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The Application of Active Lime & Cement as Soil Stabilization Materials

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ABSTRACT: This paper is elaborating the application of active lime and cement as soil stabilization material, especially in remoulded residual soil. The main focus of this paper is measuring the mixing effects of original soil + active lime + cement in soil strength and workability perspective. The original soil, which is used as filing materials, consists of sandy clay (high water content) with gravel. The active lime is supposed to have reaction with the clay material and also to reduce the water content, while cement is supposed to have reaction with sand/granular material. Mixing formula for the materials are: original soil (Sandy silt/clay with sand & gravel) + 10% Active lime + 3% Cement. The criterion for active lime is it has more than 90% of CaO which will react with the clay minerals such as Sodium or Potasium.
Keywords: Active lime, cement, clay, sand, stabilization**.**

1. PREFACE

Weather condition in mountainous area is quite unpredictable. The morning sky is clear, but heavy rain could come suddenly in the noon, and can last until evening. This event can happened even between April to September in the same year, when normally considered as dry season. Obviously this case was a disruption for the construction works, which has tight schedule. The original soil, that'll be used as filling materials, is always wet due to the heavy rain and couldn't be compacted by hand or Vibro-Compactor. Several methods have been proposed to overcome this issue, such as;

1. Importing granular material or red clay
2. Waiting the original soil to drained naturally
3. Speeding up the drying process by mixing the original soil with something that makes it quickly dry and well compacted.

The last afore mentioned method has been chosen, based on consideration of the weather, schedule and cost. The Original material is the residual soil where is located at the mountainous area (+1410 MASL) and has characteristic as follows:

Soil Description	: Sandy Silt
USCS Chart	: MH
Specific Gravity (GS)	: 2.59
Wet Unit Weight (γm)	: 1.34 t/m^3
Dry Unit Weight (γd)	: 0.58 t/m^3
Water Content (ωn)	: 131%
Liquid Limit (LL)	: 157.3%
Plastic Limit (PL)	: 46.75
Plasticity Index (PI)	: 110.6
Passing no.200	: 66%

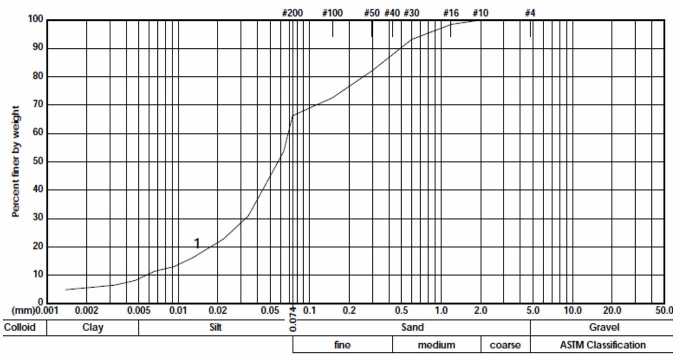

Figure 1.1 Grain Size Distribution
(source: PT. SOILENS)

To check the performance of original soil if being compacted, the original soil also was tested using standard proctor test as follow:

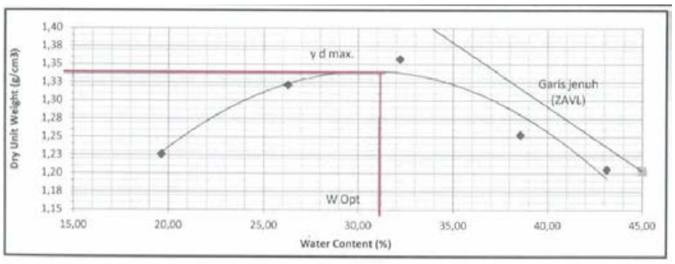

Figure 1.2 Original Soil Compaction Curve
(Source: BPJN 3 Padang Soil Lab)
Maximum Optimum Moisture Content (OMC): 31%
Maximum Dry Unit Weight (γ_d): 1.34 t/m^3

As mentioned in abstract section above, the active lime contains CaO more than 90% and was made of limestone which is burnt in the +1000°C stove. After burning process in stove, the burned limestone become active lime and has different characteristic from its original form as follows:

- Chemical compostition:
  1. Minimum CaO and MgO (%): 90
  2. Maximum CO_2 (%): 5
  3. Maximum water content (%): 5
- Physical properties:
  1. 100% passing 1" sieve.
  2. Unit weight (kN/m^3): 13

The active lime-soil reaction can be explained as follow; active lime addition in to the soil gives the calcium (Ca2+) and magnesium (Mg2+) to the soil. These ions tend to change the existing ions in the soil such as sodium (Na+) or potasium (K+). This changing will reduces the plasticity index significantly and also adsorbs the water which indicates the chemical reaction between lime & soil. Beside reducing the plasticity index and water content, the grain size distribution also changed. The new grain size, which is comprises of slightly cemented clay aggregate, mostly floculated and become to sand size particle.

2. METHODOLOGY

Several samples of original soils, active lime and cement were prepared prior to mixing and testing in laboratory. These materials have its percentage composition (By weight) in the mixing process based on its particle size distribution. The percentage of active lime is 10% and for cement is 3%. Before mixing process, the original soil, active lime & cement have been separated and measured by weight based on defined percentage. The active lime was broken by hammer until meet the grain size criteria (max 5 cm). After breakage of active lime; original soil, water & cement with certain percentage were poured together in bucket and mixed manually by hand (with gloves). The mixing process has been taken carefully since the active lime is very reactive and feels so hot in the hand. The mixing process stopped after the materials mixed well and could be indicated by colour and texture changing. The mixed materials were put into the closed bucket and left for 1 day for curing time. After curing process, the mixed materials are ready to be tested. There are several samples of mixed material with different water content added.

The laboratory tests for mixed materials are:

1. Modified Proctor
2. UU Triaxial
3. Unsoaked & Soaked CBR Laboratory
4. Consolidation
5. Grain Size Distribution

3. RESULT AND ANALYSIS

3.1 Modified Proctor Test

The first test for mixed materials was Modified Proctor Test, because the maximum dry density and optimum moisture content was obtained by this test.

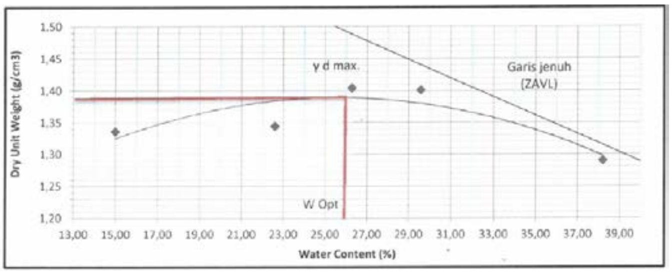

Figure 3.1 Modified Proctor Test of Mixed Material
(Source: BPJN 3 Padang Soil Lab Test)
Maximum γdry: 1.39 t/m^3
Optimum Moisture Content (OMC): 26%.

After mixing process between original soil, lime & cement, we can see the maximum dry unit weight increased from 1.34 t/m^3 become 1.39 t/m^3, and the optimum moisture content also changed from 31% become to 26%.

3.2 UU Triaxial Test

After γdry and OMC was obtained, a constitutive mixed soil sample could be formed and tested in UU Triaxial apparatus.

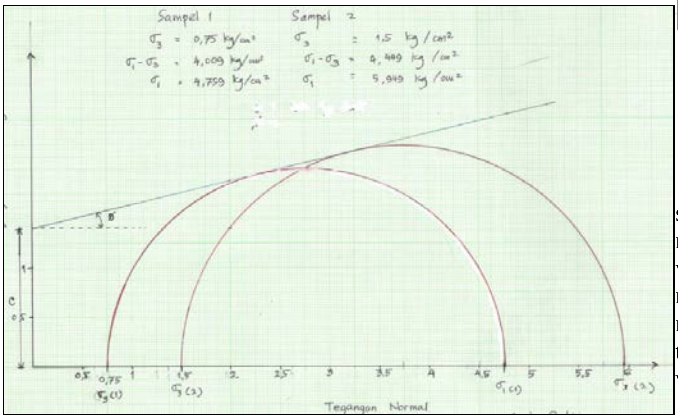

Figure 3.2 UU Triaxial Test (Source: BPJN 3 Padang Soil Lab)
Undrained Cohesion (Cu): 141.7 kN/m^2
Internal Friction Angle (φ): 13.08°

The cohesion value which was obtained by UU Test is 141.7 kN/m^2. Regarding this value, the mixed materials could be considered as very stiff material.

3.3 Unsoaked & Soaked CBR Test

Since internal plant road laid on the mixed material fill, the CBR value of this materials also was tested as part of the road design. The mixed materials were checked by soaked CBR test using SNI 1744-2012 with curing time 24 hours for unsoaked CBR and 96 hours for soaked CBR. The result as follow:

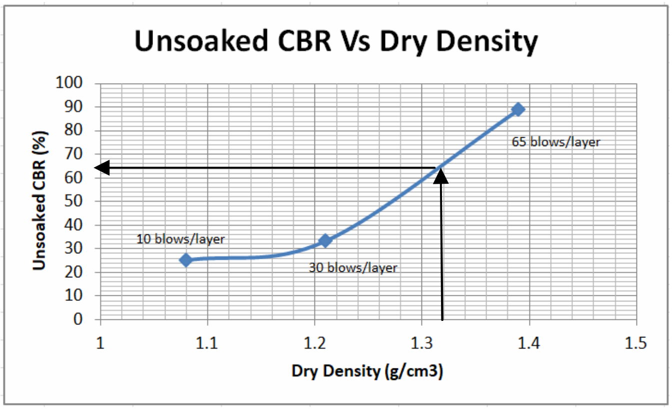

Figure 3.3 Unsoaked CBR Value
(Source: BPJN 3 Padang Soil Lab)
95% γd max : 1.32 t/m^3
Designed CBR : 66%

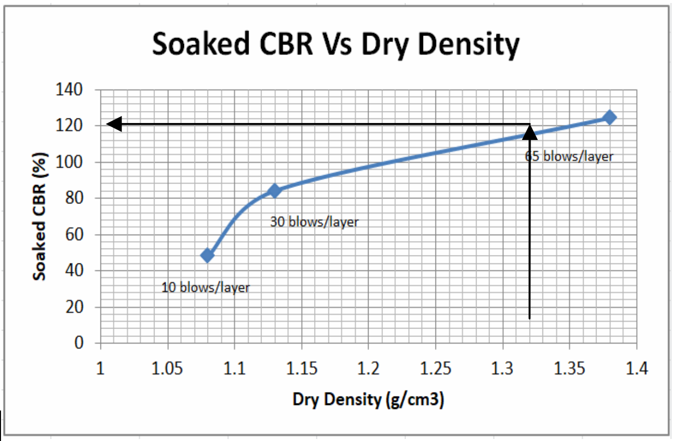

Figure 3.4 Soaked CBR Value
(Source: BPJN 3 Padang Soil Lab)
95% γd max : 1.32 t/m^3
Designed CBR : 118%

From the tests above (Figure 3.3 and 3.4), it can be seen that the soaked CBR value is higher than unsoaked CBR, this is mostly related with the curing time process, which the longer curing time will give the higher result of CBR value. Based on the road design requirement (Rigid pavement), the minimum CBR at the subgrade must be at least 6%. Thus we can conclude that the designed CBR of this mixed materials has strong enough to fulfill the requirement whether it's unsoaked or soaked CBR.

3.4 Consolidation

A constitutive sample of mixed material also was made for consolidation test (ASTM D 2435), and the result as follow (Figure 3.5):

Coefficient of Consolidation (Cv) : 0.744 m^2/year
Coefficient of Compressibility (Mv) : 0.004 m^2/MN
Permeability (k) : 8.927x10-9 m/s

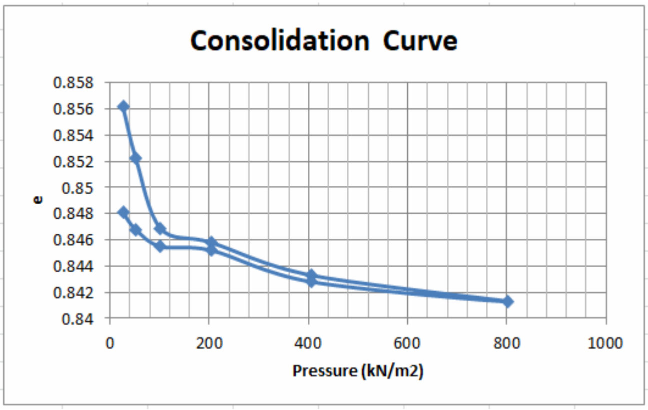

Figure 3.5 Consolidation Curve
(Source: BPJN 3 Padang Soil Lab)

From the consolidation test, which mv was obtained, the mixed material is classified as very low compressibility materials since the actual mv is less than 0.05 m^2/MN. The prediction of settlement (δ) will depend on the linear approach with mv as the main parameter,

$$\delta = m_v H \Delta\sigma' \qquad (1)$$

where:
δ = Settlement
mv = Coefficient of Compressibility
H = Layer thickness
Δσ' = Effective stress increases

3.5 Grain Size Analysis

The grain size distribution also was tested to identify the particle size distribution after mixing (Figure 3.6).

Table 2.1 Grain Size Distribution

Sieve Size (mm)	Retained (%)	Passing (%)
30.48	0.00	100.00
25.40	0.00	100.00
19.05	5.16	94.84
12.70	13.95	86.05
9.53	28.83	71.17
4.76	48.99	51.01
2.00	54.23	45.77
0.42	64.01	35.99
0.01	74.29	25.71
Pan	100.00	0.00

(Source: BPJN 3 Padang Soil Lab)
Gravel : 48.99%
Sand : 25.3%
Silt & clay : 25.71%

Already known that the majority of original soil is consist of silt/clay, but after mixing with active lime and cement, it's altered became granular material (mostly) and it's aligned with explanation in section I (The Preface) above.

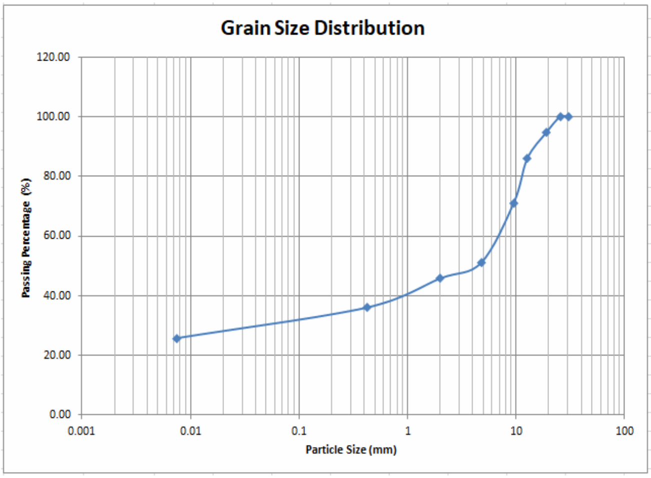

Figure 3.6 Grain Size Distribution
(Source: BPJN 3 Padang Soil Lab)

4. CONCLUSION

There are significant differences between original and improved characteristics of the soil. The remarkable characteristic differences are water content, grain size distribution and also shear strength. These advantages obviously help the construction works which was supported by this method, regarding the weather and construction schedule. The mixing process at field also has been done with tight QC supervision, especially focusing on water content, uniformity of materials, maximum lift thickness and also actual field CBR and density after compaction. Beside the percentage of lime and cement, the curing time is also important to increases soil shear strength. 1 day has been taken as curing time since water content has reached the optimum, even more days is better (see Figure 3.4 soaked CBR), the increases of the strength also have been contributed by cement contain in the mixed material. The mixed materials at site have been treated carefully to maintain its water content during the curing time, such as providing the tarpaulin sheet on the banks and also providing the sufficient drainage around the banks. These mixed material in this paper are purposed as filling material underneath the power plant facilities such as cooling tower, water treatment plant, warehouse, road, etc. which required the good bearing subgrade. Since there is limitation of this paper scope, author suggests the further investigation/experiments of this mixed material should be done to get better understanding of active lime & cement mixing behaviour on each case.

5. REFERENCES

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Figure 4.1 Applications of Mixed Materials on Site
(Source: Author's Photograph)

Figure 4.2 Applications of Mixed Materials on Site
(Source: Author's Photograph)