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Characterizing Anisotropy within the Montney Formation

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Summary

The characterization of mechanical properties in finely laminated shale can be challenging due to its highly anisotropic behavior. The presence, and angle of, bedding planes within the rock influences the strength and failure mode of the rock in response to an applied load. Therefore, investigating the impact of bedding plane orientation on the deformation and fracture characteristics of finely laminated shaley rock is crucial to characterizing the rock. This study aims to investigate the results of unconfined compression strength (UCS) testing on finely laminated Montney shale samples. Cylindrical samples are tested at the following bedding plane orientations: 0-, 10-, 20-, 30-, 40-, 50-, 60-, 70-, 80-, and 90-degrees with respect to the loading conditions. The preliminary results show that the UCS strength and failure mode are significantly influenced by the bedding plane orientations.

Theory / Method / Workflow

Blocks of shale were obtained from a quarry in Alberta, from an outcrop equivalent to that of the Montney formation. The blocks were cored at different orientations with respect to the bedding planes present in the rock. The bedding plane angle was measured from the primary axis of the core, such that 0 degrees represents the bedding planes being parallel to the axis of loading. The samples were cored with a drilling machine equipped with a 1.25-inch diamond bit core barrel, with water used as the cooling fluid. A quantity of three (3) core samples were collected from each of 0-, 10-, 20-, 40-, 50-, 60-, 70-, 80-, and 90-degree orientations. An additional six (6) samples were cored at 30 degrees, for a total of thirty-three (33) samples. The samples were encased in a plastic heat shrink tube to maintain their integrity during sample preparation and testing. The resulting samples had an approximate diameter of 32 mm and were cut to between 65-70 mm in length. The end surfaces were ground and finished using a CNC surface grinder to ensure each sample's faces were flat and parallel to each other. An example of samples cored at each angle can be seen in Figure 1 (b). For each sample, the diameter, length, and weight were recorded prior to testing. In addition, P and S wave velocities were measured for each sample.

UCS testing was conducted to determine the compressive strength and elastic properties of the Montney shale samples. The testing equipment consists of a Forney loading frame, a Vindum VP-6K high-precision/pressure metering pump, an Ashcroft GV pressure transducer (3000 psi), a 3D digital image correlation (DIC) system (two Basler acA2500–60um cameras in stereo setup), and two variable linear differential transformers (LVDTs) (LD Sensors LDS-10). The metering pump will be used to control the actuator and apply axial strain to the sample. The 3D DIC system will be utilized to measure the 3D deformation field of the sample during the experiment. Data acquisition will be conducted by connecting the pressure transducer and LVDTs to a digital acquisition system (National Instruments USB-6001). An example of the UCS testing setup including the loading frame, DIC, and LVDT arrangement is shown in Figure 1 (a).

Figure 1: (a) UCS Testing Setup with Loading Frame, DIC, and LVDT (b) Example of Samples Cored at 0° through 90°

The samples were tested in a plastic shrink tube wrap to contain the sample debris after testing. A window, approximately 25 mm x 25 mm, was cut in the shrink wrap to expose the rock. This region had a speckled pattern applied to the rock using spray paint, to allow the DIC system to track and record the deformation of the rock during testing. Samples were uniaxially loaded under a controlled rate of deformation until failure. Failure patterns were photographed, and the failure mode was recorded for each sample. The UCS of the sample was determined by the peak compressive stress produced during the test. The axial and circumferential strain were recorded by the DIC and were used to estimate the Young's Modulus (E) and Poisson's Ratio (v). In addition, the LVDTs were used to measure axial strain of the sample during testing.

Results, Observations, Conclusions

The results from the UCS tests provide insight into the anisotropic behavior of the finely laminated Monterey formation shale. The results given in the report suggested a consistent change in the elastic properties including P- and S-wave velocities, dynamic and static elastic modulus, and dynamic Poisson's ratio as bedding direction increases from 0- to 90-degrees. The type of anisotropy can be identified by the curve between uniaxial compressive strength and the bedding plane orientation angle [1]. U-shaped curves can indicate a unique plane of weakness existing in the rock while shoulder curves are indicative of continuously varying anisotropic behavior [2]. The preliminary results of the UCS testing indicate a reduced strength at intermediate angles. Shear dominant failure along the bedding panes is expected to at intermediate orientations, with tensile axial splitting occurring at more extreme orientations [2]. The report outlines the transition from tensile-dominated failure mode to shear-dominated failure observed as the bedding orientation changes. In addition, the axial strain recorded by the LVDTs and DIC system are compared and analyzed. Further conclusions are drawn by correlating the P and S wave test to the UCS failure data.

References

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