Synthesis of silica from rice husk as cement substitution for high strength concrete

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Abstract. This research was conducted to determine the effect of adding the rice husk ash (RHA) from mechano-chemical process as cement replacement for concrete. Mechano-chemical process was carried out using planetary ball mill with the rational speed at 22 rpm for 15 minutes and adding the 1M Hydrochloric Acid. This process aims to reduce the particle size of RHA. RHA will be used as cement replacement material with the composition that will be displayed in this study. Concrete was made on 10 x 10 cm cube mold and a compressive strength test was carried out after 28 days curing. Beside RHA, in this study silica fused is used as cement replacement material. Concrete with the addition of RHA from mechano-chemical process has higher compressive strength than concrete with addition of silica fused.

1. Introduction
Indonesia is known as a country that has rice as stable food. The needs of rice as a source of stable food will be increasing along with the population growth. According to data from the Indonesia Ministry of Agriculture, in 2017 Indonesia produced about 81.382.451 tons of paddy. Paddy plants consist of rice grain as the main product and rice husk as by-product that can be separated by milling process. Rice husk from milling process has weight around 20 % of total rice weight. As a by-product, rice husk are often left or burned directly in environment which can cause air pollution.

Rice husk as by product has around 90-98% silica after complete combustion [1]. Rice husk that has been burned is called rice husk ash (RHA). RHA can play role as silica source because of high value of silica after burning process. RHA can be called as Pozzolanic materials because it has high value of silica [2]. Several studies reported that RHA can be used as material for cement replacement in concrete making process. Silica contained in RHA can increase the mechanical properties of concrete like compressive strength and durability [3,4].

RHA as pozzolanic materials depends on silica value in RHA, crystallization phase of silica, size, and surface area of RHA. Controlled combustion can help to obtain more amorphous phase of silica and larger surface area of RHA. Some studies reported that combustion process below 800°C can produce rice husk ash with mainly content of amorphous silica [5]. RHA with small particle size and large surface area can be obtained by grinding process. Grinding process with planetary ball mill can be used to reduce particle size of RHA.

Beside using RHA, silica fuse also can be added in concrete making process. Silica fuse is made from high purity silica, using unique fusion technology, to ensure the highest quality. It has the same
effect of RHA because it has high silica content and amorphous silica. Around 85-99% amorphous silica can be found in silica fused [6].

In this study, we tried to combine the mechanical and chemical treatment for RHA to investigate its effect on RHA particle size. Further investigation the RHA particle size is used to analyze its effect on mechanical properties of concrete. The variable we used are 22 rpm grinding speed and 1 M hydrochloric acid.

2. Experimental

2.1 Materials

2.1.1 Rice Husk Ask Preparation
The rice husk was obtained from Paddy Mill Industry, Leuwiliang, Bogor and was dried for 8 hours under sun. NaOH, HCl, distilled water was obtained from C.V. Mitra Bersama and used as it is without any further purification.

2.1.2 Acid solution preparation
The Hydrochloric acid was obtained from CV Mitra Bersama and used without further purification. 1 M hydrochloric acid was obtained by diluting 20.72 ml of 37% HCl in 229.28 ml of water

2.1.3 Cement
The cement we used for this study is ordinary Portland cement type I from PT Indocement. This cement specifications conform to ASTM C 150 (Standard Specification for Portland Cement).

2.1.4 Aggregate
There were 2 types of aggregates used for this study. The fine aggregate is sand from Bangka province. The sand particle size range is 0 to 5 mm sieving grade. The coarse aggregate is gravel from Rumpin with particle size range from 10 to 20 mm.

2.1.5 Silica Fused
Silica fused was obtained from Chem&Size Minerals Limited, China. This silica fused would be used as cement replacement to make a concrete.

2.2 Methods

2.2.1 Grinding Proces
Rice husk was burned at 700°C for 5 hours. RHA from burning process was was left in the furnace for cooling process and removed the next day. Then, RHA was added 1 M hydrochloric acid and ground using planetary ball mill with rotational speed at 22 rpm for 15 minutes.

2.2.2 Sampling
RHA, cement, fine and coarse aggregate were placed in correct proportions in the basin. They were mixed manually and slowly add water into the basin. The same procedure was also carried out to make concrete with addition of silica fused. Before the concrete is casted to mould, first moulds have to coated with oil to prevent concrete from sticking to moulds and makes it easier to remove. Then concrete samples were casted into 10 cm x 10 cm moulds and compacted with rod and hummer to remove trapped air in the samples. After that samples were left for 24 hours.

In this study, the effect of adding RHA and silica fuse were futher studied. There were three samples in this study, concrete normal without addition of RHA (C-Normal), concrete with RHA that were
ground at 22 rpm with addition of HCl (C-Treatment) and silica fuse (C-SF) as a replacement of cement.

**Table 1. Composition of concrete**

|          | Cement | Water | Sand | C.A  | RHA |
|----------|--------|-------|------|------|-----|
| C-Normal | 483    | 267   | 973  | 1200 | 0   |
| C-Treatment | 464.5 | 267   | 973  | 1200 | 18.5|
| C–SF     | 464.5  | 267   | 973  | 1200 | 18.5|

3 Results and Discussion

3.1 Particle Size Distribution

**Table 2. The result of Particle Size measurement**

|                  | Particle Size (µm) |
|------------------|--------------------|
| RHA non Treatment| 51.02              |
| RHA Treatment    | 23.24              |
| Silica Fused     | 33.20              |

Particle size of RHA was measured using Particle Size Analyzer. Based on table 1 and Figure 1, the average particle size of RHA non treatment is 51.02 µm, RHA treatment is 23.24 µm, and silica fused is 33.20 µm. RHA non treatment has largest particle size. The large particle size can give an adverse effect. This adverse effect due to particle failure in filling the void in concrete which can reduce the compressive strength. The improvement of RHA non treatment can be done by mechano-chemical process using planetary ball mill and addition of Hydrochloric acid. Chemical treatment with hydrochloric acid can higher content of silica and lower content of impurities also chemical treatment can affect particle size of RHA because acid can react with the RHA and diminish the intercalation between the particles [7]. This process proved that mechanical and chemical mixing process was successful in reducing particle size. In this study, RHA from mechano-chemical has smaller particle size than silica fused. Smaller particle size can improve compressive strength because it can make a excellent pozzolanic reactivity and ability to fill the void in concrete [8,9].

3.2 Compressive Test

Compressive test were performed on samples after curving process for 28 days. The samples were given constant processing force. The maximum strength of concrete were shown when the concrete changes its shape due to failure.

**Table 3. The result of Compressive Strength Test of Concrete**

| Concrete | Compressive Strength (MPa) | Compressive Strength Average (MPa) |
|----------|----------------------------|-----------------------------------|
| C-Normal | 27.23                      | 26.38                             |
|          | 24.14                      |                                   |
|          | 27.77                      |                                   |
| C-Treatment | 30.4                    |                                   |
|          | 26.41                      | 28.53                             |
|          | 28.78                      |                                   |
| C-SF     | 28.24                      |                                   |
|          | 29.75                      | 28.41                             |
|          | 27.23                      |                                   |
RHA non treatment has lower properties than RHA treatment and SF like larger particle size and smaller surface area. It would make lower compressive strength due to larger particle size of RHA. So RHA non treatment is not suitable for direct use as a cement replacement in concrete making process. RHA non treatment needs additional process to improve compressive strength of concrete. In this study, mechano chemical was used to improve the properties of RHA. The result was higher compressive strength of C-Treatment. The improvement occurred because of reduction of particle size as a mechano chemical process effect. The particle size could be changed into smaller size by increasing the grinding time [10].

Based on table 3, C-Treatment had highest compressive strength than other concrete. C-Treatment had higher compressive strength than C-Normal. The result proved that addition of RHA could improve the compressive strength of concrete. C-Treatment had higher compressive than C-SF. This study has same result with study of Srinivasreddy [11]. This can be due to smaller particle size and bigger surface area which can generate excellent pozzolanic reactivity and fill the void in concrete. C-SF had lower compressive strength, it may be caused by larger particle size that could cause failure to fill the small void in concrete. The higher compressive strength with smaller particle size can prove that RHA as the result of mechano chemical process can be used as silica fused replacement in concrete making process.

4 Conclusion
The addition of RHA can improve the compressive strength of concrete. But RHA can be used directly because it has larger particle size. RHA needs addition process, mechano-chemical process, to reduce the particle size. Mechano-chemical process is proven to reduce the particle size of RHA from 51.02 µm to 23.24 µm. Based on study, concrete with addition of RHA from mechano-chemical process has highest compressive strength than normal concrete and concrete with addition of silica fused.

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