A study on the applicability of coal ash mixture to reclamation

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ABSTRACT

In general, reclamation with dredged soils requires a lot of time and cost. Few methods have been proposed to save these two factors. Using coal ash which is a co-product of thermal power generation has brought a great attention to researchers and engineers. Field tests were conducted and the results were analyzed to figure out the applicability of an artificial soil mixture with coal ash as a reclamation material. The ground composed of dredged soils and coal ash has a similar particle distribution to sand, and more cohesive and internal frictional angle than that with dredged soil only. In addition, the coefficients of horizontal consolidation and permeability were improved as well, which means the consolidation of the mixed ground could be accelerated.

Keywords: Artificial Soil Mixture(ASM), Coal Ash, Ash, Dredged Soil, Cone Penetration Test(CPTu)

1 INTRODUCTION

In order to make a land near the coastal area dredged soil is generally used as a filling material. However such a soil contains high moisture content and is too weak or soft to use for any kind of purposes. Therefore, additional treatments are required to improve their engineering properties. Unfortunately, those treatments demand a lot of time and cost. Several attempts have been made to overcome these two shortcomings. Especially, studies on the usage of industrial co-product as a filling material have widely conducted. In this study, an experimental approach was performed to figure out the applicability of coal ash that is a co-product of thermal power generation to reclamation. In order to investigate the physical and mechanical properties as well as settlement behavior of coal ash mixture a pilot test was carried out. In addition, the settlement of the original ground according to the ratio of the mixture was predicted to find out if the coal ash is adequate as a filling material.

2 FIELD TEST

2.1 Field Test Setup

The pilot test was carried out at the project area of SAEMANGUM industrial complex site 2. The test location is shown in Fig. 1.

![Fig. 1. Field Test location](image)

The test area is 280m X 130m. The dredged soils used in the tests were obtained from Kunjang Port, and the coal ash was sampled and delivered from the reclaimed land of Seocheon thermal power plant to Kunjang Port by ship. Having completed the delivery, the coal ash was mixed with sea water and transferred to the site by means of a transportation pipe. In order to obtain uniform mixture, the dredged soil and the coal ash were poured simultaneously using separate transportation pipe. The pipes were placed side by side.

During the test, the pouring volume was controlled so that the coal ash content remains less than 20%.

2.2 Site Investigation

A couple of boring investigations (BH-1, BH-2) were first carried out prior to the pilot test in order to
figure out the change of the ground status. Dividing two different grounds, a series of Piezocone penetration tests (CPTu), (CPT-1 ~ CPT-15), were performed on each ground respectively. In addition, several settlement plates (GP-1 ~ GP-4) were installed on the surface of the original ground to evaluate the settlement characteristics due to the coal ash mixed soil pouring. Fig 2 shows the locations of the boring investigations.

2.3 Soil Properties

According to the boring investigation results, the original ground is composed of reclaimed soil, silty sand, silty clay and weathered soil. On the undisturbed soil samples, basic laboratory tests such as moisture content, specific gravity liquid limit as well as plastic limit were conducted. The test results were presented in Table 1. To find out the basic characteristics of reclaimed coal ash the coal ash was first divided into two groups. One is Fly ash another is Bottom ash. Then specific gravity and particle distribution tests were carried on each group. The test results showed that the specific gravities of the fly ash and the bottom ash are 2.36 and 2.19 respectively.

### Table 1. Soil Properties

| Test ID | Depth (EL, m) | W (%) | Gs | LL (%) | PI (%) | USCS |
|---------|---------------|-------|----|--------|--------|------|
| BH-1    | -18.0         | 43.0  | 2.702 | 62.5   | 42.5   | CH   |
| BH-2    | -7.7          | 31.2  | 2.672 | -      | -      | ML   |
| -13.7   | 39.2          | 2.677 | 34.1 | 19.5   | CL     |
| -18.2   | 34.1          | 2.694 | 49.3 | 30.3   | CL     |

### Table 1. Soil Properties (continue)

| Test ID | Depth (EL, m) | quasi (kN/m²) | Ccu (kN/m²) | Cc | eo | cv (cm²/sec) |
|---------|---------------|---------------|-------------|----|----|--------------|
| BH-1    | -18.0         | 81.325        | 48.265      | 0.52 | 1.093 | 1.6E-03    |
| BH-2    | -7.7          | 29.528        | 16.579      | 0.15 | 0.879 | 3.96E-03  |
| -13.7   | 43.262        | -             | 0.49        | 1.055 | 4.00E-03 |
| -18.2   | 91.527        | -             | 0.39        | 0.923 | 2.80E-03 |

Meanwhile, the particle distribution test results showed that the fly ash is close to silt and the bottom ash is similar to sand. The particle distribution curves of each ash are shown in Fig 3.

3 CHARACTERISTICS

3.1 Physical Characteristics

Sieve analysis was performed on the mixed soils sampled at the location of the cone penetration test. According to the result, it appears that the coal ash affects the particle distribution curve, which becomes gentle and similar to that of sand. The average particle size of the coal ash mixed soil (D50) is 0.31. This is larger than that of dredged soil, of which average particle size is 0.15. From these findings, it is concluded that coal ash can improve the characteristics of compression as well as strength of dredged soil. Fig 4 shows the particle distribution curve of the coal mixed soil.

![Fig. 4. Particle size distribution curve(ASM)](image-url)

3.2 Mechanical Characteristics

The change of mechanical characteristics of the ground due to coal ash mixing was investigated by analyzing the results of the Piezocone penetration tests (CPTu). Also, direct shear tests were conducted on the samples obtained during the cone penetration test. The results show that the cohesion of the mixed soil is larger than that of dredged soil as much as 2.4 up to 4times. Likewise, the internal friction angle of the mixed soil that is more than 30 degree appears to be greater than that of the dredged soil which is 27degree. Although it is a little difficult to evaluate the CPTu test results quantitatively due to uncertainties affecting the tests location by location it appears that the tip resistance of the ground with mixed soil increases more than 2 times compared with the dredged soil ground itself. (Fig. 5, 6, 7)
Through the pore water dissipation test carried out during the pilot test, the horizontal permeability ($k_h$) and the horizontal consolidation coefficients of both the mixed soil ground and the dredged soil ground were compared each other. The horizontal consolidation coefficient was taken an average the values estimated using the equations proposed by Torstensson, Houlsby & Teh and Teh. The results show that the horizontal permeability and the horizontal consolidation coefficient of the mixed soil ground increase over all compared with the dredged soil ground. However, no quantitative trends according to measurement depth and location were observed. That might be due to the particle distribution change of the ground constructed along the location of discharge pipe. In general, coarse soil is sinking near the pipe, and the finer is sinking as distance from the pipe increases.

4 SETTLEMENT

4.1 Settlement Prediction

In order to predict the settlement characteristics of the ground after pouring the coal ash mixed soil or the dredged soil, numerical analysis was carried out based on the pilot test results. The analysis was performed using the commercial software, SAGE-crisp. The numerical analysis was conducted on the same cross section as the soil layer verified through the boring investigation. Again, the analysis was performed on two different conditions. One is the coal ash mixed soil another is the dredged soil. The predicted settlement was compared with the measured value. Fig 10 shows the cross section used for the numerical analysis.
Fig. 11 presents the result of comparison between the prediction and the measurement. With analysis separating the results with respect to the embankment height it is clear that the prediction has a good agreement with the measurement.

Looking at Fig 12, it appears that the coal ash mixed soil can accelerate the settlement of the original ground, and that the settlement increases as much as 8%.

5 CONCLUSIONS

A field test is carried out to evaluate the applicability of reclamation with coal ash mixed soil. Based on the comparison of the physical and the mechanical characteristics on both dredged soil and coal ash mixed soil the following conclusions have been derived.

1) The coal ash mixed soil has a well grade particle distribution, and the average particle size increases
2) The coal ash seems to improve the horizontal consolidation coefficient as well as permeability, which can accelerate the consolidation of the ground
3) Cohesion and internal friction angle of the coal ash mixed soil increase remarkably. It is expect that the coal ash shall have a good effect on the improvement of mechanical characteristics of the dredged soil.

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