Static and Dynamic Elastic Constants in Granite

INTRODUCTION

Five low porosity, granitic rocks were tested in hydrostatic compression and uniaxial strain with simultaneous compressional and shear wave velocity measurements. The rocks included three specimens from Kazakhstan, a fine and coarse grained granite from Mt. Katahdin, ME, and two well characterized granites, Westerly and Sierra White. The compositions, densities, and grain diameters compare closely.

The specimens were ground right circular cylinders 25.4 mm in diameter and 40±6 mm in length jacketed with 0.13 mm thick copper. Strain gages were epoxied to the jacket to measure strain parallel and normal to the core axis.

Each specimen was loaded in hydrostatic compression to 120 MPa. Subsequently, a uniaxial strain test was performed to a mean stress of approximately 250 MPa.

RESULTS

Typically, the compressional and shear wave velocities are slightly faster than 5 and 3 km s^{-1} respectively, at low pressures. Moreover, like velocities from rock to rock differ by a few percent at low pressures; and are 6 and 3.5km/sec at high pressures. Moreover, like velocities from rock to rock differ by a few percent at low pressures and less than one percent at high pressures.

Static loadings of the granites in hydrostatic compression and uniaxial strain show similar characteristics. Data collected on Sierra White granite (SWG) are shown. The stress (pressure) versus strain curves are concave upward, and there is hysteresis on unloading.

The low pressure bulk moduli of the granites range from 15 to 25 GPa. The greatest pressure sensitivity is observed for the Nickerson Lake granite and the lowest for the SWG and Westerly. With increasing pressure, the moduli asymptotically approach 50 to 60 GPa at 100 MPa.

For hydrostatic compression, the dynamic moduli exceed the static moduli at all pressures. At low pressure, the ratio of the dynamic to static moduli is nearly a factor of two. The static and dynamic Young's moduli for uniaxial strain conditions show a similar relationship. The dynamic moduli exceed the static moduli for mean stresses below 150 MPa; at 150 MPa the moduli are nearly equal.

DISCUSSION

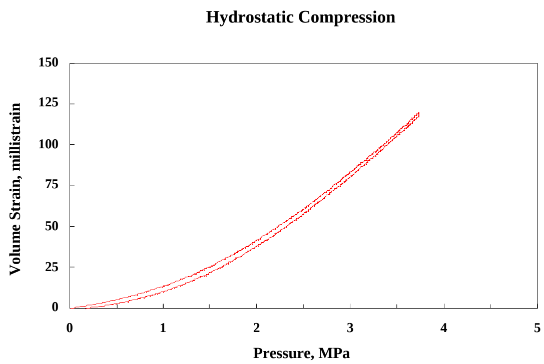
The data exhibit a consistent trend: moduli increase with increasing confining pressure or mean stress. The stress dependencies for the static measurements are greater than those for the dynamic. Since both static and dynamic measurement techniques are sampling the same rock, the reasons for the discrepancies need to be explored.

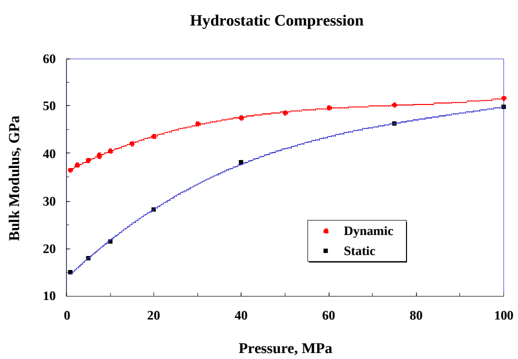
The rocks are very compressible at low confining pressures and become less compliant with increasing pressure. This effect is attributable to the closing of low aspect ratio, elliptical cracks; the lower the aspect ratio the greater the change at low pressures. Cracks close completely at high pressure and the compressibility approaches that of an uncracked rock. Since the compositions are mean grain diameters of the granites are similar, the reason for the differences in the bulk moduli between the granites is most likely related to the crack morphology and closure behavior.

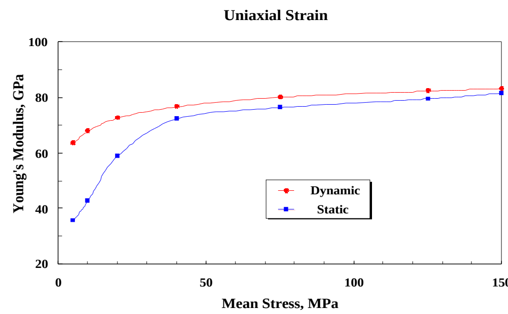
The dynamic moduli are also related to the length, number, and aspect ratio of elliptical cracks. As crack lengths decrease, the dynamic moduli increase. The models are consistent with the observations, but fail to account for the differences in static and dynamic moduli. Static and dynamic properties of granite depend on crack density and the distribution of crack lengths, yet under the same state of stress the computed elastic moduli differ, particularly at low stresses. Several explanations have been forwarded to explain these discrepancies. Two possibilities are frequency and strain amplitude.

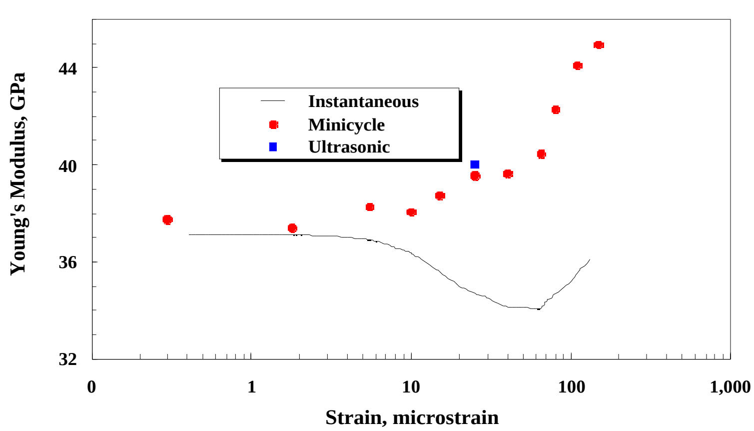
Related studies on dispersion indicate that elastic constants are independent of frequency for dry specimens, but strongly dependent on the strain level. Uniaxial compression tests on SWG indicate that crack closure is not a linear function of stress. At low strains (10^{-6} or less) static and dynamic moduli are equal. With increasing total strain, the static modulus decreases.

Bulk and Mechanical Properties of Paintbrush Tuff From Yucca Mountain, NV









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