Preliminary Study on Hand-cast Lightweight Concrete Block using Raw Rice Husk as Aggregate

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Abstract. Raw rice husk is an abundantly available waste material in Indonesia as one of rice producing countries. Due to rice husk is light in weight and convex in shape, this paper presents a preliminary application of raw rice husk as natural aggregate in order to make lightweight concrete blocks. Concrete specimens contained Portland Cement, filler, and raw rice husk, in which the mix proportion was in volumetric ratio, i.e 1.25 cement and 2.75 filler constantly, whereas dosage of rice husk varied from 8.5 to 10. The production of the concrete block was by mixing the ingredients together and then the mixture was casted and compacted on moulds by hand manually. Series laboratory experiments were accomplished to analyse the compressive strength and density. For this, four groups of mixes were prepared. The results have shown that the higher proportion of rice husk is the lower its compressive strength and the lighter its density. At proportion of 1,25 cement: 2,75 fillers: 8,5 raw rice husks, the compressive strength is 26.64 kg/cm² and this satisfies the minimum standard (25 kg/cm²). Unfortunately, the density is 1,536.73 kg/m³ and it is higher than the maximum standard of 1,400 kg/m³. Thus, it is important to research further by making and testing some improved specimens with more cement, more rice husk, and less filler to fulfil strength and density.

1. Introduction

Indonesia has long blessed with valuable fertile land and abundant rainfall, the ideal place to cultivate rice, as the main agricultural crop. On the other hand, Indonesia is presently facing thoughtful environmental degradation due to over-exploitation of its natural resources such as river sand for concrete construction material, causing an ecological imbalance of the environment. One of agricultural waste is raw rice husk that can be used for alternative substitution of river sand in the domain of conventional concrete material.

Over the last years, many researchers have developed eco-concrete by the utilization of waste materials, particularly agriculture waste. Examples of agricultural waste for eco-concrete are rice husk [1-5], bagasse fibers [6] and hemp [7-9] [10]. Additional agricultural waste in concrete mixture presents an outstanding lightweight material since there are the interconnected network of porosity which distinguishes these ingredients.

The use of concrete block in Indonesian construction industry is very popular currently. The production of concrete block is by mixing the ingredients together and then casting and compacting the mixture on molds by hand manually or with help of machines. After demolding, the fresh concrete block needs to be set and hardened in curing place for 28 days before it is assembled as a construction material. Concrete blocks have fair strength in compression dan take shape into units that single worker can lift
and handle it individually. For seismic resistant structure purposes, it is urgent to consider on the lighter materials that can reduce minimize earthquake load. Concrete blocks which consist of a lot of porosity will provide lighter material which reduces significantly for its weight. Unfortunately, the strength of lightweight concrete blocks is relatively lower than the normal block, and then it could be considered as the main weakness point. Due to the lower strength, this lightweight concrete block is not recommended to be a full load-bearing wall structure. Since the existence of a large portion of porosity, water can easily penetrate through light-weight concrete block that it must be sealed by water proofing material.

Rice husk is the shells produced during the husking operation of paddy rice and then becomes agriculture wastes. Its siliceous composition of rice husk is resistant to environmental decomposition, which can generate a significant ecological load. Around the world, there are rice husk abundantly or 20% of the 500 million tons of paddy per year [11]. In 2018 only [12], there are rice husk for nearly 11.3 million tons per year in Indonesia. Hence, utilization of rice husk in construction material can be considered as a brilliant solution. It will give significant beneficial for both better environment and construction industry. This large quantity of rice husk as agricultural waste in Indonesia brings forcefully that it can act as a sand replacement in the production of construction material, such as concrete block.

Study on rice husk concrete has been done recently [1-5]. Additional marble powder and stone powder as a filler in the rice husk concrete composition has been elaborated by Gencel et al [4] and Winarno [5] respectively. Due to huge volume of stone powder as a result of waste of stone cutting home industries in Sleman Indonesia, Winarno has utilized it as a filler for concrete block material. This research [5] focused on hollow concrete block produced with vibratory machines. The concrete block was 10 cm (thick) x 20 cm (height) x 36 cm (length) and molded in “portrait orientation”. The optimum volumetric composition was 1 PC: 0.63 filler: 6 rice husks. The condition of rice husk is saturated surface dry (SSD) in which the surfaces of the particles are "dry", but the interparticle voids are saturated with water. The compressive strength was beyond the Indonesian standard and the density was very light, about 1,018.68 kg/m$^3$. This production of rice husk hollow concrete block with vibratory machines and in “portrait orientation” needed to be handle with care seriously. Fresh concrete blocks were demolded immediately after compaction and it was relatively dry, less stable, and stiff mixture concrete. The fresh concrete blocks are then carried away on pallets to the curing place in order to set and harden. Quite often, while workers carried the fresh concrete to the curing place, they have to be calm and careful in motion to maintain this fresh concrete on their precision shape. These circumstances have caused low in productivity. Worker patience is part of the recipe to arrive at a precision concrete block. If the workers carry and handle it carelessly, the block unit will become a defective product and poor in precision.

To overcome the above situation, it might be useful if the production technique uses hand-cast manually, without vibratory machine and molds with “landscape orientation”. The fresh blocks are laid in curing place to harden and set where they were molded. Therefore, the objectives of this article are to (1) examine the strength of hand-cast solid concrete blocks with variety dosage of rice husk, and (2) investigate the density of concrete blocks in order to initiate lightweight material.

2. Materials and Methods

The amount of rice husk was collected from rice farmer in the Sleman Region, Yogyakarta, Indonesia. The concrete production was examined in Innovation Centre of Universitas Islam Indonesia, Yogyakarta. The concrete block ingredients are similar with previous study by Winarno [5], i.e Portland Cement (PC), raw rice husk (RRH as sand replacement), and filler. The filler is stone waste as a result of cutting stone blocks industry around Sleman District. The diameter of filler is approximately 0.04-0.10 mm. Four groups of mixes were examined in which the mix proportion was in volumetric ratio, i.e. 1.25 cement and 2.75 filler constantly, whereas dosage of rice husk varied from 8.5 to 10. The casting technique employed hand-cast manually, without vibratory machine and molding with “landscape orientation”. This technique would hold its shape when it was demolded. The fresh blocks were laid in curing place to harden and set where they were molded. The type of concrete block was decided to be
solid block. There were two indicators which were investigated in this study, i.e strength and density. The strength relates to the compression and the density corresponds to the unit weight.

2.1. Concrete blocks

Currently, as categorized into concrete masonry unit, concrete block is categorized into two types, i.e. hollow and solid block and may cast in smooth sides or with an ornament design. The hollow block is designed to be lighter than the solid one, making easy to handle. Moreover, the hollow allows for steel reinforcements. It is important that worker enable to easily lift and handle one unit of concrete block.

The common ingredients of concrete blocks are a blend of Portland Cement, water, and sand. Portland Cement as a bonding agent is mixed with water to produce a cementing paste through a chemical reaction or hydration. Cementing paste fills the voids inside the concrete, also it converts the mixture of concrete ingredients into plastic and workable form. Hardened concrete gains strength with time and testing this hardened concrete for quality check is important for structures.

It is well known that the cement-aggregate ratio is an important factor of the strength of concrete block. The ratio of cement to aggregate must be examined by trials with different ratios, e.g. 1:6, 1:8, 1:10, up to 1:16 based on volumetric ratio commonly. As of special importance: if the ratio is too high, the mixture will lack the cohesiveness needed for strength on matured blocks; if the proportion is too low, the strength will be in low in quality.

Besides the proportion of cement and aggregate, the need of water is very crucial. Water liable for drinking is the most suitable to mix the concrete. The ideal amount of water for mixing particularly depends on the types and mix ratio of cement-aggregate, the expected strength, and the method or technique of production. The ideal amount of water for mixture is just enough water in order to facilitate production without any impairing shape or slumping of blocks after demolding. If the mixture is lack of water, it may not flow easily in handling, working, and filling the mold. If the aggregates are dry, they may absorb some of the water. The amount of water needed is measured through a simple test for cohesiveness. It is a correct water amount if there is no excess water should be visible when a lump of concrete is squeezed in the hand. In general, the concrete mixture used for blocks has a higher percentage of aggregates and a lower dosage of water than the concrete mixtures used for the need of structural construction purposes.

In general, the production process of concrete blocks consists of three basic stages: mixing, molding, and curing. The mix ingredient generates a block with fair strength and relatively coarse surface. To ensure uniform units for construction, the sizes and shapes of most common concrete blocks have been standardized. The common block size in Indonesia is 9-10 cm thick, 18-20 cm high, and 36-40 cm wide. A single typical concrete block has about 10-14 kg in weight.

Hand-cast concrete block is convention technique to make blocks in early time. This can be casted on site by unskilled worker with cheap cost. Currently, industry of concrete block is an enormously automated digital process. Medium concrete work-shop with common small-medium machine can make up to 50 blocks per hour.

Generally, concrete blocks are used as wall materials. They are placed in courses with fresh appropriate mortar as the bed and binding material. Worker should use a level to adjust the blocks, so they are perfectly vertical as the planned and designed wall configuration. In certain area, many houses have been built by concrete block wall, probably since the sand as the main raw materials of the blocks is in a large supply in sand banks around this district.

Unit weight or density of normal concrete block is about 2,000 kg/m$^3$. Wall with normal concrete block will generate very large self-weight (or dead load). For reduction of earthquake risk, it is urgent to decrease the total dead load of the structure. This can be resolved through implementation of lightweight concrete block rather conventional concrete block. Lightweight block can be addressed with the low density of its main ingredients. With the focus of lightweight concrete in this paper, the use of sand will be substituted with rice husk. These rice husk lightweight concrete blocks promise to get building lighter, less expensive, and faster in construction.
2.2. Raw rice husk

Raw rice husks are the hard-protecting coverings of grains or seed of rice (figure 1). Many people in Indonesia are rice farmers, thus, the husks are easy to collect everywhere and low-priced. These are often dumped and/or just burned. In general, there are 0.20 kg rice husks as a result of one kg of milled white rice. In 2018, Indonesian rice farming produces approximately 11.3 million tons of raw rice husk [12].

Rice husk is formed from hard materials, including silica and lignin, and it is resistant to natural decomposition. It is urgent to alternate rice husk in order to avoid environmental degradations. Based on its physical properties, raw rice husk is in loose form that can replace fine aggregate or sand for concrete block production, as a demanding research in Indonesia.

![Figure 1. Raw rice husk (RRH)](image)

The application of RRH into the mixture of concrete block for developing eco-concrete is better solution for sustainable materials. Concrete made by RRH offers an outstanding lightweight material because there are a large proportion of porosity in convex envelope with network interconnection. This is lighter than sand. Its density is estimated at 108 kg/m$^3$ by Pacheco-Torgal et.al [13], whilst sand unit weight can attain at nearly 1,850 kg/m$^3$. Rice husk has 2 to 4 mm in width, its length is roughly 10 mm, and it is distributed homogenously. Structures constructed with lightweight materials are most suitable for construction projects in seismic vulnerable zones. Moreover, buildings with lightweight material are advised to be designed and built-in inferior soil environments, hence this will have significant cost saving in constructions.

Due to its homogenous size, the use of RRH in concrete mixture can initiate a uniform distribution of air voids within hardened concrete sample thoroughly. As a result, RRH concrete block can be lower in density than the normal concrete. Indonesian standard, SNI 03-3449-2002 [14], highlights that lightweight concrete has the maximum density at 1,400 kg/m$^3$. Application RRH into lightweight concrete block is a novel approach in order to create several benefits such as cost saving and shorter time for constructor. Figure 2 presents RRH solid concrete block.

![Figure 2. Raw rice husk concrete block](image)

(a) Units of concrete blocks  
(b) Its surface texture
2.3. Filler
In this study, one of the concrete block ingredients is filler. The fillers are stone particles, as a powder-waste produced by cutting stone industrial activity. Stone cutting wastes in the form of wet powder was taken from stone cutting home industry located in Sleman District area (figure 3) and incorporated in the batch formulation of lightweight concrete block. The main beneficial effects of filler addition in a concrete mixture are to reduce the amount of cement (cost effectiveness) in concrete without loss of strength [15] and to improve workability and stability (the packing effect) of fresh concrete [16 and 17].

![Figure 3. Stone cutting home industry](image)

Stone cutting home industries have existed in Sleman for years which generate powder-waste (or stone particles). It is like very fine sand. Deposit of this waste material in local streams can impair or pollute local people and spoil agriculture industry. It is urgent to decrease the industry's negative impact on the agricultural land located in downstream and the adverse impact on the local livelihood. Filler physical properties is presented in table 1 (taken from a previous study by Winarno [5])

| Physical test            | Values    |
|--------------------------|-----------|
| Specific gravity         | 2.41      |
| Fineness modulus         | 2.09      |
| Diameter (mm)            | 0.04-0.10 |
| Bulk density (kg/m³)     | 1.224     |

3. Results

3.1. Concrete block mixture
In general, the ingredient of concrete blocks is often mixed from cement, water, and sand. Ratio of cement to sand can be expressed by 1:6, 1:7, 1:8, or 1:9. For this article, the main mixture of the blocks consists of PC, filler, and RRH with additional of adequate water. The volumetric ratio of PC to filler of all samples was maintained constantly on 1.25 : 2.75 for all varieties. There are 4 varieties of mixture in which dosage of RRH varies from 8.5 : 9 : 9.5 ; and 10. This ratio by volumetric measurement is chosen to ease and simplify the proportion measurement by worker during mixing test. It is true that all ingredients mentioned above is only the estimated amount of raw materials. Perhaps, some error margin in determining the precise amount is still occurred.
3.2. Concrete strength and density

First of all, there are two parameters of concrete block which are examined in this study, i.e compressive strength and its density. The specimen is 22 cm high x 10 cm tick x 40 cm width. After 28 days curing, the specimens are tested systematically. Compressive test applies by increasing load gradually at the rate at 140 kg/cm² per minute till the specimens gets fracture. Maximum load at the failure divided by area of specimen expresses the compressive strength of concrete. Complying to Indonesian Standard [14] on concrete block for wall structure (SNI 03-0349-1989): compressive strength minimum for solid concrete block is 25 kg/cm².

This paper scrutinizes four batches of the mixture of PC, filler, and RRH. Each batch consists of five samples. Table 2 presents the findings of strength and density examination.

### Table 2. Compressive strength and density

| Mix batch | Sample | Weight (g) | Max load (kg) | Compressive strength kg/cm² | Density kg/m³ |
|-----------|--------|------------|---------------|-----------------------------|---------------|
|           |        |            |               | Results Standard            | Results Standard |
| A         | 1      | 13467      | 10834         | 27.09 25                    | 1530.34 1400   |
|           | 2      | 13567      | 10732         | 26.83 25                    | 1541.70 1400   |
|           | 3      | 13035      | 10372         | 25.93 25                    | 1481.25 1400   |
|           | 4      | 14006      | 10292         | 25.73 25                    | 1591.59 1400   |
|           | 5      | 13541      | 11051         | 27.63 25                    | 1538.75 1400   |
| Average   |        |            |               | 26.64 25                    | 1536.73 1400   |
| B         | 1      | 12765      | 8422          | 19.21 20                    | 1450.57 1500   |
|           | 2      | 12841      | 8341          | 20.01 20                    | 1459.20 1500   |
|           | 3      | 12336      | 8069          | 18.57 20                    | 1401.82 1400   |
|           | 4      | 13390      | 8235          | 18.68 20                    | 1521.59 1500   |
|           | 5      | 12818      | 8597          | 19.10 20                    | 1456.59 1400   |
| Average   |        |            |               | 19.11 20                    | 1457.95 1500   |
| C         | 1      | 11954      | 6327          | 15.82 15                    | 1358.41 1500   |
|           | 2      | 12045      | 6263          | 15.66 15                    | 1368.75 1500   |
|           | 3      | 11571      | 6051          | 15.13 15                    | 1314.89 1500   |
|           | 4      | 12566      | 6179          | 15.45 15                    | 1427.95 1500   |
|           | 5      | 12029      | 6444          | 16.11 15                    | 1366.93 1500   |
| Average   |        |            |               | 15.63 15                    | 1367.39 1500   |
| D         | 1      | 11143      | 4199          | 10.50 10                    | 1210.34 1500   |
|           | 2      | 11253      | 4156          | 10.39 10                    | 1200.15 1500   |
|           | 3      | 10816      | 4013          | 10.03 10                    | 1205.67 1500   |
|           | 4      | 11737      | 4108          | 10.27 10                    | 1198.36 1500   |
|           | 5      | 11239      | 4274          | 10.69 10                    | 1179.47 1500   |
| Average   |        |            |               | 10.38 10                    | 1198.80 1500   |

4. Discussion

Based on table 2, figure 4 and 5 describe the trend line of strength and density respectively from four different dosage of RRH. Results gained from four different proportions of RRH have showed that the strength decreases linearly, with equation: y=-10.456x+114.66, in which y= compressive strength and x= dosage of RRH. In relation to the strength, compression strength standard (Indonesian Standard [18]...
for concrete block, i.e 25 kg/cm² is achieved on 8.5 dosage of RRH, in which this finding arrives at the strength of 26.64 kg/cm².

![Figure 4. Result of 28-day compressive strength](image)

On the other hand, density test result is presented in figure 5. Lightweight RHH concrete blocks are performed in 9.5 and 10 dosages of RRH because their density is below 1,400 kg/m³, as Indonesian Standard. Concrete block with dosage of 8.5 RRH gets 1,536.73 kg/m³ (too heavy according to the Standard) fails to perform light-weight concrete although its strength is good enough. There are scopes for further study to evaluate improvement of strength and reduction of density by adding more cement, more rice husk, and also by reducing filler to fulfil strength and density standard.

![Figure 5. Density for different dosage of RRH](image)

5. Conclusions
Four groups of concrete block mixes have been investigated. For this preliminary study, it can be summarized that concrete block mix with dosage of 8.5 of RRH complies the strength standard but at the same time it fails to perform lightweight concrete (too heavy to comply the Standard). For better achievement, there is a need for further research to improve strength and reduce density by adding more cement, more rice husk, and less filler to fulfill strength and density standard. As this study focuses on a lightweight block, it is essential to scrutinize further acoustic and thermal insulation.

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References

[1] Pachla E C, Silva D B, Stein K J, Marango E and Chong W 2021 Sustainable application of rice husk and rice straw in cellular concrete composites Constr. Build. Material 283 122770
[2] Tayeh B A, Hisham R A and Alaskar A A 2021 Recycling of rice husk waste for a sustainable concrete: A critical review J. Cleaner Production 312 127734
[3] Lawal A Q T, Ninsima E, Odebiyi O S, Hassan A S, Oyagbola I A, Onu P, Yusuf D A and Japyem E 2019 Effect of unburnt rice husk on the properties of concrete Procedia Manufacturing 35 pp 635-640
[4] Gencel O, Benli A, Bayraktar O Y. Kaplan G, Sutcu M, Elabade W A T 2021 Effect of waste marble powder and rice husk ash on the microstructural, physico-mechanical and transport properties of foam concretes exposed to high temperatures and freeze–thaw cycles Constr. Build. Material 291 123374
[5] Winarno S 2018 Comparative strength and cost of rice husk concrete block, Proc. 5th Int. Conf. on Sustainable Built Environment, Management of Changes for Livable Environment, (Banjarmasin, Indonesia)
[6] Bilba K and Arsene M A 2008 Silane treatment of bagasse fiber for reinforcement of cementitious composites Composites Appl. Sci. Manufacture 39 95
[7] Le Troëdec M, Peyratout C, Smith A and Chotard T 2009 Influence of various chemical treatments on the interactions between hemp fibres and a lime matrix J. Euro Ceramic Society 29 1861
[8] Nguyen T T, Picandet V, Amziane S and Baley C 2009 Influence of compactness and hemp hurd characteristics on the mechanical properties of lime and hemp concrete, Euro J. Env. and Civil Eng. 13 1039
[9] Nguyen T T, Picandet V, Carre P, Lecompte T, Amziane S and Baley C 2010 Effect of compaction on mechanical and thermal properties of hemp concrete, Euro J. of Env. and Civil Eng. 14 545
[10] Arnaud L and Gourlay E 2012 Experimental study of parameters influencing mechanical properties of hemp concretes Constr. Build. Material 28 50
[11] Bhanumathidas N and Mehta P K 2004 Concrete mixtures made with ternary blended cements containing fly ash and rice husk ash Proc. Int. Conf. Seventh CANMET (Chennai, India) vol 1 p 199
[12] Anonim. Luas Panen, Produksi, dan Produktivitas Padi Menurut Provinsi, www.bps.go.id, last accessed 17 September 2019
[13] Pacheco-Torgal F, Lourenço P B, Labrincha J A, Kumar S and Chindaprasirt P 2015 Eco-efficient masonry bricks and blocks (ISBN 978-1-78242-305-8, Woodhead Publishing, Elsevier Ltd).
[14] SNI 03-3449-2002 Tata cara pencatatan campuran beton ringan dengan agregat ringan (Departemen Pekerjaan Umum)
[15] Nehdi M, Mindess S and Aitcin P C 1996 Optimization of high strength limestone filler cement mortars Cement and Concrete Res. 26 6 pp 883–893
[16] Nehdi M, Mindess S and Aitcin P. C. 1998 Rheology of high-performance concrete: Effect of ultrafine particles Cement and Concrete Res. 28 5 pp 687–697
[17] Jones M R Zheng L and Newlands M D 2003 Estimation of the filler content required to minimise voids ratio in concrete Magazine of Concrete Res. 55 2 pp 193-202
[18] SNI 03-0349-1989 Bata beton untuk pasangan dinding (Departemen Pekerjaan Umum)