that it is good to be used as mixed material for concrete. They also weigh very light. If used as lightweight concrete mix in the form of concrete bricks, it will result in a significantly lighter concrete than other concretes in general. Because of its light weight, it will have some plus points, such as ease transportation and installation, cost reduction, heat resistance, and the ability to be used as isolation of soundproof rooms.

The straws weigh lighter than most material. The earthquake load working in the building structure will be smaller. Therefore, the structure will be safer from destruction, and it will be suitable for houses located in earthquake-prone areas.

The straw ashes used as substitute for sand in mortar mix will increase mechanical strength and affect water absorption.

Based on Standar Nasional Indonesia, standard concrete must have the compressive strength between 2.5-10 MPa and water absorption level between 25-30%.

Non-structural lightweight concrete has the compressive strength between 0.35 – 6.9 MPa and specific gravity under 1900 kg/m³.

In this research, rice straws were used as forming material of concrete bricks. Conblock (concrete block) is a building component made from mixture of Portland Pozzolana cement, sand, water, with or without any other additives. It is molded in such way that it meets the requirements and can be used as a material for wall installation. The objective of this research is to investigate the compressive strength, specific gravity, and water absorption level in pressed straw concrete brick.

2. Experimental

2.1 Materials

The materials used in this research were cement, sand, water, straws and glue. The cement used had to meet prescribed requirements in the specification of group A construction material, SK SNI S-04-1989-F. The cement used was Holcim cement. The sand used was taken from River Kaliworo. It met the prescribed requirements in the specification of group A construction material, SK SNI S-04-1989-F. The straws used were in dry condition. Their average length ranged from 350 mm to 400 mm. To glue the straws, Express wood glue was used.

2.2 Experimental procedure

2.2.1 Examination of material. The sand examination was done through the following steps: the examination of water level, specific gravity, unit weight, organic content, mud content, and sand gradation which had to meet the prescribed requirements of Standar Nasional Indonesia. The examination of straws was done through the following steps: drying the straws, cutting the straws according to the dimension, and examining the specific gravity.

2.2.2 The spinning of straws. The straw spinning process was conducted by using press machine, by firstly mixing the straws with glue and then pressing the straws into hays. The straw hay bale was cut according the volume variation. The produced hay bale is shown in Figure 1. The variation of hay bale sample is shown in Table 1.
2.2.3 Concrete brick production. The specimens were concrete bricks with the measurement of length, width, and height of 400 mm, 100 mm, and 200 mm. They were made by firstly making a mixture of concrete mould with the ratio of cement: sand:water of 1:7:0.5. The concrete bricks without straws were made by putting the concrete mould approximately 1/3 of mould volume, and then compact them. This way was then conducted for 3 times until the concrete mould volume was met. The concrete bricks with straw addition were made by putting the concrete mould to the block and then compacting them until the concrete filled the block by 50 mm (first compacting). After that, the hays were put and the mortar was added, and then they were compacted to the height of hays (second compacting). Finally, the mortar was added until filling the block and then the mixture was compacted until the full concrete brick volume (third compacting). The steps are shown in Figures 2-4.
The produced samples were then stored in a location without much heat and humidity to preserve them.

2.2.4. The compressive strength test of concrete bricks. Concerning the compressive strength test of concrete bricks. Compressive strength of concrete bricks is the amount of load per area unit which cause the specimen to break if it is loaded with certain amount of compressive force produced by compressing machine. [11] The compressive strength test of concrete bricks was conducted 28 days after the production of the specimens, pursuant to the prescribed requirements of Standar Nasional Indonesia by using concrete compressive test apparatus as shown in Figure 5.

2.2.5. Specific gravity test. The concrete specific gravity is the comparison between the concrete weight and its volume. The test was conducted by weighing the weight of concrete bricks and calculating their volume. Specific gravity was calculated by using equation as follows:

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

where \( Bj \) = specific gravity, \( W \) = specimen weight, \( V \) = specimen volume.

2.2.6. Water absorption level test. Water absorption level of concrete bricks is the capability of concrete bricks to absorb water. The calculation was conducted by using the following equation.

\[ \text{Absorption} = \frac{A - B}{B} \]  

Where \( A \) : specimen weight after it is soaked in water for 24 hours, \( B \) : specimen weight after it is dried in the oven on 105°C.

3. Results and Discussion
The result of sand material test is shown in Table 2. Based on the examination result, the sand already met the requirements to be used as construction material. One of the requirements of sand, which is good to be used as construction material is having a specific gravity of 2.4-2.9.
Table 2. Properties of Sand

| Properties       | Values      |
|------------------|-------------|
| Specific Gravity | 2.39 gr/cm³ |
| Fineness Modulus | 2.48        |
| Zone             | 2           |
| Absorption       | 1.85 %      |

Examination of fine modulus of sand is a way to investigate the value of fineness or coarseness of an aggregate. The fineness or coarseness of an aggregate can affect the workability of concrete mortar. If there is too many fine aggregates found in mortar, they will cause thin layer of fine aggregate to occur, and the cement will go up.

The grain fine modulus, besides serving as the measurement of grain fineness, can also be used to find the comparison value of weight between sand and pebble. The sand gradation classification can be obtained from the sand grain fine modulus graph. The result of the fine modulus test was 2.48. If it was put in the sand grain fine modulus graph, then the sand gradation of the specimen was included to area no. 2 (rather coarse), and by it, it was included in the sand grain fine modulus which could be used as construction material.

The data of the results of compressive strength test is shown in Figure 6.

Based on Figure 6, the compressive strength of concrete bricks without straws was 5.896 MPa, while straw variation no. 7 with the volume of 0.00175 m³ had the maximum compressive strength of 1.92 MPa. It was an ideal variation for compressive strength value. The value itself met the requirements as non-structural lightweight concrete [10].

Data of the specific gravity test result of several concrete bricks variation is shown in Figure 7.
Figure 7. Brick variations versus specific gravity

The variation relation between the straw concrete bricks with specific gravity shows that the larger the volume of straws added to the concrete, the smaller the specific gravity would be. On variation of straw brick no. 7 the volume of 0.00175 m³, the value of specific gravity was 1.702 kg/m³. According to the standard of lightweight concrete, the specimen met the criteria as non-structural wall. [10]

The result of absorption test of concrete brick is shown in Figure 8.

Figure 8. Variations of brick versus water absorption level.

From the result of experiment it is apparent that the larger the dimension of hay bale added, the larger the level of water absorption would be. The largest water absorption level was found in variation 10 with the absorption value of 8.23%. The water absorption level in variation 7 was valued 3.9%. The value met the requirements under maximum limit. [9]

4. Conclusions
The optimum value of concrete bricks with straw mixed material was found in the variation of straw brick no. 7 with the volume of 0.00175 m³, with the value of compressive strength, specific gravity,
and water absorption level of 1.92 MPa; 1,702 kg/m³; 3.9%. Based on the optimum value, the brick attained prescribed standards of quality.

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