What can we learn from meter-scale rock friction experiments?

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We have been conducting meter-scale rock friction experiments using the large-scale shaking table at NIED since 2012. We have completed 5 series of experiments, each of which included about 20 experiments. One of the purposes of these experiments was to investigate the spatial scaling of the friction since the friction laws we use today were derived from centimeter-scale experiments. Another purpose was to monitor rupture evolution and local stress field using near-fault high-resolution measurements. In this talk, we will showcase some key results derived from our rock friction experiments.

Regarding the spatial scaling of friction, we recognized that the local frictional strength was not uniform on the fault and its spatial variation had a significant impact to the macroscopic frictional strength (Yamashita et al., 2015). In addition, the scaling behavior seems different between rock-on rock friction and that with a gouge layer. In the rock-on-rock case, gouge generation changes the strength in space. But if the gouge layer already exists, strength depends on the rearrangements of the gouge particles (Yamashita et al., 2018).

Regarding rupture evolution on laboratory fault, we pointed out a previously overlooked difficulty in direct measuring the two-dimensional (2D) evolution of the rupture front. Under very special condition, we could overcome this difficulty by installing 2D strain gauge arrays inside the rock sample. We found that the free surface effects at both edges of the fault had a significant effect on rupture nucleation (Fukuyama et al., 2018). In addition, the strain behavior close to the fault edge might not be the same as that on the fault, even if the sensors were installed within 10 mm away from the fault. Using numerical simulations, we could reproduce the observed strain data by extrapolating a simple friction behavior on the fault surface, suggesting that the way of deriving the friction law needs to be revised (Xu et al., 2019).

We also discovered some interesting fault behaviors during our experiments. By changing loading rate or fault surface condition, we could frequently reproduce super shear rupture events in the laboratory, which were thought to be rare in nature. By investigating the cohesive zone length of the rupture front in the supershear regime, we showed that the experimental results could reach a good match with one of the theoretical predictions Fukuyama et al. (2017). Moreover, we observed slow slip events with supersonic propagation velocity during some experiments (Fukuyama et al., 2019), whose interpretation is still underway.

The above results bridge the gap between the traditional small-scale lab experiments and the field observations, and can be useful for improving our understandings of fault rheology and earthquake physics.

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