Exploration for Wave Propagation Around Ground Loosening Using Discrete Element Method

地盤内ゆるみ検知のためのDEM弾性波伝播解析

The ground cave-in accident caused by shield tunnel excavation in Chofu, Japan in 2020 revealed that ground loosening and subsurface cavities potentially cause ground cave-ins even deep in the ground. Although ground-penetrating radar method has been utilized to detect them, its applicability is limited to the shallow ground about 1.5 m below the ground surface. This contribution is a fundamental study aimed at detecting loosening depth in the ground, with the goal of measuring dynamic waves from inside a tunnel. To understand wave propagation and particle-scale response around loosened sandy soil, this study adopts the discrete element method (DEM).

2020年に調布市で発生したシールドトンネル掘削に伴う地盤陥没事故は，大深度であっても地盤のゆるみや地下空洞が地盤陥没を引き起こす可能性を明らかにした．空洞を検知するために地中レーダー法が実用化されているが，その適用範囲は地表から 1.5 m程度の浅い地盤に限られる．そこで本研究は，トンネル内部から地下深くの地盤内のゆるみを検知するために，弾性波の伝播特性を理解することを目的とする．一連の個別要素法（DEM）数値解析を行い，ゆるんだ砂地盤周りの粒子スケール応答を評価した．

1. Modelling approach

Using U-Tokyo Supercomputer (Wisteria/BDEC-01)

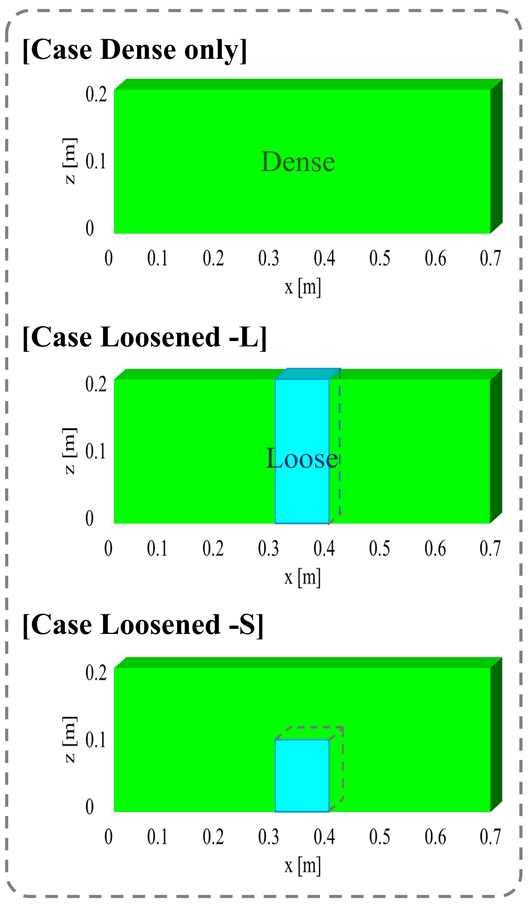
1) Particle generation
- Spherical particle

↓

2) Air-pluviation process
- Hertz-Mindlin contact model

↓

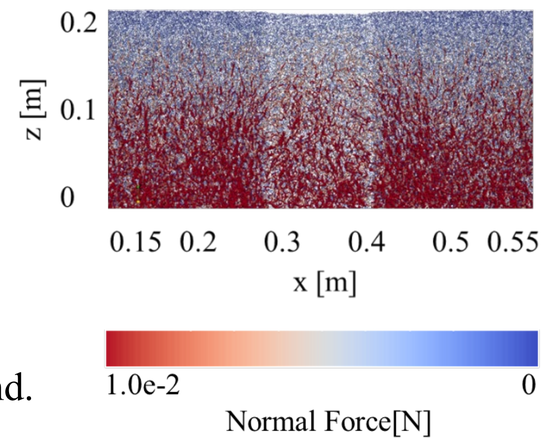
3) "Patchwork" process
- Dense + Loose ground model



2. Inter-particle contact forces

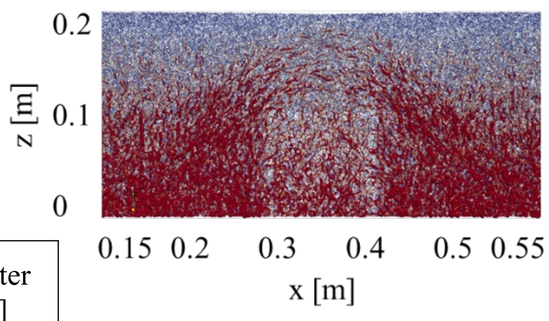
[Case Loosened –L]

- The vertical contact forces are predominant over the horizontal ones due to the effect of gravity.
- At the boundary between Dense and Loose, the horizontal forces are dominant in which soil pressure is exerted to support each other's ground.



[Case Loosened –S]

- Soil arching is generated over the loose area.



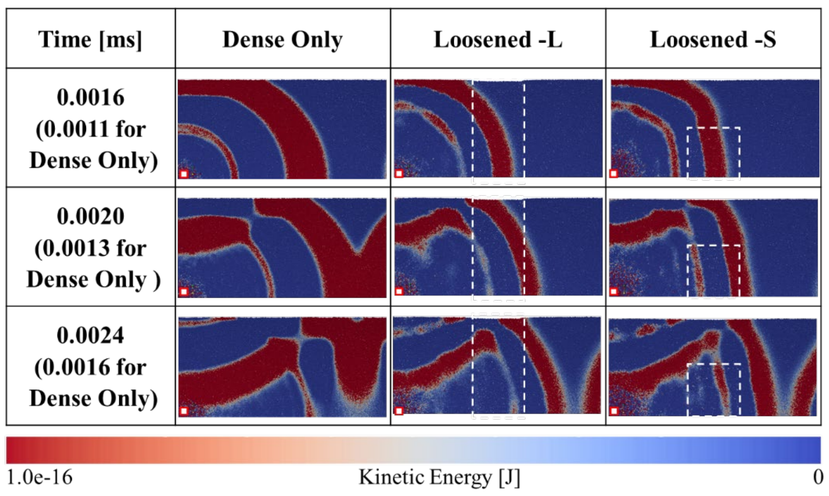
Young's modulus [GPa]	Poisson's ratio	Specific gravity	Diameter [mm]
71.6	0.23	2.65	1.4~2.2

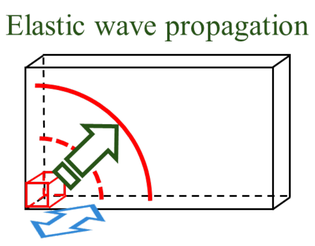
3. Wave propagation simulations

The particles inside the region of the transmitter were excited in the Y-direction to generate elastic S-waves, with a single period of cosine wave form (double amplitude displacement: 10 nm; frequency: 1 kHz)

Excitation inside Dense area

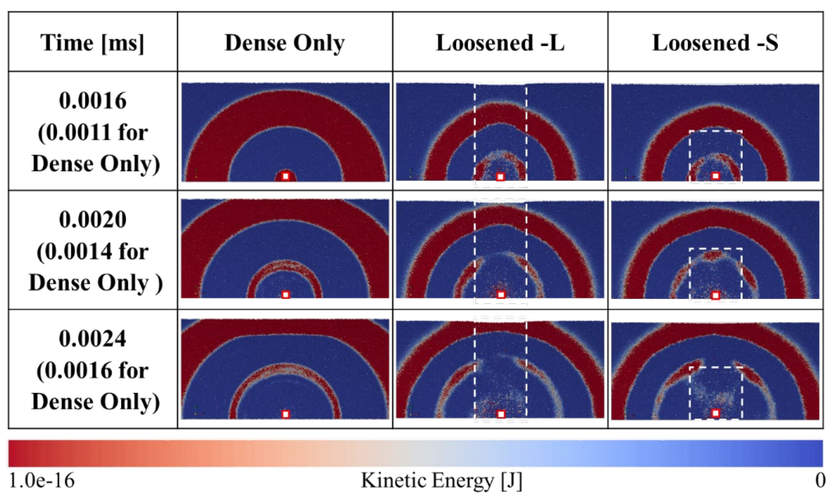
- In model grounds with loosening, the decrease in energy as the wave passes through the loose area is indicative of lowpass filtering effect.
- The property of the transmission energy is also explained by the concept of acoustic impedance (ZI)

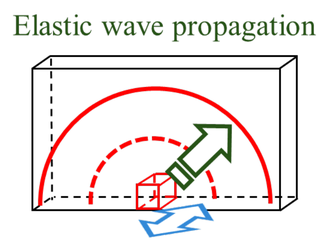




Excitation inside Loose area

- In model grounds with loosening, residual energy around the bottom loose area can be observed.
- Especially in Case Loosened -S, the first traveling S-wave is transmitted, but the second is reflected at the Loose-Dense boundary.





For further information, contact below.
Prof. Reiko Kuwano
Bw-304, Institute of Industrial Science, the University of Tokyo
TEL：+81-3-5452-6843
E-mail: kuwano@iis.u-tokyo.ac.jp

桑代和樹 Kazuki Kuwashiro (2024)
桑野研究室
東京大学 生産技術研究所 Bw-304
電話: 03-5452-6843
E-mail: kuwano@iis.u-tokyo.ac.jp