Shear behavior and pore pressure changes during velocity-stepping experiments on water-saturated clay gouge

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A mechanics of water-saturated clay gouge is critical for understanding the dynamic processes during earthquake faulting, yet remains poorly understood. We have performed the velocity-stepping (0.08 mm/s-0.8 mm/s-8 mm/s) experiments on water-saturated kaolinite clay under undrained conditions at room temperature and constant normal stress (200 kPa), using a ring shear apparatus. Shear strength and pore pressure on the shear zone and outside of the shear zone were monitored during the shearing. Our results demonstrate that the water-saturated clay gouge can be velocity strengthening: steady-state strength increases with increasing slip velocity. Pore pressure on the shear zone remains constant during the velocity at 0.08 mm/s but fluctuate during faster velocities (0.8 mm/s and 8 mm/s). Pore pressure is suddenly decreased when the slip velocity is increased, suggesting the overconsolidation state of the clay gouge at the new velocity. In contrast, pore pressure is rapidly increased when the slip velocity is decreased, suggesting that the underconsolidation state of the clay gouge at the new velocity. Using a concept of the critical state theory in soil mechanics, we consider these rapid changes in shear strength and pore pressure associated with velocity-stepping. Our finding is that there is a positive correlation between slip velocity and steady-state porosity in the shear zone. Pore pressure outside of the shear zone remains constant when the slip velocity alternated between 0.08 mm/s and 0.8 mm/s but is decreased when the velocity is increased from 0.8 mm/s to 8 mm/s. Our experiments indicate that effects of dilatancy are spatially widen at the higher slip velocity, which may contribute to the higher steady-state porosity at the higher slip velocity.