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Stabilization of Expansive Soil with 2.5%, 3.5% AND 5% SikaCim Acceleration in Susukan Subdistrict, Semarang Regency

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Abstract

Expansive clay soils are soils that swell in the presence of water and shrink when they dry out. The swelling pressure generated can cause serious damage to structures above them. Soil stabilization is needed to improve the properties of expansive soils, whether mechanically or physically. In this study, SikaCim Accelerator was used as a stabilizer, with percentages of 2.5%, .3.0%, and 5.0% from the water content needed to achieve the OMC condition in the Standard Proctor test. The purpose of this study was to determine the physical and mechanical properties of expansive clay and stable soil with curing time of 0, 7, and 14 days. The conclusion of this study was SikaCim Accelerator didn't give effective result to physical properties, this could be concluded from the results of physical properties testing which didn't indicate significant changes. Soil classification according to AASHTO remained in the same group, which was A-7-5and Mechanical properties increased CBR and UCS values, in contrast there was a decrease in swelling potential and swelling pressure with optimal values of CBR, UCS, and swelling test obtained with 2.5% SikaCim Accelerator and curing time of 7 days..

Keywords*: expansive clay soil, SikaCim accelerator, stabilization, physical properties, mechanical properties*

INTRODUCTION

The subgrade is the basic surface for the placement of parts of the building above it (Hardiyatmo, 2002). Coduto (1999) defines expansive clay soil as swell when wet and shrink when dry. According to Hardiyatmo (2018), the soil which is easily changed in volume is that which contains a lot of clay minerals, especially montmorillonite. As the clay expansive, the resulting swelling pressure can lift the building above it, causing serious damage to light buildings and pavement. Soedarmo & Purnomo (1993) said that soils that are not good can meet the required technical requirements, stabilization efforts are carried out both mechanically and by adding additives.

Previous research, Expansive Clay Soil Stabilization with *fly ash* by (Bhuvaneshwari et al., 2005), (Dash & Hussain, 2012), (Maaitah, 2012), (Jawad et al., 2014), (Leite et al., 2016), One of the major difficulties in field application is the thorough mixing of the two materials in the proportions required to form a homogeneous mass, experimental embankments 30 m long by 6m wide by 0.6 m high were successfully constructed and in-situ test undertaken proves its suitability for the construction of embankments, ash embankments, patching of lowland areas, etc., lime by (Bell, 1996), (Al-Mukhtar et al., 2010), that 5% lime is sufficient for short-term reactions involving cation exchange, in these soils and lime content exceeds the optimum limit, there is a decrease in strength, if the clay soil on a large scale contains rich silica which forms silica gel and is porous. the strengthening of the strength of the cementation is substantially offset by the loss of strength from the gel pores, thereby increasing the overall strength.

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In addition, the gel material retains a large amount of water, causing increased plasticity and swelling, fly ash and lime by (Zhang & Cao, 2002), (Wang & Sun, 2015), the addition of lime and fly ash to expansive soil was 4% - 6% and 40% - 50% of the dry weight of the soil, respectively, the effect of the addition of lime and fly ash in reducing development potential. The plastic limit increases, the liquid limit decreases, by mixing fly ash, which decreases the plasticity index, a Mix of Cement and Lime by, (Lucian, 2013) (Khemissa & Mahamedi, 2014), the best performances are obtained for a mixt treatment corresponding to 8% cement and 4% lime contents, chemical additive by (Wang & Sun, 2015), (Sun et al., 2012), showed that the residual soda had a significant effect on increasing the expansion of expansive soil. The compaction moisture content range for treated soils with soda residue was greater than for expansive soils. After 7 days of conservation, there was a remarkable increase in the compressive strength and the infinite shear strength. Furthermore, a peak occurs when the residual mixing ratio has reached 30%. The remarkable increase in cohesion reflects the increase in shear strength. However, the internal friction angle changed slightly SikaCim Accelerator is an additive for quick-drying mortar and instant leak plugs. This material has the characteristics of being very fast preparation, reducing shrinkage, having initial strength and high pressure strength.

Chen (1975) explains the relationship between the plasticity index and the potential for swelling soil. This relationship can be seen in Table 1.

Table 1 Relationship of Swell Potential with Plasticity Index (Chen, 1975)

Swell Potential	**Plastisity Index**
Low	0 – 15
Medium	15 – 35
High	35 – 55
Very High	55<

From the UCS test, it was obtained that the value of q_u is the value of the ground pressure strength of the unconditional conditions, Das (2019) Estimating the consistency of clay soils based on the value of UCS (q_u) in Table 2.

Table 2 General Relationship between Soil Consistency and Clay Soil Strength from the Unconfined Compression Test (Das, 2019)

Consistency	q_u	
	(ton/ft^2)	(kN/m^2)
Very soft	0 – 0,25	0 – 23,94
Soft	0,25 – 0,5	24 – 48
medium	0,5 – 1,48	48,1 – 96
Hard	1,00 – 2,96	96,1 – 192
Very Hard	2,00 – 4,192	192,1 – 383

The CBR value category for the subgrade strength of the road according to Applied Research Association (2001) in Table 3, while the potential value of swelling and the degree of swelling according to Hardiyatmo (2018) in Table 4.

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Table 3 Classification of Swelling Degrees (Hardiyatmo, 2018)

Swelling Degree	Swelling Potential (%)
Low	0 – 1,5
Medium	1,5 – 5
High	5,0 – 25
Very High	> 25

Location
Expansive clay samples were taken in Susukan District, Semarang Regency, precisely at coordinates 7o6'42.88 "LS, 110o26'1.79" BT.

2. Methodology

The study was conducted on native soil and stabilized soil with a mixture of SikaCim Accelerator 2.5%, 3.5%, and 5% calculated on the water requirements to reach OMC Standard Proctor conditions for 0, 7 and 14 days. This research includes the problem identification stage, literature study, preparation of tools and materials, material collection, sample mixing, and testing and discussion. Expansive clay testing is tested for its physical and mechanical properties, with the following description is water content (ASTM D2216-10), Specific gravity (ASTM D854-10), volume weight (ASTM C948-14), s*ieve analysis* (ASTM D422-14), Atterberg *Limit* (ASTM D418-08). Proctor *Standard* (ASTM D698-12), *Unconfined Compression Strength* (ASTM D2850-15), California *Bearing Ratio* (ASTM D1883-16), *Swelling* (ASTM D4546-14).

3. Result and Discussion

The results of testing of original and stabilized soil properties are in Table 5. The results of testing the consistency limits can be seen in Table 6. Plotting classification of USCS with A-Line Chart can be seen in Figure 1 through Figure 4.

Table 4 Soil Properties Test Results

Testing	**Original Soil (%)**	**Stabilized Soil (% SCA)**	**Time Curing Day**			**Unit**
			0	**7**	**14**	
Water Content (w)	31.30	2.5	31.39	31.24	31.21	%
		3.5	31.40	31.38	31.31	
		5	31.26	31.35	31.36	
Specific Gravity (G_S)	2.68	2.5	2.68	2.76	2.77	-
		3.5	2.64	2.71	2.71	
		5	2.62	2.66	2.67	
Volume Weight moist (γ_b)	1.83	2.5	1.821	1.836	1.844	gr/cm^3

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Table 5 Test Results for Consistency Limits (Atterberg Limit)

Testing	Original Soil (%)	Stabilized Soil (% SCA)	Time Curing Day			Unit
			0	7	14	
Liquid Limit (LL)	79.69	2.5	79.06	71.36	71.75	%
		3.5	78.87	71.69	73.55	
		5	78.17	72.56	75.50	
Plastic Limit (PL)	34.41	2.5	33.91	35.79	33.98	%
		3.5	33.18	34.19	34.07	
		5	33.08	33.99	34.57	
Plasticity Index (PI)	45.27	2.5	45.16	35.57	37.76	%
		3.5	45.69	37.50	39.48	
		5	45.09	38.57	40.92	
Shrinkage Limit (SL)	6.11	2.5	6.14	9.36	9.03	%

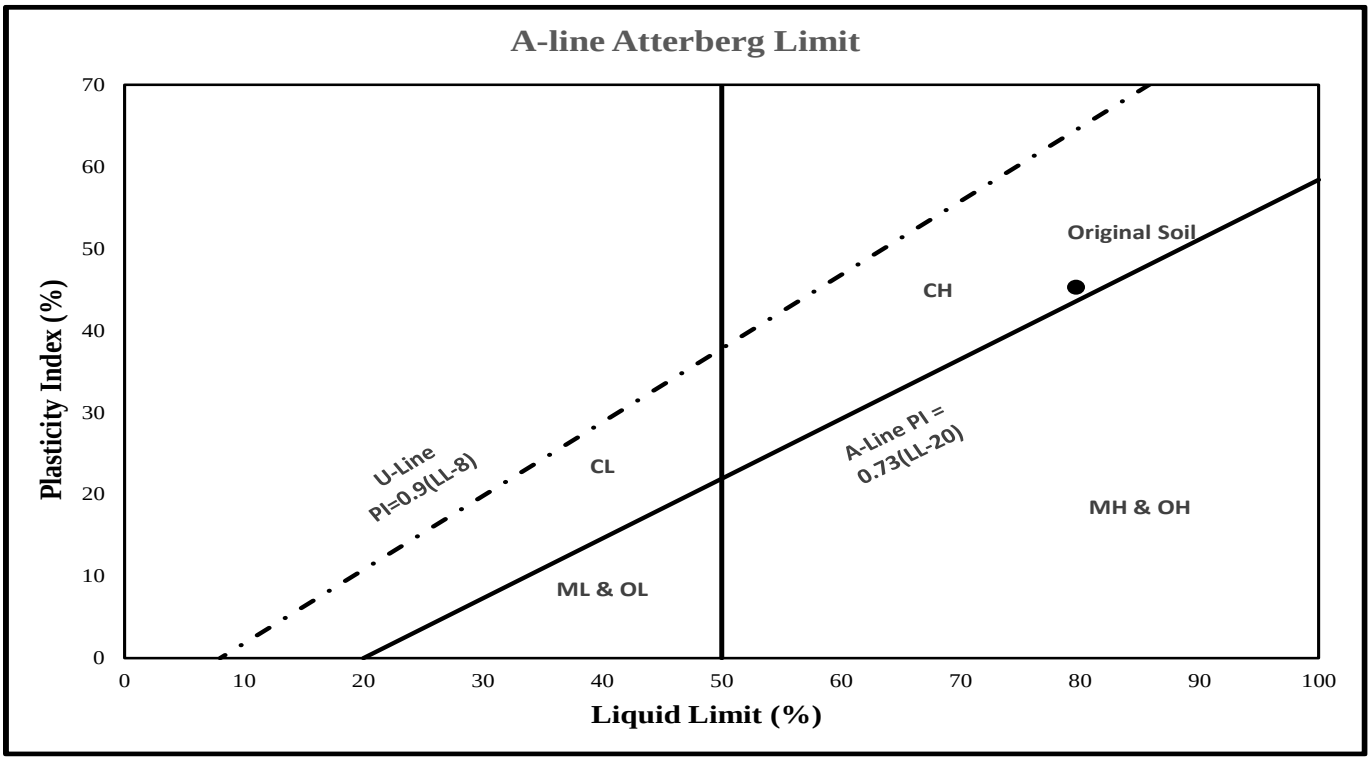

Figure 1 USCS Classification with A-Line Original Land Charts

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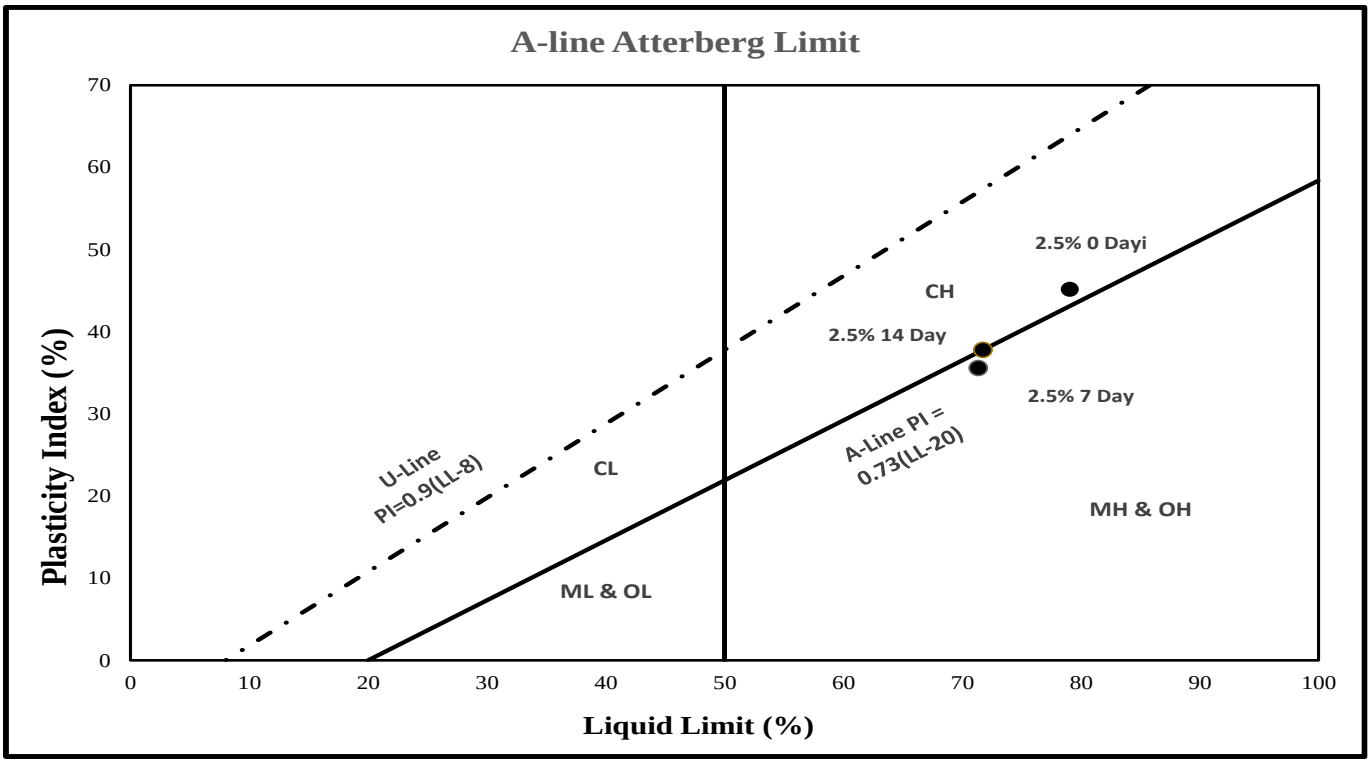

Figure 2 USCS Classification with A-Line Chart Soil Stabilized Soil at curing 2.5% SCA at Curing 0, 7, and 14 Days

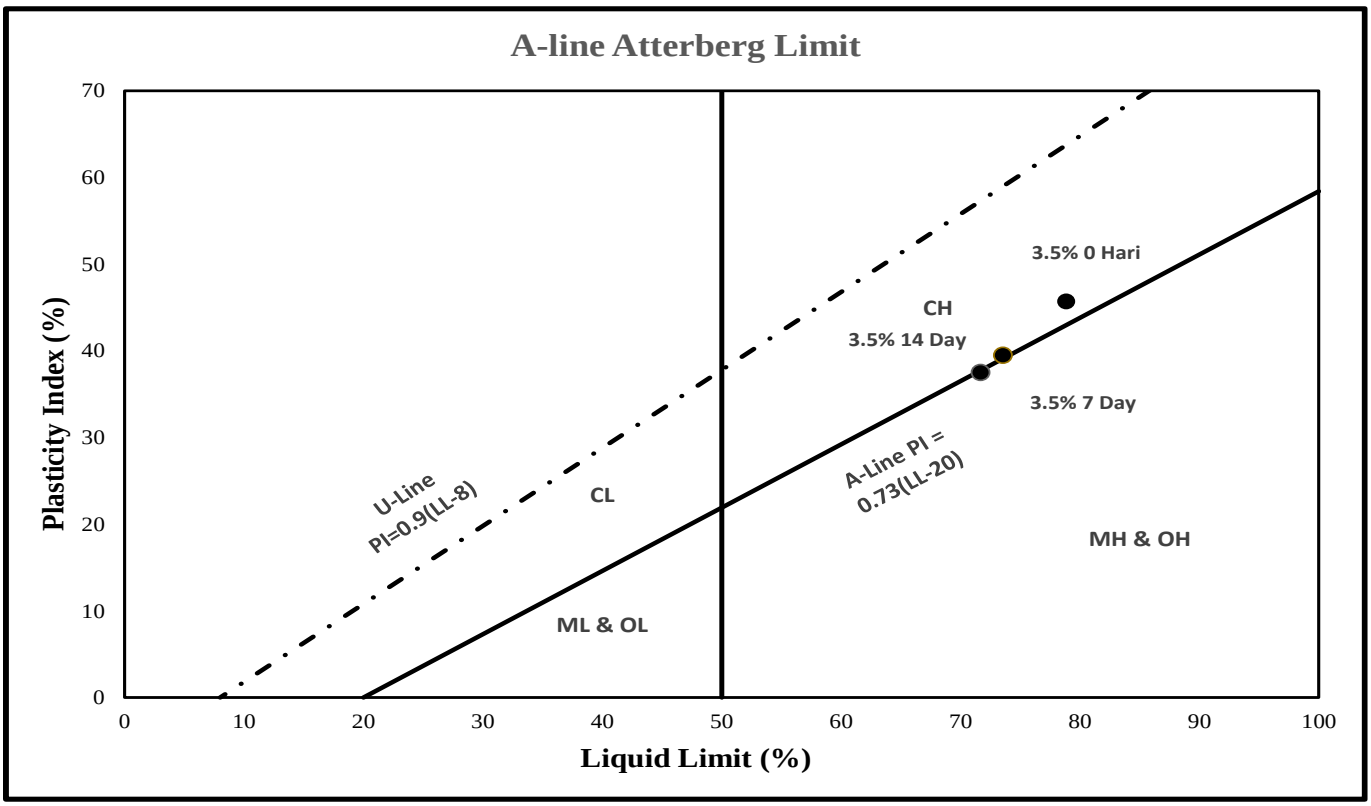

Figure 3 USCS Classification with A-Chart Stabilized Soil 3.5% SCA Level at Curing 0, 7 and 14 Days

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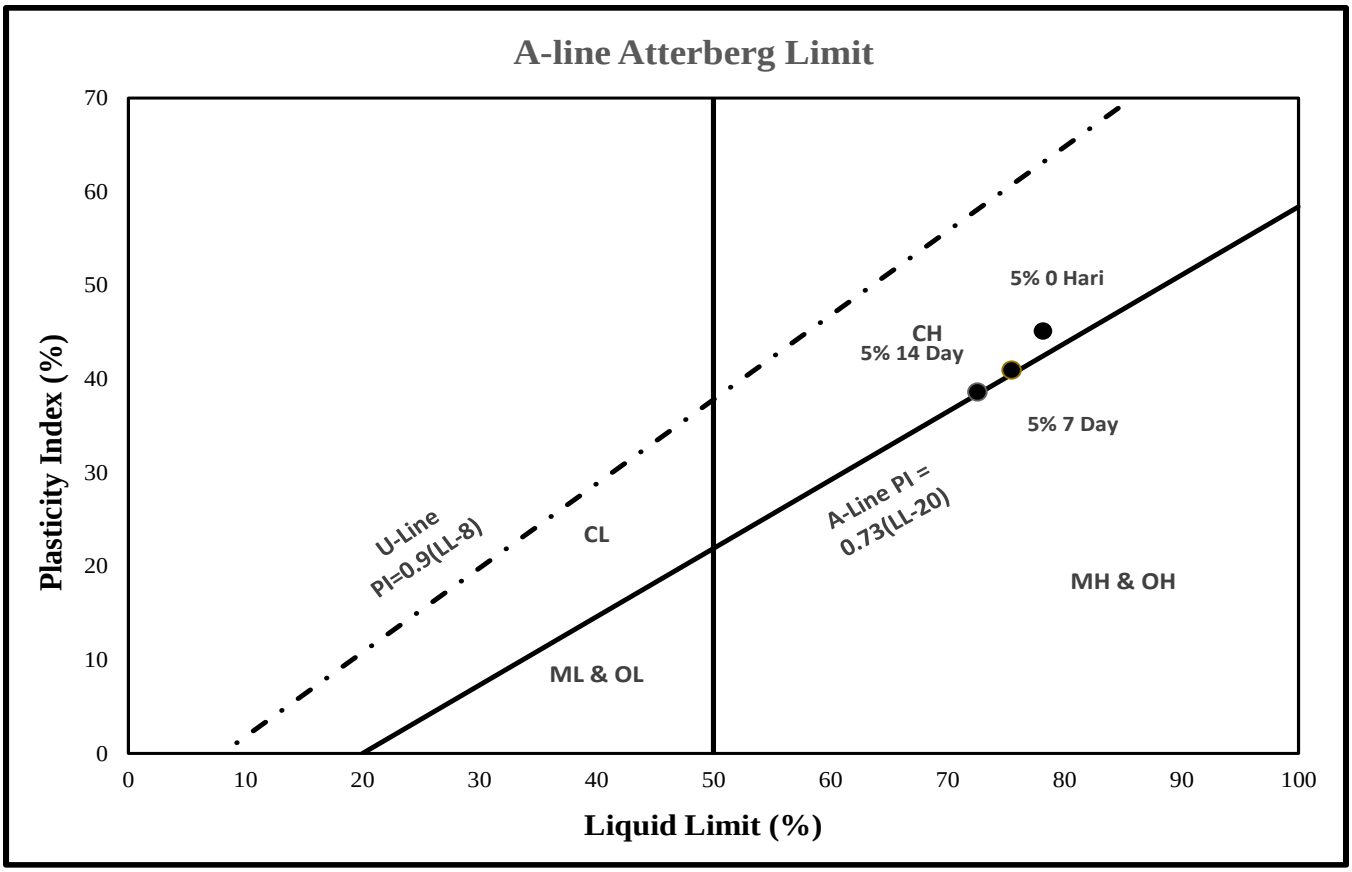

Figure 4 USCS Classification with A-Chart Stabilized Soil 3.5% SCA Level at Curing 0, 7 and 14 Days

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From the test results, it can be concluded that the addition of SikaCim Accelerator to expansive clay causes a decrease in the liquid limit (LL) and plasticity index (PI) at each mixing level. According to Chen (1975), as stated in Table 1, for the Atterberg Limit test for native and stabilized soil all PI values are categorized as "high" development potential. Addition of SCA content of 2.5% with 7 days curing time to get the most optimum, results to stabilize the soil with a decrease in PI to 35.57%, from the original soil of 45.27%, although it is still included in the high development category.

Based on the results of the plotting in Figure 2, the original soil is classified in CH soil (clay soil with high plasticity). Based on the results of plotting in Figure 3, SCA stabilized soils content of 2.5% with a time of 7 days curing time are classified on MH & OH soils (clay soils with moderate-high plasticity), whereas with 0 and 14 days curing time as classified on CH soils (clay soils with high plasticity). Based on the results of plotting in Figure 4, SCA stabilized soil with a content of 3.5% with 7 days curing time is classified in MH & OH soil (clay soil with moderate-high plasticity), whereas with 0 and 14 days curing time is classified on CH soil (clay soil with high plasticity). Based on the results of plotting in Figure 5, the SCA stabilized soil content of 5% with a time of 0, 7, and 14 days of clam is classified in CH soils (clay soil with high plasticity)

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The results of sieve analysis testing in Table 7. Soil classification based on the AASHTO system in Table 8. According to the results of the AASHTO classification, the results of sieve analysis of native and stabilized soils did not change in class, remained in the A-7-5 group, which included into clay soil with ordinary-poor quality for subgrade. It can be concluded that the addition of SikaCim Accelerator has no effect on the results of soil classification.

Table 6 Grain Analysis Test Results

Testing	Original Soil (%)	Stabilized Soil (% SCA)	Time Curing Day			Unit
			0	7	14	
Gravel	0.40	2.5	0.98	0.42	0.30	%
		3.5	0.96	0.76	0.30	
		5	0.86	0.74	0.26	
Sand	9.20	2.5	6.08	5.16	4.44	%
		3.5	5.84	5.36	4.90	
		5	5.56	4.52	3.76	
Silt	55.76	2.5	58.51	60.30	63.18	%
		3.5	59.89	63.73	68.15	
		5	60.54	61.46	65.96	
Clay	34.64	2.5	34.43	34.12	32.08	%
		3.5	33.31	30.15	26.65	
		5	33.04	33.28	30.02	

Table 7 Soil Classification According to AASHTO

Classification	Original Soil (%)	Stabilized Soil Time Curing Day 0 Hari		
		SCA 2.5%	SCA 3.5%	SCA 5%
AASHTO	A-7-5	A-7-5	A-7-5	A-7-5
	Clayey	Clayey	Clayey	Clayey
		Stabilized Soil Time Curing Day 7 Hari		
		A-7-5	A-7-5	A-7-5
		Clayey	Clayey	Clayey
		Stabilized Soil Time Curing Day 14 Hari		
		A-7-5	A-7-5	A-7-5

Soil compaction to determine optimum water content (OMC) in this study, using the Standard Proctor method. The graph determines the optimum water content in Figure 5. From the results of the Standard Proctor test, the optimum water content (OMC) is 31.30% and the dry weight content (γ_d) is 1.38 gram / cm^3.

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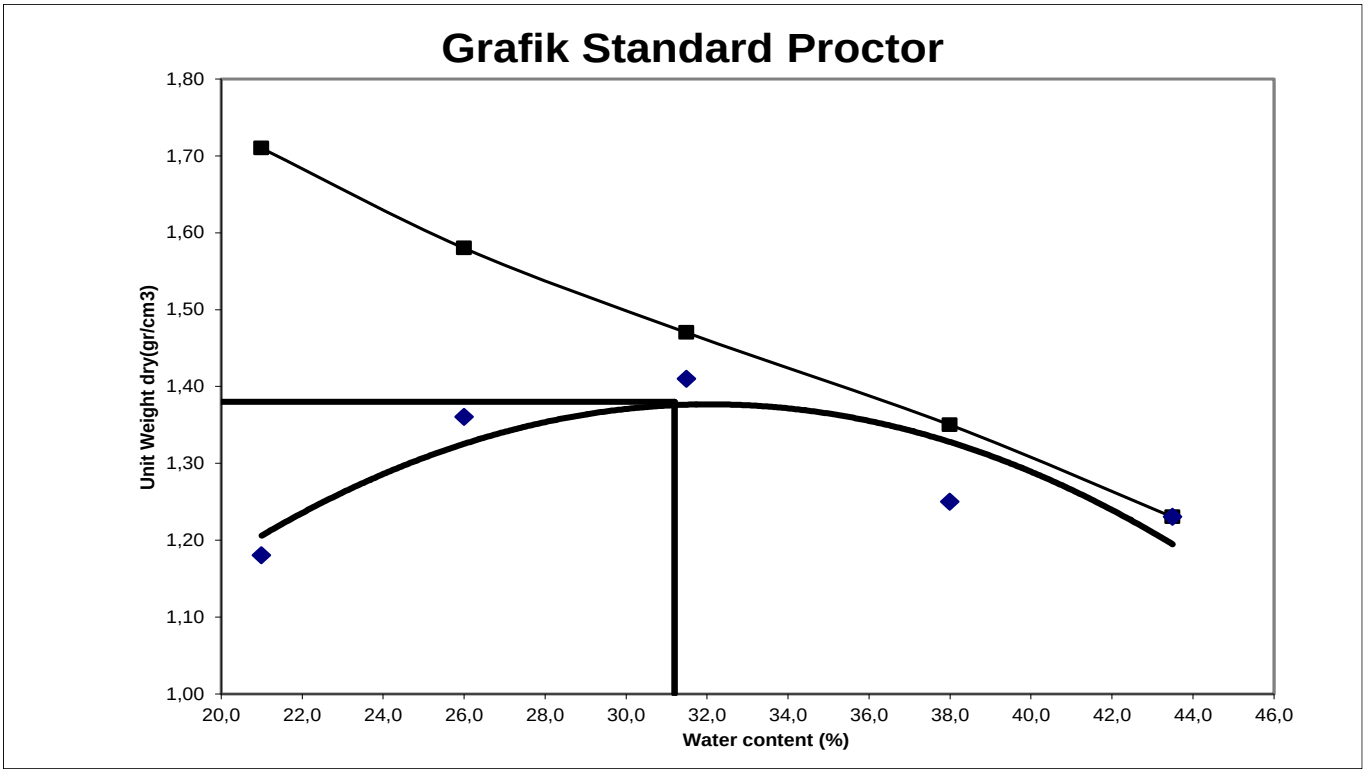

Figure 5 Proctor Standard Chart

The results of the UCS test in Table 9 and Figure 6. Based on the results of the UCS test, stabilized soil with a mixture of SikaCim Accelerator can increase its compressive strength compared to the original disturbing condition. However, the more mixture that is added does not make the compressive strength value is greater but tends to go down.

According to Das (2019), in Table 2, all q_u values can be categorized as clay with very rigid consistency. From these results it can be concluded that the maximum qu value obtained with a 2.5% SikaCim Accelerator level at a time of 7 days curing.

Table 8 q_u maximum results for UCS Testing

Curing Time (Days)	**q_u Maximum**					**Unit**
	Undisturbed Soil	***Disturbed Soil* (OMC)**	**SCA 2.5%**	**SCA 3.5%**	**SCA 5%**	
0	720.03	230.58	239.39	232.64	212.96	kN/m^2
7			289.33	254.51	218.90	kN/m^2
14			261.88	253.56	238.31	kN/m^2

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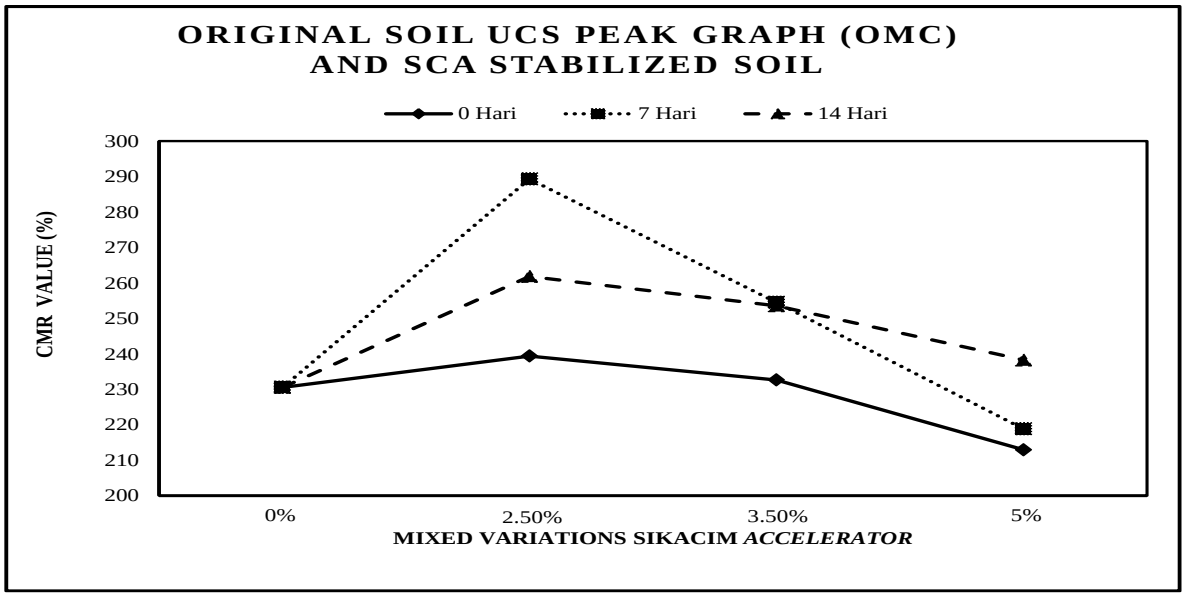

Figure 6 Graphic of the Peak of Original Soil and Stabilized Soil

CBR test results in Table 10. Based on the CBR test results, the addition of a SikaCim Accelerator mixture can increase the soil CBR value. This is based on the increasing CBR value of the original soil and reaching the optimum value in the SCA mixture of 2.5% curing 7 days unsoaked conditions. According to the Applied Research Association (2001), which in Table 3, the optimum CBR value in this test is in the medium category. However, for all CBR values, the soaked condition is in the bad category. From these results, it can be concluded that the addition of the SikaCim Accelerator mixture cannot increase the carrying capacity of the soil in unsoaked or soaked conditions. Swelling testing was carried out with an Oedometer and CBR soaked 25 blow. Swelling test results in Table 11. Based on the swelling test results in Table 11, swelling potential and swelling pressure (Oedometer) of native soil have decreased after stabilizing with the optimum value at the level of SCA addition of 2.5% on 7 days. levels. While the addition of SCA levels of 3.5% and 5% also decreased when compared to the original soil, but an increase when compared with 2.5% SCA. Whereas in the swelling potential (CBR Soaked) test the optimum decrease occurred in SCA stabilized soils with 2.5% content with a 7-days curing time. According to Hardiyatmo (2018) in Table 4, swelling potential in the original land of 8.17% is categorized as high development land, while SCA is stabilized at 2.5% on day 7 days at 4.95% including medium development. So it can be concluded that the stabilization of expansive clay with SikaCim Accelerator mixture can effectively reduce the potential for expansion of

Expansive clay soil with optimum results at a mixture of 2.5% with a time of 7 days curing.

Table 9 CBR Soil and Stabilization Test Results

CBR 25 Blow	Condition	Original Soil	SCA 2.5%	SCA 3.5%	SCA 5%	Unit
0 Hari	***Unsoaked***	5.22	5.74	5.80	5.51	%
7 Hari			7.45	7.06	7.16	%
14 Hari			7.25	6.38	6.09	%
0 Hari	***Soaked***	2.61	3.03	2.84	2.58	%
7 Hari			4.64	3.68	3.48	%
14 Hari			3.68	3.38	3.38	%

Table 10 Swelling Test Results

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Testing	Original Soil (%)	Curing Time (Hari)	Stabilized Soil (% SCA)			Unit
			2,5	3,5	5	
Swelling Potential Oedometer	8.17	0	7.72	7.94	8.07	%
		7	4.95	5.30	5.68	
		14	5.19	5.54	5.85	
Swelling Pressure Oedometer	249.86	0	246.47	247.46	248.51	kPa
		7	148.91	153.51	167.11	
		14	150.16	162.88	168.03	
Swelling Potential CBR	7.72	0	7.28	7.32	7.31	%
		7	5.03	5.23	5.60	
		14	5.25	5.49	5.76	

5. Conclusion

The research that has been done, it can be concluded as follows:
Test results of physical properties of the soil, based on the USCS classification system of native soil is clay soil with high plasticity (CH), whereas according to the AASHTO classification native soil falls into the category of clay soil with ordinary to bad ratings for subgrade (A-7-5) . For SikaCim Accelerator stabilized soils, 2.5% and 3.5% at 7 days curing are categorized as clay with moderate-high plasticity (MH & OH),
according to the USCS classification system, while according to the AASHTO classification for all stabilized soil mixture levels are included in the normal to poor assessment of clay soil (MH & OH), according to the USCS classification system. for subgrade (A-7-5). The addition of SikaCim Accelerator can reduce the liquid limit and expansive soil plasticity index, but does not change the classification value according to AASHTO.
Based on the results of Unconfined Compression Strength (UCS) and California Bearing Ratio (CBR), the addition of SikaCim Accelerator as a stabilizer can increase the compressive strength and bearing capacity of expansive clay compared to the original expansive clay. For the results of the Swelling Test Oedometer and CBR Soaked, a mixture of SikaCim Accelerator can reduce the value of swelling potential and swelling pressure (Oedometer) at 7 and 14 days curing. The results of UCS, CBR, and Swelling Test have optimum value of mixture in SikaCim Accelerator stabilized soil content of 2.5% with 7 days curing.

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