Rock physics and mechanical properties of rocks

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Strength parameters of granular materials such as sandstone are governed by three microscopic factors such as 1) strength of constituent particles, 2) geometrical structure of the particles, and 3) cementing condition between particles. Because direct strength measurements such as tri-axial testing using core samples are sometime difficult, it should be very valuable if we can define the rock strength through information taken through the geophysical logging and rock physics modelling, but limited studies have been done in this view.

Application of Discrete Element Model (DEM) to understand the shear failure phenomena have been tried and succeeded for the phenomenological understanding of the rock failure, but the relationship between the microscopic input data and macroscopic parameters such as elastic modulus, internal friction angle, and tensile strength are not clear.

The variety of the elastic velocities in rocks is within a order, but strength has vast varieties even if physical parameters such as density and porosity variety is within several tens of percent. The reason of this variety is caused by the variety of geometrical settings of the particles.

Packing density difference of the FCC (face-centered cubic lattice), 74% and BCC (Body-Centered Cubic lattice), 68% is less than 10%, but the number of the contact of FCC is 1.5 times more (12:8). In the real rocks, smaller particles fill the pore space, and number of the contact increase, so this effect is enhanced. The particle fill makes the effective elastic modulus larger, but the density is increased simultaneously, so the change of the elastic wave velocity is small.

The different scale has different heterogeneity, anisotropy and discontinuity that affect the macroscopic strength. When rock contains finite size of the fractures, and the number of the fracture is multiplied by n when diameter of the fracture become 1/t, total cross section of the fractures will be infinite when n/t is greater than 1.

Those are just thought experiments, but can illustrate how the geometrical structure of the particle influences the strength deeply.

There are some new approaches such as nano-indentation test (Ulm et al., 2007) to investigate microscopic behavior of the rock in the order of particle sizes. Improvement of the computation ability may help more complex multi-scale problems. By those efforts, more realistic microscopic physical models for rock strength will be made.

Reference-Ulm, F.-J., Vandamme, M., Bobko, C., Ortega, J.A., Statistical Indentation Techniques for Hydrate Nanocomposites: Concrete, Bone, and Shale, J.Am.Ceram.Soc., 90(9), 2677-2692, 2007.