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The effect of the intermediate principal stress on the brittle fracture of rocks

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True triaxial compression experiments on dry rectangular prisms of two crystalline rocks and a siltstone, revealed some common brittle fracture characteristics, not usually observed through conventional triaxial testing ($\sigma_2 = \sigma_3$). Several groups of tests were conducted, each for a constant σ_3 and an intermediate principal stress σ_2 that was varied from test to test between σ_2 = σ_3 and σ_2 approaching $\sigma_{1(atfailure)}$. Summarizing the major findings:

- Contrary to the Mohr criterion assumption, for constant σ_3 a consistent pattern was observed of gradually increasing strength with the rise of σ_2, until a peak was reached (sometimes as high as 30-50% over that at $\sigma_2 = \sigma_3$), followed by a gradual decline, with $\sigma_{1(atfailure)}$ always higher than the conventional-triaxial strength.

- Integrating all the true triaxial strength data in each of the rocks into a Mogi-modified Nadai strength criterion yields a well-constrained monotonically increasing power function τ_{oct} = A[$(\sigma_1 + \sigma_3)$/2]^m, where τ_{oct} is the octahedral shear stress at failure, $(\sigma_1 + \sigma_3)$/2 is the mean stress acting on the fault plane, and A and m are constants of the individual rock.

- Brittle failure under true triaxial stresses is in the form of a shear fracture or fault, striking within $\pm 10^\circ$ in the σ_2 direction and steeply dipping in the σ_3 direction. Here another major effect of the intermediate principal stress was observed, as the fault dip angle for constant σ_3 generally increased steadily as the level of σ_2 was raised. Within the range of σ_2 tested, fault dip angles increased by substantial amounts (up to 20°) from their base values when $\sigma_2 =$

σ_3. Fault plane steepening appears to be related to the strengthening of the rock with increasing intermediate principal stress magnitude. Fault dip dependence on the deviatoric stress state is consistent with the Rudnicki and Rice (1975) prediction of rock shear band orientation.

- The micromechanics of brittle failure were observed through SEM images of failed samples. Common to both crystalline rocks (a granite and an amphibolite) is the development of multitude of microcracks that are subparallel to the $\sigma_1 - \sigma_2$ plane. They localize along a steeply inclined band, which upon total failure becomes a fault dipping in the σ_3 direction. In the siltstone only few microcracks are visible, since they tend to extend intergranularly due to weak clay-rich cementation, and thus difficult to detect in this ultra-fine grained rock.

- Stress-strain recording in all three principal directions reveals another common phenomenon, namely a gradual rise in dilatancy onset with increase in σ_2 magnitude, for constant σ_3. Thus, σ_2 extends the elastic range for a given σ_3, retarding the onset of brittle failure process, and leading to higher true triaxial strength.