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Triaxial tests on artificial frozen soil samples at temperatures close to 0°C

Yuko Yamamoto and Sarah M. Springman
Institute for Geotechnical Engineering, ETH Zürich, Switzerland.

Introduction

Alpine permafrost is susceptible to global climate change. It has become clear that rising mean annual air temperature and extreme rainfall conditions cause permafrost degradation, and may lead to initiation of landslides and instabilities of permafrost slopes. Geotechnical behaviour of permafrost soil, such as creep and failure processes, especially its response to a gradual warming cycle, is necessary to investigate rock glacier dynamics and estimate the stability of permafrost slopes. Moreover, extension features in some rock glaciers are becoming apparent, which indicates that these may play a role in possible future failure mechanisms. In the laboratory, cylindrical artificial frozen soil samples were prepared in order to achieve controlled and repeatable sample states. Triaxial tests have been used to represent the stress conditions and stress paths acting on a specimen and to determine the mechanical properties of various geomaterials. This contribution will report preliminary triaxial compression and extension tests on artificial frozen soil samples conducted in a cold room at temperatures ranging between -2 and 0°C.

Methodology

Four different stress paths (AC; Axial Compression, LE; Lateral Extension, AE; Axial Extension, LC; Lateral Compression) were followed in the triaxial tests to represent the stress history and path acting on a frozen soil element in the body of a rock glacier. LE and AE stress paths can be thought to represent the unloading behaviour around the extension features. Either Constant Strain Rate (CSR) or constant stress rate tests were carried out in order to investigate strength as a function of temperature. Moreover, AC creep tests were conducted with deviatoric stresses ranging between 200 and 700 kPa in order to observe the temperature dependence of the strain rate during the secondary creep phase, particularly between temperatures from -2 to -0.5°C. All the tests were conducted under undrained conditions. The temperature (T) of the triaxial cell liquid was held constant at ±0.03°C. The artificial frozen soil samples were prepared by mixing soil grains and crushed ice, and saturating the mixture with de-aired water from the bottom up. The volumetric ice content of the frozen soil specimens were modelled from cored sample from boreholes in the Murtél-Corvatsch rock glacier, which contained more than 60% ice. The size of the test specimen was 50 mm in diameter and 100 mm in height, containing a maximum soil grain size of 4 mm. The mixture of soil grains, crushed ice, and de-aired water was frozen one dimensionally from the top, permitting the sample to be saturated fully while draining any excess water.

Results

The AC CSR tests show that an increase in strain rate results in increases in the shear strength at failure, which confirm the trends reported by many past researchers. Results of four different stress path tests show that stress paths following a positive deviatoric stress (AC, LE), whereby the vertical stress is greater than the horizontal stress, mobilise higher strengths than those with a negative deviatoric stress (AE, LC), which has important implications for rock glacier stability. A clear increase of minimum axial strain rate can be seen in the secondary creep phase with increase of temperature for the AC creep tests, especially at temperatures close to 0°C. An attempt to measure the acoustic emission during AC CSR tests may be reported.