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Testing stabilization of high-plasticity clays used in sloping terrain by adding sodium silicate

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Testing stabilization of high-plasticity clays used in sloping terrain by adding sodium silicate

C H Flórez-Góngora[1], **A T Garzón-Peña**[1], **and R D Molina-Giraldo**[1]
[1] Grupo de Investigación en Geotecnia Ambiental - GIGA, Universidad Francisco de Paula Santander, San José de Cúcuta, Colombia

E-mail: carloshumbertofg@ufps.edu.co

Abstract. High-plasticity clays can be stabilized by the addition of a small percentage of sodium silicate. Sixteen mixtures of 4000 g with different concentrations of sodium silicate at difference percentage were designed, to which were carried out physical, mechanical and chemical characterization tests that allowed to analyze the behavior at intervals of time. Physical, mechanical and chemical properties of the soil were evaluated. Using stabilization with sodium silicate in high plasticity clays, changes in the physical, mechanical, and chemical parameters of the soil were achieved. Having satisfactory results with 3% saturation, optimal concentration, at time intervals of 2 days and 1 month; Then as time passes the soil tries to return to its initial properties, which establishes that the concentration of the Silicate and its effect on the physical and mechanical properties of the soil should be checked over a longer time interval. Studying the physical, mechanical, and chemical parameters of high plasticity clays by adding multiples mixtures of sodium silicate contributes to the understanding of the soil behavior on the pressure condition.

1. Introduction

On clay soils is more likely to find problem-related with volumetric instabilities before the gain and loss of water because of the absorbing capacity a big quantity of this one and retain it in its same structure. Water produces the increasing volume on the soil and the drastic reduction of the same when the water that is being retained is expulsed. This type of soils is meant to be a problem for construction, because of the volume increase is not presented uniformly and develops differential settlements, that could severely damage the structures [1,2]. However diverse methods exist to help stabilize this type of soils; each method uses different types of stabilator agents. For improving soil properties with stabilator agents it must be done an adequate classification of the soil which helps to determine the type and quantity of the stabilator, and also the procedure to carry out the stabilization.

Nowadays the work has been done with a great number of chemical products such as sodium chloride and calcium chloride and Portland cement [3], and sulfonated oil [4], most of them with suitable results. Sodium silicate makes part of the compound chemicals group that has a wide range in physical and chemical properties. It has been used as adhesive, cementing, detergent, of flocculant, catalyst, and more. The effect generated the addition of this stabilator, to a certain type of soil, has been to increase the permanence of water in compaction, the increment of resistance against disintegrated, fold down the plastic index and expansion. Other stabilators have been tested for the same objective [5].

In this work, it was analyzed the behavior of clay soils, potentially expansive, mixed with sodium silicate. The studied soils correspond to the southeast of the metropolitan zone of San José de Cucuta, Colombia, in a project that consists of 366 households in which most them presents structure problems in the failure of the elements which are composed of, the same way, it can be observed the waves on the roads which are evidence the physical failure of typically associated problems of expansion pressure of the foundation soil and differential settlement [6]. Sodium silicate has multiple useful properties that cannot be obtained with any other alkaline salt [7-11], consider that stabilizer with sodium silicate seems to work with silica sands, and low activity clays, such as kaolinite, but not with high activity clay such as montmorillonite.

2. Methodological design

It's presented in the form the way it proceeded to the investigation development, type of investigation, general procedure, studied soils characterized, characterization of the mixes of soil and additive, the design of the mixture.

2.1. Type of investigation

The type of investigation that was used on the project was an experimental investigation because of their found principles on the scientific method in a control group for comparing the obtained results in the experimental group and searching how to describe the problem and solve the same. This work has followed the research methods provided by [12,13].

2.2. Sampling collection and location

Clay soils samples were taken from Colinas de Vista Hermosa urbanization (7°50′2″ N - 72°28′27″ W), located UTC-5 time zone an altitude of 440 meters above sea level in the municipality of Villa del Rosario to 5 km East of the city of San Jose de Cúcuta, Norte de Santander, Colombia.

2.3. Soil physical parameters

Soil parameters were measured at the university laboratory. Once the samples were taken, laboratory practices were realized for classification using the unified system of classification of soils (SUCS) and the American Association of State Highway and Transportation Officials (AASHTO). Samples depth: 1 m, 2 m, 3 m. Type of sampling: natural state. It was realized physical characterization and Atterbergh limits as liquid limit (LL), plastic limit (PL), and it was obtained the plasticity index (PI). The mechanical characterization was done through trials of unconfigured comprehension and expansion of Lambe. The chemical characterization was done through the trial of the capacity of cationic exchange (CIC) and pH.

2.4. Preparation of the characterization of mixtures

For the characterization of clay soil expansive on natural state after being subdued to sodium silicate. It was designed 16 mixtures each one of 4000 g with different concentration of sodium silicate to 1%, 1.5%, 2%, and 3%, in which it was realized trails of physical characterization, mechanical and chemical that allowed to analyses the behavior to certain time intervals of 2 days, 1 month, 2 months and 3 months. The samples altered with sodium silicate were stored in plastic bags to avoid their loss because of humidity.

2.5. Mixture design

To determine the necessary quantity of additive according to the percentage that contains the mixture, an example is presented for the calculation of a soil mixture 2% of sodium silicate. Weight sodium silicate = Ws*% sodium silicate = 4000 g*(2% / 100%) sodium silicate = 80 g sodium silicate. For the mixture, sodium silicate was dissolved in a liter of distilled water.

2.6. Physical, mechanical and chemical parameters of the mixtures

To each one of the soil mixtures- sodium silicate it was realized the same series of tests that were applied to the soil without treating for being able to establish a comparative.

3. Results

3.1. Physical parameters

The LL is the moisture content in which the soil passes from the liquid state to plastic. Figure 1 shows the relationship between the liquid limit and log time at different concentrations of sodium silicate. The concentration of 1%, represents the most unsatisfactory values that approximate the lines of the natural state. As time passes by the tests with a major concentration of sodium silicate tend to decrease the liquid limit.

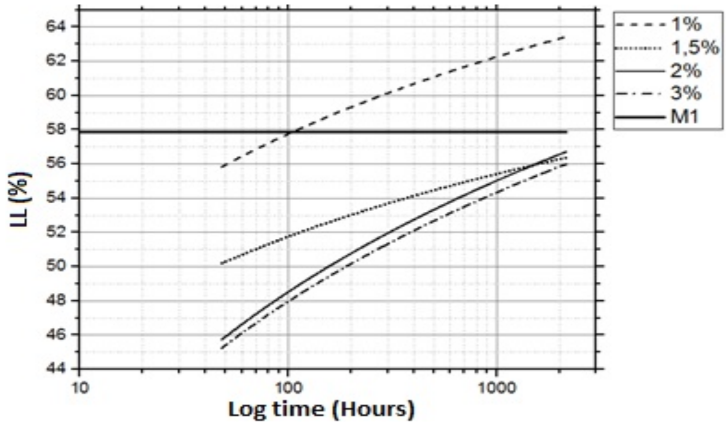

Figure 1. Relationship between the liquid limit and log time at different sodium silicate concentrations.

The PL is the moisture content which changes from a plastic state to semisolid, the soil could be considered as no plastic material. Figure 2 shows the relationship between the plastic limit and log time at different concentrations of sodium silicate. It can be observed that while silicate concentration increases and times interval, the plastic limit increases.

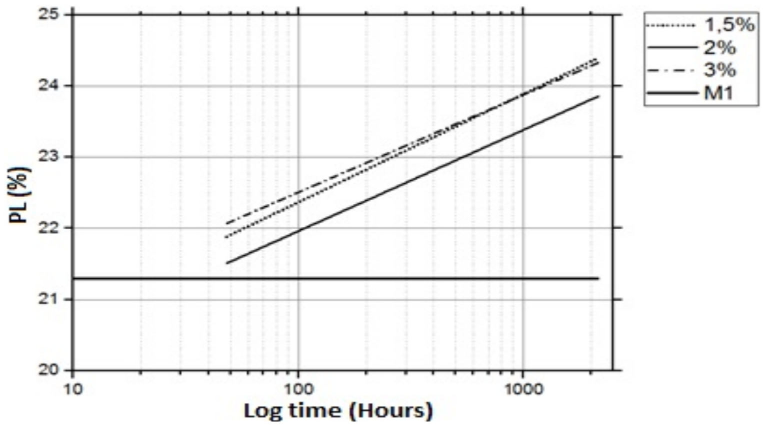

Figure 2. Relationship between the plastic limit and log time at different sodium silicate concentrations.

Through the PI can be concluded if stabilization with sodium silicate works, while time passes by Figure 3, shows the relationship between the plasticity index and log time at different concentrations of sodium silicate. During the time course, it can be observed that a higher concentration of sodium silicate lowers the plasticity index.

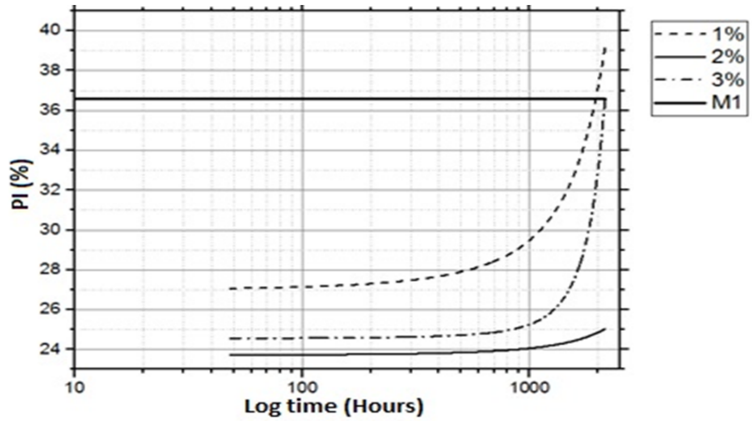

Figure 3. Relationship between the plasticity index and log time at different sodium silicate concentrations.

3.2. Mechanical parameters

The cohesion of soil can be referred to as the capacity that soil particles when they stay together like a set of internal forces. Figure 4 shows the relationship between cohesion and log time at different concentrations of sodium silicate. It can be observed a major concentration of sodium silicate in the decrease of cohesion values.

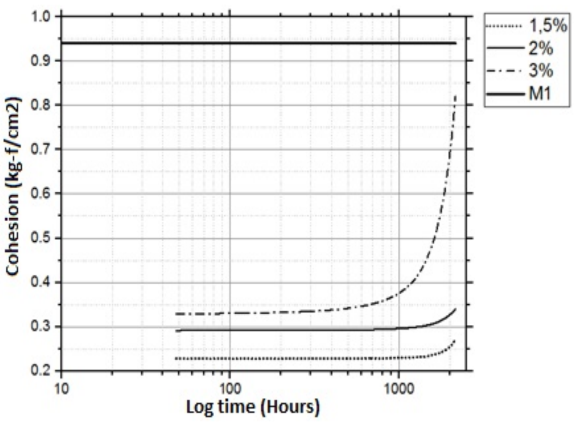

Figure 4. The relation between cohesion and log time at different concentrations of sodium silicate.

The expansion index (EI) allows determining the volumetric potential change, which indicates the expansion grade or retraction of the soil. On Figure 5 results of expansion index in different concentrations while time passes by, the concentration of 3%, presents the values of the lowest EI.

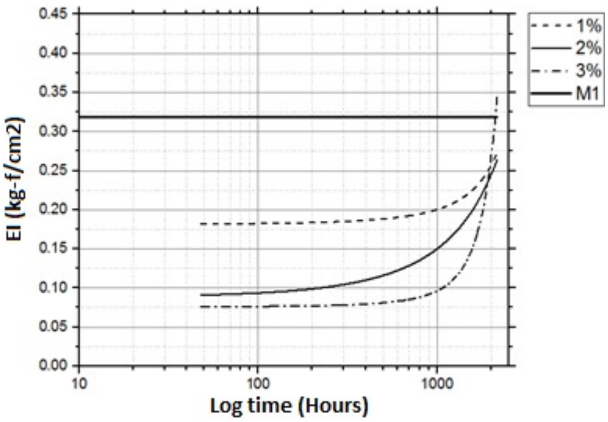

Figure 5. Relationship between cohesion and log time at different concentrations of sodium silicate.

3.3. Chemical parameter
The natural clays soils were acid. Then, when are treated with sodium silicate, tests show values over 8, which results that all them alkaline. Figure 6 shows the relationship between pH and log time at different concentrations of sodium silicate.

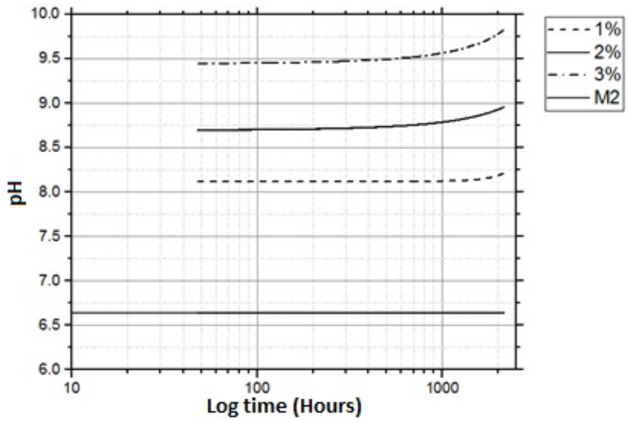

Figure 6. pH behavior at different concentrations of sodium silicate over time.

The CIC is a variable of great importance when it determines the stability of the soil. Figure 7 shows the relationship between CIC and log time at different concentrations of sodium silicate. The concentration of 3% presents a decrease of CIC.

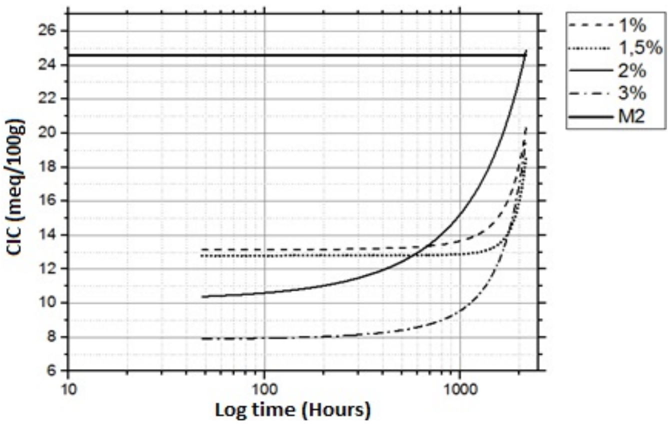

Figure 7. The capacity of cationic exchange behavior at different concentrations of sodium silicate over time.

4. Conclusions
According to the results obtained it is concluded that an addition of only 3%, denominated optimal concentration of sodium silicate, provides the appropriate conditions for the improvement of the physical, mechanical and chemical characteristics of the clay soil, which results in a less expansive soil with the possibility of having minor adverse effects on structures built on this type of high plasticity clay soil.

Atterberg indices representing the physical parameters of the soil studied, such as the LL, the PL, and IP present the downward tendency for optimal concentration, achieving stability in the soil, *i.e.*, decreasing its expansive capacity. Mechanical parameters such as cohesiveness and expansion index decrease by saturating the soil with a stabilizer for optimal concentration. The decrease in cohesiveness is not a desirable condition but does not imply a problem that cannot be solved by the effect of the geometric conditions of the structure that transmits the load to the ground, that is, the shape of the foundation.

On the other hand, the decrease in the expansion index is a safe measure for reducing soil expansion. It was determined that the CIC is indirectly proportional to the pH of the soil. The influence of sodium silicate on the pH showed that all samples in different concentrations go from acids to alkaline, providing a less expansive behavior of the soil. When a soil has a pH acid the minerals of hydroxyl group clay, such as montmorillonite and illite, are easily destabilized, which has allowed sodium silicate to act effectively. The clays in our study are classified as illite type.

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