Stabilization of clayey soils contaminated with lead and zinc nitrate using metakaolin geopolymer

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ABSTRACT

One of the most important environmental problems humans face is soil pollution, which occurs in various factors and affects different soil parameters. one way to tackle this phenomenon is the stabilization of soils. This study presents the result of using metakaolin geopolymer to stabilize contaminated clay. In this study, the primary and contaminated soil without stabilizing are subject to various tests; The results of the first phase of the experiments showed that increased contamination concentration had a negative effect on soil parameters. The results of these experiments also showed that the most critical concentration of soil contamination was among the concentrations of 10,000 ppm. Then the soil contaminated with the most critical concentration was stabilized by metakaolin geopolymer at 5, 10, and 15% weight and was re-tested and identified with various resistive in 7 days of curing time. Finally, the results achieved at this stage showed that by increasing the percentage of metakaolin geopolymer, the soil strength parameters have significantly increased, and the addition of geopolymer to contaminated soil of 10,000 ppm has resulted in stabilization of soil and improved soil properties. The results of the experiments showed that the most optimal state was the addition of 15% metakaolin geopolymer to the 10000ppm contaminated soil, in which the liquid limit increased by 39.47%, the plastic limit increased by 51.06%, the plasticity index increased by 20.68%, the optimal moisture content increased by 19.84%, Dry Unit Weight decreased by 3.23%, unconfined compression strength increased 2.28 times and CBR increased 2.31 times, compared to the unstabilized 10000ppm contaminated soil.

KEYWORDS

metakaolin-Pozzolan-Soil contamination-geopolymer-stabilization of soil

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1. Introduction

Due to the low capacity of recycling methods in Iran, the only way to dispose of waste in this country might be its burial in the soil. Naturally, soil components can absorb contaminants. Clay and clay minerals are among the soil compounds playing a critical role in sanitary engineering landfills.

In the present study, the soil specimens are collected from an industrial area around Tehran and tested through basic tests. The soil is then contaminated and treated with different concentrations by the contaminant, and basic tests are performed on the sample similar to the soil sample. Afterward, the soil contaminated with the most critical concentration is stabilized by metakaolin geopolymer. Finally, the stabilized soil specimen is subjected to various laboratory experiments to investigate the new properties of the soil.

2. Methodology

The experiments carried out in this study consist of two main stages. The first step includes the index and strength tests of base soil. Then, the soil was contaminated with concentrations of 1000, 5000, and 10,000 ppm with a curing time of 7 days. The investigated concentrations were selected from the research conducted by Li et al. (2015) and the reason for the above selection was that the contamination of clay with low plasticity with the above concentrations had not been studied before [1]. Contamination with heavy metals was done using lead nitrate and zinc nitrate in a ratio of 1:1. The soil was prepared with a moisture content of 35% to reach the liquid state. Afterward, lead nitrate and zinc nitrate were dissolved in water, followed by adding the solution to the soil. The above method is based on the method used in similar research conducted by (Abidoye et al., 2018; Chu et al., 2017; Li et al., 2015) in the research field under study [1-3].

In the next stage, soil samples were contaminated with 10,000 ppm of lead and zinc in a ratio of 1:1 and a curing time of 7 days and then were dried. In this step, metakaolin as a geopolymer precursor with 5, 10, and 15 wt.% and alkaline solution (i.e., sodium hydroxide and sodium silicate) were used to stabilize the soil at ω_{opt} and curing times of 7 days. The alkaline solution was prepared by adding sodium hydroxide at a concentration of 8 M to water. After the curing time, compaction, UCS, Atterberg, and CBR tests were carried out on each sample.

3. Results and Discussion

3.1. Atterberg limits of stabilized soil

With the increase in the percentage of stabilizer, the thickness of the double layer around the clay particles increases, and the repulsion between the clay particles increases, which causes the free movement of the particles in more water, and as a result, the flow limit and the paste limit of the soil increase [1].

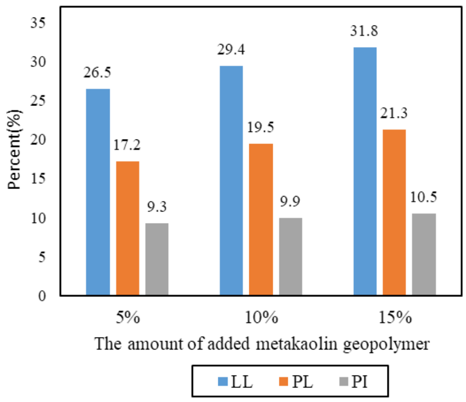

Fig 1-Changes of Atterberg Limits of contaminated soil stabilized by metakaolin geopolymer in 7 days curing time

3.2. Unconfined Compressive Strength (UCS) of the Stabilized soil

With the increasing percentage of geopolymer-metakaolin, soil cohesion increases, leading to an increase in the soil's UCS.

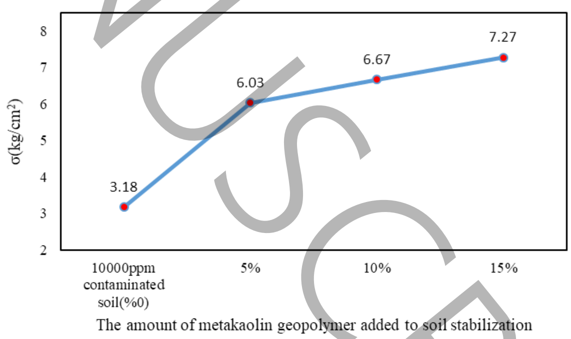

Fig. 2. The changes in maximum UCS of contaminated soil stabilized with metakaolin geopolymer cured in 7 days

3.3. California Bearing Ratio (CBR) of the stabilized soil

By increasing the stabilizer's percentage, the CBR of the soil increased compared to the soil contaminated by 10,000 ppm. Increasing the metakaolin geopolymer percentage increases soil cohesion, thereby increasing its CBR.

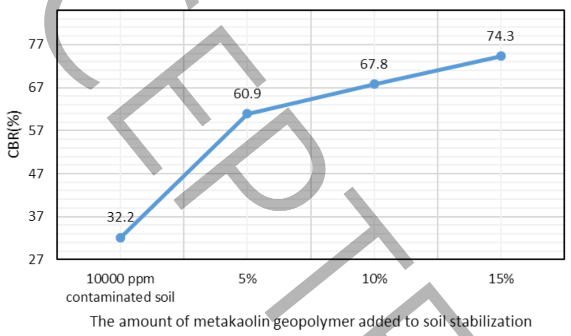

Fig 3-Diagram of the CBR variation graph of contaminated soil stabilized within 7 days in the different percentages of metakaolin geopolymer

3.4.Stabilized soil's compaction test results

According to the results from previous research by Li et al. (2015), increasing the percentage of stabilizers will increase the double layer thickness around clay particles. As a result, clay particles are placed under the same compressive energy at a further distance. Hence the dry weight of the maximum soil is reduced. As such, the particles are separated, the water retention capacity increases and the soil moisture percentage rises [1]

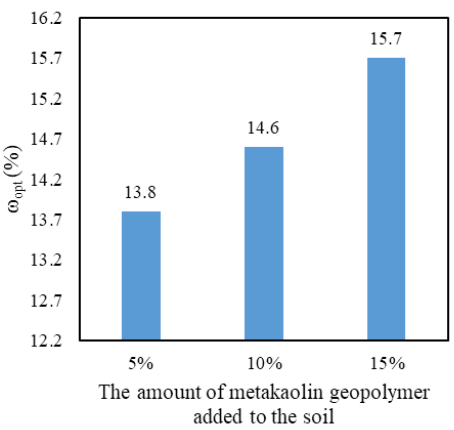

Fig 4- Diagram of changes in the optimum moisture content of contaminated soil stabilized by metakaolin geopolymer

4. Conclusions

- According to the results of compaction tests on stabilized contaminated soil, with increasing the percentage of stabilizer, the soil's ω_{opt} increased while its γ_{dmax} decreased.
- UCS experiments showed that the soil's UCS increases significantly with increasing the percentage of metakaolin geopolymer.
- CBR experiments showed that adding metakaolin geopolymer to contaminated soil at 10,000 ppm significantly increases its CBR.
- Based on the results of the Atterberg test on contaminated soil stabilized with metakaolin geopolymer, LL, PL, and PI of the soil increased with increasing the stabilizer percentage.

5. References

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