Variety of friction by double direct rotary shear tests with sandwiching two different granular materials

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[Background and Objectives]
As part of JAMSTEC's 50th anniversary celebrations, we held a project called "Non-Slippery Sand Koshien" to determine the "the non-slipperiest sand in Japan" (https://www.jamstec.go.jp/50th/suberanai/). This was a project to determine the relatively least slippery sand among 50 types of sand and rocks, such as beach sand, volcanic ash, and granite, selected from the general public in various parts of Japan through laboratory friction experiments. Therefore, the mechanical data obtained through this project will be expected to lead to an understanding of the diversity of frictional properties of natural rocks and fault materials by summarizing the data in terms of relative differences in friction coefficient. On the other hand, since the friction coefficient (frictional resistance) of granular materials is greatly affected by factors such as slip displacement, slip velocity, and slip history, it is very difficult to evaluate the difference in frictional resistance for unknown natural sand. Therefore, for the sake of "Non-Slippery Sand Koshien", we constructed a "friction experiment system to evaluate the relative frictional resistance of different granular materials ", and evaluated the frictional properties of granular materials obtained through this project.
[Method]
"Non-Slippery Sand Koshien" was carried out based on a friction experiment of powdered materials using a rotary friction apparatus. Two different granular materials are placed between two parallel layered simulated fault planes (25 mm diameter circles), and shear stresses of the same magnitude are applied simultaneously from the same direction. When the shear stress exceeds a certain level, one of the granular materials starts to slip. Using this method, we can confirm that the frictional resistance of the granular material on the rotated side is relatively low, and record the shear stress of the sliding granular material. In the "Non-Slippery Sand Koshien" tournament, the first sand to rotate a quarter turn was declared the loser, and the winner of the 50 sand tournaments was determined from the sand that did not slip until the end of the tournament. The simulated rock that sandwiched the powder was made of metal with rough grooves on its surface. At the beginning of the game, the shear stress was increased at a constant acceleration (4 Nm/min) while the vertical stress was fixed at 4 MPa. When the speed reached 0.1 rpm, the rotation was controlled at a constant speed of 0.1 rpm. 1 g of dry granular sample with diameter less than 1 mm were used. The mineral composition, particle size, and average density of all granular samples were measured, and the relationship with representative shear stress was evaluated.
[Results]
The winner of the match was "powdered oyster shells cultivated in Wakasa Bay (Fukui Prefecture), which were baked and crushed". As is to be expected, the sand particles that won the match tended to have a higher maximum shear stress. In particular, granular materials artificially crushed from solidified rocks (igneous rocks, sedimentary rocks, and ores) were recognized to have higher maximum shear stress than natural granular materials such as beach sand and river sand, and tended to win the higher rankings. Granular materials with lower quartz content and larger average grain size tended to have higher peak friction. On the other hand, among the natural sands, sands with high magnetite (iron sand) and spinel content and high average density tended to have lower friction. All of these factors can affect friction, but

it is clear that there is a large friction gap between artificially crushed rock fragments and natural sand. The major difference between artificially crushed sand and natural sand is that the former has an angular particle shape and the latter is rounded. The winner of "baked and crushed oyster shell " is composed by a flat-shaped grains, which suggests that not only the circularity but also the flatness has a significant impact on the friction. When the flat particles are lined up in layers the contact area between the particles is increased, that results in the increase in the friction.

Keywords: friction, granular material, shear stress

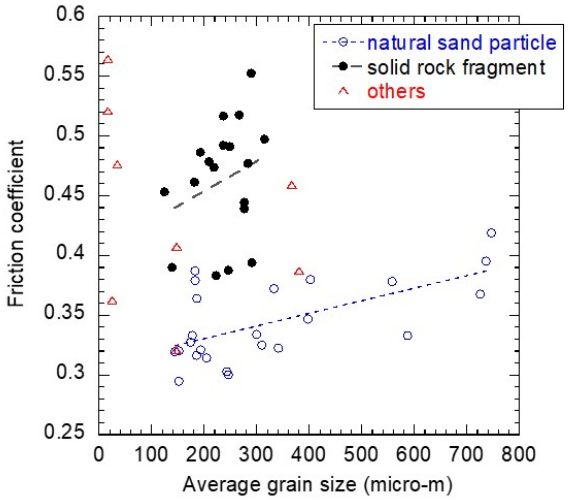

図1.「すべらない砂甲子園」で得られた平均粒径とピーク摩擦の関係
Figure 1 Correlation between grain size and friction coefficient obtained from Non-Slippery Koshien.

