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Stabilization of Liang Anggang Sand with Fly Ash and Cement as Subgrade Improvement Materials

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ABSTRACT: The more coal production is produced; the more waste is coming from the combustion process which leads to the environmental pollution. Waste from burning coal in the form of fly ash can be used as a mixture of subgrade stability in highway construction. The purpose of this study is to determine the characteristic value of each combination of fly ash, Liang Anggang sand and cement as a mixture of subgrade layer materials. The test objects consist of 10 combinations of fly ash, Liang Anggang sand and cement. Some tests were conducted such as Atterberg Limits, Specific Gravity, Sieve Analysis, Compaction and CBR test, respectively. From all combinations of the test objects, the best combination that suits the characteristic values of a subgrade layer mixture is a combination of minimum 6% of CBR specification and a maximum of 6% of Plasticity Index (PI). The recommended economical combination for landfill soil is a combination of test objects with a composition of 75% fly ash, 20% Liang Anggang sand and 5% cements.

KEYWORDS: fly ash, Liang Anggang sand, cement, subgrade, california bearing ratio

I. INTRODUCTION

Coal is found widely in many areas in Kalimantan, Indonesia. Coal processing produces waste in the form of fly ash, resulted an accumulation of coal waste. The utilization of coal waste can reduce the increasing amount of fly ash. Coal production in Indonesia reached 87.7 million tons for coal-fired power plants in 2019. Fly ash coal is industrial waste generated from burning coal which consists of fine particles. Fly ash is flowed from the combustion chamber through the boiler in the form of a jet of smoke. Fly ash itself does not have the ability to bind like cement, but with the presence of water and its fine particle size, the silica oxide contained in fly ash reacts chemically with calcium hydroxide formed from the cement hydration process and produce a substance that has binding ability. The fly ash content is 84% of the total coal ash. The grain gradation and fine particle of coal fly ash can fulfill the AASHTO M17 requirements. The use of mineral filler in asphalt concrete mixture is to fill the voids in the mixture, to improve the binding power of asphalt concrete, and to improve the stability of the mixture. The main components of fly ash coal coming from power plants are silicate (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3); the rest are carbon, calcium, magnesium and sulfur. The chemical properties of coal fly ash are influenced by the type of coal burned and the techniques for storing and handling it [1].

Research on coal waste as a material for highway construction has often been carried out both as a surface layer, foundation layer and bottom soil layer. Fly ash can be used as a filler for paved mixtures for surface layers [2]. The use of fly ash as a cement substitution material on the asphalt cement foundation layer can also be done and meet the required specifications [3]. Stabilized clay soils using fly ash can be used as a subgrade layer in road construction. Fly ash content and mixed moisture content affect the CBR value [4].In addition to using fly ash, bottom ash can also be used as a soil stabilization material along with the use of fly ash [5]. Fly ash can also be used for soil stabilization by adding addictive substances in the form of lime and enzymes [6][7].

Based on the description above, this study was conducted using a combination of a fly ash mixture, sand and cement. The sand used is the sand from Liang Anggang, South Kalimantan. The purpose of this study is to know the characteristics of the combination of sand, cement and fly ash and to find out the economical combination of mixture composition.

II. RESEARCH METHOD

The composition of the test object consists of a mixture of fly ash, sand and cement in each test. In this study 10 mixed combinations were made. One composition of the test object mixture was made as many as 5 pieces for five kinds of tests. The compositions of the mixture and the number of research samples can be seen in table 1.

Table 1. Mixture Compositions and Number of Samples

No	Combination	Composition			Sum
		Fly Ash	Sand (LA)	Cement	
1	Comb 1	50%	40%	10%	5
2	Comb 2	55%	40%	5%	5
3	Comb 3	60%	35%	5%	5
4	Comb 4	65%	30%	5%	5
5	Comb 5	70%	25%	5%	5
6	Comb 6	75%	20%	5%	5
7	Comb 7	80%	15%	5%	5
8	Comb 8	85%	10%	5%	5
9	Comb 9	90%	5%	5%	5
10	Comb 10	95%	5%	0%	5
Total					50

The test object is then tested with 5 types of tests, namely atterberg limits, specific gravity, sieve analysis, compaction and California Ratio (CBR) tests, respectively. From the test results, based on the existing compositions, it can be seen whether the test objects meet the requirements of embankment, selected embankment or do not meet the existing specifications. The specifications of embankment and selected embankment must comply with the Bina Marga Specification listed in table 2 [8].

III. RESULTS AND DISCUSSION

This research has been tested on a combination of *fly ash*, sand and cement, which aims to determine the characteristic value of each test object. The tests carried out in this study are Atterberg limits, specific gravity, sieve analysis, compaction, and CBR tests.

A. Atterberg Limits Test

To determine the plasticity index value of the combination of fly ash, sand, and cement, atterberg limits test was carried out in the form of liquid limit and plastic limit tests. The results of atterberg limits tests of each combination can be seen in table 3.

From table 3, it can be seen that out of 10 combinations of fly ash, sand and cement produce a Non-Plastic Index (NP) plasticity value. Based on the specification requirements, all mixed combinations meet the requirements of the plasticity index value for embankment and selected embankment.

Table 2. Specifications of embankment and selected embankment

No	Types of Examinations	Result	Specifications	
			Embankment	Selected embankment
1	Atterberg Limit			
	- Liquid Boundary (LL)		-	-
	- Plastic Boundary (PL)		-	-
	- Plastic Index (PI)		-	Max 6%
2	Sieve Analysis		-	-
3	Spesific Gravity (GS)		-	-
4	*Active = PI / Clay Content		< 1.25	-
5	Standard Compaction	DDM	-	-
		OCM	-	-
6	CBR (%)	DDM at 95% DDM	Min 6%	Min 10%

Source: Dirjen Bina Marga, 2010

Table 3. PI Calculation of All Combinations

No	Comb	Atterberg Limit			PI Specifications	
		LL (%)	PL	PI	Embankment	Selected embankment
1	Comb 1	14,249	-	Non-Plastic	-	Max. 6%
2	Comb 2	12,961	-	Non-Plastic		
3	Comb 3	13,909	-	Non-Plastic		
4	Comb 4	14,566	-	Non-Plastic		
5	Comb 5	12,014	-	Non-Plastic		
6	Comb 6	16,107	-	Non-Plastic		
7	Comb 7	14,419	-	Non-Plastic		
8	Comb 8	17,883	-	Non-Plastic		
9	Comb 9	17,441	-	Non-Plastic		
10	Comb 10	18,582	-	Non-Plastic		

B. Specific Gravity (SG) Test

Table 4 shows the results of Specific Gravity test of 10 mixed combinations. It can be seen combination 9 has the smallest GS value of 2,524 gr/cm^3, whilst the highest GS value is occupied by combination 2 with a value of 2,587 gr/cm^3.

C. Sieve Analysis Test

Based on USCS system for sieve analysis and classification, table 5 shows that all combinations of mixtures falls into Fine Sand category which has more than 50% of the entire composition of the mixture.

Table 4. Specific Gravity Test Results

No.	Combination	SG (gr/cm^3)
1	Comb 1	2.583
2	Comb 2	2.587
3	Comb 3	2.576
4	Comb 4	2.566
5	Comb 5	2.563
6	Comb 6	2.556
7	Comb 7	2,555
8	Comb 8	2.548
9	Comb 9	2.524
10	Comb 10	2.547

Table 5. Sieve Analysis Test Results

No.	Combination	Percentage (%)				
		Gravel (> 2 mm)	Coarse sand (0.6-2.0 mm)	Medium sand (0.2-0.6 mm)	Fine sand (0.05-0.2 mm)	Fine sand (0.05-0.2mm)
1	Comb 1	7.19	10.71	17.32	10.32	54.47
2	Comb 2	7.19	10.71	17.51	10.89	53.71
3	Comb 3	6.29	9.37	15.78	10.89	57.68
4	Comb 4	5.39	8.03	14.04	10.89	61.65

5	Comb 5	4.49	6.69	12.31	10.89	65.62
6	Comb 6	3.59	5.35	10.58	10.59	69.65
7	Comb 7	2.70	4.02	8.84	10.89	73.56
8	Comb 8	1.80	2.86	7.11	10.89	77.53
9	Comb 9	0.90	1.94	5.57	11.47	80.73
10	Comb 10	0.90	1.34	5.57	11.47	80.73

D. Compaction Test

Maximum Dry Density (DDM) value and Optimum Moisture Content (OMC) from compaction test can be seen in table 6.

Table 6. Maximum Dry Density (DDM) and Optimum Water Factor (OMC) values

No.	Combination	Maximum Dry Density (gr/cm^3)	Optimum moisture content(%)
1	Comb 1	1.90	13.85
2	Comb 2	1.84	12.58
3	Comb 3	1.82	13.35
4	Comb 4	1.87	14.63
5	Comb 5	1.93	12.31
6	Comb 6	1.94	16.48
7	Comb 7	1.89	14.76
8	Comb 8	1.85	17.62
9	Comb 9	1.85	16.15
10	Comb 10	1.78	18.62

The maximum dry density (DDM) of 10 mixed combinations ranges from 1.78 – 1.90 gr/cm^3 while the optimum water ratio (OMC) is in the range between 12.31 – 18.62%.

E. California Bearing Ratio (CBR) Test

The CBR value for embankments should not be less than 6% while for selected embankment should not be less than 10%. CBR test results can be seen in Table 7.

Table 7. The Results of CBR Test

No.	Combination	CBR Soaked (%)
1	Comb 1	181.90
2	Comb 2	81.67
3	Comb 3	88.85
4	Comb 4	106.51
5	Comb 5	116.08
6	Comb 6	127.15
7	Comb 7	118.17
8	Comb 8	106.80
9	Comb 9	81.08
10	Comb 10	45.17

According to the Bina Marga Specifications, embankment must have a CBR value of 6% minimum and selected embankment must have a CBR value of at least 10%, respectively. Table 7 shows that all mixture combinations have CBR values that meets the specification standards as a embankment and selected embankment. In this case, taking into account the economic value of the pavement thick layer, the CBR value of more than 10% should be used as the selected embankment.

From all mixture combinations in Table 7, CBR values are ranging from 45.17% - 181.90%. Taking into consideration, the CBR values determine the thickness of road pavement. The larger the CBR value, the thinner the road pavement and vice versa. In order to obtain an economical one, a combination of mixtures with the smallest cement composition is chosen. The less cement used, the cheaper the cost required. In summary, the most economical combination of mixtures is combination 6 with a composition of 75% fly ash, 20% sand, 5% cement with a CBR value of 81.08 %.

IV. CONCLUSION

The research findings can be summarized as follows:

1. Results show that all combinations meet sufficient characteristic values used as a mixture of subgrade layer with a CBR value of at least 6% and a maximum PI of 6%. As a result, the combination of fly ash, sand, and cement can be used as a mixture of subgrade layers as chosen embankment on highway construction.
2. The recommended economical combination is combination 6, composed of 75% fly ash, 20% sand and 5% cement.

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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