International Journal of
Civil Engineering (IJCE)
ISSN (P): 2278–9987; ISSN (E): 2278–9995
Vol. 10, Issue 2, Jul–Dec 2021; 45–62

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

THE USE OF LIME STONE (DOMATO) AS EXPANSIVEMATERIAL FOR SOIL IMPROVEMENT(CASE STUDY: ROAD TOMATA - BETELEME)

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ABSTRACT

The phenomenon of expansive soil is a serious problem in geotechnical engineering that must be addressed immediately. The losses that must be borne by the community are in the form of material and non-material losses. Expansive land in the Tomata - Beteleme location often experiences shrinkage, which can cause minor damage to buildings and pavement. This study aims to determine the effect of lime stone on the bearing capacity of expansive subgrade through testing the physical and mechanical properties of the soil. The method used was to mix lime stone with variations of 3 %, 6 %, 9 %, 12 % and 15 %. Free compressive strength test and triaxial test were reviewed at curing time of 1, 7, 4, and 28 days. The results of the physical properties test showed that the clay soil of Taliwan Village, Tomata Subdistrict, North Morowali Regency in the USCS classification system was classified as CL soil type with a plasticity index value of 14.82 %. The highest free compressive strength test was variation lime stone 15 % with 28 days of ripening. The highest triaxial test was variation lime stone 15 % with 28 days of ripening.

KEYWORDS: *Expansive Soil, Lime Stone, Free Compressive Strength, Triaxial*

Article History

Received: 30 Oct 2021 | Revised: 01 Nov 2021 | Accepted: 08 Nov 2021

INTRODUCTION

Road development as a form of transportation infrastructure has an important role in the socio-economic development of the region. In addition, roads also play an important role in forming and strengthening national unity to strengthen national defence and security.

Street Tomata – Beteleme is a national road section across the middle of Sulawesi, part of Central Sulawesi Province, which connects South Sulawesi Province and Southeast Sulawesi Province. This road section is the main road that connects North Morowali Regency, Morowali, with the city of Palu as the capital city of Central Sulawesi Province. Based on this, the middle causeway is the main route that acts as the backbone of the road network system on the island of Sulawesi (Trans Sulawesi).

The length of street Tomata – Beteleme is 50.94 km, it takes ± 1 hour to pass this road section because most of this section is in a stable condition but there are several points where landslides occur on the road. The typical road damage that occurs on the Tomata – Beteleme road segment generally consists of soil movement / landslides and damage to the pavement surface.

The topography of this section consists of 3 (three) types, namely: flat areas, ravines, and ravines, and prone to landslides. Most of the landslides/soil movements occur on the side of the slope and the side of the ravine. The impact of this slope movement causes the pavement to crack so that water enters the pavement and damages the pavement structure. In a typical flat area the damage that occurs is in the form of a wavy pavement surface which results in longitudinal cracks in the pavement. The handling carried out on this road segment is the reconstruction of the resurfaced road, the installation of geomembranes and the installation of concrete piles.

LITERATURE REVIEW

According to Sukirman (1992) flexible pavement construction consists of layers that are placed on top of the compacted subgrade. These layers function to receive the traffic load and spread it to the layers below it. In general, the road pavement construction layer consists of:

- Surface Course
- Base Course
- Subbase Course
- Subgrade

According to Silvia Sukirman (1995) in terms of the original soil surface, the subgrade layers are divided into:

- Subgrade, excavated soil.
- Subsoil, embankment soil.
- Subsoil, native soil.
- Road Construction Subgrade

The subgrade layer is a layer of soil that serves as a place for laying the pavement layer and supports the construction of the road pavement above it. According to the Bina Marga specification standard, subgrade is the top layer of the road embankment with a thickness of 30 cm which has certain requirements according to its function, namely, with regard to density and carrying capacity (CBR).

The subgrade can be in the form of compacted original soil if the original soil is good or fill soil imported from other places or stabilized soil and others. Judging from the original soil surface, the subgrade layers are divided into:

- Subgrade, Native Soil (At-Grade).
- Subgrade, Backfill (At-Fill).
- Subgrade, Excavated Soil(At-Cut)

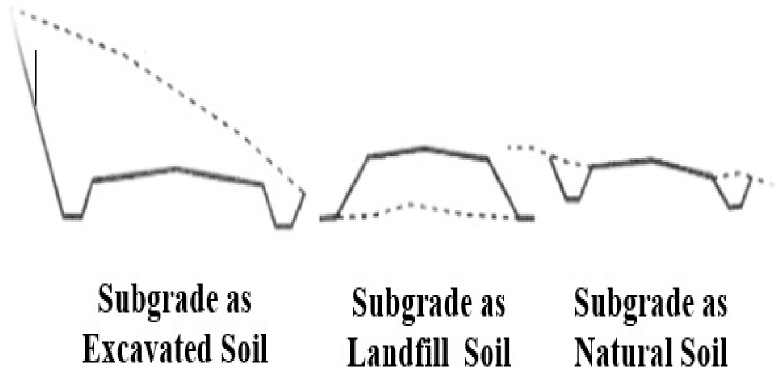

Figure 1: Types of Subgrade as Seen from the Original Subsurface Elevation.

Soil Classification

The classification systems commonly used in civil engineering are the AASHTO classification system and the Unified classification system (USCS). In general, classification is based on particle size obtained from sieve analysis for sandy soils. From a technical point of view (LD. Wesley, 1997), soils can be classified into: gravel, sand, silt and clay.

Table 1: Soil Classification Based on Grain Size

No.	Kind of Soil	Size Limits
1	Boulder	>8 inch (20 cm)
2	Cobblestone	3 inch - 8 inch (8 - 20 cm)
3	Gravel	2 mm - 8 mm
4	Course Sand	0,6 mm - 2 mm
5	Med Sand	0,2 mm - 0,6 mm
6	Fine Sand	0,06 mm - 0,2 mm
7	Silt	0,002 mm - 0,06 mm
8	Clay	< 0,002 mm

Expansive Subgrade

According to the Manual for Handling Expansive Soil for Road Construction of the Ministry of Public Works in 2005, what is meant by expansive soil is soil or rock with clay content that has the potential for shrinkage due to changes in water content.

A number of problems with civil engineering buildings that are often encountered in the field are the result of poor technical properties of the soil, which are characterized by high soil moisture content, high compressibility and low bearing capacity. Some of the types of soil that have these bad properties are soils that are easy to experience large shrinkage (Sudjianto, 2012).

(A) Expansive Soil (Smoothed) (B) Expansive Soil (Chunks)
Figure 2: Expansive Soil Material

Characteristics of Expansive Soil

Expansive soil has different characteristics from other types of soil, namely as follows:

Clay Minerals

Clay minerals that cause volume changes generally contain montmorillinite or vermiculite, while illite and kaolinite can be expansive if the particle size is very fine.

Soil Chemistry

Increasing the concentration of cations and increasing the valence of cations can inhibit soil development. For example, the Mq++ cation will give a smaller expansion compared to Na+.

Plasticity

Soils with a high plasticity index and liquid limit have a greater potential for swelling.

Soil Structure

Flocculated clay tends to be more expansive than dispersed clay.

Dry Fill Weight

Soil that has a high dry density shows a small distance between particles, this means a large repulsion force and a high development potential.

Expansive Soil Classification

In the field, if there are cracks and or surface gaps in the clay deposit due to the drying process, it is an indication of the expansive potential. From experience it appears that the problem of expansive behaviour on the surface of the soil is characterized by high plasticity, stiffness and there are cracks in over consolidated clay. For the identification of expansive soils in the laboratory, several classification methods have been developed. Generally, soils with a plasticity index (IP) of less than 15 % will not exhibit expansive behaviour.

The plasticity index (IP) is the parameter that is most often used as an initial indicator, because the characteristics of plasticity and the nature of changes in soil volume are closely related and influenced by colloid-sized particles. The Atterberg limit and clay grain content were used by Skempton (1953) for the identification of expansive clays.

Chemical Content (Minerals)

According to Chen (1975), clay particles are in the form of sheets that have a certain surface. Clay minerals are formed through a complex process from a variety of materials or parent rocks, including: feldspar, mica and limestone. The process of change includes disintegration, oxidation, hydration and melting. Clay particles are defined as soil particles having a grain diameter of < 0.002 mm. With such a small particle size, the electrical forces acting on the surface of the particles are much larger than the gravitational forces. These particles are said to be in a colloidal position. These colloidal particles are mainly composed of clay minerals derived from weathering rocks.

Material Limestone (Domato)

Domato/limestone is a part of carbonate rock which is composed by dominant carbonate minerals (Kusumadinata, 1983). Domato/limestone itself consists of non-clastic limestone and clastic limestone. Non-clastic limestone is a colony of marine animals, including Coelementrata, Molluscs, Protozoa and Fosaminifera or this limestone is often also called coral limestone, because the main constituent is coral. The main constituent of limestone is the mineral calcite (CaCO3), while other carbonate minerals that can be present are dolomite (Ca Mg (CO3)2), aragonite (Ca CO3), magnesite-rich calcite (MGCO3) and siderite (Fe CO3).. Other minerals can also be present as impurity minerals formed during deposition such as magnesite, clay, and sand minerals. The presence of these impurity minerals can be the basis for classifying limestone.

If the limestone is heavily polluted by magnesite, it is called dolomite, if the mineral impurity is clay it is called clay limestone and if the impurity is quartz, it is called quartz limestone. The colour of limestone is strongly controlled by the presentation of the dominant constituent minerals and impurity minerals.

Figure 3: Lime Stone Material

Lime Stone as Expansive Soil Stabilizing Material

The use of lime as a soil stabilizing agent has been widely used for subbase buildings or subgrade improvements on highways. Generally there are 2 main purposes of using lime for soil stabilization, namely:

- Lime to modify soil properties, namely to reduce plasticity, reduce or eliminate swelling-shrink properties, increase ease of work, increase grain diameter and others.
- Lime is intended for permanent soil stabilization for this matter, the criteria are based on bearing capacity, durability and so on.

Table 2: Gradation Requirements for Lime Stabilized Base and Subbase

Layer	Grain Size	Percent Pass (%)
Layer - Foundation	1,5 in	100
(base – course)	¾ in	70 - 100
	No. 4	45 - 70
	No. 40	10 - 40
	No. 200	0 - 20
Foundation Layer - Bottom	1,5 in	100
(subbase - course)	No. 4	45 - 100
	No. 40	10 - 50
	No. 200	0 - 20

OVERVIEW OF THE RESEARCH LOCATION

The road access from Palu City - Beteleme with distance 397 km is fully connected by road, the condition of the road is 100 percent paved with a road width of 7 meters and can be passed by two-wheeled and four-wheeled vehicles. Palu City and Beteleme can be reached by land for approximately 8 hours drive, while the distance from Tomata (km. 346+000), Beteleme (km. 397+000) is 50.94 km (Sk. Minister of PUPR No. 290/ktps/m/2015).

Figure 4: Map of North Morowali Regency, Central Sulawesi Province.

Figure 5: Location of Tomata – Beteleme.

Overview of the Subsoil Condition of Tomata - Beteleme

According to the Tomata formation, the Tomata – Beteleme subgrade is composed of a cross between sandstone, conglomerate, claystone and tuff, with lignite insertion. The sandstone is brownish-grey, gray to brown, fine-grained to coarse-grained gravel, well-layered in some places, there are layers of layers up to 30 cm thick, less dense to dense.

Also found is coarse-grained green sandstone composed almost entirely of ultramatic rock. Component conglomerates with a thickness of 10 cm, occasionally 30 cm are tightly bound by coarse brown sandstone. Claystone is gray, brownish to reddish brown which is limestone containing Mollusc Fossils.

Figure 6: Condition of the Tomata – Beteleme Road Which Is Heavily Damaged.

Tomata – Beteleme. Road

The Tomata - Beteleme road section is the National Cross East Sulawesi road section in Central Sulawesi. According to the Decree of the Minister of Public Works and Public Housing No. 248/KPTS/M/2015 the Tomata – Beteleme road section as a Primary-1 collector road (JKP-1) with a length of 50.94 km, which connects Central Sulawesi Province, South Sulawesi Province, and Southeast Sulawesi Province, by crossing the Regency Poso, North-Morowali Regency, and Morowali Regency. Prior to 2015, the Tomata – Beteleme road was one of the worst roads in Central Sulawesi Province. This road section suffered damage on average reaching 60 percent. The average road width is 4.50 m, the side channel is not functioning yet standard. The road damage is 50.70 km and it takes approximately 3.50 hours to travel by land.

RESEARCH METHOD

The sequence of the research is presented in Figure 7, which starts from the preliminary survey, data collection, manufacture of test objects and laboratory testing of the studied material, data analysis which ends with drawing conclusions and research recommendations.

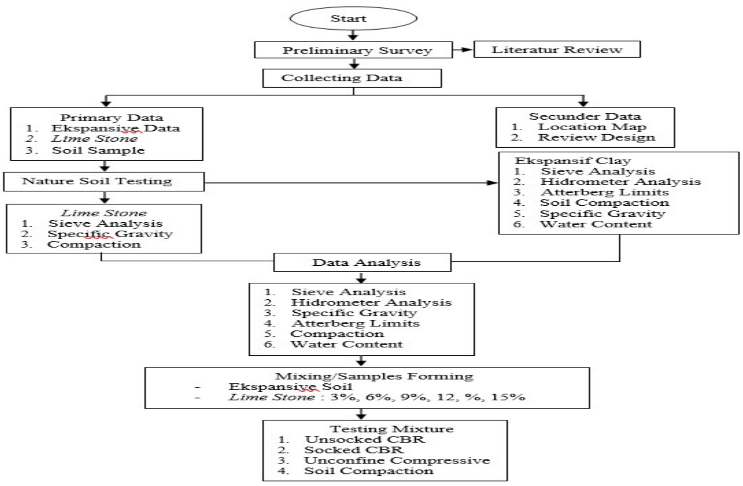

Figure 7: Research Flowchart.

Mix Planning

The research was conducted at the Soil Mechanics Laboratory, Faculty of Engineering, Tadulako University, including the following tests:

Original Land (Expansion) and Lime Stone

The original soil test consists of testing the specific gravity. Sieve analysis aims to obtain the joint distribution or percentage of grains of both fines aggregate and coarse aggregate. The Atterberg limits are generally expressed as a consistency index or water content limit, including the liquid limit and the plasticity limit. Liquid limit to determine the water content at the liquid limit conditions of the soil sample. The liquid limit is the water content limit at which a type of soil changes from a liquid state to a plastic state. The plastic limit is the water content limit where a type of soil changes from a plastic state to a semi-solid state, while for Lime Stone testing only specific gravity testing and sieve analysis are carried out.

Real Soil Mix (Expansion) with Lime Stone

Experimental testing of compaction of the original soil mixture with Lime Stone with variations of 3 %, 6 %, 9 %, 12 % and 15 % of the maximum dry weight of the original soil with optimum moisture content. For examination of the free compressive strength of the original soil and Lime Stone mixture with variations of 3 %, 6 %, 9 %, 12 % and 15 % of the maximum dry weight of the original soil. The curing time was 1, 7, 14, and 28 days for each variation of the addition of Lime Stone.

For the original soil test sample with Lime Stone in detail, can be seen as table below:

Table 3: Test Samples for Original Soil

No.	Testing	Number of Tests
1	Specific Gravity	2 Testing
2	Sieve Analysis Hydrometer	2 Testing
3	Liquid Limit + Plastic Limit	1 Testing

Table 4: Lime Stone Test Sample

No.	Testing
1	Specific Gravity
2	Sieve Analysis

Table 5: Original Soil Compaction Experiment Sample + Lime Stone

Testing	Mixed Variations
Mix Test Compression	
Modified	Vative Land
	Expansive Soil + Lime Stone 3 %
	Expansive Soil + Lime Stone 6 %
	Expansive Soil + Lime Stone 9 %
	Expansive Soil + Lime Stone 12 %
	Expansive Soil + Lime Stone 15 %

Table 6: CBR Test Samples Unsoaked Expansive Soil + Lime Stone

Testing	Mixed Variations
Mix Test CBR Compression	
Unsoaked CBR	Expansive Soil
	Expansive Soil + Lime Stone 3 %
	Expansive Soil + Lime Stone 6 %
	Expansive Soil + Lime Stone 9 %
	Expansive Soil + Lime Stone 12 %
	Expansive Soil + Lime Stone 15 %

Table 7: Expansive Soil + Lime Stone CBR Test Samples

Testing	Mixed Variation
Mix Test CBR Compression	
Soaked CBR	Expansive Soil
	Expansive Soil + Lime Stone 3 %
	Expansive Soil + Lime Stone 6 %
	Expansive Soil + Lime Stone 9 %
	Expansive Soil + Lime Stone 12 %
	Expansive Soil + Lime Stone 15 %

Table 8: Expansive Soil Unconfined Compressive Strength Test Sample + Lime Stone

Testing	Curing	Mixed Variations
Unconfined Compressive Strength	1 day	Expansive Soil + Lime Stone 3 %
		Expansive Soil + Lime Stone 6 %
		Expansive Soil + Lime Stone 9 %
		Expansive Soil + Lime Stone 12 %
		Expansive Soil + Lime Stone 15 %

Table 9: Expansive Soil Unconfined Compressive Strength Test Sample + Lime Stone

Testing	Curing	Mixed Variations
Unconfined Compressive Strength	7 days	Expansive Soil + Lime Stone 3 %
		Expansive Soil + Lime Stone 6 %
		Expansive Soil + Lime Stone 9 %
		Expansive Soil + Lime Stone 12 %
		Expansive Soil + Lime Stone 15 %

Table 10: Expansive Soil Unconfined Compressive Strength Test Sample + Lime Stone

Testing	Curing	Mixed Variations
Strong Check Press Free	14 days	Expansive Soil + Lime Stone 3 %
		Expansive Soil + Lime Stone 6 %
		Expansive Soil + Lime Stone 9 %
		Expansive Soil + Lime Stone 12 %
		Expansive Soil + Lime Stone 15 %

Table 11: Expansive Soil Unconfined Compressive Strength Test Sample + Lime Stone

Testing	Curing	Mixed Variations
Unconfined Compressive Strength	28 days	Expansive Soil + Lime Stone 3 %
		Expansive Soil + Lime Stone 6 %
		Expansive Soil + Lime Stone 9 %
		Expansive Soil + Lime Stone 12 %
		Expansive Soil + Lime Stone 15 %

RESEARCH RESULTS AND DISCUSSIONS

Soil Physical Characteristics

Physical characteristics of the soil are tested to determine the type of soil to be compacted. From the results of testing the physical properties of the soil obtained data as shown in Table 12.

Table 12: Results of Testing for Physical Properties of Soil

No	Test Types		Test Result
1	Expansive soil grain size analysis	Pass No.200	40.62 %
2	Granule size analysis *lime stone*	Retained No.200	95.84 %
3	The average density of the expansive soil		2.778
4	Specific gravity *lime stone*		2.353
5	Liquid Limit (LL)		41.22 %
6	Plastic Limit (PL)		26.40 %
7	Soil Water Content		13.77 %

Soil Grain Analysis Test

Soil grain analysis tests carried out were expansive soil sieve analysis and lime stone tests. Sieve analysis to determine the distribution of granules through the No. 10 sieve and retained No. 200 using a standard sieve. The test results of the expansive soil sieve analysis are in Table 13, while the results of the lime stone sieve analysis are in Table 13.

From Table 13 the results of the expansive soil sieve analysis test can be seen that the percentage of grains retained by the No. 200 sieve is 59.38 % and is included in the sand with 50 % of the coarse fraction that passes the No. 4 sieve, which is 100 % of the grains that pass.

From Table 13 the results of the lime stone sieve analysis test can be seen that the percentage of grains retained by the No. 200 sieve is 95.84 % and is included in the division of coarse grained soil (sand) with 50 % of the grains retained by the No. 200 sieve.

Table 13: Expansive Soil Sieve Analysis Test Results

Filter No.	Sieve Diameter Hole (mm)	Retained Weight (gr)	Retained Cumulatife (gr)	% Retained	% Finer Passing
2"	50.80	0.00	0.00	0.00	100.00
1"	25.00	0.00	0.00	0.00	100.00
3/4"	19.00	0.00	0.00	0.00	100.00
3/8"	9.500	0.00	0.00	0.00	100.00
4	4.750	0.00	0.00	0.00	100.00
10	2.000	3.00	3.00	0.19	99.81
20	0.850	16.00	19.00	1.20	98.80
40	0.420	168.00	187.00	11.76	88.24
80	0.180	658.00	845.00	53.15	46.85
100	0.150	37.00	882.00	55.48	44.52
200	0.075	62.00	944.00	59.38	40.62
PAN		**645.87**	**1589.87**	**100.00**	**0**

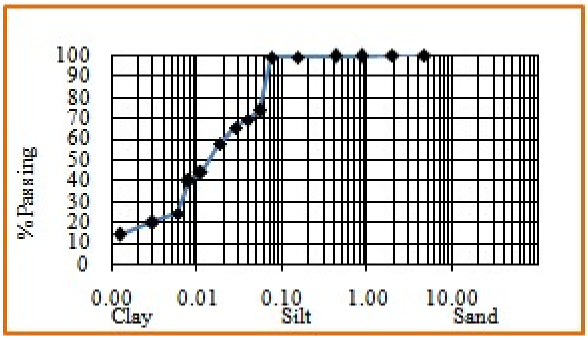

Figure 8: Expansive Soil Sieve Analysis

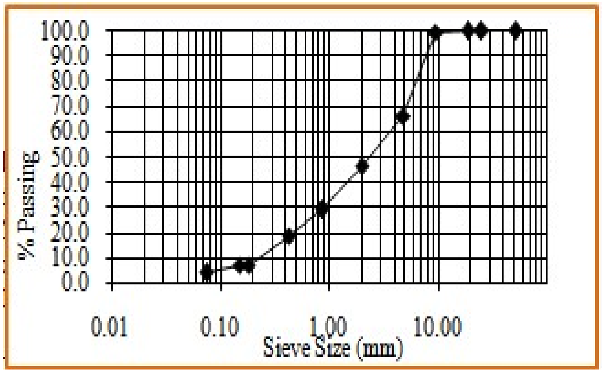

Figure 9: Sieve Analysis of Lime Stone Sieve

Table 14: Lime Stone Sieve Analysis Test Results

Filter No.	Sieve Diameter Hole (mm)	Weight Stuck (gr)	Cumulatife Stuck (gr)	% Stuck	% Finer Pass
2"	50.80	0.00	0.00	0.00	100.00
1"	25.00	0.00	0.00	0.00	100.00
3/4"	19.00	0.00	0.00	0.00	100.00
3/8"	9.500	10.02	10.02	0.65	99.35
4	4.750	508.82	518.84	33.85	66.15
10	2.000	303.25	822.09	53.64	46.36
20	0.850	261.25	1083.34	70.68	29.32
40	0.420	160.92	1244.26	81.18	18.82
80	0.180	176.45	1420.71	92.69	7.31
100	0.150	3.66	1424.37	92.93	7.07
200	0.075	44.61	1468.98	95.84	4.16
PAN		63.73	1532.71	100.00	0

Hydrometer Analysis

Hydrometer analysis is a method for calculating the grain size distribution of soil based on the sedimentation of the soil in water, sometimes also called the sedimentation test. This hydrometer analysis aims to determine the distribution of fine-grained soil grains. The results of the expansive soil hydrometer analysis test can be seen in Figure 10.

From the appearance of the particle size distribution of the soil above, it can be seen that quantitatively Silt (silt) dominates the proportion of this soil sample as much as 84.92 %, followed by Clay (Clay) as much as 13.93 % and Sand Fraction (Sand) as much as 1.14 %.

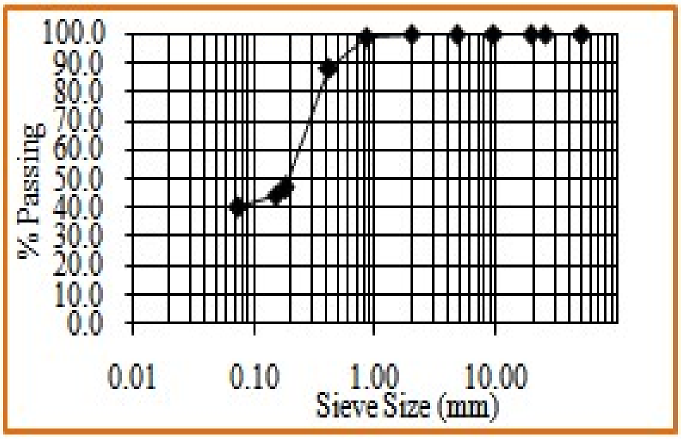

Figure 10: Original Soil Grain Size Distribution

Atterberg Consistency Test

Liquid Limit Test (LL)

The LL test aims to determine the liquid limit of the soil. LL is defined as the water content of the soil at the liquid limit state and the plastic limit (water content at the condition of the soil transition from plastic to liquid) or when tested using a Cassagrande tool, which is separated by 3 mm and reunited by 0.5 inch on the 25th blow. The liquid limit is used to determine the size of the grains passing the No. 40 sieve.

Plastic Limit Test (PL)

The PL test is defined as the water content at the position between the plastic and semi-solid regions, which is the percentage of water content at which the soil with a cylinder diameter of 3.2 mm begins to crack when rolled. Plasticity Index (PI) is the difference between the liquid limit and the plastic limit which is the water content interval where the soil is still plastic. The results of testing the liquid limit and plastic limit of the expansive soil can be seen in Figure 11.

The results of the liquid limit test as shown in Figure 11 show that the smaller the value of the plasticity index (PI) of the soil, the less the potential for development. If the value of the Plasticity Index (PI) is greater, the number of clay particles in the soil will increase. If the Plasticity Index (PI) is low in silt soil, a slight reduction in the water content will result in the soil becoming dry and vice versa if the water content increases slightly, the soil becomes liquid.

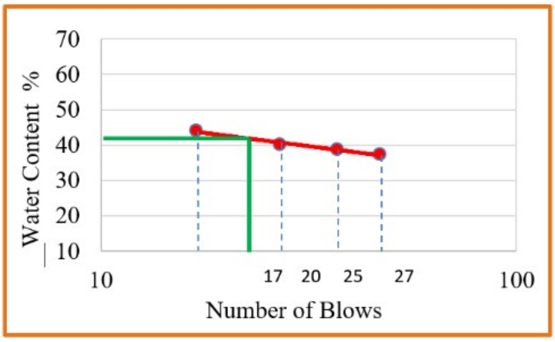

Figure 11: Liquid Limit and Plastic Limit Test Results

Table 15

LL	PL	PI = LL - PL
41.22	26.40	14.83

Testing Soil Moisture

Soil water content testing aims to determine the water content in the test soil. Moisture content is the ratio between the weight of water contained in the soil with the weight of dry soil grains expressed in percent (%). The results of testing the soil water content can be seen in Table 16.

From the results of testing the soil water content, the average soil water content value is 13.77 %.

Table 16: Soil Moisture Test Results

Unit Moisture Test		Water Content	
		A	B
Grail + Wet Ground	gram	42.52	36.58
Cup + Dry Soil	gram	38.32	33.40
Water Weight	gram	4.20	3.18
Cup Weight	gram	9.06	9.28
Dry Soil Weight	gram	29.26	24.12
Water Content	%	14.35	13.18
Average Water Content	%	13.77	

Soil Density Test

Soil density testing aims to determine the specific gravity of a soil sample. The specific gravity of the soil is the ratio of the weight of the soil grains to the weight of distilled water in the air with the same weight at a certain temperature, usually taken at a temperature of 27°C. The results of the expansive soil density test can be seen in Table 17 and the specific gravity of lime stone soil can be seen in Table 18.

Table 17: Expansive Soil Density Test Results

Nomor test		Sampel 1	
Nomor Picnometer		A	B
Berat picnometer (W1)	gram	70.560	69.190
Berat picnometer + Contoh (W2)	gram	89.780	82.880
Berat Picnometer + Contoh + Air (W3)	gram	187.720	183.180
Berat Picnometer + Air Pada t 0 (W4)	gram	175.400	174.430
Koreksi Suhu	gram	175.207	174.238
Suhu	°C	29.000	29.000
Berat Contoh, Wt = W2 - W1	gram	19.220	13.690
W5 = W2 - W1 + W4	gram	194.620	188.120
Isi Contoh tanah, V = W5 - W3	cc	6.900	4.940
Berat Jenis Contoh, Gs = Wt / V		2.786	2.771
Berat Jenis Rata-rata (Gs)		2.778	

Table 18: Test Results for Lime Stone Soil Density

Nomor test		Sampel 1	
Nomor Picnometer		A	B
Berat picnometer (W1)	gram	70.610	69.250
Berat picnometer + Contoh (W2)	gram	121.590	113.400
Berat Picnometer + Contoh + Air (W3)	gram	203.620	199.880
Berat Picnometer + Air Pada t 0 (W4)	gram	174.600	174.240
Koreksi Suhu	gram	174.408	174.048
Suhu	°C	29.000	29.000
Berat Contoh , Wt = W2 - W1	gram	50.980	44.150
W5 = W2 - W1 + W4	gram	225.580	218.390
Isi Contoh tanah, V = W5 - W3	cc	21.960	18.510
Berat Jenis Contoh, Gs = Wt / V		2.321	2.385
Berat Jenis Rata-rata (Gs)		**2.353**	

Mechanical Characteristics of Soil

Soil Compaction Test(Modified Proctor Test)

Compaction is the event of increasing dry volume weight by dynamic loads. Due to dynamic loads, the soil grains are closer to each other as a result of reduced air voids. The test results of soil compaction for each grade of Lime Stone mixture can be seen in Table 19. To obtain the correlation between the maximum dry volume weight relationship and the optimum moisture content in the mixture variation, it is shown in Figure 12.

Table 19: Mixed Compaction Test Results Table 5.7 Mixed Compaction Test Results

Mixed Variations	Wopt (%)	ɣd
Expansive Soil0 %	14.99 %	1.383
Expansive Soil+ Lime Stone 3 %	15.87 %	1.309
Expansive Soil+ Lime Stone 6 %	14.99 %	1.383
Expansive Soil+ Lime Stone 9 %	11.19 %	1.401
Expansive Soil+ Lime Stone 12 %	6.38 %	1.425
Expansive Soil+ Lime Stone 15 %	5.45 %	1.458

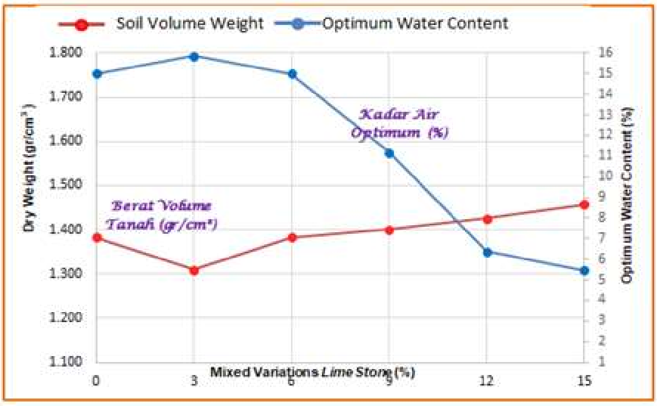

Figure 12: Effect of Soil Volume Weight and Optimum Moisture Content of Lime Stone Mix.

Unconfined Compressive Strength Test

This test is to determine the parameters of the shear strength of the soil. The axial stress applied over the test object is gradually increased until the test object collapses. The results of the free compressive strength test are shown in Table 20. The increase in the value of the free compressive strength (qu) can be seen in Figure 13.

From the experimental results of the free compressive strength of an expansive mixture of lime stone in Figure 13, it can be seen that in general the lime stone material has a great influence on the increase in the compressive strength of the soil. However, the curing time always affects the compressive strength of the soil. At the percentage of lime stone 3 %, 6 %, 9 %, and 12 % the compressive strength of the soil showed a consistent increase with increasing curing time. The peak of the increase in compressive strength was the addition of 15 % lime stone with 28 days curing. This is caused by the cementation phase and the pozzolanic reaction in lime stone, where the reaction between Silica and Alumina in the soil is expansive. Lime Stone with water will produce Calcium Hydrate Silica (CSH) compounds, where this reaction forms granules (binders) in the soil with a slow time, so that the soil becomes dense and hard.

Table 20: Unconfined Compressive Strength Test Results

Mixed Variety	1 Day	7 Day	14 Day	28 Day
	qu (kg/m²)			
Expansive Land + *Lime Stone 3%*	0,264	0,276	0,338	0,547
Expansive Land + *Lime Stone 6%*	0,306	0,307	0,384	0,559
Expansive Land + *Lime Stone 9%*	0,320	0,308	0,429	0,670
Expansive Land + *Lime Stone 12%*	0,333	0,450	0,443	0,740
Expansive Land + *Lime Stone 15%*	0,380	0,533	0,593	0,911

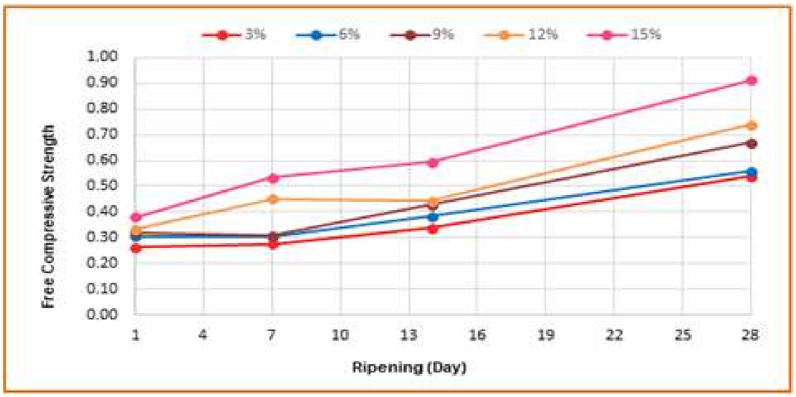

Figure 13: Correlation between Unconfined Compressive Strength Value and Curing Time for Lime Stone Mixture Variations

Laboratory CBR Testing (California Bearing Ratio)

CBR testing aims to determine the CBR value of soil and soil aggregate mixture compacted in the laboratory at a certain water content to be used for Sub Base (fill) or Sub Grade (subgrade) road construction. The CBR test in this study was divided into two parts, namely CBR without immersion and CBR immersion, using different variations of Lime Stone mixtures.

Unsoaked CBR

Figure 14 shows that the original CBR Unsoaked soil of 12.31 % tends to increase with a variation of 3 % lime stone by 17.32 %. The addition of the lime stone mixture variation resulted in an increase in the carrying capacity of the CBR relatively constant at a percentage of 3 % to 15 % ranging from 17.32 % - 26.92 %. The highest/optimal increase in CBR value without immersion was when the lime stone percentage was 15 % at 26.92 %.

Table 21: Unsoaked CBR Test Results

Mixed Variations (%)	CBR Value (%)
0	12.31
3	17.32
6	20.67
9	20.93
12	21.70
15	26.92

CBR Soaked

The results of the CBR Soaked test with 56 collisions in Figure 14 show that the original CBR Soaked soil of 5.97 % tends to increase with a mixture of 3 % lime stone variations of 11.24 %. With the addition of the percentage of lime stone mixture variation, it shows a linear increasing trend of Soaked CBR value.

Table 22: Results of Soaked CBR Testing

Mixed Variations (%)	CBR Value (%)
0	5.97
3	11.24
6	11.94
9	13.25
12	14.04
15	15.27

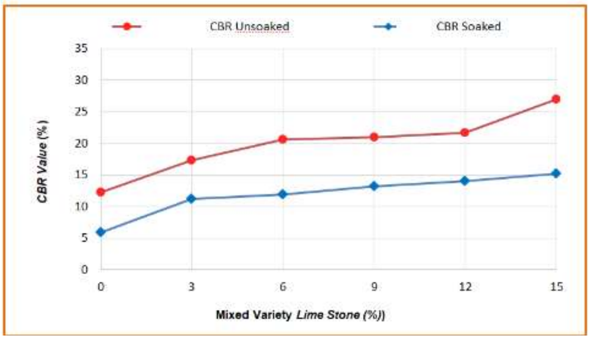

Figure 14: Relationship of CBR Value to Lime Stone Variation

CONCLUSIONS AND SUGGESTIONS

Conclusions

- From the results of the Unsoaked CBR test, 56 collisions showed that the addition of lime stone (domato) 3 %, 6 %, 9 %, 12 % and 15 % can increase the CBR value by 17.32 %, 20.67 %, 20.93 %, 21.70 % and 26.92 % of original soil CBR value.
- From the results of the CBR Soaked test with 56 collisions, it shows that the addition of lime stone (domato) 3 %, 6 %, 9 %, 12 % and 15 % can increase the CBR value by 11.24 %, 11.94 %, 13.25 %, 14.04 % and 15.27 % of original soil CBR value.

- From the results of Lyne Analysis of Energy Dispersive X-Ray Spectroscopy (EDS) expansive soil from Ensa Village, Tomata District, North Morowali Regency with a chemical content dominated by Silicate (Si) 25.64 % and Aluminate (Al) 13.43 % with a ratio of 2 :1 the original soil sample can be categorized as expansive soil.
- For variations of expansive soil mixture + lime stone 15 % optimum moisture content is 5.45 % with a maximum dry weight of 1.458gr/cm^3 from the results of Lyne Analysis EDS with the dominant chemical content of Silicate (Si) 22.37 % and Aluminate (Al) 14,28 %, while the other elements are only a small part.

Suggestions

Based on the research that has been done, the following can be suggested:

- The process of mixing expansive soil variations with lime stone must be considered completely evenly so that a more even/homogeneous mixture is obtained.
- To increase the carrying capacity of the soil in expansive clay, stabilization with chemicals such as lime and resin can be carried out.
- It is necessary to carry out testing with different soil types.

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