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High velocity friction experiments suggesting dynamically weak, but statically strong faults

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We have conducted high-velocity friction experiments on fault gouge from Chelungpu fault, central Taiwan, with accelerating and decelerating slip history, trying to reproduce more realistic seismic fault motion. We propose a simple empirical equation for observed behavior with such a slip history; (1) initial strengthening, (2) then dramatic slip- and velocity-weakening, and (3) finally fault healing upon deceleration. The equation will be useful in modeling earthquake rupture propagation. Experiments were conducted on disaggregated fault gouge from TCDP drill core using a high-velocity rotary shear apparatus; the first series of tests at constant slip rates, and the second series at accelerating slip rate to a peak velocity of 2 m/s and then at decelerating slip rate in a similar manner shown in a seismic-inversion result. Constant slip-rate experiments exhibited dramatic slip weakening as recognized in previous studies.

The second series of experiments were started from a certain initial stress close to static friction of a fault, fault motion was accelerated from stationary to the peak velocity within about 6 seconds, and then fault motion decelerated back to stationary after another 4 seconds. Fault exhibit three distinct stages with such a slip history; the initial strengthening from initial frictional coefficient of 0.6 to about peak friction of 0.7-0.9 with decimeters of slip, followed by slip-weakening to the lowest friction of about 0.1, and finally friction recovered to about 0.4-0.5 during the healing stage. The initial strengthening will act as a barrier that a fault has to overcome to grow into a large earthquake, and we model this portion as a slip-strengthening process. The weakening and healing behaviors are modeled using velocity-dependent steady-state friction

combined with slip-evolution towards the steady-state friction. Such coseismic fault constitutive behavior suggests that a fault weakens dramatically during coseismic slip, but it recovers strength shortly after the passage of the earthquake rupture front. Brune (1969, 1970) postulated a very similar idea ("abrupt locking model") several decades ago to explain the low heat flow observed around active faults and the apparent pulse-like behavior of earthquake fault ruptures. Our results may verify Brune’s model, and in such circumstances, faults may be weak dynamically but statically strong. The dynamic stress, driving seismic fault motion, can be much greater than the static stress drop.