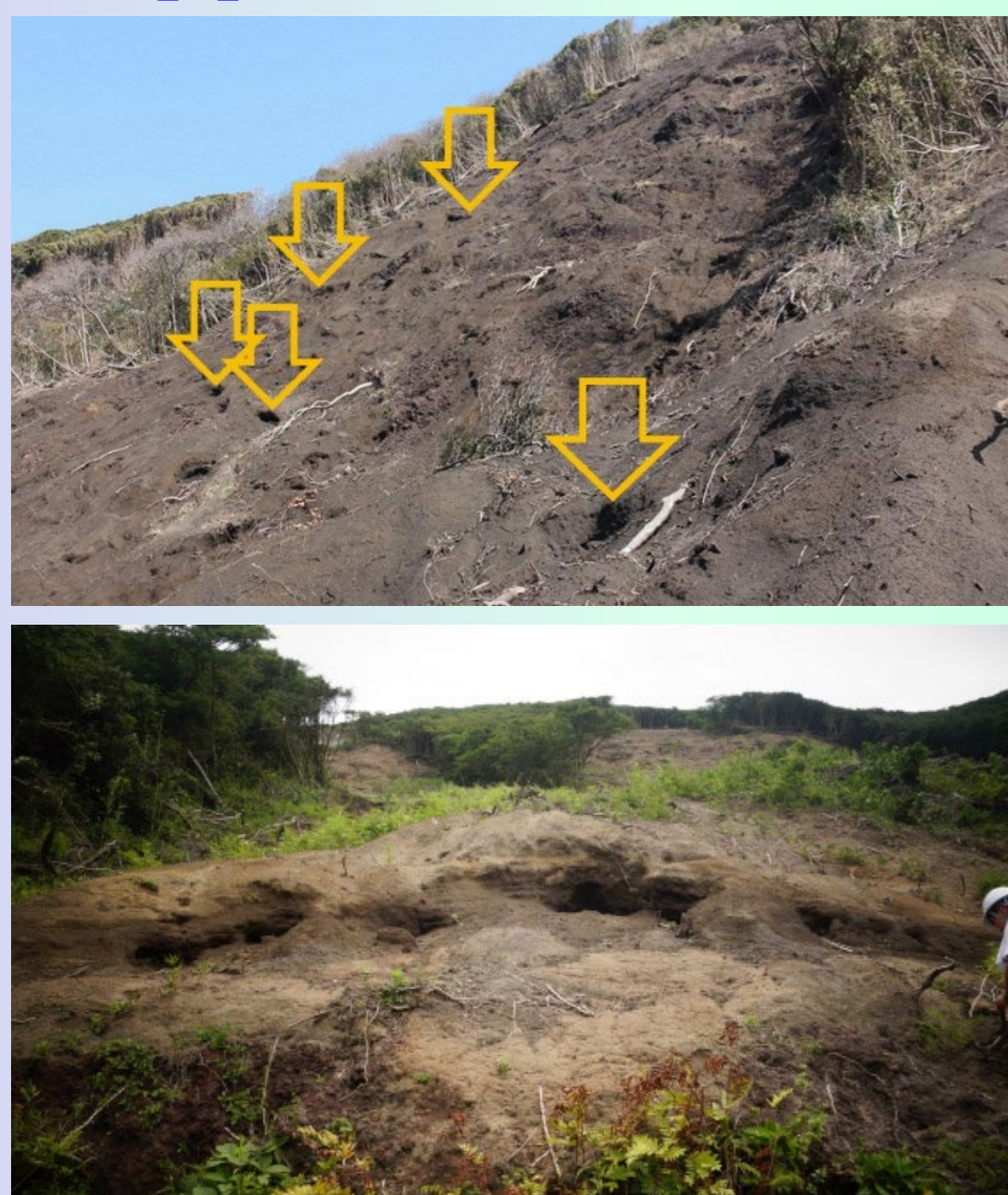


Piping, known as a complex phenomenon of internal erosion, presents a great risk for hydraulic structures. In order to investigate the mechanical properties of sand with internal pipes, artificial piping was created by dissolving glucose column in a hollow cylindrical specimen of Toyoura sand. In this research, triaxial compression(TC), triaxial extension(TE) and torsional shear(TS) tests were conducted on specimens with vertical pipes before shearing. Piping propagation during water infiltration was observed with Glip Gauges, and gap sensors were used to obtain shear modulus before and after piping effect by conducting small torsional cyclic loadings. Finally, monotonic torsional shear were applied to all the specimens until failure.

盛土や斜面に繰返し雨水が浸透することにより土粒子が流出しパイプ状の水みちができる場合があり、ソイルパイプと呼ばれる。浸透した雨水を速やかに排水する効果が期待されるものの、何らかの理由で水みちが閉塞された場合は一転して危険であるうえ、土構造内に空隙を有することになり構造上の弱点となりうる。本研究では、中空ねじり試験供試体内にグルコースを溶解させることにより人工的なパイプ生成を試み、供試体の変形強度特性に対するパイプの数や拘束圧、土の密度の影響を調べた。

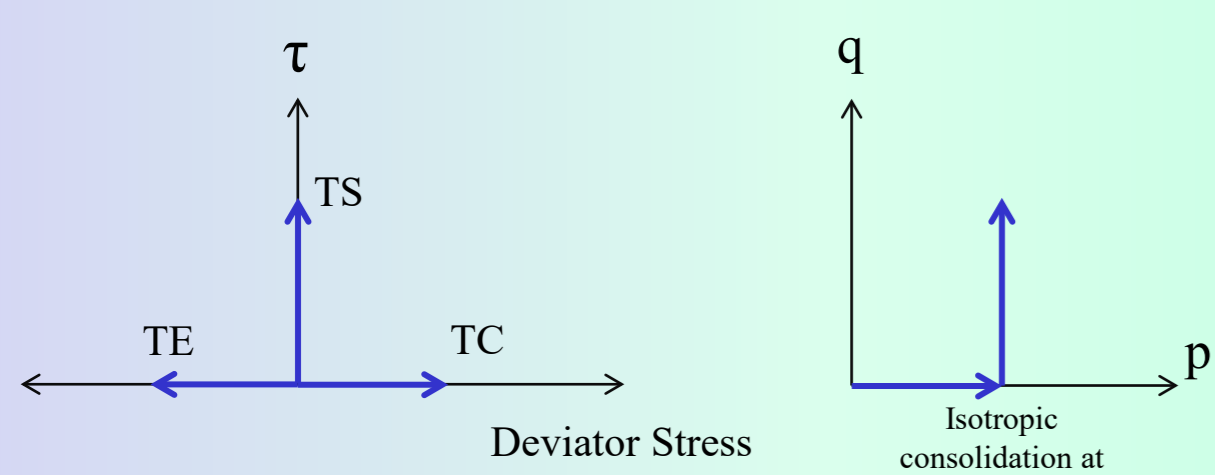
### 1. Soil pipe



- ❖ Piping, which often occurs in hydraulic works, involving the removal of subsurface soils in a continuous tunnel to a free or escape exit.
- ❖ Landslide caused by piping has drawn much attention recently.

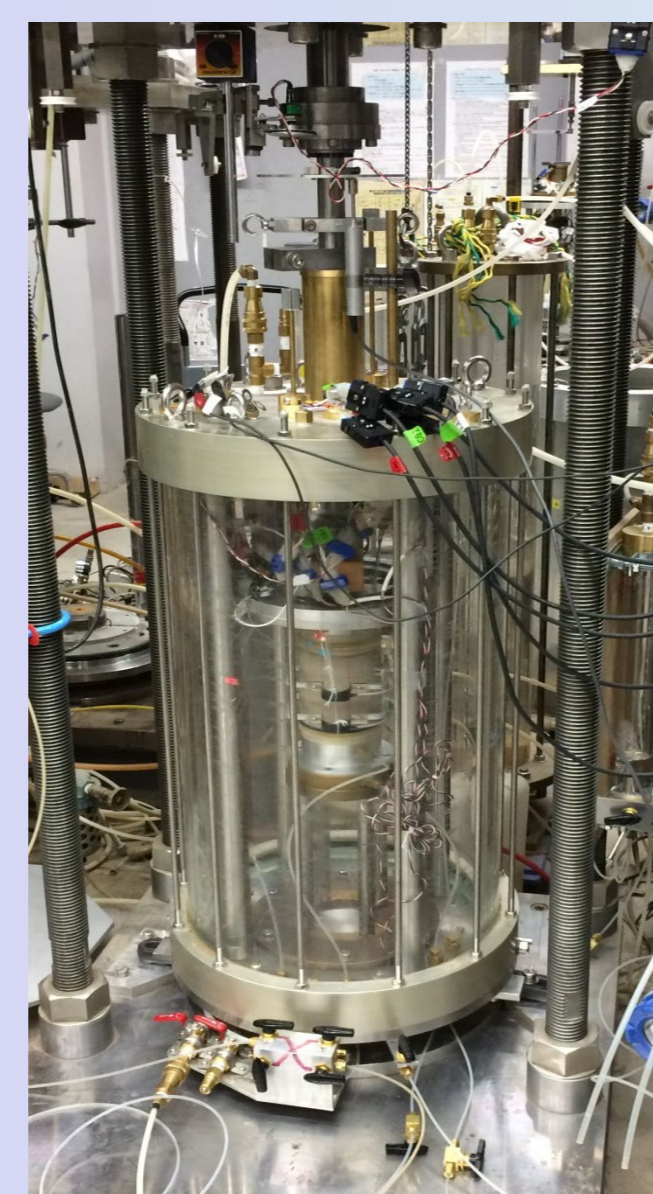
### 3. Testing procedure

#### Stress path before shearing

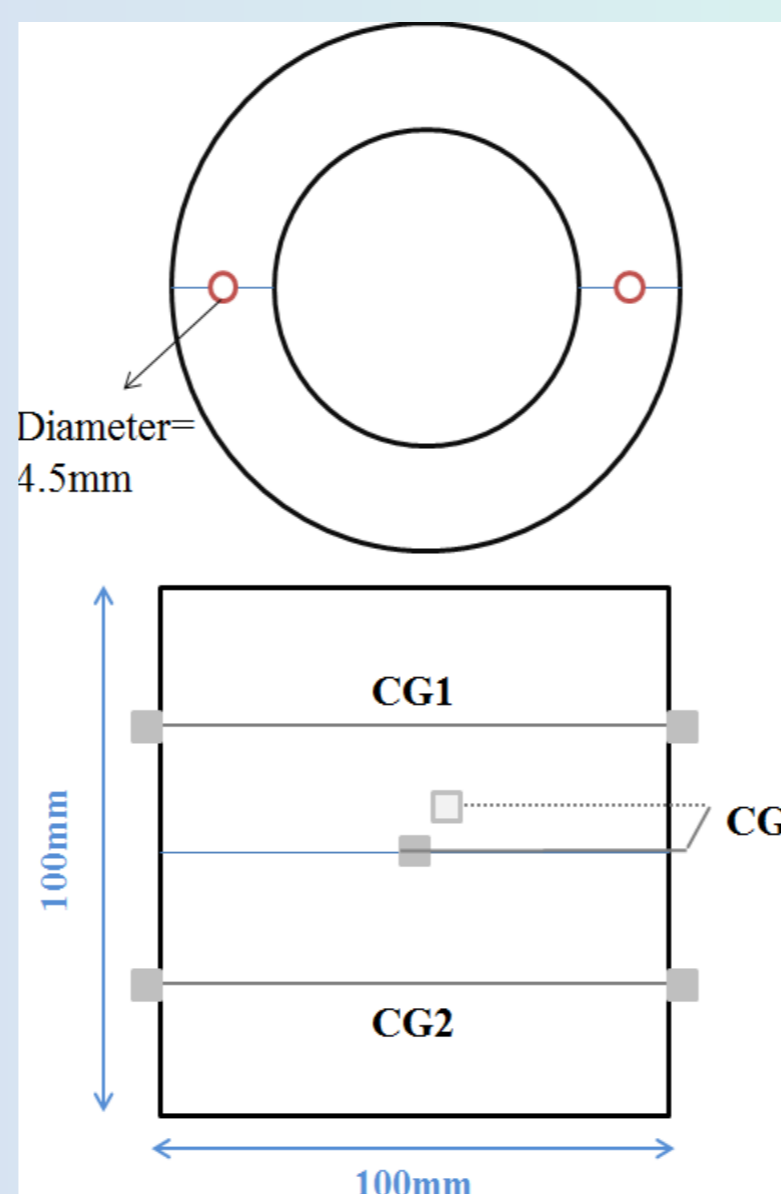


- ❖ Specimen with relative densities around 75% were tested, and the number of internal pipe (Dia.=4.5mm) was 0 and 2.
- ❖ Specimens were erected at isotropic stress of 30kPa and then the confining pressure was increased to 60kPa.
- ❖ After isotropic consolidation around 12 hours, 1300ml water was infiltrated into specimen, with the aim of completely dissolving the glucose pipe.
- ❖ Triaxial compression and triaxial extension was conducted while kept  $p'$  constant; for simple shear test,  $\tau$  was applied at .
- ❖ Small torsional cyclic loading were conducted at the initial dry state, after water infiltration and during TC (triaxial compression), TE (triaxial extension) and TS(torsional shear) under certain stress state.
- ❖ Monotonic torsional shear test were applied for all the specimens at last.

### 2. Testing apparatus and stress path



Hollow cylindrical torsional shear apparatus

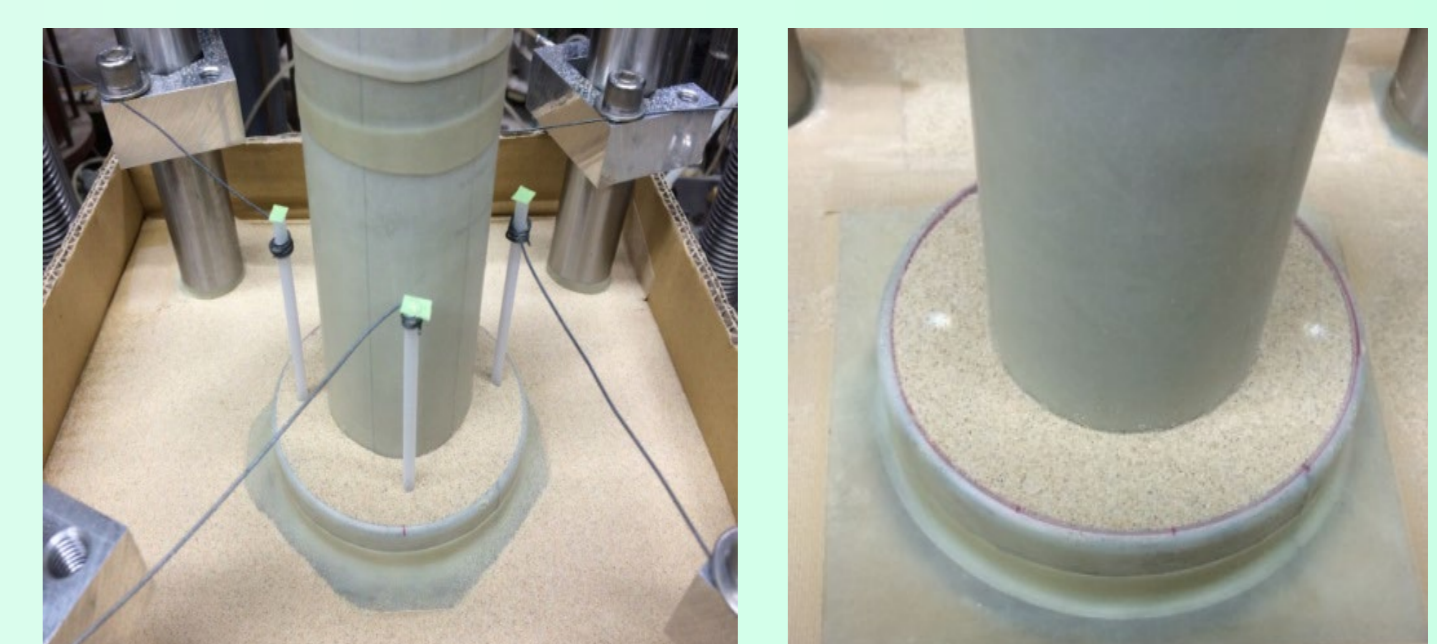


Arrangement of Clip Gauges (Radial strain measurement)

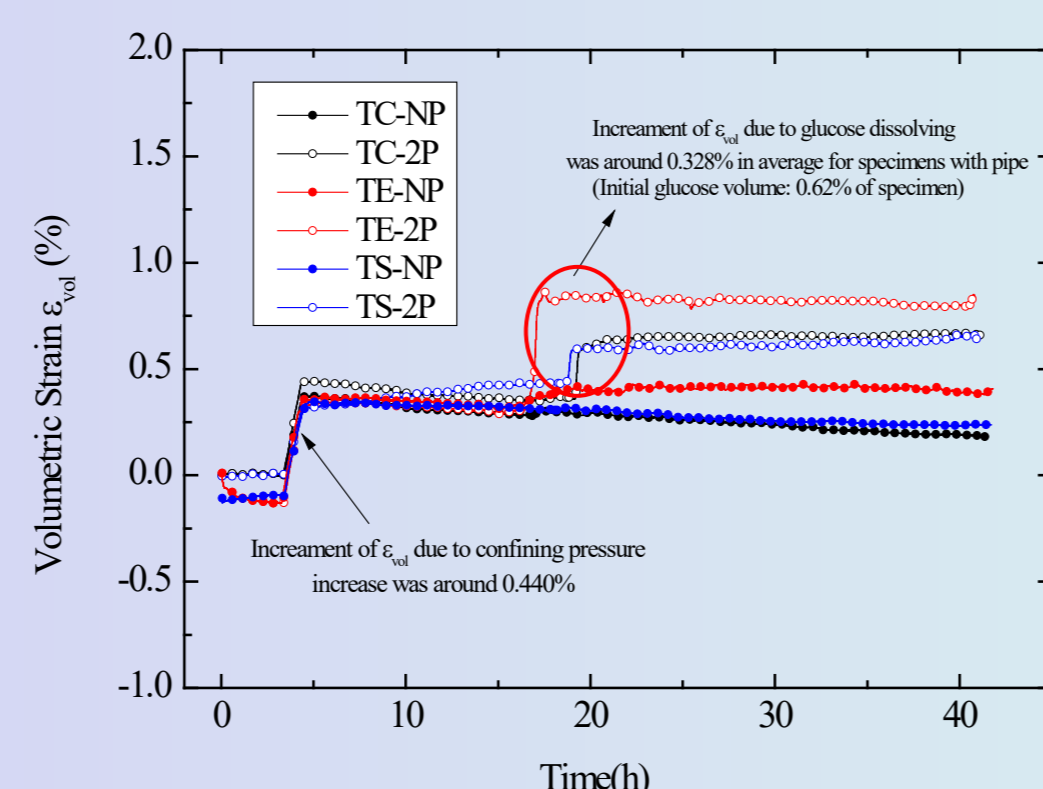


Gap Sensor (Shear modulus measurement during small torsional cyclic loadings)

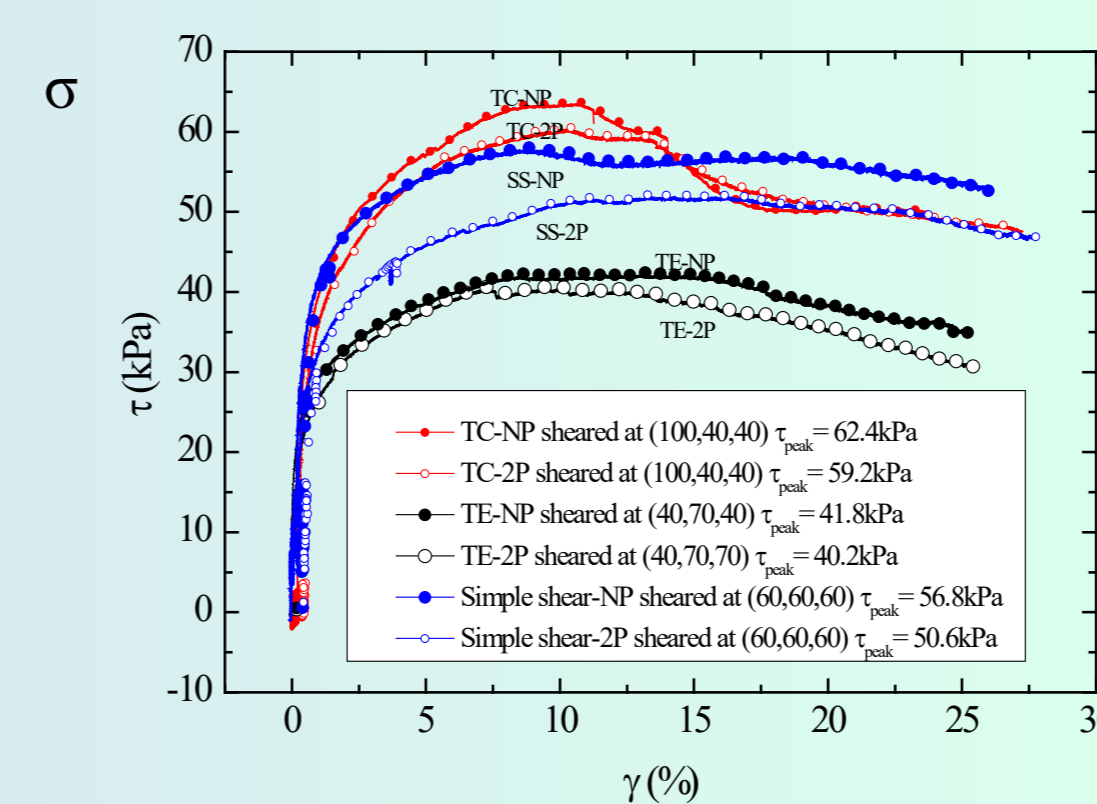
#### Specimen with glucose pipe



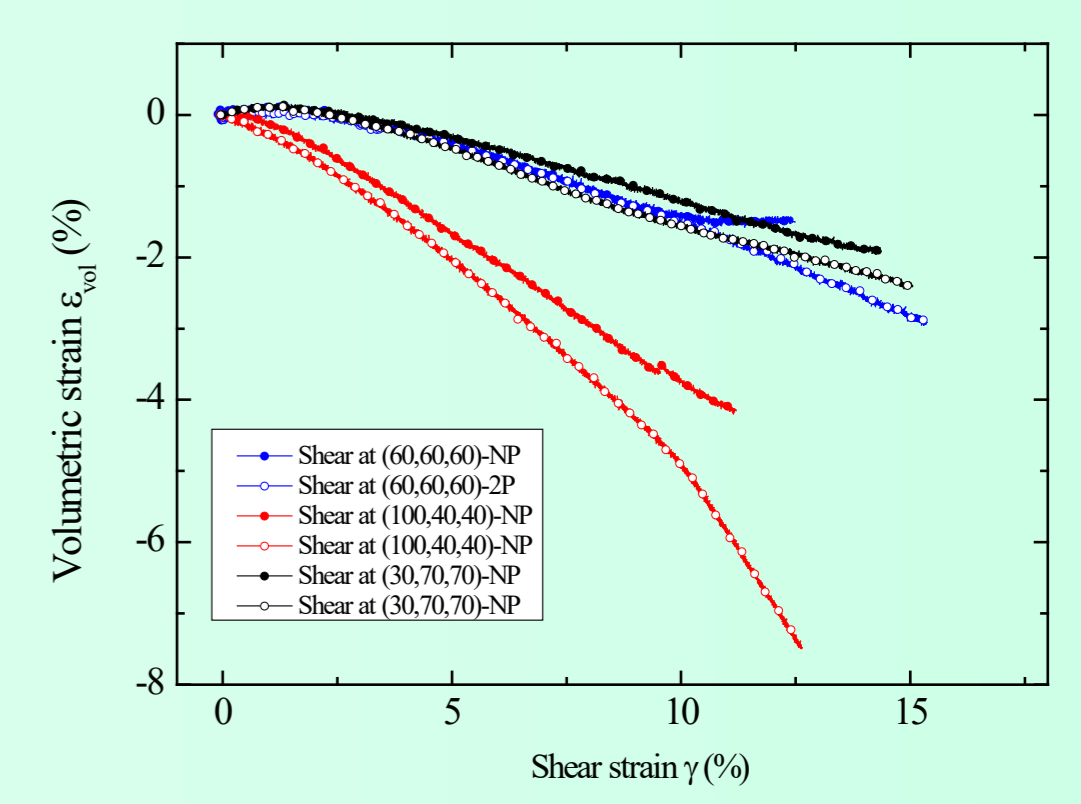
### 4. Results



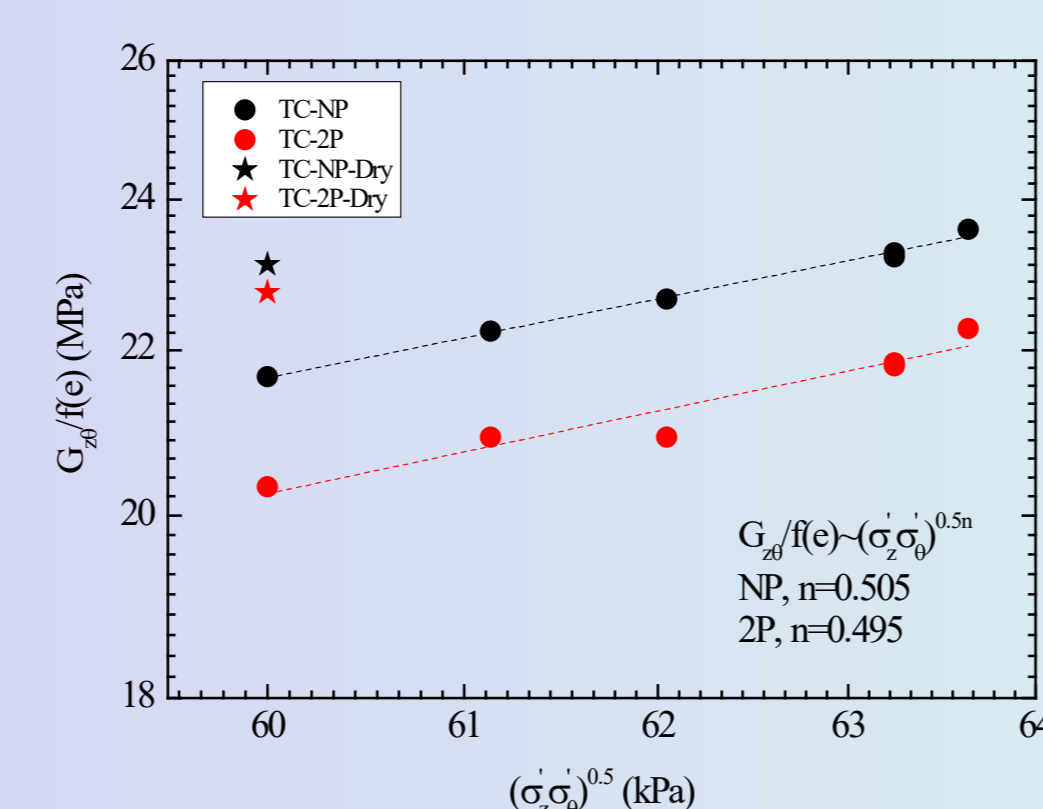
Volumetric strain variation before shearing



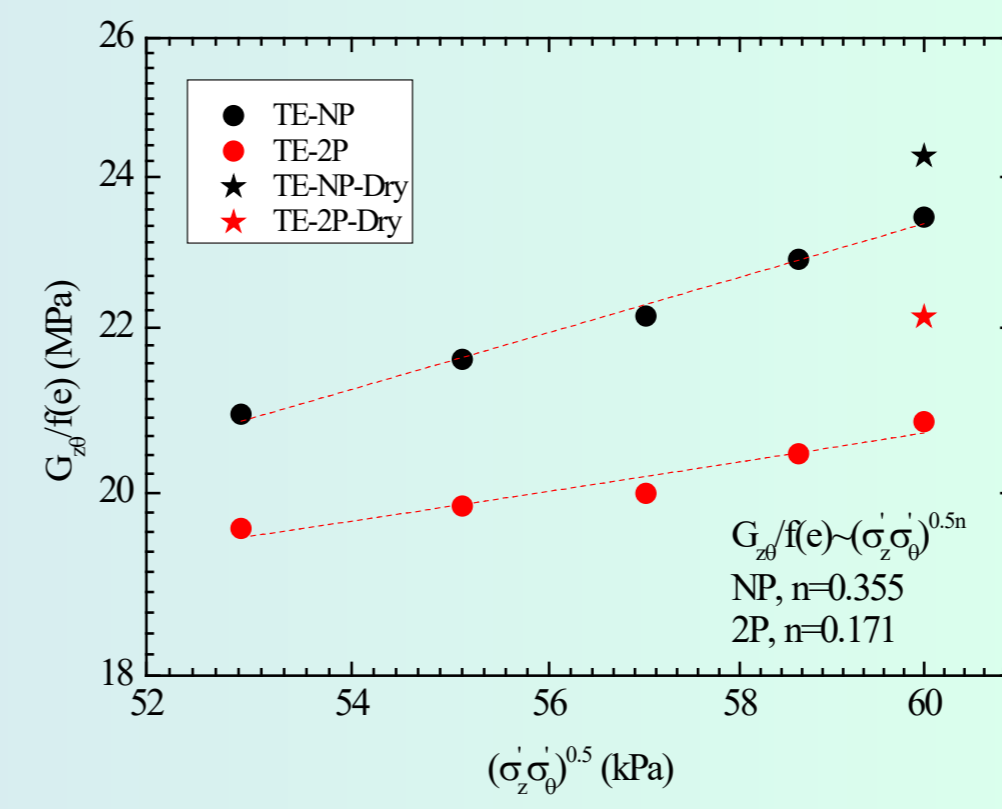
Shear stress vs. shear strain



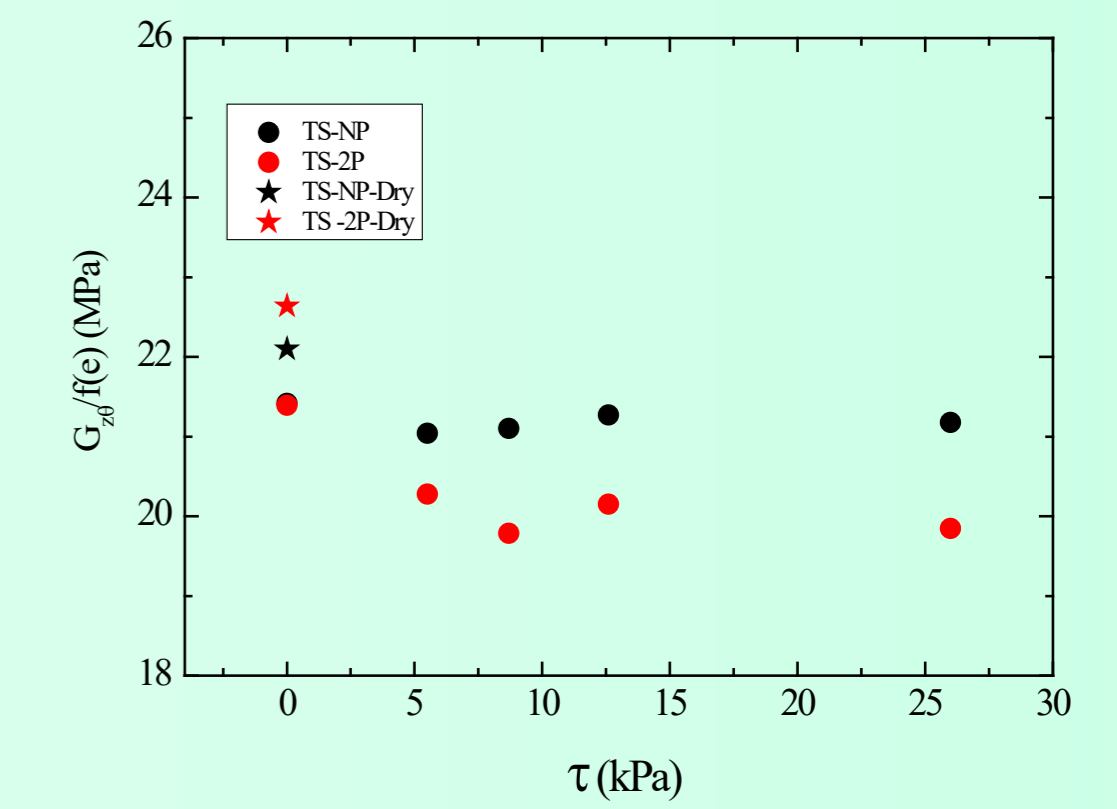
Volumetric strain during shearing



Shear modulus variation during triaxial compression



Shear modulus variation during triaxial extension



Shear modulus vs. Shear Strength

### 6. Summary

- ❖ Internal erosion in the form of piping was successfully created in sand by glucose power.
- ❖ Decrease of shear modulus  $G$  was observed in specimens subjected to piping effect.
- ❖ Shear starting from triaxial compression showed the highest resistance while triaxial extension the lowest. Larger difference of peak shear strength between specimen with and without pipe was found at simple shear test.
- ❖ For  $G$  measured during TE,  $n$  computed from the function of  $G \sim (\sigma_z \sigma_r)^{0.5n}$  was not normal possibly due to the limitation of the data number. Still, more degradation was observed in specimen subject to piping effect.