

THE USE OF BLACK BAMBOO AS A SUBSTITUTE FOR COARSE AGGREGATE TO INCREASE CONCRETE COMPRESSIVE STRENGTH

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ABSTRACT

The use of waste as an alternative building material is 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 has driven the development of mix designs that meet strict quality and compressive strength standards, while also considering environmental sustainability. Advancements in concrete technology are driving research initiatives to improve the quality and efficiency of its use, with innovations in material selection and implementation methodologies. This aims to meet increasing demands and address construction challenges. Modern concrete is required to perform optimally in shorter timeframes, necessitating effective additives for performance enhancement. Recent research has integrated bamboo waste from the craft industry as a concrete mixture component, accelerating project implementation and providing a sustainable solution for waste management.

The author is interested in conducting an in-depth study on increasing the compressive strength of concrete by integrating bamboo waste. The concrete studied has a quality of f'_c 25 MPa (K-300) and was 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 substitute for coarse aggregate. The study title, “The Use of Bamboo Waste as a Partial Substitute for Coarse Aggregate to Enhance Concrete Compressive Strength,” reflects the research objectives and the utilization of sustainable materials in modern construction. Based on the results of the research conducted and the discussion in the previous chapter with variations of black bamboo waste at 0%, 10%, and 15%, 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% black bamboo waste showed a decrease in compressive strength, reaching 305 kN (f'_c 17.60 MPa = 70%), and variation 2 with 15% black bamboo waste also showed a decrease, reaching 309 kN (f'_c 17.83 MPa = 71%).

Keywords : Coarse Aggregate, Concrete, Bamboo, Compressive Strength, Variation.

INTRODUCTION

The use of waste as an alternative building material has become a rapidly growing trend and is seen as an effective solution to various environmental problems, particularly in developing countries around the world. Advancements in concrete technology have become the primary driver for various research initiatives aimed at improving the quality and efficiency of its use. Referring to the characteristics of concrete composition outlined earlier, the author

expresses a strong interest in conducting an in-depth study on the potential for enhancing concrete compressive strength by integrating bamboo waste. The concrete considered in this study has a compressive strength of $f'c$ 25 MPa, equivalent to K-300, and was tested at various time intervals—7 days, 14 days, and 28 days—to assess the effectiveness and performance of the bamboo additive. The results of this testing are expected to provide significant data on the viability of using bamboo waste as a partial substitute for coarse aggregate in concrete mixtures.

METHODS

The method applied in this study was the 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 was the compressive strength of normal concrete with a value of $f'c$ 25 MPa, which is equivalent to K-300 class concrete. The black bamboo waste used in this study as a substitute for some of the coarse aggregate in the concrete mixture is 1 cm to 2 cm in size.



The concrete mix design was carried out based on SNI 03-2834-2000 concerning “Procedures for Preparing Normal Concrete Mix Designs.” The purpose of this concrete mix design was to determine the composition or proportions of the materials for concrete preparation. The tests were conducted at 7, 14, and 28 days. The mix design results were obtained for one cylindrical test specimen measuring 15 cm x 30 cm. The mix design for normal quality $f'c$ 25 MPa or equivalent to K-300. Concrete specifications:

- 1) Planned concrete strength = $f'c$ 25 MPa;
- 2) Cylindrical 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/m³;
- 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) Design concrete strength, $F_{cr} = f'_c + 1.64 \times S = 25 + 1.64 \times 5 = 33.2$ MPa;
 13) Free water-cement ratio = 0.475;
 14) Free water content;
 Free water content for unbroken aggregate 175 kg/m³, free water content for broken aggregate (crushed stone) 205 kg/m³;
 Free water content = $(2/3 \times 175) + (1/3 \times 205) = 185$ kg/m³.
 15) Water-cement ratio = $185 / 0.475 = 390$ kg/m³.
 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.
 Concrete density = 2360 kg/m³.
 Combined aggregate content = $2360 - 390 - 185 = 1785$ kg/m³.
 Sand content = $39\% \times 1785 = 696.15$ kg/m³.
 Split content = $1785 - 696.15 = 1088.85$ kg/m³.
 18) Theoretical mix proportion;
 Volume:
 = 3 units x concrete cylinder volume
 = 3 x (area of the circle x t)
 = 3 x $(1/4 \times \pi \times d^2 \times t)$
 = 3 x $(1/4 \times 3.14 \times 0.152 \times 0.3)$
 = 0.0159 m³

Table 1. Test Mixture Proportion 0.0159 m³

	Cement (kg)	Water(kg)	Agregat	
			Fine (kg)	Coarse (kg)
Theoretical mixture proportion	1	0,475	2,09	3,45
Each m ³	390	185	696,15	1088,85
Each test mixture = 0.0159 m ³	$0,0159 \times 390 = 5,88$	$0,0159 \times 185 = 2,94$	$0,0159 \times 696,15 = 11,07$	$0,0159 \times 1088,85 = 17,31$

For the experiment, the mixture proportion was added with the shrinkage rate. The shrinkage rate of the mixture was around 10%–20%, and 15% was taken, resulting in the following mixture proportion with the shrinkage rate:

Table 2. Mixture Proportions with Shrinkage Figures

	Cement (kg)	Water (kg)	Agregat	
			Fine (kg)	Coarse (kg)
Theoretical mix proportion	1	0,475	2,09	3,45
Each m ³	390	185	696,15	1088,85

Each test mix = 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 proportion with a shrinkage factor of 7.5%	1	0,55	2,09	3,45
Each m ³	420	199	748	1170
Each test mix = 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

For the use of sand substitute material, black bamboo pieces are used at 10% and 15%. The weight of the black bamboo pieces can be seen below. The weight of black bamboo pieces needed as a 10% sand substitute = 10% black bamboo pieces . sand weight . cylinder volume = 0.34 kg. The weight of black bamboo pieces required as a 15% sand substitute = 15% black bamboo 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 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 3. Slump Test Results Data

Mix Variations	Slump Value	Unit
Concrete f'c 25 MPa	11	cm
Concrete f'c 25 MPa with 10% black bamboo waste	9	cm
Concrete f'c 25 MPa with 15% black bamboo waste	8	cm



Slump Test Results for Concrete Test Specimens Variation 2

Compressive strength testing of concrete refers to SNI 1974-2011 regarding the Procedures for Testing the Compressive Strength of Concrete 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 to normal concrete. This correction factor applies to both dry and wet conditions during loading. Values not listed in the table should 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 is 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 in kN and digital display. The results of the compressive strength testing of concrete can be seen in Tables 5 to 7 and Figures 4 and 5 below.

Table 4. Results of Cylinder Concrete Compression Test at 7 Days

No.	Test Item	Date of Manufacture	Date of Testing	Age of Test Item (days)
1	f _c 25	30 Jan 2025	7 Feb 2025	7
2	f _c 25	30 Jan 2025	7 Feb 2025	7
1	10% PBW	30 Jan 2025	7 Feb 2025	7
2	10% PBW	30 Jan 2025	7 Feb 2025	7
1	15% PBW	30 Jan 2025	7 Feb 2025	7
2	15% PBW	30 Jan 2025	7 Feb 2025	7

Table 5. Results of Cylinder Concrete Compression Test at 14 Days

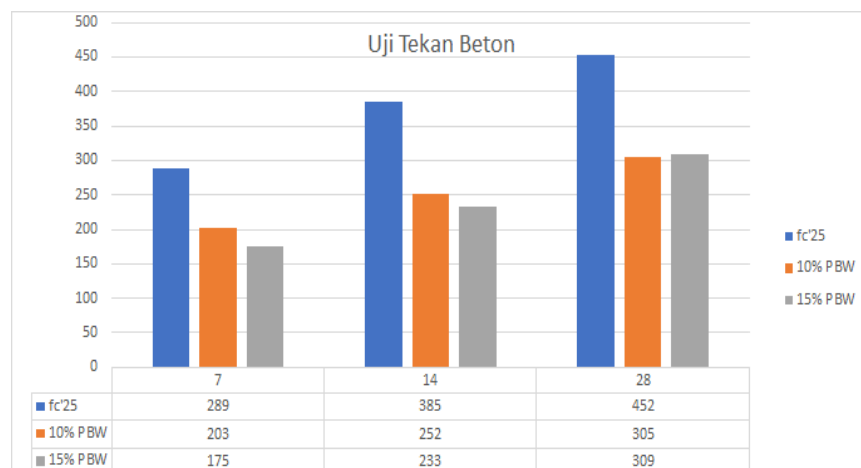
No.	Test Item	Date of Manufacture	Date of Testing	Age of Test Item (days)
1	f _c 25	30 Jan 2025	14 Feb 2025	14
2	f _c 25	30 Jan 2025	14 Feb 2025	14
1	10% PBW	30 Jan 2025	14 Feb 2025	14
2	10% PBW	30 Jan 2025	14 Feb 2025	14
1	15% PBW	30 Jan 2025	14 Feb 2025	14
2	15% PBW	30 Jan 2025	14 Feb 2025	14

Test Object Weight (kg)	Actual Compressive Strength (kN)	Average Compressive Strength (kN)	Percentage of Average Compressive Strength (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		

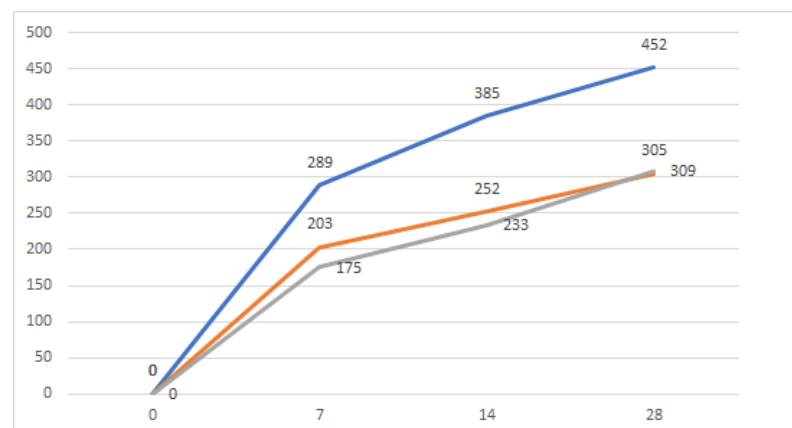
Table 6. Results of Cylinder Concrete Compression Test at 28 Days

No.	Test Item	Date of Manufacture	Date of Testing	Age of Test Item (days)
1	f'c 25	30 Jan 2025	28 Feb 2025	28
2	f'c 25	30 Jan 2025	28 Feb 2025	28
1	10% PBW	30 Jan 2025	28 Feb 2025	28
2	10% PBW	30 Jan 2025	28 Feb 2025	28
1	15% PBW	30 Jan 2025	28 Feb 2025	28
2	15% PBW	30 Jan 2025	28 Feb 2025	28

Test Object Weight (kg)	Actual Compressive Strength (kN)	Average Compressive Strength (kN)	Percentage of Average Compressive Strength (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		



Normal Concrete Compression Test Bar Diagram, Variation 1 and Variation 2



Normal Concrete Compression Test Graphs, Variation 1 and Variation 2

CONCLUSION

Based on the results of the research conducted and the discussion in the previous chapter with variations of black bamboo waste at 0%, 10%, and 15%, 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% black bamboo waste showed a decrease in compressive strength, reaching 305 kN (f'_c 17.60 MPa = 70%), and variation 2 with 15% black bamboo waste also showed a decrease, reaching 309 kN (f'_c 17.83 MPa = 71%).

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