Development of An Oedometric Core-Barrel For in Situ Measurement of The Thaw Consolidation Behavior of Permafrost

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CONTEXT

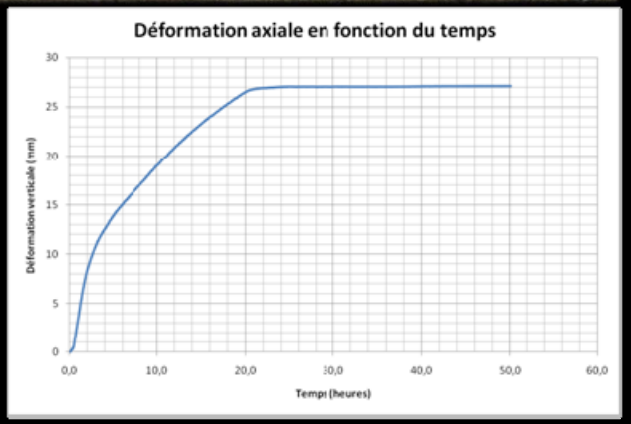
Main issues
in permafrost region

- Thaw settlement
- Mechanical behaviour of soil during thawing

CONTEXT

Current practice for Geotechnical characterization of permafrost

- Sampling frozen ground
- Thaw consolidation testing in laboratory



CONTEXT

Frozen Samples
from site to laboratory

1) Sampling frozen soil
+
2) Keeping samples frozen during shipping

- Complex
- Expensive
- Long

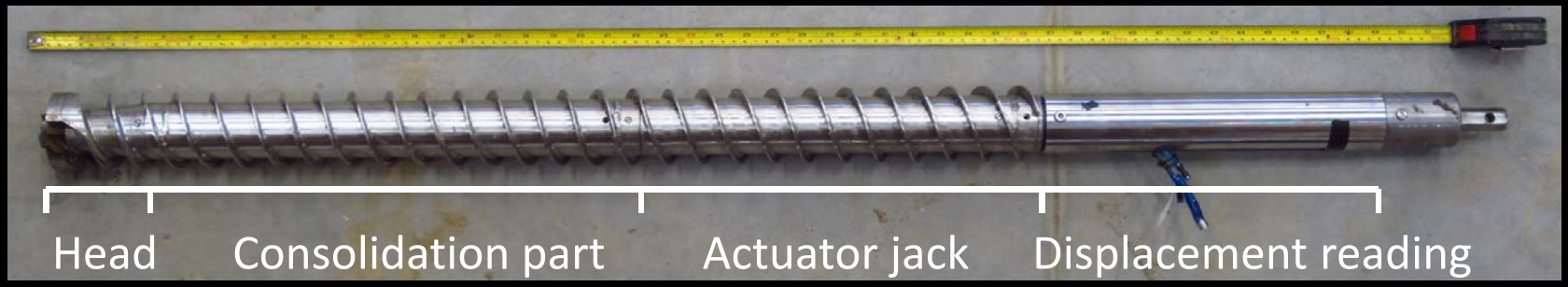
OBJECTIVE

Improve the ability to characterize
thaw-sensitive permafrost
by developing a core-barrel
for in situ thaw-consolidation testing

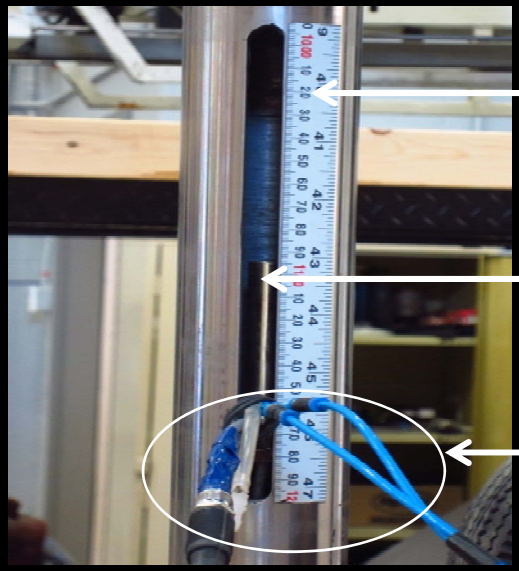
METHODOLOGY – DESIGN REQUIREMENTS

Consolidation testing	• Thaw settlement under a range of loads • Rapid consolidation
Drilling equipment	• Portable light drill • Dry drilling
Coring	• Ice-rich soils • Working depth (top of permafrost) reached by casing (max 2 m)
Practical aspect	• Easy maintenance in the field

PROTOTYPE



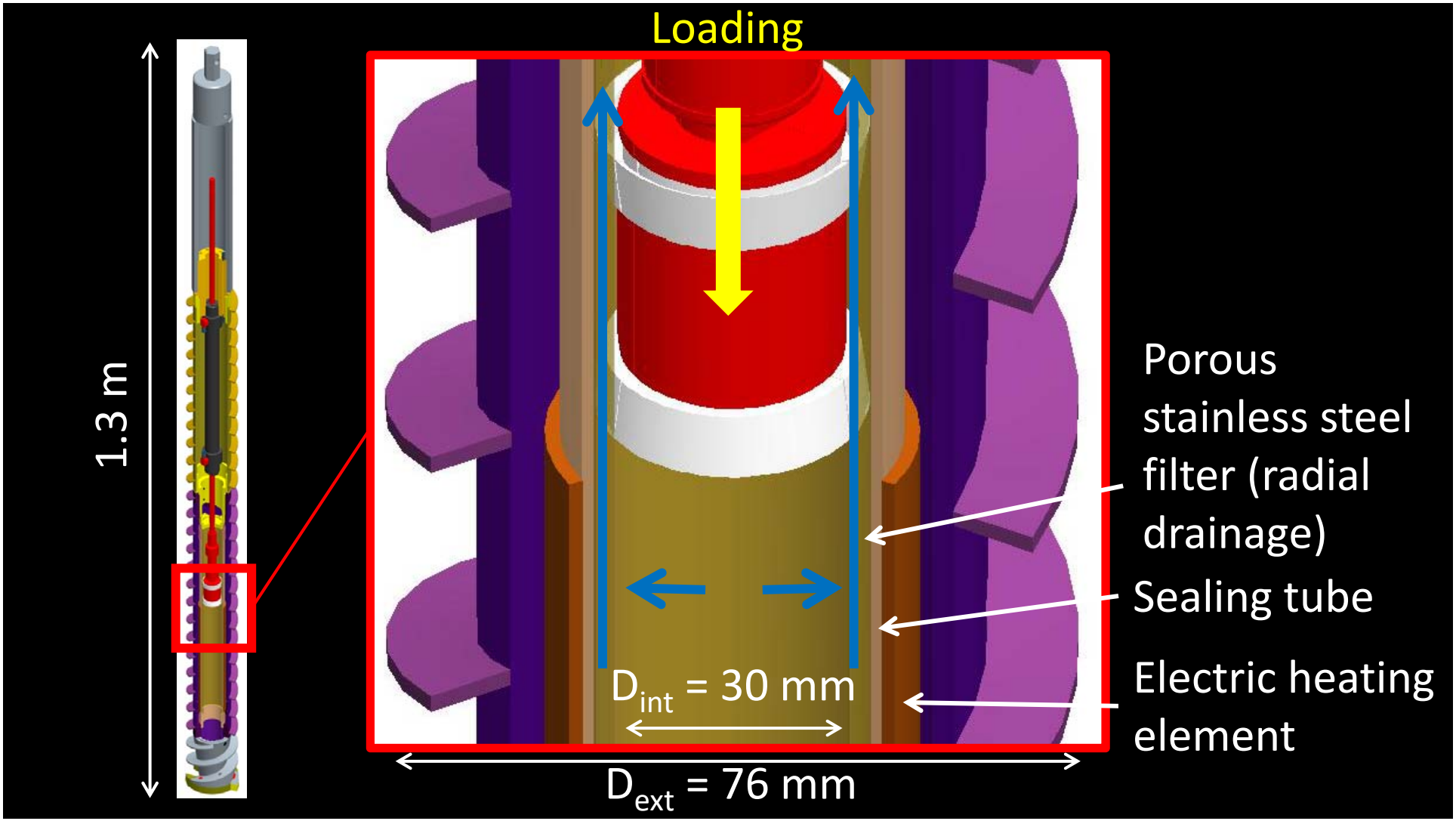
Clean cutting by sawing and shaving



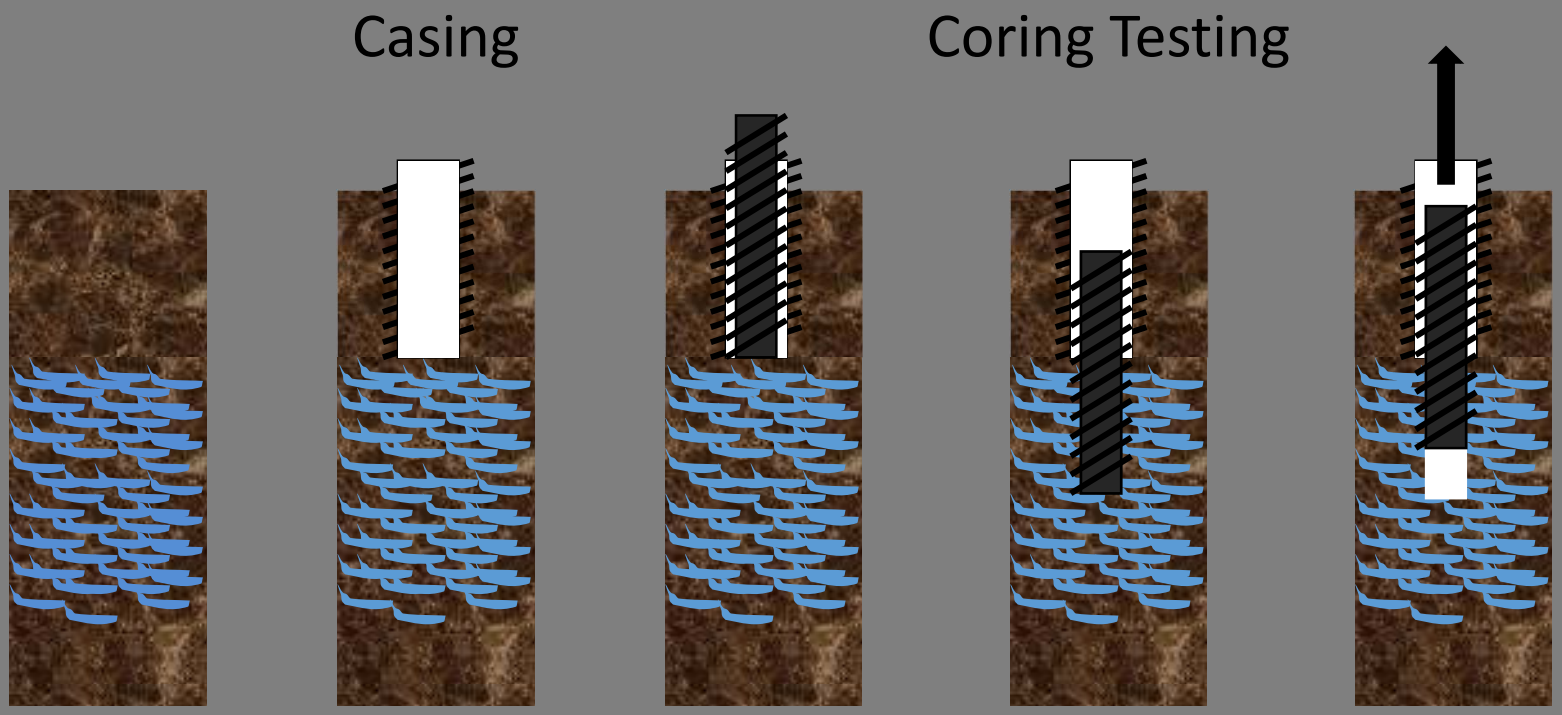
Sliding caliper

Actuator rod

Electric connections, pneumatic connectors and evacuation of drained water


Loading
1.3 m
Porous stainless steel filter (radial drainage)
Sealing tube
Electric heating element
D_{int} = 30 mm
D_{ext} = 76 mm

Prototype – Principle of Use

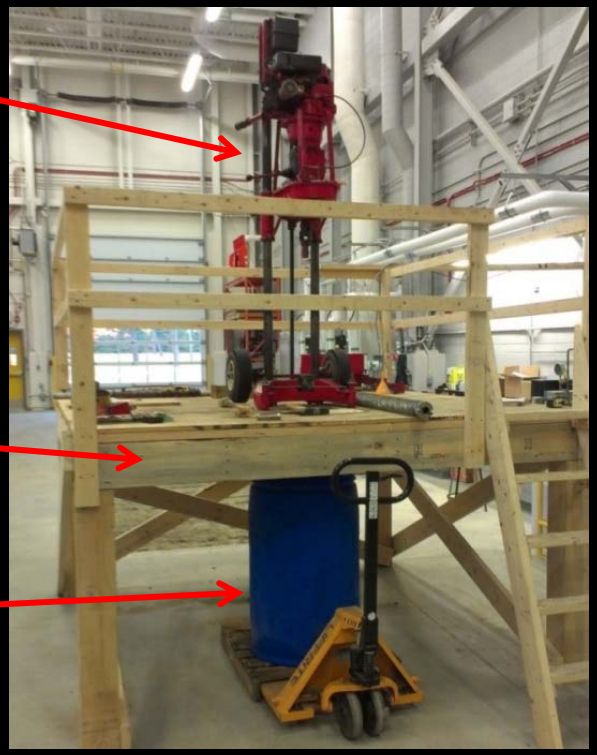


LABORATORY TESTING

Minuteman drill

Platform

Soil barrel



Laboratory testing on fine (silt) and coarse (sand) soils

with reconstituted ice lenses

Test cases

	Silt	Sand
Average thickness of ice lenses	4.6 cm	2.2 cm
Average thickness of soil layers	7.4 cm	4.3 cm
% of excess ice	40%	33 %

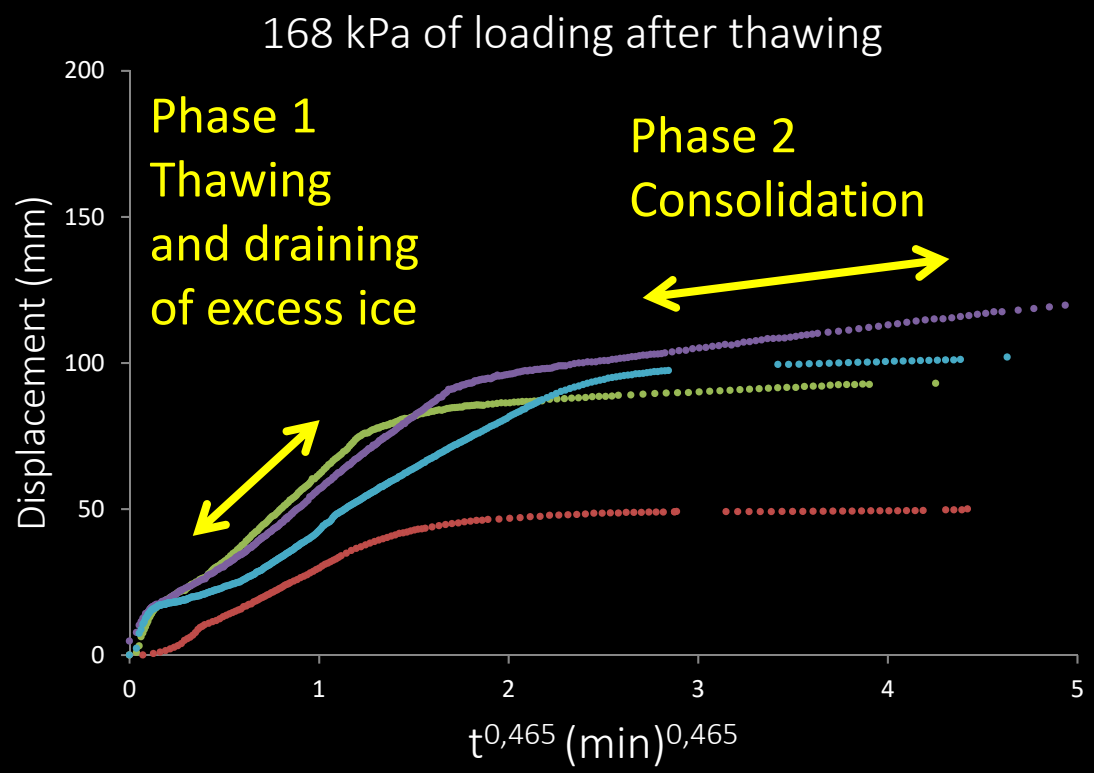
LABORATORY TESTING - RESULTS

Radial drainage : displacement as a fonction of time^{0,465} (McKinley, 1961)

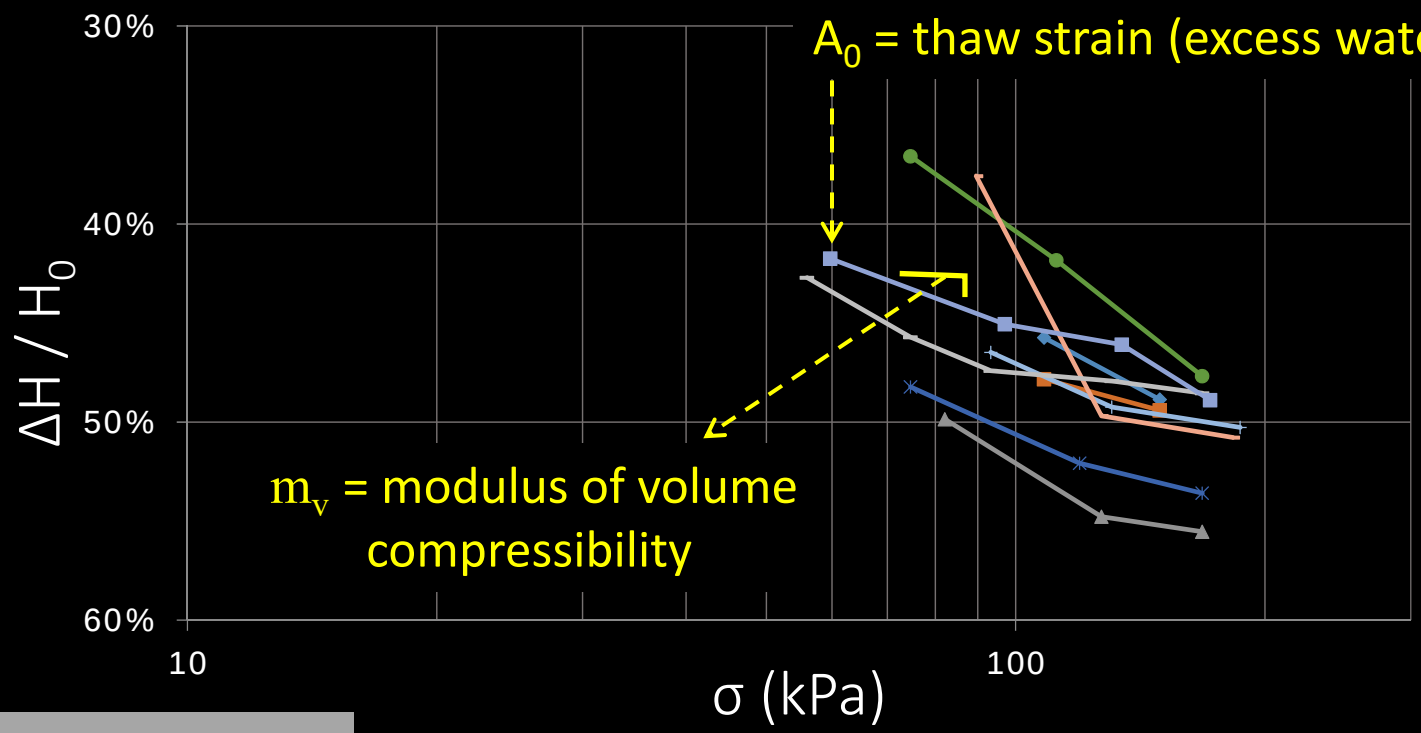
Coring

Thawing
20-40 min

Loading
168 kPa

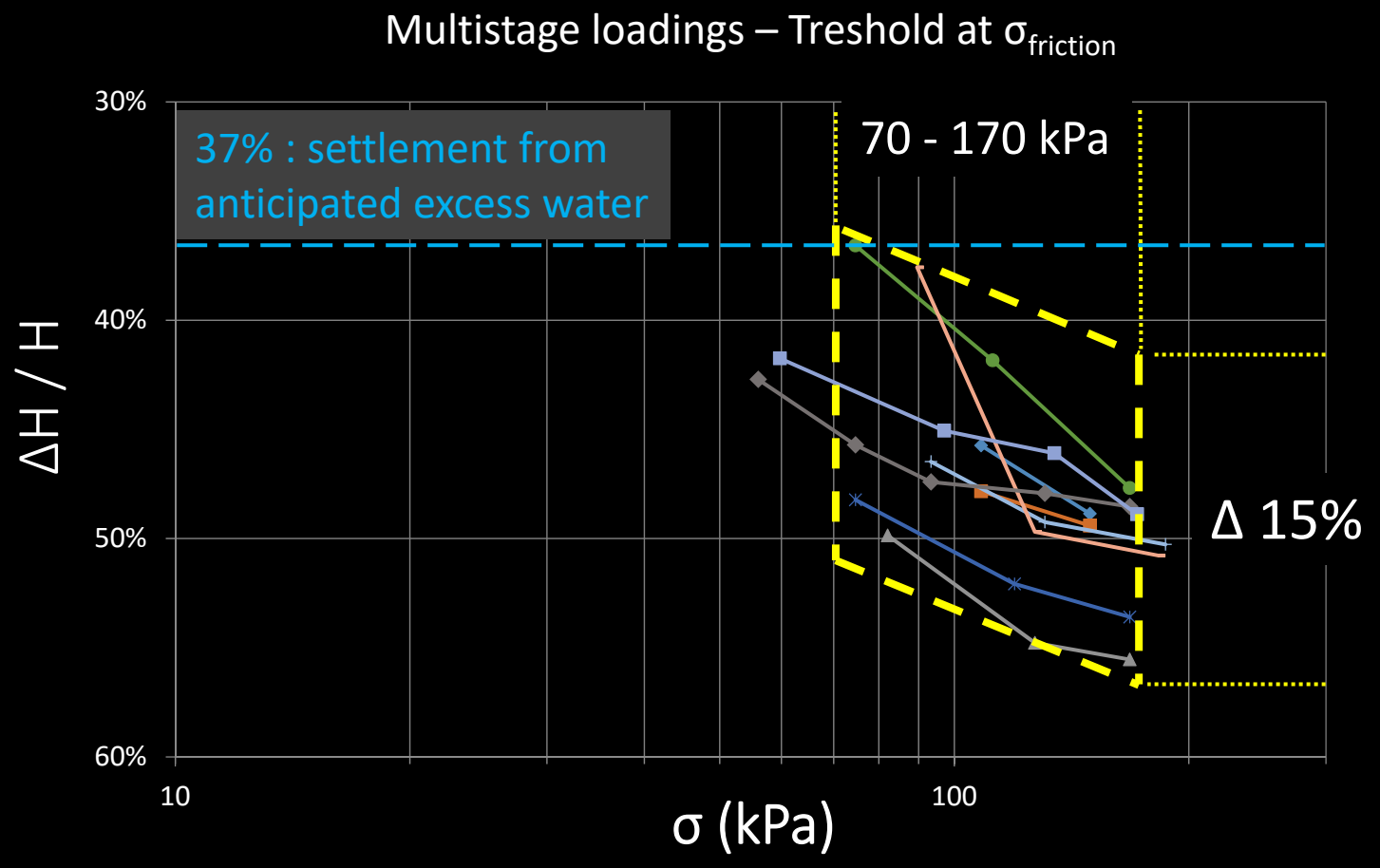


Normalized displacement as a function of applied load (ice rich silty sand)



$$\frac{\Delta H}{H_0} = A_0 + m_v \Delta \sigma$$

LABORATORY TESTING - RESULTS



LABORATORY TESTING - SYNTHESIS

- Settlement due to drainage of excess water
  - +/- 10% relative error
- Consolidation rate
  - Problems with data recording (manual)
- Modified compression index $C_{c\varepsilon}$
  - Appears overestimated : validating results by standard oedometer tests
  - Influence of friction : limiting the applicable loading range

CONCLUSION

The prototype developed allows to :

Perform rapid in situ thaw-consolidation tests under a range of vertical loads, instead of bringing frozen samples to a lab

Estimate thaw-consolidation soil properties such as A0, m_v and $C_{c\varepsilon}$

Consolidation speed

Improvements : Managing friction
Displacement reading
Cleaning routine

Next step : Field test validation

BENEFITS

Following a presentation of the technology at the 2015 International Conference on Cold Regions Engineering, the oedometric core barrel was qualified as a "major breakthrough in permafrost engineering" by experts in attendance.

Collaboration between Laval University (Civil and Mechanical Engineering Departments) and Arquluk partners will allow making final adjustments to the prototype and performing field tests.

The technology is protected by a Canadian patent and the final product will be manufactured and commercialized.

Arquluk
Permafrost engineering research program
Programme de recherche en ingénierie du pergélisol

THANK YOU!

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