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Effect of Freeze-Thaw Cycles on the Hydraulic Conductivity of a Compacted Clayey Soil from Nazlou Region of Urmia City, Iran, and on a Geosynthetic Clay Liner

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Abstract

The effect of freeze-thaw cycles on the hydraulic conductivity (HC) of compacted clay liner (CCL) and geosynthetic clay liners (GCLs) in water retaining structures and municipal solid waste landfills is a key issue in designing barrier systems in those structures. In this study the effect of freeze-thaw cycles on the hydraulic conductivity of a compacted clayey soil from Nazlou Region of Urmia City and a geosynthetic clay liner; and the effect of effective stress on the hydraulic conductivity change of clayey soil in freeze-thaw cycles was investigated. The flexible-wall triaxial hydraulic conductivity apparatus was used to measure the HC of specimens subjected to freeze-thaw. During the freezing process ice lenses grow in soil sample and when the ice lenses melt, a network of cracks is left and thus the HC increases. Increasing the effective stress reduces the increased hydraulic conductivity due to freeze-thaw. The results show that on the contrary to compacted clayey soil, the application of freeze-thaw cycles do not significantly affect the HC of GCL even when GCL sample is subjected to extreme climatic conditions during which it continues to exhibit good performance as a hydraulic barrier.

Keywords: Freeze-thaw cycles, Hydraulic conductivity, Compacted clay, Geosynthetic clay liners

1. INTRODUCTION

Compacted clayey soils and geosynthetic clay liners are often used as hydraulic barriers. Examples of their use include water retaining structures and municipal solid waste landfills. In cold regions, compacted clay and geosynthetic clay liner barriers may be subjected to cycles of freeze-thaw during the winter periods. Since their primary purpose is to minimize flow, low hydraulic conductivity is of paramount importance therefore the effect of freeze-thaw cycles on the hydraulic conductivity of compacted clayey soils and geosynthetic clay liners in water retaining structures and municipal solid waste landfills is a key issue in designing barrier systems in those structures.

Geosynthetic clay liners (GCLs) have attracted considerable recent attention with respect to their use in geoenvironmental applications [1, 2]. This has included a growing interest in the use of GCLs in environments subject to prolonged periods of subzero temperature and freezing and thawing [2].

In this study the effect of freeze-thaw cycles on the hydraulic conductivity of a compacted clayey soil of Nazlou Region of Urmia City and a geosynthetic clay liner, and the effect of effective stress on the hydraulic conductivity change of clayey soil in freeze-thaw cycles was investigated.

2. PREVIOUS STUDIES

When the temperature in moist soil drops below 0°C, the water supercools and ice crystals penetrate in larger pores. As the water changes phase to ice, its volume increases about 9 % due to the development of a hexagonal crystalline structure. The crystals grow until they interfere with each other and adjacent soil particles [3]. The thickness and spacing of the ice lenses depend on the relative magnitudes of the rate of freezing, temperature gradient, pressure, and availability of water [4].

If the surface temperature is below 0°C, a freezing front advances into the soil [5]. The freezing of pore water induces an increase in ice pressure and a decrease in pore water pressure [6]. Because of the decrease of in water pressure at the freezing front, water migrates from the underlying soil through the