Stabilization of clay using slag and fly ash with reference to UCT value (Case study: Jalan Kadusentar, Pandeglang District-Banten)

W Fathonah*, D E Intari, E Mina, R I Kusuma and Mahfudoh
Civil Engineering Department, Faculty of Engineering, University of Sultan Ageng Tirtayasa, Cilegon 42435, Indonesia
*E-mail: woelandari@untirta.ac.id

Abstract. Expansive soils have low soil bearing capacity so that's causes often problems in buildings. One ways to repair soil bearing capacity is improve the strength of original soil with chemical stabilization methods using slag and fly ash. The research goals were to find out the effect of adding slag and fly ash with reference to unconfined compressive strength value and physical properties of the soil before and after stabilizing with slag (10%, 20% and 30%) and fly ash (20%) and to know classification soil on jalan Kadusentar, Pandeglang District - Banten based on USCS classification. The results of this study obtained original soil types including the MH category is non-organic clay with high plasticity. The UCT value of original soil was 1,407 kg/cm². Addition of slag and fly ash increased the value of unconfined compressive strength and can improve the physical properties of the soil by decreasing the value soil plasticity index. The maximum UCT value is the percentage of 20% fly ash and 10% slag of 8,393 kg/cm² including hard consistency with unconfined compressive strength values greater than 4 kg/cm² with curing time for 14 days.

1. Introduction
Soil has an important role in the civil construction, either building or road construction. Every soil in each region has different type and ultimate bearing capacity. The failure of construction occurs by the low capacity of subgrade’s ultimate bearing. Based on the AASHTO soil classification, it is known that one of the subgrade’s type that has low carrying capacity is clay type. This research used the clay from Jalan Kadusentar, Pandeglang District-Banten that contains site CBR of 2.9% and Plasticity Index (PI) of 20.475%, this shows that the soil has high plasticity that made the swell-shrink of soil is high and caused the hole, cracks, and wavy road. The soil needs to be repair with stabilization method by mix the undisturbed soil with slag and fly ash. Slag is the waste of steel smelting, mostly consist of steel oxidation and silicate with flat and sharp shape. Slag can be used to be replacement of aggregate because it has the same stable chemical characteristic and physically the same as sand. Slag can bond and harden if react to water, so it can be the material for soil stabilization. Fly ash is the waste of coal combustion in thermal power station’s oven that has fine form and has pozzolanic character [1-2].

The aim of this research are to determine the soil classification based on Unified Soil Classification System (USCS) and value of unconfined compression strength soil with adding slag and fly ash mixture. The use of slag and fly ash can increase the ultimate bearing capacity because its pozzolanic and self-cementing character that able to stiffen and increase the power if it reacted with water.
2. Literature Review

Kusuma et al proposed the adding of coal waste in clay using unconfined compression test [3], and coal waste able to increase the unconfined compression strength value is 5.472 kg/cm\(^2\) in the mixture of 20% coal waste and curing for 28 days. Tora proposed the adding steel slag mixture [4], and steel slag able to decrease index plasticity (PI) and increase the unconfined compression strength value is 2.40 kg/cm\(^2\) in the mixture of 20% slag with 28 days of curing. Mina and Kusuma proposed clay stabilization using fly ash with reference to CBR value [5]. Based on the CBR test, the result shows that fly ash percentage is 20% and able to increase the CBR value is 38.6%. The adding of fly ash able to decrease the liquid limit and plastic limit then the index of plasticity tends to decrease as well. Sitorus proposed the adding of steel waste in clay using CBR test [6], the CBR value that was obtained by the 11% steel wash mixture with 1 day curing is 8.78%. By the rising of steel waste content, CBR value is keep rising up to 11% of steel waste mixture, then decreased and constant after 11% of steel waste mixture, however the CBR value is still greater than the original’s soil.

3. Research Methodology

This research consists of literature study and direct experiment in laboratory. Literature study is used from the beginning of the research until the analysis and conclusion. Direct experiment at laboratory consist of soil physical characteristic test, mixture the soil with slag and fly ash, compaction process, and unconfined compression strength test. In this research used the additional material of slag and fly ash mixture with the 10%, 20% and 30% of slag percentage and with 20% of fly ash. Curing period is 0 day, 7 days, 21 days and 28 days. Stages of this research and started with:

1. Collect the data
2. Survey and take the sample that will be the research object on the location
3. Obtain the physical characteristic of soil which are particle size analysis, atterverg limits, specific gravity, and water content.
4. Obtain the mechanical characteristic of soil which is soil compaction test
5. Conduct the unconfined compression strength test of sample that has been mixed with additional material as percentage as mentioned before, and the curing with mentioned variations
6. Conduct the Atterberg limits test, soil return to the soil that mixed with additional material in each mixture variation
7. Analysis the complete result then made the conclusion and idea for the next research.

4. Discussion

4.1. Soil property characteristics

Additive materials used are slag taken from PT.Krakatau Steel and fly ash taken from Suryalya PLTU. Slag and fly ash passed through sieve no. 40 (See Figure 1a and Figure 1b). Soil samples are crushed using a rubber hammer before being tested (See Figure 1c). Then the soils, water and additive materials are mixed according to the needs that have been calculated (See Figure 1d). Table 1 shows the result of particle size analysis, liquid limit, plastic limit, index of plasticity, specific gravity and soil compaction:

| No | Characteristic          | Value    |
|----|-------------------------|----------|
| 1  | Sieve Analysis          | 78.30%   |
| 2  | Specific Gravity        | 2.701    |
| 3  | Liquid Limit            | 58%      |
| 4  | Plastic Limit           | 37.525%  |
| 5  | Plasticity Index        | 20.475%  |
| 6  | Optimum Water content   | 35.40%   |
| 7  | Dry Volume Weight       | 1.28%    |
The result of particle size in the table 1. shows that the existing soil condition at Jalan Kadusentar Pandengang District - Banten is included in fine category of soil. Because the soil passed through Sieve no. 200 for more than 50% which is 78.3%.

![Soil samples and additive materials for testing: (a) slag passed through sieve no. 40 ; (b) fly ash through sieve no. 40; (c) existing soil; (d) soil mixed with slag and fly ash](image)

**Figure 1.** Soil samples and additive materials for testing: (a) slag passed through sieve no. 40 ; (b) fly ash through sieve no. 40; (c) existing soil; (d) soil mixed with slag and fly ash

### 4.2. Soil classification

Data from the particle size test, liquid limit, plastic limit and index of plasticity then matched to the table of USCS soil classification system. The result of this particle size analysis and atterberg limits can be concluded that according to the system at Jalan Kadusentar Pandengang District - Banten is included to MH soil class which is in-organic clay, silty clay, and fine sand [7-8].

![Graph of Relation Liquid Limit and Plasticity Index](image)

**Figure 2.** Graph of Relation Liquid Limit and Plasticity Index
4.3. The result of unconfined compression strength test
UCT is a test of the axial pressure of the sample when it is failure or when the axial strain reaches 20% [9]. UCT data taken three data and then taken the average value, the test is stopped until the soil samples has broken or shortened 20% of the samples height before being tested (See Figure 4).

On the figure 3. Relation of stress-strain can determine the qu value that taken in the maximum point. Taken from the qu graph = 3.900 kg/cm².

![Relation of Stress-Strain](image)

**Figure 3.** Graph of Relation Stress-Strain

4.4. The Value of unconfined compression strength with the period of curing
Figure 5 illustrates the relation of qu towards slag and fly ash percentage. It is shown that optimal qu value is obtained by the mixture with 20% of fly ash and 10% of slag. The more additional mixture, the dryer the soil will become so there’s a decrease of qu, this is caused of slag and fly ash’s characteristic to absorb water. Optimum qu is in the percentage of 20% fly ash + 10% slag as big as 8.393 kg/cm² with the curing period for 14 days long. Existing soil at Jalan Kadusentar Pandengang District - Banten is 1.407 kg/cm² including the stiff consistency and UCT value of 1-2 kg/cm² and qu after the mixing of soil with 20% fly ash + 10% slag content is 8.393 kg/cm² with 14 days of curing period including Hard consistency with the UCT value of >4kg/cm² [10-11].

![Figure 4](image)

**Figure 4.** (a) Unconfined Compression Test (UCT); (b) Test specimen after UCT testing
4.5. *The Value of unconfined compression strength with the percentage of slag and fly ash*

Figure 6 illustrates the relation of qu and curing period. It is shown that by adding the percentage of slag + 20% slag ash, qu value is increasing and optimum in 14 days curing then decrease to 21 days curing and 28 days curing. This matter is may be caused by the excess pozzolanic material that consisted in slag and fly ash in clays, so the cementation cannot be done, and the longer curing period, water will vaporize and caused the soil to be more fragile and the qu is decreasing.

4.6. *The result of soil’s properties with additional material*

| Material Percentage         | Liquid Limit (LL) % | Plastic Limit (PL) % | Plasticity Index (PI) % | Category       |
|-----------------------------|---------------------|----------------------|-------------------------|----------------|
| 0% Fly ash + 0% slag        | 58,000              | 37,525               | 20,475                  | High Plasticity|
| 20% Fly ash + 10% slag      | 37,200              | 30,650               | 6,550                   | Low Plasticity |
| 20% Fly ash + 20% slag      | 32,800              | 27,300               | 5,500                   | Low Plasticity |
| 20% Fly ash + 30% slag      | 29,700              | 25,040               | 4,660                   | Low Plasticity |
Tabel 2 showed that clays which contain more slag and fly ash, have lower plasticity index value. The lowest plasticity index on the percentage of 20% fly ash and 30% slag is 4.66%.

5. Conclusion

Based on USCS system soil at the research site is included in MH class which is inorganic clay, silty clay, fine sand with the liquid limit is 58%, plastic limit is 37.525% and plasticity index of 20.475% that can be classified as cohesive clays with high plasticity index, so this soil needs to be repaired. The adding of slag and fly ash in the soil able to increase the unconfined compression strength. The result with the 0 day curing is 1.407 kg/cm². The highest qu is 8.393 kg/cm² in the percentage of 20% fly ash + 10% slag is considered in Hard Consistency and able to decrease the plasticity index to <7% which means that soil is classified as low plasticity. Therefore, soil is really decent to be use as road subgrade because the soil property that improved by the decreased of swell-shrink of soil.

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