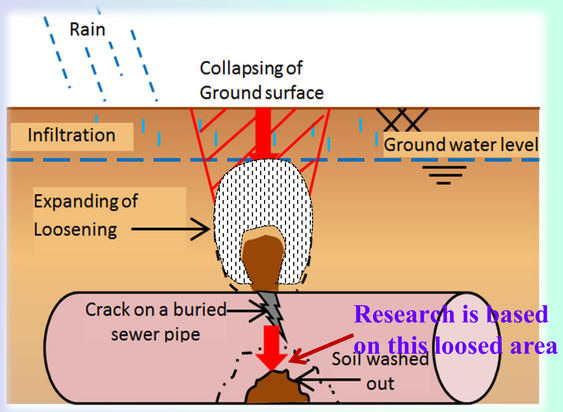
EVALUATION OF LOOSED GROUND ASSOCIATED WITH UNDERGROUND CAVITIES BY TRIAXIAL TESTING

地盤内空洞まわりのゆるみ領域の力学特性の評価

Ground cave-in happens in all over the world, which usually starts from internal erosion and finally leads to underground cavities. Ground loosening is a common phenomenon which is always associated with expansion of such initially formed cavities. The main objective of this research is to analyze the variation of mechanical properties of loosed soil associated with cavities. Small triaxial experiments for uniform fine (Toyoura) sand were conducted with an artificial cavity in the specimen. The loosening was formed by passing water through and the variation of stresses, strains, stiffness and shear strength were evaluated before and after loosening. In addition, one triaxial test was scanned by X-ray Computed Tomography to visualize the loosening formation in 3-dimensional ground.

地盤内の土砂が何らかの理由により流出して空洞ができると、その空洞が成長し進展して地表に到達し地盤陥没が引き起こされる危険性があります。空洞の進展過程においては通常空洞上部に地盤の密度が低下したゆるみ領域が形成される事が知られていますが、実態についてはまだあまりよく分かっていません。本研究ではゆるみの範囲や力学特性を定量的に把握することを目指し、三軸供試体内に人工的に空洞やゆるみを作り、ゆるみが供試体の変形・強度特性に与える影響を明らかにしました。またX線CTスキャナを用いて地盤内部のゆるみ形成を可視化しました。

1. Introduction to ground cave-in

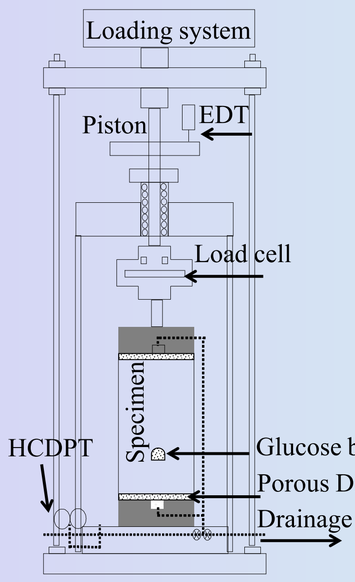


- Damaged sewer pipes cause many cave-ins. In this research, specially attention will be paid on evaluating of mechanical properties of loosed ground above the initial cavity.

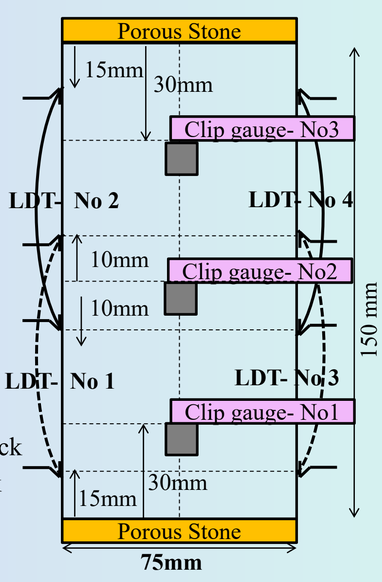
3. Testing procedure

- Toyoura sand was tested at two different relative densities (Dr = 60% and 35%) and sand was placed by air pluviation while inserting the cylindrical glucose block. (Dia.=12mm, height=15mm, void ratio =0.25%)
- Specimens were erected at isotropic state of 25kPa.
- Isotopic stress increment from 25 to 50 kPa was applied and then controlled at 50kPa till starts shearing at the end.(Stress path shown under No.2)
- Small cyclic loadings were applied to evaluate the stiffness and Poisson's ratio before and after ground loosening is formed.
- Special arrangement of sensors allowed to measure radial and axial strains separately at loosed soil closer to cavity and normal soil away from it.
- One specific test was repeated under the same control conditions. Extend of loosening was visualized by capturing series of X-ray images before/after infiltrating, after drainage and at several stages during shearing.

2. Testing apparatus, Stress path and material properties

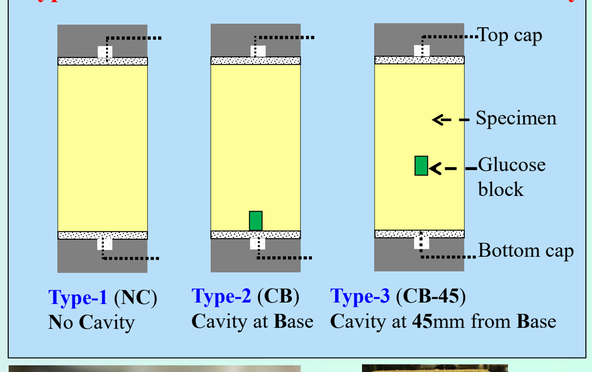


Testing apparatus



Arrangement of sensors

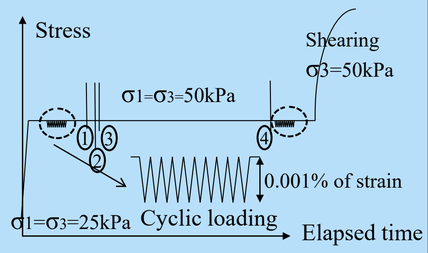
3 types of tests based on location of the initial cavity



Type-1 (NC) No Cavity | **Type-2 (CB)** Cavity at Base | **Type-3 (CB-45)** Cavity at 45mm from Base

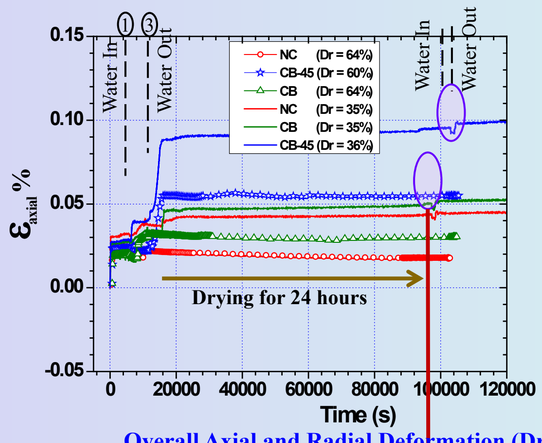
Artificially formed cavities and loosening (after shearing)

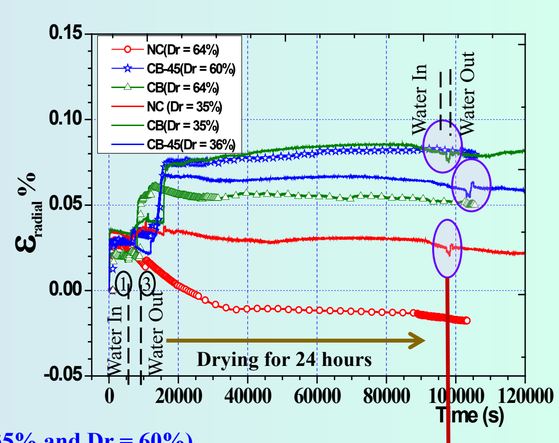
Stress and water movement path



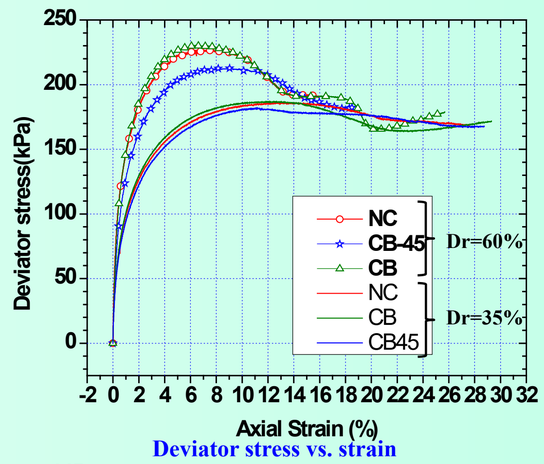
 # Step 1- Inserting water from bottom cap with rate of 14-16 ml/min and draining from top cap.
 # Step 2- Once 1500ml of water is passed through; both the bottom and top cap valves are closed and hold the water inside the specimen for a short time. (Nearly 10 mints)
 # Step 3 to 4- Then the top cap was open to atmosphere while the drainage was started from bottom cap.

4. Results

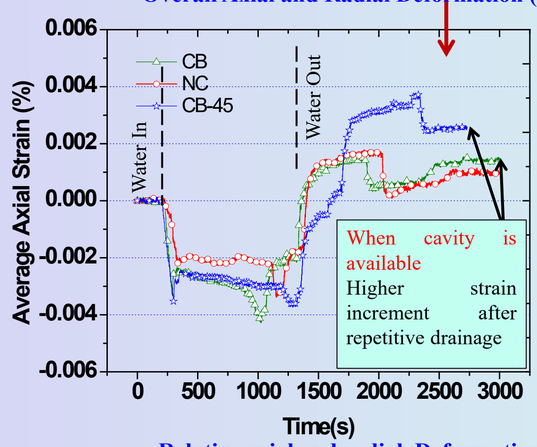


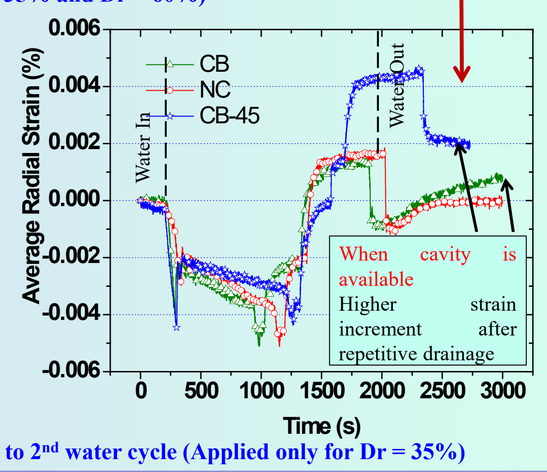


Overall Axial and Radial Deformation (Dr = 35% and Dr = 60%)

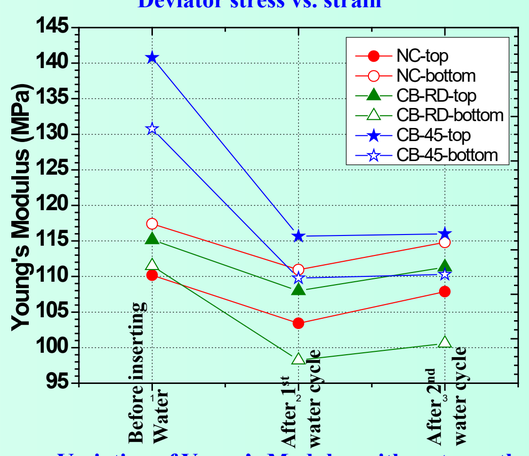


Deviator stress vs. strain



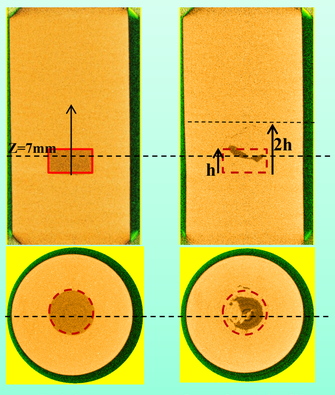


Relative axial and radial Deformation due to 2nd water cycle (Applied only for Dr = 35%)



Variation of Young's Modulus with water path

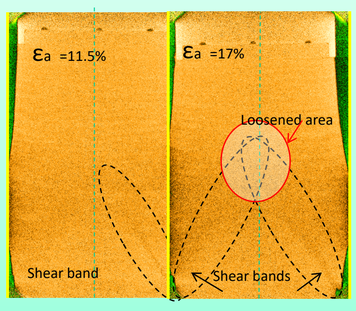
5. Visualization of loosening in triaxial specimen by X-ray CT



Initial

After 2nd infiltration and drainage

- Ground loosening was spread in vertical direction similar to two times of initial cavity.
- No significant deformation in radial direction.
- Shear band formed as crossing through the loosened part.



6. Summary

- When the initial cavity is closer to ground surface, the deformations are increasing significantly and shear strength is also decreasing.
- Repetitive water infiltration is supporting further propagation of ground loosening and increases the radial and axial deformations.
- When the cavity is located more than 10 times of the height of cavity, the effect of cavity on shear strength is negligible.
- When the cavity was located at the bottom part of the specimen, the ground stiffness has reduced at the bottom than the top part. However the scale of reduction is larger when the initial cavity moves towards the surface.
- Stiffness seems slightly increased after 2nd infiltration while strains are increased.

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