Application of rice husk ash in high strength concrete

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Abstract. Rice husk ash waste would cause dangerous environmental problems in soil and air. One of the solutions to overcome the environmental impact of rice husk ash is by processing it into a partial substitute for cement. The purpose of this study was to analyze the compressive strength of high strength concrete. The method used was experimental research by utilizing rice husk ash as a cement substitute in concrete with a percentage of 0%, 5%, 10%, 15%, 20%, and the addition of superplasticizer. The test object was made with a diameter of 10 cm and a height of 20 cm. The test object was treated using clean water. The strength of concrete with rice husk ash as a cement substitute was tested based on absorption and compressive strength of concrete on day 7 and day 28. Thus, the optimum compressive strength was obtained in the variation of 10% rice husk ash as the cement substitution. Based on this study, the highest average compressive strength was found in concrete with a variation of 10% rice husk ash, which was 38.5 MPa at 7 days and 56.2 MPa at 28 days.

1. Introduction

Rice husk ash waste causes dangerous environmental problems in the soil and air. One solution to overcome the environmental impact of rice husk ash is by processing rice husk ash waste into a partial substitute for cement, which will reduce the substance in the amount of carbon dioxide (CO₂) emitted annually in the atmosphere [1].

Hutanabolon Village, Tukka District, Central Tapanuli Regency is one of the places that has many rice fields, and most villagers work as rice farmers. The farmers harvest their rice twice a year. The rice field area is approximately 335 ha, and rice production is around 1320 tonnes/ha. The rice is then brought to a rice mill or refinery that produces rice and leaves about 110,550 tonnes/ha of rice husks in a year (Central Bureau of Statistics of Central Tapanuli Regency). After rice husk is burned, it will produce rice husk ash. Burning rice husk becomes a source of silica reaching 80-95% while burning 1 kg of rice husk produces 150 gr of rice husk ash. Therefore, it is necessary to use rice husk ash waste to reduce its impact on the environment. Hence, the authors conducted a study using rice husk ash mixed in concrete to produce economical and environmentally friendly concrete.

Rice husk ash is the result of the remaining rice husk burning. During the process of converting rice husk to ash, the burning process removes organic substances and leaves a burning residue that is rich in silica (SiO₂). In addition, rice husk ash has many benefits, one of which is to increase the strength of
concrete because rice husk ash has pozzolan properties [2].

2. Literature review

2.1 High strength concrete

High strength concrete is concrete that has a greater compressive strength equal to 41.4 MPa. The strength of concrete can be increased by adding additional materials or changing materials in the concrete mixture. One of the influencing factors to obtain high strength concrete is the gradation of coarse aggregates. If the aggregate gradation has a smaller size and varies in size, the pores in the concrete become smaller because the smaller grains will fill the holes or voids between the larger aggregates [3].

Production of high strength concrete requires suppliers to optimize three aspects that affect the strength of concrete, namely cement paste, aggregates and adhesion of cement to aggregate. These aspects need to be considered in all aspects of production, such as material selection, mix design handling, and pouring. Quality control is also an important part, which requires full cooperation between suppliers, planners, and contractors [4].

2.2 Superplasticizer

Superplasticizer is an additive to concrete that can increase the workability of concrete. The addition of this additive to the concrete mixture has been proven to improve concrete performance in almost all aspects, such as strength, ease of production, durability, and other performances in meeting the demands of modern technology so that the compressive strength of concrete is high. In addition, superplasticizer has a big influence on increasing workability [5].

2.3 Rice husk ash

Rice husk is the waste from rice mills where the husk produced is the second largest part after rice. Rice husks are usually burned around rice mills, and the burning will result in the form of rice husk ash. The rice husks used in this study were dry rice husks. The rice husk is the outermost part of the rice grain when the rice milling process is carried out. The hard layer covering the caryopsis consists of two halves, namely lemma and palea, which are linked together. The process of milling rice will obtain about 20-30% of husk and around 50-63.5% of bran and milled rice from the initial weight of grain (Agricultural Research and Development Agency). Rice husk density is relatively small, with about 122 kg/m$^3$, 8-10 mm long, 2-3 mm wide, and 0.2 mm thick [6]. Various chemical compositions of rice husk ash are caused by rice types, differences in soil types, harvest years, burning temperatures, cooling methods, and geographical conditions [7].
Rice husk ash is the remaining result of rice husk burning. During the burning process, the rice husk ash contains about 85–95% silica, most of which is amorphous. Rice husk ash has many benefits, one of which is to increase the strength of the concrete because rice husk ash has pozzolanic properties and has a relatively high content of amorphous silica. Several ways can be done to obtain concrete with high compressive strength, including the constituent components that need to be considered [8].

| No. | Parameter                  | Unit | Result | Method   |
|-----|----------------------------|------|--------|----------|
| 1   | Silica (SiO₂)              | %    | 90.2   | Gravimetry |
| 2   | Iron Oxide (Fe₂O₃)         | %    | 0.10   | AAS      |
| 3   | Calcium Oxide (CaO)        | %    | 2.27   | Titrimetric |
| 4   | Potassium Oxide (K₂O)      | %    | 0.34   | ASS      |

3. Research methods

3.1. Mix design planning

In this study, rice husk ash was used as a cement substitution in concrete with a percentage of 0%, 5%, 10%, 15%, 20%, and the addition of a superplasticizer. The following table depicts a comparison of the material composition and the total material requirements needed to make all test objects.

|                    | Cement (kg) | Gravel (kg) | Sand (kg) | Water (kg) | HRWR (l) |
|--------------------|-------------|-------------|-----------|------------|----------|
| 1                   | 682.519     | 990.932     | 538.793   | 197.931    | 4.095    |
| 1.45               | 1.45        | 0.79        | 0.29      | 0.006      |

The table below shows the material requirements for normal concrete and concrete with variations of rice husk ash.
Table 3. Requirements of material for normal concrete and concrete variations of rice husk ash waste

| Material         | Variations of Rice Husk Ash | Unit |
|------------------|-----------------------------|------|
|                  | 0%    | 5%   | 10%  | 15%  | 20%  |
| Cement           | 7.381 | 7.012| 6.643| 6.274| 5.91 |
| Sand             | 7.33  | 6.901| 6.901| 6.901| 6.901|
| Gravel           | 10.17 | 11.20| 11.20| 11.20| 11.20|
| Rice Husk Ash    | 0     | 0.369| 0.738| 1.107| 1.476|
| Superplasticizer | 0.046 | 0.046| 0.046| 0.046| 0.046|
| Water            | 2.14  | 2.237| 2.237| 2.237| 2.237|

3.2. Making test objects

The test objects were made with a diameter of 10 cm and a height of 20 cm. The test objects were treated using clean water.

3.3. Testing phase

The testing phase consisted of testing the absorption of concrete and the compressive strength of the test objects at 7 days and 28 days.

4. Results and discussions

4.1. Results of absorption test at 7 days and 28 days

The results of the absorption test on the concrete at 7 days can be seen in the following table.

Table 4. Absorption test of concrete at 7 days

| Variation | Sample Name | Absorption (%) | Mean (%) |
|-----------|-------------|----------------|----------|
| Normal    | Bn-1        | 1.509          |          |
|           | Bn-2        | 1.354          | 1.441    |
|           | Bn-3        | 1.461          |          |
|           | B5-1        | 1.431          |          |
| 5%        | B5-2        | 1.447          | 1.403    |
|           | B5-3        | 1.331          |          |
|           | B10-1       | 1.347          |          |
| 10%       | B10-2       | 1.266          | 1.297    |
|           | B10-3       | 1.277          |          |
|           | B15-1       | 0.997          |          |
| 15%       | B15-2       | 1.184          | 1.065    |
|           | B15-3       | 1.084          |          |
|           | B20-1       | 1.320          |          |
| 20%       | B20-2       | 0.582          | 0.932    |
|           | B20-3       | 0.892          |          |

The results of the absorption test on the concrete at 28 days can be seen in the table below.
Table 5. Absorption test of concrete at 28 days

| Variation | Sample Name | Absorption (%) | Mean (%) |
|-----------|-------------|----------------|----------|
| Normal    | Bn-1        | 1.432          |          |
|           | Bn-2        | 1.351          | 1.422    |
|           | Bn-3        | 1.485          |          |
|           | B5-1        | 1.474          |          |
| 5%        | B5-2        | 1.446          | 1.470    |
|           | B5-3        | 1.490          |          |
|           | B10-1       | 1.233          |          |
| 10%       | B10-2       | 1.324          | 1.276    |
|           | B10-3       | 1.270          |          |
|           | B15-1       | 1.053          |          |
| 15%       | B15-2       | 1.133          | 1.104    |
|           | B15-3       | 1.125          |          |
|           | B20-1       | 1.015          |          |
| 20%       | B20-2       | 0.882          | 0.907    |
|           | B20-3       | 0.826          |          |

4.2. Results of compressive strength of concrete

The results of the compressive strength test on concrete at 7 days are shown in the following table.

Table 6. Compressive strength test of concrete at 7 days

| Variation | Sample Name | Compressive Strength (Mpa) | Mean (Mpa) |
|-----------|-------------|----------------------------|------------|
| Normal    | Bn-1        | 33.8                       | 33.97      |
|           | Bn-2        | 32                         |            |
|           | Bn-3        | 36.1                       |            |
|           | B5-1        | 34.2                       |            |
| 5%        | B5-2        | 35.1                       | 34.27      |
|           | B5-3        | 33.5                       |            |
|           | B10-1       | 39.6                       |            |
| 10%       | B10-2       | 35.6                       | 38.50      |
|           | B10-3       | 40.3                       |            |
|           | B15-1       | 31.2                       |            |
| 15%       | B15-2       | 34.7                       | 32.70      |
|           | B15-3       | 32.2                       |            |
| 20%       | B20-1       | 31.6                       |            |
|           | B20-2       | 28.61                      | 28.64      |
|           | B20-3       | 25.7                       |            |

The results of compressive strength on concrete at 28 days can be seen in the table below.
### Table 7. Compressive strength results of concrete at 28 days

| Variation | Sample Name | Compressive Strength (Mpa) | Mean (Mpa) |
|-----------|-------------|----------------------------|------------|
| Normal    | Bn-1        | 44.4                       | 44.83      |
|           | Bn-2        | 43.5                       |            |
|           | Bn-3        | 46.6                       |            |
|           | B5-1        | 51.4                       | 51.53      |
| 5%        | B5-2        | 49.9                       |            |
|           | B5-3        | 53.3                       |            |
|           | B10-1       | 55.6                       | 56.20      |
| 10%       | B10-2       | 55.3                       |            |
|           | B10-3       | 57.7                       |            |
|           | B15-1       | 49.4                       |            |
| 15%       | B15-2       | 44.9                       | 45.63      |
|           | B15-3       | 42.6                       |            |
|           | B20-1       | 35.6                       |            |
| 20%       | B20-2       | 35.2                       | 32.30      |
|           | B20-3       | 26.1                       |            |

### 4.3. Discussions

The comparison of absorption of concrete at 7 days and 28 days is shown in the following graph.

![Figure 2](image)

**Figure 2.** Graph comparing mean absorption of concrete at 7 days and 28 days, with variations of rice husk ash of 0%, 5%, 10%, 15%, 20% as the cement substitute.

Based on Figure 2, it can be seen that the absorption value of concrete at 7 days and 28 days had nearly the same pattern. However, the absorption at 28 days had a higher percentage than concrete at 7 days, where the maximum absorption occurred at a 5% variation, whereas the minimum absorption occurred at a 20% variation. The following graph compares the compressive strength of concrete at 7 days and 28 days.
Figure 3. Graph comparing the mean compressive strength of concrete at 7 days and 28 days, with variations of rice husk ash of 0%, 5%, 10%, 15%, 20% as the cement substitute.

Based on figure 3, it can be seen that the greatest compressive strength in concrete at 7 days was 38.50 MPa at 10% variation, while the lowest compressive strength was 28.64% at 20% variation. The strength continued to improve until the concrete was 28 days, where the strength of concrete with a variation of 10% rice husk ash and 0.6% superplasticizer became 56.20 MPa, whereas the concrete with a variation of 20% rice husk ash waste became the lowest with 32.30 MPa.

Based on the present study, the addition of rice husk ash as a cement substitute can increase the compressive strength of high strength concrete at a 10% variation where the compressive strength increase was 25.36% compared to the 0% variation. This is obtained from the content of rice husk ash, which was similar to cement and the function of rice husk ash as a pozzolan. Rice husk ash has been used as a highly reactive pozzolanic material to improve the microstructure at the interface transition area between cement paste and high strength concrete aggregate. The physical properties of rice husk ash waste, which is smooth and contains adequately high silica can close the pores of the concrete and can improve the concrete strength [9].

5. Conclusions

Based on the study that has been done and results and discussion that has been presented, it can be concluded that:

1. The mean compressive strength values in concrete at 7 days after the compressive test on the variation of 0%, 5%, 10%, 15% and 20% rice husk ash were 33.97 MPa, 34.27 MPa, 38.50 MPa, 32.70 MPa, and 28.64 MPa respectively, whereas the mean compressive strength values in concrete at 28 days were 44.83 MPa, 51.53 MPa, 56.20 MPa, 45.63 MPa, and 32.30 MPa, respectively.

2. The highest mean compressive strength in concrete at 28 days was found in the variation of 10% of rice husk ash with 56.20 MPa. Thus, the optimum compressive strength was obtained in the variation of 10% rice husk ash as the cement substitution.

3. Based on the present study, the minimum absorption value was 0.932% for the 20% variation, while the maximum absorption value was 1.441% for normal concrete. Therefore, there was a decrease of 35.32% for concrete at 7 days. Meanwhile, the minimum absorption value for concrete at 28 days was 0.907% for the 20% variation, and the maximum absorption value was...
1.470% for normal concrete. The pattern was similar, and the values are not much difference between the absorption of concrete at 7 days and 28 days.

4. Based on the slump test, the slump obtained from normal concrete was 12.7 cm while concrete with a variation of 5%, 10%, 15%, and 20% rice husk ash obtained 11.5 cm, 10.8 cm, 9.5 cm, and 8 cm, respectively. It can be concluded that the slump value decreased with the addition of rice husk ash.

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