Engineering and Technology Journal e-ISSN: 2456-3358
Volume 08 Issue 11 November -2023, Page No. – 3092-3102
DOI: 10.47191/etj/v8i11.18, I.F. – 7.136

Analysis of the Utilization of Combustion Waste Ash from Palm Kernel Shell as a Substitute for Fine Aggregates in Cement Treated Base Class B

Utami Sylvia Lestari[1], Fauzi Rahman[2], Nor Izha Subagja[3], Muhammad Khairil Mukmin[4], Maulana Ivan Aulia Arham[5], Dewi Puspita[6]
[1,2,3,4,5,6]Civil Engineering Study Program, Universitas Lambung Mangkurat, Indonesia Jl. Brigjen H. Hasan Basri, Kalimantan Selatan 70123

ABSTRACT: The Cement Treated Base Class B is a layer of pavement located between the lower base layer and the surface layer. This pavement layer uses fine aggregate materials (sand), palm kernel ash, and cement as its binding materials. The palm kernel ash is the main solid waste product from boiler combustion and can be utilized as a sand composition reducer in concrete production due to its chemical properties, which are nearly similar to cement. This research aims to determine the characteristics of the base mixture by utilizing palm kernel ash when combined in the Cement Treated Base Class B mixture for flexible pavement. With the specified composition, it is expected that when compression strength testing is conducted, the obtained compression strength values will meet the specified specifications. After testing, it was found that the Cempaka sand type is more effective and economical to use because its compression strength value almost meets the specified range of 35 kg/cm2 to 45 kg/cm2, which means it falls within the standard compression strength specification.

KEYWORDS: Cement Treated Base layer, pavement, palm kernel ash

I. INTRODUCTION

Road pavement is a layer situated above a compacted subgrade, designed to carry traffic loads, distribute these loads both horizontally and vertically, and ultimately transfer them to the subgrade without exceeding its allowable bearing capacity [1]. A road pavement consists of various layers arranged from bottom to top, including the subgrade, subbase course, base course, and surface course. To address the technical weaknesses of the base layer pavement, composite pavement techniques are used. Composite pavement, including the use of Cement Treated Base (CTB), is increasingly being applied in the construction of new roads [2].

In the development of infrastructure, the waste ash from palm kernel combustion can be utilized as an additive in road pavement. This ash can also be used to strengthen soil structures, fill the pores between soil particles, and dry in hard layers, making the soil compact and stable, thereby increasing its load-bearing capacity and strength. Palm Kernel shell is a dark solid fuel material with a coconut-like shell and something round inside, found in the coconut fruit and covered with fibers. After undergoing the combustion process, this shell becomes charcoal [3].

Meanwhile, palm oil fiber is a solid fuel material that resembles hair. When processing light brown palm oil, these fibers are found in the second part of the palm oil after the coconut fruit oil. The heat generated by the fibers is lower than that produced by the shells, so the ratio of shells to fibers burns faster into ash [4].

Based on previous research, palm kernel ash contains silica, making it suitable as a substitute in concrete production. Therefore, based on the information provided above, research will be conducted to develop Cement Treated Base Class B Layer using palm kernel ash as an additive from palm kernel waste, utilizing various sand types to determine the characteristics of the CTB base layer for roads [5].

The research aims to investigate the characteristics of CTB base materials, including the composition of ash, cement, and sand that meet predefined specifications, as well as to compare the compressive strength test results of the three types of sand used. The characteristics of the Cement Treated Base Class B Layer mixture will be evaluated based on specified specifications, ranging from 45 kg/cm^2 to 55 kg/cm^2 [6].

II. METHOD

A. *Research Setting*

This research was conducted in the Civil Engineering Laboratory, Universitas Lambung Mangkurat, Indonesia. The research began with a literature review using materials from the library, followed by conducting material tests in the laboratory.

B. Research Procedure

The research procedure was done in stages namely material preparation, material testing, and mix design. On the material preparation stage. The researchers prepared the following materials:

- Tiga Roda cement (Portland Composite Cement);
- Sand from Palangka, Barito Sand, and Cempaka Sand;
- Palm Kernel Ash.

The next stage was material testing. Before mixing the materials, testing was conducted on the materials used. These tests included the following:

- Testing the moisture content of fine aggregate;
- Testing the mud content of fine aggregate;
- Testing the organic content of fine aggregate;
- Testing the sieve analysis of fine aggregate;
- Testing the volume weight of fine aggregate;
- Testing the specific gravity and absorption of fine aggregate;
- Testing the volume weight of cement;
- Testing the specific gravity of cement;
- Testing the normal consistency of cement;
- Testing the setting time of cement.

The last stage was mixing the design. The mix design for Cement Treated Base Class B Layer (CTB) in this research used the proportioning method for Portland Pozzolan Cement type 1 (PPC), fine aggregate (sand), and Palm Kernel Ash. Below is the mix design table (proportions of Portland Pozzolan Cement type 1 (PPC), fine aggregate (sand), and Palm Kernel Ash based on the composition of CTB mix, including sand, cement, and palm kernel ash. The cement content used is 15% of the CTB mix composition, with variations in the reduction of sand at 70%, 65%, 60%, 55%, 50%, and 45% of the total mix composition, and variations in the addition of Palm Kernel Ash at 15%, 20%, 25%, 30%, 35%, and 40% of the total composition of CTB Class B mix, as specified in Tables 1, 2, and 3.

Tabel 1. The mix design for Cement Treated Base Class B layer with Palangka sand

Var	Sample Number	Sand Content (%)	Cement Content (%)	Ash Content (%)	Total CTB Mix Composition (%)
1	1A	70	15	15	100
	1B				
	1C				
2	2A	65	15	20	100
	2B				
	2C				
3	3A	60	15	25	100
	3B				
	3C				
4	4A	55	15	30	100
	4B				
	4C				
5	5A	50	15	35	100
	5B				
	5C				
6	6A	45	15	40	100
	6B				
	6C				

Table 2. The mix design for Cement Treated Base Class B layer with Barito sand

Var	Sample Number	Sand Content (%)	Cement Content (%)	Ash Content (%)	Total CTB Mix Composition (%)
1	1D	70	15	15	100
	1E				
	1F				
2	2D	65	15	20	100
	2E				
	2F				
3	3D	60	15	25	100
	3E				
	3F				
4	4D	55	15	30	100
	4E				
	4F				
5	5D	50	15	35	100
	5E				
	5F				
6	6D	45	15	40	100
	6E				
	6F				

Tabel 3. The mix design for Cement Treated Base Class B layer with Cempaka sand

Var	Sample Number	Sand Content (%)	Cement Content (%)	Ash Content (%)	Total CTB Mix Composition (%)
1	1G	70	15	15	100
	1H				
	1I				
2	2G	65	15	20	100
	2H				
	2I				
3	3G	60	15	25	100

	3H				
	3I				
4	4G	55	15	30	100
	4H				
	4I				
5	5G	50	15	35	100
	5H				
	5I				
6	6G	45	15	40	100
	6H				
	6I				

After the materials were mixed, the casting was carried out with the planned composition mentioned above. After casting, the samples were soaked for 7 days, followed by conducting a compressive strength test.

III. RESEARCH RESULTS

A. *Data Analysis*

Fine Aggregate Testing

The fine aggregate (sand) used in the research underwent testing first. The test results are presented in Table 4:

1). Moisture Content Testing

Moisture Content = $\frac{A-B}{B} \times 100\ \%$

2). Mud Content Testing

Weight of dry test specimen (A)

Weight of test specimen retained on sieve no. 200 (B)

Mud Content = $\frac{A-B}{A} \times 100\ \%$ (2)

3). Organic Content Testing

After conducting the test, the result was that the sand wash water had a tea-like color, indicating that the sand contained a sufficient amount of organic matter. It is recommended to wash the sand thoroughly before using it as a material.

4). Sieve Analysis Testing

After conducting the sieve analysis test, the results of the weight of fine aggregate on each sieve number were obtained, as shown in Tables 4, 5, and 6.

Tabel 4. Sieve analysis data for fine aggregate Palangka sand

Sieve analysis for fine aggregate Palangka sand					
Sieve No.	Retained Weight		Retained Weight Cumulative (%)	Passed Weight	
	Gram	%		Gram	%
No.12	2	0,2	0,2	998	99,8
No.16	4	0,4	0,6	994	99,4
No.30	61	6,1	6,7	933	93,3
No.50	334	33,4	40,1	599	59,9
No.100	390	39	79,1	209	20,9
Pan	209	20,9	100	0	0
Total	1000	100	226,7		
		MHB	2,267		

When viewed in Table 4, it is seen that the weight of fine aggregate (sand) retained and passing through sieves #12, #16, #30, #50, and #100. On sieve #12, the retained sand weighs 2 grams and the passing sand weighs 998 grams. On sieve #16, the retained sand weighs 4 grams and the passing sand weighs 994 grams. On sieve #30, the retained sand weighs 61 grams and the passing sand weighs 933 grams. On sieve #50, the retained sand weighs 334 grams and the passing sand weighs 599 grams. On sieve #100, the retained sand weighs 390 grams and the passing sand weighs 209 grams, with 209 grams of sand retained in the pan. After conducting the Sieve Analysis test, it can be concluded from Figure 2 above that the tested sand sample falls into the category of Fine Aggregate Zone III or moderately fine graded sand [7].

Table 5. Sieve analysis data for fine aggregate Barito sand

Sieve analysis for fine aggregate Barito sand					
Sieve No.	Retained Weight		Retained Weight Cumulative (%)	Passed Weight	
	Gram	%		Gram	Gram
No.12	6	0,6	0,6	994	99,4
No.16	78	7,8	8,4	916	91,6
No.30	257	25,7	34,1	659	65,9
No.50	332	33,2	67,3	327	32,7
No.100	232	23,2	90,5	95	9,5
Pan	95	9,5	100	0	0
Total	1000	100	300,9		
		MHB	3,009		

Then, Table 5 shows the weight of fine aggregate (sand) retained and passing through sieves #12, #16, #30, #50, and #100. On sieve #12, the retained sand weighs 24 grams and the passing sand weighs 976 grams. On sieve #16, the retained sand weighs 260 grams and the passing sand weighs 716 grams. On sieve #30, the retained sand weighs 332 grams and the passing sand weighs 384 grams. On sieve #50, the retained sand weighs 341 grams and the passing sand weighs 43 grams. On sieve #100, the retained sand weighs 35 grams and the passing sand weighs 8 grams, with 8 grams of sand retained in the pan. After conducting the Sieve Analysis test, it can be concluded from Figure 3 above that the tested sand sample falls into the category of Fine Aggregate Zone I or coarsely graded sand.

Table 6. Sieve analysis data for fine aggregate Cempaka sand

Sieve analysis for fine aggregate Cempaka sand					
Sieve No.	Retained Weight		Retained Weight Cumulative (%)	Passed Weight	
	Gram	%		Gram	Gram
No.12	14	1,4	1,4	986	98,6
No.16	88	8,8	10,2	898	89,8
No.30	246	24,6	34,8	652	65,2
No.50	323	32,3	67,1	329	32,9
No.100	206	20,6	87,7	123	12,3
Pan	123	12,3	100	0	0
Total	1000	100	301,2		
		MHB	3,012		

Finally, Table 6 shows the weight of fine aggregate (sand) retained and passing through sieves #12, #16, #30, #50, and #100. On sieve #12, the retained sand weighs 14 grams and the passing sand weighs 986 grams. On sieve #16, the retained sand weighs 88 grams and the passing sand weighs 898 grams. On sieve #30, the retained sand weighs 246 grams and the passing sand weighs 652 grams.

The percentage of fine aggregate (sand) that passes through sieves when presented in graphical form can be observed in Figures 1, 2, and 3.

On sieve #50, the retained sand weighs 323 grams and the passing sand weighs 329 grams. On sieve #100, the retained sand weighs 206 grams and the passing sand weighs 123 grams, with 123 grams of sand retained in the pan. After conducting the Sieve Analysis test, it can be concluded that the tested sand sample falls into the category of Fine Aggregate Zone I or coarsely graded sand.

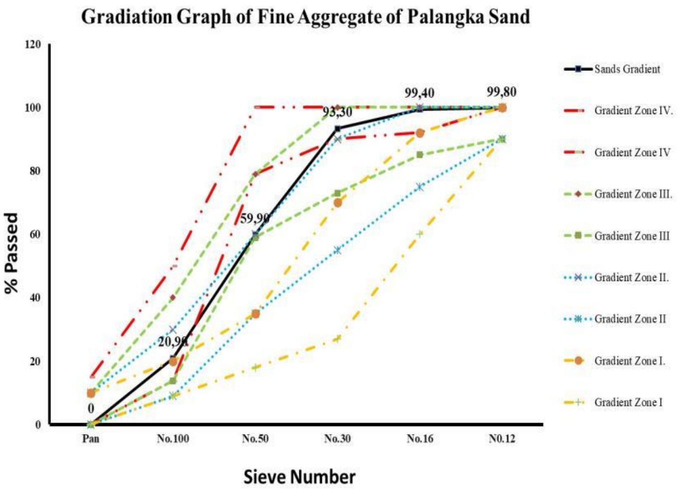


Figure 1. Percentage Passing Palangka Sand

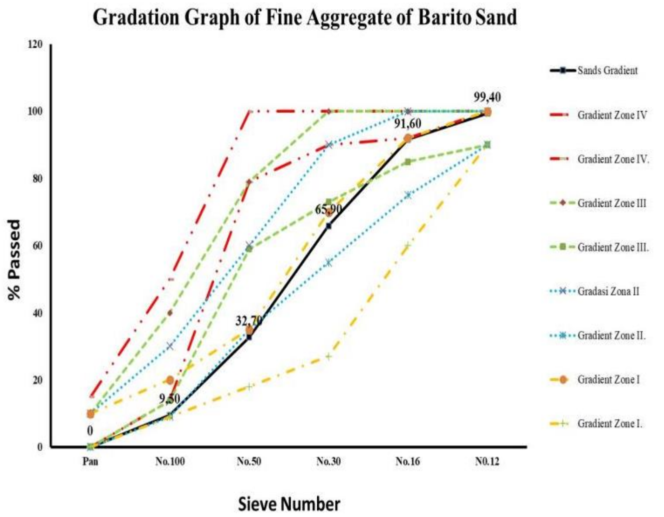


Figure 2. Percentage Passing Barito Sand

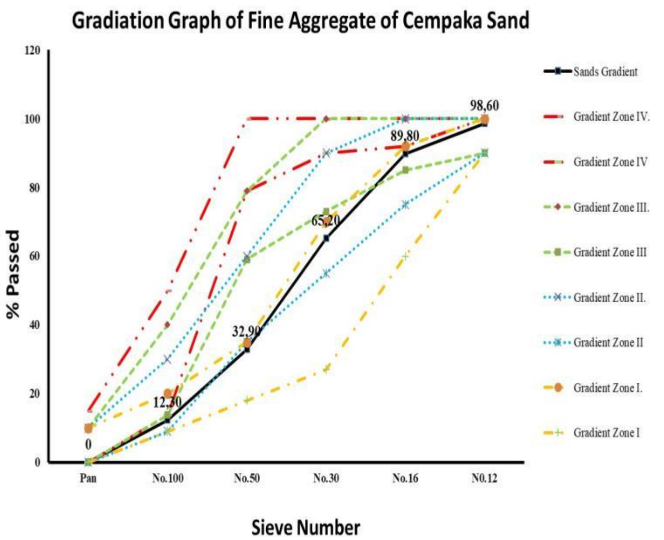


Figure 3. Percentage Passing Cempaka Sand

Volume Weight Testing

The comparison of the volume weight results of fine aggregate, Palangka sand, under three conditions (loose, shaking, and compaction) is as follows:

Loose Condition = 1.53 gr/cm^3
Shaking Condition = 1.72 gr/cm^3
Compaction Condition = 1.73 gr/cm^3

The requirements for the sand are: *γloose < γshaking < γcompaction* = 1,59 < 1,57 < 1,73

From the above results, it can be concluded that the compaction condition has the highest volume weight value compared to the shaking and loose conditions.

Specific Gravity and Absorption Testing of Aggregate

From the calculations above, the data for Fine Aggregate, Palangka Sand, are as follows:

Apparent Specific Gravity = 2.649
Bulk Specific Gravity on Dry Basis = 2.621
Bulk Specific Gravity SSD Basis = 2.632
Percentage Water Absorption = 0.402%

From the obtained experimental data, the researchers can determine the volume of water to be used in concrete mixing so that the intended mix ratio is not reduced due to the absorption of fine aggregate. With the appropriate adjustment of the mix ratio after correcting for water volume, the researchers can determine the required volume of fine aggregate for concrete mixing. If tested using the method of weighing materials, the specific gravity of Palangka sand is 0.754.

B. Cement Characteristic Testing

The cement used undergoes the following tests:

Cement Volume Weight Testing

Comparison of volume weight under various conditions, where the compaction condition has a higher volume weight than the other conditions:

γloose < γshaking < γcompaction
1.00 gr/cm3 < 1.11 gr/cm3 < 1.16 gr/cm3

Cement Specific Gravity Testing

The results of the practical experiments indicate that PCC cement (Three-Wheel Portland cement) used in the study has a specific gravity of 3.20, which can be categorized as good-quality cement.

Normal Consistency Testing of Cement

$$\text{Normal Consistency} = \frac{\text{weight of water}}{\text{weight of cement}} \times 100\% \qquad (3)$$

From the normal consistency testing, it is determined that the normal consistency value is 28.2%. According to SNI ASTM C 187-04, normal consistency of cement is the time when the cement starts to set when mixed with water. The data from the conducted testing is within the specified range of ±10 mm.

Cement Setting Time Testing

The initial setting time of PCC cement (Three-Wheel Portland cement) in this test is 85 minutes/ 1 hour, 25 minutes, and the final setting time is 120 minutes/ 2 hours.

C. Palm Kernel Shell Ash Examination

The ash used in this study is fly ash resulting from the combustion of a mixture of palm kernel shells and fibers. The ash used in the study is from the same source as previous ash material examinations, and the results can be seen in Table 7, while the chemical content test can be seen in Table 8.

Table 7. Results of palm kernel shell ash examination

No	Examination Type	Examination Value	Method
1	Weight	1,79 gr/cm3	SNI 15-0232-2004
2	Moisture Content	52,65%	
3	Normal Consistency	31%	
4	Volume Weight a. Loose Condition b. Compaction Condition c. Shaking Condition	 0,502 gr/cm3 0,608 gr/cm3 0,622 gr/cm3	

Source: Rahman et al., 2020 [8]

Table 8. Results of chemical content examination of palm kernel shell ash

Parameter		Unit	Result	Method
Analysis of Ash (*Dry Basic*)	Silicon Dioxide as SiO2	Percentage by weight	55,39	ASTM D 6349-13
	Aluminium Trioxide as Al203	Percentage by weight	5,74	
	Iron Oxide as Fe2O3	Percentage by weight	4,17	
	Calcium Oxide as CaO	Percentage by weight	9,24	
	Magnesium Oxide as MgO	Percentage by weight	9,44	
	Sodium Dioxide as Na2O	Percentage by weight	0,59	
	Potassium Oxide as K2O	Percentage by weight	7,99	
	Manganese Oxide as MnO2	Percentage by weight	0,20	
	Titanium Dioxide as TiO2	Percentage by weight	0,32	
	Phosphorus Pentoxide as P2O5	Percentage by weight	5,86	
	Sulphur Trioxide as SO3	Percentage by weight	0,53	
	Undetermined	Percentage by weight	0,53	

Source: Rahman et al., 2020 [9]

From Table 8, the sum of compounds SiO2 + Al2O3 + Fe2O3 is 65.3%, which is more than 50% but less than 70%, and the compound Sulphur Trioxide (SO3) is 0.53%, which is less than 5%, and Sodium Dioxide (Na2O) is 0.59%, which is less than 1.5% [9]).

D. Cement-Water Ratio (CWR) Planning

The Cement-Water Ratio is the amount of water added to the cement mixture. The Cement-Water Ratio can be determined by looking at the CWR chart and calculating the weight of the cement mixture. The Cement-Water Ratio used in this study is CWR = 0.9. Based on the Cement-Water Ratio (CWR) formula, the amount of water is obtained as follows.

$FAS = W/C$ .... (1)

$C = FAS/W$ .... (2)

$W = FAS \times C$ .... (3)

$W = 0{,}9 \times 3{,}033 = 2{,}7297\ \ell$

However, in field application, the calculated Cement-Water Ratio (CWR) does not meet the required concrete consistency for making a test specimen. Therefore, a Trial and Error method is conducted to determine the amount of water needed for each test specimen [10].

E. Analysis of CTB Class B Test Specimens for Palangka Sand, Barito Sand, and Cempaka Sand

The following are the results of research conducted in the Civil Engineering Laboratory, Universitas Lambung Mangkurat, Faculty of Engineering, using the pre-planned composition. With specified requirements of 35 - 45 kg/cm2 and soaking treatment for 7 days after casting. The data on the compressive strength test results can be seen in Tables 9, 10, and 11.

Table 9. Compressive strength test results for CTB Class B with Palangka Raya sand

Varia-tion	Sampel number	Material						Sample Weight (Kg)	Compressive Strength Test Result (Kg)	Compressive Strength Test Result (Kg/Cm2)	Average	Requirement (Kg/Cm2) CTSB	Information
		Palm Kernel Shell Ash		Cement		Palangka Raya sand							
		Percentage (%)	Weight (Kg)	Percentage (%)	Weight (Kg)	Percentage (%)	Weight (Kg)						
	1A							11.19	11000	62.28			
1	1B	15%	2.183	15%	4.458	70%	26.962	11.07	9500	53.79	58.50		Excluded
	1C							11.01	10500	59.45			
	2A							10.53	10000	56.62			
2	2B	20%	2.911	15%	4.458	65%	24.943	10.6	9000	50.96	50.96		Excluded
	2C							10.57	8000	45.29			
	3A							10.68	8200	46.43			
3	3B	25%	3.639	15%	4.458	60%	23.024	10.63	8200	46.43	44.73		Included
	3C							10.41	7300	41.33			
	4A							10.56	8000	45.29		35-45	Included
4	4B	30%	4.367	15%	4.458	55%	21.106	10.55	6800	38.50	39.25		
	4C							10.62	6000	33.97			
	5A							10.28	7000	39.63			Included
5	5B	35%	5.094	15%	4.458	50%	19.187	10.4	5500	31.14	36.42		
	5C							10.32	6800	38.50			
	6A							9.57	5400	30.57			
6	6B	40%	5.822	15%	4.458	45%	17.268	9.55	4000	22.65	26.23		Excluded
	6C							9.54	4500	25.48			

(Source: Results of Analysis)

Table 10. Compressive strength test results for CTB Class B with Barito sand

Varia-tion	Sampel number	Material						Sample Weight (Kg)	Compressive Strength Test Result (Kg)	Compressive Strength Test Result (Kg/Cm2)	Average	Requirement (Kg/Cm2) CTSB	Information
		Palm Kernel Shell Ash		Cement		Barito sand							
		Percentage (%)	Weight (Kg)	Percentage (%)	Weight (Kg)	Percentage (%)	Weight (Kg)						
	1D							10.82	7000	39.63			
1	1E	15%	2.183	15%	4.458	70%	25.722	10.71	6400	36.23	34.73		Excluded
	1F							10.92	5000	28.31			
	2D							10.59	7500	42.46			Included
2	2E	20%	2.911	15%	4.458	65%	23.884	10.86	7500	42.46	39.63		
	2F							10.71	6000	33.97			
	3D							10.56	8000	45.29		35-45	Included
3	3E	25%	3.639	15%	4.458	60%	22.047	10.57	6200	35.10	43.78		
	3F							10.59	9000	50.96			
	4D							10.61	8000	45.29			Excluded
4	4E	30%	4.367	15%	4.458	55%	20.210	10.66	8500	48.12	47.18		
	4F							10.70	8500	48.12			

5	5D	35%	5.094	15%	4.458	50%	18.373	10.20	8500	48.12	50.96		Excluded
	5E							10.33	9000	50.96			
	5F							10.21	9500	53.79			
6	6D	40%	5.822	15%	4.458	45%	16.535	9.68	10000	56.62	52.84		Excluded
	6E							9.83	9000	50.96			
	6F							9.86	9000	50.96			

(Source: Results of Analysis)

Table 11. Compressive strength test results for CTB Class B with Cempaka sand

Varia-tion	**Sampel number**	**Material**						**Sampel Weight (Kg)**	**Com-pressive strength test result (Ton)**	**Compres-Sive strength test result (Kg/Cm2)**	**Ave**	**Req (Kg/Cm2) CTSB**	**Infor-mation**
		Palm Kernel Shell Ash		**Cement**		**Cempaka sand**							
		Percentage (%)	**Weight (Kg)**	**Percent-tage (%)**	**Weight (Kg)**	**Percen-tage (%)**	**Weight (Kg)**						
1	1G	15%	2.183	15%	4.458	70%	27.004	10.44	6500	36.80	33.97	35-45	Excluded
	1H							10.61	6500	36.80			
	1I							10.56	5000	28.31			
2	2G	20%	2.911	15%	4.458	65%	25.075	10.52	5900	33.40	36.61		Included
	2H							10.50	6500	36.80			
	2I							10.55	7000	39.63			
3	3G	25%	3.639	15%	4.458	60%	23.147	10.32	6400	36.23	38.12		Included
	3H							10.32	6800	38.50			
	3I							10.27	7000	39.63			
4	4G	30%	4.367	15%	4.458	55%	21.218	10.39	7000	39.63	42.09		Included
	4H							10.43	7500	42.46			
	4I							10.40	7800	44.16			
5	5G	35%	5.094	15%	4.458	50%	19.289	10.07	7500	42.46	44.73		Included
	5H							10.02	8000	45.29			
	5I							9.98	8200	46.43			
6	6G	40%	5.822	15%	4.458	45%	17.360	9.25	8000	45.29	46.24		Excluded
	6H							9.37	8500	48.12			
	6I							9.38	8000	45.29			

(Source: Results of Analysis)

Tables 9, 10, 11 show the compressive strength test results for CTB Class B using three different types of sand in the material mix, with ash content ranging from 15% to 40%. Meanwhile, the sand content varies from 70% to 45% in the mix of Cement Treated Base Class B (CTB).

Meanwhile, Graphs in Figures 4, 5, and 6 depicted the compressive strength test results for CTB Class B using three different types of sand.

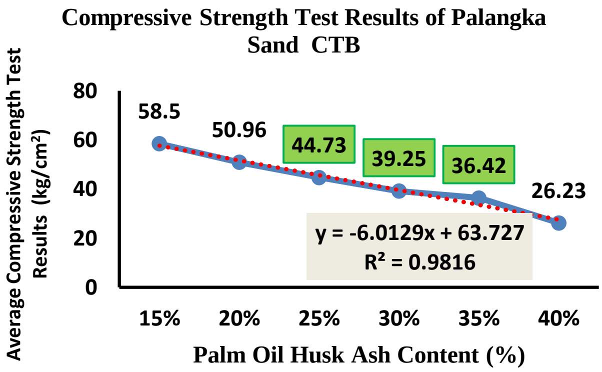


Figure 4. Compressive strength test graph for Palangka sand CTB

In Figure 4, it can be seen that only mix compositions of Palm Kernel Shell Ash at 25%, 30%, and 35% meet the specified CTB Class B specifications, with average compressive strength test results of 44.730 kg/cm2, 39.255 kg/cm2, and 36.420 kg/cm2, respectively.

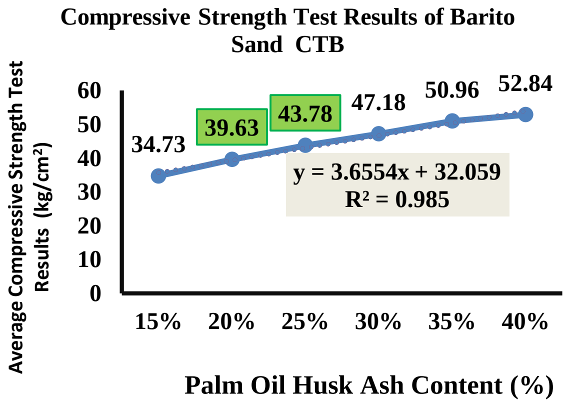


Figure 5. Compressive strength test graph for Barito sand CTB

Then, in Figure 5, only mix compositions of Palm Kernel Shell Ash at 20% and 25% meet the specified requirements, with average compressive strength test results of 39.63 kg/cm2 and 43.78 kg/cm2 for CTB Class B.

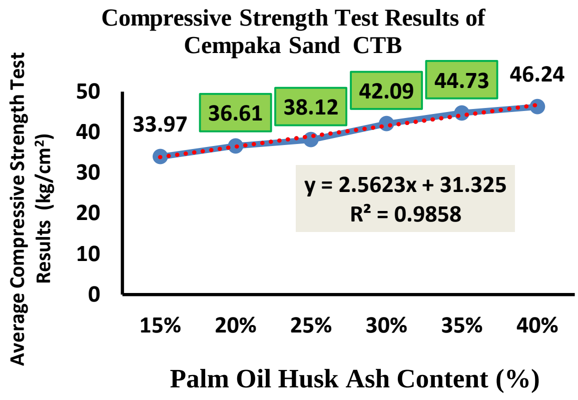
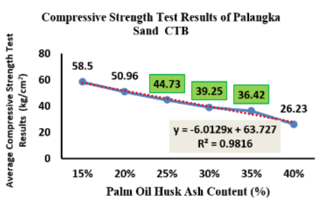
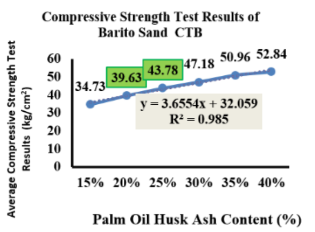
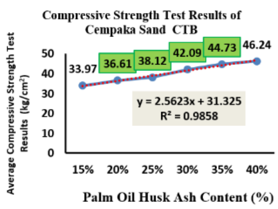


Figure 6. Compressive strength test graph for Cempaka sand CTB

In Figure 6, it is known that only mix compositions of Palm Kernel Shell Ash at 20%, 25%, 30%, and 35% meet the specified requirements, with average compressive strength test results of 36.61 kg/cm2, 38.12 kg/cm2, 42.09 kg/cm2, and 44.73 kg/cm2 for CTB Class B.

Below is a table of the overall results and comparison of three types of fine aggregates and the comparison of compressive strength test results conducted in the laboratory, which can be seen in Table 12.

Table 12. Comparison of fine aggregates and compressive strength test graph for CTB Class B

<table>
<tr><th colspan="2" rowspan="2">Examination types</th><th colspan="3">Sand types</th></tr>
<tr><th>Palangka Raya sand</th><th>Barito sand</th><th>Cempaka sand</th></tr>
<tr><td colspan="2">Moisture Content</td><td>2.67%</td><td>0.30%</td><td>2.10%</td></tr>
<tr><td colspan="2">Silt Content</td><td>2.65%</td><td>2.88%</td><td>5%</td></tr>
<tr><td colspan="2">Organic Content</td><td>Standard color No. 2</td><td>Standard color No. 2</td><td>Standard color No. 2</td></tr>
<tr><td colspan="2">Specific Gravity</td><td>0.754</td><td>0.722</td><td>0.758</td></tr>
<tr><td rowspan="3">Bulk Density</td><td>Loose Condition</td><td>1.53 gr/cm3</td><td>1.46 gr/cm3</td><td>1.58 gr/cm3</td></tr>
<tr><td>Shaking Condition</td><td>1.72 gr/cm3</td><td>1.54 gr/cm3</td><td>1.68 gr/cm3</td></tr>
<tr><td>Compaction Condition</td><td>1.73 gr/cm3</td><td>1.57 gr/cm3</td><td>1.71 gr/cm3</td></tr>
<tr><td colspan="2">Aggregate Gradation</td><td>Zone III Gradation (Moderately Fine Sand)</td><td>Zone I Gradation (Coarse Sand)</td><td>Zone I Gradation (Coarse Sand)</td></tr>
<tr><td colspan="2">Compressive Strength Test Graphs</td><td></td><td></td><td></td></tr>
</table>

IV. DISCUSSION

The results of the fine aggregate gradation are categorized into 4 zones: Zone I, Zone II, Zone III, and Zone IV. Zone I is coarse sand, Zone II is moderately coarse sand, Zone III is moderately fine sand, and Zone IV is fine sand.

After conducting gradation testing on the fine aggregates used in this research, it was found that Palangka Sand falls into Zone III gradation (Moderately Fine Sand). Meanwhile, Barito Sand and Cempaka Sand fall into Zone I gradation (Coarse Sand), as shown in Table 12 above. During the compressive strength testing, it was observed that the type of sand used also has an impact on the compressive strength results. Coarser fine aggregates tend to lead to higher compressive strength, while finer fine aggregates tend to result in lower compressive strength.

V. CONCLUSION

From the conducted research, the following conclusions are drawn:

1. For the CTB mix composition with Palangka Sand, an increased use of Palm Kernel Shell Ash composition in a CTB Class B mix with a reduced sand composition will lead to a decrease in concrete compressive strength.
2. For the CTB mix composition with Barito Sand and Cempaka Sand, an increased use of Palm Kernel Shell Ash composition with a reduced sand composition will lead to an increase in concrete compressive strength.
3. Mix compositions that meet the specifications for Cement Treated Base Class B (CTB) are as follows:
   a. For the CTB mix composition with Palangka Raya Sand, compositions of 25%, 30%, and 35% Palm Kernel Shell Ash meet the specifications.
   b. For the CTB mix composition with Barito Sand, compositions of 25% and 30% Palm Kernel Shell Ash meet the specifications.
   c. For the CTB mix composition with Cempaka Sand, compositions of 25%, 30%, 35%, and 40% Palm Kernel Shell Ash meet the specifications.
4. Based on the gradation testing results for the three sands mentioned above, a comparison was made, revealing that Palangka Raya Sand falls into Zone III gradation (Moderately Fine Sand), while Cempaka Sand and Barito Sand fall into Zone I gradation (Coarse Sand). Therefore, coarser fine aggregates tend to result in higher compressive strength, while finer fine aggregates tend to result in lower compressive strength.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ACKNOWLEDGMENT

The authors thank Universitas Lambung Mangkurat, under the Ministry of Education, Culture, Research, and Technology, provided research funding through the *Program Dosen Wajib Meneliti* (PDWM) for the year of 2023. This funding was allocated through the University Budget Implementation Document (DIPA) for Fiscal Year 2023, identified as Number: SP DIPA-023.17.2.677518/2023, dated November 30, 2022. This initiative aligns with the Rector's Decree of Universitas Lambung Mangkurat, Number: 615/UN8/PG/2022, dated May 31, 2023.

REFERENCES

1. Nurkholis. 2017 Analisis Kekuatan Cement Treated Base (CTB) dengan Tambahan Zat Aditif Menggunakan Variasi Kandungan Tanah dan Pasir untuk Lapis Pondasi Atas Jalan.
2. Umboh AH, Sumajouw MDJ, and Windah RS. 2014 Pengaruh Pemanfaatan Abu Terbang (fly ash) dari PLTU II Sulawesi Utara Sebagai Substitusi Parsial Semen Terhadap Kuat Tekan Beton. *J Sipil Statik*, 2(7):352–8.
3. Wardani S. 2008 Pemanfaatan Limbah Batu Bara (Fly Ash) Untuk Stabilitas Tanah Maupun Keperluan Teknik Sipil Lainnya dalam Manggurangi Pencemaran Lingkungan. Pengukuhan Guru Besar Fak Tek Univ Diponogoro. 1–71.
4. Telaumbanua JJP. 2017 Penggunaan Fly Ash dan Bottom Ash Boiler Pabrik Kelapa Sawit Sebagai Adsorben untuk Mengadsorpsi Zat Warna pada Limbah Cair Buatan, 1–90.
5. Setiawati M. 2018 Fly Ash Sebagai Bahan Pengganti Semen Pada Beton. Seminar Nasional Sains dan Teknol [Internet], 17:1–8. Available from: https://jurnal.umj.ac.id/index.php/semnastek/article/view/3556
6. Direktorat Jenderal Bina Marga. 2020 Spesifikasi Umum Bina Marga 2018 Untuk Pekerjaan Konstruksi Jalan dan Jembatan (Revisi 2). Kementerian Pekerjaan Umum dan Perumahan Rakyat (Oktober):1036.
7. Nasional BS. Metode Pengujian Tentang Analisis Saringan Agregat Halus dan Kasar. SNI 03-1968-1990. 1990;1–5.
8. Rahman F, Dwika D, and Setiyawan B. 2020 Studi Eksperimental Sifat Mekanik Beton Normal Dengan Menggunakan Abu Dasar Limbah Hasil Pembakaran Campuran Cangkang Dan Serabut Kelapa Sawit Sebagai Pengganti Agregat. J Teknol Berkelanjutan (*Sustainable Technology Journal*) [Internet], 48(1):48–56. Available from: http://jtb.ulm.ac.id/index.php/JTB

9. Rahman F, Hidayat G, and Bertiani N. 2020 Serabut Kelapa Sawit Sebagai Substitusi Semen, 21(2):227–42.
10. Badan Standardisasi Nasional. 2015 SNI 2049:2015: Semen Portland. Standar Nasional Indonesia, 5;1–147.