EGU2020-14338
https://doi.org/10.5194/egusphere-egu2020-14338
EGU General Assembly 2020

Modelling rock walls destabilization caused by hydrostatic pressure in frozen/unfrozen bedrock (Hochvogel & Zugspitze, Germany)

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One of the most important but still unknown destabilizing factors of rock faces in periglacial environments is the contribution of water in terms of hydrostatic pressure (e.g. Piz Cengalo in 2017). Its presence has often been registered in major rock failures, but it has never been quantified. Perched water table >>20m above virtually impermeable permafrost bedrock can cause excessive hydrostatic stress on affected rockwalls. Climate change related intensification of rainstorms as well as permafrost degradation promote water accumulation. An increase in rockfall activity due to higher water pressure peaks is therefore expected, thus intensifying the risk for humans and infrastructures.

Here we conduct a hydromechanical stability analysis at two study sites in the Northern Calcareous Alps where this effect has been observed. We use the distinct element method developed in the software UDEC (Itasca); the required geometric and mechanical model input parameters were obtained from previous studies with direct investigations and laboratory tests in frozen/unfrozen conditions. Infiltration from rainfall or snow/ice melting is expected to create extreme pressure peaks, especially when permafrost seals fractured rock.

Here we present results from:

- the permafrost affected Zugspitze summit (Wetterstein Range), where sealing permafrost allows the meltwater to accumulate in the active layer. This causes high hydrostatic pressure, evaluated by relative gravimetry methods and with the help of a fracture mapping.
- a preparing high-magnitude rock fall at the Hochvogel (Allgäu Alps), where perched water could destabilize up to 260’000 m³. Displacement measurements on the summit showed acceleration following intense precipitation.

Our model proves that a column of water can bring the Zugspitze north face to instable equilibrium. This happens with different intensities according to frozen/unfrozen conditions and various depth of the active layer, if the hydrostatic pressure is adequate (0.2-0.4 MPa = 20-40 m water column).

Water could also increase the destabilization rates of the south-east face of Hochvogel by adding hydrostatic pressure. A Factor of Safety < 1 is reached when other water-related factors are considered, like: (i) reduction of cohesion in saturated joints, (ii) decrease of the interface friction

angle in fractures and (iii) accelerates weathering along the shear plane

How to cite: Stoll, V., Scandroglio, R., and Krautblatter, M.: Modelling rock walls destabilization caused by hydrostatic pressure in frozen/unfrozen bedrock (Hochvogel & Zugspitze, Germany), EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-14338, https://doi.org/10.5194/egusphere-egu2020-14338, 2020