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Effect of Using Ion Exchange Solution in Increasing Bearing Capacity of Clayey Soils with Various Plasticity Index (PI)

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ABSTRACT: At the most of executive project in Iran, using Tetrabromomethane (CBR+4) ion stabilizer solution is a chemical ion-exchange experiments. The necessity of present study is the investigation about the characteristics of strength behavior of clayey soils with various plasticity index (PI) stabilized by this method. The performance of stabilized soil samples by CBR+4 ion-exchange solution in wetting-drying and freeze-thaw cycles also been studied for the first time in this study. Firstly, in soil stabilization with CBR+4 solution the required amount of the stabilizer is determined, according to the amount of soils ion exchange, which is determined by a laboratory chemical test. Then, the samples are built in their optimum moisture content and maximum dry densities and after curing the samples for two weeks, dry samples are tested. Soils samples are also tested in saturated condition after two weeks curing time. Saturated samples showed more increase in strength compared to dry samples. Stabilized soil sample are also tested under 1 to 4 freeze-thaw and wetting-drying cycles. Tests results showed that using CBR+4 stabilizer increase bearing capacity of clayey soils. This increase is higher in soils with lower PI. Although freeze-thaw and wetting-drying cycles reduce soils bearing capacity, their strength are significantly more than the un-stabilized samples and is acceptable.

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1- Introduction

Use of traditional geotechnical engineering techniques for infrastructure, such as the replacement of unsuitable soils for stiff and resistant embankment, is often problematic, not only for their high costs, but even more for environmental reasons. In roads, for instance, the use of granular bases becomes unsuitable when the extraction site is at a significant distance from the construction site [1].

Application of stabilization agent on soils has a long history. Many materials such as lime [2], fly ash [3] and organic polymers [4] were used as stabilizing agents. When lime is added to a clayey soil it has an immediate effect on the properties of the soil. With adding lime, cation exchange begins to take place between the metallic ions associated with the surfaces of the clay particles and the calcium ions of the lime. One of the ways to make clayey soils suitable for construction is altering the properties of soil. This way increases the strength, reducing compressibility, swelling or shrinkage and the durability of soils. Ion exchange is one of the methods for stabilization of clayey soils. It is well-known that the swelling properties of expansive soils significantly are affected by cation exchange capacity [5]. Ion exchange occurs when some of the additive such as fly ash, lime, cement and ion exchange solution are added to these soils. There are many ion-exchange solutions soil stabilizer and one of the best and most economical ion-exchange solution was used in this paper and it is CBR^{+4}.

The objective of this paper is to investigate the bearing ratio capacity of two clayey soils that are stabilized with CBR^{+4} ion exchange solution. The tests were carried out on three clayey soils with different doses of CBR^{+4}. The test results also were discussed in detail and compared with each other.

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2- Materials

2- 1- Soil

In this experimental study the Abyek clay were used as basic material. Then different bentonite contents (0, 10 and 20 wt. %) were added to Abyek clay to achieve different plasticity indexes. Two soils are classified as low plasticity soil according to the unified soil classification system (ASTM D422-87) and their name according to USCS is CL (clayey soil with low plasticity) and one soil is classified as high plasticity soil. The optimum moisture contents and maximum dry densities of soils were obtained according to ASTM D4318 (Table 1). Engineering properties of mentioned soils are presented in Table 2.

Soil samples for CBR test were compacted with their optimum moisture contents value and the respective dry densities.

Table 1: Compaction properties of tested clayey soils

Soil	Maximum dry unit weight (γ_d) (gr/cm^3)	Optimum moisture content (ω_{opt}) (%)
A	1.84	16.2
B	1.79	17
C	1.76	17.9

Table 2: Engineering properties of tested clayey soils

Soil	LL	PL	PI	USCS
A	34.8	21.7	13.1	CL
B	41.7	21.9	19.8	CL
C	52	24.1	27.9	CH

2- 2- CBR^{+4} Solution

CBR^{+4} solution is a stabilizer for anionic soils that can improve the bearing capacity of a variety of clayey soils. Soils that normally are not suitable for road construction can now be treated with CBR^{+4} for base and sub-base. Clay minerals inherently have a predominantly negative electrical or anionic charge, this causes the clay minerals to have strong attraction for any cation that are presented. These negative clay minerals attract cations like iron filings to a magnet and will react with water. Normal temperatures and compaction pressure will not remove them. This layer of water is known as the electrostatic diffused double layer of adsorbed water [5].

3- Experimental Program

3- 1- Test Procedure

To study the effect of various amounts of ion exchange CBR^{+4} on the bearing ratio of clayey soils with various plasticity index (PI), a series of California Bearing Ratio (CBR) tests were conducted on soaked samples for different amount of CBR^{+4} solution. For soaked condition, the samples were immersed in water for 96 hours. The purpose of different amounts of ion exchange solution is to investigate the effect of each variable on bearing ratio of different soil samples. In order to investigate the effect of freeze- thaw cycles, after removing of water, samples were put inside the freezer for 24 hours at -15 °C and then were placed at the lab for 24 hours to thaw. For wetting- drying cycles, samples were placed 24 hours out of the water and in the lab for the loss of moisture and then 24 hours in the water to increase moisture.

3- 2- - Preparation of Samples

The bearing ratio mold is a rigid metallic cylinder with an inner diameter of 152 mm and a height of 178 mm that 61 mm of its height is filled with a circular metal disk. To prepare the samples, oven-dried clayey soils were mixed with their optimum moisture content. The soil that was mixed with its optimum moisture was placed in five layers at the bottom of the mold. Each layer was compacted by 56 blows of a 44.5-N rammer dropped from a height of 457 mm. To prepare the soaked samples, the mold containing clayey soil was immersed in water, allowing free access of water to the top and bottom of the samples, and was allowed to soak for 96 hours (ASTM D1883-99).

3- 3- California Bearing Ratio (CBR) Test

The bearing ratio is one of the fundamental parameters used to demonstrate the behavior of soil in geotechnical projects including roads, railroads, pavements and airport runways. To demonstrate the influence of different variables on the bearing ratio of the clayey soil stabilized with CBR^{+4} solution, a series of bearing ratio tests were carried out on stabilized and un-stabilized specimens.

The bearing ratio tests were conducted under dry and soaked condition according to ASTM D1883-99. CBR tests are conducted with a mechanical loading machine equipped with a movable base that moved at a uniform rate of 1.27 mm/min. The diameter of the piston is 49.6 mm. The loads were recorded as a function of penetration depth up to a penetration of 10 mm.

4- Results and Discussion

Bearing ratio tests were carried out for both stabilized and un-stabilized clayey soils with different amounts of CBR^{+4} at optimum moisture contents values of each soils. In this study different ion exchange solution doses were considered for three clayey soils to investigate the influence of the amount of this stabilizer on the strength of soaked and dry samples.

Figure 1 shows CBR values versus various doses of CBR^{+4} for dry soils. Based on these finding, it can be inferred that dose of CBR^{+4} doesn't play any significant role in the behavior of soil with higher plasticity index and this can be due to less ion exchange. It shows that soil with higher PI can't properly accept cation (positive charge) from CBR^{+4} solutions. With increasing CBR^{+4} more than specific value, more solution without any reaction remains in the soil and this can deteriorate its strength.

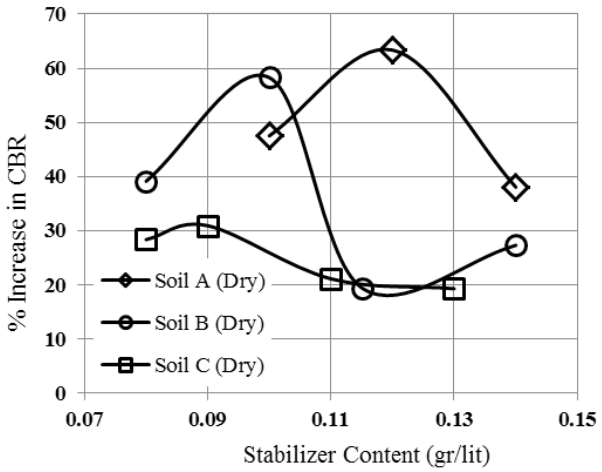

Figure 1: Increase in CBR versus different stabilizer content

Figure 2 shows CBR values versus number of freeze-thaw cycles. As it is seen, it can be inferred that number of freeze-thaw cycles affect the resistance of samples.

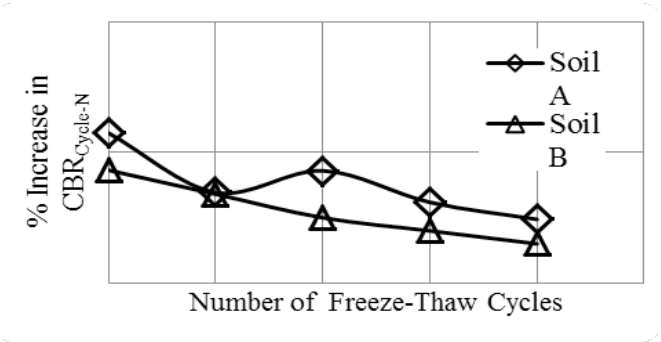

Figure 2: Decrease in CBR versus number of freeze-thaw cycles

Figure 3 shows CBR values versus number of wet-dry cycles. Based on these finding, it can be noted that number of wet-dry cycles affect on the resistance of samples and lead to decrease of resistance.

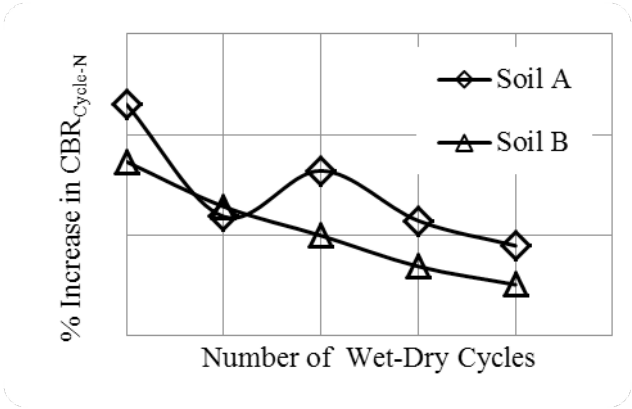

Figure 3: Decrease in CBR versus number of wet-dry cycles

5- Conclusion

To study the behavior of clayey soils that have been stabilized with CBR^{+4} ion exchange solutions, several CBR tests were conducted on the stabilized and un-stabilized soils. The following conclusion can be drawn from the test results:

- CBR^{+4} solution is a stabilizer that has cation ions and can be used for soils that have anion ions.
- Plasticity index (PI) of clayey soils plays a fundamental role in stabilization with CBR^{+4}. This study showed that the stabilization efficiency decreases with increasing PI. Adding excessive does of CBR^{+4} solution have a negative effect, because some of this stabilizer remains in the soil without any reaction and reduces the strength of soil.
- Apply freeze-thaw cycles in clay soils with different PI that stabilized by ion exchange solution CBR^{+4} generally reduces resistance of samples.
- Apply wetting-drying cycles in clay soils with different PI that stabilized by ion exchange solution CBR^{+4} generally reduces resistance of samples.

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