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Numerical and Experimental Investigation of Optimal Soil Improvement with Lime and Cement and Its Impact on Reduction of Settlement in West Tehran Wastewater Treatment Plant

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ABSTRACT: In this research, lime and cement additives were used to stabilize clay and therefore to reduce the settlement in raft foundations. Lime and cement were mixed with clay and the effect of the use of these two additives on the stabilization of fine clay soil in the laboratory was investigated. Soil samples in normal state and combination with different percentages of lime and cement equal to 3%, 6%, and 8% dry weight of soil for laboratory tests including Atterberg limits test, grading test, standard compaction test, uniaxial compressive strength test, and California bearing ratio test. Also, the consolidated undrained triaxial compression strength test (CU) and direct shear tests were used. The results showed a decrease in the plasticity and maximum dry density of soil and an increase in optimum moisture content, compressive strength, and also the California bearing ratio of clay by adding these two materials. The cohesion and internal friction angle obtained from consolidated undrained triaxial compression strength tests (CU) and direct shear tests increase with increment of cement and lime percentages. After laboratory tests, the effects of the use of soil improvement with depths of 1m, 2m, 4m, 6m, 8m, and 10m using Plaxis2D software suggests that as the depth of improvement increases, the number of settlement decreases, which is a lot different from that of the plate loading test before improvement while the difference between the results obtained from Plaxis2D and plate loading test after improvement is negligible.

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1. INTRODUCTION

Cement and lime are among the stabilizing materials that have a favorable effect on clay soils. Cation exchange takes place between the calcium ion of lime and the various cations that accumulate on the surface of the soil, causing the clay particles to move closer together, a process called flocculate. The second category of reactions, namely long-term reactions (pozzolanic), increase the strength of clay soils [1]. Studies show that the strength behavior of soils improves after stabilization with lime. Cement, which is another additive used to stabilize the soil, has pozzolanic materials and along with water, it becomes a binder and binds the soil grains together. In cement-stabilized soils, the strength increases over time. In the early days, the increase in strength is faster, but over time, the rate of increase in strength decreases [2].

2. METHODOLOGY

West Tehran treatment plant units will include a complete biological treatment system by activated sludge method with the ability to remove nitrogen and phosphorus along with sludge processing facilities. First, the prepared soil grading was done at a depth of 5 to 5.4 meters, and then the liquid and plastic limits of the soil were measured. Samples mixed with cement were treated for 7 days and samples mixed with lime for 28 days at 23 °C. To prevent the carbonation of lime and cement and to prevent the reduction of moisture, treatment of the samples was done in plastic coatings [3]. The amount of lime and cement for the experiments is equal to 3%, 6%, and 8% by weight of dry soil. The laboratory program in this research includes the following phases: A) primary laboratory tests including grading, Atterberg limits, and standard compaction tests; B) uniaxial compressive strength test, direct shear test, consolidated undrained triaxial compression strength test (CU), and California bearing ratio (CBR) in different amounts of lime and cement; C) plate load test at the project construction site. After performing laboratory experiments, Plaxis2D software was used to estimate the amount of settlement under a mat foundation with a width of 20m and a uniformly distributed load of 1 kg/cm^2. To validate the accuracy of the results of the settlement based on the load, the plate loading test was performed on-site.

3. RESULTS AND DISCUSSION

According to Figs. 1 and 2, by mixing lime and cement with soil, the maximum dry density and plasticity index compared to natural soil is changed. The amount of change depends on the type of additive. So that lime and cement up

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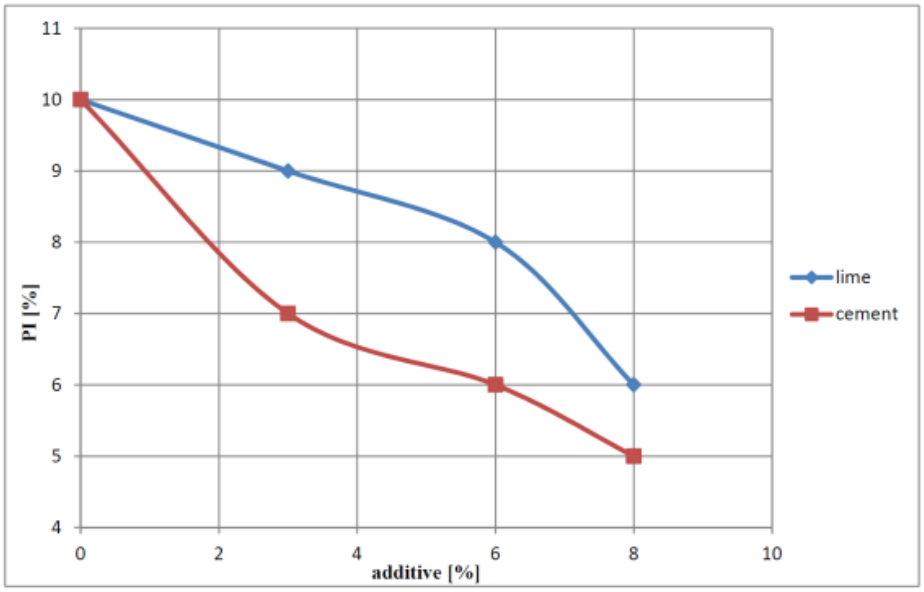

Fig. 1. Plasticity index diagram for soil mixed with different percentages of lime and cement

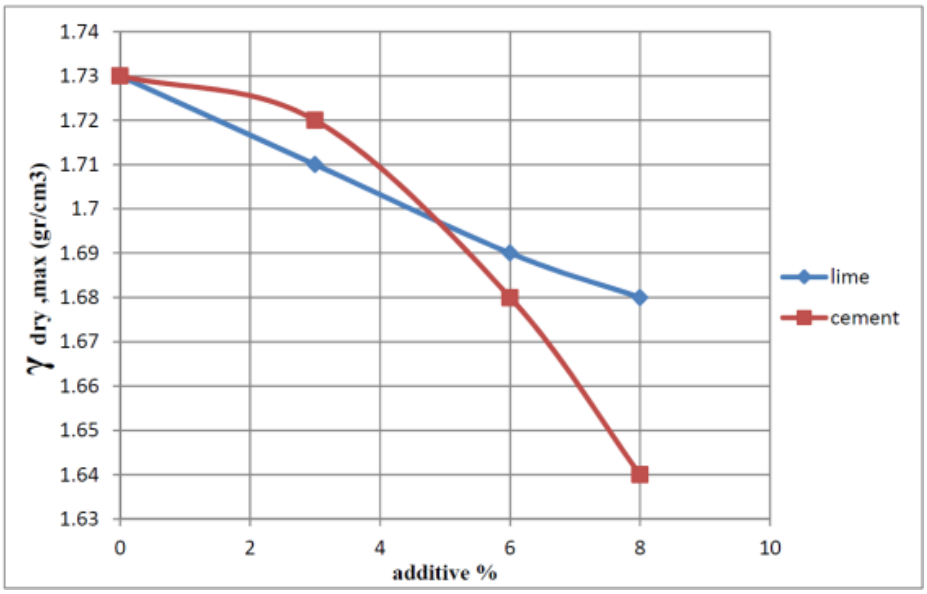

Fig. 2. Maximum dry density diagram for soil mixed with different percentages of lime and cement

to 8% of dry soil weight reduce the maximum dry density and range of soil plasticity index.

As can be seen in Figs. 3 and 4, by increasing the percentage of mixing cement and lime into natural soil, the percentage of optimum moisture has increased. The reason for this event is theoretically flocculation of the aggregates and the increase of the plastic limit for lime and the agglomeration of the soil particles for cement which is due to the hydration of the cement [4-6].

The amount of compressive strength with the addition of cement up to 8% and the amount of California bearing ratio with the increase of cement and lime has increased up to the same amount.

4. CONCLUSION

1- Cement causes more reduction in the range of soil plasticity index than lime.

2- The optimum soil moisture percentage increases with increasing lime and cement.

3- The maximum dry density of stabilized soil decreases with increasing lime and cement.

4- Both additives increase the California bearing ratio. The effect of cement is more effective.

5- Additives increase the uniaxial compressive strength of the soil, but cement is more effective.

6- The results of direct shear and consolidated undrained triaxial (CU) tests show cohesion and internal friction angle

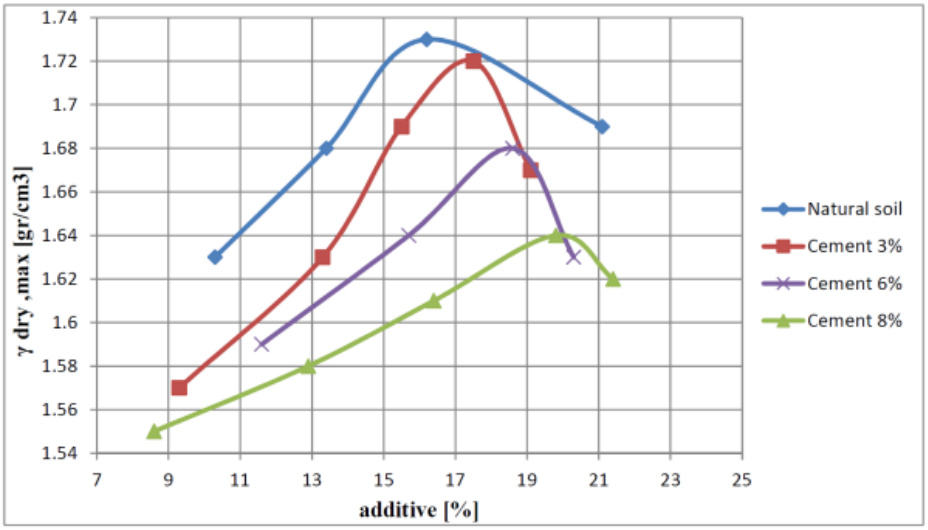

Fig. 3. Maximum dry density versus optimal moisture content for different percentages of cement

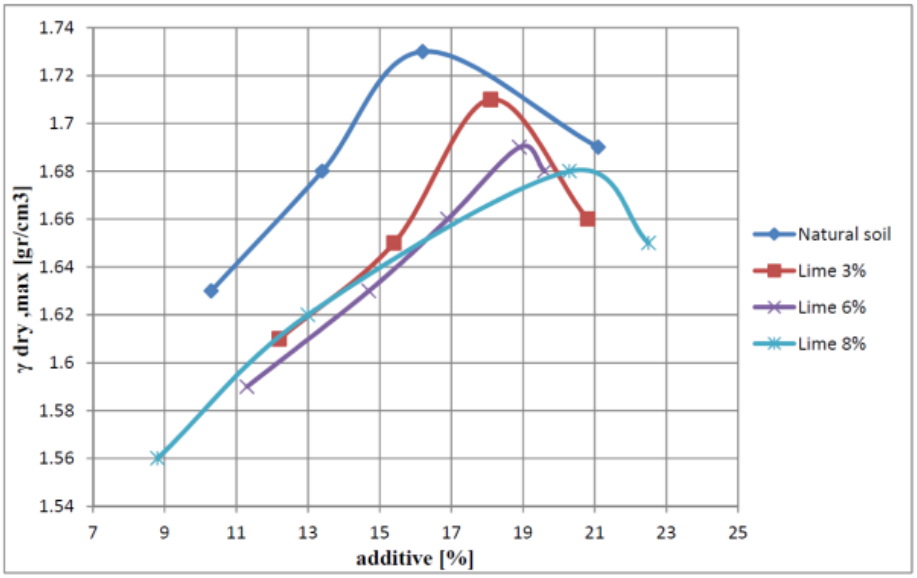

Fig. 4. Maximum dry density versus optimal moisture content for different percentages of lime

of the soil increases by adding both materials.

7- The addition of lime and cement has reduced settlement.

8- By increasing the percentage of lime and cement and improving depth, soil settlement decreases.

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