Evaluation of Bottom Ash Composition on Modified Hollow Brick Design with Sago Husk as Filler

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Abstract. Improvement of hollow brick models demands profound analysis in terms of their behavior on mechanical properties as some shape variations provide different characteristics on stress concentration. Additional waste filler i.e. sago husk and utilization of bottom ash are expected to deliver better results based on strength, weight and economic factor. This paper aims to analyze experimentally and analytically those 7 shapes variations of modified hollow bricks design with additional admixtures which consists 1,1% of sago husk and 4 composition of bottom ash i.e. 0% ; 10% ; 20% ; and 25%. Some works were conducted in laboratory, and followed by mathematical stress analysis of hollow shape characteristics. The results show that 10 – 20% bottom ash composition share maximum value of compressive strength, with model 1 is the greatest (17.8 Mpa). Mathematical analysis provides similar results as well, where the stress concentration of model 1 was not amplified with subsequent hollow position. In conclusion, all model still appropriate to be utilized for housing, especially in element selection for lightweight bricks that meet the requirements for strength.

1. Introduction

Improvement of power plant capacity in South East Sulawesi, Indonesia, has involved some natural resources e.g. coal for coal fired power plant in which the coal fly ash and coal bottom ash are generated. This power plant is located in Ni Tanasa, Konawe. Despite immense amount of their production every year worldwide, reusing product of coal ash, mainly in civil engineering applications e.g., is hardly to achieve 30% of its total production [1].

Some studies have been conducted to evaluate utilization of fly ash and bottom ash as partial replacement or substitutive material in modified conventional bricks, in addition to other waste material used as filler and inner burning at firing process. Although fly ash and bottom ash reduced workability of fresh concrete due to their higher water absorption, the compressive strength of concrete indicated better results [2]. It is also obtained that none of the study demonstrated negative impact of bottom ash utilization in concrete. 30% fly ash was argued as best ratio as cement replacement [2] while the code [3] limits for 20% fly ash in concrete. As replacement both fine and
coarse aggregates, fly ash and bottom ash did not share negative effects, where 80% ratio was illustrated as the best composition.

In terms of clay bricks, non-plastic component for body formulation is required. Bricks tend to be high in drying and firing shrinkage, hence cracks occur during those processes. Bottom ash has drawn better performance to meet the requirement, as the substitution of sand, where shrinkage might be reduced and the body is successfully stabilized during the process, by creating higher percentage of median pore [4]. Furthermore, through dehydroxilation, degree of moisture decreased due to the presence of bottom ash as effective flux, with its combination with sandy clay that might result in pre-heat and cooling cracking provided self-act. Therefore, presumption of utilization of bricks with bottom ash will secure the advantages of improvement of bricks performance in their physical and mechanical properties.

Inclusion of some local wastes e.g. reed and sago husk in brick production has promising objective in adapting to environment and sustainability issues, and gained positive results in matching the criteria in codes for wall bricks following some experimental and numerical studies [5 – 12]. This might generate economic impact in housing sectors, not only in private sectors, but also in public sectors and support economic growth without ignoring environmental impact i.e. emission and energy used in building compared to building with concrete block. 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 [13]. Combining those recycled admixtures with bottom ash will also reduce CO emission significantly, with careful allocation of their proportion to get compromise between mechanical and thermal effect that leads on cracking on bricks surface [14].

As strong – light building becomes more preferable in light of major earthquake recently occurring in Indonesia, total mass of house should gain interest to reduce lateral force impact due to strong earthquake. This paper is to scrutinize variation of bottom ash composition with modified 1.1% of sago husk - hollow clay bricks. Previous study [15] demonstrated that the compressive strength of bottom ash – sago husk clay bricks can hit 24 Mpa maximum. Provided proper gap with minimum requirement of compressive strength (10.6 Mpa), this study is supposed to evaluate the best composition of bottom ash.

2. Sample preparation, hollow brick design and methodology
The procedures of this experimental study were as follows:

- Preparation of clay, sago husk and bottom ash. The clay is taken from Punggolaka, Kendari, categorized as silty clay with sand following sieve analysis and atterberg limit test [16]. Sago husk was obtained from Konawe and bottom ash was from Nii Tanasa power plant.
- Sago husk was dried by direct sunlight.
- Clay, sago husk and bottom ash were weighed in accordance to their mass in composition planned i.e. 1.1% sago husk with 4 (four) variation of bottom ash (0%, 10%, 20% and 25%).
- Setting up 6 (six) mold medium as models of hollow bricks, as can be seen on figure 1. 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 area reductions are 9%, 19%, 15%, 20%, 27% and 30% respectively.
- Brick’s making was started at laboratory, at room temperature (25-32 °C) and at humidity 76-81%, firstly to mix up clay with fine sago husk, bottom ash and certain amount of water hence they could be formed and unattachable.
- Next step was molding the bricks in certain size hollow model for specific composition in presenting actual scale at the work shed in the drying process, molded bricks were exposed to fan with certain amount speed, direct sunlight and oven. Additionally, to secure uniform heat
transferred on bricks surfaces, bricks were covered with alluminium foil and burning process was performed with stove and zinc plate where the firing temperature was measured and maintained at approximately 550°C on bricks, with medium heating rate.

Once the procedures were meticulously performed, some physical and mechanical tests were precisely conducted to obtain accurate result of those properties.

2.1. Density and water absorption
Density measurement was conscientiously performed every steps of molding, drying, prior to and after firing process. Since density and water absorption are alike related to weight and dimension measurement, the values could be established in the same time. Bulk density is defined as sample mass in one unit of its volume and water while water absorption is percentage of dry weight to its saturated weight. Water absorption test was carried out based on [17] for every age of curing specimens. Normally, density of clay brick is from 1.60 gr/cm³ to 2.00 gr/cm³, and it can be lessen by some engineered purpose i.e. additional inner burning admixtures.

2.2. Colour, texture and shape
Brick colour will vary based on its raw material and firing process. Normal red/brownish orange colour for clay bricks is affected as the bottom ash is mixed with clay hence the colour might be dark brown. Bricks shape should meet proper length, width and thickness as mentioned in code. Bricks surface is maintained plan and rough, square, producing loud sound when it is tapped, no crack, and unbreakable [18].

2.3. 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 [19-22]. Brick must not be very dry to secure bond capacity due to high amount of water absorption. Salt content in brick is prevented to avoid reduction of its preservation as its crystallization covers more than 50% of bricks surface.

2.4. Compressive strength
Compressive strength, as mechanical properties, was tested in according to ASTM C67-11 only on bricks stretcher face area, where the minimum requirement is 10.40 Mpa as stated in code [17]. Based on previous research [5-11], hygroscopic material e.g. sago husk, reed, might accelerate the time and increase the compressive strength.

Figure 1. Design models and labelling of bricks. Figure 2. Detail dimension of hollow bricks section.
3. Results and discussion

3.1. Physical and mechanical properties

Based on visual inspection, some cracks occurred in pre-heating due to inconsistent water distribution in bottom ash position. Moreover, number of hollow section is also proportional to number and width of cracks since stress concentration of the hollow section that can be expanded for sequence hollow. Drying process of modified bricks took 5-6 hours, which is faster than conventional bricks that took 5 to 7 days. Therefore, production rate is increased by utilization of bottom ash. Area reduction of hollow to non hollow section follows by reduction in weight and compressive strength.

![Figure 3. Modified bricks after molding.](image)

![Figure 4. Bulk density of modified bottom ash brick with 1,1% sago husk](image)

The density measurement demonstrated values between 1.29 up to 1.66 g / cm³ (figure 4). It can be seen that higher bottom ash composition yield lower bulk density due to its water absorption capacity of bottom ash in certain time with 8 – 15% difference between 0% bottom ash and 25% bottom ash. Based on the graph and difference percentage, it is indicated that the bulk density will remain steady after 25% bottom ash after significant (logarithmic) decrease from 0 and 10% bottom ash.

All models, either hollow or non hollow section share similar color i.e. darkest brown. Consistent values of linear shrinkage in all axis (length, width and thickness) were demonstrated by all models with approximately 90%, as stated in the standard to guarantee isotropic properties of bricks. Furthermore, the initial rate of absorption (IRA) of all models is 0.18% in general and it is still considered suitable with ASTM C67-14.
Figure 5 illustrates that 1,1% sago husk bricks with all variation of bottom ash meet requirement for structural bricks i.e. more than 10.4 Mpa. For hollow section, model 1 deliver best value for compressive strength. Model 3 and 4 share lowest value, respectively. Nevertheless, either structural or non structural purpose, their performance is deemed suitable for building element. 20% bottom ash yield excellent result than other composition, where it increases from 0% and decreases after 20%. 10% bottom ash also share fine result in terms of compressive strength.

**Figure 5.** Compressive strength of modified fly ash brick.

4. Conclusion

Utilization of bottom ash with local waste i.e. sago husk could be established in housing sectors, since all properties are well satisfied, both structural and non structural components. 10% and 20% composition of bottom ash in this admixtures might yield better requirement for light and strong building due to their result on bulk density and compressive strength. However, workability in molding process should be vigilantly executed as cracks are comfortable to occur provided water distribution is not uniform in bricks body.

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