THE USE OF RICE HUSK ASH IN ENHANCING THE MATERIAL PROPERTIES OF FLY ASH-BASED SELF COMPACTED GEOPOLYMER CONCRETE

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Abstract. Concrete is a material that is needed for building construction or others is increasing. Construction increased as cement use increased. The continued use of cement will cause environmental damage, cement is the 8th largest source of carbon gas emissions in the world. One of the revolutionary developments using environmentally friendly materials as a substitute for cement is geopolymer concrete. Alternative materials rich in silica and alumina for the manufacture of geopolymer concrete, namely adding rice husk ash (RHA), fly ash, silica fume, glass powder, as substitute for cement. A cement substitute can use RHA as partial substitute for geopolymer concrete based on fly ash, which is rich in silica and alumina. For the binder, an activator is needed, the activator usually uses NaOH and Na₂SiO₃. The purpose of this study was to determine the effect of rice husk ash as a partial substitution of fly ash on split tensile strength and porosity of geopolymer concrete and determine the optimum percentage of use of RHA to produce tensile strength and porosity in geopolymer concrete with material calculations using EFNARC 2005. Geopolymer concrete which binders using 14M NaOH and Na₂SiO₃, and binders namely Fly ash and rice husk ash, with variations for RHA 0%, 5%, 10%, 15%. Sample in the form of cylinder with diameter of 150 mm and height of 300 mm for tensile strength and cylinder with diameter of 2 inches and height of 5 mm for porosity. The specimens were treated for 28 days with room temperature curing. From the data obtained, it can be concluded that there is an effect of RHA to increase tensile strength and reduce porosity in geopolymer concrete with an optimum variation of 10%, with an optimum tensile strength of 1.061 MPa, and minimum porosity of 13.13%.

Keywords: Rice Husk Ash, Fly ash, Self Compacting Geopolymer Concrete, Porosity, Tensile strength.

1. Introduction
Concrete is a material that is needed by the community. Concrete was chosen in construction because it is easily formed according to the desired construction. In the period 2010-2019, construction development in Indonesia according to the 2019 Indonesian statistics center has increased by 343.44%. The ground reality, there are also obstacles, namely too tight a reinforcement which results in difficulty in compaction. So this constraint encourages the concept of concrete technology, namely self-compact concrete or often known as Self Compacting Concrete (SCC). Self Compacting Concrete is a special concrete that does not require compaction. It will flow and be compacted by its own weight. The SCC requirements were designed under i) Fillability, ii) Passability and, iii) Separation resistance [1]. The increasing use of concrete causes the use of cement to also increase the use of cement can have a big negative impact on the environment. Cement is the source of about 6-7% of carbon dioxide (CO₂) emissions in the world [2]. Joseph Davidovits mentioned that the creation of 1 ton cement releases approximately 0.85 - 1 ton of carbon dioxide [3]. In this case, an environmentally friendly cement substitute adhesive is needed. Geopolymer concrete is an alternative material to substitute for cement, but due to its viscosity, it causes solidification. To solve this problem, Self Compacting Geopolymer Concrete (SCGC) has been introduced.
SCGC is produced through industrial use using products such as Fly ash, Ground Granulated Blast Furnace Slag (GGBS), waste glass powder, silica fumes, and rice husk ash, materials containing extra alumina and silica can be used. These ingredients can be activated by adding alkaline solutions (Sodium Hydroxide and sodium silicate) [1]. As an alternative to geopolymer concrete, fly ash (FA) can also be used. FA is an industrial waste with pozzolanic properties obtained from steam power plants. Because the amount is quite large, reaching 8.31 million tons in 2019 (ESDM, 2019), fly ash must be managed properly so as not to cause negative impacts on the surrounding environment in the form of air pollution, environmental pollution, and ecosystem degradation. Fly ash contains silica dioxide (SiO2), aluminum (Al2O3), iron (Fe2O3), and calcium (CaO), magnesium, potassium, sodium, titanium, and sulfur [4]. Another alternative material for making geopolymer concrete is adding rice husk ash as a substitute for cement. In Indonesia alone, rice husk ash is very abundant. Data on the Central Statistics Agency, BPS, in 2014 rice production in Indonesia was 70.85 million tons of milled dry unhulled rice. The ash content of rice husk itself has quite high silica (SiO2), ranging from 83-98% [2]. The high silica content in rice husk has the potential to replace a more expensive source of silica and at the same time can take advantage of the economic quality of rice husk ash.

Geopolymer concrete with rice husk ash and fly ash material has been widely studied, including researching the effect of using solid material fly ash and husk ash on the compressive strength of geopolymer concrete. The use of solid materials in the form of fly ash and rice husk ash with a ratio of 110.32331 MPa, 7.09309 MPa, 3.051927 MPa, 2.960489 MPa (100: 0; 80:20; 60:40; 20:60; 0:100),[5] From the 00: 0, 95:5, 90:10, 85:15, 80:20, 75:25. The results of the concrete compressive strength test according to the composition of the solid material aged 28 days are 21.20305 MPa, 4.078025 MPa, results of these studies and ideas, a study of fly ash-based geopolymer concrete with partial substitution of rice husk ash with a review of split tensile strength and porosity was generated. The purpose of this research is 1) To determine the effect of variations in rice husk ash as a partial substitution of fly ash on the tensile strength of concrete and concrete porosity. 2). To determine the percentage of use of rice husk ash as an optimum partial substitution of fly ash to produce maximum split tensile strength in concrete and to produce minimum porosity in concrete.

2. Theoretical Foundation

2.1 Material of Concrete Maker

2.1.1 Aggregates. Aggregates are mineral grains of natural products in the form of rock, which are naturally disintegrated or the result of crushing stones with a machine. Aggregates are grained materials such as gravel, crushed stone, and kiln slag, which are used [11]. The aggregate used is in accordance with the aggregate used with concrete in general according to the SNI (Indonesia National Standard) 1990.

2.1.1.1 Fine Aggregate. Fine aggregate in the manufacture of concrete is sand as a filler between the cavities in the concrete, with a grain size of 0.15 mm - 5 mm. The fine aggregate garage should conform to the specifications of SK SNI-04 1989[12]

2.1.1.2 Coarse Aggregate. Coarse aggregate is crushed stone which has grain sizes ranging from 5 mm - 40 mm. Coarse aggregate is required to be sharp grained, hard, eternal with various gradations. The coarse aggregate quality is good according to the standard SK SNI-04 1989 [12].

2.1.2 Binder. Precursors or also known as binders are the basic ingredients for forming polymers that contain high silica and alumina, produced through industrial use using products such as fly ash, GGBS, waste glass powder, silica fume, and rice husk ash, materials containing alumina and extra silica can be used. [1]

2.1.2.1 Fly Ash. Fly ash is a material that comes from solid waste that is produced from the rest of coal burning. Fly ash is categorized as hazardous waste. So that the use of fly ash as a substitute for cement
(binder/precursor) can be useful for saving the environment around us and able to reduce the use of Portland cement in concrete making applications. The following are the results of the Jepara PLTU fly ash test

**Table 2.1** test results for fly ash content [13]

| Parameter   | Unit       | Fly Ash Test Result |
|-------------|------------|---------------------|
| Specific gravity |          | 2.49                |
| SiO$_2$     | % weight  | 45.27               |
| Al$_2$O$_2$ | % weight  | 20.07               |
| Fe$_2$O$_3$ | % weight  | 10.59               |
| CaO         | % weight  | 13.32               |
| MgO         | % weight  | 2.83                |
| K$_2$O      | % weight  | 1.59                |
| Na$_2$O     | % weight  | 0.98                |
| P$_2$O$_5$  | % weight  | 0.41                |
| SO$_3$      | % weight  | 1.00                |
| MnO$_2$     | % weight  | 0.07                |

Source: The test results of PT Jaya Ready Mix fly ash by Sucofindo
From the table above it is known that fly ash from PLTU Jepara is included in Fly Ash type F with CaO content > 5% and a SiO$_2$ + Al$_2$O$_2$ + Fe$_2$O$_3$ content > 70% (ACI Manual of Concrete practice 1993 part 1 226.3R-3)

2.1.2.2 Rice Husk Ash. Rice husks are the skins for covering rice, where the rice husks which are coarse and thick have become quite a lot of waste in Indonesia. Rice husk ash has a silica content of up to 90%. One of the ways to use rice husk waste is to process it into the SCGC binder by burning the husks into ash.

**Table 2.2** Results of Rice Husk Ash Test Content [14]

| Composition of Rice Husk Ash | % Weight |
|------------------------------|----------|
| SiO$_2$                      | 86.90 – 97.30 |
| K$_2$O                       | 0.58 – 2.50  |
| Na$_2$O                      | 0.00 – 1.75  |
| CaO                          | 0.20 – 1.50  |
| MgO                          | 0.12 – 1.96  |
| Fe$_2$O$_3$                  | 0.00 – 0.54  |
| P$_2$O$_5$                   | 0.20 – 2.84  |
| SO$_3$                       | 0.10 – 1.13  |
| Cl                           | 0.00 – 0.42  |

2.1.3 Admixture. Admixture is an additional material in concrete that serves to modify the characteristics of concrete. Admixture is required so that the SCGC fresh concrete mixture meets the EFNARC Self Compacting Concrete workability criteria. There are several types of additives according to ASTM C 494 [15]. The added material (admixture) used for geopolymer concrete is the type F admixture, namely the superplasticizer, which functions to reduce the amount of mixing water to produce concrete with a certain consistency.

2.1.4 Alkali Activator. Activator is an added material that can increase the microbiological breakdown in the pile of organic matter. Alkali activates the precursors by dissolving them into the monomers [SiO$_4$] and [AlO$_4$]. The alkalis used are NaOH and Na$_2$SiO$_3$. NaOH functions as an activator
of the Al and Si elements contained in fly ash and rice husk ash so that it can produce strong polymer bonds. [16]
In this study using solid NaOH dissolved in water with a molarity of 14 M.
Na2SiO3 is used in the synthesis process to accelerate the geopolymerization reaction and at the same
time improve the mechanical properties of the geopolymer. When it reacts with water, sodium silicate
will form orthosilicic acid (Si(OH)4) and NaOH, so that it will supply soluble silica and OH- ions [17].

2.2 Mix Design Planning Method
The self-compacting concrete mix design method is a modification of the mix design method in general
combined with Okamura's simple mix design. By determining in advance the ratio of the amount of
coarse aggregate to fine aggregate. Self-compaction can be obtained by controlling the binder water
factor and superplasticizer dosage. The planning of a self-contained solid concrete mix design was
carried out using EFNARC (The European Federation of Specialist Construction Chemicals and
Concrete Systems) in 2005.
The specifications for self-compacting concrete (SCC) include:
(a) Coarse aggregate used is a maximum of 50% of the volume of solid aggregate.
(b) The volume of fine aggregate is determined to be only 40% - 55% of the total volume of mortar. (c)
The ratio of the volume of water to the binder is set between 0.85-1.1 depending on the nature of the
binder.
(d) The superplasticizer dosage and the air-binder factor are determined thereafter to obtain compaction
independently.

| Material     | Content Against Weight (Kg/m3) | Level of Volume (L/m3) |
|--------------|--------------------------------|------------------------|
| Binder       | 380-600                         | 150-210                |
| Water        | 150-210                         | 270-360                |
| Coarse       | 750-1000                        |                        |
| Aggregate    |                                 |                        |
| Fine Aggregate |                                | usage of 45%-55% from weight |
| Cement Water Factor | 0.3-0.55                   | 0.85-1.10              |

2.3 Tensile Strength
The tensile strength of concrete is the indirect tensile strength value of the cylindrical concrete specimen
obtained from the loading of the test object which is placed horizontally parallel to the surface of the
test machine presser table is pressed according to SNI 2002 concerning split tensile strength [18]. The
tensile strength test serves to evaluate the shear strength resistance of the structural components. The
split tensile strength calculation is calculated according to SNI 03-2491-2002.
The split tensile strength is calculated as follows:
Fct = 2P / (π.L.D)

Information :
fct = tensile strength (kg/cm2)
P = maximum test load (kg)
L = length of specimen (cm)
D = diameter or width of the specimen (cm)
2.4 Porosity
Concrete porosity is a level that describes the density of the mixture of concrete materials and is closely related to the permeability of concrete, namely the percentage of pores or spaces in concrete to the total volume of concrete or the size of the amount of empty space in a particular material and in this case is geopolymer. [19].
Concrete porosity testing aims to determine the amount/amount of pores contained in the concrete. The pores of the concrete are not completely closed by the cement paste. These pores are usually filled with air or contain water which are interconnected and are called concrete capillaries. The increase in the porosity value indicates that the concrete has a large enough pore due to the evaporation of water and the expansion of the concrete filling material. This is one of the causes of the decline in the quality of concrete in bearing loads, especially the ability of concrete to carry compressive loads. The formula for calculating porosity in this concrete uses the ASTM C 642-90 standard.
This concrete porosity test uses the ASTM C 642-90 standard. The formula for calculating porosity in concrete is as follows:
Porosity = \((C-A)/(C-D)\) x 100%
Information:
C : weight after immersion in air (gram)
A: weight after drying in oven in air (gram)
D: weight after boiling and immersing in water (gram)

3. Research Methodology

3.1 Material Preparation

3.1.1 Fly Ash. Fly ash used is type F obtained from PT. Jaya Mix

3.1.2 Rice Husk Ash. Rice husk ash used in this study was waste of rice husk ash from brick burning
- The husk ash that has been collected is then sieved using a sieve number 200, until the desired weight of rice husk ash is met.

3.1.3 Activator (NaOH 14 M and Na2SiO3). NaOH used in this study using solid NaOH / flakes
- Solid NaOH is weighed as much as 560 g for molarity of 14 M
- Mix the weighed NaOH into a measuring container and add distilled water up to 1L
- Let the NaOH solution stand 24 hours before use
- Na2SiO3 used liquid Na2SiO3 / water glass, which will later be mixed with dissolved NaOH.

3.1.4 Fine Aggregate. Examination of fine aggregate includes testing of sludge content, moisture content, specific gravity, organic matter content, and grain gradation

| Table 3.1 Fine Aggregate Testing Standards |
|-------------------------------------------|
| Material Test                             | Standards Used   |
| Sludge levels                             | SNI-1970-2008    |
| Water content                             | SNI-03-1968-1990 |
| Organic Substance Levels                  | SNI-1970-1992    |
| Bulk Specific Gravity (SSD)               | SNI-1970-2008    |
| Gradation                                 | SNI-03-1968-1990 |
| Modulus of Refinement                     | SNI-03-1968-1990 |

3.1.5 Coarse Aggregate. Coarse Aggregate Inspection, including grain grading, specific gravity, and abrasion
### Table 3.2 Coarse Aggregate Testing Standards

| Material Test               | Standards Used  |
|----------------------------|-----------------|
| Bulk Specific Gravity (SSD)| SNI-1970-2008   |
| Absorption                 | SNI-1970-2008   |
| Gradation                  | SNI-03-1968-1990|
| Modulus of Refinement      | SNI-03-1968-1990|

#### 3.2 Mix Design

The results of the calculation of material requirements for 4 test samples for split tensile strength and porosity of SCC concrete using the EFNARC 2005 method.

- The need for an activator for the test object requires a 1:1 ratio (NaOH: Na2SiO3) with a weight of 2.13 kg per 4 samples of split tensile strength and 4 samples of porosity
- The water requirement for each variation uses a constant of 3.48 L.
- Admixture requirements for each constant variation of 0.116 L.

### Table 3.3 Mix design calculations

| Percentage of rice husk ash (ASP) | 2. RH A | 3. FA | 4. Gravel | 5. Sand |
|----------------------------------|--------|------|----------|--------|
| 0 %                              | 0      | 7.73 | 18.01    | 21.34  |
| 5 %                              | 0.38   | 7.35 | 17.96    | 21.69  |
| 10 %                             | 0.77   | 6.96 | 17.94    | 21.63  |
| 15 %                             | 1.16   | 6.57 | 17.85    | 21.57  |

#### 3.3 Manufacture of Sample

- Manufacture of cylindrical tensile strength specimens (diameter 150 mm height 300 mm) and for cylindrical porosity (diameter 50.8 mm and height 50 mm)
- Variations in the proportion of rice husk ash used are 0%, 5%, 10%, and 15%
- Curing by leaving it at room temperature for 28 days
- Tensile strength and porosity testing at the age of 28 days

#### 3.4 Standards for testing tensile strength and porosity

The split tensile strength test uses the standard SNI 03-2491-2002 rules. The split tensile strength test uses the ASTM C 642-90 standard

### Table 3.4 Flow Table
4. Result and Discussion

4.1 Fine Aggregate Testing Result

The tests carried out include testing of sludge content, moisture content, organic matter content, specific gravity, and gradation. The test results are presented in Table 4.1.

| Material Test       | Result   | Standard | Information                                      |
|---------------------|----------|----------|--------------------------------------------------|
| Sludge levels       | 5.28 %   | < 5%     | Does not meet the requirements                   |
| Water content       | Light yellow | -       | The decrease in strength (0-10%)               |
| Organic Substance Levels | 2.86 % | 1-3%     | Fulfill the requirements                        |
| Bulk Specific Gravity (SSD) | 2.5 | 2.5-2.7 | Includes a normal fine aggregate                |
| Gradation           | 3.139    | 1.5-3.8  | Fulfill the requirements                        |
| Modulus of Refinement | Including | Region II | Can be used                                     |

4.2 Coarse Aggregate Testing Result

The tests carried out to include specific gravity testing and grading. The test results are presented in Table 4.2.

Table 4.2 Test Results for Coarse Aggregate Materials
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### Material Test Result

| Parameter                  | Result   | Standard | Information                                      |
|----------------------------|----------|----------|--------------------------------------------------|
| Abrasion                   | 21.77%   | < 27%    | Meets K225 quality concrete                      |
| Bulk Specific Gravity (SSD)| 2.51     | 2.5-2.7  | Includes normal coarse aggregate                 |
| Grading                    | 20 mm    | -        | Max size 20 mm                                   |
| Modulus of Refinement      | 6.73     | 3.00-8.00| Includes a normal coarse aggregate               |

#### 4.3 Rice Husk Ash Testing Result

The test carried out is a specific gravity test.

**Table 4.3 Density Testing Results of Rice Husk Ash**

| Parameter   | Results | Standard | Information           |
|-------------|---------|----------|-----------------------|
| Specific Gravity | 2.136   | 2.1-2.14 | Including normal rice husk ash |

#### 4.4 Tensile Strength

The split tensile strength test is carried out on concrete that has reached the age of 28 days. The results of the split tensile strength test are presented in the following Table 4.1.

**Table 4.1 Tensile Strength Test Results**

| Sample | Percentage   | Tensile Strength (MPa) |
|--------|--------------|-------------------------|
| 1      | 0%FA/ 0% ASP | 2.663                   |
| 2      | 100%FA/ 5% ASP | 0.759                |
| 3      | 95% FA/ 5% ASP | 0.945                |
| 4      | 90%FA/ 10% ASP | 1.061                |
| 5      | 85%FA/ 15% ASP | 0.905                |

To find out whether the variation of rice husk ash is significant or not, it can be done by using the F test. It was obtained that the F test value was 4.16 with an F table of 4.54 (F count > F table = not significant). The effect of rice husk ash variation was not significant on the tensile strength of concrete.

In the study the value of control concrete for split tensile strength with a variation of 0% rice husk ash of 0.759 MPa, in concrete with a variation of 10% rice husk ash, the average value of split tensile strength was 1.061 MPa (percentage increase of 28.64%).

![Figure 4.1 Tensile Strength Graphic](image-url)
The addition of rice husk ash in this study increased the split tensile strength although it was not significant and had a high enough reduction than normal concrete. The addition of 5% -15% rice husk ash increased from geopolymer concrete 0% rice husk ash. This is due to the content of Si and Al in rice husk ash, this polymer bond will be stronger and can influence the tensile strength of the geopolymer concrete. The high Si content will reduce Ca(OH)2 and produce calcium hydrate as an adhesive. When reacting with water, CaO in rice husk ash and fly ash will produce calcium hydroxide Ca(OH)2 and release heat. The Ca(OH)2 and SiO2 reaction will produce calcium silicate hydrate (CSH) which functions as an adhesive.

\[ \text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{heat} \]

\[ \text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O} \] [4]

The addition of rice husk ash substitution of more than 10% will reduce the split tensile strength value in the concrete, which should have the SiO2 content from fly ash and or rice husk ash reacting with Ca (OH) 2. The presence of too high a Si content in the geopolymer mortar causes Si to not react and results in a decrease in the value of compressive strength [2]. In addition, the amount of calcium hydroxide from the hydration reaction is less, so a lot of silica is deposited, and causes a decrease in the compressive strength of the geopolymer concrete [20]. This is because the CaO content in rice husk ash is in the range 0.2-1.5% and fly ash is in the range 13.32% lower than the cement content which has a CaO content of 62.91%. [21]. Although the SiO2 content in fly ash and rice husk ash was higher than cement. CaO also affects the formation of calcium hydrate (CSH) as an adhesive. [4]

The use of Na2SiO3 and NaOH and curing at room temperature also raises another thing, namely the hardened test object began to appear white flakes on the surface of the test object, after 28 days it was seen on the test object, that the higher the variety of rice husk ash, the less white spots that were caused on the test object. This is because the less silica and aluminate content, the more it reacts with OH where \( \text{HO-Si} \) binds with [\( \text{ALO}_4 \)] and reacts with Na to form Si-O-Al and releases NaOH. NaOH is what reacts again with air to form Na2CO3 and CaCO3 in the form of a white precipitate. And Na2 is a white powder that is reactive with water and CO2 in the air. The reaction with CO2 molecules occurs in the pores of the geopolymer by turning the needle-colored crystals white. [22]

![Figure 4.2 White spots on 28 days old specimen](image)

4.5 Porosity
To find out whether the variation of rice husk ash is significant or not, it can be done with the F test. The F test value was 4.45 and the F table was 4.54 (F count > F table = insignificant). The effect of rice husk ash variation was not significant on the porosity of the concrete. Porosity testing is carried out on concrete that has reached the age of 28 days. The results of the split tensile strength test are presented in the following Table.

| sample | percentage | Porosity (%) |
|--------|------------|--------------|
| 1      | 0%FA/ 0% RHA | 11.427       |
| 2      | 100%FA/ 5% RHA | 15.15       |
| 3      | 95% FA/ 5% RHA | 14.21       |
| 4      | 90%FA/ 10% RHA | 13.13       |
| 5      | 85%FA/ 15% RHA | 14.28       |
In the study, the value of non-geopolymer porosity control concrete was 11.427%. In concrete with a variation of 0% rice husk ash, the average porosity value was 15.15% (the percentage increase was 33.83%).

![Porosity Graph](image)

**Figure 4.3 Porosity Graph**

Variation 0% rice husk ash has high porosity, the addition of rice husk ash in the study lowers the porosity although it is not significant and has a high enough difference from normal concrete. The addition of 5%-15% rice husk ash decreased the porosity of the 0% geopolymer concrete rice husk ash. The use of fly ash and rice husk ash in this study has increased the value of porosity compared to concrete using cement. This occurs because the lack of bonding in the concrete with an activator is not the same as that of cement with water, so the pores are not completely closed, because the stronger the concrete bond, the smaller the pores will be. The Fe content of fly ash (10.59%) is higher than the Fe content in cement (3-8%) [13]. Fe content also affects the formation of bonds in geopolymer concrete, the presence of FeO3 reaction to air forms Fe(OH)2 which produces air bubbles during the stirring time, if the hardening gets faster, the air bubbles have no chance to escape which causes trapping of air in the concrete so that concrete tends to be hollow [17]. From the porosity test results, it can be seen that the more the rice husk ash content, causing the porosity value to also decrease, because the higher the Si-Al bond, the stronger the bond, the more the rice husk ash content increases the binding time on the paste [23]. If the addition of rice husk ash of more than 10% causes the percentage of porosity to increase, this is because the Si content is too high which causes Si to not react and reduces the bond in geopolymer concrete [24].

5. Conclusion

- Variation of rice husk ash as a substitute for partial substitution of Fly Ash in geopolymer concrete did not have a significant effect on split tensile strength and porosity.
- The optimum variation of rice husk ash was 10% for the split tensile strength and porosity of the geopolymer concrete, the maximum tensile strength was 1.061 MPa and the minimum porosity was 13.33%.

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