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Permeability of shallow nankai subduction zone and its role for mechanical property

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Megasplay faults branching upward from the plate-boundary interface (subduction zone) is thought to be active and contributed to generate recurrent ravaging tsunamis. The rupture and coseismic slip must have propagated to frontal thrust (or shallow portion of decollement) and caused tsunamigenesis as well. Rock physical property and stress state in addition to fault geometry are key parameters that influence on the rupture path of the branching faults in subduction zones. Therefore we measured permeability and frictional properties of core materials retrieved from the megasplay fault zone (site C0004) and the frontal thrust (site C0007) in the shallow part of the Nankai subduction zone in the Nankai Trough during IIODP Expedition 316.

Friction tests were performed by using the rotary shear testing apparatus in Kochi Core Center. The core samples were crushed and then disaggregated to gouges ($<$0.2 mm of grain size) before experiments. 1g of the gouge powder was placed between a pair of solid-cylindrical Indian sandstone specimens (10^{-15} to 10^{-16} m^2 of permeability), 25mm in diameter. Teflon sleeve was used to prevent gouge powders from leaking during rotation of a sandstone cylinder. We rotated one side of Indian sandstone cylinder at a constant speed during friction test at about 1.5 MPa of normal stress. Permeability was measured before and after 7.9 m slip displacement at high (1.05 m/s) and low velocities (0.013 m/s), from which we estimated the shear-induced permeability change in an experimental fault gouge.

After sliding, permeability increased for dry gouge and decreased for wet gouge. The high-velocity friction test under dry condition yielded a larger reduction in permeability than the low-velocity friction test, whereas the opposite trend was observed in wet conditions. These trends are observed in megasplay fault material and the frontal thrust material in common. We attribute the velocity dependence on the permeability change after wet experiment to the effects of thermal/mechanical pore pressurization upon shear-induced compaction, because the pore pressurization by frictional heating has prevented further compaction and permeability reduction in high velocity tests.

The large friction coefficient of the megasplay fault material in the slow and wet friction tests is explained by higher permeability and homogeneous shear deformation that promotes faster shear-induced compaction. On the contrary, the lower friction coefficient and a smaller reduction in permeability due to friction in the frontal thrust sample is due to the slower shear compaction stemming from the formation of localized shear texture and lower gouge permeability. The similarity in post-shear permeability under wet condition in high-velocity friction for the two gouges may account for the similar friction coefficients, assuming that the thermal pressurization process controls high-velocity frictional behavior. Symmetric boudin structure observed after high-velocity friction test may represent evidence of hydrofracturing induced by pore pressurization.

Our results indicate that large stress drop is expected for the megasplay fault during seismic slip, and it may enhance the large slip displacement than in the frontal thrust. Therefore a risk of tsunami genesis could be higher if seismic rupture is propagated to the megasplay fault not to the frontal thrust in Nankai subduction zone.

Keywords: permeability, Subduction earthquake, friction coefficient, NantroSEIZE