Utilization of Sago Husk as Filler in Modified Structural Bottom Ash –Hollow Bricks upon Traditional Production

Kurniati Ornam, Masykur Kimsan, La Ode Ngkoimani, Santi, S. B. Amri, and Syafrianto Amsyar

***Abstract*—This study performed investigation of physical and mechanical properties of hollow brick design with sago husk as filler and its combination with 10% bottom ash. As previous works showed excellent result in those properties, and 5.6 MPa gap for compressive strength with the minimum requirement, it was expected that hollow design of bricks still provided good results. Six models of hollow bricks were developed by considering stress concentration factor that might affect compressive strength. Those models were examined with three composition of sago husk filler, i.e. 1.1%, 2.2% and 2.5%. Similar method of production was conducted. It can be concluded from the result that all developed models could be used for both structural and non-structural element of wall housing. The bulk density varied from 1.3 to 1.8 kg/cm^3 and the IRA was approximately 0.18%. Therefore, utilization of hollow brick design for building will provide better performance in terms of strength and building weight.**

***Index Terms*—Bottom ash-hollow brick, sago husk, density, humidity, compressive strength, stress concentration.**

I. Introduction

Mining activities South East Sulawesi, Indonesia, have engendered economic growth in addition with activities in infrastructure projects by both public and private sectors. During the course of those, housing sectors have proliferated almost at the whole region, with 7% average annual growth in past decade; hence they require extra open space to create buildings. On the other hand, sago, one of traditional food in this particular object of study, is constantly created waste on its production, while its husk is potentially used for admixtures in bricks [1]. Therefore, environment and sustainability issues have gained awareness from local researchers by conducting study on their environmental impact and modified friendly materials for buildings [2]-[9].

Utilization of modified clay bricks with recycled admixtures is one of main interest in recent research development, since bricks are non-structural element of building and to some extent, they might be considered as structural element that contribute in building strength. It was found that a house built of clay bricks consumes less 16-25% energy and less 13-57% initial investment costs than one built of concrete blocks, sand lime bricks or prefabricated concrete walls [10]. Utilization of waste as filler in bricks also reduces 50% cost of production [2]-[7].

Furthermore, firing process of clay bricks generates a range of gas emissions into the atmosphere, where higher heating rates will significantly reduce emissions, provide insignificant effect on the water absorption and initial rate of absorption, and however, decrease the compressive and tensile strength [11]. Appropriate filler composition with the lowest grinding will lead to the best compromise between mechanical and thermal results compared to the conventional bricks [12].

Another essential thing to be considered is weight of the bricks. Total mass of building is related to lateral force that the building will experience when earthquake occurs. Utilization of filler as inner burning is one of the solution. Therefore, hollow design of brick is necessary to be developed to reduce weight, and consequently, reduces earthquake loading in building and increase safety level of disaster mitigation. This paper is aimed to investigate physical and mechanical properties of modified bottom ash - hollow clay bricks with sago husk as filler. As mentioned in previous study [1], it was found that the compressive strength of fly ash - sago husk clay bricks will yield 16 MPa minimum. Although Sago husk as filler reduce weight until 14.3%, it creates pores, and reduces compressive strength. On the other hand, fly ash will improve bond capacity and accelerate drying process in clay bricks production. Since there is still 5.6 MPa gap from minimum requirement of compressive strength (10.6 MPa), this work is expected to establish some hollow brick design that meet code requirement, in terms of mechanical and physical properties.

II. Brick Properties and Hollow Brick Design

The clay mixture used in this study is evaluated by ASTM D-2487 [13], where some tests were performed i.e. sieve analysis and atterberg limit, and yield on *silty clay with sand* classification group. The sago husk was acquired from its original sources, in Konawe, and the bottom ash is obtained from power plant near Kendari city. Physical properties of bricks are properties without any treatment on bricks. some of them are ASTM C67-14, 2014 [13]-[19].

A. Density

Density is defined as sample mass in one unit of its volume. As mentioned in code [14]-[18], required density of clay brick is between 1,60 gr/cm^3 and 2,00 gr/cm^3, and it might be reduce by some engineered purpose. It will be measured at

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certain room temperature and humidity.

B. *Colour, Texture and Shape*

Brick colour will vary based on clay colour, additive material colour (if any) and firing process. Common colour for clay bricks is brownish orange. Provided the bottom ash is mixed with the clay, the colour might be dark brown. Bricks shape should match with adequate length, width and thickness as mentioned in code. Bricks surface is anticipated to be seemed plan and rough, square, appropriate colour, producing loud sound when it is tapped, no crack, and unbreakable.

C. *Initial Rate of Absorption and Salt Content*

Initial rate of absorption is defined as the number of grams of water absorbed in one minute over 30 square inches of brick bed area [14]-[18]. Brick is prevented to be very dry to maintain bond capacity due to high amount of water absorption. Brick is demanded not to consist of soluble salt to avoid reduction of its preservation as its crystallization covers more than 50% of bricks surface.

D. *Compressive Strength*

Properties of brick with treatment is called mechanical properties. Compressive strength is one of them as stated on ASTM C67-14, 2014 where the minimum requirement is 10,40 Mpa. Based on previous research [2]-[8], it suggested that using hygroscopic material will accelerate the time and increase the compressive strength.

E. *Hollow Brick Design and Dimension*

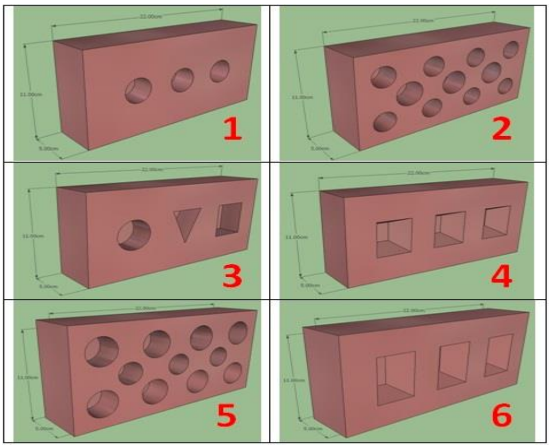

Fig. 1. Design models and labeling of bricks.

As can be seen from Fig. 1, there are six design of hollow bricks. All models are 22 cm in length, 11 cm in wide, and 5 cm in thickness. The hollow section used in the designs are circle, square and triangle which the detail dimension is as on Fig. 2.

The design of hollow brick is respected to stress concentration factor near the hollow part. Distance between 2 (two) nearly hollow parts is maintained that the stress concentration factor is not amplified.

III. Sample Preparation and Methodology

This work was performed at normal temperature (25-32ºC) and at humidity 76-81%. Bricks production was held in laboratory as how it is performed in the work shed i.e. mixing, molding, drying, burning and arrangement. Following those process, some laboratory tests were carried out to examine physical and mechanical properties i.e. measuring weight, water absorption, IRA and compressive strength test of modified hollow bricks.

Clay, bottom ash and sago husk were utilized as raw materials. Then, sago husk is dried by direct sunlight. Following that process, the sago husk were then cut in small pieces with 1,2 cm in length by using knife or cutters [1]. In mixing process, 3 (three) compositions of clay and sago husk were evaluated i.e. 1.1%; 2.2%; and 2.5%. Those compositions were also mixed with 10% bottom ash [20]-[22]. Brick's production was started by mixing clay with fine sago husk and certain amount of water in consequence they could be formed and unattachable.

Subsequently, the bricks for each compostion were molded in certain size of rectangular mold (22 × 11 × 5 cm^3) and specific hollow model. To provide similar situation at the work shed in the drying process, molded bricks were dried by fan, direct sunlight and oven. Moreover, burning process was replaced by stove, zinc plate and alluminium foil which is represented to gain uniform heat transfer in the whole brick body. The firing temperature was measured and maintained at approximately 550ºC on bricks, with approximately 600ºC of fire temperature, with medium heating rate.

IV. Result and Discussion

In accordance with area reduction for hollow section, there is also reduction in weight and compressive strength. Normally, as concluded in previous study, drying and burning time were also shorter than conventional clay bricks production. While it took 2 hours for non-hollow bricks, it required 3-4 extra hours to deal with molding process of hollow bricks due to its workability.

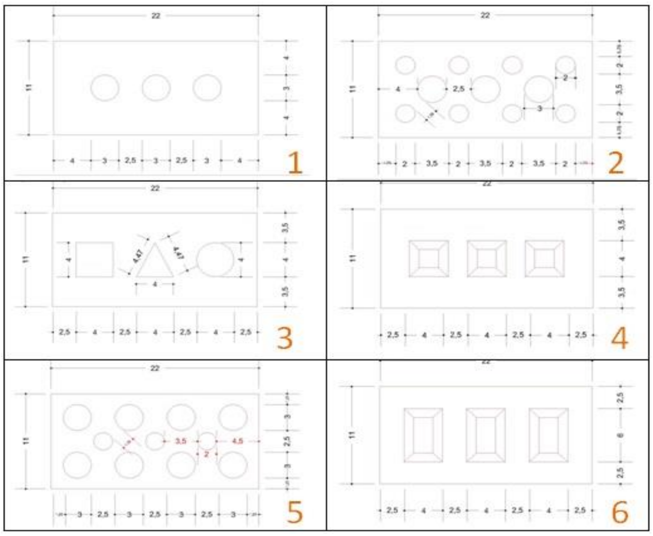

Fig. 2. Detail dimension of hollow bricks section (cm).

Measurement of density presented values between 1.34 up to 1.81 g / cm^3 (Fig. 4). Some models did not meet ASTM requirement [14]-[19]. Nevertheless, they provide good standard for light building criteria in anticipating earthquake.

Higher or lower density of a brick is affected by material component and composition, mixing process, and the length and method of the drying and burning process.

Fig. 3. Modified bricks after molding.

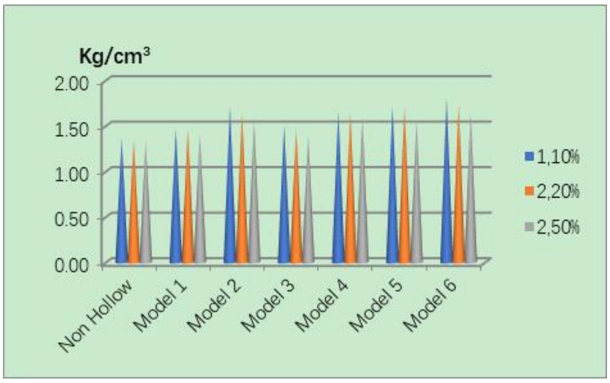

Fig. 4. Bulk Density of modified fly ash brick.

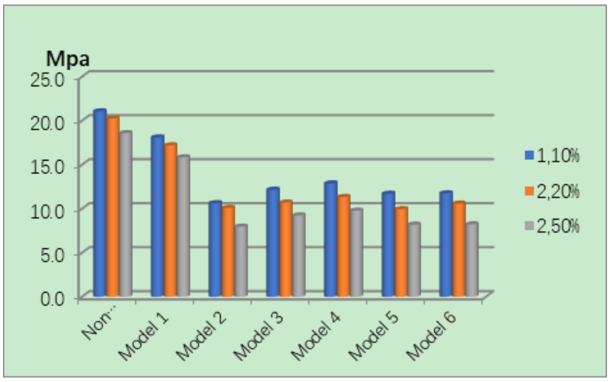

Fig. 5. Compressive strength of modified fly ash brick.

Modified bottom ash - hollow bricks colour follows the non - hollow colour i.e. darkest brown resulted from raw materials, the composition of the mixture, and the burning process. Linear shrinkage of all models showed consistent values in all axis direction, approximately 90%, hence they still meet the standard. The initital rate of absorption, in average, the IRA value of all models, 0.18%, still met the requirement from the ASTM C67-14.

From the data obtained (Fig. 5), it can be concluded that the bottom ash bricks with additional 1,1% sago husk filler for all models meet requirement for structural bricks. Model 2 and 5 share lowest value. However, their performance is fine for building component, both structural and non-structural element. Reduction of circle diameter might provide better results, as stress concentration factor decreases. Other models with 1.1% to 2.5% sago husk filler result more than 10.4 MPa, minimum requirement in ASTM C67-14. Model 1 is the best hollow brick design since it has highest compressive strength for all filler composition compared to other model.

V. Conclusion

Alternative hollow brick design of modified bottom ash clay bricks with sago husk as filler, could be utilized for both structural and non-structural element as required in ASTM. Stress concentration factor and area reduction determine the reduction of compressive strength, where it can be inferred from model 2 and 5 that has significant difference from the other models. Consequently, hollow design will share lower bulk density, which is good for earthquake mitigation.

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