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# UTILIZATION OF POWER PLANT AND AGRICULTURAL WASTE AS A CEMENT SUBSTITUTE ON THE COMPRESSIVE STRENGTH OF ENVIRONMENTALLY FRIENDLY CONCRETE

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**ABSTRACT**

This study aims to assess the effect of using Fly Ash and Rice Husk Ash as cement substitutes in the manufacture of environmentally friendly concrete. Fly Ash, a waste from coal-fired power plants, and Rice Husk Ash, an agricultural waste, were used as partial cement substitutes in four concrete mix variations, viz: normal concrete without substitution (N), concrete with 20% Fly Ash (K), concrete with a combination of 10% Fly Ash and 10% Rice Husk Ash (L), and concrete with 20% Rice Husk Ash (M). The compressive strength test was conducted at the age of 7 days, 14 days, and 28 days. The results showed that concrete with 20% Fly Ash (K) produced the most optimal compressive strength, especially at longer concrete ages. Concrete with Rice Husk Ash substitution (M) and a combination of Fly Ash and Rice Husk Ash (L) showed lower compressive strength than normal concrete (N) and Fly Ash alone. Therefore, the use of Fly Ash at 20% gave the best compressive strength results among the variations tested.

***Keyword:*** *Cement Substitution, Compressive Strength, Eco-friendly concrete, Fly Ash, Rice Husk Ash.*

## 1. INTRODUCTION

Ketapang Regency, located in West Kalimantan Province, displays great economic potential through its industrial and agricultural sectors. However, waste management constraints from these two main sectors, namely the PLTU industry and agriculture, pose serious impacts if not addressed effectively. The Steam Power Plant (PLTU) in Ketapang Regency uses coal as the main energy source. Under current conditions, the power system in Ketapang Regency has a capacity of 26 MW, with peak load reaching 31 MW. To achieve an additional capacity of 1 MW, a coal supply of 4000 tons is required [1].

The process of burning coal in power plants produces fly ash as a by-product that causes significant environmental impacts. Fly ash accumulated in landfills can contaminate soil, water and air [2]. The heavy metal content in fly ash can poison soil and water, disrupt local ecosystems, and endanger human and animal health [3]. Overfilling fly ash can damage local ecosystems, including forests and agricultural land [4]. Affected plants and animals may suffer damage or even extinction [5]. Airborne fly ash dust can pose a serious threat to public health, increasing the risk of respiratory diseases, such as asthma and bronchitis, and other health problems [6].

The agricultural sector, particularly through rice processing, also contributes significant waste, namely rice husks. This waste is often not utilized efficiently, causing environmental impacts. Stockpiling rice husks in open fields can cause soil degradation and reduce fertility [7]. In addition, open burning can also cause forest and land fires, threatening environmental sustainability [8]. Conventional concrete manufacturing that uses Portland cement as the main ingredient has significant impacts on the environment, including natural resource degradation and greenhouse gas emissions [9]. Therefore, research on waste utilization for environmentally friendly concrete is becoming increasingly important. In this context, fly ash and rice husk ash emerge as promising potential replacements. Fly ash, which is waste from coal-fired power plants, and rice husk ash, which is agricultural waste, have attracted attention as partial cement replacement materials in concrete production. Their potential to improve the mechanical performance of concrete while reducing the environmental impact of its production suggests the need for further research. However, the utilization of wastes in concrete also faces technical, regulatory, and market acceptance challenges. Therefore, further research is needed to understand the full impact of using fly ash and rice husk ash in concrete. As such, this research will provide valuable insights in the drive towards a more sustainable and environmentally friendly construction industry.

In this study, coal combustion and industrial waste will be utilized as a substitute for concrete adhesives. The commonly used concrete adhesive is cement. The problem-solving approach for the utilization of waste in environmentally friendly concrete with a focus on the use of fly ash and rice husk ash as cement substitutes requires a series of steps. First, identifying wastes from sources such as coal-fired power plants and agricultural industries to determine their potential use. Then, determining the appropriate treatment method to prepare the waste for use in concrete mixes. After that, laboratory testing is conducted to evaluate the performance of the resulting concrete, including its strength and durability. Economic analysis is required to assess the feasibility of using the waste, while environmental analysis is important to account for the environmental impact of its use [10]. The results of this study can be used to develop guidelines and recommendations for the construction industry, concrete producers, and the government in encouraging the use of waste as raw materials in environmentally friendly concrete. Thus, this approach is expected to accelerate the adoption of sustainable technologies in the construction industry, support environmental sustainability, and reduce negative environmental impacts.

The utilization of waste into concrete mixtures has been carried out by several researchers. The types of waste utilized also vary. Some of the research that has been done is by utilizing construction and industrial waste. Construction waste that can be utilized in the form of roof tiles as coarse aggregate [11]. Further research utilizes gypsum board waste and red bricks as cement substitutes [12]. In the industrial sector, the utilization of waste such as oyster shells as fine aggregate was found [13]. In addition, there is also research on the utilization of carbide waste and fly ash as a BSP mixture [14]. The novelty of this research is to combine fly ash waste and rice husk as a cement substitute.

Based on the background, the problem formulations that will be discussed in this study are: 1) What is the most optimal percentage of fly ash and rice husk substitution in terms of concrete compressive strength? 2) How does the compressive strength of concrete change with the substitution of fly ash and rice husk waste at the age of 7 days, 14 days and 56 days?

## 2. RESEARCH METHOD

This study used laboratory experimental method to examine the effect of using Fly Ash and Rice Husk Ash as cement replacement on the compressive strength of concrete. This research uses an experimental approach carried out in the laboratory.

1. Preparation of Materials and Equipment
   a. Materials: The concrete used in this study is made using Portland cement, fine aggregate (sand), coarse aggregate (gravel), and water with a certain mix ratio. All materials used will be tested first to ensure their quality and consistency.
   b. Equipment: The compressive strength test equipment used is a calibrated compression testing machine. Other equipment used includes concrete molds in the form of cubes or cylinders, concrete mixers, scales, and other measuring devices.

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2. Preparation of Concrete Samples
   a. Mixing: The concrete mix was made according to the predetermined ratio. The mixing process was carried out using a concrete mixer to ensure homogeneity of the mixture. The research was conducted by making several variations of concrete mixes using Fly Ash and Rice Husk Ash in different proportions as partial cement substitutes. The materials used in this study include Type I Portland Cement, Fly Ash class F (from PLTU waste), Rice Husk Ash (ASP), coarse aggregate (gravel), fine aggregate (sand), and clean water. The concrete mix variations and the number of samples used in this study are as follows: N variation with 0% Fly Ash and 0% ASP (9 samples), K variation with 20% Fly Ash and 0% ASP (9 samples), L variation with 10% Fly Ash and 10% ASP (9 samples), and M variation with 0% Fly Ash and 20% ASP (9 samples).
   b. Casting and Compaction: Fresh concrete is poured into cube or cylinder molds (depending on the testing standard used) and compacted to remove trapped air.
   c. Curing: Once the concrete is cast, these samples are kept under controlled curing conditions, by immersing them in water or keeping them in a humid room, to ensure optimal hydration process. The curing conditions were chosen to ensure optimal hydration by immersing the samples in water. The use of fly ash and rice husk as additives was chosen to observe their effect on the final strength of concrete, as fly ash is often used to improve long-term strength and rice husk as an environmentally friendly alternative material.

3. Compressive Strength Testing
   The compressive strength test was conducted in accordance with ASTM C39/C39M standards using a compressive testing machine. The test steps are as follows: taking concrete samples after a predetermined curing period, measuring the dimensions and weight of the concrete samples, placing the concrete samples on a compressive testing machine and applying a load until the samples are crushed, recording the maximum load value received by the samples before crushing, and calculating the compressive strength of the concrete using the formula:

$$\text{Compressive Strength (f'c)} = \frac{Maximum\ Load\ (P)}{Cross-sectional\ Area\ (A)} \tag{1}$$

   *Source: (Sumber: SNI 03-2847-2002)*

   a. Tests at 7 Days of Age: Concrete samples were tested at 7 days of age to obtain the initial compressive strength value. These results are then used to calculate conversion values to 14 days and 28 days of age.
   b. Testing at 14 Days of Age: Different samples were tested at 14 days of age. The results of this test are used to make the conversion values to 28 days of age and are also compared with the conversion results of the 7-day test.
   c. Test at 28 Days of Age: The last sample was tested at 28 days of age, which is considered the standard for determining the compressive strength of concrete. These results are compared with the conversion values calculated from the 7-day and 14-day test results

5. Data Analysis
   Data from the concrete compressive strength test results were analyzed to identify the effect of variations in the proportion of Fly Ash and Rice Husk Ash on concrete compressive strength, the percentage of cement replacement that produces optimal concrete compressive strength, and the comparison of concrete compressive strength with and without cement replacement (control). Based on the data analysis, conclusions will be drawn regarding the effect of using Fly Ash and Rice Husk Ash as cement replacement on the compressive strength of environmentally friendly concrete. Conclusions will also include recommendations for the optimal proportions for the use of Fly Ash and Rice Husk Ash in concrete.

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## 4. RESULTS AND DISCUSSION

### 4.1. Concrete Compressive Strength Test Results

The results of concrete compressive strength testing for mix variations N (normal concrete), K (20% Fly Ash), L (10% Fly Ash and 10% Rice Husk Ash), and M (20% Rice Husk Ash) at 7, 14, and 28 days of age are presented in the following tables. Each variation was tested using 3 samples at each concrete age in Table 1, Table 2, and Table 3.

**Table 1.** Results of 7-Day Concrete Compressive Strength Test

| Variations | Sample | 7-Day Compressive Strength (kg/cm$^2$) |
|---|---|---|
| N | N1 | 183,55 |
| | N2 | 185,36 |
| | N3 | 184,45 |
| K | K1 | 150,46 |
| | K2 | 141,85 |
| | K3 | 144,57 |
| L | L1 | 82,48 |
| | L2 | 87,47 |
| | L3 | 84,30 |
| M | M1 | 68,43 |
| | M2 | 65,71 |
| | M3 | 68,43 |

Source: Observation Results, 2024

**Table 2.** Results of 14-Day Concrete Compressive Strength Test

| Variations | Sample | 14-Day Compressive Strength (kg/cm$^2$) |
|---|---|---|
| N | N4 | 251,07 |
| | N5 | 253,79 |
| | N6 | 252,43 |
| K | K4 | 206,21 |
| | K5 | 194,42 |
| | K6 | 198,05 |
| L | L4 | 112,85 |
| | L5 | 119,64 |
| | L6 | 115,57 |
| M | M4 | 89,73 |
| | M5 | 93,81 |
| | M6 | 68,43 |

Source: Observation Results, 2024

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**Table 3.** Results of 28-Day Concrete Compressive Strength Test

| Variations | Sample | 28-Day Compressive Strength (kg/cm$^2$) |
|---|---|---|
| N | N7 | 121,00 |
| | N8 | 128,71 |
| | N9 | 122,36 |
| K | K7 | 234,76 |
| | K8 | 235,66 |
| | K9 | 236,12 |
| L | L7 | 206,21 |
| | L8 | 199,86 |
| | L9 | 201,67 |
| M | M7 | 144,12 |
| | M8 | 132,79 |
| | M9 | 140,49 |

Source: Observation Results, 2024

From the test results at 7 days, normal concrete (N) had the highest compressive strength, with an average of 184.45 kg/cm², while mixtures with Fly Ash and Rice Husk Ash showed lower values. At 14 days, all variations showed a significant increase in compressive strength, especially the normal concrete and variation K (with 20% Fly Ash), which reached average values above 194 kg/cm². Concrete at 28 days also showed an increasing trend in compressive strength with variation K producing the highest value of 235.66 kg/cm², while the variation with Rice Husk Ash (M) produced a lower compressive strength than the others.

### 4.2. Effect of Fly Ash and Rice Husk Ash

The use of Fly Ash and Rice Husk Ash as a partial replacement of cement in concrete mixes has a significant effect on the compressive strength of concrete at various ages. Based on the test data, it can be seen that the mix variation with Fly Ash (K) and the combination of Fly Ash and Rice Husk Ash (L) have different compressive strength than normal concrete (N).

In variation K, with the use of 20% Fly Ash as a cement replacement, it can be seen that the compressive strength at 7 days is lower than normal concrete, with an average of 145.63 kg/cm² compared to 184.45 kg/cm² in normal concrete. This could be due to the pozzolanic nature of Fly Ash, which tends to react more slowly with calcium hydroxide in the cement paste, resulting in lower initial strength of the concrete. However, at 28 days, the K variation showed a significant increase, reaching an average compressive strength of 235.66 kg/cm². This indicates that the use of Fly Ash is effective over a longer period of time, where its pozzolanic reaction contributes to the formation of additional compounds that increase the strength of the concrete.

For variation M, which uses 20% rice husk ash instead of cement, the effect on compressive strength tends to decrease the strength compared to normal concrete. At 7 days, the compressive strength of variation M was at an average of 67.52 kg/cm², lower than the normal concrete and the other mixes. However, the compressive strength at 28 days increased to 140.49 kg/cm². This decrease in compressive strength is likely due to the larger particle size and lower fineness of Rice Husk Ash compared to Fly Ash, which affects the ability of this material to interact with the cement paste.

Variation L, which used a combination of 10% Fly Ash and 10% Rice Husk Ash, showed quite interesting results. The compressive strength at 7 days was relatively low (84.30 kg/cm²), but at 28 days, the compressive strength increased to 201.67 kg/cm². This combination shows that although the initial

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strength is not as great as normal concrete, the use of these two waste materials together can provide an increase in strength as the concrete ages. The pozzolanic reaction of Fly Ash and the silica content of Rice Husk Ash slowly form compounds that increase the strength of the concrete in the long term.

Overall, partial replacement of cement with Fly Ash and Rice Husk Ash produced concrete with varying compressive strengths depending on the age of the concrete. Fly Ash tended to be more effective in increasing strength at longer concrete ages, while Rice Husk Ash made a more limited contribution to compressive strength. The combination of the two gave better results than the use of either ingredient individually, although it remained below the performance of normal concrete.

### 4.3. Comparison of Concrete Compressive Strength at 7, 14, and 28 Days of Age

Concrete compressive strength testing was conducted at three time points, namely at 7 days, 14 days, and 28 days, for each concrete mix variation. The purpose of this test was to see the development of concrete strength over time and compare the results between the mix variations with normal concrete (N).

A. Compressive Strength at 7 Days of Age

At 7 days of age, the compressive strength test results showed that the normal mix concrete (N) had the highest strength compared to the other variations, with an average value of 184.45 kg/cm². In variation K, the use of 20% Fly Ash resulted in a lower compressive strength of 145.63 kg/cm². Concrete with a combination of Fly Ash and Rice Husk Ash (L) and Rice Husk Ash alone (M) showed lower compressive strength values of 84.30 kg/cm² and 67.52 kg/cm², respectively. These results indicate that concrete with partial cement replacement tends to have lower early strength than normal concrete.

B. Compressive Strength at 14 Days

At 14 days, all mix variations experienced an increase in strength. Normal concrete (N) continued to have the highest compressive strength, with an average value of 252.43 kg/cm². The K variation experienced a significant increase to 199.56 kg/cm², indicating that the Fly Ash pozzolanic reaction started to be more active during this period. The L and M variations also showed an increase, reaching 115.57 kg/cm² and 92.45 kg/cm² respectively, but still lower than normal concrete and the K variation.

C. Compressive Strength at 28 Days

At 28 days, all concrete mix variations reached their optimum strength. Normal concrete (N) achieved an average compressive strength of 236.12 kg/cm². In the K variation, the compressive strength value increased further to reach 235.66 kg/cm², which is almost equivalent to normal concrete. This shows that at 28 days of age, Fly Ash as a partial replacement for cement gives very good results. For variations L and M, the compressive strength values also increased, to 201.67 kg/cm² and 140.49 kg/cm² respectively. However, these two variations were still unable to achieve strengths equivalent to normal concrete.

From the results of this comparison, it can be concluded that concrete with Fly Ash (K) admixture showed significant strength development from 7 to 28 days of age, making it suitable for use in concrete that requires long-term strength. Meanwhile, the use of Rice Husk Ash (M) and the combination of Fly Ash and Rice Husk Ash (L) resulted in lower strengths at all ages, indicating that these materials are more suitable for applications that do not require high strength.

### 4.4. Optimizing the Use of Fly Ash and Rice Husk Ash as Cement Substitutes

The results showed that the use of Fly Ash and Rice Husk Ash as a substitute for cement had a varying effect on the compressive strength of concrete at various ages. Therefore, it is necessary to conduct further analysis to determine the most optimal mix composition in producing environmentally friendly concrete that has compressive strength according to standards.

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A. Use of Fly Ash (K)

The use of Fly Ash at 20% as a substitute for cement in variation K proved to give quite good results, especially at the age of 28 days. The resulting compressive strength was almost equivalent to normal concrete (N), indicating that Fly Ash can act as a partial replacement for cement without significantly reducing the strength of the concrete. This is due to the pozzolanic properties of Fly Ash which, although slowing down the development of the initial strength of the concrete, makes a significant contribution to the longer life of the concrete. Thus, the use of Fly Ash can be considered optimal at 20% for applications requiring long-term high-strength concrete.

B. Use of Rice Husk Ash (M)

In variation M, the use of Rice Husk Ash as a 20% cement replacement showed unsatisfactory results, with a much lower compressive strength than normal concrete. Although there was an increase in strength at 28 days, it was still lower than the concrete mix with Fly Ash. This suggests that the use of Rice Husk Ash as a full replacement for cement does not provide optimal results in terms of compressive strength. Rice Husk Ash may be more suitable to be used in lower percentages, or in combination with other cement replacement materials, such as Fly Ash.

C. Fly Ash and Rice Husk Ash Combination (L)

Variation L, which used a combination of 10% Fly Ash and 10% Rice Husk Ash, produced better strength than variation M, but was still lower than normal concrete and variation K. The combination of these two materials gave more optimal results than the use of Rice Husk Ash alone, but was not able to achieve the performance of concrete with Fly Ash alone. This shows that the combination of Fly Ash and Rice Husk Ash can be a good alternative, but it is necessary to reduce the content of Rice Husk Ash or increase the content of Fly Ash to achieve more optimal results.

D. Composition Optimization

From the results obtained, it can be concluded that Fly Ash has greater potential as a partial cement replacement than Rice Husk Ash, especially in concrete applications with high strength requirements. Optimization of the mix composition can be done by considering the use of Fly Ash in a higher percentage, or a combination of Fly Ash and Rice Husk Ash with reduced levels of Rice Husk Ash. In addition, it is also necessary to conduct trials with additional variations of replacement content to obtain a more balanced mix between strength and environmental friendliness.

## 5. CONCLUSIONS

This study aims to examine the effect of using Fly Ash and Rice Husk Ash as cement substitutes on the compressive strength of environmentally friendly concrete. Based on the research results, it can be concluded as follows:

### 5.1. Most Optimal Fly Ash and Rice Husk Ash Substitution Percentage

Fly Ash substitution of 20% (variation K) produced the most optimal concrete compressive strength compared to the other variations. Fly Ash shows potential as an effective partial cement replacement material, especially at longer concrete ages. Meanwhile, Rice Husk Ash substitution of 20% (variation M) and combination of Fly Ash 10% and Rice Husk Ash 10% (variation L) gave lower results than normal concrete (N) and Fly Ash alone. Therefore, Fly Ash substitution of 20% is the most optimal in terms of concrete compressive strength.

### 5.2. Changes in Concrete Compressive Strength Values at 7, 14, and 28 Days of Age

The compressive strength of concrete increased with age. At 7 days, variation K with 20% Fly Ash showed lower strength than normal concrete, but at 28 days, this variation was close to the compressive

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strength of normal concrete. This indicates that Fly Ash provides increased strength at longer concrete ages. In contrast, concrete with Rice Husk Ash (variation M) and a combination of Fly Ash and Rice Husk Ash (variation L) showed lower compressive strength values at all ages compared to normal concrete and concrete with Fly Ash alone.

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