Transport and frictional properties of Chelungpu, Shuangtung and Shuichangliu faults and their implication for fault motions

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1999 Taiwan Chi-Chi earthquake brought about remarkable contrast in seismic behaviors between the northern and southern parts. The northern part is characterized by fast velocity and large displacement, and the southern part had much smaller displacements, but the levels of accelerations were higher. Shallow drilling penetrating Chelungpu Fault conducted in the north and the south revealed marked difference in the fault zones. This suggests that the difference of physical properties for fault rocks might have induced such contrast of the fault motions. Furthermore, high fluid pressure is observed at depths of Taiwan oil field. This high fluid pressure exerts significant effects on the earthquake fault motion because of increasing permeability and decreasing of the strength of fault.

In this study, transport and frictional properties for fault rocks at Chi-Chi earthquake area, and weakening behavior during the earthquake were estimated the from the experimental results.

Shallow borehole core samples for the northern and the southern sites, and outcrop samples for the three main thrusts (Chelungpu, Shuangtung and Shuichangliu Faults) are selected for laboratory experiment to investigate the variation of fault properties between north and south and the depth variation of fault zones. The influence overpressure on the fault motions was evaluated as well.

Permeability of fault rocks for the northern site showed 10^-16 to 10^-18 m^2 at the depth of 1 to 3 km, and for the south, permeability showed 10^-15 to 10^-17 m^2, which is one order larger than that for the south. For surface outcrop of Chelungpu Fault, permeability is large ranging from 10^-15 to 10^-16 m^2, and 10^-16 ~10^-17 m^2 for Shuichangliu Fault, and smallest for Shangtung Fault ranging from 10^-17 to 10^-19 m^2. On the other hand there are small differences in specific storage among faults, and values are from 10^-9 to 10^-10 Pa^-1.

High frictional gouge experiments were conducted at dry condition with 1.03 m/s in speed and 0.6 to 0.9 MPa in normal stress. There are small differences in high velocity frictional behaviors among faults. Frictional coefficient suddenly increases up to 0.67 to 1.08, then gradually decreases down to 0.15 to 0.22 with slip. Fault weakening distance, Dc, which is critical parameter for the determination of fault stability showed from 6.4 m to 13 m. Hydraulic properties and high velocity frictional properties were incorporated in the thermal pressurization analysis. Thermal pressurization is ineffective for the south of Chelungpu Fault, on the contrary weakening is relatively enhanced by thermal pressurization for the north. Thermal pressurization is most effective for Shuangtung Fault, and Dc becomes 0.3 to 1 m at 3 to 6 km depth. Thermal pressurization is less effective for Shuichangliu Fault. If Shuangtung fault represents deeper part of Chelungpu fault, one may argue that thermal pressurization would be effective at depths of Chelungpu fault. However, basin analysis in the focal area implied that overpressure might developed within and below the depth of the fault, and this overpressure suppresses thermal pressurization.

The low velocity gouge frictional tests showed remarkable differences among faults. Frictional coefficient is the highest for Chelungpu Fault gouge, and the lowest for Shuichangliu Fault gouge. Velocity dependence on the friction showed velocity weakening in the north and velocity strengthening in the south.

The results of thermal pressurization analyses were consistent with seismic behavior of the Chi-Chi earthquake. However, the velocity strengthening, which may enhance the friction during slip, is controversial to large displacement in the north, and other weakening mechanisms might be a key to explain this paradox. Dc determined in high velocity frictional test and thermal pressurization analysis were quite similar to that of seismically evaluation.