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The Effect of Matos Soil Stabilizer as An Addition Mixture on Index Properties of Soil Stabilized with Cement

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Abstract: All civil engineering constructions are built on or supported by soil, making the stability and safety of the structures dependent on the soil's bearing capacity. In road pavement structures, poor-quality pavement layers can lead to reduced support for the road pavement layers. Therefore, stabilization efforts are undertaken to address this issue. The objective of this research is to investigate the influence of matos soil stabilizer mixtures with varying matos content of 0%, 1%, 2%, 4%, and 8%, combined with a cement content of 5%, and different curing times of 0, 7, and 14 days on the classification and index properties of the soil. The results indicate that the index properties of the soil improve with different curing times of the cement and matos mixtures. This can be observed through a decrease in the soil's plasticity index, an increase in bulk density, a decrease in permeability coefficient, a decrease in water content and wet unit weight of the soil with longer curing periods. Additionally, the soil classification shows a more granular nature compared to the original soil.

Keywords: Soil Stabilization, Matos, Soil Stabilizer, Index Properties, Cement

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1. Introduction

Stabilization is an effort to improve the properties and parameters of the natural soil to make it suitable or meet the requirements for its intended use [1]. One of the methods of stabilization is chemical stabilization, which involves the use of additive materials such as fly ash, lime, cement, asphalt, and also the addition of additives. One of the recently used additives for soil stabilization is matos soil stabilizer.

Considering the above, this research aims to demonstrate that matos soil stabilizer, as an additive material, can enhance soil stability and reduce the use of cement as a stabilizing agent. Therefore, the objective of this study is to investigate the influence of the mixture of matos soil stabilizer and cement, as well as the variation in curing time, on the classification and index properties of the soil tran.

2. Materials and Methods

The soil samples for this study were collected from the Peniraman quarry located on Nusapati Highway, Sungai Pinyuh District, Mempawah Regency and Matos Soil Stabilizer from PT. Wakatuli Cipta Ciptama, Yogyakarta. The study involved two main activities: field work, which involved

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sampling, and laboratory work, which included sample testing. The soil samples used in this study comprised both undisturbed and disturbed soil.

Soil stabilization is an effort to enhance soil parameters by incorporating matos and cement as soil stabilizing agents. This allows for the evaluation of changes in the physical properties of the soil before and after stabilization is conducted.

The index properties tests carried out were Water Content (ASTM D 2216-19) [2], Unit Weight (ASTM-D 7263) [3], Specific Gravity (ASTM-854-02) [4], Atterberg limit (ASTM-4318) [5], Hydrometer analysis (ASTM-7928) [6], Sieve Analysis (ASTM-D 422-63) [7], Permeability [8]. The test results obtained are then adjusted based on the General Specifications for 2018 road and bridge works (revision 2)

Table 1 Aggregate Foundation Later Attributes [9]

Properties	Aggregate Fondation Layer			Drainage Layer
	Class A	Class B	Class C	
Abrasion of coarse aggregate (SNI 2417:2008)	0 - 40 %	0 - 40 %	0 - 40 %	0 - 40 %
Broken Granules, Ratained on Sieve No.4 (SNI 7619:2012)	95/90[1)]	55/50[2)]	55/50[2)]	80/75[3)]
Liquid Limit (SNI 1967:2008)	0 - 25	0 - 35	0 - 35	-
Plasticity Index (SNI 1966:2008)	0 - 6	4 - 10	5 - 15	-
Plasticity Index Product with % of Passing Sieve No.200	max. 25	-	-	-
Clay Clumps and Easily Break Granules (SNI 4141:2015)	0 - 5%	1 - 5%	2 - 5%	3 - 5%
CBR Soaked (SNI 1744:2012)	min.90%	min.60%	min.50%	-
Comparison Between the Percentage of Passing Sieve No.200 and No.40	max.2/3	max.2/3	-	-
Coeffisient of Uniformity: $C_v = D_{60}/D_{10}$	-	-	-	> 3.5

In this research, testing was carried out to examine the index properties of soil using a combination of cement and matos soil stabilizer. The variations in the mixture involved blending the natural soil with 5% cement and adding five different levels of matos soil stabilizer: 0%, 1%, 2%, 4%, and 8%. Each mixture variation underwent different curing periods, specifically 0 days, 7 days, and 14 days.

Table 2 Test Mixture Variations Code

No	Mixture Variations	Variations Code
1	Distrubed Soil + 0% Cement + 0% Matos	S
2	Distrubed Soil + 5% Cement + 0% Matos	SC
3	Distrubed Soil + 5% Cement + 1% Matos	SCM-01
4	Distrubed Soil + 5% Cement + 2% Matos	SCM-02
5	Distrubed Soil + 5% Cement + 4% Matos	SCM-03
6	Distrubed Soil + 5% Cement + 8% Matos	SCM-04

The data obtained from the test results is subsequently analyzed based on the conducted tests. The soil classifications are determined according to the standards set by USDA, USCS, and AASHTO, using the results of the analysis. Additonally, the analysis results are adjusted to comply with the general specifications for road and bridge construction work in 2018 (revision 2).

3. Results

3.1. Testing The Index Properties Of The Undistrubed Soil

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Table 3 Undistrubed Soil Test Results

No	Test Type	Test Result
1	Water Content (Undisturbed Soil) (w = %)	41.017
2	Unit Weight (Tanah Tak Terganggu) (γw = gr/cm^3)	1.272
3	Water Content (Compacted Soil) (w_{opt} = %)	24.155
4	Unit Weight (γw = gr/cm^3)	1.143
5	Spesific Gravity (Gs)	2.611
6	Liquid Limit (LL = %)	43.290
7	Plastic Limit (PL = %)	29.038
8	Plasticity Index (IP = %)	14.252
9	Shrinkage Limit (SL = %)	29.935
10	Particle Size Distribution Analysis (%)	
	• Sand	24.000
	• Silt	60.000
	• Clay	16.000

3.2. Results of the Influence of the Addition of Matos Soil Stabilizer and Cement on Index Properties

Table 4 Results of Specific Gravity Testing

Sample		Specific Gravity (Gs)	Percentage Increase (%)
Curing 0 Day	S	2.611	-
	SC	2.689	2.992
	SCM-01	2.720	4.176
	SCM-02	2.726	4.397
	SCM-03	2.750	5.344
	SCM-04	2.757	5.591
Curing 7 Days	S	2.613	0.098
	SC	2.696	3.258
	SCM-01	2.723	4.304
	SCM-02	2.735	4.775
	SCM-03	2.753	5.460
	SCM-04	2.760	5.730
Curing 14 Days	S	2.614	0.117
	SC	2.697	3.299
	SCM-01	2.725	4.382
	SCM-02	2.737	4.840
	SCM-03	2.755	5.540
	SCM-04	2.762	5.781

Table 5 Results of Water Content Testing

Sample		Water Content (w) (%)	Percentage of Decline (%)
Curing 0 Day	S	24.155	-
	SC	23.957	0.822
	SCM-01	23.660	2.050
	SCM-02	23.381	3.205
	SCM-03	22.770	5.737
	SCM-04	21.769	9.880
Curing 7 Days	S	24.109	0.192
	SC	23.733	1.749
	SCM-01	23.507	2.682
	SCM-02	23.234	3.814
	SCM-03	22.297	7.693
	SCM-04	21.434	11.266
Curing 14 Days	S	23.954	0.833
	SC	23.532	2.582
	SCM-01	23.323	3.445
	SCM-02	23.041	4.612
	SCM-03	22.145	8.324
	SCM-04	20.917	13.407

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Table 6 The Results of Unit Weight Testing

Sample		Volume Weight (γwet) Laboratory Test	Volume Weight (γwet) Empirical Formula
Curing 0 Day	S	1.811	1.816
	SC	1.820	1.822
	SCM-01	1.820	1.826
	SCM-02	1.838	1.836
	SCM-03	1.857	1.864
	SCM-04	1.866	1.869
Curing 7 Days	S	1.811	1.816
	SC	1.820	1.819
	SCM-01	1.820	1.824
	SCM-02	1.829	1.834
	SCM-03	1.848	1.856
	SCM-04	1.857	1.864
Curing 14 Days	S	1.811	1.813
	SC	1.811	1.816
	SCM-01	1.820	1.821
	SCM-02	1.829	1.831
	SCM-03	1.848	1.854
	SCM-04	1.848	1.856

Table 7 Results of Plasticity Index Analysis

Sample		Plasticity Index (%)	Percentage of Decline (%)
Curing 0 Day	S	14.252	-
	SC	13.056	8.389
	SCM-01	12.546	11.969
	SCM-02	12.113	15.011
	SCM-03	10.475	26.500
	SCM-04	8.155	42.776
Curing 7 Days	S	14.132	0.843
	SC	12.139	14.825
	SCM-01	11.823	17.042
	SCM-02	10.945	23.202
	SCM-03	8.511	40.279
	SCM-04	6.061	57.472
Curing 14 Days	S	14.062	1.336
	SC	11.560	18.888
	SCM-01	10.972	23.014
	SCM-02	10.351	27.370
	SCM-03	8.124	42.997
	SCM-04	5.069	64.433

Tabel 8 Permeability Test Results

Sample		Permeability Coefficient (k)
Curing 0 Day	S	0.00000267
	SC	0.00000227
	SCM-01	0.00000207
	SCM-02	0.00000177
	SCM-03	0.00000167
	SCM-04	0.00000148
Curing 7 Days	S	0.00000261
	SC	0.00000197
	SCM-01	0.00000167
	SCM-02	0.00000138
	SCM-03	0.00000129
	SCM-04	0.00000091
Curing 14 Days	S	0.00000257
	SC	0.00000177
	SCM-01	0.00000129
	SCM-02	0.00000110
	SCM-03	0.00000091
	SCM-04	0.00000082

Table 9 Results of Hydrometer Test and Sieve Analysis of Soil at 0 Day of Curing

	S	SC	SCM-01	SCM-02	SCM-03	SCM-04
D	**Passes Percentage (%)**	**Passes Percentage (%)**	**Passes Percentage (%)**	**Passes Percentage (%)**	**Passes Percentage (%)**	**Passes Percentage (%)**
0.0013	10.104	0.000	0.000	0.000	0.000	0.000
0.0031	20.207	7.947	5.920	3.942	1.960	1.958
0.0060	30.311	15.894	13.814	9.855	9.802	7.831
0.0084	36.373	31.788	27.628	19.710	15.684	13.704
0.0196	56.580	49.668	47.363	41.391	35.288	33.281
0.0303	66.683	57.615	53.283	49.275	45.090	37.196
0.0750	83.280	82.304	77.320	70.592	64.668	57.904
0.1250	90.940	87.390	85.252	78.856	68.266	65.634
0.1800	95.240	92.150	87.874	85.618	80.808	68.924
0.2500	97.280	94.604	90.964	90.214	87.618	71.996
0.4250	98.780	98.408	93.556	96.108	93.906	78.424
0.8500	99.700	99.814	97.316	99.582	98.708	92.216

Table 10 Results of Hydrometer Test and Sieve Analysis of Soil at 7 Days of Curing

	S	SC	SCM-01	SCM-02	SCM-03	SCM-04
D	**Passes Percentage (%)**	**Passes Percentage (%)**	**Passes Percentage (%)**	**Passes Percentage (%)**	**Passes Percentage (%)**	**Passes Percentage (%)**
0.0013	10.10	0.000	0.000	0.000	0.000	0.000
0.0031	20.21	7.947	1.973	3.942	1.960	1.958
0.0060	28.29	13.907	11.841	9.855	9.802	7.831
0.0084	32.33	21.854	21.708	19.710	15.684	11.746
0.0196	54.56	41.721	39.469	37.449	31.367	23.492
0.0303	64.66	55.629	47.363	45.333	35.288	33.281
0.0750	82.14	67.170	66.190	62.498	59.642	52.234
0.1250	90.38	71.264	69.778	68.550	62.676	56.872
0.1800	94.81	77.124	75.680	73.164	68.448	61.986
0.2500	97.12	82.690	80.604	78.420	76.056	66.958
0.4250	98.76	88.658	87.868	83.152	83.346	76.010
0.8500	99.68	94.560	96.218	90.284	93.556	91.676

Table 11 Results of Hydrometer Test and Sieve Analysis of Soil at 14 Days of Curing

D	S Passes Percentage (%)	SC Passes Percentage (%)	SCM-01 Passes Percentage (%)	SCM-02 Passes Percentage (%)	SCM-03 Passes Percentage (%)	SCM-04 Passes Percentage (%)
0.0013	10.10	0.000	0.000	0.000	0.000	0.000
0.0031	22.23	1.987	3.947	3.942	1.960	1.958
0.0060	28.29	9.934	7.894	7.884	7.842	7.831
0.0084	34.35	19.867	13.814	11.826	13.723	11.746
0.0196	58.60	39.735	35.522	33.507	29.407	27.408
0.0303	66.68	51.655	41.443	37.449	35.288	33.281
0.0750	80.51	68.642	66.834	60.074	52.984	41.310
0.1250	89.00	75.950	70.898	64.584	61.440	44.264
0.1800	93.91	81.778	79.882	73.966	73.324	49.460
0.2500	96.11	88.026	85.636	80.236	80.786	54.360
0.4250	98.09	92.512	92.782	87.982	89.030	64.556
0.8500	99.42	97.798	98.466	96.238	96.552	87.392

Table 12 Soil Classification Results [10]

Curing	Sample	USDA Classification	USCS Classification	AASHTO Classification
0 Day	S	Silty Loam	ML	A-7-6
	SC			
	SCM-01			
	SCM-02			A-7-5
	SCM-03			
	SCM-04	Sandy Loam		A-5
7 Days	S	Silty Loam	ML	A-7-6
	SC			
	SCM-01			A-7-5
	SCM-02			
	SCM-03	Sandy Loam		A-5
	SCM-04			A-4
14 Days	S	Silty Loam	ML	A-7-6
	SC			
	SCM-01			A-7-5
	SCM-02			
	SCM-03	Sandy Loam		A-5
	SCM-04			A-4

4. Discussion

The decrease in water content with the increase in matos variation in the cement mixture, and the decrease in water content over curing time is due to the evaporation of water in the soil as a result of the hydration reaction between cement and water.

There is a decrease in the wet bulk volume of the soil for each variation of matos soil stabilizer added with 5% cement, both in non-curing and curing conditions for 7 and 14 days. This is consistent with the reduction in water content that occurs.

The decrease in the Plasticity Index is caused by the decrease in the Liquid Limit which continues to decrease with the increase in the content of matos in the 5% cement and soil mixture, curing time, and the increase in the Plastic Limit. The value of the Plasticity Index is the difference between the Liquid Limit value and the Plastic Limit value.

The results indicate that an increase in the matos content in the cement leads to a decrease in the permeability coefficient value, resulting in slower water seepage in the soil. This is because the cement fills the pores between soil particles.

Based on the obtained results, the addition of cement and matos soil stabilizer to the disturbed soil led to a decrease in the percentage passing the No. 200 sieve or the sieve with a diameter of 0.075 mm, regardless of the curing time. Therefore, the addition of cement and matos soil stabilizer, as well as the curing time, can cause changes in the particle size of the soil.

From the soil classification results, it can be observed that with the addition of various matos and cement variations to the soil for different curing conditions, there are changes in the soil types, characterized by an increase in sandy particles and a decrease in clay particles.

5. Conclusions

Based on the research conducted, it was found that increasing the concentration of matos mixed with cement in the soil leads to an increase in the bulk density (Gs) of the soil. This can be attributed to the changes in the soil composition, as observed in the gradation analysis results. Increasing the concentration of matos added to cement in the soil leads to a decrease in the optimum moisture content of the soil. The reduction in moisture content also occurs during the curing process, where longer curing durations result in further moisture reduction. This can be attributed to the pozzolanic reactions taking place in the soil. Consistent with the decrease in moisture content, the wet bulk volume of the soil also decreases. The reduction in wet bulk volume of the soil is influenced by the moisture content, where higher moisture reductions result in a decrease in the wet bulk volume of the soil. Conversely, the dry bulk volume of the soil increases for each respective variation of the mixture. The value of the plasticity index continues to decrease, which is attributed to the changes in the liquid limit and plastic limit values. As a result, the plasticity of the soil undergoes changes. The increase in the proportion of matos in the cement results in the coarsening of the soil texture and grain size, both in non-curing and curing for 7 and 14 days. This phenomenon is attributed to the pozzolanic reaction, which causes the soil particles to bind together. The increasing addition of matos to the cement results in a decrease in the coefficient of permeability (k), both in non-curing and curing for 7 and 14 days. This is due to the process of cementation, which leads to the formation of pore clogging and reduces the ability of water to flow through the soil. However, it should be noted that this issue contradicts the coarsening of the soil texture caused by stabilization, as the test specimen is compacted, resulting in a more granular soil structure. The soil classification results according to the USDA method, for the soil mixed with cement and varying levels of matos, showed an increase in the percentage of sand particles. This increase was observed in both non-curing and curing for 7 and 14 days. The highest increase occurred in the variation with 8% matos and a curing time of 14 days, where the percentage of sand particles was 62%, silt particles were 36%, and clay particles were 2%. The soil classification according to AASHTO and USCS methods underwent changes due to the addition of cement and matos, as well as changes resulting from curing time. These changes were influenced by a decrease in the liquid limit (LL) and plasticity index (IP), causing the soil classification point to shift towards the lower left direction. The plasticity index value of 5.069% with the highest matos content and a curing time of 14 days has fulfilled the requirements for the construction of the subgrade layer for Class B road foundations.

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