The stability of clay using Portland cement and calcium carbide residue with California bearing ratio (cbr) value

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Abstract. Clay is a type of soil which is often used for stabilization. This is caused by its properties which are very hard in dry conditions and plastic in the medium content of water. However, at a higher level of water, clay will be cohesive and very lenient causing a large volume change due to the influence of water and also causing the soil to expand and shrink for a short period of time. These are the reasons why stabilization is needed in order to increase bearing capacity value of the clay. Stabilization is one of the ways to the condition of soil that has the poor index properties, for example by adding chemical material to the soil. One of the chemical materials that can be added to the soil is calcium carbide residue. The purpose of this research is to know the fixation of index properties as the effect of adding 2% PC and calcium carbide residue to the clay, and to know the bearing capacity value of CBR (California Bearing Ratio) as the effect of adding the stabilization agent and to know the optimum content of adding calcium carbide residue. The result of the research shows that the usage of 2% cement in the soil that has CBR value 5.76%, and adding 2% cement and 9% calcium carbide residue with a period of curing 14 days has the largest of CBR value that is 9.95%. The unsoaked CBR value shows the increase of CBR value up to the mixture content of calcium carbide residue 9% and, decreases at the mixture content of calcium carbide residue 10% and 11%.

Keywords: clay, cement, calcium carbide residue, soil stabilization, CBR

1. Introduction

Soil is a construction material that can be obtained directly in the field, but still just like the other materials, this soil only can be used after its quality has been improved as needed. If the soil is being used without improving the quality, the result may cause low stability and large subsidence. Subsidence is used to explain the vertical movement mechanism in the pile due to its own weight; settlement is vertical movement on the ground due to weight of the pile above. If the soil in the field tends to be very
loose or easily pressed or unsuitable for construction material, then it needs to be stabilized. Stabilization process can be done with increasing the soil density, adding inactive materials to increasing cohesion, adding substances that can cause chemical and physical changes of the soil, lower the water table, and replace the poor soil [1].

Clay is fine grained and has plastic properties, where the plasticity is an ability of the soil to adjust the soil deformation after being mixed with water. If the fine-grained soil contains clay minerals, then the soil can be squeezed (remoulded) without causing cracks [3]. This cohesive property is caused by the absorption of water (adsorbed water) around the surface of the clay. In early 1900, Atterberg developed a method to explain the consistent properties of fine-grained soil at varying water content. If the water content is very high, the mixture of soil and water will become mushy. Therefore, based on the water content, soil can be categorized into four basic states: solid, semi-solid, plastic and liquid. Atterberg limits shows the occurrence of soil form from solid to viscous liquid in accordance with its water content. From this Atterberg limits testing, we will be able to obtain parameters of liquid limit (LL), plastic limit (PL) which is the condition of soil consistency [2]

\[
\text{IP} = \text{LL} - \text{PL}
\]  

Compaction in done to increase soil strength so as to increase the bearing capacity of the foundation; compaction can reduce soil degradation and increase slope stability/embankment. The soils particle slip over each other and move into a densely packed position. The dry unit weight after compaction first increase as the moisture content increase [2]. At a certain moisture content, the maximum dry volume weight is theoretically obtained if the pores of the soil do not contain air, when the degree of saturation is 100% can be written as follows:

\[
\gamma_{zav} = \frac{G_s \gamma_w}{1 + e}
\]

where:
- \(\gamma_{zav}\) = unit weight at zero air voids
- \(\gamma_w\) = unit weight of water
- \(e\) = void ratio
- \(G_s\) = specific gravity

2. Research Methods

2.1. Materials Preparation
- Soil samples used in this study were taken from PTPN II, Patumbak, Deli Serdang, North Sumatra. The soil taken is categorized as a clay with low to medium water content.
- Preparing cement
  Cement used was Portland cement type I, with trademark ‘Semen Padang’ (PPC / Portland Pozzolan Cement).
- Preparing Calcium Carbide Residue/CCR
  The additive material used in this research is calcium carbide residue that came from welding’s residue which was obtained from the carbide welding workshop industry on Sei Serayu, Medan Baru District, North Sumatera.

2.2. Stages of Research
The stage of research and the number of samples used can be seen in the flowchart below
3. Research Result

3.1 Soil Testing

Table 1. Data of Physical Nature of Soil and CCR

| No.  | Testing          | Soil   | CCR    |
|------|------------------|--------|--------|
| 1.   | Water Content    | 17.89% | 8.27%  |
| 2.   | Specific Gravity | 2.65   | 2.391  |
| 3.   | Liquid Limit     | 45.49% | Non Plastic |
| 4.   | Plastic Limit    | 15.19% | Non Plastic |
| 5.   | Plasticity Index | 30.30% | Non Plastic |
| 6.   | Percentage of sieve analysis soil no. 200 | 52.28% | 12.89% |
According to the classification system of USCS, this soil is included in the CL (Clay - Low Plasticity) group which is inorganic clay with low to medium plasticity. And according to the classification system of AASHTO, the sample of soil could be classified as type of A-7-6 soil.

Table 2. Test Results of Chemical Analysis of Calcium Carbide Residue

| No. | Chemical compounds       | Result |
|-----|--------------------------|--------|
| 1.  | Silicon oxide (SiO$_2$)  | 4.4%   |
| 2.  | Calcium oxide (CaO)      | 33.6%  |
| 3.  | Magnesium oxide (MgO)    | 3.77%  |
| 4.  | Aluminium oxide (Al$_2$O$_3$) | 0.74% |
| 5.  | Iron(III) oxide (Fe$_2$O$_3$) | 0.17% |

It is seen in Table 2 that CaO compounds are more dominant than other compounds and they are the most needed compounds in chemical processes with clay soils that will produce high calcium ions which can bind around the clay particles so as to reduce the adsorption capacity of water.

Table 3. Chemical composition of cement

| Composition                  | In General | Quick Hardening | Low Heat | Sulfate Resistant |
|------------------------------|------------|-----------------|----------|------------------|
| Calcium oxide (CaO)          | 63.1 %     | 64.5 %          | 60 %     | 64 %             |
| Silicon oxide (SiO$_2$)      | 20.6 %     | 20.7 %          | 22.5 %   | 24.4 %           |
| Aluminium oxide (Al$_2$O$_3$)| 6.3 %      | 5.2 %           | 5.2 %    | 3.7 %            |
| Iron(III) oxide (Fe$_2$O$_3$)| 3.6 %      | 2.9 %           | 4.6 %    | 3.0 %            |

3.2 Tests of Physical and Mechanical Properties of Soil with Additive Materials

The results obtained from the test of samples that have been mixed with additive materials show that cement and volcanic ash can improve the physical and mechanical properties of the soil. Figure 2 shows that with the addition of additive material, the Liquid Limit value of soil will decrease. The more percentage of CCR, the smaller its liquid limit. Meanwhile Figure 3 shows that the value of plastic limit is increasing. Figure 4 is a graph of the Plasticity Index value of each mixed variation. The decline in value of the plasticity index may reduce the potential of soil to expand and shrink.

![Figure 2. Graph between Liquid Limit (LL) with mixed variation of CCR](image)
Figures 3 and Figure 4 show the maximum dry unit weight and the optimum water content value of each mixed variation.

**Figure 3.** Graph between Plastic Limit (PL) with mixed variation of CCR

**Figure 4.** Graph between Plastic Index (PI) with mixed variation of CCR

Figures 5 and Figure 6 show the maximum dry unit weight and the optimum water content value of each mixed variation.

**Figure 5.** Graph between Maximum Dry Unit Weight ($\gamma_d$) with mixed variation of CCR
The results of the California Bearing Ratio shown in graphical form in Figure 7. The effect of mixing calcium carbide residue on clay to its strength can be seen from the results of CBR testing in un soaked condition, with each variation of soil mixed with cement and calcium carbide residue with curing time for 14 days. Figure 7 shows the effect on adding 2% PC and variation of CCR addition from 2% to 11% to CBR value. It is seen that the increase of percentage of CCR mixture causes the CBR value increases until then percentage of CCR reached 9% and decreases at the percentage 10% and 11%, but this decrease is not significant to the CBR value because the CBR value obtained at mixing of 10% and 11% CCR is still higher than the initial CBR value (0% PC and CCR mixture). The mixing of CCR at 9% is an effective mixing that can increase the bonding between soil grains and CCR, causing the clay strength to increase as well.

4. Conclusions

From the research that has been done, it can be concluded as follows:

1. Based on the classification system of Unified Soil Classification System (USCS), soil is included in the group of CL which is inorganic clay with low to medium plasticity.

2. Based on the classification system of American Association of State Highway and Transportation Officials (AASHTO), this soil could be classified as type of soil A-7-6.
3. Based on Atterberg limits test on original soil obtained that the liquid limit, plastic limit and plasticity index of soil are 45.49%, 15.19%, and 30.30%. The addition of 2% PC+11% CCR has the lowest plasticity index which is equal to 18.33%, plastic limit which is equal to 18.14% and liquid limit value which is equal to 36.47%, meanwhile calcium carbide residue is a non-plastic material.

4. Based on proctor standard test obtained optimum water content and maximum dry weight volume of original soil are 21.24 % and 1.317 g/cm$^3$. While the highest maximum dry weight value obtained from a mixture of 2% PC + 9% CCR which is equal to 1.497 g/cm$^2$ with optimum water content 19.32% and 14 days of curing time.

5. CBR laboratory test shows that the CBR value of original soil is 5.76% and the optimum CBR value obtained on the addition of 2% PC + 9% CCR is 9.95%.

6. From the results of the research, the addition of 2% PC + 9% CCR has the highest CBR value of 9.95%.

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