Improved Prediction of Thaw Settlement in Cohesionless Permafrost Sediments

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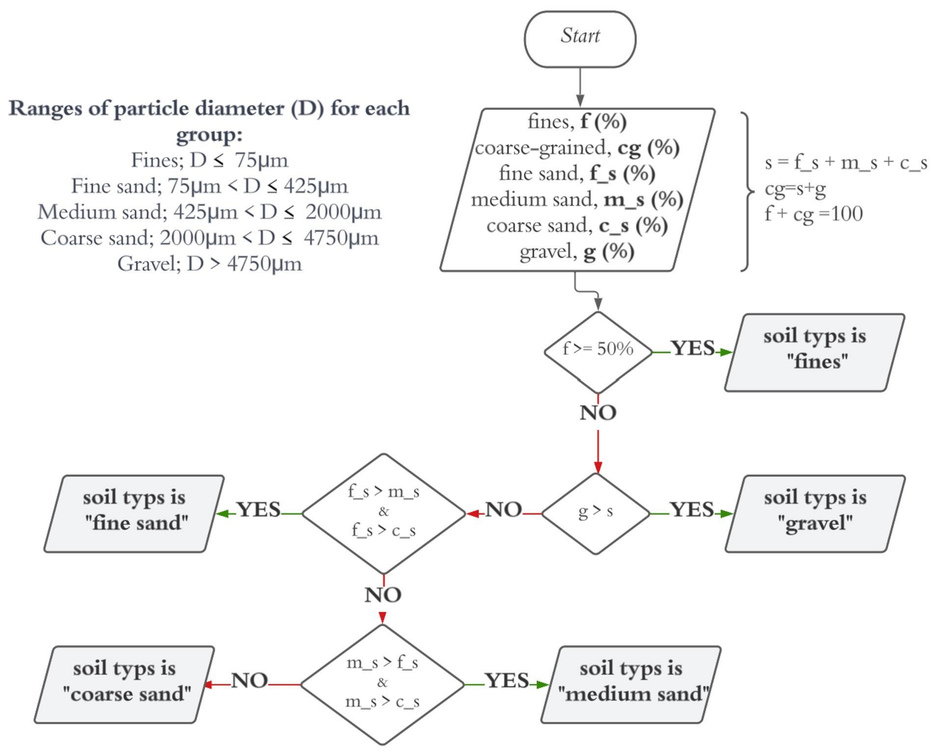
INTRODUCTION: Thaw settlement is a well-documented challenge for infrastructure development in permafrost regions. The capacity to more accurately predict thaw strain is critical for enhancing the planning and design of structures in these regions.

OBJECTIVE: To estimate thaw strain in cohesionless permafrost sediments by obtaining an average thawed void ratio for five different types of these sediments including fines, fine sand, medium sand, coarse sand, and gravel.
Premise: Laboratory-measured minimum void ratio can be used to draw conclusions on the thawed void ratio of coarse-grained permafrost samples.

METHODOLOGY:

Step 1: Obtaining average minimum void ratio for different subgroups of cohesionless soils
Resource: A dataset of minimum void ratio (e_{min}) and median particle size (D_{50}) with 637 observations [1].
Challenge: How to group these samples only based on D_{50}?

Step 2: Defining thresholds to group minimum void ratio data based on D_{50}
Resource: Two additional sets of published data on detailed grain size distributions for similar sediments, comprising a total of 873 samples [2,3].
Method:
☑ Calculated percentage of fines, fine sand, medium sand, coarse sand, and gravel for samples and classified the samples as below:

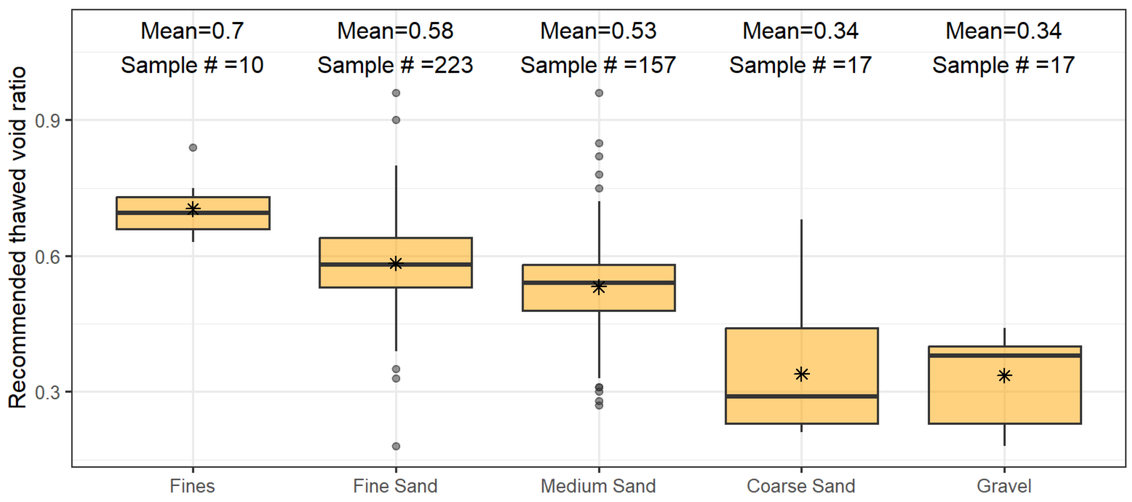


☑ Established D_{50} limits for each group, using 10th and 90th percentiles of D_{50} within each group

Soil type	#	Lower limit (µm)	Upper limit (µm)
Fines	405	0	80
Fine sand	353	80	375
Medium sand	77	375	2240
Coarse sand	11	2240	6090
Gravel	27	6090	16000

☑ Grouped samples in the index void ratio dataset using the established threshold for D_{50} and obtained e_{min} (assumed equivalent to thawed void ratio) range in each group (shown on following boxplot)

RECOMMENDED THAWED VOID RATIOS FOR DIFFERENT SOIL TYPES:



VALIDATION:

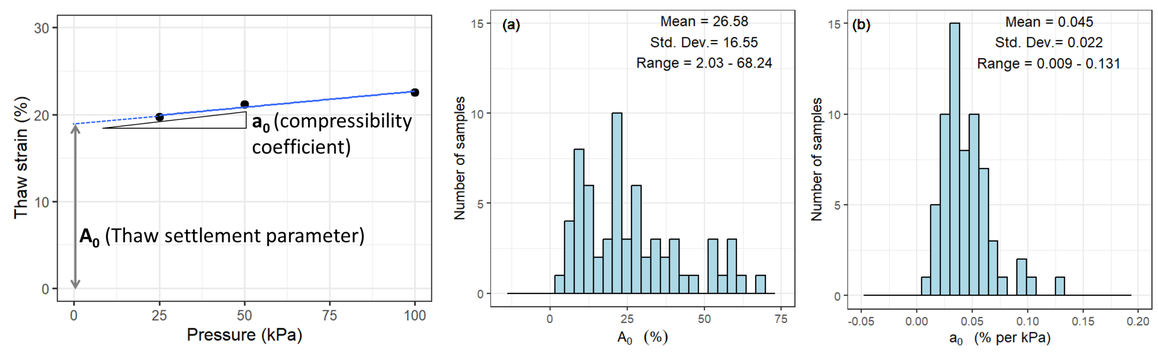
Comparing estimated thaw stain using recommended thawed void ratios to lab-measured haw stain
Resource: A dataset containing grain size distribution, initial void ratio, and measured thaw strain for 60 coarse-grained permafrost samples from Nunavik, QC [4].
Method:

- Estimated thaw strain (s) using initial void ratio (e_i) and thawed void ratio (e_{th}):

$$s = \frac{e_i - e_{th}}{1 + e_i}$$

- Compared estimated thaw strain with measured thaw strain

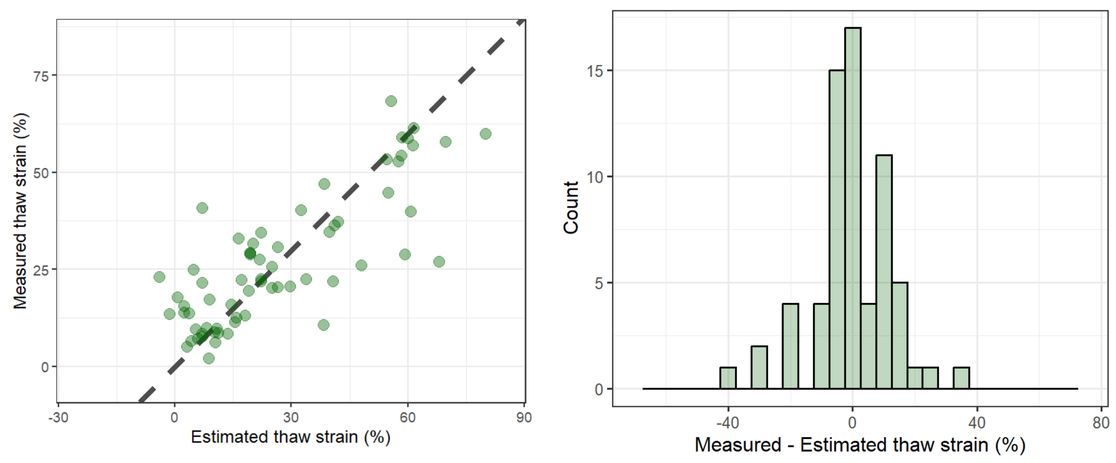
MEASURED THAW STRAINS:



Example of thaw settlement test result [4]

- Small compressibility coefficient
- A_0 can be used as a representative of total strain for coarse-grained sediments

RESULTS:



COMPARISON WITH EXISTING METHODS

Method	Bias (%)	Error (%)	R^2
Ladanyi (1994)	5.3	13.11	0.51
Nixon and Ladanyi (1978)	8.3	15.61	0.47
Speer et al. (1973)	5.4	12.70	0.57
This study	**-0.1**	**12.66**	**0.65**

- Improved accuracy compared to the previous method
- Reduced bias compared to the previous method

IMPACT OF THE STUDY:

☑ Integrated with thermal modeling, this study offers a straightforward yet effective method for predicting thaw settlement using commonly reported index properties.
☑ This study provides an enhanced estimation of anticipated settlement, contributing to more effective planning and design.

REFERENCES

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4. Allard, M., Chiasson, A., St-amour, A.B., Aubé-michaud, S., Mathon-Dufour, V., L'Hérault, E., and Bilodeau, S. 2020a. Caractérisation géotechnique et cartographie améliorée du pergélisol dans les communautés nordiques du Nunavik, Inukjuak. (Similar reports for other villages including Ivujivik, Kangiqsualujjuaq, Kangiqsujuaq, and Kuujjuaq)

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