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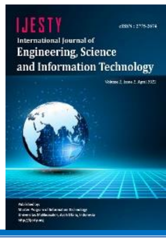

The Effect Of Limestone and Fly on Clay Stabilization of CBR and Soil Compressive Strength

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Abstract

The subgrade is the road access construction project must have a firm soil bearing capacity to withstand its load. Clay soil has high water content and expands quickly. Various ways have been done to overcome it; one is improving the original soil properties using the stabilization method. The research was conducted to stabilize expansive clay soil using fly ash and limestone with a percentage of fly ash of 5%, 10%, 15%, 20% fly ash, and 25% limestone. Existing soil was used from a good pad construction project in Ujung Pangkah, Gresik, East Java. The tests carried out are specific gravity, Atterberg, compaction, CBR, and UCT tests. The CBR test was conducted to determine the appropriate CBR value to support DDT. The compressive strength of the soil was tested using the UCT test. The study results of the effect of fly ash and limestone are an increase in the dry weight of the earth and a decrease in soil water content. The rise in CBR and maximum soil compressive strength with a mixture variation of 20% fly ash + 25% limestone, Qu is 2.98 kg/cm 2, and CBR is 10.56%. This is due to a decrease in the water content, thereby increasing the dry weight of the soil.

Keywords: *Clay Soil Stabilization, CBR, Soil Compressive Strength.*

1. Introduction

Road access is required for mobilization on civil construction projects [1]. Every road construction requires a subgrade with a soil-bearing capacity that can withstand the dynamic load of the road. The subgrade is essential because it supports the entire traffic and construction load [2] [3].

The access development project in the excellent pad construction project located on the coast of Ujung Pangkah, Gresik, East Java, is a former pond area. A soil investigation test was carried out at 12 borehole points at the project site. The Dynamic Cone Penetrometer (DCP) test on the top of the soil layer shows varying CBR results [4] [5]. The maximum CBR value at borehole 8 is 5.09%, and the lowest CBR value at borehole 2 is 1.09%. The results of the soil characteristics test (Atterberg limit) showed that the original soil had LL > 50%. As demonstrated from soil testing results, the soil layer is dominated by clay soil [6]. Clay soil is soil with a high shrinkage value; the water content significantly affects the physical and mechanical behavior of the soil. Under these conditions, soil stabilization is necessary to increase the compressive strength of the soil and the CBR of the existing soil [7] [8].

Limestone can be used as a stabilization admixture. Limestone is a sedimentary rock composed of calcite and aragonite, two different calcium carbonate variants ($CaCO_3$). According to Ibrahim's research (2014), the addition of 18% limestone to the existing expansive clay soil with a drying time of 14 days can increase the compressive strength of the earth. Besides limestone, the material used as a mixture is fly ash. According to Ernawan's research (2018), Silica Oxide (SiO_2) content in fly ash can bind water particles in clay soil [9] [10].

Referring to the background of the problem, this study observes the effect of adding limestone, fly ash, and a mixture of fly ash and limestone to the CBR value and compressive strength of the soil [11] [12].

2. Method

This research was conducted using an experimental method carried out in the laboratory. This study uses tests based on Standard Nasional Indonesia (SNI) and the American Society for Testing Materials (ASTM) [13] [14] [15]. Existing soil was excavated from a good pad construction project in Ujung Pangkah, Gresik, East Java, using deep bore methode by an earth auger machine. Initial tests were carried out to determine the characteristics of the existing soil sample by specific gravity, Atterberg limit test, water content test, compaction test, and sieve analysis [16] [17].

After the soil sample is classified, the test specimen is made with a predetermined percentage. The model consists of existing soil and mixtures, fly ash, and limestone [18]. Furthermore, the density test, CBR of a laboratory-compacted soil test [19], and Unconfined Compressive Strength Test (UCT) were compared as compawchart for this study, as shown in Figure 1 [20].

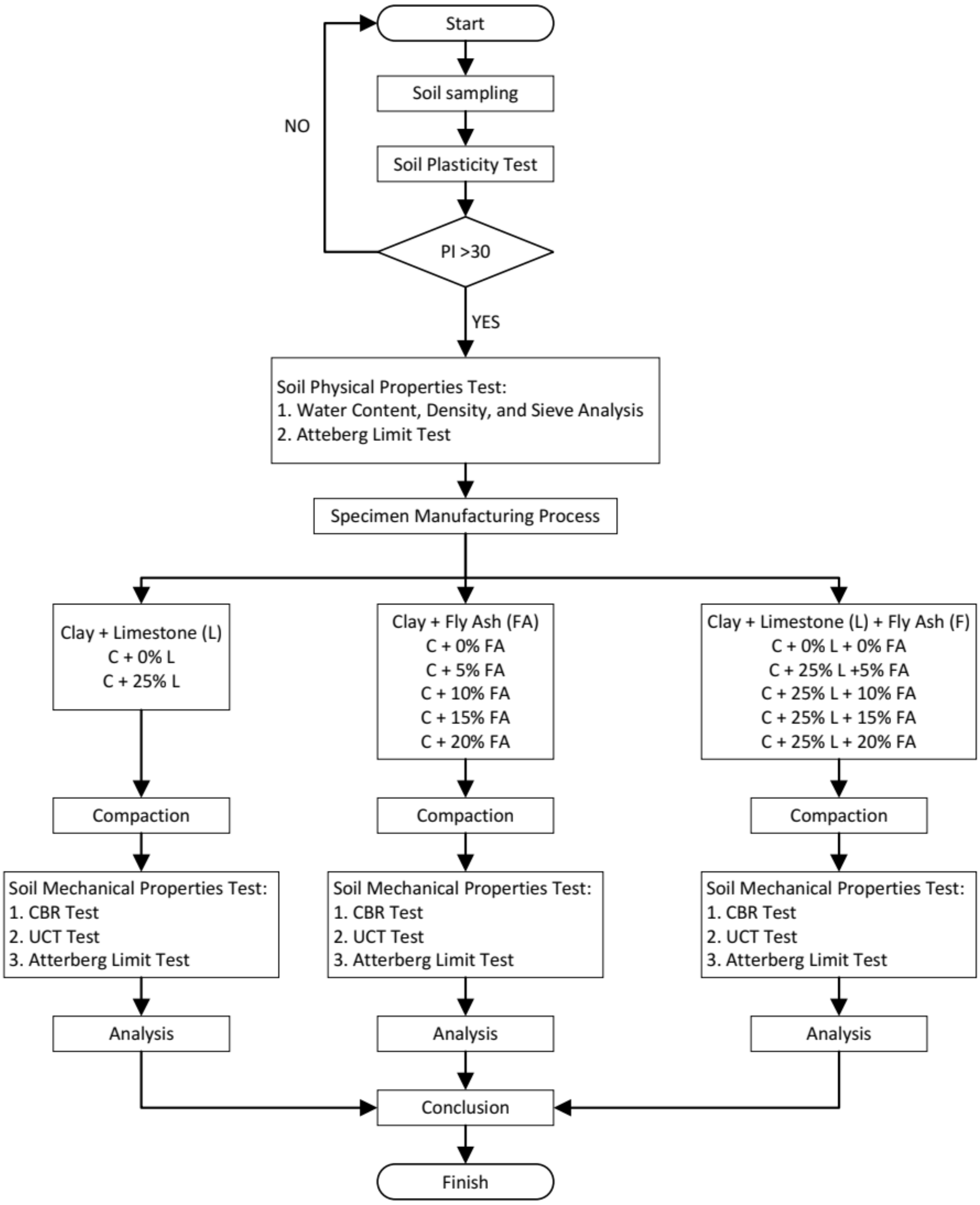


Fig 1. Flowchart

3. Result and Discussion

Table 1. Existing Soil Test Results

No	Description	Test Result	Remarks
1	Water Content	30.85%	
2	Existing Soil Density	30.85%	
3	Specific Gravity	2,701	Inorganic Clay
4	Liquid Limit	129.40 %,	The high degree of plasticity
5	Plastic Limit	46.10%	
6	Plasticity Index	83.80%	Very high Plasticity Index (PI)
7	CBR Tanah Asli	5.07%	Requirement CBR > 6%, CBR test results do not support DDT
8	No. 200 Sieve Passing Percent	57.40%	
9	Soil Classification (USCS)	CH	Fat clay
10	Soil Classification (AASHTO)	A-7-5	

Based on the Atterberg limit test results, the existing soil in Ujung Pangkah has a Plastic Index (PI) value of 83.80% with a high liquid limit (LL) of 129.40%. The LL and PI results of the existing soil based on AASHTO (Figure 2) are located in A-7-5, so the classification of the existing soil is classified as "CH" (fat clay) according to USCS (Figure 3).

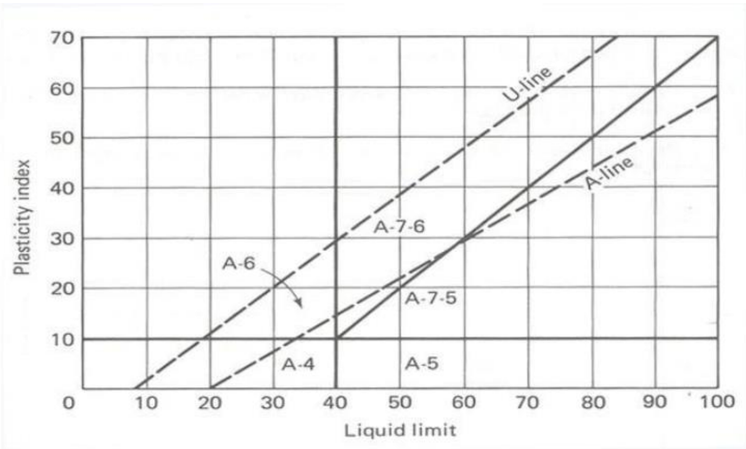


Fig 2. Classification of Soil According to AASHTO

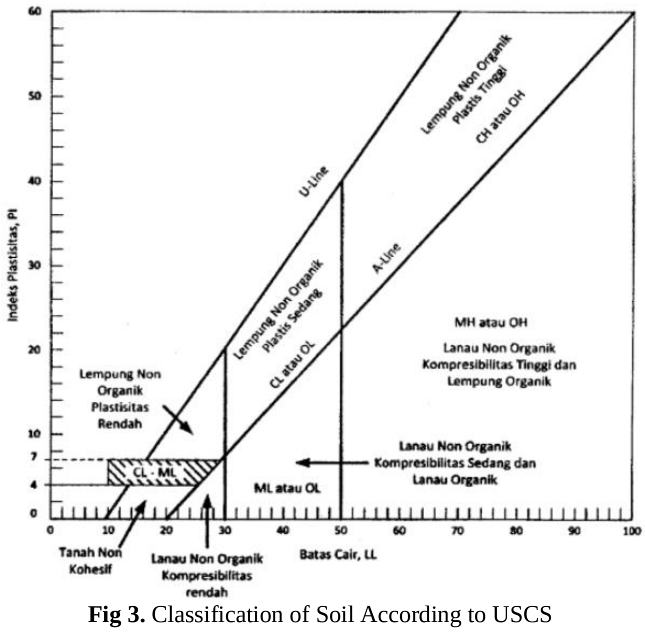


Fig 3. Classification of Soil According to USCS

Table 2. Compacted Soil Dry Density

Samples	Dry Density (kN/m3)
Existing Soil + 5% Fly Ash	13,88
Existing Soil + 10% Fly Ash	13,94
Existing Soil + 15% Fly Ash	14,04
Existing Soil + 20% Fly Ash	14,07
Existing Soil + 25% Limestone	14,06
Existing Soil + 5% Fly Ash + 25% Limestone	14,13
Existing Soil + 10% Fly Ash + 25% Limestone	14,23
Existing Soil + 15% Fly Ash + 25% Limestone	14,22
Existing Soil + 20% Fly Ash + 25% Limestone	14,34

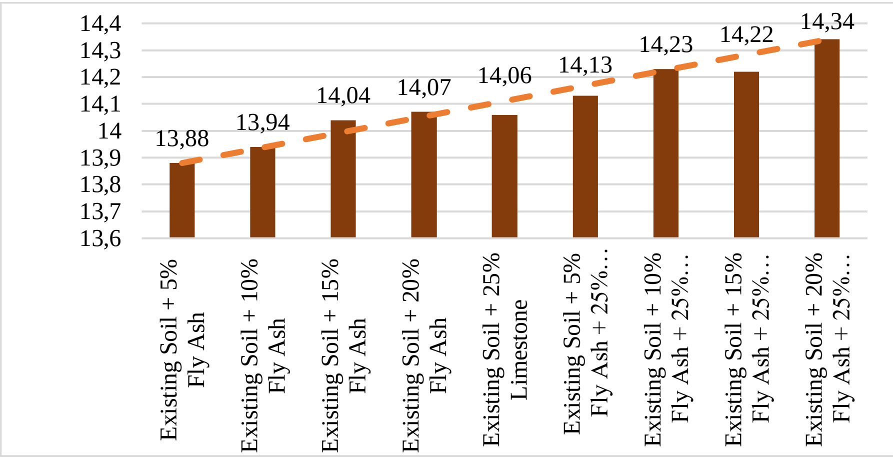


Fig 4. Compacted Soil Dry Density Comparison

The composition of the mixture in the compaction of the test soil sample is soil with a variety of 25% limestone, and the percentage of fly ash is 5%, 10%, 15%, 20%, and 25%. The dry density test results are shown in Figure 3. The maximum dry density is found in the addition of 20% Fly Ash + 25% Limestone. This is due to fly ash, which has pozzolanic and self-cementing properties that can bind calcium hydroxide and limestone to the soil and reduce the water content in the clay soil. With the addition of 25% limestone, the dry density of the soil increased to 14.06 kN/m3. This is due to the mineral content of limestone, namely calcium hydroxide ($Ca(OH)_2$), calcium oxide (CaO), and calcium carbonate ($CaCO_3$), which can bind clay minerals and fill cavities in clay particles.

Table 3. CBR-Laboratory Compacted Soil Test Results

Samples	CBR 0,1”	CBR 0,2”	Swelling
Existing Soil + 5% Fly Ash	5,89	5,41	0,61
Existing Soil + 10% Fly Ash	8,42	7,65	0,52
Existing Soil + 15% Fly Ash	10,03	9,85	0,44
Existing Soil + 20% Fly Ash	10,33	10	0,37
Existing Soil + 25% Limestone	10,03	9,85	0,61
Existing Soil + 5% Fly Ash + 25% Limestone	10,33	10,16	0,5
Existing Soil + 10% Fly Ash + 25% Limestone	10,26	9,95	0,42
Existing Soil + 15% Fly Ash + 25% Limestone	10,72	10,26	0,37
Existing Soil + 20% Fly Ash + 25% Limestone	10,56	10,1	0,3

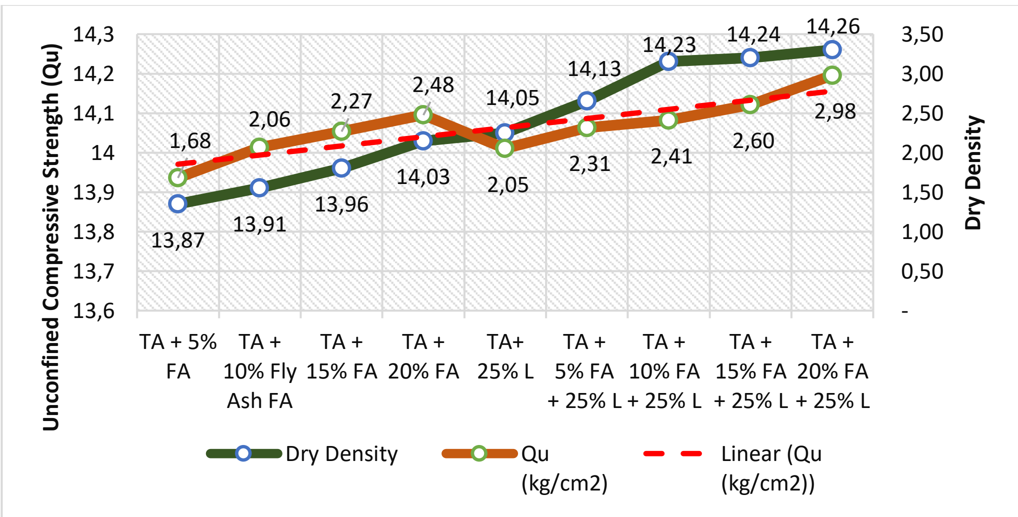
Fig 4. CBR-Swelling Results Comparison

The CBR value increases with the increase in the dry density value. The addition of 20% Fly Ash resulted in a rise in CBR to 10.33 and an increase in dry density to 14.07 kN/m3. When the existing soil is mixed with 25% limestone, the CBR value decreases by 0.02% to 10.03%, with a dry density of 14.03 kN/m3. Mixing the existing soil with two stabilizers also increases the CBR value, as adding 20% Fly Ash + 25% limestone increases the CBR to 10.56%.

Based on the results of the CBR test, changes in the CBR value were inversely proportional to changes in the swelling value. Mixing the existing soil with 20% Fly Ash + 25% Limestone causes the swelling value of the earth to decrease to 0.3. As the CBR increases, the swelling of the soil subsides.

Table 4. UCT Test Result

Samples	Qu (kg/cm^2)	Cu (kg/cm^2)
Existing Soil + 5% Fly Ash	1,68	0,84
Existing Soil + 10% Fly Ash	2,06	1,03
Existing Soil + 15% Fly Ash	2,27	1,13
Existing Soil + 20% Fly Ash	2,48	1,24
Existing Soil + 25% Limestone	2,05	1,03
Existing Soil + 5% Fly Ash + 25% Limestone	2,31	1,16
Existing Soil + 10% Fly Ash + 25% Limestone	2,42	1,21
Existing Soil + 15% Fly Ash + 25% Limestone	2,60	1,30
Existing Soil + 20% Fly Ash + 25% Limestone	2,98	1,49



Based on the results of the UCT test, it is known that there is an increase in the compressive strength of the soil, along with an increase in the percentage of fly ash and limestone. The maximum expansion of unconfined compressive strength (Qu) occurred with the addition of 20% Fly Ash + 25% Limestone to 2.98 kg/cm^2. Based on Table 5. Soil Classification Based on Unconfined Compressive Strength, compressive strength results are between stiff (Qu: 1.68 kg/m2) and very stiff soil (Qu: 2.98 kg/m2). In the graph of UCT results, it is known that the value of Qu is directly proportional to the dry density. So, with the maximum Qu value found in the addition of 20% fly ash + 25% limestone, it can be assumed that the composition can increase the compressive strength of the existing soil optimally.

Table 5. Soil Classification Based on Unconfined Compressive Strength

Soil Classification	UCT Result
Very Soft	< 0,25 kg/cm^2
Soft	0,25 – 0,50 kg/cm^2
Firm / Medium	0,50 – 1,00 kg/cm^2
Stiff	1,00 – 2,00 kg/cm^2
Very Stiff	2,00 – 4,00 kg/cm^2
Hard	> 4,00 kg/cm^2

The increase in soil compressive strength was due to the reaction of lime and fly ash minerals, which could bind potassium hydroxide particles from the clay to increase the compressive strength of the existing soil and the bearing capacity of the subgrade soil.

4. Conclusion

The conclusions of this study are:

1. The addition of a mixture of limestone to the existing soil by 25%, the results of the laboratory CBR test (unsoaked) obtained an increase in the CBR of the earth by 74.73% compared to the existing soil to 10.03% at 0.1" penetration and 9.85% at 0.2" penetration with swelling of 0.61%. Based on the results of UCT, the compressive strength of the soil (Qu) increased to 2.05 kg/cm2, and the value of undrained soil cohesion (Cu) was 1.03 kg/cm2.
2. In the Fly Ash test material, with a percentage of 5%, 10%, 15%, and 20%, the maximum value of CBR is in the addition of 20% fly ash with a discount of 10.33%, there is an increase in the CBR of the existing soil by 79.9%. The UCT test found that the soil's unconfined compressive strength (Qu) was 2.48 kg/cm2 and the undrained soil cohesion (Cu) was 1.24 kg/cm2. It can be concluded that the addition of fly ash affects the CBR value and the compressive strength of the soil.
3. The CBR and UCS tests were carried out using a mixture of existing soil and limestone + fly ash as additives. The maximum value of CBR-laboratory compacted soil test results (unsoaked) was found in the added material of 25% limestone + 20% fly ash of 10.72% at 0.1" penetration and 10.26% at 0.2" penetration. In the UCT test, the soil unconfined compressive strength (Qu) was 2.98 kg/cm2, and the undrained soil cohesion (Cu) was 1.4924 kg/cm2. The addition of limestone and fly ash can increase the dry density and cause an increase in the CBR of the soil and the value of the compressive strength of the earth.
4. The addition of fly ash and limestone to clay soil can increase the CBR and compressive strength of the ground due to the presence of fly ash and limestone minerals that can bind water particles.

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