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EVALUATION OF COMPRESSIVE STRENGTH OF CONCRETE WITH REPLACEMENT OF CONVENTIONAL COARSE AND FINE AGGREGATES USING PALM KERNEL SHELL AND COCONUT HUSK

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Abstract

Concrete is a widely used construction material, but its production has a negative impact on the environment. This study aims to determine the effect and optimal percentage of using palm kernel shells and coconut fiber in concrete mixtures on the compressive strength of concrete. The research method involved making a variety of concrete mixes with the replacement of conventional aggregates by palm kernel shells as coarse aggregate and coconut fiber as fine aggregate. Four mix variations were tested: A (1% coconut fiber, 5% palm kernel shell), B (2% coconut fiber, 5% palm kernel shell), C (1% coconut fiber, 10% palm kernel shell), and D (2% coconut fiber, 10% palm kernel shell). Compressive strength testing was conducted at 7, 14, and 28 days of concrete age. The analysis showed that variation A, with 1% coir and 5% palm kernel shell, produced the closest compressive strength to normal concrete. ANOVA tests confirmed the significant effect of these mixtures on compressive strength. The contribution of this research lies in the development of alternative concrete materials that are more environmentally friendly, utilizing agricultural waste to reduce dependence on natural resources and lower the carbon footprint of the construction industry.

***Keywords**: Aggregate, Coconut Husks, Compressive Strength, Concrete, Palm Kernel Shell.*

1. INTRODUCTION

Concrete is the most widely used construction material worldwide due to its high strength and ability to be molded to the needs of various structures (Irahadi et al., 2020). However, traditional concrete production has significant environmental impacts, especially in terms of natural resource use and carbon emissions (Raji, et.al., 2024; Alaneme, et al., 2023; Premana & Kerdiati, 2022). As awareness of environmental issues increases, there is a strong drive to find alternative materials that are more environmentally friendly and sustainable.

Indonesia, as one of the world's largest palm oil producers, produces large amounts of agricultural waste, including palm kernel shells and coconut fiber (Ermawati & Saptia, 2013). This waste is often underutilized and can become an environmental problem if not managed properly (Haryanti et al., 2014). Using palm kernel shells and coconut husks as aggregate substitutes in concrete not only has the potential to reduce agricultural waste but can also reduce reliance on conventional aggregates, which are a limited source.

Ketapang Regency, located in West Kalimantan, is one of the areas with many palm oil processing industries (Wardanu, 2014). This industry produces a significant amount of palm oil waste, in the form of palm kernel shells (Siswanto, 2020). In addition, the most common waste is husks waste (Setyowati & Puspa D, 2019). Husks waste is obtained from local traders, where young coconuts are obtained from beverage sellers and old coconuts from coconut milk sellers (Indahyani, 2011). Managing this waste by utilizing it as an ingredient in concrete production can not only reduce the environmental burden but also provide a practical solution for waste management in the area.

This research focuses on evaluating the compressive strength of concrete by replacing conventional aggregates with palm kernel shells and coconut husks. Palm kernel shell has good hardness and wear resistance characteristics (Nakkeeran et al., 2023; Vachlepi, 2015). While coconut husk has strong and flexible fibers that can improve the mechanical properties of concrete (Ananda, 2021). By utilizing these two materials, it is expected to obtain concrete that is not only environmentally friendly but also has adequate performance for construction applications.

Research on the utilization of palm oil waste and coconut husk for concrete manufacturing in Indonesia shows great potential in improving the sustainability and efficiency of concrete materials. Vitri and Herman's research shows that palm kernel shells can be used as a substitute for aggregate in concrete with a maximum percentage of 30%, although the resulting concrete compressive strength has not reached the initial target (Vitri & Herman, 2019). Oktarina found that the use of palm kernel shells increased the compressive strength of lightweight concrete bricks by 18.64%, exceeding the quality standard of solid concrete bricks IV (Oktarina, 2018). Meanwhile, Saputra et al. noted a significant decrease in the compressive and tensile strength of concrete using palm kernel shells after burning at high temperatures, which affected the porosity of the concrete (Saputra et al., 2022). On the other hand, Marfranklin's research showed that the highest compressive strength of concrete with the addition of coconut fiber was at a percentage of 0.3% (Marfranklin & Risdianto, n.d.). Research by Prahara et al's research found that an increase in compressive strength of up to 9% can be achieved by using coconut fiber additives as a substitute for 1.5% cement and an increase in split tensile strength of up to 19.7% can be achieved by using 2% coconut fiber additives. (Prahara et al., 2015).

The novelty of the research to be carried out is to combine the utilization of oil palm shell waste and coconut fiber in the manufacture of environmentally friendly concrete. It is expected that this combination can optimize the mechanical properties of concrete while increasing the sustainability of construction materials.

Based on the above background, the problem formulations in this study are 1) How does the use of palm kernel shells and coconut fiber as a substitute for conventional aggregates affect the compressive strength of concrete? And 2) What is the optimal percentage of the use of palm kernel shells and coconut fiber in concrete mixtures to achieve maximum compressive strength? So that the objectives of this study are 1) to determine the effect of using palm kernel shells and coconut fiber as a substitute for conventional aggregates on the compressive strength of concrete. And 2) determine the optimal percentage of the use of palm kernel shells and coconut fiber in concrete mixes to achieve maximum compressive strength. The results of this research are expected to make a meaningful contribution to the development of more sustainable construction materials and support efforts to reduce the environmental impact of the construction industry.

2. METHODOLOGY

This research is an experimental study that aims to evaluate the effect of using palm kernel shells and coconut fiber as a substitute for conventional aggregates on the compressive strength of concrete. The independent variable in this study was the percentage replacement of conventional aggregates with palm kernel shells and coconut fiber. The dependent variable measured was the compressive strength of concrete. In addition, there were control variables that included cement type, water type, water-cement ratio, and curing conditions, all of which were kept constant to ensure accurate and consistent results.

The materials used are Portland cement, crushed stone, sand, palm kernel shells, coconut fiber, and water. While the tools used are digital scales, shovels, cube molds measuring 15 cm x 15 cm x 15 cm, soaking tubs, hammers, piercing rods, and compression testing machines.

This study involved several variations of concrete mixes with replacement of conventional aggregates by palm kernel shells and coconut fiber at various percentages. A description of the sample variations can be seen in Table 1. Because Vitri and Herman's (2019) research showed non-optimal results with a percentage substitution of up to 30%, this study used a percentage of 5% and 10%.

Table 1. Sample Variations Using Coconut Husks and Palm Shells

Variations	Percentage		Number of samples
	Coconut fiber	Palm kernel shell	
Normal	0%	0%	9
A	1%	5%	9
B	2%	5%	9
C	1%	10%	9
D	2%	10%	9

The activity begins with material preparation and preparation of material requirements. Followed by the sample making process. After 24 hours after molding, the samples were removed from the mold and soaked in a tub. Samples are removed according to the age of the concrete and then the concrete compressive strength test is carried out.

Data analysis in this study used statistical analysis. Descriptive statistics were used to calculate the mean, median, and standard deviation of the compressive strength for each concrete mix variation (Nasution, 2017). ANOVA was applied to determine whether there were significant differences in the compressive strength of concrete between groups with varying percentages of aggregate replacement. The ANOVA test was used to test the following hypotheses:

H0 = There is no significant effect of using palm kernel shells and coconut fiber as a substitute for conventional aggregates on the compressive strength of concrete.

H1 = There is a significant effect of using palm kernel shells and coconut fiber as a substitute for conventional aggregates on the compressive strength of concrete.

3. RESULTS AND DISCUSSION

3.1 Concrete compressive strength test data

Table 2 shows the data of concrete compressive strength values of 45 samples at the age of concrete 7 days, 14 days and 28 days. sample A is a sample with a composition of 1% coconut fiber and 5% palm shell, B is a sample with a composition of 2% coconut fiber and 5% palm shell, C is a sample with a composition of 1% coconut fiber and 10% palm shell, D is a sample with a composition of 2% coconut fiber and 10% palm shell, N is a normal sample without a mixture of coconut fiber and palm shell.

Table 2. Data on the compressive strength of concrete at 7 days, 14 days, and 28 days

Sample	7 DAYS			Sample	14 DAYS			Sample	28 DAYS		
	Strength (kN)	Strength (kg/m^2)	Average		Strength (kN)	Strength (kg/m^2)	Average		Strength (kN)	Strength (kg/m^2)	Average
A1	218	99		A4	327	148		A7	458	208	
A2	220	100	99	A5	330	150	149	A8	462	209	208
A3	219	99		A6	329	149		A9	460	208	
B1	167	76		B4	251	113		B7	351	159	
B2	172	78	78	B5	258	117	117	B8	361	164	164
B3	177	80		B6	266	120		B9	372	168	
C1	212	96		C4	318	144		C7	445	202	
C2	215	97	97	C5	323	146	146	C8	452	205	204
C3	218	99		C6	326	148		C9	457	207	
D1	99	45	46	D4	149	67	69	D7	208	94	97
D2	105	48		D5	158	71		D8	221	100	

Sample	7 DAYS			Sample	14 DAYS			Sample	28 DAYS		
	Strength (kN)	Strength (kg/m²)	Ave rage		Strength (kN)	Strength (kg/m²)	Ave rage		Strength (kN)	Strength (kg/m²)	Ave rage
D3	102	46		D6	153	69		D9	214	97	
N1	405	184		N4	437	198		N7	478	217	
N2	409	185	185	N5	433	196	198	N8	472	214	214
N3	408	185		N6	441	200		N9	468	212	

3.2 Statistical Description

Based on the data in Table 2, the compressive strength values of concrete were analyzed descriptively based on the age of concrete at 7 days, 14 days, and 28 days. Each can be seen in Table 3, Table 4, and Table 5.

Table 3. Statistical Description of 7-Day Compressive Strength of Concrete

Variations	Average	Standard Deviation	Minimum	Maximum	Range
A	99,33	0,58	99	100	1
B	78	2	76	80	4
C	97,33	1,53	96	99	3
D	46,33	1,53	45	48	3
N	184,67	0,58	184	185	1

Table 4. Statistical Description of 14-Day Compressive Strength of Concrete

Variations	Average	Standard Deviation	Minimum	Maximum	Range
A	149	1	148	150	2
B	116,67	3,51	113	120	7
C	146	2	144	148	4
D	69	2	67	71	4
N	198	2	196	200	4

Table 5. Statistical Description of 28-Day Compressive Strength of Concrete

Variations	Average	Standard Deviation	Minimum	Maximum	Range
A	208,33	0,58	208	209	1
B	163,67	4,51	159	168	9
C	204,67	2,52	202	207	5
D	97	3	94	100	6
N	214,33	2,52	212	217	5

The descriptive statistical results present the average, standard deviation, minimum, maximum, and range of compressive strength for different concrete mix variations at 28 days of curing. This analysis provides a comprehensive view of the variability and distribution of compressive strength across the tested variations, highlighting differences in performance between each mix.

At 7 days, concrete with variation A showed a higher compressive strength (99.33 kg/m²) compared to variations B (78.00 kg/m²), C (97.33 kg/m²), and D (46.33 kg/m²), although much lower than normal concrete (184.67 kg/m²). This shows that the replacement of conventional aggregates with palm kernel shells and coconut husks has a significant effect on the compressive strength of concrete at 7 days. This replacement did not reach the equivalent value of normal concrete, but still gave better results compared to the other variations.

At 14 days, variation A (149.00 kg/m²) showed a significant increase in compressive strength compared to variations B (116.67 kg/m²), C (146.00 kg/m²), and D (69.00 kg/m²). Normal concrete (198.00 kg/m²) remained superior, but the increase in variation A indicates that the use of palm kernel shells and coconut husks began to make a positive contribution in increasing the strength of the concrete.

At 28 days, variation A (208.33 kg/m²) showed almost the same compressive strength as normal concrete (214.33 kg/m²), with a very small difference. Variation C (204.67 kg/m²) also showed quite good results, although it was not comparable to normal concrete. Variations B (163.67 kg/m²) and D (97.00 kg/m²) showed much lower results. Thus, it can be concluded that variation A (1% coir, 5% palm kernel shell) provides the optimal combination to achieve compressive strengths close to normal concrete, although the use of palm kernel shell and coir may not completely replace conventional aggregates effectively at higher concrete ages.

3.3 Effect of Palm Kernel Shells and Coconut Buttons on the Strength Value of Concrete

The effect of using palm kernel shells and coconut husks as a substitute for conventional aggregates on the compressive strength of concrete was analyzed by ANOVA test. This analysis aims to test the hypothesis that has been determined. The analysis was carried out respectively for the age of concrete 7 days, 14 days, and 28 days. The ANOVA test results can be seen in Table 6.

Tabel 6. Hasil Uji ANOVA

Concrete Age	F statistic	P value	ANOVA Conclusion	H0
7	4232,29	$4,3.10^{-16}$	Significant ($p < 0.05$)	rejected
14	1328,6	$1,4.\ 10^{-16}$	Significant ($p < 0.05$)	rejected
28	860,76	$1,2.\ 10^{-16}$	Significant ($p < 0.05$)	rejected

The results of the ANOVA analysis showed that the use of palm kernel shells and coconut fiber as a substitute for conventional aggregates had an effect on the compressive strength of concrete at all tested concrete ages, namely 7 days, 14 days, and 28 days. For the 7-day concrete age, the F statistic value was 4232.29 with a p value of 4.30e-16. This very small p value indicates that there is a difference in the compressive strength of concrete between the mix variations at 7 days. Therefore, the null hypothesis (H0), which states that the use of palm kernel shell and coconut husk has no effect on the compressive strength of concrete, is rejected. Therefore, the null hypothesis (H0) is again rejected, and the alternative hypothesis (H1), which states that the use of palm kernel shell and coconut husk has an influence on the compressive strength of concrete, is accepted.

At 14 days, the F statistic was 1328.60 with a p value of 1.40e-13. Therefore, the null hypothesis (H0) was again rejected, and the alternative hypothesis (H1), which states that the use of palm kernel shell and coconut husk has an effect on the compressive strength of concrete, was accepted..

Similarly, at 28 days of concrete age, the F statistic value was 860.76 with a p value of 1.22e-12. Therefore, the null hypothesis (H0) is rejected, and the alternative hypothesis (H1) is accepted.

From the data provided in Table 3, Table 4, and Table 5, it can be seen that the compressive strength of concrete increases with the age of the concrete. At 7 days of age, variation A (with 1% coconut fiber and 5% palm kernel shell) had an average compressive strength of 99.33 kg/m^2, variation B (with 2% coconut fiber and 5% palm kernel shell) of 78 kg/m^2, variation C (with 1% coconut fiber and 10% palm kernel shell) of 97.33 kg/m^2, variation D (with 2% coconut fiber and 10% palm kernel shell) of 46.33 kg/m^2, and variation N (normal, no mixture of coconut fiber and palm kernel shell) of 184.67 kg/m^2. At 14 days, the compressive strength for variation A increased to 149 kg/m^2, variation B to 116.67 kg/m^2, variation C to 146 kg/m^2, variation D to 69 kg/m^2, and variation N to 198 kg/m^2. At 28 days, the compressive strength for variation A reached 208.33 kg/m^2, variation B reached 163.67 kg/m^2, variation C reached 204.67 kg/m^2, variation D reached 97 kg/m^2, and variation N reached 214.33 kg/m^2.

This analysis shows that concrete gets stronger with age, which is the nature of concrete. This shows that the compressive strength of concrete increases with age (Siahaan and Sumajouw, 2020). However, the effect of the addition of coconut fiber and palm kernel shell on the compressive strength of concrete shows that all variations with the mixture have a lower compressive strength than normal concrete (N) at each age. This is also widely found in several studies of concrete aggregate replacement, that normal concrete still has the highest compressive strength (Polii et al., 2015). Nonetheless, variations A and C (with 1% husks) showed better results compared to variations B and D (with 2% husks), suggesting that lower proportions of husks may be more effective in maintaining concrete strength. This also supports some studies where the compressive strength of normal concrete is greater than that of variation concrete (Zalukhu et al., 2017). Thus, the addition of husks and palm kernel shell does affect the compressive strength of concrete, but the right mix needs to be determined to optimize concrete strength.

3.4 Percentage of Variation that Produces the Most Optimal Concrete Compressive Strength

From the data analysis of the compressive strength values of concrete at 7 days, 14 days, and 28 days, it can be seen that variation A (with 1% coconut fiber and 5% palm kernel shell) consistently has the most optimal compressive strength value compared to the other variations (B, C, and D) when compared to variation N (without a mixture of coconut fiber and palm kernel shell). At 7 days, variation A had a compressive strength value of 99.33 kg/m^2, while variation N had a compressive strength value of 184.67 kg/m^2. Although the compressive strength value of variation A was lower than that of variation N, variation A still had the highest value among the other mix variations. At 14 days, variation A had a compressive strength value of 149 kg/m^2, while variation N reached 198 kg/m^2. Again, variation A showed the closest value to variation N. At 28 days, variation A reached a compressive strength value of 208.33 kg/m^2, while variation N reached 214.33 kg/m^2. Variation A has a value that is very close to variation N, indicating that the combination of 1% coconut fiber and 5% palm kernel shell in concrete is the most optimal in approaching the strength of normal concrete. Thus, it can be concluded that variation A is the most optimal in producing concrete compressive strength values close to the compressive strength values of concrete without a mixture of coconut fiber and palm kernel shell.

4. CONCLUSIONS

Based on the results of the research conducted, it can be concluded as follows:

1. The use of palm kernel shells and coconut husks as a substitute for conventional aggregates in concrete mixtures has a significant effect on the compressive strength of concrete. The test results showed that the addition of coconut fiber and palm kernel shell resulted in a decrease in the compressive strength value of concrete compared to normal concrete without admixture (variation N). However, the decrease is still within acceptable limits, especially in certain variations.
2. Of the various variations tested, variation A (with 1% coconut fiber and 5% palm kernel shell) showed the most optimal results. At 7 days, 14 days, and 28 days, variation A consistently produced concrete compressive strength values that were closest to normal concrete compressive strength values (variation N). The compressive strength value for variation A at 7 days was 99.33 kg/m², at 14 days was 149 kg/m², and at 28 days was 208.33 kg/m². Based on these results, it can be concluded that the optimal percentage of the use of palm kernel shell and coconut husk in concrete mixtures to achieve maximum compressive strength is 1% coconut husk and 5% palm kernel shell.

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