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EXTENDED ABSTRACT

Behavior Comparison of Marl and Dredged Soil Stabilized with Electric Arc Furnace (EAF) and Basic Oxygen Furnace (BOF) Steel Slags

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1. Introduction

Tabriz marl soil are Lake Carbonated sediments. The percentage of organic matter in this soil is less than 6%; and does not fit into the classification of organic soils. The carbonate content of this soil is from 10 to 35%. The classification of this soil is mostly CH and in some cases MH (Mahouti and Katabi, 1397). Dredged soil is not much different from conventional fine-grained soil and can be used in a variety of applications with stabilization. Due to poor geotechnical properties; they are stabilized for use in dredging materials in engineering applications (Chan and Shahri, 2016). To stabilize the soil; Stable stabilizers (such as steel slag and industrial waste) have been proposed to replace cement. In the meantime, the environmental compatibility (safety in terms of pH and harmful substances, such as heavy metals and toxic substances) of BOF slag (as soil stabilizer and filler) has been confirmed. Therefore, the use of steel slag; In addition to reducing project costs and environmental problems caused by lime and cement production (reducing CO2 emissions and energy consumption), it does not pollute the environment and eliminates the problem of accumulation of by-products of the industry (Proctor et al., 2000; Motz and Geiseler, 2001; Kang et al., 2019).

2. Methodology

2.1. Experimental study

In this Study, Tabriz Marl and Persian Gulf Dredged (PGD) Soil are stabilized with Electric Arc Furnace (EAF) and Basic Oxygen Furnace (BOF) Steel Slags. Based on AASHTO, Classification of both soils are A-3. According to Iranian Manual no. 268 (268, 2003) and PCA Handbook (Portland Cement Association, 1992), the recommended amount of cement for A-3 soil stabilization is 9% and about 7 to 11%. Therefore; According to the purpose of the study to use fine-grained slag instead of cement and the weaker adhesive properties of slag than cement; 9, 12, 15 and 20 percent of fine-grained slag were considered for soil stabilization. To compare the effect of stabilization, Unconfined Compressive Strength (UCS) tests were done.

2.2. Specimens

Due to the lack of adhesion properties in the PGD soil, it was not possible to make a sample of it. Therefore, the selected specimens were:

- Marl soil;
- Marl soil stabilized with 9%, 12%, 15% and 20% of BOF slag fine grains (passing no. 40 sieve);

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- Marl soil stabilized with 9%, 12%, 15% and 20% of EAF slag fine grains (passing no. 40 sieve);
- PGD soil stabilized with 9%, 12%, 15% and 20% of BOF slag fine grains (passing no. 40 sieve);
- PGD soil stabilized with 9%, 12%, 15% and 20% EAF slag fine grains (passing no. 40 sieve);.

After preparing the samples, they were cured in a humidity room for 7 days.

3. Results and discussion

3.1. UCS Test Results

Fig. 1 compares the Ultimate UCS strengths of the tested samples. As can be seen in this figure, EAF slag has no significant effect on the growth of marl soil strength. This effect is less in the case of PGD soil. In the case of soil stabilization, BOF slag has developed a higher strength. In the case of marl, the noticeable increase in ultimate strength of up to 3.8 kg/cm^2 confirms this. Also, it can be clearly seen that increasing the amount of BOF slag after 12% reduces the final strength of the stabilized marl soil. Therefore, 12% of BOF slag can be considered as the optimal value. In the case of PGD soil, there is no optimal amount; as the amount of additive increases, the UCS strength of the stabilized PGD soil increases. Therefore, for PGD soil, applying 20% BOF slag increases the strength up to 1.8 kg/cm^2. The strength of this sample is close to 0.64 the strength of the marl soil sample stabilized with 20% BOF slag; and 0.47 of the maximum UCS strength of marl soil. Due to the similar classification of both soils used in the study, the difference between these two types of soils is chemically and the amount of fine grains (clay minerals) (PI number). PGD soil is obtained from the marine environment; therefore, this soil contains some sulfate. On the other hand, PGD soil does not have fine garins. These reasons have caused the difference between the stabilization behavior of these soils and fine-grained steel slag. This can be clearly seen in Figure 1. The ultimate strength of fine-grained marl soils stabilized in most samples is higher than that of stabilized dredged soils. In fact, only the final strength of the PGD soil with 20% BOF sample is comparable to marl soil samples.

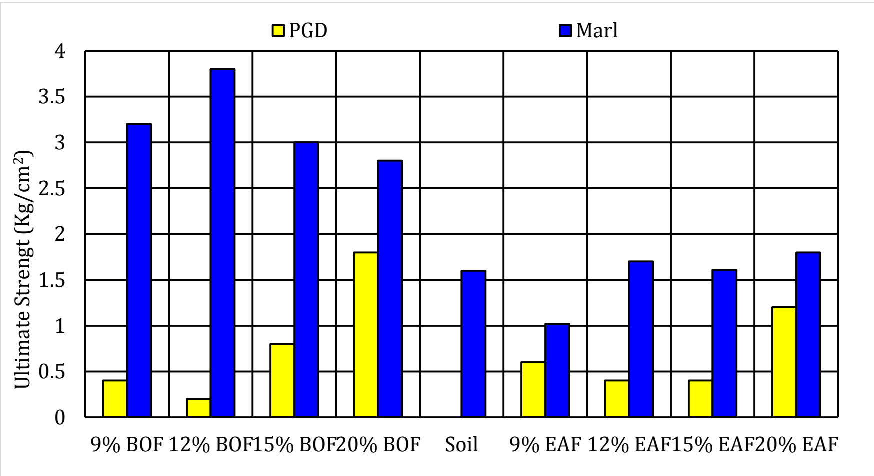

Fig. 1. Comparison of ultimate strength of Marl and PGD soils stabilized with EAF and BOF fine-grained steel slag and marl soil

3.2. Elastic Modulus (E_{50}) Comparison

Figure 2 shows the values of the Elastic Modulus (E_{50}) of the stabilized specimens. Except for soil sample stabilized with 9% EAF slag; as the amount of slag increases, the amount of Elastic Modulus (E_{50}) of the stabilized PGD soil samples increases. The growth of this coefficient is higher in the case of BOF-stabilized samples. In the case of marl soil samples stabilized with EAF, there is not much growth compared to the virgin sample and the elasticity of samples contain 9% and 15% of EAF slag has also decreased. Of all the specimens, BOF-stabilized marl specimens are in the best condition. The value of the Elastic Modulus (E_{50}), like the UCS strength, is maximum in a sample with 12% BOF slag. By increasing the amount of BOF slag to 15% and 20%, the value of Elastic Modulus (E_{50}) decreases.

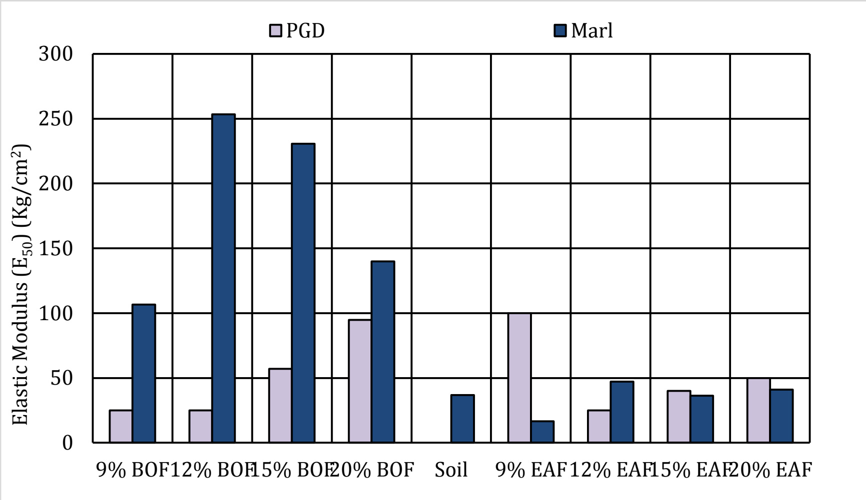

Fig. 2. Comparison of Elastic Modulus (E_{50}) of Marl and PGD soils stabilized with EAF and BOF fine-grained steel slag and marl soil

4. Conclusions

Based on studies performed by UCS Tests on marl and PGD soils stabilized with EAF and BOF steel slags, the following results can be inferred:

• The average UCS Strength of PGD soil is 1.6 kg/cm^2 and its average final strain is 10%. As the BOF slag contain increases to 12%, the UCS Strength of the stabilized marl increases and then decreases. Therefore, 12% of BOF steel slag is considered as the optimum value. The increase in UCS Strength of marl soil stabilized with BOF steel slag is about 140%. In general, BOF slag caused the brittle behavior of the studied marl soil.

• The addition of EAF steel slag does not cause much change in the UCS Strength of marl soil; Even the use of 9% EAF slag reduces the strength by up to 40%. The maximum increase in the stabilization resistance of marl soil in this case is 13%, which is obtained by adding 20% of EAF slag. EAF slag fines soften marl soil behavior.

• Stabilization of PGD soil with BOF slag is more successful than stabilization with EAF slag. The maximum UCS Strength of stabilized PGD soil is achieved for 20% BOF slag. However, the UCS Strength of these samples is significantly different from that of stabilized marl soil samples; the maximum strength of the stabilized marl is 2.11 times that of the stabilized PGD soil sample.

• Adding 12% of EAF slag to the marl soil increases the Elastic Modulus (E_{50}) to 47.22 kg/cm^2. This value is the largest increase of Elastic Modulus (E_{50}) due to stabilization with EAF slag. Stabilization of marl soil with 12% BOF slag (optimum value) increases the Elastic Modulus (E_{50}) of marl soil from 36.92 to 253.33 kg/cm^2. Clearly, the addition of 12% BOF slag has the greatest effect on stabilizing marl soils. In the case of PGD soil, the maximum Elastic Modulus (E_{50}) in a sample with 9% EAF slag is 100 kg/cm^2. In the case of other stabilized PGD soil samples; Addition of 20% BOF slag resulted in an increase in the Elastic Modulus (E_{50}) from 25 to 94.74 kg/cm^2. Obviously, in the case of Elastic Modulus (E_{50}), like UCS strength, the stabilization of marl soil had a more significant effect than PGD soil; So that the maximum Elastic Modulus (E_{50}) of stabilized marl soil is more than 2.5 times that of stabilized PGD soil.

• Due to the similarity of EAF and BOF Steel slags and the classification of soils used in this study; The main reason for the difference in the measured values is the lack of fine grains (clay minerals) and the presence of sulfate ions in the PGD soil and the effect of these substances on the chemical reactions between the soil and the fine-grained steel slag in the stabilization process.

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