Residual Strength of Ice Filled Rock Joints

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1 INTRODUCTION

A number of landslide and rock fall events in recent years have been connected with the warming permafrost in high mountain areas. This study investigates the shear strength of ice filled rock joints based on a series of direct shear tests. Artificial samples made of concrete with an idealised saw-tooth surface are used as described in detail by Günzel (2008). Two sample types are used: "concrete-ice" samples, simulating an infill thicker than the amplitude of the joint roughness and "sandwich" samples where the ice filling is equal to the amplitude of the surface roughness (1mm).

2 SHEAR STRENGTH OF ICE-FILLED JOINTS

2.1 *Peak shear strength*

At low normal stresses the peak shear strength of the concrete-ice samples was found to increase linearly with the normal stress (Figure 1); this is interpreted as sliding of the ice against the concrete surface. However, for higher normal stresses the relationship becomes parabolic. This is interpreted as plastic deformation of the ice itself. The sandwich samples yielded very scattered results with a trend of decreasing shear strength with increasing normal stress (Günzel, 2008).
The peak strength and the medium strength of the concrete saw-tooth surface without ice are also indicated in Figure 1.

2.2 *Residual shear strength*

It has to be noted that the ice temperatures at residual strength are slightly higher than at peak strength. This is due to the heat created by the motor of the shear box apparatus during experiments.
As shown in Figure 1, the residual strength of concrete-ice samples behaves differently to the peak strength. For both sample types the linear relationship continues throughout the whole series of experiments. Similarly, the angle of friction of the sandwich samples is 28° and 30° for ice temperatures of -1°C and -3°C respectively. Thus the residual strength appears to depend much less on the sample type or the ice temperature than the peak strength.

3 DISCUSSION AND CONCLUSIONS

The normal stresses used in the experiments were too small to erode the saw-tooth surfaces of the concrete in the samples without ice. Therefore the mean friction angle (ϕ_{mean} = 42°) of the saw-tooth surface is used instead of a true residual friction angle. The results show that unlike the peak strength, the residual strength of the ice-filled joints is always less than that of the unfilled joints.
The results of residual shear strength suggest that the residual strength is purely governed by friction between the ice and concrete surfaces rather than deformation of the ice itself. This interpretation is also supported by the fact that there is no significant difference in the residual strength of the two sample types despite their different behaviour at peak strength. However, the strongly reduced dilation of both concrete-ice and sandwich samples after peak suggests that there must be a combination of frictional sliding and deformation of the ice itself, which requires further investigation.

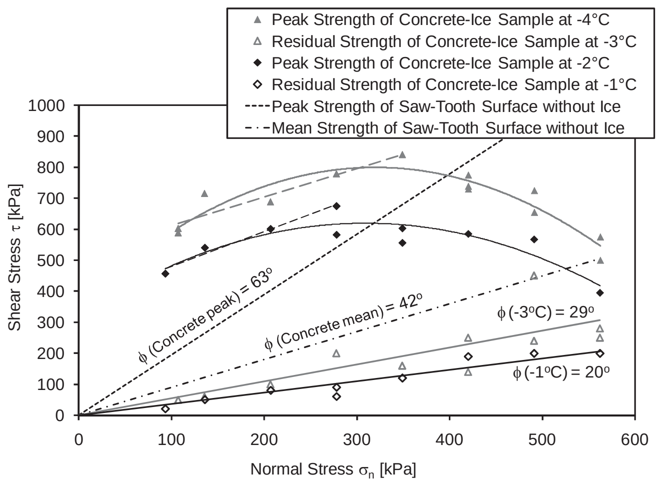

Figure 1. Peak shear strength and residual shear strength results of concrete-ice samples and saw-tooth surfaces without ice.

References

Günzel, F.K. 2008. Shear Strength of Ice-Filled Rock Joints. *Ninth International Conference on Permafrost, Fairbanks Alaska, 29 June–3 July 2008*: 581-586.