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Effect of Soil Physical Parameters and Foam Injection Ratio on Soil Shear Strength in EPB Tunneling

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Abstract

EPB machines have been the most applicable for tunneling in urban areas over the last decades. To increase soil consistency, reduce machine torque, and stabilize the tunnel face in EPB tunneling, foam injection is essential. The shear strength of the soil in the EPB chamber affects the machine torque. Therefore, in this research, the effects of soil water content, clay percentage, foam injection ratio, and soil granular size on the shear strength are investigated. The Isfahan subway line 2 in Iran was selected as a case study. Based on the results of the vane shear test, the shear strength of soil first increases rapidly and then gradually with an increase in soil particle size, and particle size is the most significant parameter that controls the shear strength of soil samples. The result of the analysis also indicates that increasing FIR up to 40% can lead to a 44% reduction in soil shear strength and, as a result, a decrease in excavation power. Increasing the clay percentage from 20 to 40 percent reduces the soil shear strength by up to 36 percent. The lowest shear strength of soil is achieved when the water content is 5 percent. By increasing the FIR from 10 to 20 percent, the shear strength of samples decreases rapidly and remains constant when the FIR rises up to 40 percent.

Keywords: Isfahan subway line 2, EPB tunneling, FIR, Water content, Particle size distribution function

1. Introduction

The most popular full-face machines applied for soft tunneling while the working face is unstable are slurry and earth pressure balance (EPB) machines. In recent decades, due to recent developments, the lack of separation plants, and cost benefits, EPB machines have been applied in a wide range of ground conditions and are more widespread compared to slurry machines [1-3]. For the efficient application of EPB machines, the conveying of excavated materials and the ability to apply pressure on the face mean that the soil workability must be increased in the EPB chamber. Soil workability depends on soil geotechnical parameters such as plastic limit, liquid limit, water content, and granular size distribution, and it can be modified by the use of additives such as polymers, surfactants, and clay. Increasing soil workability through foam and polymer injection in the EPB chamber is called soil conditioning, which is one of the key factors in EPB tunneling. Proper soil workability results in faster conveying of excavated soil, lower excavation power, higher penetration rate, and a reduced risk of cutterhead clogging [4-6].

In EPB tunneling, soil conditioning can be done based on the excavation data that are recorded by a data logger and through trial and error. However, the application of some simple tests to optimize soil conditioning and determine the type and quantity of additives during excavation is easier, faster, and more practical [7]. The first attempts to design soil conditioning using laboratory test results were done by the European Federation for Specialist Construction Chemicals and Concrete (EFNARC) [8]. Although these tests were not done on soil samples, they are applicable to optimize soil conditioning design [3,9-10]. One of the main and simple tests applied to analyze the effects of additives on soil consistency and workability is the slump test [7,11-18]. Another class of tests includes a rotating blade inside a mixture of soil and chemical additives. In this group of tests, based on blade torque variation and energy consumption, the effect of foam injection and other additives on power and soil cohesion reduction is investigated [1,16,19-23]. An apparatus that can be used to investigate the effect of foam injection on soil shear strength is the vane shear test [3,24].

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