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Stress corrosion-controlled rates of mode I fracture propagation in calcareous bedrock

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Surface bedrock on natural rock slopes is subject to constant and cyclic environmental stresses (wind, water, wave, ice, seismic or gravitational). Studies indicate that these stresses range up to several hundred kPa, generally too low to cause macroscopic changes in intact rock, although clear evidence of fracture generation, crack propagation and weathering of bedrock illustrates the effect of environmental stresses at the Earth's surface. We suggest that material degradation and its extent, is likely to be controlled by the rate of stress corrosion cracking (SCC). Stress corrosion is a fluid-material reaction, where fluids preferentially react with strained atomic bonds at the tip of developing fractures. Stress corrosion in ferrous and siliceous materials is often accepted as the fracture propagation and degradation rate-controlling process where materials are subject to stresses and fluids. Although evidence for chemical weathering in propagating bedrock fractures is clear in natural environments, the physical system and quantification of stress corrosion in natural rocks is yet to be addressed.

Here, we present preliminary data on the relationship between stresses at levels commonly present on natural rock slopes, and material damage resulting from stress corrosion under constant or cyclic tensile loading. We undertake single notch three-point bending tests (SNBT) on fresh calcareous bedrock specimens (1100x100x100mm) over a two-month period. Two beams containing an artificial notch are stressed to 75% of their ultimate strength, and a constant supply of weak acid is applied at the notch tip to enhance chemical reactions. A third, unloaded, beam is also exposed to weak acid in order to elucidate the contribution of stress corrosion cracking to the material degradation. Stresses at the tip of propagating cracks affect the kinetics of the chemical reaction in the specimen exposed to both loading and corrosion, leading to an increase in degradation, and greater stress relaxation. These changes in material properties are monitored using strain gauges, acoustic emission sensors, changes in P-wave velocity, and records of time to failure where appropriate.

Our preliminary studies indicate changes in material properties are concentrated in the region of predicted tensile stress intensification. Reactions seem to favourably occur at the stressed bonds around the crack tip. The rate of chemical dissolution and further propagation of the fracture at the notch tip appears to be enhanced by the level of stress applied to the specimen. This provides the foundation for a suite of repeated experiments in which we plan to test corrosion-controlled rates of degradation across a range of loading conditions. The improved understanding into micro-mechanical controls, will contribute to the assessment of rock fall production rates and erosion processes in natural environments as well as natural building stones.