

Effect of palm shell ash and phosphoric acid chemical solution on subgrade material towards CBR value

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Abstract. Soil stabilization is a process of mixing soil with particular materials to restore engineering properties of soil which is an attempt to change or fix the engineering properties of soil in fulfilling particular technical requirement. The examination result of soil as a subgrade coating conducted in this study is classified as expansive soil. Unfixed subgrade condition may cause various damages on road pavement. Thus, in this study, subgrade repairment was administered by utilizing stabilization method of a mixture palm shell ash (PSA) and phosphoric acid chemical solution. The experiment aims to decrease dependency of cement as stabilization material in regular usage, in order to save cost in economic aspect of infrastructure. This study intends to analyze the effect of palm shell ash and phosphoric acid addition towards CBR value as subgrade construction layer of road pavement. The study outcomes shows several conclusions: (1) the decreasing value of optimal water content, plastic index, and swelling; (2) the increasing value of unsoaked CBR, soaked CBR, and isolated CBR. (3) the stabilization material mixture has been achieved, therefore it can be used as subgrade repairment on expansive soils for minimum standard of subgrade coating for road pavement.

1. Introduction

Soil stabilization is a process of mixing soil with particular materials to restore engineering properties of soil which is an attempt to change or fix the engineering properties of soil in fulfilling particular technical requirement [1]. This process involves soil mixing with other soils to acquire the required gradation, or any other factory materials mixing which improve engineering properties of soil. Therefore, engineering properties of soil such as compressibility carrying capacity, permeability, treatment amenity, swelling potential, and water content alteration sensitivity can be transformed by utilizing the most convenient treatment such as compaction by mixing soil palm shell ash and phosphoric acid chemical solution. This experiment aims to decrease dependency of cement as stabilization material in regular usage, in order to save cost in economic aspect of infrastructure [2]. The study aims to measure the effect of Palm Shell Ash (PSA) and Phosphoric Acid mixture as stabilization material towards subgrade (improved soil) repairment from CBR value aspect.



2. Literature review

2.1. Subgrade

Subgrade (native soil layer) is a part of road body surface that is prepared for the placement of construction on its top which is pavement construction [3]. The strength, durability and thickness of road pavement construction depends verily on properties and carrying capacity of the subgrade which serves as traffic load receiver that was distributed by pavement construction. Based on the native soil surface, the underlayer soil can be divided into:

- *Subgrade*, excavated soil
- *Subgrade*, stacked soil
- *Subgrade*, native soil

For the best problem prevention that occurred on subgrade, it should have a minimum standard as coating material of road pavement. Table 1 below is the description of subgrade minimum standard as coating material of.

Table 1. Minimum standard of subgrade material in road pavement layer.

| Parameter | Minimum Standard | Unit | Source |
|-------------------------------|------------------|------|---------------------------------|
| <i>Plasticity Indeks</i> (PI) | < 18 | % | <i>Holz & Gribbs (1956)</i> |
| Activation (PA) | ≤ 1,25 | - | Pd T-10-2005-B |
| CBR | ≥ 6 | % | Manual Desain Perkerasan |

2.2. Soil classification

Classification system of soil divides it into group and sub-group based on engineering properties such as grain size distribution, liquid limit, and plasticity. Two main classification systems which is used regularly are American Association of State Highway and Transportation Official (AASHTO) and The Unified Soil Classification System (USCS). AASHTO system is primarily used to classify the base soil for roadway. Soil that contains mass of distilled water is equal with the load on specific temperature. Value of density will affect to several aspects include soil strength, soil mass, etc.

3. Soil testing

Soil testing includes of physical properties and engineering properties tests. Physical properties involves on Atterberg Limit test and hydrometer analysis. While engineering properties test involves compaction test and CBR test.

3.1. Physical properties test

3.1.1. Liquid limit test. Based on SNI 03-1965 liquid limit test is a comparison between water mass inside the soil and grain soil mass measured in percent.

3.1.2. Content mass test. Based on SNI 03-1964 Soil content mass is a comparison between mass soil and soil volume of original condition in the field. The greater the dry soil mass is, the higher its density is.

3.1.3. Density test. Based on SNI 03-1964 Specific Gravity (Gs) of soil is a comparison between grain soil mass and distilled water mass with equal volume on specific temperature. Value of Specific Gravity will affect several matters such as soil strength, soil mass, etc.

3.1.4. Atterberg limits test. Soil consistency limits or Atterberg limits is known to cover liquid limit, plastic limit and shrinkage limit.

3.1.5. Soil grain size analysis test. Soil grain size serves as a basic to classify the name of various type of soil. In accordance with the size of soil grain, the analysis can be performed in three ways namely filter analysis, hydrometer analysis and combined analysis [4].

3.2. Mechanical properties test

3.2.1. Compaction test. Compaction is a process where air from the soil pore is excluded by using mechanical method to bind the soil. The purpose of compaction test in the laboratory is to determine maximum dry mass content and optimum soil water content.

3.2.2. CBR test. CBR test has another function besides measuring strength value of base soil which is a measurement to determine the layer thickness of compaction [5].

4. Material

4.1. Palm shell ash

Palm Shell Ash (PSA) is a solid waste derived from palm shell incineration as fuel to produce steam in the process of palm oil mill [3].

4.2. Phosphoric acid chemical solution

Phosphoric acid is technically a clear condensed liquid ranging from colorless to murky black color. The liquid mostly contains P_2O_5 and commonly used in industrial field [6]. Phosphoric acid is produced by smelting anhydrate phosphate to the water. Both inorganic phosphate and organic phosphate reside inside the soil inorganic form of this phosphate consists of Ca, Fe, Al, and F substances. Meanwhile, organic phosphate is retrieved from plants and microorganism that consists of nucleic acid, phospholipid and fitin. The addition of phosphoric acid or other phosphate compounds into the soil are able to increase the strength and carrying power water resistance of the soil. When the phosphoric acid was added up to the soil, it triggers a reaction between phosphoric acid and cation inside the soil which produces aluminum and iron compounds, primarily aluminum metaphosphate [7]. Figure 1 shows the characteristics (color, texture) of Palm Shell Ash and Phosphoric Acid chemical solution.



Figure 1. Characteristics of the study material (Color/Texture).

5. Analysis methodology

This study was performed in laboratory scale. It utilized expansive soil materials retrieved from Gedebage area in Bandung. The soil will be mixed with palm shell ash and phosphoric acid chemical solution which then tested using CBR to acknowledge the characteristics of the soil carrying capacity. CBR testing will be conducted in Geotechnical Laboratory of Civil Engineering program of State Polytechnic of Bandung. Augmenting phosphoric acid chemical solution to the expansive soils is conducted in sequent by 4,5%, 7,5%, and 10,5%. While the addition of palm shell ashes consistently

about 8% from each mass of the testing subjects. The percentage is accumulated based on the book of soil mechanism by Joseph E. Bowles second edition about compaction and soil stabilization. Stages of this study are first performed by preparing the soil, properties index testing to determine the classification of the soil as expansive soil or loam soil. The next stages are soil compaction test and CBR test. The soil is taken from the location of Floating Mosque project construction of Bandung city in Gede Bage area. The chemical solution of phosphoric acid is retrieved from the chemical store and palm shell ash (PSA) is retrieved from PT. Perkebunan Nusantara VIII, Bogor. The soil has been prepared for the require condition in dry-air area in order to filter and administer water content which then being tempered for road compaction by utilizing standard proctor method. The CBR test becomes the last stage follows. On the other hand, soil sample that has been mixed with palm shell ashes and phosphoric acid chemical solution is performed under dry-air soil condition which uses optimum water content from the compaction testing result from each native soil and mixture soil. Hence, Palm shell ash and phosphoric acid chemical solution can be solved properly or homogeneous. Figure 2 shows type of testing performed.



Figure 2. type of testing performed.

6. Discussion and data analysis

This part will describe the result of the study, both subgrade properties test (physical and mechanic properties) before and after the mix with stabilization material. The description as follows:

6.1. Result test of subgrade physical properties

Table 2. Result test of subgrade physical properties.

| <i>Index Properties</i> | Unit | Value on the mixed Soil | | | |
|-------------------------|------|-------------------------|----------------------|----------------------|-----------------------|
| | | Initi. (1) | PSA 8% + PA 4,5% (2) | PSA 8% + PA 7,5% (3) | PSA 8% + PA 10,5% (4) |
| Density | | 2,59 | - | - | - |
| Plastic limit | % | 38 | 34 | 31 | 31 |
| Liquid limit | % | 85 | 48 | 43 | 40 |
| Plasticity Index | % | 46 | 15 | 12 | 9 |
| Activation (PA) | % | 1,03 | 0,33 | 0,28 | 0,21 |

Based on the result of a mixed subgrade physical properties test on Table 2, Plasticity Index of native soil (1) about 46%. Based on Pd T-10-2005-B, it indicates that Subgrade with a Plasticity Index > 32% is categorized as loam which contains a very high swelling nature. It can be resolved that mixture (4) can decrease Plasticity Index for about 80,43% from the Plasticity Index mixture (1). While the result of PA in the native soil (1) by 1,03. Based on Pd T-10-2005-B, the results shows that Subgrade with PA (phosphoric acid) < 1,25 is categorized as loam soil with normal activation and medium swelling level.

6.2. Result test of a mixed subgrade mechanical properties

Table 3. Result test of mechanical properties subgrade.

| <i>Index Properties</i> | <i>Unit</i> | Value in Mixed Soil | | | |
|-------------------------|--------------------|----------------------------|---------------------------------|---------------------------------|----------------------------------|
| | | Initi. (1) | PSA 8% + PA 4,5% (2) | PSA 8% + PA 7,5% (3) | PSA 8% + PA 10,5% (4) |
| Compaction test | Gr/cm ³ | 1,180 | 1,175 | 1,170 | 1,167 |
| | w _{opt} | 31,00 | 30,90 | 30,87 | 30,82 |
| | | | Unsoaked | | |
| CBRI Isolation 0 day | % | 8,6 | 1,7 | 2,5 | 2,7 |
| CBRI Isolation 7 day | % | - | 3,8 | 4,5 | 4,6 |
| CBRI Isolation 14 day | % | - | 11,4 | 7,0 | 9,3 |
| | | | Soaked | | |
| CBRI Isolation 0 day | % | 1,2 | 1,27 | 1,7 | 3,3 |
| CBRI Isolation 7 day | % | - | 1,75 | 3,5 | 3,9 |
| CBRI Isolation 14 day | % | - | 3,1 | 8,6 | 12,0 |
| | | | (swelling) | | |
| Isolation 0 day | % | 3,37 | 2,49 | 1,28 | 1,40 |
| Isolation 7 day | % | - | 3,74 | 2,14 | 0,45 |
| Isolation 14 day | % | - | 2,53 | 0,1 | 0,001 |

Based on the overall soaked CBR testing result in isolation, it can be concluded that isolated soaked CBR of day zero (0) had suffered an increase of CBR value by 175% in the mixture (4) from the mixture condition (1). Nevertheless the highest increase occurred on soaked CBR isolated condition of 14 days about 900 % in the mixture (4) from the mixture condition (1) in the isolation preion of day zero (0). To understand the result displayed on Table 7, below is the description of value change in each of mechanical mixture properties test by graphic.

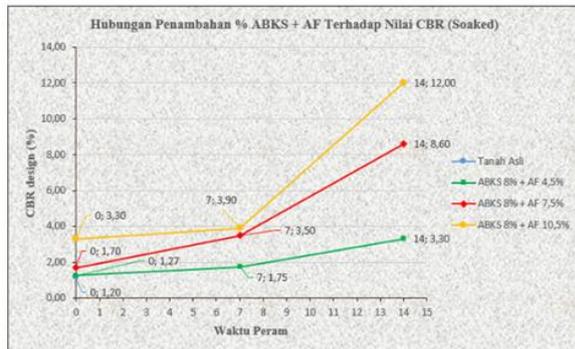


Figure 3. Graphic of Relation Admixture % PSA + PA towards CBR value in soaked and isolated condition.

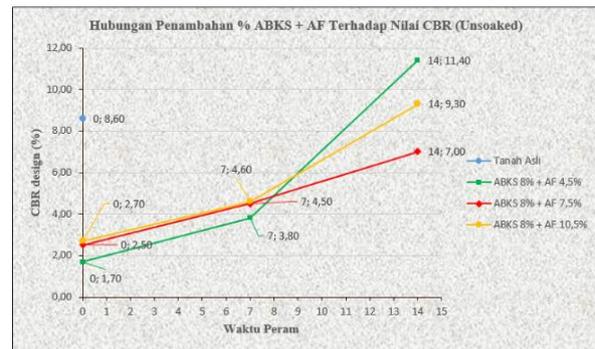


Figure 4. Graphic of Relation Admixture % PSA + PA towards CBR value in Unsoaked and isolated condition.

7. Conclusion

From the elaboration above, it may conclude that There is a decline of optimum water content and value of dry mass content for about 0,58% and 1,10% in the mixture(4) from mixture condition (1), There is a decline of Plasticity Index value about 80,43% in the mixture (4) from the mixture condition (1), There is a downgrade shift of Unsoaked CBR value and an increase of Soaked CBR in isolated condition by 68,60% and 175% in the mixture (4) from the mixture condition (1). However, the highest increase occurred in Unsoaked CBR and Soaked CBR for 14 days isolation in total of 8,13% and 900% in the mixture (4) from the mixture condition (1) in the isolation period of day zero, There is a shift of swelling value decline respectively for about 58,45% on the mixture (4) from mixture condition (1) isolated condition on day zero (0) and 99,97% on the mixture of (4) isolated condition in 14 days than the mixture (1) in isolated condition of day zero, There is a Trend that almost in a tune both physically and mechanically between the increase of stabilization materials amount with the result from each of the test.

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