Effect of using clamshell ash as stabilization material for clay

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Abstract. Clamshells are the waste of clams which are usually consumed by people. Clamshells contain 66.70% of CaO, the chemical compounds that have pozzolanic properties, which can be used as a substitute for cement. The purpose of this study was to determine the effect of the addition of clamshell ash to the index value of soil properties, soil classification, soil plastic properties, free compressive strength value, and CBR value. The test was carried out with Unconfined Compression Test (UCT) and California Bearing Ratio (CBR). The result showed that according to AASHTO this soil was classified as A-7-6 (9) and according to USCS it was classified as CL (Clay - Low Plasticity). The original soil sample had a moisture content of 34.43%; specific weight of 2.65%; liquid limit of 47.33%; plastic limit of 17.45%; and plasticity index of 29.88%. The values of unsoaked design CBR and UCT for the original soil were 6.29% and 1,42 kg/cm². Meanwhile, among all the variations, the mixture of 12% clamshell ash reached the optimum value of soaked design California Bearing Ratio and free compressive strength in Unconfined Compression Test which were 8.13% and 2.39 kg/cm².

1. Introduction
In technical terms, soil is defined as solid material (both mineral and organic) located on the surface of the earth which continues to change and is influenced by factors such as main material, climate, organisms, topography, and time. Soil can generally be referred to as gravel, sand, silt, or clay, it depends on the size of the predominant particles in the soil. Soil consists of 3 components, they are air, water, and solid materials. Air does not affect the technical properties of soil, but water does. The space between the grains can be partially or completely filled with water or air. Soil is a composition of two or three different phases, namely gas, liquid and solid [1].

In general, soil is classified according to its technical characteristics and its relationship in building the foundation and the buildings on it. Modern classification systems are designed to facilitate the estimation of soil properties and behavior based on field observations. The most widely used technical classification to determine soil type is Unified Soil Classification System (USCS). The USCS classification has three main groups, they are soils with coarse particle size (sand and gravel), fine particles (clay and silt), and soils with high organic content (peat). The soil classification system that is often used beside USCS classification system is AASHTO Soil Classification System. In this classification system, soil is classified into seven major groups, namely A-1 to A-7 [1, 2].
2. Research Methods
This research used experimental methods and was carried out at the Laboratory of Soil Mechanics, Department of Civil Engineering, Universitas Sumatera Utara. The soil samples used were soil with and without clamshell ash.

Mixture variations of clamshell ash applied in this research are 2%, 4%, 6%, 8%, 10%, 12%, 14%, 16%, 18% and 20% of the total weight with 3 days of curing period.

2.1. Test Performed

Tests conducted in the laboratory were the physical properties of soil and soil mechanical tests. The soil physical properties tests consist of Water Content Test, Specific Gravity Test, Volume Weight Test, Atterberg Limit, and Sieve Analysis. Soil mechanical tests consist of standard compaction test, CBR, and UCT.

2.1.1. Standard Compaction Test
This test is needed to determine the optimum moisture content and to determine the maximum dry unit weight. This is very necessary because in the Mix Design process that will be carried out it can be likened that the mixed soil sample is considered to have field density and field moisture content such as undisturbed soil [3].

2.1.2. California Bearing Ratio (CBR)
In this study, soaked design CBR test was used so that the conditions in the laboratory were closer to the field conditions. Laboratory CBR is the determination of the CBR value of soil material samples, aggregates or soil mixtures, and aggregates that are compacted in the laboratory with certain moisture content. This test is used to evaluate the strength of subgrade, sub-base and foundation materials including remolded materials [4].

2.1.3. Unconfined Compression Test (UCT)
This test is carried out to determine the value of the free compressive strength of disturbed, remolded, and compacted soil samples [5].

3. Test Results
From the research that has been done, the obtained results are as follows:

3.1. Index properties of soil and stabilizer

| No | Testing                  | Soil     | Clamshell Ash |
|----|--------------------------|----------|---------------|
| 1  | Water Content            | 34.43%   | -             |
| 2  | Specific Gravity         | 2.65     | 2.55          |
| 3  | Liquid Limit             | 47.33%   | Non plastic   |
| 4  | Plastic Limit            | 17.45%   | Non plastic   |
| 5  | Plasticity Index         | 29.88%   | Non plastic   |
| 6  | Sieve Analysis passing No. 200 | 48.81%   | 2.57 %        |
From the data in Table 1, according to AASTHO classification system, the sample was included in the soil type A-7-6 and according to USCS classification system, the sample was included in the CL group, namely inorganic clays with low to moderate plasticity [6, 7].

3.2. Testing the physical properties of the soil using stabilizing agents

This test is carried out on soil that has been mixed with stabilizers, so that the effect of the stabilizers can be seen from each determined variation level, from the liquid limit value, and also the plasticity index value. Atterbeg test results at each level of variation are shown in Table 2.

| No | Samples          | Liquid Limit (LL) | Plastic Limit (PL) | Plastic Index (PI) |
|----|------------------|-------------------|--------------------|--------------------|
| 1  | Soil without CA | 47.33             | 17.45              | 29.88              |
| 2  | Soil + 2% CA    | 37.31             | 16.07              | 21.24              |
| 3  | Soil + 4% CA    | 36.82             | 16.65              | 20.17              |
| 4  | Soil + 6% CA    | 36.25             | 17.30              | 18.96              |
| 5  | Soil + 8% CA    | 35.67             | 17.94              | 17.73              |
| 6  | Soil + 10% CA   | 34.71             | 18.15              | 16.56              |
| 7  | Soil + 12% CA   | 34.01             | 18.71              | 15.30              |
| 8  | Soil + 14% CA   | 33.45             | 19.11              | 14.34              |
| 9  | Soil + 16% CA   | 32.18             | 19.63              | 12.55              |
| 10 | Soil + 18% CA   | 31.50             | 20.15              | 11.34              |
| 11 | Soil + 20% CA   | 30.81             | 20.77              | 10.03              |

3.3. Compaction test for soil without Clamshell Ash (CA)

In this test, the relationship between the optimum moisture content and maximum dry unit weight will be obtained [8, 9]. Method of testing is conducted by Standard Proctor compaction test, in which the tools and materials used include:

- Mold Ø 10.2 cm, with internal diameter Ø 10.16 cm.
- Soil compaction hammer with 2.5 kg hammer mass and 30 cm drop.
- Soil samples which passed through sieve No.4.

The results of the Standard Proctor compaction test on the soil without any stabilizing agents showed that the optimum water content was 21.12% and the maximum dry unit weight was 1.34 g/cm³.

3.4. Compaction test for soil with Clamshell Ash (CA)

The test results can be seen in Table 3.
Table 3. The results of Compaction Test on Soil with the addition of Clamshell Ash (CA)

| No | Samples          | $\gamma_{d \ max}$ (gr/cm³) | $W_{opt}$ (%) |
|----|-----------------|-----------------------------|---------------|
| 1  | Soil without CA | 1.34                        | 21.12         |
| 2  | Soil + 2% CA    | 1.34                        | 22.66         |
| 3  | Soil + 4% CA    | 1.41                        | 22.53         |
| 4  | Soil + 6% CA    | 1.45                        | 22.48         |
| 5  | Soil + 8% CA    | 1.45                        | 22.26         |
| 6  | Soil + 10% CA   | 1.47                        | 22.11         |
| 7  | Soil + 12% CA   | 1.60                        | 21.64         |
| 8  | Soil + 14% CA   | 1.49                        | 21.90         |
| 9  | Soil + 16% CA   | 1.46                        | 22.61         |
| 10 | Soil + 18% CA   | 1.31                        | 22.78         |
| 11 | Soil + 20% CA   | 1.30                        | 22.83         |

From Table 3 above, it can be seen that the maximum dry unit weight value increased after adding 2% to 12% of clamshell ash, but it decreased again in the mixture of 14% to 20% of clamshell ash. The increase in maximum dry unit weight occurs because the stabilizing agent fills the pore cavities in the soil, which in the original soil conditions, the pore cavities are filled with water and air. Due to the presence of stabilizers in the soil cavity, the percentage of water contained in the soil decreases. The increase in the number of solid particles in the soil has an impact on increasing the dry unit weight compared to the original soil conditions. Meanwhile, the decrease in soil dry unit weight occurs because the soil has passed the effective addition of stabilizers. The amount of stabilizer that increases compared to the weight of the original soil that does not change will reduce the binding ability so that it will reduce the stickiness between the grains on the soil and water so that the soil becomes easily cracked.

The results showed that the maximum optimum water content was 21.90%, it was obtained from 14% of CSA variation. This decrease in optimum water content happened due to the stabilizing agents forced water out of the soil pores and the cavities in the soil that contain water were replaced by stabilizing agents so that water could not re-enter the soil micropores, as a result, the percentage of water contained in the soil decreased. The increase in optimum water content happened due to the stabilizing agent, clamshell ash, caused the soil to become warm so that the mixture required more water content to bond with each other. And this is because the increasing percentage of stabilizer material and the original weight of the original soil is fixed, resulting in reduced binding capacity of the mixture. The increase in the percentage of stabilizing agent with the original soil weight which remains also results in a reduction in the binding capacity of the mixture.

3.5. CBR Test

The effect of mixing clams in clay soil on the strength of the clay soil can be seen from the CBR test results in soaked condition, in which each variation of soil that has been mixed with clamshell ash with 3 days of curing and soaking time for 1 day. Testing in unsoaked condition is relatively faster [4]. This study tested the samples in soaked condition because the field was in water-saturated state. The bond between the grains is the ability to interlock between the grains and to glue the surface of the grains, the stronger the bonds between the grains will
result in higher CBR value and vice versa. The CBR test conducted in this study was intended to see whether the increase of the Clamshell Ash (CA) percentage would affect the CBR value.

Table 4. CBR Test Result

| No | Samples           | CBR Value |
|----|-------------------|-----------|
| 1  | Soil without CA   | 6.29      |
| 2  | Soil + 2% CA      | 7.14      |
| 3  | Soil + 4% CA      | 7.44      |
| 4  | Soil + 6% CA      | 7.61      |
| 5  | Soil + 8% CA      | 7.88      |
| 6  | Soil + 10% CA     | 8.02      |
| 7  | Soil + 12% CA     | 8.13      |
| 8  | Soil + 14% CA     | 8.07      |
| 9  | Soil + 16% CA     | 8.08      |
| 10 | Soil + 18% CA     | 7.44      |
| 11 | Soil + 20% CA     | 7.14      |

Figure 1 shows the effect of adding clamshell ash on the soil to the CBR value. There is an increase in the CBR value on the soil mixed with clamshell ash compared to the original soil, this was caused by the pozzolan/cement nature of the clamshell ash. The highest CBR value obtained was 8.13% from a mixture of 12% clamshell ash. However, in further addition the CBR value tended to decrease because the weight of the soil volume decreased due to the soil pores were filled with clamshell ash mixture causing the penetration results in the CBR test to decrease. The decrease also occurred due to the result of compaction which also decreased along with the addition of the mixture of clamshell ash, it happened because the CBR value was very dependent on soil density.
3.6. UCT Test
In this test, we will obtain the relationship between the value of free compressive strength \((q_u)\) in the original and remolded soil, and the value of free compressive strength \((q_u)\) in each soil variation that has been mixed with clamshell ash with 3 days of curing time. Furthermore, from the results of the \(q_u\) value, the cohesion value \((c_u)\) which is equal to \(\frac{1}{2} q_u\) will be obtained.

The free compressive strength test was conducted on each variation of the clamshell ash mixture. Table 5 shows the value of soil compressive strength \((q_u)\) obtained in each variation of the mixture and Table 6 shows the comparison of soil compressive strength \((q_u)\) value between the original and remolded soil.

| No | Samples         | \(q_u\) (kg/cm\(^2\)) | \(c_u\) (kg/cm\(^2\)) |
|----|-----------------|------------------------|------------------------|
| 1  | Soil without CA | 1.42                   | 0.71                   |
| 2  | Soil + 2% CA    | 0.73                   | 0.36                   |
| 3  | Soil + 4% CA    | 0.96                   | 0.48                   |
| 4  | Soil + 6% CA    | 1.24                   | 0.62                   |
| 5  | Soil + 8% CA    | 1.48                   | 0.74                   |
| 6  | Soil + 10% CA   | 1.86                   | 0.93                   |
| 7  | Soil + 12% CA   | 2.08                   | 1.04                   |
| 8  | Soil + 14% CA   | 2.39                   | 1.19                   |
| 9  | Soil + 16% CA   | 2.32                   | 1.16                   |
| 10 | Soil + 18% CA   | 2.19                   | 1.09                   |
| 11 | Soil + 20% CA   | 1.67                   | 0.83                   |
| 12 | Soil without CA | 1.24                   | 0.62                   |

| Strain (%) | Original soil \(q_u\) (kg/cm\(^2\)) | Remolded soil \(q_u\) (kg/cm\(^2\)) |
|------------|--------------------------------------|--------------------------------------|
| 0.5        | 0.30                                 | 0.16                                 |
| 1          | 0.46                                 | 0.23                                 |
| 2          | 0.69                                 | 0.41                                 |
| 3          | 1.18                                 | 0.54                                 |
| 4          | 1.42                                 | 0.61                                 |
| 5          | 1.16                                 | 0.71                                 |
| 6          | 1.08                                 | 0.57                                 |
| 7          | 0.83                                 | 0.39                                 |
Fig. 2 Graph of the relationship between soil compressive strength ($q_u$) and strain

In Figure 2, it can be seen that the compressive strength value of the soil on the original soil was 1.42 kg/cm and on the remolded soil was 0.71 kg/cm². There is a significant decrease where this decrease was caused by damage to the soil structure received by the artificial soil (remolded). The characteristic of decreasing soil strength due to structural damage is called sensitivity. This sensitivity value will determine the soil classification according to its sensitivity [10].

$$\text{Sensitivity} = \frac{q_u \text{ undisturbed}}{q_u \text{ remoulded}} = \frac{1.42}{0.71} = 2.00$$

The soil sample used in this study has a sensitivity ratio of 2.00 which makes it classified as medium sensitivity soil. This means that the structural damage experienced by the soil does not have a major effect on changes in the compressive strength or shear strength of the soil.
Figure 3 shows that the compressive strength of the original soil ($q_u$) was 1.42 kg/cm². Then with the addition of clamshell ash, the compressive strength value increased, but only up to the mixture of 12% clamshell ash, in this mixture, the maximum soil compressive strength value was 2.39 kg/cm². However, in further addition, the compressive strength value tended to decrease because the adhesion between the grains of soil and water shrank so that the soil becomes easily broken when it was given vertical pressure.

4. Conclusion

It can be concluded that the clamshell ash can be used as stabilizing agent with a mixture of 12% of CA. The maximum CBR and compressive strength value for this mixture was 8.13% and 2.39 kg/cm². From the results of the Proctor Standard test, the optimum moisture content of the original soil was 21.12% and the maximum dry unit weight was 1.34 g/cm³, while the optimum moisture content and maximum dry unit weight of all mixtures were obtained at the variation of 12% CA where the optimum water content was 21.64% and the maximum dry unit weight was 1.60 g/cm³.

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