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Grain size segregation in a fault gouge model

Ryo Itoh[1*]

[1]Earthquake Research Institute

In Chelungpu fault gouge, the presence of reverse grain size segregation (RGSS), which is marked by the concentration of large grains in the upper part of the gouge layer, is observed [Bouiller et al., 2009]. Gravity kinetic sieving, which is considered as a mechanism of RGSS, needs gravity and substantial voids. If RGSS occurs by this mechanism in a fault, it means there are substantial voids in a fault gouge when faults slip. Of course, gouge layer has few voids because general effective normal stress is in a magnitude of 100 MPa. However, if thermal pressurization (which is a mechanism to increase pore pressure by frictional heating on a fault) occurs, effective normal stress reduces and voids increase in a fault gouge. Then, RGSS in a fault gouge is considered as a convincing proof of thermal pressurization.

However, we have to be careful that this idea is based on an assumption that RGSS occurs by gravity kinetic sieving. Recently, [Fan and Hill, 2011] found that segregation in pipe flow occurs by mechanism which is not kinetic sieving. If this mechanism works in a fault gouge, RGSS in a fault gouge is not a proof of thermal pressurization.

In this paper, I check whether RGSS occurs even if there is no pore fluid and there are few voids by 2-dimensional DEM simulation. For simplicity, fault gouge is composed of 2 kinds of grain which are different in size.

Granular material simulation in a condition that only rocks slip shows that RGSS occurs if the gouge porosity is large and it seems to occur by gravity kinetic sieving. While, RGSS seems to relate with non-linear velocity profile, too (RGSS occurs when velocity profile is non-linear). Then, simulation with artificial non-linear velocity profile is done in order to check which is essentially important for RGSS. As a result, RGSS occurs even if the gouge porosity is low. It is mentioned that RGSS occurs even if the porosity is 0.146 and this value is extremely low. According to this, occurrence of RGSS doesn't mean porosity is high. Regardless of porosity, RGSS occurs with non-linear velocity profile. Next, simulation is done in which the mass and size of 2 kinds of grain are changed independently. RGSS occurs when 2 kinds of grain are the same mass and different in size. On the other hand, RGSS doesn't occur when they are different in mass and the same size. Then, I found that RGSS is induced by the difference not in mass but in grain size. As a result, essential cause of RGSS in a low-porosity gouge is (1) non-linear velocity profile (2) grain size (not mass).

However, why and how non-linear velocity profile is produced in a fault gouge is unknown. Understanding of mechanism how to build non-linear velocity profile in a granular layer is a future work.

Keywords: segregation, gouge, thermal pressurization, non-linear, grain