Experimental Study of Natural Materials Utilization as a Stabilization Agent on Soft Soil

T Hariantoi, N Marfu’ah*, I Raufi, and T B C Leatemia

1Department of Civil Engineering, Faculty of Engineering, Hasanuddin University, Makassar, South Sulawesi, Indonesia

*Email: nurulmarfuah.nm@gmail.com

Abstract. Chemical soil stabilization is known as the most economical method compared to others. The development of stabilization materials has led to studies of the utilization of natural materials and waste materials to replace cement and lime which has become the most popular binder agent ever known. This research utilizes natural minerals such as overboulder, zeolite and Palm Oil Fuel Ash (POFA) as its binder agents. The amount of natural material varies at intervals 3% - 15% by the weight of soil. Additional of natural materials is done to increase bearing capacity as a subbase layer, which is based on FHWA standards CBR minimum is 20%. California Bearing Ratio (CBR) tests were carried out to see the effect of each material on the bearing capacity of soft soil. Curing period varies at 7 days, 14 days and 28 days. The results show, by adding natural minerals such as overboulder, zeolite, and POFA increasing the CBR value up to 5 times, 6 times and 5 times compared to untreated soil and close to the CBR value of cement stabilized soil. Referring to FHWA standards, we can conclude that natural materials can be used for stabilization materials on subbase layer.

1. Introduction
In the world of construction, soil is a very important materials in supporting durability of a construction building. Reference [1] states that soil is construction materials which is available directly in the field, so this will be very economical if it can be used directly as a subbase materials, specifically at the locations that difficult to accessing sirtu. However, the soil must have a high bearing capacity. In order to gain a high bearing capacity, stabilization is carried out. The most popular method for increasing the bearing capacity of soil is the chemical stabilization method. This method is usually done by adding pozzolanic materials like cement and lime [2]. But, utilization of cement are avoided because the production process are considered not environmentally friendly [3]. Therefore, finding alternative materials become the needs of sustainable developments. As technological advancement in material measurement, the development of chemical material in research of stabilization leads to the utilization of wastes and other natural materials such as the utilization of fly ash [4], waste of Buton asphalt [5], fiber waste [6], and utilization of bacteria [7].

2. Materials and Method
2.1. Materials
Materials in this research divided into two kinds: soil and the stabilization material. The stabilization material that used in this research is natural materials such as overboulder, zeolite and burning palm oil shells which is known as palm oil fuel ash (POFA). We will explain each materials as follows:
2.1.1. Soil
Soil samples used in this study was taken around the Engineering Faculty, Gowa Regency. For untreated soil, physical and mechanical characteristics were tested to determine the initial condition of the soils before addition of materials. Testing method of these samples refers to the ASTM laboratory testing standards (American Standards for Testing and Materials), while USCS (Unified Soil Classification System) and AASHTO (American Association of State Highway and Transportation Officials) were used as its standard classification system.

Figure 1. Soft soil location

2.1.2. Palm Oil Fuel Ash
This is often called as ashes produced from palm oil solid waste at temperatures around 800°C-1,000°C at a steam power plant in a palm oil mill. The palm oil industry produces solid waste such as fiber, shells and empty plants. The extraction process of 100 tons of fresh tan and fruit will produce 20 tons of shells, 7 tons of fiber, and tons of empty tons [8]. POFA can be used as pozzolan, which is a fine material containing silica and alumina which can react and form cement material. POFA contain high silicon dioxide and have the potential to be used as a cement alternative. POFA is a promising pozzolanic material and is widely available in all parts of the world. Utilization of the right POFA can reduce the use of cement and reduce the volume of waste so that it is very beneficial for environmental sustainability [9].

2.1.3. Overboulder
This is commonly known as overburden materials or buton asphalt cover. This material is rarely used. However, it is known that overboulder has a deposit almost 800 million tons in Buton Island. [10] stated that, according to X-Ray Diffraction (XRD) data mineral that contained in OB in the form: CaO of 79.64%, SiO₂ of 9.63%, so based on these results OB has the potential as a pozzolanic material that can be used as a stabilization material on soft soils.

2.1.4. Zeolite
Zeolite has several properties including: easy release of water due to heating, but also easy to bind water molecules in moist air. Because of its nature, zeolites are widely used as drying agents in industrial fields. But lately, zeolite known containing a lot of silica which potentially to used as pozzolanic material like overboulder and POFA. In this study, all the stabilization materials that used is the fraction that passed no. 200 sieve.

This is caused by the reactivation of stabilization material which is strongly influenced by the degree of fineness of the grains [11]. In other words, the higher the specific surface area of the stabilization material, the faster the reaction between soil and stabilization material.
2.2. Research Methodology

In Table 1 the amount of stabilization materials is presented. The percentage of material used are POFA 5% and 10% with a curing period of 7 days and 28 days, zeolite 3% with a curing period of 14 days and 28 days and overboulder 5%, 10% and 15% with a curing period of 7 days, 14 days and 28 days. Curing aims to maximize the performance that occurs between its stabilization material and soil.

| No. | Specimens     | Percentage (%) | Curing Time (days) |
|-----|---------------|----------------|--------------------|
| 1   | Untreated Soil| 0              | 0                  |
| 2   | POFA          | 5 and 10       | 0, 7 and 28        |
| 3   | Zeolite       | 3              | 0, 14 and 28       |
| 4   | Overboulder   | 5, 10 and 15   | 0, 7, 14 and 28    |

The specimens making and testing for California Bearing Ratio is referred to ASTM standard D1883 - 16. Where the samples are made with dimensions of 15.2 cm x 17.8 cm and compacted with 56 layers of bedding. This sample was made using a standard pounder weighing 5 lbs. The CBR sample then cured with time varies from 7 days, 14 days and 28 days.

3. Results and Discussion

3.1. Soil Classification

Based on the laboratory results, (Unified Soil Classification System) standard clay material used in this study included in the classification of CH or inorganic clay and fertile soils with high plasticity. Based on the AASHTO (American Association of State Highway and Transportation Officials) standards, the soil used in this study is classified as A-7-6.

| No  | Characteristics                | Unit | Result  |
|-----|---------------------------------|------|---------|
| 1   | Specific Gravity (Gs)           |      | 2.71    |
| 2   | Initial Water Content (Wn)      | %    | 12.17   |
| 3   | Sieve Analysis                  |      |         |
| 4   | a. Sand                         | %    | 31.60   |
|     | b. Silt                         | %    | 19.28   |
|     | c. Clay                         | %    | 49.12   |
| 5   | Atterberg Limits                |      |         |
|     | a. Liquid Limit (LL)            | %    | 58.37   |
|     | b. Plastic Limit (PL)           | %    | 29.08   |
|     | c. Plasticity Index (PI)        | %    | 29.29   |
| 6   | Standard Proctor Test           |      | 20.16   |
|     | a. Dry density (γd max)         | gr/cm³ | 1.41 |
|     | b. Optimum Water Content (wopt) | %    | 25.28   |

| Mechanical Properties | Unit | Result |
|-----------------------|------|--------|
| CBR Unsoaked          | %    | 6.84   |

3.2. Effect of Mineral Additions on CBR Value

3.2.1. CBR Value Due to Additional of Palm Oil Fuel Ash

Figure 2 shows the effect of adding POFA on CBR value by curing period 7 days and 28 days.
Figure 2. CBR value due to additional of POFA

Based on datas shown, additional of palm oil fuel ash increase CBR value. The peak was obtained at 28 days by increasing CBR value 4 times at 5% POFA and 5 times at 10% POFA comparing to untreated soil which is the CBR value is 6.84%. From the figure, we can conclude, additional of 10% POFA is better than 5% POFA.

3.2.2. CBR Value Due to Additional of Overboulder
Figure 3 shows the effect of Overboulder addition to CBR value in curing period 7 days, 14 days and 28 days [10]. Based on datas shown, additional of overboulder increase CBR value. The peak of CBR value was obtained in the 28 days curing period by increasing the CBR value each: 3 times greater at 5% addition, 4 times greater at 10% addition and 5 times greater at 15% addition compared to CBR value of untreated soils. From Figure 3, we can conclude, 15% overboulder is the most effective percentage.

Figure 3. CBR Value Due to Additional of 5%, 10% and 15% Overboulder
3.2.3. *CBR Value Due to Additional of Zeolite*

Based on the data attached to Figure 4, it can be seen that the CBR value increases with increasing curing period. The addition of zeolite by 3% can increase the CBR value. It can be seen, the peak increase in CBR value is obtained during the 28 day curing period with a value 6 times greater than the CBR value of untreated soil.

![Figure 4. CBR Value Due to Additional of 3% Zeolite](image)

3.3. *Comparison of the Materials Effect on CBR Value*

Below is shown a comparison of zeolite, POFA and Overboulder datas on its optimum content in this research (3% zeolite, 20% POFA and 15% Overboulder). This comparison aims to determine the effectiveness of all the stabilization material for increasing CBR Value.

![Figure 5. Comparison of 3% Zeolite, 10% POFA and 15%Overboulder](image)
As we can see, at data without curing (0 day), the CBR value of 15% Overboulder addition has the lowest value at 10.34%, then followed by 10% POFA at 15.44%, and the highest obtained by 3% zeolite addition which the value is 23.23%. After cured 28 days, the trend of this stabilization material is slightly different from 0 days. The lowest CBR value is shown by 10% POFA addition where the CBR value is 33.28%, then followed by 15% Overboulder addition with a CBR value 38.22%, and the highest obtained by 3% zeolite addition with CBR 40.8%.

By comparing data at 28 days, zeolite obtained the highest CBR value among all materials. Where the CBR value increased 5 times in the addition of Overboulder, 6 times in the addition of zeolite and 5 times in the addition of POFA compared to CBR value of untreated soil which is 6.84%. Zeolite is consistently shows a significant increase in CBR values more than POFA and Overboulder, even without curing (0 days), additional of zeolite has greatly increased the CBR value almost 4 times from untreated soil.

Federation of Highway Association Standard requires a minimum CBR value for the subbase layer is 20%. The results shows that in general the average value meets the requirements for utilize as subbase layer except, the addition of overboulder and POFA without curing.

4. Conclusion
1. The addition of all natural materials increases CBR value and as we can see the longer the curing period, the higher CBR value that can be obtained
2. Based on FHWA standards about CBR minimum for subbase layer, zeolite, POFA and overboulder can be used as a stabilization material.
3. From the following materials, zeolite has the best performance compared to POFA and Overboulder.

References
[1] Bowles, J., 1986. Physical and Geotechnical Properties of Soils (In Bahasa). Jakarta: Erlangga.
[2] B M Das. 2000. Chemical and Mechanical Stabilization. Transportation in the New Era Millenium.
[3] R Cahyaputra and A Pratiwi. 2013. Green Strategy Sebagai Jawaban “Now and the Future” Semen Indonesia. Surabaya.
[4] S Nuradin, L Samang, J Patanduk, T Harianto. 2016. Performance of Fly Ash on Soft Soil Stabilization with Natural Fiber Reinforcement as Landfill Cover Layer. Inersia. [In Bahasa]
[5] T. Harianto, S H Nur, I Rauf and N Marfu‘ah. 2019. Study of CBR Value of Lightweight Geomaterial (Soil-EPS) Stabilized by Waste of Buton Asphalt (In Bahasa). Prosiding Seminar Nasional Teknik Sipil 2019. Surakarta.
[6] T Harianto, S Hayashi, Y J Du and D Suetsugu. 2008. Effects of Fiber Additives in the Desiccation Crack Behavior of the Compacted Akaboku Soil as A Material for Landfill Cover Barrier. J. Water Air Soil Pollution. pp 141-149.
[7] Hasriona, L Samang, T Harianto, M N Djide. 2018. Bearing capacity improvement of soft soil subgrade layer with Bio Stabilized Bacillus Subtilis. MATEC.
[8] T E Tay, G Liu, V B C Tan, X S Sun, D C Pham. 2008 Progressive Failure Analysis of Composites. J.Composite Materials. 42(18): 1921-1966.
[9] W Tangchirapat, C Jaturapitakkul, P Chindaprasirt. 2009. Use of Palm Oil Fuel Ash as a Supplementary Cementitious Material For Producing High-Strength Concrete. J. Construction and Building Materials, 23(7): 2641-2646.
[10] N Dhani, L Samang, T Harianto, A R Djamaluddin. 2018. Characteristics Study of Over Boulder Asbuton as Pozzalanic Material for Soft Soil Stabilization. International Seminar On Infrastructure Development, Manado.
[11] M Janz & S.E.Johansson. 2002. The Function of Different Binding Agents in Deep Stabilization. Swedia: Swedish Deep Stabilization Research Centre.