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The Effect of Clay on Soil Abrasivity in the results of LCPC Test

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ABSTRACT: LCPC test is one of the most common methods for assessing the abrasivity of rock particles and soil grains. Regarding the lack of a standard testing procedure to determine the abrasivity of soils, the test has become very popular in recent decades. In this paper, LCPC tests were used to study the effect of clay on soil abrasivity. Mixing crushed silica grains and clay particles, different abrasive samples were produced in the testing program. Different moisture contents and stress levels were applied during the tests. The amount of consumed energy for each test was calculated as well with measuring and recording the consumed power of electromotor during the tests. The results showed that the level of water content has a considerable effect on the obtained LCPC abrasivity coefficient values. The recorded wears are minimum when the moisture content is in the range between the plastic limit and the liquid limit of the clay. However, abrasivity coefficients show an increasing trend with the moisture content when the moisture is greater than the liquid limit of existing clay. Based on the results, abrasivity is nearly zero in pure clay samples. Increasing the applied stress levels on the soil samples increases the soil abrasivity. However, increasing the clay content of the tested samples decreases the effect of stress levels on the observed trends. In the pure clay samples, no correlation was obtained between the applied stress levels and LCPC abrasive coefficient.

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1. INTRODUCTION

The development of cities and the growing demand for underground spaces has increased the application of mechanized excavation methods in recent decades. Time and cost are two important effecting factors in mechanized tunneling methods. Ground abrasivity is a decisive parameter in assessing the time and cost of a project. There are several methods for estimating the wear of rock cutting tools. However, the suitable methods for the soil are very limited.

Generally, the existing knowledge about the effect of soil composition and ground condition on the interaction between soil and cutting tools is very limited. In this study, the effect of clay particles on the abrasivity of different soil samples was investigated with performing LCPC tests. The results showed that clay particles alone are not abrasive. However, the existence of these particles in the composition of a coarse-grained soil in the presence of moisture changes the abrasive capacity of soil sample drastically. The results also showed that increasing the percentage of clay particles decreases the effect of stress levels on the abrasivity of tested samples.

2. METHODOLOGY

LCPC abrasivity tests were performed in our studies. The central laboratory of bridges and roads[1] in France has developed the test in the 1980s. The French standard of P18-579 describes the testing device [1]. Figure 1 shows the used testing apparatus. Wear parts were made of St37 grade steel with a hardness range of 60–75 Rockwell B (HRB). Mixtures of crushed angular Silica grains and Talc clay particles were used as abrasive samples. The particle size range of silica grains was 4.0 – 6.3 mm, based on the recommended standards [2, 3]. The liquid limit (LL) and the plastic limit (PL) of the clay part were measured as well, and the obtained values were 29% and 22%, respectively. Seven different abrasive mixtures with the different Silica: Talc ratios of 100:0, 80:20, 60:40, 40:60, 20:80, and 0:100 were tested underwater contents of zero, 5, 10, 15, 20, 25, and 30 percent and the stress levels of zero, 1.00, 1.65, 2.27, 2.88, and 3.49 kPa. In sum, the testing program included 252 LCPC tests. The following equation was used to calculate the LCPC abrasivity coefficient (LAC) of the samples [4]:

$$LAC = \frac{m_0 - m}{M} \quad (1)$$

Where m_0 is the initial mass of the steel propeller, m is the mass of the worn propeller after performing the test, and M is the mass of the abrasive sample, which is equal to 500g (= 0.0005t).

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Fig. 1. LCPC testing device used in the experimental studies

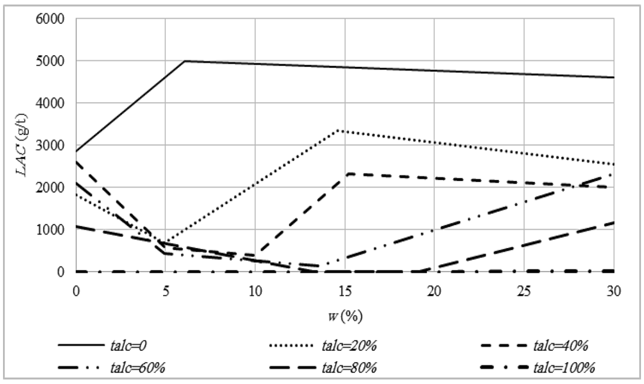

Fig. 2. The trends of LAC variations with the change of water content in different abrasive mixtures (the applied stress is equal to 3.45 kPa)

3. RESULTS AND DISCUSSION

Figure 2 shows the graphs of LAC variations with the changes of moisture content under the applied stress level of 3.49 kPa. Increasing water content in the pure Silica sample increases the abrasivity coefficient. However, after a primary increasing of LAC values, the wear amounts remain more or less constant. As we can see from the figure, changing the percentage of Talc changes the fitted trends drastically. In the Talc – Silica mixtures, increasing water content decreases LAC values. However, adding more water to the abrasive mixture the trend lines become ascending. Assuming that the Talc part absorbs whole water, the moisture contents, which the Talc part reaches to its plastic and liquid limits, were calculated for different mixtures. Investigations showed that when the range of water content is smaller than the plastic limit, increasing moisture amounts decreases LAC values. The minimum LAC values are obtained in the moisture range between the plastic and liquid limits. Passing the liquid limit, LAC values increase with the increase of water content. From the rheological point of view, Talc particles adhere together with adding water in the first step. This traps coarse silica grains between adhered Talc part and prevents the abrasive silica grains to hit to the steel propeller. Consequently, the recorded wear amounts decrease. Between the plastic and liquid limits, the abrasive mixture behaves as a plastic medium with the minimum hits between coarse grains and the steel propeller. Passing the liquid limit, the Talc part behaves as a viscous fluid and the Silica grains get more freedom to move and hit the propeller. LAC values increase in this range of moisture content.

Increasing the percentage of Talc part, the trend lines in Figure 2 shift down. For the pure Talc sample, the trend line coincides on the horizontal axis. This means that the clay part is not abrasive. This is an important point. Because clay particles alone are not abrasive. However, their presence in the soil mixture can change its abrasive behavior depending on the amount of water content.

Investigations on the changes of LAC trends with the applied stress levels revealed that the abrasivity of samples increases with the increase of the applied stress levels. However, the effect of stress levels in the samples, which contain more coarse grains, is greater. Actually, coarse-grained soils are compressible. However, soil compressibility reduces with the reduction of their particle size, and it totally disappeared in clay particles. Therefore, when the major part of the abrasive sample is comprised of clay particles, applying stress does not change its compaction and consequently its abrasive behavior.

4. CONCLUSIONS

In this paper, the effect of clay particles, water content, and stress levels on the abrasivity of various Silica – Talc mixtures were investigated. The results showed that:

• The clay particles alone are not abrasive. However, their existence in the abrasive sample has a great effect on its abrasivity.

• Changing the amount of water content in the tested mixtures changes the obtained LAC values.

• Increasing moisture amount decreases LAC values in the first step. The minimum values are obtained when the water content is in the range between the plastic and liquid limits. Passing the liquid limit of the clay part, LAC increases with the increase of water content.

• The rheological behavior of the abrasive mixture has a key role in the abrasivity. When clay particles adhere together, the Silica grains trap between them, and the abrasivity of mixture decreases. However, in the water contents greater than the liquid limit, the clay part behaves as a viscous fluid and the mobility of the Silica particles increases in the abrasive mixture. This leads to increase the recorded wears.

• Soil compressibility is effective on its abrasivity. The more the clay particles share, the less the soil compressibility. Therefore, increasing the percentage of clay particles decreases the effect of applied stress levels on the compaction of the abrasive mixture and consequently on the trends of LAC values.

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