Shedding light on the intricacies of numerical simulations of soil behavior

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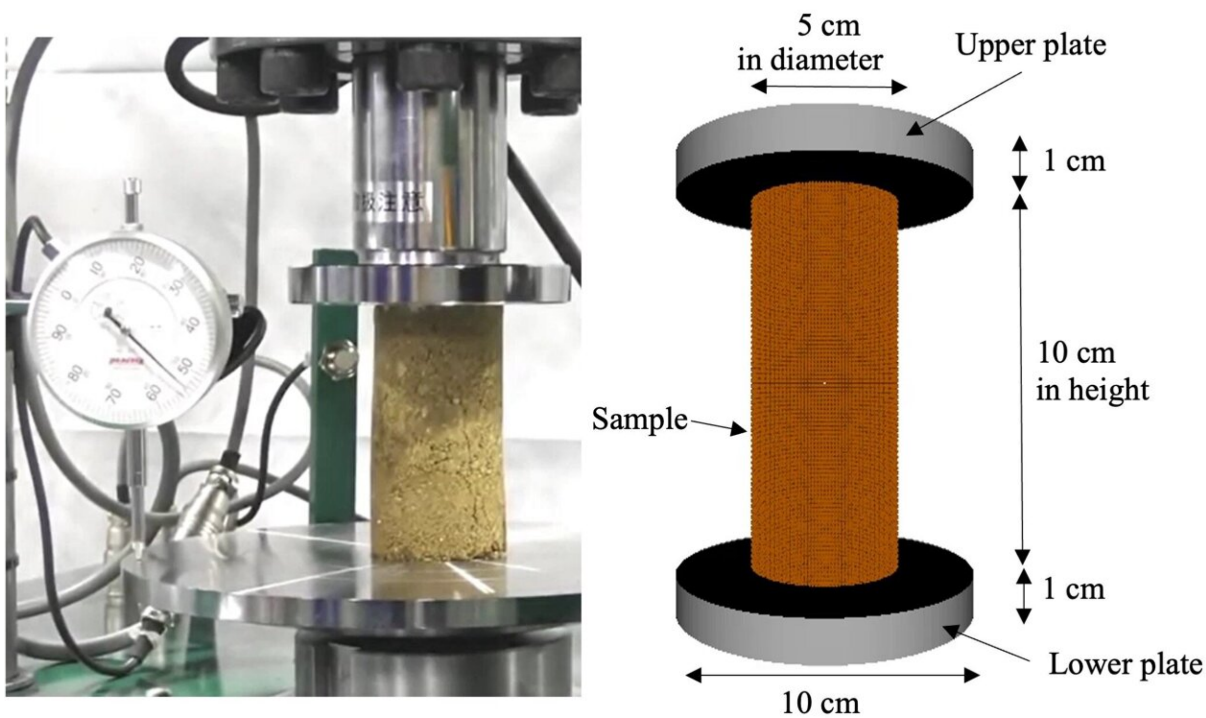

The goal of this study was to accurately match experimental data obtained from compression tests in particle-based simulations of soil behavior. Thanks to a comprehensive sensitivity analysis, the researchers shed light on the effects of several simulation and model parameters on the accuracy of the simulation results. Credit: Shinya Inazumi from Shibaura Institute of Technology

A solid understanding of soil mechanics and behavior is one of the fundamental pillars of geotechnical engineering. The stability and resilience of many modern geotechnical structures, including building foundations, dams, bridges, and embankments, rely on appropriate modeling based on accurate measurements of soil properties.

Over the past few decades, unprecedented growth in computing power has turned numerical simulations of soil behavior into an attractive tool in geotechnical engineering. Numerical simulations can help researchers understand complex soil behavior under various conditions by representing soil as a set of interacting particles.

Moreover, numerical simulations can help engineers in the design, analysis, and optimization of geotechnical structures, ensuring their long-term safety without disregarding cost-efficiency.

However, traditional methods for analyzing soil mechanics sometimes fail to replicate the complex nature of the soil. This is especially true for soil in its rigid state, where particles are packed and interlocked, giving rise to characteristics typical of solid materials, such as strength and stiffness. Thus, there's a pressing need to improve numerical simulations of soil in its rigid state to complement our current understanding of soil in its fluid state.

In a recent study published in the *Civil Engineering Journal*, a team of researchers from Shibaura Institute of Technology, including Professor Shinya Inazumi, set out to address this challenge.

The researchers focused on numerical simulations carried out using the moving particle semi-implicit (MSP) method, which models the fluid motion of a collection of interacting particles based on several physical principles. Their goal was to leverage the MSP method to accurately simulate unconfined compression tests on soil samples in a way that accurately reflects the dual nature of the soil, which the Bingham fluid biviscosity model describes.

"Existing models struggle to accurately represent soil when it is in its rigid state, where traditional fluid mechanics principles did not adequately apply," explains Prof. Inazumi.

To this end, the team progressively adjusted their numerical simulations via trial-and-error to precisely match the results of compression experiments conducted on undisturbed sand and clay samples. By delving into the intricacies of the simulation process, this approach highlighted the effects of parameters such as interparticle distance, initial time interval, and plastic viscosity on the accuracy and computational costs of the simulations.

Additionally, they also performed a comprehensive sensitivity analysis of simulation parameters influencing the Bingham fluid biviscosity model, such as yield strength and critical shear strain.

"Previous studies often overlooked the interrelationship between different soil parameters and their collective effect on simulation accuracy," comments Prof. Inazumi, "There was a clear need for a more holistic approach that could not only improve simulation accuracy but also provide a robust framework for future study."

The conclusions derived from these analyses will help establish reliable methodologies for simulating the behavior of different soil types. In turn, this will lead to new standards for simulation accuracy in the field of geotechnical engineering, which would have a direct impact on many real-world applications.

"Higher simulation accuracy when predicting soil behavior under load means that engineers can design structures with a better understanding of soil conditions; this leads to not only enhanced safety but also costeffectiveness by minimizing over-engineering," remarks Prof. Inazumi.

It is worth noting that a better understanding of soil behavior acquired through simulations allows for the development of better prediction models for disaster prevention and risk mitigation. Such models are essential in earthquake- and landslide-prone areas, where proper design can greatly reduce the risk of catastrophic failure in geotechnical structures.

Additionally, this study could have notable implications in environmental engineering, land use management, and urban planning.

"Accurate soil analysis is critical for determining the suitability of land for various purposes, be it residential, commercial, or agricultural use. By understanding the stress–strain characteristics of the soil with greater precision, planners, and developers can make more informed decisions, thereby optimizing land use and reducing environmental impact," says Prof. Inazumi.

More information: Sudip Shakya et al, Applicability of Numerical Simulation by Particle Method to Unconfined Compression Tests on Geomaterials, *Civil Engineering Journal* (2024). DOI: 10.28991/CEJ-2024-010-01-01

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