USE OF FACTORIAL DESIGN TO MODEL HYDRAULIC CONDUCTIVITY OF A SANDY SOIL CHEMICALLY STABILIZED WITH LIME

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Abstract: A laboratory study was conducted to evaluate the effects of lime stabilization over the hydraulic conductivity of a sandy soil from Botucatu Formation (São Paulo State, Brazil) with the intend to generate a less permeable material. The experiment was performed using the technique of factorial design 3^2, with the two factors: moisture content (MC) and lime percentage (LP), varying on three levels each. The MC levels were 6.4, 7.6 and 8.8%, and the LP levels, 4.0, 8.0 and 12.0%. Hydraulic conductivity was measured in constant-head permeameters. The samples of stabilized and natural soils were compacted, at the same compaction ratio, inside the permeability columns. With the results of the characterization, was performed a statistical analysis, resulting in regression model as a function of the variable factors. Thus it was possible to evaluate the effect of moisture and lime ratios and establish response surface, showing the hydraulic behavior of the stabilized soil. Lime stabilization can decrease the hydraulic conductivity and MC represent the most significant factor on the mixtures. This method allows a better understanding of lime and water amount influence.

Keywords: soil stabilization, soil-lime, factorial design

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1 – INTRODUCTION

A landfill liner corresponds to a low permeable barrier projected to prevent water and contaminant percolation. As sandy soils present high hydraulic conductivity it can´t, in most cases, be used as landfill liner material.

Lime can modify soil properties through cation exchange, flocculation and agglomeration, and pozzolanic reaction with clay particles [1], so with a correct dosage it can generate a material with high quantity of fine particles and lower the voids.

Statistical design of experiments can be used for optimisation of linear and non-linear systems [2]. Factorial designs allow the effects of several different factors to be analysed and combined into a response model.

This paper evaluates the soil-lime hydraulic behavior, focusing on the influence of moisture and lime rates, aiming to produce results that can aid future landfill liner projects.

2 – MATERIALS AND EXPERIMENTAL PROCEEDINGS

The soil used on this project is from Botucatu Formation (São Paulo State, Brazil), according to Embrapa [3] the samples can be classified as sand or loamy sand. The grain size distribution of the samples demonstrates it has 6.1% of clay, 3.9% of silt, 48.0% of fine sand and 42.0% of medium sand. USCS [4] determines it can be classified as SP-SC, poorly graded sand with clay.

The investigation was performed using the technique of factorial design 3^2, with the two factors: moisture content (MC) and lime percentage (LP), varying on three levels each. It were used a hydrated lime, type CH-III (Itaú), and water supplied by the local utility.

The hydraulic conductivity tests were carried out on constant head permeameters. The samples of stabilized (CA) and natural (PD) soils were compacted, at the same compaction ratio, inside the permeability columns. After a period of 120 days of water percolation, statistical analysis allowed us to assess the significance of the effects and the achievement of statistical models.

3 – RESULTS AND DISCUSSIONS

Table 1 presents the soil-lime and natural soil mixtures compositions used on the factorial design of experiments and it´s respective results. These results correspond to the final period of 100 to 120 days of water percolation through the cells, i.d. the final period on Figure 1. The statistical analysis were carried with this three readings (K_1, K_2 and K_3) presented on Table 1, and $\bar{K}$ is the mean value of K.

Table 1. Soil-lime mixtures compositions and hydraulic conductivity results.

Mixture	Composition		Hydraulic Conductivity (K)			
	w (%)	Ca (%)	K_1	K_2	K_3	$\bar{K}$
CA-01	6,4	4,0	4,777E-07	4,571E-07	4,292E-07	4,546E-07
CA-02	6,4	8,0	3,992E-07	3,727E-07	3,538E-07	3,752E-07
CA-03	6,4	12,0	2,702E-07	2,641E-07	2,630E-07	2,658E-07
CA-04	7,6	4,0	1,561E-07	1,551E-07	1,577E-07	1,563E-07
CA-05	7,6	8,0	2,383E-07	2,561E-07	2,533E-07	2,492E-07
CA-06	7,6	12,0	2,519E-07	2,541E-07	2,356E-07	2,472E-07
CA-07	8,8	4,0	1,693E-07	1,705E-07	1,802E-07	1,733E-07
CA-08	8,8	8,0	1,994E-07	1,842E-07	1,927E-07	1,921E-07
CA-09	8,8	12,0	6,167E-08	6,080E-08	6,427E-08	6,224E-08
PD-01	6,4	0,0	3,278E-07	3,013E-07	3,215E-07	3,169E-07
PD-02	7,6	0,0	1,055E-06	1,052E-06	1,093E-06	1,067E-06
PD-03	8,8	0,0	9,383E-07	9,892E-07	9,764E-07	9,680E-07

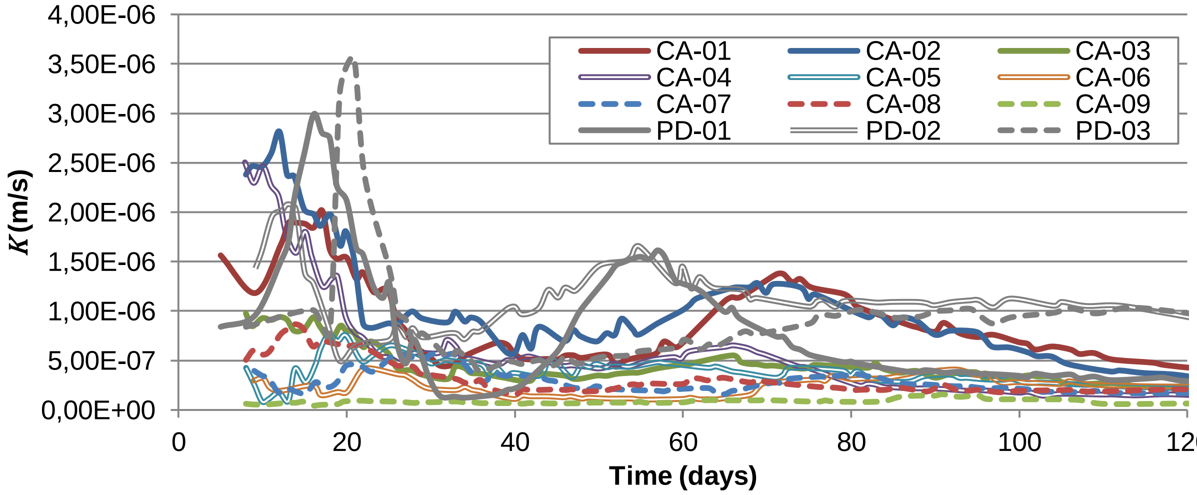

Figure 1. Hydraulic Conductivity vs. Time

With the hydraulic conductivity results and the MC and LP ratios, the regression equation was obtained (Eq. 1), using a model with linear and quadratic terms and interactions between them. MC is represented as x_1 and LP as x_2.

$$K_{CA} = 1.220\cdot10^{-5} - 3.072\cdot10^{-6}\cdot x_1 + 1.925\cdot10^{-7}\cdot x_1^{2} - 1.227\cdot10^{-6}\cdot x_2 + 3.282\cdot10^{-7}\cdot x_1\cdot x_2 - 3.942\cdot10^{-10}\cdot x_1\cdot x_2^{2} - 2.091\cdot10^{-8}\cdot x_1^{2}\cdot x_2 \quad \text{(Eq. 1)}$$

Figures 2 and 3 graphically represents the effect of MC and LP on hydraulic conductivity value for the soil-lime mixtures evaluated. According to Figure 2, K decreases more significantly with the increase of the MC than LP.

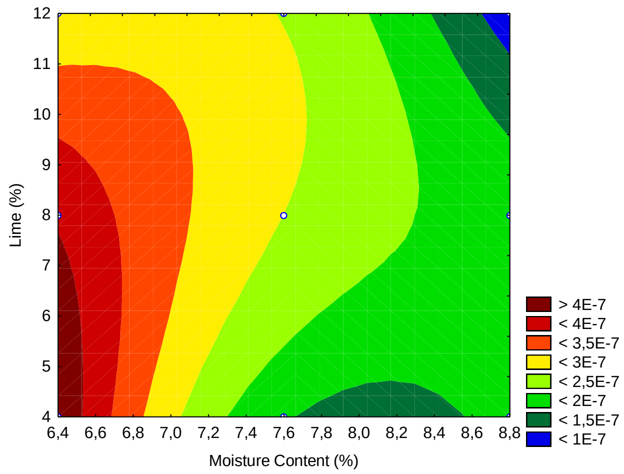

Figure 2. Response surface

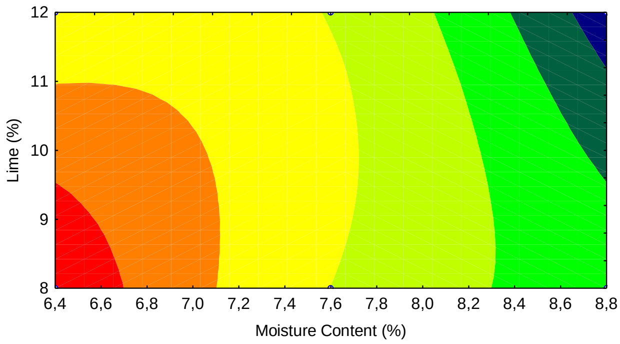

Figure 3. Half response surface

At high rates of LP, as demonstrated on Figure 2 and 3, lime becomes more relevant to the K decrease. It can be explained by the consumption of water by lime on hydration and chemical reaction with soil particles.

4 – CONCLUSION

The experimental design using a 3^2 fractional factorial design and the use of the response surface methodology proved to be efficient in the hydraulic conductivity analysis.

Lime stabilization could reduce hydraulic conductivity of the studied sandy soil and through the combined analysis it were possible to realize when moisture content becomes more relevant to accomplish better results.

5 – REFERENCES

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