Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(2) (2021) 153-154
DOI: 10.22060/ceej.2020.16461.6238

Evaluation of a by-product and enviromental-friendly chemical additives for clay soils with different mixing and curing methods

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ABSTRACT: Soil stabilization is one of the most important methods of improving the soil in geotechnical engineering. Traditional stabilizers such as cement and lime have long been used and investigated, however, the use of these materials has environmental problems. Calcium lignosulphonate is a natural polymer produced from waste from the paper and timber industry. In this study, the effect of adding different percentages of ligno on Atterberg limits, compressive properties, and uniaxial clay strength is investigated, the effect of ligno addition by different mixing methods on soil strength and soil morphology is also investigated. The results of experiments showed that adding ligno generally improves soil mechanical properties, decreases soil plasticity index (PI), and increases soil strength and ductility. For the soil used in this study, the optimum percentage of calcium lignosulfonate additive was determined 1% soil by dry weight, which was able to increase the soil resistance from 322 to 828 kPa (2.5 times increase) after 28 days.

Review History:

Received: 6/1/2019
Revised: 7/15/2019
Accepted: 10/9/2019
Available Online: 4/27/2020

Keywords:

Soil Stabilization
Calcium Lignosulfonate
Clay
Eco-friendly
Mixing Method

1. INTRODUCTION

Clay soils that are spread all over the world have little resistance and, if moist, swell and squeeze and settle due to incoming loads [1]. To solve the problem, the soil should be improved. One of the best and most cost-effective ways to improve is soil stabilization. Many researchers have investigated the properties of traditional stabilizers such as cement, lime, fly ash, etc., and have shown that adding these materials to soil increases the strength and durability of clay soils and reduces their swelling potential [2,3]. But their use has been restricted in recent years due to health and environmental problems. For example, these substances increase soil and groundwater pH, causing corrosion of buried structures in the soil and reducing their useful life. Soil stabilization with these materials mechanically causes the soil to show brittle behavior that can be hazardous when the soil is under dynamic loads. In the process of producing these stabilizers, in addition to consuming a lot of energy, large amounts of greenhouse gases are released into the atmosphere, causing significant environmental damage [4]. Many researchers are trying to stabilize the soil using waste materials. Calcium lignosulphonate is obtained from the waste paper and timber industry during an industrial process, and according to available statistics, 50 million tons of waste is disposed of annually [5].

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2. METHODOLOGY

1. Materials

The soil used in this study was sampled from the southern part of Tehran province at a depth of 50 cm. The results of soil identification experiments are shown in Table 1

The calcium lignosulfonate used is the scrap and waste of the paper and timber industry that is obtained during the industrial process after the wood chips are removed. The size and shape of calcium lignosulfonate powder are very similar to cement and its grain size is about 10 to 25 microns.

2. Laboratory tests

The Atterberg limits Experiment was performed to investigate the changes in the plasticity index due to the addition of ligno on the stabilized and non-stabilized specimens. In this experiment, LS was added to 0.5, 0.75, 1, 2, and 4% soil dry weight, additive, and mixed well.

To determine the effect of the additive on soil compaction characteristics, a standard compaction test was conducted to investigate the changes in optimum moisture content and maximum dry weight as a result of ligno addition, also to investigate the effect of calcium lignosulfonate addition on shear strength of unconfined compressive strength test on unstabilized and stabilized specimens with 0.5, 0.75, 1, 2, 4% soil dry weight after 7,14,28 days were performed. It should be noted that in soil stabilization, especially chemical

Table 1- Characteristics and physical properties of the soil used in this study

Properties of soil	content
Classification by unified system	CL
Liquid limit	24.3%
Plastic limit	13.9%
Plasticity Index	10.4%

stabilization of soils, the method of mixing with soil is of particular importance. The more appropriate the distribution of the additive, the more links and reactions will be achieved. In this study, considering the physical state of calcium ligno sulfonate, three different mixtures of mixing were investigated.

3. RESULTS

The addition of calcium lignosulfonate increases the plastic limit and liquid limit, but the slope of the plastic limit increase (PL) is higher than the liquid limit (LL), thus reducing the plasticity index (PI). The addition of calcium lignosulfonate resulted in a slight reduction in the maximum specific weight of the soil, from 1.74 to 1.65 g / cm3. The reduction in maximum specific dry weight in clay soils can be due to the bonding between the soil particles and the slight trapping of the soil between the grains. This causes the clay grains to not settle in the densest possible state and to trap a small amount of water or air between the soil particles.

Stress-strain diagrams of samples stabilized with different percentages of calcium lignosulfonate indicate that the addition of calcium lignosulfonate increased the unconfined resistance. The highest resistance obtained was 1% of the additive, which is the optimum additive percentage for this type of soil. According to the stress-strain diagram, with increasing additive percentage, in addition to increasing resistance to natural soil, the behavior of the sample becomes noticeably ductile. For example, the specimen stabilized with 4% calcium lignosulfonate reached after 28 days from 322kpa to 590kpa (80% increase) and tolerated up to 17% strain. This means that if the amount of calcium lignosulfonate added is higher than the optimum value, in addition to increasing resistance to unstabilized soil, the soil ductility will increase. The optimized sample with the optimum percentage of additive (1% calcium lignosulfonate) also reached 828kpa (2.5-fold increase) after 28 days of curing. The reason that the samples are formed by the addition of calcium lignosulfonate can be attributed to the formation of hydrogen bonds (which are highly flexible) and the trapping of a small amount of air between the soil grains during the bond formation. Increased soil strength due to stabilization with calcium lignosulfonate is due to the formation of inter-particle bonds (ionic, covalent, and hydrogen). Stress-strain diagram of samples treated with 1% calcium lignosulfonate in different mixing methods after 28 days showed that the highest resistance was obtained by mixing method2 and the least resistance was obtained by mixing method1. The difference in the amount of resistance is due to the better distribution of the additive among the soil grains.

4. CONCLUSION

The test results showed a decrease in the plasticity index. The results of the standard compaction test showed that by adding calcium lignosulfonate the optimum moisture content increased and maximum dry density decreased. These changes are due to the trapping of small amounts of weather between the soil particles.

The unconfined compressive strength test showed that the soil strength was generally increased by the addition of calcium lignosulfonate and the highest increase in strength was observed in the 1% additive-stabilized sample, which increased from 322kpa to 828kpa(2.5-fold increase).

The results of the unconfined compressive strength test of samples mixed with different methods showed that the mixing method had a significant effect on the compressive strength of the specimens. A sample mixed with method 2 was 80% more resistant than sample mixed with default method1.

Investigation of soil morphological changes using electron microscopy (SEM) test results showed that due to the addition of calcium lignosulfonate, boundaries between clay particles and soil grains formed by forming hydrogen bonds and covalent bonds.

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HOW TO CITE THIS ARTICLE

A. S. Giahi, M. Jiryaei Sharahi, B. Mohammadnezhad, Evaluation of a by-product and enviromental-friendly chemical additives for clay soils with different mixing and curing methods, Amirkabir J. Civil Eng., 53(2) (2021) 153-154.

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