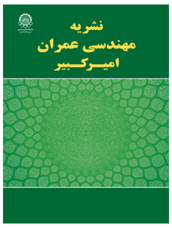

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Evaluation of the Effect of Nano-Clay and Pressure Change on the Self-Healing Properties of Clay Soils

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ABSTRACT: Some factors such as soil mass settlement, earthquake activities, and hydraulic failure causing tensile forces in the earth's structures and, consequently, cracks creation and development of water leakage from cracks. In this study, to reduce possible damage caused by cracking and its extension to the erosion of internal structures, the effects of nano-clay on the self-healing properties of clayey soils have been investigated. In this study, the effect of nano-clay additive, pressure, and time elapsed on crack restoration in clay was evaluated. To perform experiments, two types of cracks with thicknesses of 0.5 and 1 mm with a depth of 50 mm were created in the samples and the montmorillonite nano-clay was used as an additive. Twelve tests with different percentages of nano-clay, without pressure and at pressures of 50 to 500 kPa in two steps after the cracking (first day) and 24 hours after the creation of crack (second day) were performed for samples with a thickness of 0.5 and 1 mm. The flow rate is measured in all tests and was the basis for judging the impact of each factor. The results showed that when the cracked sample is made with one millimeter, under non-pressure conditions, in about 60 minutes, approximately 500 ml of water passes through the crack. However, when the sample contains 2 and 5% nano-clay, the amount of water passing through the crack within 60 minutes, would be 40 and 5 ml, respectively. This decrease in the volume of passing water shows the positive effect of nano-scale fine grains on cracking closure.

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1- Introduction

Cracks in soil structures may be a result of a variety of conglomerates, vibration activities, and hydraulic issues that can cause internal erosion in the body of these structures and can cause hydraulic failure if left unattended [1]. Erosion is a progressive process and may occur in the body or the dam. The erosion begins at the drainage focus point and gradually forms a conduit that is washed out by the hydraulic gradient, which expands along the flow and eventually reaches the reservoir. When the conduit approaches the reservoir, a high flow of water can occur at high speeds and may result in damages [2].

In the past, this phenomenon has caused catastrophic events and has caused significant damages and financial losses, so providing methods to reduce leakage and erosion in impermeable and earth dams is very important and economical. The use of stabilizers to correct and reduce soil erosion potential is one of the most effective ways to prevent internal erosion in soil structures. Nowadays, the use of chemical additives is one of the most common methods of increasing soil erosion resistance in soil structures [3].

2- Methodology

To investigate the factors affecting self-healing, clay soil with a unit weight of 1.83 g/cm3, a specific gravity of 2.66, a liquid limit of 31.8, a plastic limit of 18, and optimum moisture content of 15% were considered. The curvature of this soil is shown in Fig. 1. As shown in this figure, 95% of the soil particles are smaller than one millimeter.

To investigate the influence of different factors on the self-healing properties of clay soils, samples with identical conditions were fabricated and tested. These specimens were made with a diameter of 150 mm and a height of 50 mm along with a standard 30 mm sand layer at the top and bottom of the specimen as a filter and protective layer. During the tests, two types of cracks with diameters of 0.5 and 1 mm were made by steel blades. Pressure source, outlet water measurement, and curve drawing were segmented using the obtained results. All experiments were evaluated at three-time intervals one hour after cracking, one day after cracking, and two days after cracking, and water output from cracks was measured.

To test the self-healing properties of cracks in the clay, a test device was designed and manufactured. The three main parts of this machine are the overhead application system,

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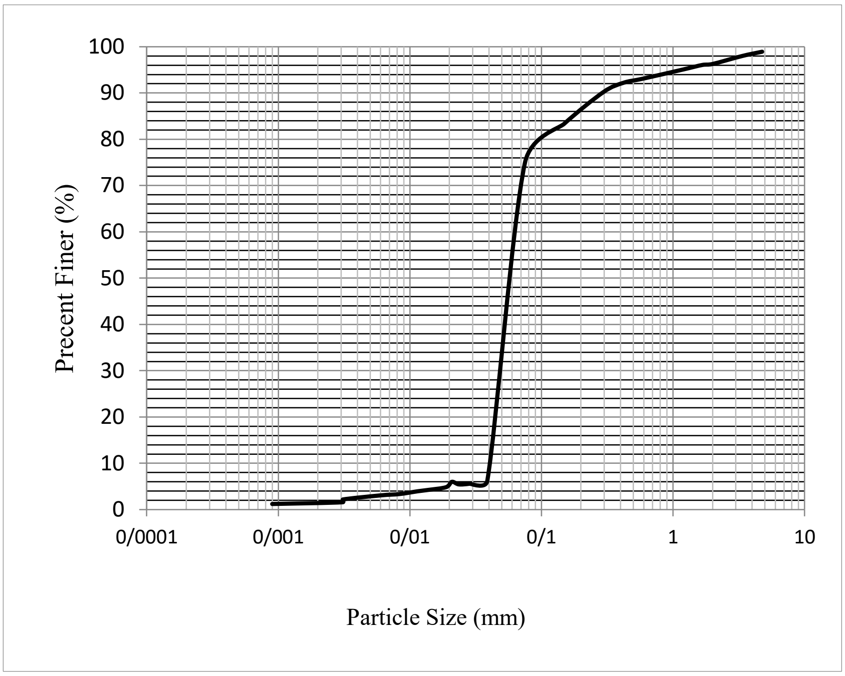

Fig. 1. Grain size distribution

Fig. 2. Soil sample

the soil, and filter system, and the measuring system. The overhead application system is divided into three parts: (1) Pressure source, (2) Pressure tank in the test machine, and (3) Water storage tank. The working process of this part of the machine is that after supplying pressure by an air compressor, the pressure in the range of 0 to 500 kPa is driven by a high-pressure hose and regulator valve into the storage tank.

The test mold was 3 mm thick, stainless steel, and was resistant to water, moisture, and pressure. The mold height and diameter were 15 and 15 cm, respectively (Figs. 2 and 3). After attaching the top piece to the mold, the overall height of the mold reaches 45 cm. At the top of the mold, there was an embedded faucet, in which water is poured onto the sample, as well as a pressure gauge at the top of the mold, which can be used to control the pressure on the sample. The pressure applied by the air pump was connected to the inlet valve of the measuring gauge and its pressure level can be controlled. Below the mold, a funnel was attached to the mold that guides the outlet water centrally to the measuring vessel. One of the benefits of this mold is that the dimensions of the device have been selected so that a suitable workspace can be provided while preparing the specimen and, most importantly, that cracking in the specimen range will not cause any damage until the original test is performed. The outflow of water and pressure was the same compared to that of the beginning of the experiment (Fig. 4).

Fig. 3. Crack created in samples

Fig. 4. Self-healing process

3- Results and Discussion

On the first day, the sample with no additive and with 1 mm cracking had the highest volume of water output. However, in two samples containing 2% and 5% nano-clay, the cracking was largely restored after one hour, so that in the sample with 2% nano-clay, the volume of water output decreased from 160 to 89 ml. The presence of the additive percentages had a significant effect on reducing the outlet water from the cracks, which was reduced to 10 ml after 5 hours of cracking in the sample by 5% additive and they have created cracks.

4- Conclusion

Considering the importance of the self-healing process in clay soils, the need to better understand this issue and how to accelerate this process is felt more and more. In this paper, the effect of various factors such as nano-clay additive and overhead pressure on the self-healing properties of clay soils was investigated. For this purpose, a device has been designed and manufactured that can apply different pressures to the specimen. In the experiments carried out in this study, two types of cracks were created in samples. The following results obtained:

Nano-clay additive increased optimum soil moisture content and decreased the maximum dry weight of soil. According to the results obtained from the tested conditions, the optimum content of nano clay was 5%. The nano-clay additive improved the cracking condition by reducing the amount of water passing from 168 to 55 ml in a sample containing 5% nano-clay with one millimeter cracking one hour later. However, the remarkable thing is the price of the nano-clay additive that needs to be taken into consideration. The passage of time was one of the effective factors in improving the condition of the created cracks. In this study, the time of one day and two days after leaving the study was investigated. The results showed that the passage of time is very effective in improving the crack condition in the fine-grained soils and the same effect that 5% nano-clay additive can have on the behavior of the sample can be created in the sample over a day. In addition to factors such as the presence of additives and the passage of time, the pressure change can also affect the crack condition. A gradual increase in pressure will increase the water passing through the cracks. The important point is that the instantaneous pressure is zero to 500 kPa and in the same amount of time the water passes through the cracks was less than when the pressure gradually reaches 500 kPa.

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