Review 1 (by anonymous referee)

Dear referee,
we thank you very much for your interesting, constructive and valuable suggestions and comments related to the content and editorial issues. We carefully addressed all of them and listed the changes in detail hereafter.

Philipp Mamot, on behalf of all co-authors

RC = Referee comment
AR = Author response

Line 55/Figure 1:
RC: “Also give the coordinates of the Zugspitze location”
AR: As suggested by the referee, we provided the coordinates of the Zugspitze location in the text (lines 59-61 in the revised manuscript):
“The limestone samples used for the precedent laboratory tests by Mamot et al. (2018), to which this study refers, were picked from the Zugspitze (47°25’21" N,10°59’13" E, 2900 m a.s.l.), Germany.”

Line 65:
RC: “Sample preparation: Please comment on the alignment of mica parallel to the surfaces of the samples used in the experiments: presumably the samples were cut parallel to the foliation. How does the mica content on the sample surface compare with the mica content in the thin sections? Were the samples cut through mica-rich bands (weak bands and therefore more likely to form fractures in a rock mass)? How many samples were prepared and what was the variation of these samples in terms of mica content?”
AR: We revised the information on the sample preparation and the mica content. A part of the text was shifted from Sect. 2.1 to the second paragraph of Sect. 2. in the following way (lines 62-69 in the revised manuscript):
“A thin section analysis was added to the direct shear tests to determine the mineral composition and the amount of mica in the rock samples. The thin sections were taken from the same rock blocks from which the cylinders for the shear tests were cored. Two thin sections were prepared of each, the gneiss and the mica schist; the results were averaged per rock type. One thin section was produced of the limestone. To account for the anisotropic nature of both gneiss and mica schist, all samples (Sect. 2.1 and 2.2) were prepared from

cuts parallel to the foliation of the rocks. As such, we assume a similar mica content for both the thin sections and the sample surfaces in the shear tests.
[…]
2.1 Petrographical analysis
The thin section analysis was conducted through cross polarised light microscopy with an Olympus DP26 microscope..."

As we only prepared two thin sections per rock type, we cannot give a variation in terms of the mica content.
However, we expanded the supplementary material (xlsx.-file) by the measured mineral compositions of the rock types used for the laboratory tests. This novelty was added to the section "Data availability" (lines 163-164 in the revised manuscript):
*"Data availability. All data which refer to the test conditions and samples, as well as the measured shear stress values and mineral compositions, are provided in the Supplements in a *.xlsx file."*

Line 68-69:
RC: "A strain rate is compared with an acceleration. Please make sure that you compare like for like."
AR: We changed the related sentence as follows (line 77-78 in the revised manuscript):
"(iii) We applied a constant strain rate of $5\times10^{-3}s^{-1}$ provoking brittle fracture of ice and thereby representing the well-advanced stage of rock slope failure."

Line 83:
RC: "I suggest to replace "stronger polarity" with "higher concentration of negative surface charges"."
AR: We modified the wording as proposed (line 94 in the revised manuscript).

Line 94:
RC: "Replace "rock-ice" with "concrete-ice"
AR: We exchanged the wording as proposed (line 105 in the revised manuscript).

Figure 2 and Figure A1:
RC: "I recommend to include the limestone data points from Figure A1 into Figure 2, as this makes it easier for the reader to directly compare the data. It may become necessary to increase the size of Figure 2."
AR: We combined both figures as suggested by the reviewer. For this, we also changed the caption of Fig. 2:

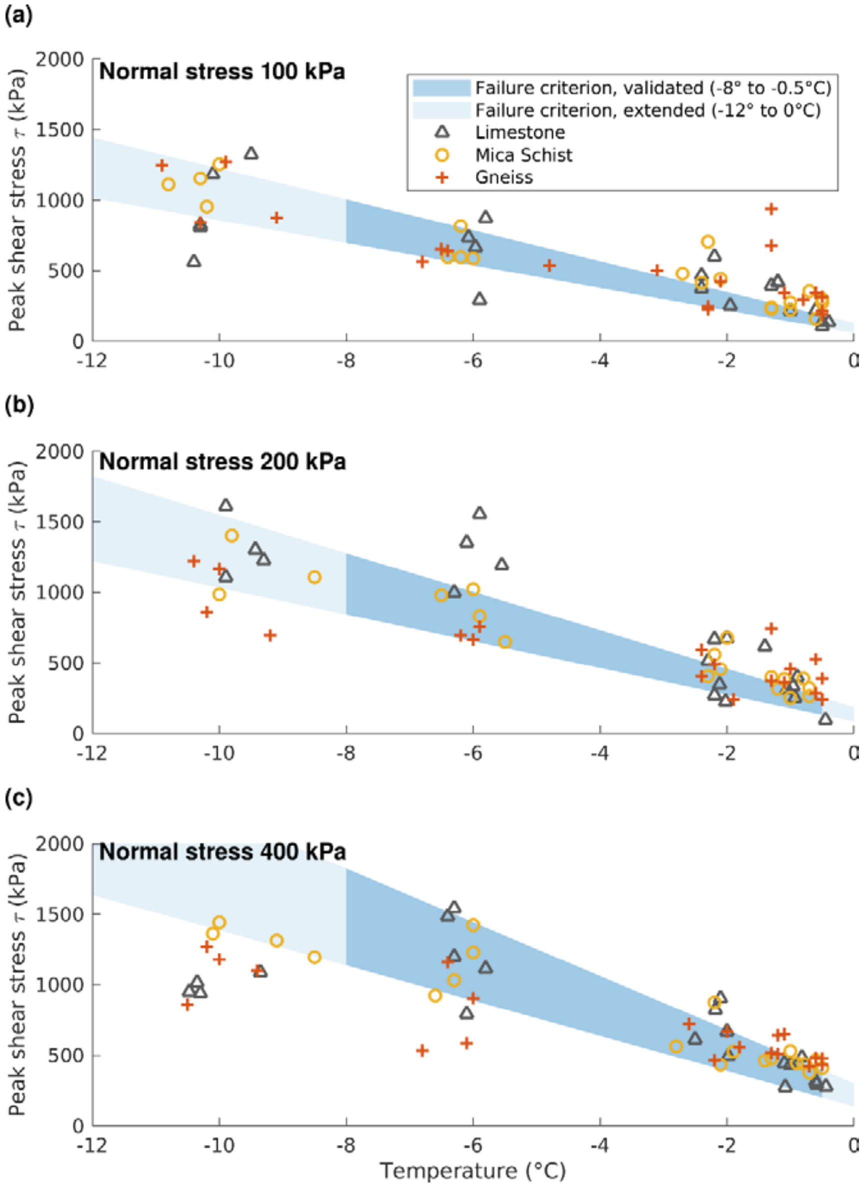

Figure 2. *Peak shear strength across sub-zero temperature of ice-filled rock joints constituted of gneiss (red crosses), mica schist (orange circles) and limestone (grey triangles). The relationships are plotted for normal stresses of a) 100 kPa, b) 200 kPa and c) 400 kPa. The limestone data are added from previous tests by Mamot et al. (2018). The validated range of the failure criterion by Mamot et al. (2018) is marked in dark blue while an extended section to −12 °C and to 0 °C is displayed in light blue.*

Further, we modified the in-text-link to Fig. A1 as follows (line 105 in the revised manuscript): *"This pattern is also visible in the previous tests with limestone (grey triangles in Fig. 2) and…"*

Figure 3:
RC: "Please add a comment on the reliability of the data: how was the failure type observed? Can you give an error estimate for the failure type identification?"

AR: We added a short comment on this in the methods Section 2.2 (line 81-83 in the revised manuscript):
"As in the tests by Mamot et al. (2018), the type of failure was identified qualitatively by visual inspection of the failure surfaces immediately after removing them from the shear apparatus. Samples which did not allow a definite failure type classification were assigned to the mixed failure."

Lines 129-132:
RC: "Point (i): Please comment on the alignment of mica parallel to the surfaces of the samples used in the experiments: natural rock fractures form along mica platelets that are not perfectly parallel. A cut rock surface therefore will expose cuts through a mica grain rather than the surface of the silica sheet. Can you give an estimate how the surface charges of a cut surface differ from the surface charges of a natural fracture?"
AR: The missing information was provided as follows (lines 141-143 in the revised manuscript):
"(i) They are foliated and have typically a high amount of mica aligned subparallel within major shear planes. This property and the resulting effect of the surface charge are expected to be more emphasised along natural joints than along the tested surfaces, as these were cut within intact rock samples."

Lines 129-132:
RC: "Point (ii): I agree with the statement; however, in your experiments you use surfaces with the same roughness. Can you comment on the effect of the different surface roughness on the shear strength of natural joints in limestone vs. joints in gneiss or mica schist?"
AR: We expanded Point (ii) by the following information on the effect of a different rock type-dependent surface roughness on the shear strength of natural joints (lines 144-149 in the revised manuscript):
"(ii) The platy and subparallelly aligned mica grains lead to a very low surface roughness potentially reducing the shear strength. This effect will become more relevant at temperatures close to 0 °C where we observe a higher proportion of fractures along the rock-ice interface. As it is hard to define a representative surface roughness for typically diverse natural fractures, and to guarantee reproducibility of the laboratory rock surfaces, we standardised the joint surface roughness in our tests. Therefore, we assume the effect of varying surface roughness and its dependence on the rock type to be visible in natural fractures, but not in our tests."

Lines 129-132:
RC: "Point (iii): I suggest to replace "presumably" with "possibly". Please comment to what

extent the reduction of shear strength from (ii) and the increase of shear strength from (iii) cancel each other out."

AR: We exchanged the wording from "presumably" to "likely" (line 150 in the revised manuscript).

Further, we added a short comment on how the reduction of shear strength from (ii) and the increase of shear strength from (iii) cancel each other out (lines 150-154 in the revised manuscript):

"(iii) The strong negative surface charge results in an elevated adhesion and equilibrium freezing point which likely leads to a higher peak shear strength.

Due to the uniform surface roughness in the presented tests, we are not able to determine the extent to which the reduction in shear strength by a lower surface roughness (see ii) may offset the increase in shear strength by a strong negative surface charge (see iii). But, overall, we expect the observed mica-dependent higher shear strength close to 0 °C to be suppressed slightly."

Line 136:

RC: "I suggest to replace "systematic increase" with "slight increase". The highest points of the data clouds of the silica samples are higher than the highest points of the limestone samples; however, the data clouds overlap and about half of the limestone data points are also above the failure criterion."

AR: We exchanged the wording as proposed by the referee (line 158 in the revised manuscript).
