Study of the behavior of a contaminated soil using the encapsulation technique

Etude du comportement d'un sol contaminé en utilisant la technique d'encapsulation

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ABSTRACT: This study aimed to analyze the behavior of a zinc chloride contaminated soil when subjected to the encapsulation technique. This technique consists of inserting a cementing agent such as cement or lime, which reacts with the contaminated soil, solidifying the treated layer and chemically stabilizing the contaminant. Geotechnical characterization tests, unconfined compressive strength tests and leaching tests were performed as well as the leachate chemical analysis. Through the test and chemical analysis mentioned it was possible to determine not only the toxicity of the leachate but also the adequate encapsulant content for immobilizing the contaminant in the case of infiltration water into the contaminated soil. The research results were satisfactory, since there was a reduction of leachate toxicity when the sample had higher contents of encapsulant. Moreover, it was also possible to note from the unconfined compressive strength test, a resistance gain of the contaminated soil as long the encapsulant content increased.

RÉSUMÉ : Cette étude visait à analyser le comportement d'un sol contaminé au chlorure de zinc lorsqu'il est soumis à la technique d'encapsulation. Cette technique consiste à introduire un agent de scellement tel que du ciment ou de la chaux qui réagit avec le sol contaminé, la solidification de la couche traitée chimiquement et en stabilisant le contaminant. essais de caractérisation géotechnique, des tests de résistance à la compression uniaxiale et des essais de lixiviation ont été effectués ainsi que l'analyse de lixiviation chimique. Grâce à l'analyse chimique d'essai et a mentionné qu'il était possible non seulement de déterminer la toxicité de la solution de lixiviation mais également la teneur en agent d'encapsulation suffisant pour immobiliser le contaminant dans le cas des eaux d'infiltration dans le sol contaminé. Les résultats de la recherche ont été satisfaisants, car il y avait une réduction de la toxicité des lixiviats lorsque l'échantillon avait des teneurs plus élevées de encapsulant. En outre, il a également été possible de constater à partir du test unconfined de résistance à la compression, un gain de résistance du sol contaminé tant la teneur en encapsulant augmenté.

KEYWORDS: encapsulation, zinc chloride, cement, contaminant.

1 INTRODUCTION

Along with the industrial development of Brazil several environmental problems emerged, such as greenhouse gas emissions, pollution of water systems caused by environmental accidents, soil contamination originated from improper disposal of waste, among others. Therefore, contaminated areas increased and consequently the need for the development of conservation programs and environmental management appeared.

There are several remediation processes, from the removal of contaminated soil, confining the material in solid waste landfills or disposing in landfarmings, up to the pumping technique with external treatment (pump and treat) in order to preserve the aquifers (Azambuja et al, 2000). Among these remediation processes, is the contaminant encapsulation technique.

The encapsulation is a process consisting the complete coating of a toxic particle by an encapsulating agent, such as lime or Portland cement. The main purpose of encapsulation technique is to contain the contaminant and prevent it from entering the environment. This is done by producing a solid mixture of soil contaminated with the cementing agent, which will reduce the contaminant solubility and mobility when exposed to a fluid (Wiles, 1987).

There are some physical and chemical tests that are necessary to ensure the efficiency of the encapsulation technique. Among the physical tests, the compaction test and the unconfined compressive strength test, are the ones that will provide us with the soil physical parameters. Furthermore, chemical analyzes should be made in the leachate obtained from the leaching test (U.S. Army Corps of Engineers, 1995).

The zinc chloride used as a contaminant on this research is usually applied in oil refining, as a food additive, on electroplating processes and within catalyst, steel and colorant industries. In addition to being harmful to human health in large amounts, it can also be considered a contaminant for soil and water. Therefore, a remediation study of a zinc chloride contaminated soil proves to be important not only to reduce groundwater contamination chances in accident cases, but also to preserve human health.

Therefore, this study aims to apply the encapsulation technique in a clay soil contaminated with 10% of zinc chloride. The encapsulating agent used was the Portland cement (PC-V) high early strength, in two different percentages, 5 and 10%. Thus, it was determined the optimal mixture of soil, cement and zinc, for the contaminant encapsulation to be efficient and not affect the groundwater. Moreover, it was possible to analyze the physical behavior from the unconfined compressive strength test of several mixtures and in different cure times.

2 EXPERIMENTAL PROGRAM

2.1 Materials

The soil used in this study comes from a slope located in the Pontifical Catholic University of Rio de Janeiro. According to the Unified Soil Classification System (USCS),the soil was classified as high plasticity silt. The results obtained for liquid limit, plastic limit, plasticity index and activity of clays index indicated: LL = 61.3%, PL = 33.1%, PI = 28.2% and Activity = 0.47. The clay fraction of the soil was classified as inactive due to the value of the activity of clays index. The specific gravity was determined by pycnometer method and indicated a value of 2.74. The high early strength Portland cement (PC-V HES) from the Lafarge Company was used as the encapsulating agent.

The contaminant used in this research was zinc cholide derived from a company called B'Herzog chemicals.

2.2 Experimental tests

In this research were made compaction tests, unconfined compressive strength test and leaching tests made on a permeameter for different mixtures as: pure soil, soil + 10% zinc chloride, soil + 10% zinc chloride + 5% cement and soil + 10% zinc chloride + 10% cement. The compression test was made to obtain the molding parameters (optimum moisture content – ω_{opt} and maximum dry unit weight - γ_d^{max}) from the specimens for the unconfined compressive strength and leaching test. It was made four compression test, one for each mixture. The test was performed with normal Proctor energy according to standards NBR7182 (ABNT, 1986) and NBR12023 (ABNT, 1992) for mixture with cement.

2.2.1 Unconfined Compressive Strength Test

The unconfined compressive strength test aims to determine the unconfined compressive strength of specimens thatare subjected to an axial stress, with deformation control through a LVDT (Linear Variable Differential Transformer. For this test, the specimens were compacted statically into three layers inside a split metal mold, with 5 cm in diameter and 15 cm height where the height obtained by thebody-specimens was 10cm and its density controlled from the height and weight of each layer. It was molded two samples for each mixture and determined the average for each test. For specimens with cement were made tests for zero, seven, and twenty-eight days of curing and the specimens were immersed in water for four hours before the test. The press used to break the specimens is from Test Top brand, with a maximum capacity of 10kN and the strainrate used was 0,4079mm/min. The unconfined compressive strength test were performed according to the following standards NBR 12770 (ABNT, 1992) and NBR 12025 (ABNT, 1990).

2.2.2 Leaching Test

The leaching test was adapted to a permeameter, whereit was possible, through percolation, get the leachate, which was sent for chemical analysis in the chemistry laboratory of Pontifical Catholic University of Rio de Janeiro. For this test, the specimens were compacted in a tripartite metal mold, with 4,04cm in diameter and 10cm height, where the height of the specimens were 7,8cm. Specimens with cement remain three days curing before the being tested. The specimens were installed on the pedestal of the permeameter chamber, with filter paper and porous stone at the ends and encased in a latex membrane fixed by O-rings. Then, the chamber was closed and filled with water. Samples were initially saturated through counter pressure, with 50kPa increasing steps until confining pressure of 350-400kPa was achieved. Water was then forced to percolate inside the sample. For the percolation to be ascendant, top pressure was always kept 50kPa higher than base pressure, which was always 5kPa lower than confining pressure. The top cap was connected to an air-water interface, where it was collected leached out of the upward percolation of water in the specimen. After collected, the leached was sent to chemical analysis, carried out in equipment of X-Ray Fluorescence.

Samples of 2 g of each mixture, pure soil and pure zinc were sent for chemical analysis in the chemical laboratory of the Pontifical Catholic University of Rio de Janeiro, as well as the leachate collected after the test in permeameter.

3 RESULTS AND ANALYSIS

From Figure 1, it is noteworthy that in the unconfined compressive strength test results for 0 days of cure, specimens of soil contaminated with 10% of zinc chloride presented significantly lower strength (140kPa) when compared to pure soil specimens (300kPa). Cement-added samples presented different performances. While the higher axial strength from the sample with 10% of zinc chloride + 5% of cement is similar to the sample with 10% of zinc chloride, the higher axial strength from the sample with 10% of zinc chloride + 10% of cement is similar to the pure soil specimen.

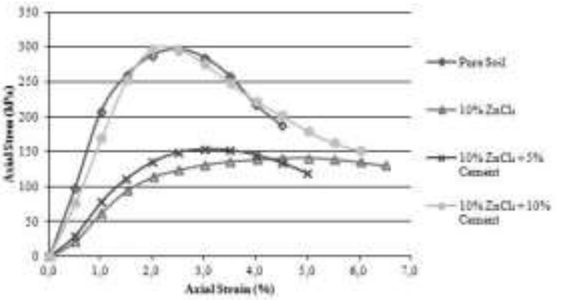

Figure 1. Unconfined compressive strength test for zero days of cure

It was possible to notice similar behaviors for cement-added mixtures that cured for 0, 7 and 28 days respectively, as shown in Figure 2 and 3. In zero days of cure, mixtures presented a high strength. On 7 days of curing, this strength reduced or remained similar to that of 0 days, depending on the mixture. Tests conducted after 28 days curing presented higher strength results, varying from 200 to 300 kPa. It is worth mentioning that during curing time chemical reactions occur, making mixtures that go through 7 days of cure less resistant than those in 0 and 28 days. Therefore, the cure time is even more important in this case, once chemical reactions occur until a certain time and then the resistance starts increasing, reaching higher values after 28 days of curing.

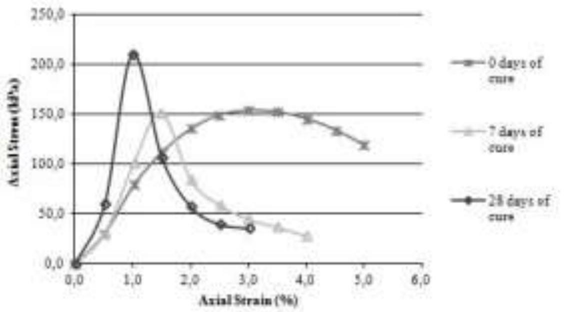

Figure 2. Unconfined compressive strength test: 10% of zinc chloride + 5% of cement

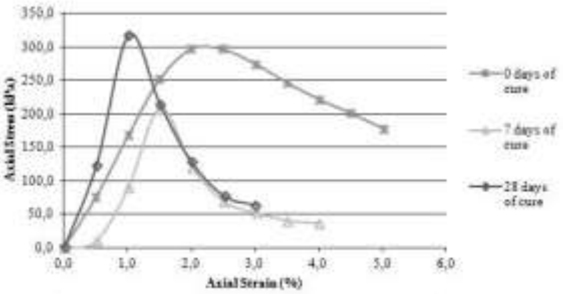

Figure 3. Unconfined compressive strength test: 10% of zinc chloride + 10% of cement

Depending on the mixture, the leaching took 1 to 5 days to percolate the specimen. The mixture of 10%$ZnCl_2$ took 5 days and the mixture of 10%$ZnCl_2$ + 5% cement only 1 days. After collected, the leached was sent to chemical analysis, carried out in equipment of X-Ray Fluorescence and from the results, it could be perceived that zinc concentration significantly reduced for the mixture containing greater amounts of cement, as shown in Table 1. Within the leached from the soil sample with 10% zinc chloride, for example, a zinc concentration of 72.3% was observed, while the sample containing 10% of zinc chloride and 5% of cement presented only 20.6% zinc concentration, and the sample comprised of 10% of zinc chloride and 10% of cement resulted in only 7.8% of zinc. It confirms a correlation of decrease in zinc concentration for increased concentrations of cement and the viability and efficiency of the cement encapsulation technique to treat zinc chloride contaminated soils.

Table 1. Leaching test results

Parameter	*Pure Soil*	*10% $ZnCl_2$*	*10%$ZnCl_2$ +5% Cement*	*10%$ZnCl_2$ + 10% Cement*
Zinc (%)	-	72.3	20.6	7.8
Chlorine (%)	-	26.7	30.5	34.7
Calcium (%)	-	0.8	39.6	46.5
Sulfur (%)	0,7	0.2	0.8	0.8
Manganese (%)	-	-	8.5	10.2
Iron (%)	43,9	-	-	-
Aluminum (%)	25,8	-	-	-
Silicon (%)	25,9	-	-	-
Titanium (%)	3,7	-	-	-

4 CONCLUSION

From this study, it was observed that the unconfined compression strength of the soil increased with the increase of cement in the mixtures and with the increase of cure time. The presence of zinc chloride, in turn, makes the soil less resistant. It was also noted that the more resistant the mixture, the lower the mass loss at the end of the test. The chemical analysis of the leachate shows that the higher the percentage of cement in the mixture, less zinc is leached by water. Therefore, to the concentrations used in this research, the encapsulation technique with cement becomes effective to remedy a soil contaminated by zinc. Thus, water infiltration into the soil will not transport the zinc particles to the groundwater. Finally, it can be said that the encapsulation technique was successful for not only increased soil resistance, but also reduced the concentration of zinc in the leachate.

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