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Fly Ash Utilization Analysis as A Substitute of Cement in Cement Treated Base (CTB)

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ABSTRACT: Cement Treated Base (CTB) is a pavement layer located between the sub-base and surface layers. This pavement layer uses fine aggregate (sand) and cement as a binder. Fly ash is coal burning waste that can be used as an added material for road pavement. This study aimed to analyze the use of fly ash in the cement treated base pavement mixture. Fly ash was used as a substitute of cement. The composition used consists of fine aggregate (sand), cement, fly ash and water. The compressive strength test was carried out on variations in the composition of the test object. The requirements for CTB specifications were to have compressive strength test results ranging between 45 kg/cm^2 – 55 kg/cm^2 at the age of the test object for 7 days. After being tested, it was found that the composition of 70% fine aggregate (sand), 5% Portland cement, and 25% fly ash had an average compressive strength of 49.823 kg/cm^2.

KEYWORDS: Cement Treated Base, Fly Ash, Compressive Strength Test

I. INTRODUCTION

Road pavement is a part of the road that is paved with a certain construction layer that has a certain thickness, stiffness, strength, and stability so that it can transfer the traffic load that passes on it to the subgrade layer. Based on the binding material, road pavement is divided into two types, namely rigid pavement and flexible pavement. Flexible pavement using asphalt binder consists of several types of layers, namely subgrade, subbase course, base course, and surface course. The material used for the foundation layer must be of good quality aggregate and meet the gradation criteria and the required material properties so it is easily compacted and has a strong bearing capacity to withstand the planned traffic load [1]. Road pavement using composite pavement has begun to be widely implemented in the construction of new roads, including the use of Cement Treated Base (CTB).

In infrastructure development, Fly Ash is a waste of coal combustion that can be used as an added material for road pavement [2]. Even the government urges its people to use waste as road pavement material [3]. In addition, Fly Ash can also be used to strengthen the soil structure, fill the pores between soil particles, dry quickly into a hard layer so that the soil becomes dense and stable, causing the increasing in the soil carrying capacity [4]. In a study on geopolymer paste with fly ash binder material, it has a longer binding time than conventional paste using cement as a binder [5].

Utilization of coal waste as a subgrade stabilization material as well as road construction is an effective solution to prevent environmental pollution caused by coal waste in relatively large amounts [6]. With the characteristics possessed by fly ash, it is expected to be a good mineral substitute for high quality concrete. The chemical properties of fly ash used are almost the same as cement so that it can be used as a partial substitute for cement as a high-quality concrete mixture. Replacing fine aggregate with dust, and adding fly ash to cement can increase the compressive strength of high-strength concrete [7]. The use of fly ash and bottom ash as fine aggregate in cement mortar mixtures has also been carried out [8].

Definitely, the casting process using guidelines for the manufacture and maintenance of concrete test objects in the laboratory must be in accordance with SNI [9]. Portland Cement of Tiga Roda Brand used in casting to obtain great strength in a short time [10]. Casting is done by using a vibrator vertically so cement can penetrate the bottom of the mold with the purpose that it produces a density in that part [11].

The use of variations of cement in the CTB will produce differences in the strength of the compressive strength value [12]. Another study stated that the chemical composition of fly ash affects the strength of concrete [13]. Fly ash is very suitable to use as a substitute for cement in road pavement stabilization. However, its use is only in low-level applications [14].

Fly ash waste from PT. PLN Asam Asam is excessive. It is unfavorable if fly ash waste is just thrown away. CTB (Cement Treated Base) is a mixture of cement, water, and fine aggregate that goes through a laboratory grading process. These materials are mixed with a mixer (molen machine) which can produce a semi-wet concrete mixture with a minimum moisture content. The use of CTB is usually in road pavement construction as a sub-base or upper foundation (Base Course) construction layer. The purpose of this study was to determine the characteristics of the mixture of cement treated base (CTB) as the foundation layer for the road using Fly Ash additives. The composition of the CTB which consists of water, fly ash, cement, and sand must meet the specified specifications, which fulfill the requirements for a compressive strength test of 45 kg/cm2 – 55 kg/cm2 [11].

II. RESEARCH METHOD

This research began with a literature study through the existing literature. Furthermore, research was conducted at the Civil Engineering Laboratory of Lambung Mangkurat University.

The stages of research implementation were as follows.

1. Preparation of materials used for research
   a. Using Tiga Roda Brand Portland cement.
   b. Using fine aggregate in the form of sand from Palangka Raya, Central Kalimantan Province.
   c. Using Fly Ash taken from the PT. PLN Asam Asam, Tanah Laut Regency, South Kalimantan Province
2. Fine Aggregate Tests
   a. Water content test
   b. Mud content test
   c. Organic content test
   d. Filter analysis test
   e. Test volume weight
   f. Aggregate specific gravity and absorption test
3. Testing of Cement Characteristics:
   a. Cement Volume Weight Test
   b. Cement Specific Gravity Test
   c. Normal Cement Consistency Test
   d. Cement Time Bonding Test
4. Mix Planning
   The planning of the Cement Treated Base (CTB) mixture in this study used a mixture of Portland Composite Cement (PCC), fine aggregate (sand), fly ash and water. In this study, two variations of the composition of the CTB mixture were planned. The goal was to ensure the right composition to fit into the CTB specification. Composition I used 5% fly ash variation while composition II used 1% fly ash variation.
5. Making of test objects
   The test object used was a cylinder with a diameter of 15 cm and a height of 30 cm.
6. Treatment of the test object
   The soaking treatment for 7 days
7. Compressive Strength Test
9. Data Analysis and Conclusion

The requirements for the loose compressive strength of grade A cement aggregate foundation (CTB) at the age of 7 days were 45 – 55 kg/cm2 [11].

The research flow chart can be seen in Figure 1.

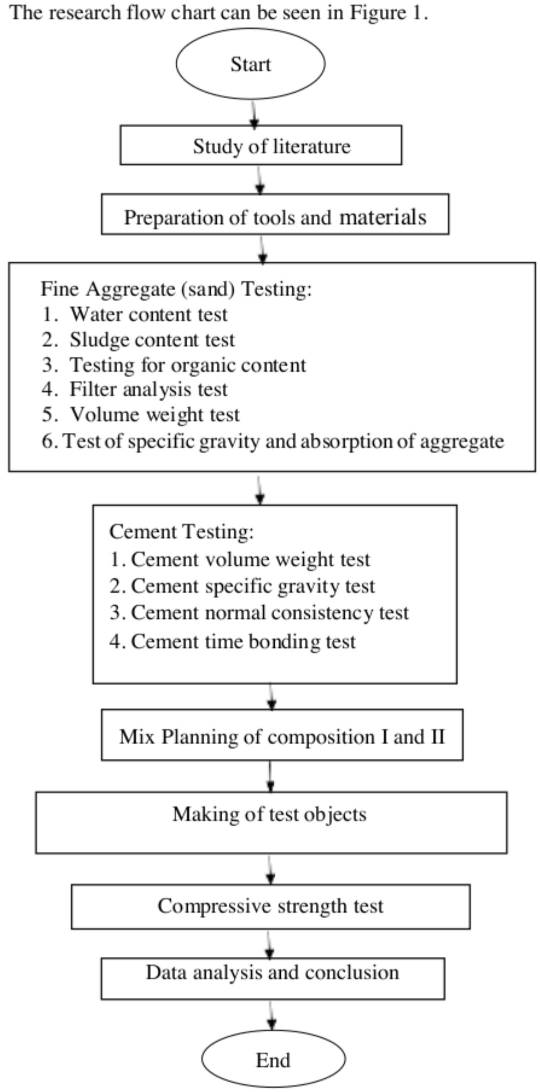

Figure 1. Research Flow Chart

III. RESULTS AND DISCUSSION

A. Fine Aggregate Test

From the test results of fine aggregate (sand) obtained 6.382% water content and 12% mud content. While the Organic Content Test obtained a tea-like color which meant that the aggregate contained sufficient organic content. It is recommended to wash the sand first before using it as a material.

In the Sieve Analysis Test, the fine aggregate weight was obtained for each sieve number as shown in Table 1.

Table 1. Sieve Analysis Result Data of Fine Aggregate

Sieve Analysis of Fine Aggregate					
Sieve Number	Retained Weight		Cumulative Retained Weight (%)	The Weight that Passed Through the Sieve	
	gram	percentage (%)		gram	percentage (%)
No.12	2	0.2	0.2	998	99.8
No.16	4	0.4	0.6	994	99.4
No.30	140	14	14.6	854	85.4
No.50	316	31.6	42.6	538	53.8
No.100	504	50.4	96.6	340	3.4
Pan	34	3.4	100	0	0
Total	1000	100			

Source: the results of analysis

After the Sieve Analysis was tested, it can be concluded that the fine aggregates tested were in the good gradation category.

From the weight-volume test, the ratios of the volume-weight results of fine aggregates treated under 3 conditions (loose, shaken and compacted) were as follows:

a. The weight-volume of loose condition = 1.48 gr/cm3
b. The weight-volume of shaking condition = 1.57 gr/cm^3
c. The weight-volume of compaction condition = 1.60 gr/cm^3

From the results, it can be concluded that the volume weight in the compaction condition has the largest volume weight value compared to the shaking and release conditions.

From the results of the aggregate density and absorption tests, the following data were obtained:

a. Apparent specific = 2.667 gr
b. Bulk specific gravity on dry basic = 2.610 gr
c. Bulk specific gravity SSD basic = 2.631 gr
d. Percentage water absorption = 0.806%

B. Testing of Cement Characteristics

Before being used, cement was tested through several tests. The tests carried out were the cement volume weight test, the cement specific gravity test, the cement normal consistency test, and the cement adhesive time test.

The results of the Cement Volume Weight Test obtained the following results:

a. The weight-volume of loose condition = 1.00 gr/cm3
b. The weight-volume of shaking condition = 1.09 gr/cm3
c. The weight-volume of compaction condition = 1.24 gr/cm3

The results of the Cement Specific Gravity Test showed that the PCC cement (Portland cement of Tiga Roda Brand) used had a specific gravity of 3.20 gr/cm3 which was categorized as good quality cement.

Normal consistency test of cement obtained a normal consistency value of 27.60 %. Meanwhile, the cement binding time test found that the initial setting time for the PCC cement (third wheel Portland cement) in this test was 105 minutes / 1 hour 45 minutes. While the final binding time was 165 minutes / 2 hours 45 minutes.

C. Composition I Mix Planning

The planning of the mixture of materials and the amount of water used for each mixture of Composition I can be seen in Table 2.

Table 2. Composition I Mix Planning

No	Material						Total Weight (kg)
	Fly Ash		Cement		Fine Aggregate (sand)		
	(%)	Weight (kg)	(%)	Weight (kg)	(%)	Weight (kg)	
1	0%	0	30 %	3.033	70%	8.954	11.987
2	5 %	0.363	25 %	2.528		8.954	11.845
3	10 %	0.726	20 %	2.022		8.954	11.702
4	15 %	1.089	15 %	1.517		8.954	11.560
5	20 %	1.452	10 %	1.011		8.954	11.417
6	25 %	1.815	5 %	0.506		8.954	11.275

Source: the results of analysis

The manufacture of test objects was carried out based on Table 2. The test object was made in the form of a cylinder with a diameter of 15 cm and a height of 30 cm. The making of test objects can be seen in Figure 2.

Figure 2. Making a Cylindrical Test Object

Furthermore, 2 test objects were made from each type of mixture. There were 12 test objects made for composition I mix planning. The test objects subsequently immersed in water for 7 days. The process of immersing objects into water can be seen in Figure 3.

Figure 3. The Treatment of Immersing the Test Object into Water for 7 days

In addition, the compressive strength test was carried out on each test object. The testing of test objects using compressive strength test equipment can be seen in Figure 4.

Figure 4. Testing the test object using the Compressive Strength Test tool

D. Analysis for Test Objects of Composition I

The results of the compressive strength test of composition I can be seen in table 3.

Table 3. The Compressive Strength Test Results of Composition I

No	Fly Ash	Compressive Strength (ton/mm²)	Compressive Strength Conversion		Average Compression Strength (kg/cm²)
			MPa	kg/cm²	
1	0%	31.3	17.721	177.212	172.116
2		29.5	16.702	167.021	
3	5%	28.0	15.853	158.528	157.113
4		27.5	15.570	155.697	
5	10%	25.3	14.324	143.241	140.977
6		24.5	13.871	138.712	
7	15%	16.3	9.229	92.286	90.587
8		15.7	8.889	88.889	
9	20%	12.8	7.247	72.470	73.319
10		13.1	7.417	74.168	
11	25%	8.4	4.756	47.558	50.106
12		9.3	5.265	52.654	

Source: the results of analysis

The results of the average compressive strength test of composition I can be seen in Figure 5.

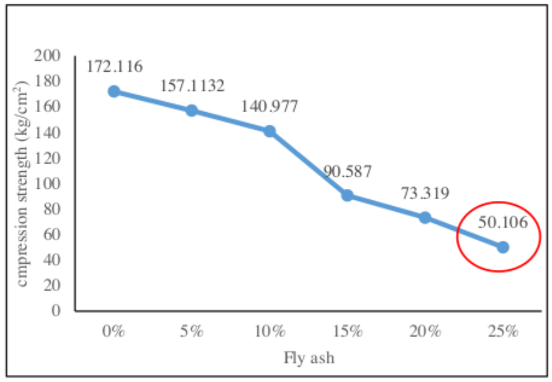

Figure 5. The Compressive Strength Test Results of Composition I

From the experimental results, only a mixture of 25% Fly Ash composition was included in the specified specifications, namely the results of the average compressive strength test of 50.106 kg/cm². Further research was carried out to obtain more accurate results in accordance with the CTB specification target of 45-55 kg/cm². Intending to obtain the composition of CTB that was in accordance with the specifications, the composition of Fly Ash used was 20% - 26% fly ash with an interval of 1%. This was done to obtain a tighter range of variations.

E. Composition II Mix Planning

The planning of the mixture of materials and the amount of water used for each mixture of composition II can be seen in Table 4.

Table 4. Composition II Mix Planning

No	Materials: Fly Ash		Cement		Fine Aggregate (sand)		Total Weight (kg)
	(%)	Weight (kg)	(%)	Weight (kg)	(%)	Weight (kg)	
1	20%	1.452	10%	1.011		8.954	11.417
2	21%	1.525	9%	0.910		8.954	11.389
3	22%	1.597	8%	0.809		8.954	11.360
4	23%	1.670	7%	0.708	70%	8.954	11.332
5	24%	1.743	6%	0.607		8.954	11.303
6	25%	1.815	5%	0.506		8.954	11.275
7	26%	1.888	4%	0.404		8.954	11.246

Source: the results of analysis

3 test objects were made from each mixture. There were 21 test objects totally made for composition II. Furthermore, the test object was immersed for 7 days and the compressive strength test was carried out.

F. Analysis for Test Objects of Composition II

The results of the strength test of composition II can be seen in Table 5.

Table 5. The Compressive Strength Test Results of Composition II

No	Variations of Fly Ash	Compressive Strength (ton/mm²)	Compressive Strength Conversion MPa	Compressive Strength Conversion kg/cm²	Average Compression Strength (kg/cm²)
1	20%	13.2	7.473	74.735	73.980
2		13.1	7.417	74.168	
3		12.9	7.304	73.036	
4	21%	12.7	7.190	71.904	71.526
5		12.8	7.247	72.470	
6		12.4	7.021	70.205	
7	22%	11.9	6.737	67.374	68.318
8		12.3	6.964	69.639	
9		12.0	6.794	67.941	
10	23%	11.2	6.341	63.411	64.355
11		11.5	6.511	65.110	
12		11.4	6.454	64.544	
13	24%	10.5	5.945	59.448	59.259
14		10.7	6.058	60.580	
15		10.2	5.775	57.749	
16	25%	9.2	5.209	52.088	49.823
17		8.5	4.812	48.125	
18		8.7	4.926	49.257	
19	26%	7.1	3.963	39.632	40.953
20		7.0	3.963	39.632	
21		7.7	4.360	43.595	

Source: the results of analysis

The data on the average compressive strength test results of composition I can be seen in Figure 6.

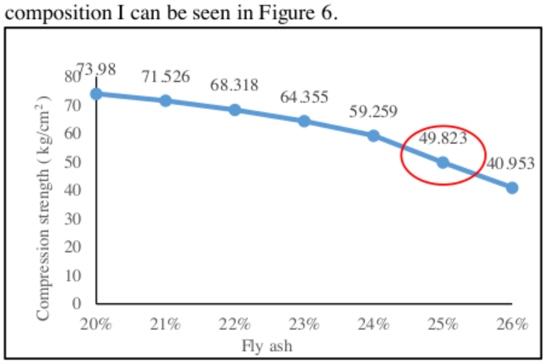

Figure 6. Compressive Strength Test Results of Composition II

From the research on composition II, it was known that only the composition of the 25% Fly Ash mixture passed the CTB specification. The composition of 70% fine aggregate, 5% cement, and 25% Fly Ash obtained the results of the compressive strength test in accordance with the Cement Treated Base (CTB) Specification, which was 49.823 kg/cm².

IV. CONCLUSION

Based on the research, the conclusions that can be drawn are:

1. The more Fly Ash in a mixture composition of Cement Treated Base (CTB), the more compressive strength of the concrete will decrease.
2. The composition of 70% sand, 5% cement, and 25% fly ash aged 7 days has a compressive strength test value of 49.823 kg/cm². The composition passes the Cement Treated Base (CTB) specification, which has a compressive strength test value of 45 – 55 kg/cm².

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.

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