New technique for monitoring soil freezing will make building on permafrost safer

March 15 2022

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Skoltech researchers and their colleagues from JSC Research Center of Construction have demonstrated the practical utility of their previously patented method for determining at what temperature soil freezes and

how much unfrozen water it contains. Monitoring these two parameters is crucial for building and maintaining roads, bridges, houses, factories, etc. in the permafrost region—particularly in the era of global warming, which causes soil thawing and instability. The technique is precise, fast, relatively inexpensive, and applicable to different types of soils. The paper detailing the tests of this so-called water potential method came out in the journal *Cold Regions Science and Technology*.

"Whenever you build something on permafrost in the Arctic region, you have to know at what temperature that particular soil freezes and what the residual content of liquid water in it is. These parameters affect the soil's mechanical properties and are essential for calculations that ensure the stability of housing, transport infrastructure, and industrial facilities such as factories, pipelines, and oil wells," said the first author of the study, Leading Research Scientist Evgeny Chuvilin from Skoltech. "This is even more relevant for structures that give off heat, such as thermal power stations, and in the context of global warming as the environments populated by frozen soils are heating up."

The necessary measurements can be made using nuclear magnetic resonance or the contact method, but the former is so expensive only major research centers can afford it, and the latter is time-consuming and not exactly cheap either, as it requires large soil samples, which have to be frozen with costly refrigeration equipment.

Together with his co-authors Principal Research Scientist Vladimir Istomin and Research Scientist Boris Bukhanov, both also of Skoltech, Chuvilin devised an alternative technique—the water potential method, which relies on comparatively cheap hardware. Patented in 2018, it involves drying up the sample in a stepwise manner and registering the associated change in the binding energy of water in the pores with soil particles and the vapor pressure above the wet sample—these values can then be used to calculate the freezing point and unfrozen water content.

The water potential method is fast and does not require sample refrigeration, making the measurements cheaper. The team also demonstrated its efficiency by validating it against conventional techniques.

"We showed that the method works on natural soils of various particle size, mineral composition, salinity, and total organic carbon content," Chuvilin said. "The results were in good agreement with direct measurements, including nuclear magnetic resonance, which means that our method provides the necessary degree of precision. We can therefore recommend it for determining the freezing point and unfrozen water content for different soil types."

The research reported in this story is the latest installment in a series of studies presenting and elaborating the water potential method. By validating this novel technique against conventional methods and expanding the range of soils it has been shown to be applicable to, the team is sending a message to civil engineers who could directly benefit by adopting the new approach.

"Now those people who are not necessarily interested in the intricate physics of the process but have this specific problem they need to address, can get down to using the technique. Our study supplies the answers to the questions they will likely have: Will it work on soil of a given type? Just how accurate is it? What temperature range is it suitable for?" Chuvilin said. "We highlight the advantages and show the end user that ours is a valid and highly competitive technique for solving their problem."

More information: Evgeny M. Chuvilin et al, Freezing point and unfrozen water contents of permafrost soils: Estimation by the water potential method, (2022). DOI: 10.1016/j.coldregions.2022.103488

Provided by Skolkovo Institute of Science and Technology