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Optimization of Normal Concrete Mixture with the Addition of Fiberglass and Rice Husk Ash

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ABSTRACT

This study aims to determine the effect of using fiberglass and rice husk ash waste in making normal concrete. The variations of fiberglass used are 0%, 0.2%, 0.4%, and 0.6% of the weight of cement, while the variations of rice husk ash waste used as a partial replacement of cement are 0%, 5%, 10%, and 15%. Testing was carried out on concrete for ages of 7, 14, and 28 days, focusing on the compressive strength and flexural strength of concrete.This research was conducted at the Material Testing Laboratory of the Civil Engineering Department of the Manado State Polytechnic, with a research period of four months and the methods used were experimental and data analysis.The results of this study indicate that the addition of fiberglass fibers increases the compressive strength of concrete, while the use of rice husk ash waste as a partial replacement of cement shows varying effects on the compressive strength value, with a decrease in the higher percentage of rice husk ash. The optimal combination of 0.6% fiberglass and 5% rice husk ash provides an increase in the flexural strength of concrete where the flexural strength for 14 days is 2.99 Mpa, and the concrete age of 28 days is 3.36 MPa. This study provides insight into the potential use of alternative materials to improve the quality and sustainability of concrete construction

INTRODUCTION

The demand for environmentally friendly and sustainable construction materials continues to rise in line with the rapid growth of the construction sector in many countries, including Indonesia. One of the primary materials in construction is concrete, which consists of a mixture of cement, fine aggregate, coarse aggregate, and water. However, large-scale concrete production significantly contributes to increased carbon dioxide emissions due to high cement consumption. Consequently, various studies have explored the use of alternative materials as partial replacements or additives in concrete mixtures to mitigate environmental impacts while improving construction efficiency. One promising approach involves the utilization of industrial and agricultural waste as supplementary or replacement materials in concrete.

Rice husk ash (RHA), a byproduct of burning rice husks, contains a high amount of silica and has potential as a pozzolanic material in concrete mixtures. Its use not only serves as a partial cement replacement but also supports sustainable agricultural waste management. Research by Hardjito and Antoni (2013) revealed that RHA can enhance concrete durability and reduce its porosity when appropriately processed and applied. On the other hand, fiberglass—due to its excellent mechanical properties, such as high tensile strength and corrosion resistance—has been widely used in civil engineering applications, including as reinforcement in composite materials. The addition of fiberglass in concrete is believed to improve its mechanical characteristics, such as tensile strength and crack resistance. Ismail and Al-Hashmi (2008) found that incorporating fibers into concrete mixtures enhances mechanical performance, particularly in controlling cracking behavior.

Nonetheless, studies examining the combined use of RHA and fiberglass in normal concrete remain limited. Most existing research addresses either RHA or fiberglass separately. The lack of empirical data exploring the synergistic effects of both materials within a single concrete mixture indicates a significant research gap that requires systematic experimental investigation.

This study focuses on the phenomenon of how the combination of fiberglass and rice husk ash affects the compressive strength characteristics of normal concrete. By designing concrete mix variations that incorporate RHA as a partial cement substitute and fiberglass as an additive, the research aims to determine the extent to which this combination influences the mechanical quality of concrete. Compressive strength is selected as the primary parameter of observation, as it is a critical indicator for assessing the structural performance of concrete.

The main objective of this research is to evaluate the effect of using rice husk ash and fiberglass on the compressive strength of normal concrete. Through a laboratory experimental approach, the study measures compressive strength across different mix compositions and compares them with standard normal concrete as a control. The outcomes of this research are expected to provide a scientific basis for designing alternative concrete mixtures that are both efficient and environmentally friendly.

Scientifically, this research contributes to the development of concrete technology through the utilization of industrial and agricultural waste materials. It can serve as a reference for academics in further exploring innovative concrete additives. Practically, the findings can be applied by construction practitioners seeking to implement more economical and sustainable concrete alternatives. From a policy standpoint, the use of rice husk ash in construction materials supports integrated and productive agricultural waste management programs.

METHODS

1. Type and Approach of Research

This research employs a quantitative approach with a laboratory experimental method. An experimental design was chosen because the study aims to assess the influence of varying material compositions—specifically fiberglass and rice husk ash—on the mechanical properties of concrete, particularly compressive strength. This approach is suitable for examining causal relationships through direct manipulation of variables (Creswell, 2014).

2. Research Location and Duration

The research was conducted at the Materials and Construction Laboratory, Department of Civil Engineering, Politeknik Negeri Manado. The entire experimental process, from material preparation to specimen testing, was carried out over a two-month period from February to March 2024.

3. Research Samples

The object of this study is normal concrete modified with the addition of fiberglass and rice husk ash (RHA) as partial cement replacements. The concrete mix design follows the Indonesian National Standard (SNI 03-2834-2000). Cylindrical specimens with a diameter of 15 cm and a height of 30 cm were prepared, totaling 30 specimens divided into five mix variations, including a control group with normal concrete.

Specimen fabrication involved mechanical mixing of materials using a concrete mixer, casting into cylindrical molds, and compacting. After 24 hours, the specimens were demolded and cured in water for 28 days. Compressive strength testing was conducted using a hydraulic compression testing machine in accordance with ASTM C39/C39M-18 standards (Neville, 2011).

4. Research Procedure

The research procedure consisted of the following steps:

1. Material preparation, including the collection and measurement of cement, sand, gravel, water, fiberglass, and rice husk ash.
2. Casting of concrete specimens, beginning with mixing, molding, and 28-day curing.
3. Compressive strength testing, conducted after the curing period.
4. Data analysis, to evaluate the effects of fiberglass and RHA on concrete strength.

This sequence is consistent with methodologies employed by Farooq et al. (2022) in studies on the impact of fibers and pozzolanic materials on concrete performance.

5. Data Analysis Technique

The compressive strength test results were analyzed using descriptive-comparative statistical methods. The average strength of each mix variation was calculated and compared to determine the influence of fiberglass and RHA. Percentage change analysis was also conducted to quantify increases or decreases in compressive strength relative to the control group. This method aligns with quantitative approaches commonly used in construction materials research (Mindess et al., 2003).

RESULTS AND DISSCUSION

The experimental data revealed varying effects of fiberglass and rice husk ash (RHA) addition on concrete strength. For the control concrete (0% FG, 0% RHA), the average compressive strengths recorded were 16.41 MPa (7 days), 19.17 MPa (14 days), and 20.43 MPa (28 days), aligning with the target compressive strength ($fc' = 20$ MPa).

Effect of Fiberglass: The incorporation of fiberglass tended to reduce early-age compressive strength. For instance, at 7 days: concrete with 0.2% FG achieved 12.86 MPa; 0.4% FG reached 13.08 MPa; and 0.6% FG recorded 13.04 MPa—all values lower than the control (16.41 MPa). A similar pattern was observed at 14 days: 0.2% FG = 15.99 MPa, 0.4% FG = 14.54 MPa, and 0.6% FG = 14.69 MPa, whereas the control attained 19.17 MPa. These results are consistent with literature; Chandramouli et al. (2010) reported that the addition of glass fibers generally reduces compressive strength in concrete

However, at 28 days, concrete with 0.6% FG showed an increased compressive strength of 21.17 MPa, surpassing the control (20.43 MPa), while 0.2% FG and 0.4% FG yielded 16.98 MPa and 18.76 MPa, respectively. This improvement might be attributed to the effective fiber distribution, which helps mitigate internal stress concentration—corroborating Chandramouli's findings that fibers enhance flexural strength (up to +58%) even though their effect on compressive strength is variable.

Flexural strength results also showed a positive trend with fiberglass addition. The control mix produced average flexural strengths of approximately 2.89 MPa (14 days) and 3.28 MPa (28 days). The optimum variation (0.6% FG + 5% RHA) achieved 2.65 MPa (7 days), 2.99 MPa (14 days), and 3.36 MPa (28 days). The 28-day flexural strength of 3.36 MPa represented an increase of around 2.4% over the control. These findings align with studies confirming that glass fibers significantly improve concrete's flexural performance. Fibers generally act as bridging elements within the concrete matrix, enhancing flexural load capacity and delaying crack propagation.

Effect of Rice Husk Ash (RHA): As a pozzolanic material, RHA contains amorphous silica that reacts with calcium hydroxide to form additional calcium silicate hydrate (C–S–H) gel, which enhances concrete density and strength. Experimental results showed that replacing cement with RHA up to 5% yielded a 28-day compressive strength of 20.00 MPa—almost equal to the control (20.43 MPa). At 10% RHA, the compressive strength was 18.89 MPa, while at 15% RHA, it dropped sharply to 16.47 MPa. These findings indicate that RHA content between 5–10% can still maintain concrete quality near the control level, but levels above 10% lead to significant strength reduction. This aligns with Hasan et al. (2022), who reported that optimal RHA levels for high-performance concrete are around 10%. Zaid et al. (2021) also emphasized that cement replacement with ~10% RHA (in combination with steel fibers) retains compressive strength, while levels beyond 15% result in reduced performance.

Thus, the present data confirm that RHA substitution exceeding ~10% is not recommended due to declining concrete strength. Additionally, RHA affects concrete durability and workability. Hasan et al. (2022) observed that RHA improves compressive, splitting tensile, and flexural strengths by approximately 3–7%, while also enhancing microstructural density. However, a slump reduction due to decreased workability was also observed, supporting Hasan's assertion. Therefore, the use of superplasticizers is advised when incorporating high RHA content.

Discussion: These experimental findings align with existing literature. Fiber addition (fiberglass) presents a common trade-off: slightly reduced early compressive strength but improved flexural performance. Under flexural loading, fibers bridge local tensile zones around cracks, increasing the concrete's deformation capacity before failure. Meanwhile, RHA offers ecological and economic advantages by reducing cement usage and enhancing long-term strength at optimal levels. However, excessive RHA (>10–15%) introduces surplus carbon content and porosity, reducing quality—as reflected by the poorest results in the 15% RHA group.

The combination of 0.6% FG and 5% RHA yielded the best overall balance: 28-day compressive strength = 21.17 MPa (highest), and flexural strength = 3.36 MPa (highest). This mixture met the design strength and demonstrated enhanced flexural performance, making it suitable for structural elements requiring improved tensile–flexural capacity. Therefore, the 0.6% fiberglass + 5% RHA combination is recommended as the optimum proportion.

CONCLUSION

This study demonstrates that the incorporation of fiberglass (FG) and rice husk ash (RHA) affects the mechanical performance of normal concrete in distinct ways. The addition of fiberglass tends to reduce early-age compressive strength but significantly enhances flexural strength at later ages. Conversely, RHA, as a pozzolanic material, improves concrete strength up to an optimal level of 5–10%, beyond which mechanical properties deteriorate due to increased porosity and unreacted silica.

The experimental results indicate that the combination of 0.6% FG and 5% RHA yields the highest 28-day compressive strength (21.17 MPa) and flexural strength (3.36 MPa), surpassing the control mix. This optimum mix composition improves tensile–flexural performance without sacrificing compressive strength, making it suitable for structural elements requiring enhanced durability and crack resistance.

Therefore, it is concluded that a hybrid concrete mix incorporating 0.6% fiberglass and 5% rice husk ash offers an effective, sustainable, and structurally sound alternative to conventional concrete for moderate-strength applications.

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