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Mechanical changes in thawing permafrost rocks and their influence on rock stability at the Zugspitze summit, Germany – a research concept

Philipp Mamot, Riccardo Scandroglio, and Michael Krautblatter
Chair of Landslide Research, Technical University of Munich, Munich, Germany

During the last century, alpine permafrost warmed up by 0.5 to 0.8 °C in the upper decameters. Its degradation can influence the stability of rock slopes in alpine environments. An increasing number of rockfalls and rockslides of all magnitudes are reported to originate from permafrost-affected rock faces which reveal massive ice at their detachment scarps after failure.
Discontinuity patterns and their mechanical properties present a key control of rock slope stability. These fractures are considered to experience considerable mechanical changes during transition from frozen to unfrozen state: the shear resistance of rocks is reduced in terms of decreased critical fracture toughness of intact rock bridges and shear strength; compressive strength and tensile strength of the intact rock are reduced in the same way. The impact of rising rock temperature on rock-mechanical properties which control early stages of destabilization remains poorly understood.
In this study we combine rock-mechanical testing in the laboratory with geotechnical, kinematic and geophysical monitoring at the Zugspitze summit, Germany, to investigate the influence of thawing rock on its rock-mechanical properties focusing on mechanisms of destabilization along discontinuities. Our investigations will contribute to a better rock-ice-mechanical process understanding of degrading permafrost rocks.
To assess stability conditions at the Zugspitze summit we conduct field work at an unstable area of about 104 m3 of rock at the crest at 2885 m a.s.l. that is affected by degrading permafrost. This is indicated by a persistent ice filled cave with direct contact to the area of instability.
Our preliminary work consists of i) continuous and discontinuous fracture displacement measurements since 2009 which reveal deformation rates of 0.06 to 1.7 cm/year, ii) electrical resistivity (ERT) and seismic refraction tomography (SRT) in the August of 2014 and iii) uniaxial compressive strength and tensile strength tests as well as P-wave velocity measurements of dozens of frozen and unfrozen Zugspitze limestone samples.
Our future tasks are as follows:
i) To assess the spatial permafrost distribution in the slope we plan to conduct further laboratory-calibrated ERT and SRT. A dense rock temperature measuring network as well as nearby weather stations will supply input data for a simple thermal model of the rock slope.
ii) To assess the spatial and temporal pattern of rock instability at the test site we will continue measuring discontinuity movements.
iii) Undertaking rock-mechanical laboratory tests on Zugspitze limestone and to focus on temperature related changes of friction along rock discontinuities without ice infill and fracture toughness KIIc of intact rock bridges. These tests will be carried out with a direct shear box in unfrozen and frozen state. The measurement of P-wave velocity of the same rock samples will help to upscale rock toughness values to the rock slope at the study site.
We aim at developing and calibrating a discontinuum mechanical model of stability changes in thawing permafrost rocks.

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