Superfast Propagation of Slow Slip Rupture in Large-scale Rock Friction Experiments

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A very rapid propagation of slow slip events was observed during large-scale rock-on-rock friction experiments. We have been conducting large scale rock friction experiments assisted by large scale shaking table at NIED. In this study, we employed a pair of vertically stacked meta-gabbro rock specimens whose nominal fault area is 1.5m long and 0.1m wide. We applied a constant normal stress of 6.7MPa and constant loading velocity to the bottom sample which is fixed to the shaking table (top block is fixed to the ground). We conducted the experiments under three different loading velocities: 0.01mm/s, 0.1mm/s, 1mm/s, whose total displacements were 8mm, 40mm, 400mm, respectively. Here, we focus on the experiments with 0.01mm/s. We installed 60 semiconductor strain gauge sensors on both sides of the fault (30 for each side), 10mm off the sliding surface at an interval of 50mm. In addition, we installed 16 broadband acoustic sensors (Olympus V103-RM) on both sides (8 for each side), 70mm off the fault at an interval of 180mm. And we digitized the data at an interval of 1MHz and 10MHz for strain gauge and acoustic sensors, respectively.

In most experiments, we observed precursory slow slip events that preceded the unstable main rupture along the fault, as summarized in Ohnaka (2013). During such precursory slow slip events, foreshocks sometimes occurred, especially when gouge layer had already been formed. High frequency wave radiation was observed either when the slip velocity became transiently fast at some portion of the fault during the slow slip events, when the rupture front of precursory slow slip event reached the edge of the fault, or when foreshocks occurred. In either case, the radiated waves contained high frequency components.

Very different from the precursory slow slip events, we observed emergent slow slip events, which started to slip almost instantaneously and emitted low frequency waves. These events tended to occur at the former part of the experiment where total amount of slip was short and thus gouge layer might not be well developed. These events accounted for about 5-10% of the total stick slip events, suggesting that they are not rare in the experiments. Apparent rupture velocities exceeded S-wave speed of the rock sample (3.6km/s) and sometimes approached the P-wave velocity (6.9km/s). Compared to precursory slow slip - unstable slip events, emergent slow slip events caused similar stress drop but smaller slip displacement. Although we do not have clear explanations for such unusually fast rupture propagation data at this moment, we confirmed that these events surely occurred on the sliding surfaces where precursory slow slip - unstable slip occurred. Therefore, it should be quite interesting and important to understand these phenomena.