

UTILIZATION OF WASTE PETUNG BAMBOO PIECES AS PARTIAL SUBSTITUTION OF COARSE AGGREGATE TO IMPROVE COMPRESSIVE STRENGTH OF CONCRETE

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ABSTRACT

Utilizing waste as an alternative building material is becoming an effective solution to environmental problems and is popular in developing countries. On the other hand, the concrete industry, a key component of construction, continues to innovate to improve quality and efficiency. The increasing demand for concrete is driving the development of mix designs that meet stringent quality and compressive strength standards, while taking into account environmental sustainability. Advances in concrete technology spur research initiatives to improve its quality and efficiency of use, with innovations in material selection and execution methodologies. This is aimed at meeting the increasing needs and overcoming construction challenges. Modern concrete is required to perform optimally in less time, requiring effective additives for performance enhancement. Recent research has integrated bamboo waste from the handicraft industry as a component of concrete mixes, increasing the speed of project execution and providing a sustainable solution in waste management. The authors were interested in conducting an in-depth study on increasing the compressive strength of concrete by integrating waste bamboo pieces. The concrete under study has the following grades f'_c 25 MPa (K-300) and tested at 7, 14, and 28 days to assess the effectiveness of bamboo as an additive. The test results are expected to provide significant data on the viability of bamboo waste as a partial substitution for coarse aggregate. The title of the study, "Use of Waste Bamboo Pieces as Partial Substitution for Coarse Aggregate to Increase the Compressive Strength of Concrete," reflects the objectives of the study and the utilization of sustainable materials in modern construction. Based on the results of the research that has been carried out and the discussion in the previous chapter with the variation of waste bamboo pieces 0%, 10% and 15%, the conclusions can be drawn, namely as follows the results of compressive strength testing on normal concrete at the age of 28 days reach 452 kN (f'_c 26,1 MPa = 104%), while variation 1 of 10% waste bamboo cuttings experienced a decrease in compressive strength, reaching 305 kN (f'_c 17,60 MPa = 70%), and variation 2 15% waste bamboo cuttings decreased, reaching 309 kN (f'_c 17.83 MPa = 71%).

Keywords: Coarse aggregate, concrete, bamboo, compressive strength, variation.

INTRODUCTION

The utilization of waste as an alternative building material has become a rapidly growing trend and is seen as an effective solution to address various environmental issues, particularly in various developing countries around the world. Advances in concrete technology today have been a major driver for various research initiatives aimed at improving

its quality and efficiency of use. Referring to the compositional characteristics of concrete previously described, the authors express great interest in conducting an in-depth study on the potential for increasing the compressive strength of concrete by integrating waste bamboo pieces. The concrete considered in this study had a $f'c$ grade of 25 MPa, which is equivalent to K-300, and was tested at various time intervals, namely at 7 days, 14 days, and 28 days, to measure the effectiveness and performance of the bamboo additive. The results of these tests are expected to provide significant data on the viability of using bamboo waste as a partial substitution for coarse aggregate in concrete mixes.

METHODS

The method applied in this study was an experimental method, which involved the use of independent and dependent variables. The independent variable in this study was bamboo waste, which was used as a substitute for some of the coarse aggregate in the concrete composition. The dependent variable observed in this study is the compressive strength of normal concrete with a value of $f'c$ 25 MPa, which is equivalent to K-300 class concrete. The total number of samples required in this study can be seen in Table 1 below:

Table 1. Number of Research Samples

No.	Cylindrical Test Object Sample	Number of Samples			Amount
		Based on Testing Age			
		7 days	14 days	28 days	
1.	Normal concrete f'c 25 (MPa) or equivalent to K-300	3	3	3	9
2.	Addition of bamboo waste as a partial replacement for coarse aggregate with a variation of 10%	3	3	3	9
3.	Addition of bamboo waste as a partial replacement for coarse aggregate with a variation of 15%	3	3	3	9
Total Test Objects					27

Source: Research Data Processing at the Pioneer Concrete Laboratory, 2024.

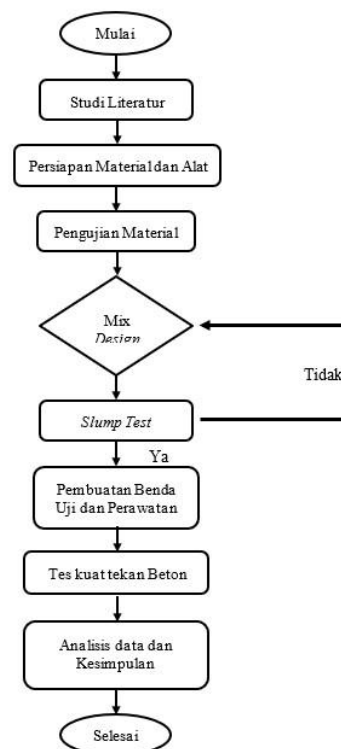
The wulung bamboo waste used in this study as a substitute for some of the coarse aggregate in the concrete mixture was 1 cm to 2 cm in size.



Source: Research Documentation, 2024.

Figure 1. Wulung Bamboo Cutting Waste

The flowchart of this research is as follows:



Source: Research Documentation, 2024.

Figure 2. Research Flow Diagram

RESULTS AND DISCUSSION

The design of concrete mixes is based on SNI 03-2834-2000 concerning “Procedures for Preparing Normal Concrete Mix Designs.” The purpose of this concrete mix design is to determine the composition or proportions of the materials used in the concrete mix. The tests are conducted at 7, 14, and 28 days. The mix design results are based on a single test specimen of a 15 cm x 30 cm cylinder. The mix design is for normal-strength concrete with a compressive strength of f'_c 25 MPa or equivalent to K-300. Concrete design specifications:

- 1) Concrete strength = f'_c 25 MPa;
- 2) Cylinder test specimen = $\varnothing$ 15 cm x 30 cm;

- 3) Standard deviation = 7 MPa;
- 4) Cement type = Type 1;
- 5) Slump height set = 10 ± 2 cm;
- 6) Maximum FAS value = 0.6;
- 7) Minimum cement content = 275 kg/m^3 ;
- 8) Sand specific gravity (SSD) = 2.54;
- 9) Split specific gravity (SSD) = 2.56;
- 10) Maximum particle size = 40 mm;
- 11) Sand particle size distribution = Grade No. 2;
- 12) Designed concrete strength, $F_{cr} = f'_c + 1.64 \times S = 25 + 1.64 \times 5 = 33.2 \text{ MPa}$;
- 13) Free water-cement ratio = 0.475;
- 14) Free water content;

Free water content for unbroken aggregate 175 kg/m^3 , free water content for broken aggregate (crushed stone) 205 kg/m^3 ;

Free water content = $(2/3 \times 175) + (1/3 \times 205) = 185 \text{ kg/m}^3$.
- 15) Water-cement ratio = $185 / 0.475 = 390 \text{ kg/m}^3$.
- 16) Specific gravity of the aggregate mixture;

Percentage of sand = $(36\% + 42\%) / 2 = 39\%$

Percentage of crushed stone = $100\% - 39\% = 61\%$

Specific gravity of the aggregate mixture = $(39\% \times 2.54) + (61\% \times 2.56) = 2.55$.
- 17) Bulk density of concrete;

The bulk density of concrete is determined using a graph based on specific gravity and free water content.

Bulk density of concrete = 2360 kg/m^3 .

Combined aggregate content = $2360 - 390 - 185 = 1785 \text{ kg/m}^3$.

Sand content = $39\% \times 1785 = 696.15 \text{ kg/m}^3$.

Split content = $1785 - 696.15 = 1088.85 \text{ kg/m}^3$.
- 18) Theoretical mix proportion;

Volume:

= 3 units $\times$ volume of concrete cylinder

= $3 \times (\text{area of circle} \times t)$

= $3 \times (1/4 \times \pi \times d^2 \times t)$

= $3 \times (1/4 \times 3.14 \times 0.152 \times 0.3)$

= 0.0159 m^3

Table 2. Test Mix Proportion 0.0159 m^3

	Cement (kg)	Water (kg)	Aggregate	
			Smooth (kg)	Rough (kg)
Theoretical mix proportions	1	0,475	2,09	3,45
Each m^3	390	185	696,15	1088,85
Each test mixture = 0.0159 m^3	$0,0159 \times 390 = 5,88$	$0,0159 \times 185 = 2,94$	$0,0159 \times 696,15 = 11,07$	$0,0159 \times 1088,85 = 17,31$

Source: Research Data Processing, 2024.

For the experiment, the mixture proportion was added with the shrinkage rate. The mixture shrinkage rate was around 10%–20%, with 15% taken, so that the mixture proportion with the shrinkage rate was obtained as follows:

Table 3. Mixture Proportion with Shrinkage Rate

	Cement (kg)	Water (kg)	Agregat	
			Smooth (kg)	Rough (kg)
Theoretical mix proportions	1	0,475	2,09	3,45
Each m ³	390	185	696,15	1088,85
Each test mixture = 0.0159 m ³	0,0159 x 390 = 5,88	0,0159 x 185 = 2,94	0,0159 x 696,15 = 11,07	0,0159 x 1088,85 = 17,31
Mix ratio with a shrinkage rate of 7.5%	1	0,55	2,09	3,45
Each m ³	420	199	748	1170
Each test mixture = 0.0159 m ³	0,0159 x 425,5 = 6,67	0,0159 x 212,75 = 3,38	0,0159 x 809,5 = 12,87	0,0159 x 1266,2 = 20,13

Source: Research Data Processing, 2024.

For the use of bamboo wulung pieces as a sand substitute at 10% and 15%, the weight of the bamboo wulung pieces can be seen below:

The weight of bamboo wulung pieces required as a 10% sand substitute = 10% bamboo wulung pieces × sand weight × cylinder volume = 0.34 kg.

The weight of bamboo wulung pieces required as a 15% sand substitute = 15% bamboo wulung pieces × sand weight × cylinder volume = 0.51 kg.

The slump test is conducted while the concrete is still fresh. This test is performed using an Abram cone or truncated cone with an upper diameter of 10 cm, a bottom diameter of 20 cm, and a height of 30 cm, equipped with handles to lift the device so that the fresh concrete can be removed, and a slump cone tamper with a diameter of 16 mm and a maximum length of 60 cm (SNI 1972-2008). The test is conducted to determine the workability value of the fresh concrete mixture. The lower the slump value, the more difficult it is to mix, pour, transport, and compact. The average slump value for the three variations was 97 mm. The average slump value in this study is still within the initial design slump range of 60–180 mm. The slump values obtained can be seen in Table 4 below.

Table 4. Slump Test Results Data

Mixed Variations	Slump Value	Unit
Concrete f'c 25 MPa	11	cm
Concrete f'c 25 MPa with 10% variation of wulung bamboo waste	9	cm
Concrete f'c 25 MPa with 15% variation of wulung bamboo waste	8	cm

Source: Research Data Analysis, 2024.



Source: Research Documentation, 2024.

Figure 3. Slump Test Results for Concrete Test Specimen Variation 2

The concrete compressive strength test refers to SNI 1974-2011 regarding the Procedures for Testing Concrete Compressive Strength using cylindrical test specimens. The calculation of concrete compressive strength uses the formula:

$$\text{Compressive Strength} = P / A \dots\dots\dots (1)$$

P = Axial compressive force (N)

A = Cross-sectional area (mm²)

If the ratio of length (L) to diameter (D) of the test specimen is less than 1.8, the results obtained must be corrected by multiplying them by the appropriate correction factor. The correction factor applies to lightweight concrete with a density between 1600 kg/m³ and 1920 kg/m³ and for normal concrete. This correction factor applies to both dry and wet conditions during loading. Values not listed in the table must be determined by interpolation. The correction factor applies to concrete compressive strength ranging from 15 MPa to 45 MPa (SNI 1974-2011). Compressive strength testing of concrete was conducted on test specimens at 7 days, 14 days, and 28 days using a concrete compression testing machine (Compression Testing Machine) with readings on the machine using kN units and a digital display. The results of the concrete compressive strength testing can be seen in Tables 5 to 7 and Figures 4 and 5 below.

Table 5. Results of Cylinder Concrete Compression Testing at 7 Days of Age

No.	Test Object	Date of Creation	Test Date	Age of Test Object (days)
1	f'c 25	30 Nov 2024	7 Des 2024	7
2	f'c 25	30 Nov 2024	7 Des 2024	7
1	10% PBW	30 Nov 2024	7 Des 2024	7
2	10% PBW	30 Nov 2024	7 Des 2024	7
1	15% PBW	30 Nov 2024	7 Des 2024	7
2	15% PBW	30 Nov 2024	7 Des 2024	7

Weight of Test Object (kg)	Actual Strong Pressure (kN)	Average Compressive Strength (kN)	Average Compressive Strength Percentage (kN)
12,268	286,3	289	66,72 %
12,27	291,8		
12,24	194	203	46,86 %
12,24	212,9		
12,24	191	175	40,40 %
12,25	159,2		

Source: Research Data Processing, 2024.

Table 6. Results of Cylinder Concrete Compression Test at 14 Days

No.	Test Object	Date of Creation	Test Date	Age of Test Object (days)
1	f'c 25	30 Nov 2024	14 Des 2024	14
2	f'c 25	30 Nov 2024	14 Des 2024	14
1	10% PBW	30 Nov 2024	14 Des 2024	14
2	10% PBW	30 Nov 2024	14 Des 2024	14
1	15% PBW	30 Nov 2024	14 Des 2024	14
2	15% PBW	30 Nov 2024	14 Des 2024	14

Weight of Test Object (kg)	Actual Strong Pressure (kN)	Average Compressive Strength (kN)	Average Compressive Strength Percentage (kN)
12,3	384	385	88,88 %
12,294	385,8		
12,284	245,5	252	58,18 %
12,288	257,9		
12,268	252,8	233	53,79 %
12,25	213,3		

Source: Research Data Processing, 2024.

Table 7. Results of Cylinder Concrete Compression Test at 28 Days

No.	Test Object	Date of Creation	Test Date	Age of Test Object (days)
1	f'c 25	30 Nov 2024	28 Des 2024	28
2	f'c 25	30 Nov 2024	28 Des 2024	28
1	10% PBW	30 Nov 2024	28 Des 2024	28
2	10% PBW	30 Nov 2024	28 Des 2024	28
1	15% PBW	30 Nov 2024	28 Des 2024	28
2	15% PBW	30 Nov 2024	28 Des 2024	28

Weight of Test Object (kg)	Actual Strong Pressure (kN)	Average Compressive Strength (kN)	Average Compressive Strength Percentage (kN)
12,312	456,3	452	104,35 %
12,306	447,2		
12,292	292,3	305	70,41 %
12,296	317,6		
12,302	309,9	309	71,33 %
12,298	309		

Source: Research Data Analysis, 2024.

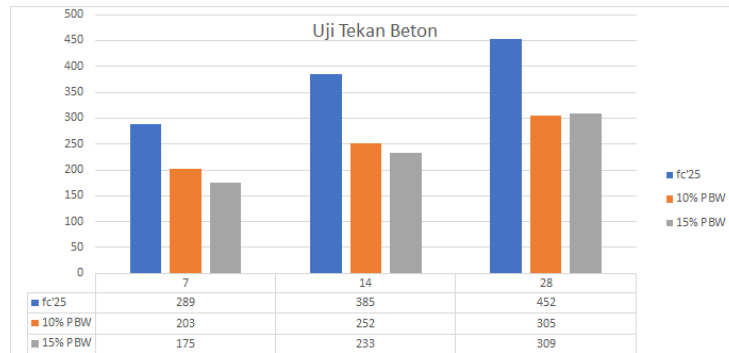


Figure 4 Bar Diagram of Normal Concrete Compression Test, Variation 1 and Variation 2

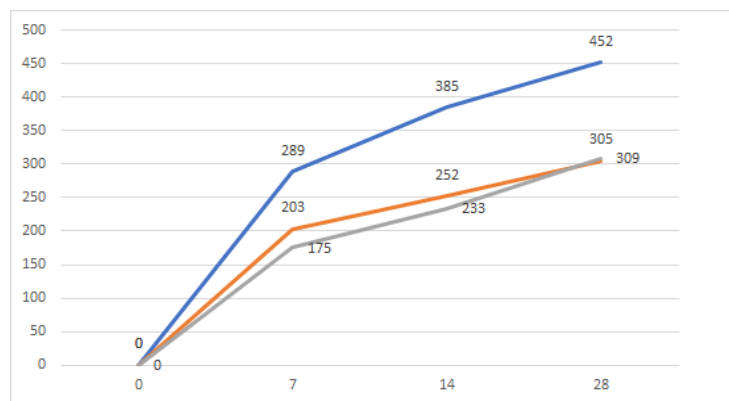


Figure 5 Normal Concrete Compression Test Graph, Variation 1 and Variation 2

CONCLUSIONS

Based on the results of the research conducted and the discussion in the previous chapter with variations of 0%, 10%, and 15% wulung bamboo waste, the following conclusions can be drawn:

The compressive strength test results for normal concrete at 28 days reached 452 kN (f'_c 26.1 MPa = 104%), while variation 1 with 10% bamboo wulung waste showed a decrease in compressive strength, reaching 305 kN (f'_c 17.60 MPa = 70%), and variation 2 with 15% bamboo wulung waste also showed a decrease, reaching 309 kN (f'_c 17.83 MPa = 71%).

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