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The Effect of Matos Soil Stabilizer Addition to Fly Ash Stabilized Road Foundation Layer on the Index Properties of Soil

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Abstract
In pavement construction, it consists of subgrade, foundation layer and overburden. In working on landfill, the quality of the landfill can beimproved by stabilization. Stabilization is a way to improve the properties and parameters of the soil, so that the soil is suitable or qualified to be used according to its function. One of the ways to stabilize soil is by chemical stabilization. In this research using additives such as fly ash & matos soil stabilizer. The soil samples weretaken from Peniraman Quarry, Mempawah Regency. Also, the fly ash used comes from the waste of Paiton power plant, Probolinggo Regency. The tests carried out were testing the physical properties of the soil. The results obtained were then adjusted to the lower foundationlayer of the road with specifications based on the 2018 General Specifications, Road and Bridge Construction Work (Revision 2). The test was carried out with a mixture of 10% fly ash and variations of matos soil stabilizer 2 - 8%, stabilization was carried out with a curingperiod of 0 - 14 days. From the results of the soil test, the plasticity indexwas found to be 14.252%. From the test results of the highest mixture variation, which is a mixture of soil + 10% fly ash + 8% matos soil stabilizer with a curing period of 14 days. The test results obtained a plasticity index of 7.295%, so it can be concluded that the higher the percentage of matos soil stabilizer used, the plasticity index value of thesoil decreases and has met the requirements in the construction of the lower foundation layer of the road (B class).

Keywords: *Fly ash, plasticity index, sub base course, matos soil stabilizer*

1. Introduction

To obtain a good quality road, planning is required in accordance with the technical requirements of the road. In road pavement construction consists of subgrade, foundation layer and cover layer. The foundation layer and subgrade contribute to providing a supporting foundation for the flexible pavement structure and rigid pavement structure. The foundation layer plays an important role in the overall quality and durability of pavement construction, because the pavement is located on top of the foundation layer.

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Therefore, the foundation layer as a place to put the pavement must be thoroughly known for its index properties in order to support the construction above it properly.

In the construction of soil backfill, the quality of the landfill can be improved by stabilization. Stabilization is an action to improve soil properties and parameters so that the soil is suitable for its requirements and use. One of the ways to stabilize soil is by chemical stabilization. Chemical stabilization is a way to improve soil properties by adding an additive to the soil. one way of chemical stabilization is by using additives such as matos soil stabilizer and fly ash.

Matos soil stabilizer is a fine powder consisting of additional inorganic mineral content that works to compact (solidifying) and stabilizing. In its application, matos soil stabilizer requires other materials as a binder so that it can be mixed with soil.

2. Materials and Methods

2.1 Research Location

Soil location and research materials to be carried out are as follows:

1. Soil

Soil samples are taken from Peniraman Quarry which is located in Mempawah Regency.

2. Fly Ash

The fly ash used was C-class fly ash from the waste of the Paiton Power Plant, Probolinggo Regency, East Java.

3. Matos Soil Stabilizer.

Matos Soil Stabilizer which is used comes from PT Joglo Matos Nusantara, Yogyakarta.

4. Water

The water used in this study was fresh water and free from sediment and free from chemical.

2.2 Theoritical Structure

Soil stabilization is a measure to change the original structure or properties of soil to adjust it to construction requirements and to fulfill the requirements when using certain materials. Soil stabilization types are divided into three types: mechanical stabilization, chemical stabilization and hydraulic stabilization. Chemical soil stabilization which is currently widely used to improve subgrade is stabilization with the addition of fly ash, if fly ash mixed with soil there will be a process of selfcementing due to the influence of pozzolan or natural hardening properties of fly ash because of compaction and water conditions.

Matos Soil Stabilizer is a fine powder consisting of additional inorganic mineral content that strengthen and stabilize the soil physically and chemically. Matos can also accelerate the curing time of the stabilization mixture. Soil index properties are soil characteristics based on the shape, color size, grain size and texture of the soil. The index properties tests carried out were:

1. Water content test (ASTM D2216-80)
2. Unit weight test (ASTM D2973-83)
3. Specific gravity test (ASTM D854-83)
4. Permeability test (ASTM D653)
5. Atterberg limits test (ASTM D4318-00)
6. Hydrometer analysis (ASTM D422-72)
7. Soil grain gradation analysis (ASTM D422-63)

The results obtained were then adjusted to the lower foundation layer of the road with specifications based on the 2018 General Specifications, Road and Bridge Construction Work (Revision 2) in the following table:

Table 1 Properties of aggregate foundation layers

Sifat – sifat	Lapis Fondasi Agregat			Lapis Drainase
	Kelas A	Kelas B	Kelas S	
Abrasi dari Agregat Kasar (SNI 2417:2008)	0 - 40 %	0 - 40 %	0 - 40 %	0 - 40 %
Butiran pecah, tertahan ayakan No.4 (SNI 7619:2012)	95/90[1)]	55/50[2)]	55/50[2)]	80/75[3)]
Batas Cair (SNI 1967:2008)	0 - 25	0 - 35	0 - 35	-
Indek Plastisitas (SNI 1966:2008)	0 - 6	4 - 10	4 - 15	-
Hasil kali Indek Plastisitas dengan % Lolos Ayakan No.200	maks.25	-	-	-
Gumpalan Lempung dan Butiran-butiran Mudah Pecah (SNI 4141:2015)	0 - 5 %	0 - 5 %	0 - 5 %	0 - 5 %
CBR rendaman (SNI 1744:2012)	min.90 %	min.60 %	min.50 %	-
Perbandingan Persen Lolos Ayakan No.200 dan No.40	maks.2/3	maks.2/3	-	-
Koefisien Keseragaman : $C_v = D_{60}/D_{10}$	-	-	-	> 3,5

(*Source: GENERAL SPECIFICATIONS 2018 (Revision 2) DIVISION 5)*

Activity is the result of the ratio between the plasticity index and the percentage of clay size fraction (percentage by weight of grains smaller than 0.002 mm).

2.3 Data

This research tested several soil samples taken from the location of the soil to be studied. The additives used for chemical stabilization were fly ash and matos soil stabilizer, with curing time for 0,7 and 14 days. The tests carried out were testing the index properties of disturbed soil samples and using the results of mechanical properties test samples with the same soil data and mixture variations finished by taking unconfined compression strength (UCS) test samples, to test their index properties.

Table 2 Variety of soil, fly ash and matos mixtures

Num.	Soil (%)	Fly ash (%)	Matos (%)	Variety Code	Description
1	100	0	0	S	T.A 100 %
2	90	10	0	SF	T.A 90% + F.A 10%
3	88	10	2	SFM-2	T.A 88% + F.A 10% + M 2%
4	86	10	4	SFM-4	T.A 86% + F.A 10% + M 4%
5	84	10	6	SFM-6	T.A 84% + F.A 10% + M 6%
6	82	10	8	SFM-8	T.A 82% + F.A 10% + M 8%

Table 3 The number of test samples

Num.	Variety Code	Mixture Composition	Curing Time (day)		
			0	7	14
1	S	T.A 100 %	1	1	1
2	SF	T.A 90% + F.A 10%	1	1	1
3	SFM-2	T.A 88% + F.A 10% + M 2%	1	1	1
4	SFM-4	T.A 86% + F.A 10% + M 4%	1	1	1
5	SFM-6	T.A 84% + F.A 10% + M 6%	1	1	1
6	SFM-8	T.A 82% + F.A 10% + M 8%	1	1	1
Number of Samples			6	6	6
			18		

2.4 Analysis Method

The data obtained from the test results are then classified by the soil classification method based on the standards set by the USDA, USCS, and AASHTO, using the test analysis results. In addition, the results of the analysis are adjusted to the general specifications for road and bridge construction work in 2018 (revision 2) for determining the class of the foundation layer.

3. Result and Data Analysis

3.1 Fly Ash Content Test Results

Table 4 Chemical content analysis results on fly ash

Num.	Sample Name	Test Type	Result	Unit	Test Method
1.	*Fly Ash*	*Loss of Ignition (LOI)*	1,27	%	ASTM D 7348-13

Chemical content analysis of fly ash:

Num.	Sample Name	Test Type (Oxides)	Readings 1	Readings 2	Unit	Test Method
1	Fly Ash (10,0738g)	MgO	1	1,1	%	*X-Ray Fluorescence* *
2		Al_2O_3	8,82	8,86		
3		SiO_2	28,5	28,6		
4		K_2O	1,3	1,29		
5		CaO	19,4	19,4		
6		TiO_2	1,35	1,3		
7		V_2O_5	0,05	0,06		
8		Cr_2O_3	0,03	0,04		
9		MnO	0,54	0,54		
10		Fe_2O_3	34,6	34,5		
11		CuO	0,05	0,05		
12		MoO_3	3,1	3,1		
13		BaO	0,36	0,42		
14		HgO	0,9	0,8		
15		Na_2O	No Intensity	No Intensity		

SiO_2, Al_2O_3, Fe_2O_3 = 28,55% + 8,84% + 34,55%
= 71,94 % > 50%
CaO = 19,4% > 10%

Based on the test results on the chemical content onfly ash, in Table 5. and the test results in Table 6 loss of ignition (LOI), and the average chemical composition of fly ash in Table 1, the class classification of fly ash according to ASTM 618-78 is class C fly ash.

3.2 The Results on the Index properties of Soil

Table 3 Index properties testing result of soil

Num.	Type of Test	Test Result
1	Water Content (Undisturbed Soil) (w = %)	41,017
2	Unit Weight (Undisturbed Soil) (γw = gr/cm³)	1,272
3	Water Content (Soil Compaction Test Result) (Wopt = %)	24,155
4	Unit Weight (γw = gr/cm³)	1,143
5	Specific Gravity (Gs)	2,611
6	Liquid Limit (LL = %)	43,29
7	Plastic Limit (PL = %)	29,038
8	Plasticity Index (IP = %)	14,252
9	Shrinkage Limit (SL= %)	29,935
10	Grain Distribution Gradation Analysis Test Result (%)	
	• Sand	24
	• Silt	60
	• Clay	16

3.3 Equations

Table 4 Specific gravity test result

	Sample	Variety	Specific	Decreasement
14 Days Curing	T.A + 0% F.A + 0% M	S	2,614	0,117
	T.A + 10% F.A + 0% M	SF	2,336	-10,522
	T.A + 10% F.A + 2% M	SFM-2	2,343	-10,242
	T.A + 10% F.A + 4% M	SFM-4	2,345	-10,186
	T.A + 10% F.A + 6% M	SFM-6	2,356	-9,751
	T.A + 10% F.A + 8% M	SFM-8	2,358	-9,698
	T.A + 10% F.A + 8% M	SFM-8	2,361	-9,552
7 Days Curing	T.A + 0% F.A + 0% M	S	2,613	0,087
	T.A + 10% F.A + 0% M	SF	2,347	-10,121
	T.A + 10% F.A + 2% M	SFM-2	2,351	-9,941
	T.A + 10% F.A + 4% M	SFM-4	2,357	-9,731
	T.A + 10% F.A + 6% M	SFM-6	2,362	-9,523
	T.A + 10% F.A + 8% M	SFM-8	2,366	-9,363

Table 4 Specific gravity test result (continuation)

From the table above, it shows that the specific gravity value of the soil is likely to decrease with each time after curing, this is caused by the soil changes due to the addition of fly ash, which causes the solidification and clumping between the mixture of soil, fly ash and matos soil stabilizer.

3.4 Equations

Table 5 Specific gravity test result

	Sample	Variety Code	Water Content (w) %	Decreasement Percentage (%)
0 Days Curing	T.A + 0% F.A + 0% M	S	24,178	0
	T.A + 10% F.A + 0% M	SF	22,000	9,008
	T.A + 10% F.A + 2% M	SFM-2	21,400	11,490
	T.A + 10% F.A + 4% M	SFM-4	20,870	13,682
	T.A + 10% F.A + 6% M	SFM-6	19,550	19,141
	T.A + 10% F.A + 8% M	SFM-8	19,100	21,002
7 Days Curing	T.A + 0% F.A + 0% M	S	24,109	0,285
	T.A + 10% F.A + 0% M	SF	21,581	10,743
	T.A + 10% F.A + 2% M	SFM-2	20,810	13,930
	T.A + 10% F.A + 4% M	SFM-4	20,275	16,143
	T.A + 10% F.A + 6% M	SFM-6	18,967	21,552
	T.A + 10% F.A + 8% M	SFM-8	18,672	22,771
14 Days Curing	T.A + 0% F.A + 0% M	S	23,954	0,926
	T.A + 10% F.A + 0% M	SF	20,658	14,560
	T.A + 10% F.A + 2% M	SFM-2	20,254	16,228
	T.A + 10% F.A + 4% M	SFM-4	19,685	18,583
	T.A + 10% F.A + 6% M	SFM-6	18,384	23,964
	T.A + 10% F.A + 8% M	SFM-8	18,163	24,877

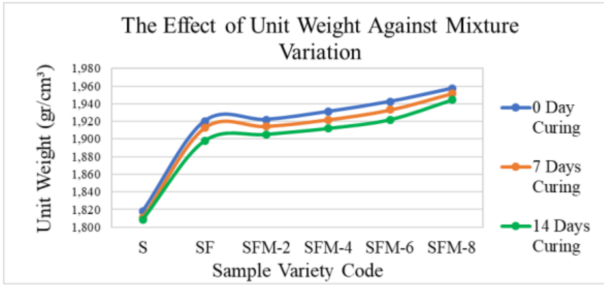
It was observed that there was a reduction in water content with every increasing variation of matos soil stabilizer into fly ash, this occurred because the soil voids that were previously filled with water were replaced by fly ash.

3.5 Unit Weight Test Results

Table 6 Unit Weight Test Results

	Sample	Variety Code	Unit Weight (γ_{wet}) gr/cm³ Laboratory Test	Unit Weight (γ_{wet}) gr/cm³ Empirical Formula
0 Day Curing	T.A + 0% F.A + 0% M	S	1,818	1,817
	T.A + 10% F.A + 0% M	SF	1,920	1,915
	T.A + 10% F.A + 2% M	SFM-2	1,922	1,919
	T.A + 10% F.A + 4% M	SFM-4	1,931	1,951
	T.A + 10% F.A + 6% M	SFM-6	1,942	1,938
	T.A + 10% F.A + 8% M	SFM-8	1,957	1,956
7 Days Curing	T.A + 0% F.A + 0% M	S	1,811	1,816
	T.A + 10% F.A + 0% M	SF	1,913	1,909
	T.A + 10% F.A + 2% M	SFM-2	1,915	1,910
	T.A + 10% F.A + 4% M	SFM-4	1,922	1,941
	T.A + 10% F.A + 6% M	SFM-6	1,933	1,929
	T.A + 10% F.A + 8% M	SFM-8	1,952	1,949

Table 6 Unit Weight Test Results (Continuation)



3.6 Liquid Limit Test Result

Table 7 Liquid limit test results

	Sample	Variety Code	Liquid Limit %	Liquid Limit Decreasement Percentage %
0 Day Curing	T.A + 0% F.A + 0% M	S	43,290	0
	T.A + 10% F.A + 0% M	SF	41,970	3,049
	T.A + 10% F.A + 2% M	SFM-2	41,343	4,497
	T.A + 10% F.A + 4% M	SFM-4	41,069	5,131
	T.A + 10% F.A + 6% M	SFM-6	40,297	6,913
	T.A + 10% F.A + 8% M	SFM-8	39,629	8,456
7 Days Curing	T.A + 0% F.A + 0% M	S	43,230	0,138
	T.A + 10% F.A + 0% M	SF	41,884	3,249
	T.A + 10% F.A + 2% M	SFM-2	41,230	4,758
	T.A + 10% F.A + 4% M	SFM-4	40,859	5,615
	T.A + 10% F.A + 6% M	SFM-6	40,111	7,343
	T.A + 10% F.A + 8% M	SFM-8	39,575	8,582
14 Days Curing	T.A + 0% F.A + 0% M	S	43,209	0,188
	T.A + 10% F.A + 0% M	SF	41,624	3,849
	T.A + 10% F.A + 2% M	SFM-2	41,118	5,017
	T.A + 10% F.A + 4% M	SFM-4	40,488	6,472
	T.A + 10% F.A + 6% M	SFM-6	39,940	7,739
	T.A + 10% F.A + 8% M	SFM-8	39,421	8,937

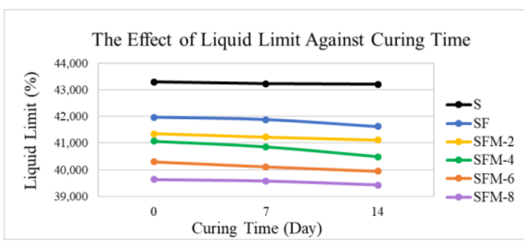


Figure 3 Graph of the effect on liquid limit against curing time

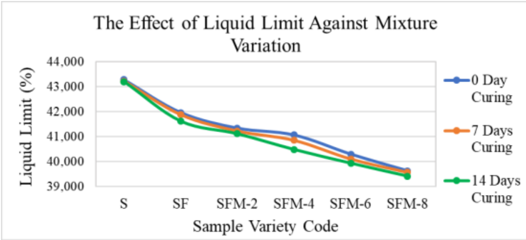


Figure 4 Graph of the effect on liquid limit against mixture variation

From the graph that shows the value of liquid limit against curing time and mixture variations hasreduced, the lowest reduction is located in the SFM- 8 variation with a curing time of 14 days, which is 39,421%.

3.7 Plastic Limit Test Results

Table 8 Plastic limit test results

	Sample	Variety Code	Plastic Limit (%)	Plastic Limit Decreasement Percentage (%)
0 Day Curing	T.A + 0% F.A + 0% M	S	29,038	0
	T.A + 10% F.A + 0% M	SF	30,276	4,263
	T.A + 10% F.A + 2% M	SFM-2	30,542	5,179
	T.A + 10% F.A + 4% M	SFM-4	30,810	6,102
	T.A + 10% F.A + 6% M	SFM-6	31,581	8,757
	T.A + 10% F.A + 8% M	SFM-8	32,055	10,391
7 Days Curing	T.A + 0% F.A + 0% M	S	29,097	0,203
	T.A + 10% F.A + 0% M	SF	30,341	4,488
	T.A + 10% F.A + 2% M	SFM-2	30,612	5,420
	T.A + 10% F.A + 4% M	SFM-4	30,916	6,468
	T.A + 10% F.A + 6% M	SFM-6	31,610	8,855
	T.A + 10% F.A + 8% M	SFM-8	32,087	10,501
14 Days Curing	T.A + 0% F.A + 0% M	S	29,147	0,375
	T.A + 10% F.A + 0% M	SF	30,421	4,763
	T.A + 10% F.A + 2% M	SFM-2	30,715	5,775
	T.A + 10% F.A + 4% M	SFM-4	31,339	7,923
	T.A + 10% F.A + 6% M	SFM-6	31,907	9,881
	T.A + 10% F.A + 8% M	SFM-8	32,126	10,635

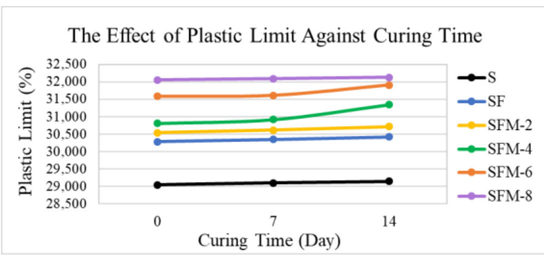


Figure 5 Graph of the effect on plastic limit againstcuring time

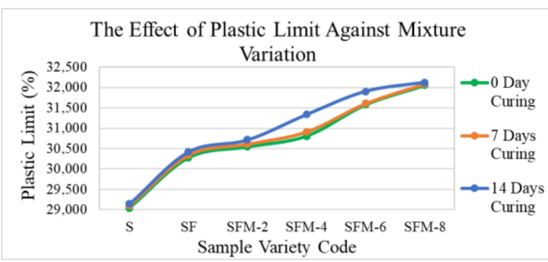


Figure 6 Graph of the effect on plastic limit against mixture variation

From the graph that shows the value of plastic limit against curing time and mixture variations has increased, the highest increasement is located in the SFM-8 variation with a curing time of 14 days, which is 32,126 %.

3.8 Plasticity Index Test Results

Table 9 Plasticity index test results

	Sample	Variety Code	Liquid Limit %	Liquid Limit Decreasement Percentage %
0 Day Curing	T.A + 0% F.A + 0% M	S	43,290	0
	T.A + 10% F.A + 0% M	SF	41,970	3,049
	T.A + 10% F.A + 2% M	SFM-2	41,343	4,497
	T.A + 10% F.A + 4% M	SFM-4	41,069	5,131
	T.A + 10% F.A + 6% M	SFM-6	40,297	6,913
	T.A + 10% F.A + 8% M	SFM-8	39,629	8,456
7 Days Curing	T.A + 0% F.A + 0% M	S	43,230	0,138
	T.A + 10% F.A + 0% M	SF	41,884	3,249
	T.A + 10% F.A + 2% M	SFM-2	41,230	4,758
	T.A + 10% F.A + 4% M	SFM-4	40,859	5,615
	T.A + 10% F.A + 6% M	SFM-6	40,111	7,343
	T.A + 10% F.A + 8% M	SFM-8	39,575	8,582
14 Days Curing	T.A + 0% F.A + 0% M	S	43,209	0,188
	T.A + 10% F.A + 0% M	SF	41,624	3,849
	T.A + 10% F.A + 2% M	SFM-2	41,118	5,017
	T.A + 10% F.A + 4% M	SFM-4	40,488	6,472
	T.A + 10% F.A + 6% M	SFM-6	39,940	7,739
	T.A + 10% F.A + 8% M	SFM-8	39,421	8,937

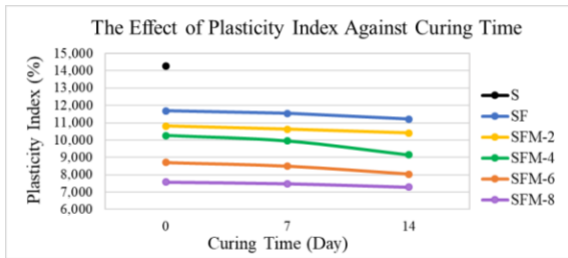


Figure 7 Graph of the effect on plasticity index against curing time

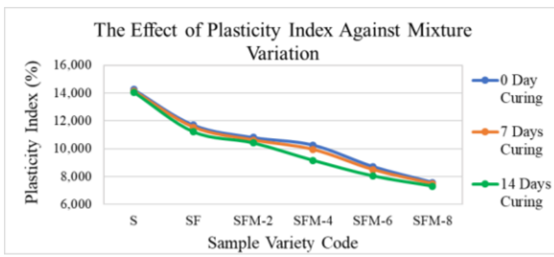


Figure 8 Graph of the effect on plasticity index against mixture variation

From the graph that shows the value of plasticity index against curing time and mixture variations has reduced, the lowest reduction is located in the SFM- 8 variation with a curing time of 14 days, which is 7,295 %.

3.9 Permeability Test Result

Table 10 Permeability test results

	Sample	Variety Code	Permeability Coefficient (cm/sec)	Decreasement Percentage (%)
0 Day Curing	T.A + 0% F.A + 0% M	S	2,6736,E-06	0
	T.A + 10% F.A + 0% M	SF	3,5396,E-06	-32,388
	T.A + 10% F.A + 2% M	SFM-2	3,1119,E-06	-16,391
	T.A + 10% F.A + 4% M	SFM-4	2,9437,E-06	-10,099
	T.A + 10% F.A + 6% M	SFM-6	2,7149,E-06	-1,544
	T.A + 10% F.A + 8% M	SFM-8	2,5299,E-06	5,375
7 Days Curing	T.A + 0% F.A + 0% M	S	2,6119,E-06	2,309
	T.A + 10% F.A + 0% M	SF	3,1754,E-06	-18,766
	T.A + 10% F.A + 2% M	SFM-2	2,9437,E-06	-10,099
	T.A + 10% F.A + 4% M	SFM-4	2,7770,E-06	-3,866
	T.A + 10% F.A + 6% M	SFM-6	2,6119,E-06	2,309
	T.A + 10% F.A + 8% M	SFM-8	2,3874,E-06	10,707
14 Days Curing	T.A + 0% F.A + 0% M	S	2,5709,E-06	3,844
	T.A + 10% F.A + 0% M	SF	3,0066,E-06	-12,452
	T.A + 10% F.A + 2% M	SFM-2	2,7149,E-06	-1,544
	T.A + 10% F.A + 4% M	SFM-4	2,4891,E-06	6,903
	T.A + 10% F.A + 6% M	SFM-6	2,2460,E-06	15,996
	T.A + 10% F.A + 8% M	SFM-8	1,9269,E-06	27,929

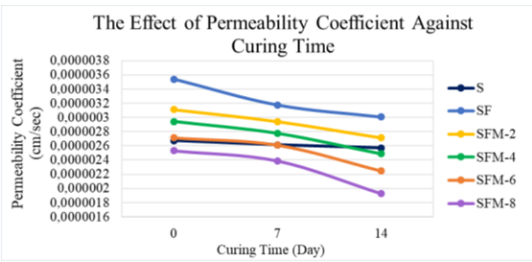


Figure 9 Graph of the effect on permeability coefficient against curing time

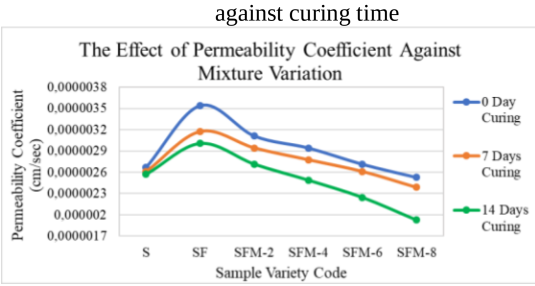


Figure 10 Graph of the effect on permeability coefficient against mixture variation

From the graph that shows the value of permeability coefficient against curing time and mixture variations has reduced, the lowest reduction is located in the SFM-8 variation with a curing time of 14 days, which is 1,926 x 10-6 cm/sec.

3.10 Hydrometer Test Results and Sieve Analysis

Table 11 Hydrometer test results and sieve analysis of 0-day curling

D (mm)	S Percent Passed (%)	SF Percent Passed (%)	SFM-2 Percent Passed (%)	SFM-4 Percent Passed (%)	SFM-6 Percent Passed (%)	SFM-8 Percent Passed (%)
0,0013	10,101	1,864	1,861	5,583	5,586	3,729
0,0030	20,202	13,046	13,027	13,027	16,758	13,052
0,0059	30,304	20,501	24,194	24,193	27,930	20,510
0,0081	36,364	31,683	29,777	31,637	35,379	26,104
0,0189	56,567	44,729	44,665	46,525	44,689	41,020
0,0293	66,668	50,320	48,387	50,247	52,137	44,749
0,0750	83,280	75,596	78,860	80,634	77,740	72,504
0,1250	90,940	77,388	80,800	83,376	80,252	82,680
0,1800	95,240	80,260	83,780	86,534	82,658	89,506
0,2500	97,280	82,920	86,640	88,880	84,906	92,760
0,4250	98,780	87,164	88,900	90,994	87,884	94,928
0,8500	99,700	95,462	93,140	94,614	93,796	97,346

Table 12 Hydrometer test results and sieve analysis of 7-day

D (mm)	S Percent Passed (%)	SF Percent Passed (%)	SFM-2 Percent Passed (%)	SFM-4 Percent Passed (%)	SFM-6 Percent Passed (%)	SFM-8 Percent Passed (%)
0,0013	9,826	7,434	3,721	3,725	5,595	1,867
0,0030	19,652	13,010	11,163	13,039	13,054	14,932
0,0059	27,513	22,303	20,465	14,901	24,243	22,398
0,0081	31,444	29,738	24,186	27,940	31,703	31,731
0,0189	53,061	42,748	42,791	42,842	44,757	44,797
0,0293	62,887	50,183	50,233	46,567	54,081	50,396
0,0750	82,138	85,618	75,962	73,940	78,058	80,778
0,1250	90,384	88,052	77,496	79,210	83,000	82,334
0,1800	94,810	90,636	80,134	86,016	86,040	84,746
0,2500	97,118	92,992	82,748	90,302	88,440	86,774
0,4250	98,760	95,454	85,692	93,082	90,500	88,920
0,8500	99,682	100,000	95,050	96,612	95,180	92,778

curing

Table 13 Hydrometer test results and sieve analysis of 14-day curing

3.11 Clay Activity

Table 14 Activity value of clay

D (mm)	S Percent Passed (%)	SF Percent Passed (%)	SFM-2 Percent Passed (%)	SFM-4 Percent Passed (%)	SFM-6 Percent Passed (%)	SFM-8 Percent Passed (%)
0,0013	9,828	7,418	5,572	1,858	7,450	1,863
0,0030	21,621	12,981	13,001	13,006	14,900	16,767
0,0059	27,518	24,108	20,431	20,437	26,075	26,082
0,0081	33,414	29,671	27,860	27,869	33,525	35,398
0,0189	57,001	44,506	40,862	40,875	46,562	50,302
0,0293	64,863	51,924	46,434	44,590	52,149	54,028
0,0750	82,138	78,860	75,132	74,630	78,518	78,940
0,1250	90,384	80,800	78,118	77,816	80,704	80,844
0,1800	94,810	83,780	80,590	80,268	82,908	82,688
0,2500	97,118	86,640	82,888	82,570	84,970	84,750
0,4250	98,760	88,900	86,186	86,066	88,266	87,098
0,8500	99,682	93,140	92,176	92,156	94,156	92,308

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Table 14 Activity value of clay

	Sample	Variety Code	Plasticity Index (PI) %	Sieve Passed Num. 200	Activity	Description
0 Day Curing	T.A + 0% F.A + 0% M	S	14,252	83,280	0,171	*Low*
	T.A + 10% F.A + 0% M	SF	11,694	75,596	0,155	*Low*
	T.A + 10% F.A + 2% M	SFM-2	10,801	71,940	0,150	*Low*
	T.A + 10% F.A + 4% M	SFM-4	10,259	80,634	0,127	*Low*
	T.A + 10% F.A + 6% M	SFM-6	8,716	77,740	0,112	*Low*
	T.A + 10% F.A + 8% M	SFM-8	7,574	72,504	0,104	*Low*
7 Days Curing	T.A + 0% F.A + 0% M	S	14,133	82,138	0,172	*Low*
	T.A + 10% F.A + 0% M	SF	11,542	85,618	0,135	*Low*
	T.A + 10% F.A + 2% M	SFM-2	10,618	75,962	0,140	*Low*
	T.A + 10% F.A + 4% M	SFM-4	9,943	73,940	0,134	*Low*
	T.A + 10% F.A + 6% M	SFM-6	8,502	78,058	0,109	*Low*
	T.A + 10% F.A + 8% M	SFM-8	7,487	80,778	0,093	*Low*
14 Days Curing	T.A + 0% F.A + 0% M	S	14,062	82,138	0,171	*Low*
	T.A + 10% F.A + 0% M	SF	11,203	78,860	0,142	*Low*
	T.A + 10% F.A + 2% M	SFM-2	10,403	75,132	0,138	*Low*
	T.A + 10% F.A + 4% M	SFM-4	9,150	71,940	0,127	*Low*
	T.A + 10% F.A + 6% M	SFM-6	8,032	78,518	0,102	*Low*
	T.A + 10% F.A + 8% M	SFM-8	7,295	78,940	0,092	*Low*

The value of clay activity (A) of soil stabilized with fly ash and matos soil stabilizer ranges from 0.102 to 0.172, so the clay samples stabilized with fly ash and matos soil stabilizer are considered inactive clays. With low swelling potential and swelling potential as much as 1.5%.

3.12 USDA Soil Classification Method

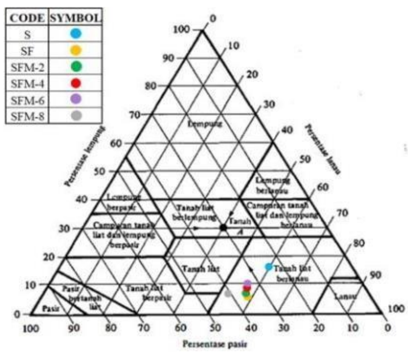

Figure 11 The triangular graph of USDA soil classification method (0-day curing)

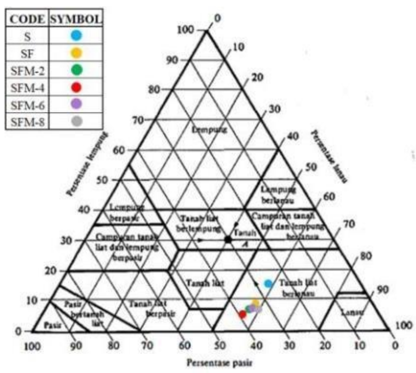

Figure 12 The triangular graph of USDA soil classification method (7-day curing)

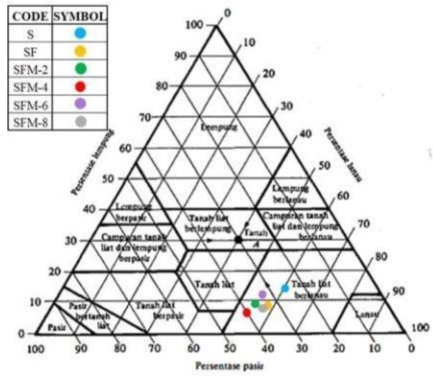

Figure 13 The triangular graph of USDA soil classification method (14-day curing)

Table 15 Recapitulation of USDA soil classification method

	Sample	Variety Code	USDA Soil Classification
0 Day Curing	T.A + 0% F.A + 0% M	S	Silty Clay
	T.A + 10% F.A + 0% M	SF	
	T.A + 10% F.A + 2% M	SFM-2	
	T.A + 10% F.A + 4% M	SFM-4	
	T.A + 10% F.A + 6% M	SFM-6	
	T.A + 10% F.A + 8% M	SFM-8	
7 Days Curing	T.A + 0% F.A + 0% M	S	Silty Clay
	T.A + 10% F.A + 0% M	SF	
	T.A + 10% F.A + 2% M	SFM-2	
	T.A + 10% F.A + 4% M	SFM-4	
	T.A + 10% F.A + 6% M	SFM-6	
	T.A + 10% F.A + 8% M	SFM-8	
14 Days Curing	T.A + 0% F.A + 0% M	S	Silty Clay
	T.A + 10% F.A + 0% M	SF	
	T.A + 10% F.A + 2% M	SFM-2	
	T.A + 10% F.A + 4% M	SFM-4	
	T.A + 10% F.A + 6% M	SFM-6	
	T.A + 10% F.A + 8% M	SFM-8	

From the classification results using the USDA method, it can be concluded that the addition of matos soil stabilizer to soil stabilized with fly ash in different curing times does not increase or decrease the type of granules. The grain type in all variations is silty clay.

3.13 USCS Soil Classification Method

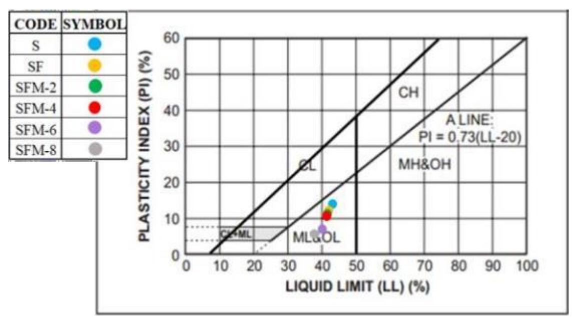

Figure 14 The Graph of USCS soil classification method (0-day curing)

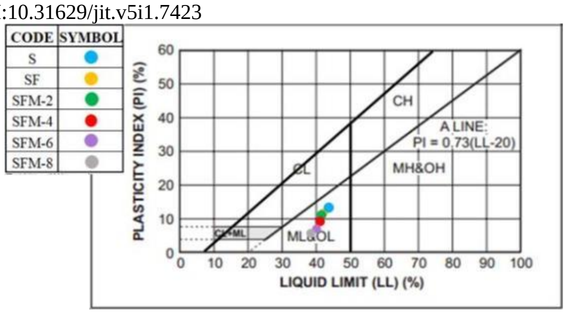

Figure 15 The Graph of USCS soil classification method (7-day curing)

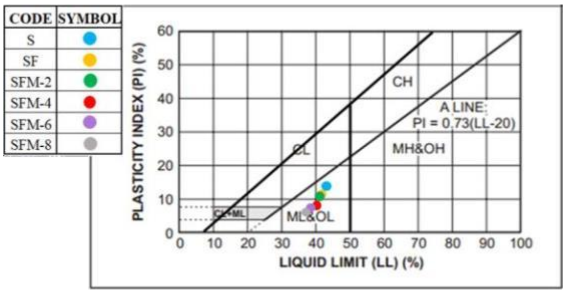

Figure 16 The Graph of USCS soil classification method (14-day curing)

Table 16 Recapitulation of USCS soil classification method

	Sample	Variety Code	USCS Soil Classification
0 Day Curing	T.A + 0% F.A + 0% M	S	ML
	T.A + 10% F.A + 0% M	SF	
	T.A + 10% F.A + 2% M	SFM-2	OL
	T.A + 10% F.A + 4% M	SFM-4	
	T.A + 10% F.A + 6% M	SFM-6	
	T.A + 10% F.A + 8% M	SFM-8	
7 Days Curing	T.A + 0% F.A + 0% M	S	ML
	T.A + 10% F.A + 0% M	SF	
	T.A + 10% F.A + 2% M	SFM-2	OL
	T.A + 10% F.A + 4% M	SFM-4	
	T.A + 10% F.A + 6% M	SFM-6	
	T.A + 10% F.A + 8% M	SFM-8	
14 Days Curing	T.A + 0% F.A + 0% M	S	ML
	T.A + 10% F.A + 0% M	SF	
	T.A + 10% F.A + 2% M	SFM-2	OL
	T.A + 10% F.A + 4% M	SFM-4	
	T.A + 10% F.A + 6% M	SFM-6	
	T.A + 10% F.A + 8% M	SFM-8	

It can be seen that the soil and the soil after being stabilized with 10% fly ash are classified as ML, after adding matos soil stabilizer, the soil classification changes due to a decrease in the liquid limit and plasticity index, causing the soil mixture with fly ash and matos soil stabilizer to be classified as OL.

3.14 AAHSTO Soil Classification Method

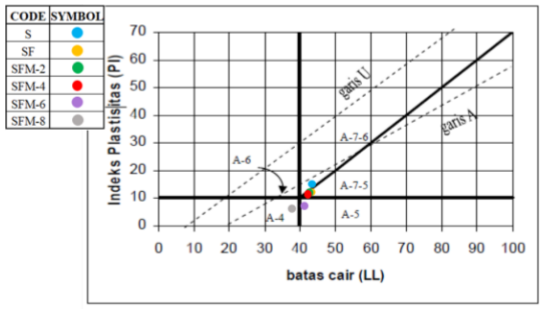

Figure 17 The Graph of AAHSTO soil classification method (0-day curing)

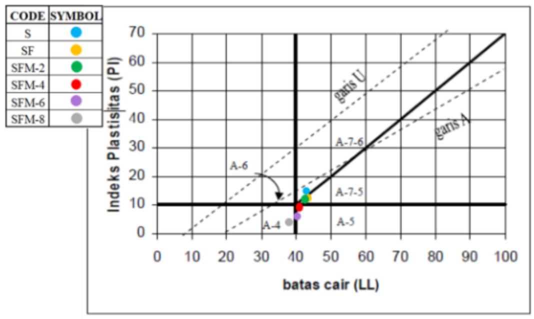

Figure 18 The Graph of AAHSTO soil classification method (7-day curing)

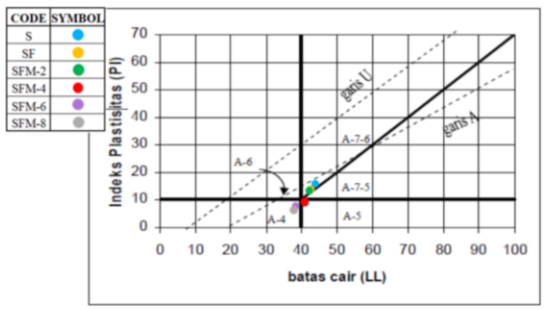

Figure 19 The Graph of AAHSTO soil classification method (14-day curing)

Table 17 Recapitulation of AAHSTO soil classification method

	Sample	Variety Code	AAHSTO Classification	F	GI
0 Day Curing	T.A + 0% F.A + 0% M	S	A-7-6	83,280	13,353
	T.A + 10% F.A + 0% M	SF	A-7-5	75,596	9,546
	T.A + 10% F.A + 2% M	SFM-2	A-7-5	71,940	8,092
	T.A + 10% F.A + 4% M	SFM-4	A-7-5	80,634	9,541
	T.A + 10% F.A + 6% M	SFM-6	A-5	77,740	7,806
	T.A + 10% F.A + 8% M	SFM-8	A-4	72,504	6,036
7 Days Curing	T.A + 0% F.A + 0% M	S	A-7-6	82,138	12,964
	T.A + 10% F.A + 0% M	SF	A-7-5	85,618	11,689
	T.A + 10% F.A + 2% M	SFM-2	A-7-5	75,962	8,821
	T.A + 10% F.A + 4% M	SFM-4	A-5	73,940	7,922
	T.A + 10% F.A + 6% M	SFM-6	A-5	78,058	7,691
	T.A + 10% F.A + 8% M	SFM-8	A-4	80,778	7,406
14 Days Curing	T.A + 0% F.A + 0% M	S	A-7-6	82,138	12,911
	T.A + 10% F.A + 0% M	SF	A-7-5	78,860	9,896
	T.A + 10% F.A + 2% M	SFM-2	A-7-5	75,132	8,493
	T.A + 10% F.A + 4% M	SFM-4	A-5	71,940	6,994
	T.A + 10% F.A + 6% M	SFM-6	A-4	78,518	7,441
	T.A + 10% F.A + 8% M	SFM-8	A-4	78,940	6,931

It was observed that the soil was categorized as A-7- 5 group. The soil with a mixture of 10% fly ash is categorized in the A-7-5 group, while the soil with a mixture of 10% fly ash and 2% matos soil stabilizer is categorized in the A-7-5 group, which is a clayey soil, and the soil with a mixture of 10% fly ash and 4, 6, 8% matos soil stabilizer is categorized in the A-5 and A-4 groups, which is a silty soil.

4. Conclusion

From the results of the research done, several conclusions can be obtained as follows:

1. Based on the results of specific gravity (Gs) test on soil stabilized with fly ash and matos soil stabilizer, it is summarized that the more the percentage of matos soil stabilizer increases in soil, the more the specific gravity value decreases.

2. Based on the plasticity index test results, it can be summarized that, plasticity index (PI), the more variation of matos soil stabilizer, the lower the plasticity index value, the lowest plasticity index value is located in the variation of 10% fly ash and 8% matos soil stabilizer with a curing time of 14 days, which is 7.295%.

3. Based on the results of permeability test on soil stabilized with fly ash and matos soil stabilizer, it can be summarized that, the higher the percentage of matos soil stabilizer in the soil, the smaller the value of permeability coefficient (k). The lowest permeability coefficient is located in the variation of 10% fly ash and 8% matos soil stabilizer with a curing time of 14 days, which is 1.9269 x 10-6 cm/sec.

4. The value of clay activity (A) of soil stabilized with fly ash and matos soil stabilizer ranges from 0.102 to 0.172, so the clay samples stabilized with fly ash and matos soil stabilizer are considered inactive clays. With low swelling potential and swelling potential as much as 1.5%.

5. The test results of the peniraman soil has plasticity index (PI) of 14.252%, then the peniraman soil does not meet the requirements on the plasticity index (PI) value for the sub-base course/ aggregate foundation layer B class, which is PI 4 - 10%.

6. The test result of soil stabilized with 10% fly ash with curing time of 14 days has plasticity index (PI) of 11.203%, then the soil stabilized with fly ash does not meet the requirements on the plasticity index (PI) value for sub-base course/ aggregate foundation layer B class, which is PI 4 - 10%.

7. The addition of matos soil stabilizer to a mixture of soil and 10% fly ash can accelerate the plasticity index value for the requirements of the PI value in sub-base course, this can be proven in the variation of 88% soil + 10% fly ash and 2% matos soil stabilizer with a curing time of 14 days, the PI value is 10.403%, while the variation of 86% soil + 10% fly ash and 4% matos soil stabilizer with a curing time of 7 days, the PI value is 9.943%, with the PI requirements for the sub-base course/ aggregate foundation layer B class, which is PI 4 - 10%.

8. It can be concluded that the addition of matos soil stabilizer to the foundation layer stabilized using fly ash on the index properties of the soil, meets the requirements on the plasticity index (PI) value for the sub-base course/ aggregate foundation layer B class, which is PI 4 - 10%.

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