MECHANICAL BEHAVIOUR OF MARGINALLY FROZEN SOILS

Permafrost engineering research program
Programme de recherche en ingénierie du pergélisol

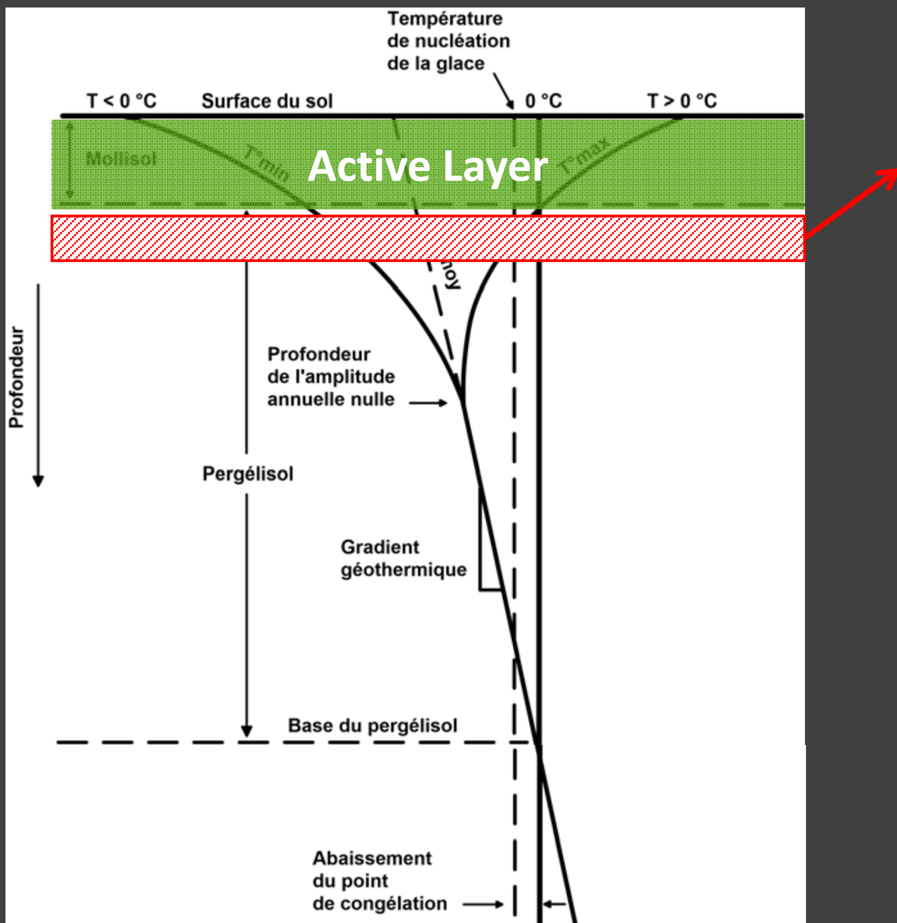
MATHIEU DURAND-JÉZÉQUEL ing. jr. MSc., SNC Lavalin

GUY DORÉ ing. PhD, Professor
Laval University / Centre for Northern Studies

JEAN-PASCAL BILODEAU ing. PhD, Research Engineer, Lecturer
Laval University

ARQULUK SYMPOSIUM Whitehorse, February 21st, 2018

CONTEXT

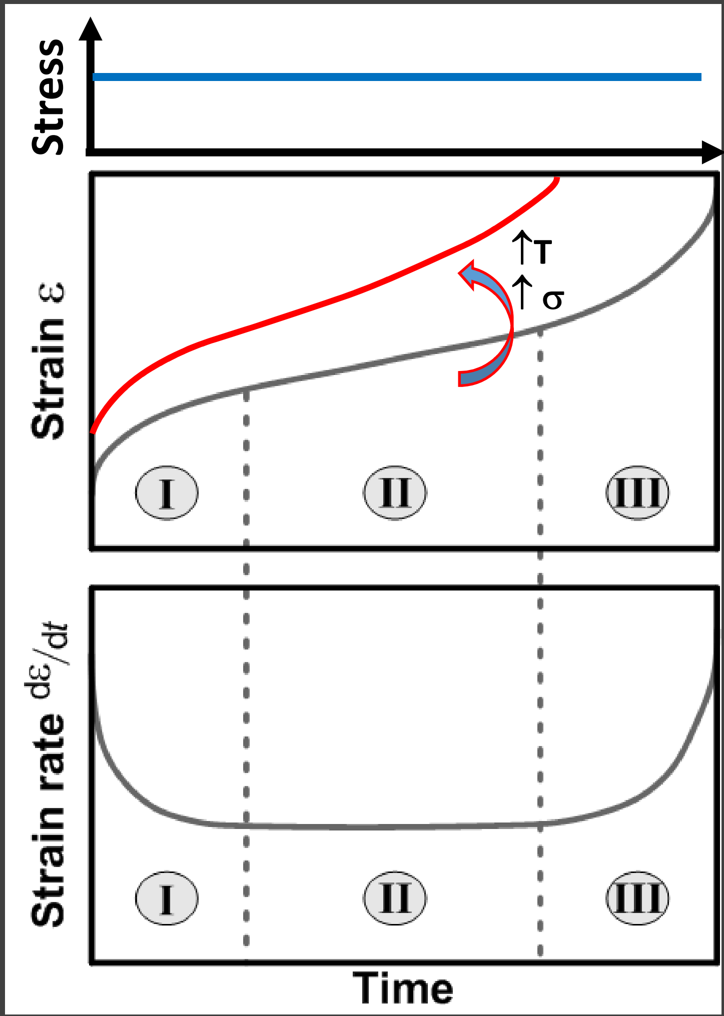


Marginally Frozen Soil

- During summer $T \approx 0$ °C
- Typically ice-rich

Sensitive to creep!

Creep of frozen soils



RESEARCH OBJECTIVE

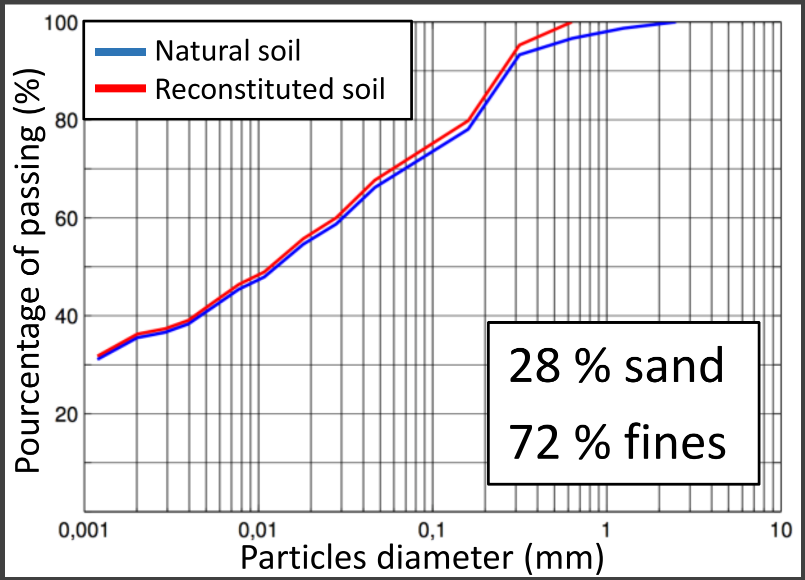
Creep of infrastucture built on sensitive permafrost are generally attributed to static weight of the embankment

Objective

Quantify the effect of repeated loading on the behaviour of marginally frozen soils

METHODOLOGY

Samples reconstituted in laboratory



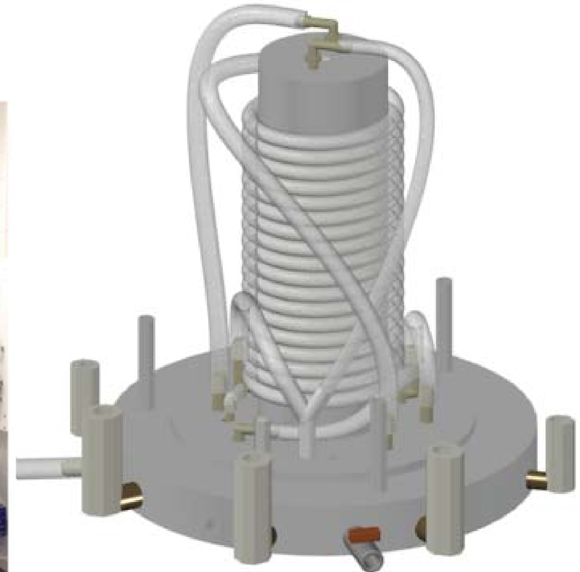
$w = 50\% = 1.8w_L$

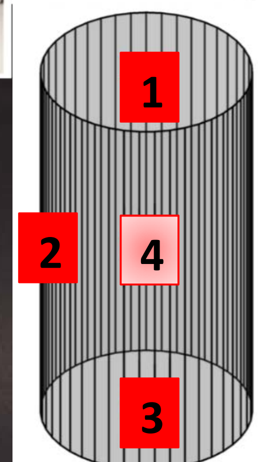
$S_R \approx 100\%$

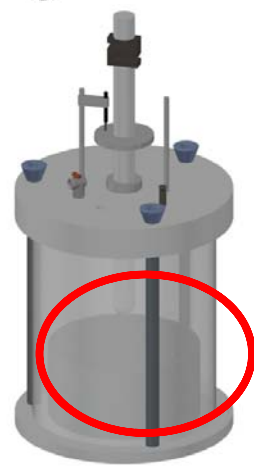
METHODOLOGY

Modified triaxial cell

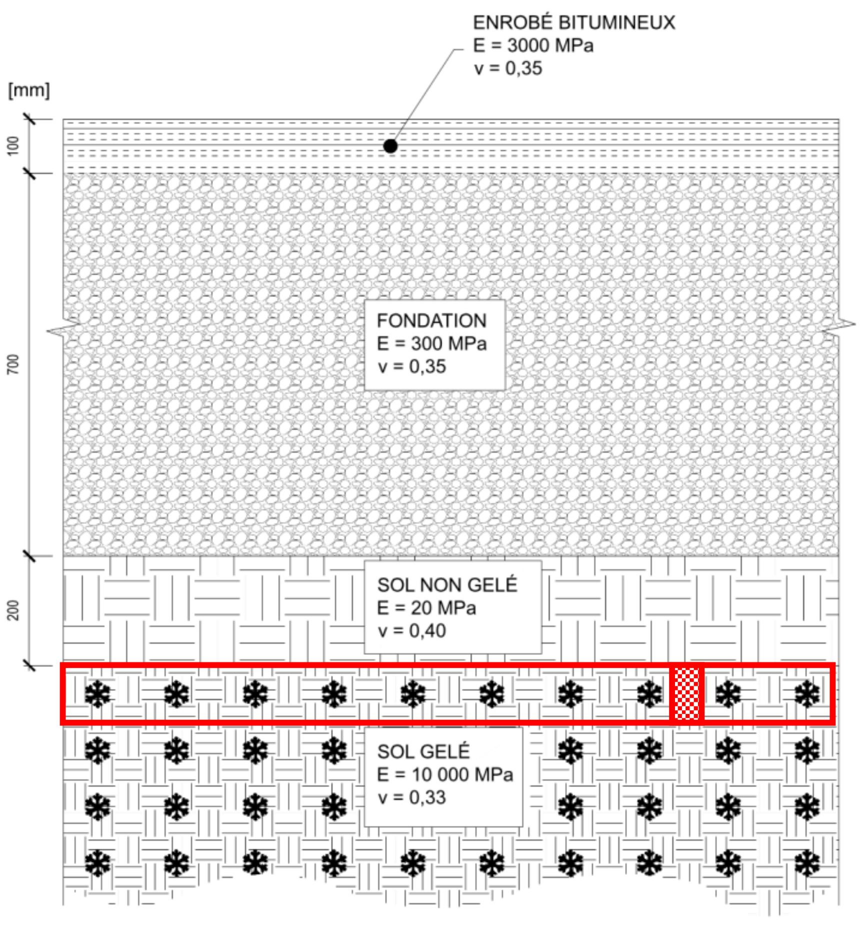
- Accurate control of temperature all around the sample
- Independant control of temperature at 3 positions around the sample
- Drainage of unfrozen water through the base of the cell







METHODOLOGY



Test parameters

Static Load

$\sigma v = 20$ kPa

$\sigma h = 10$ kPa

WinJULEA

$\sigma = 700$ kPa

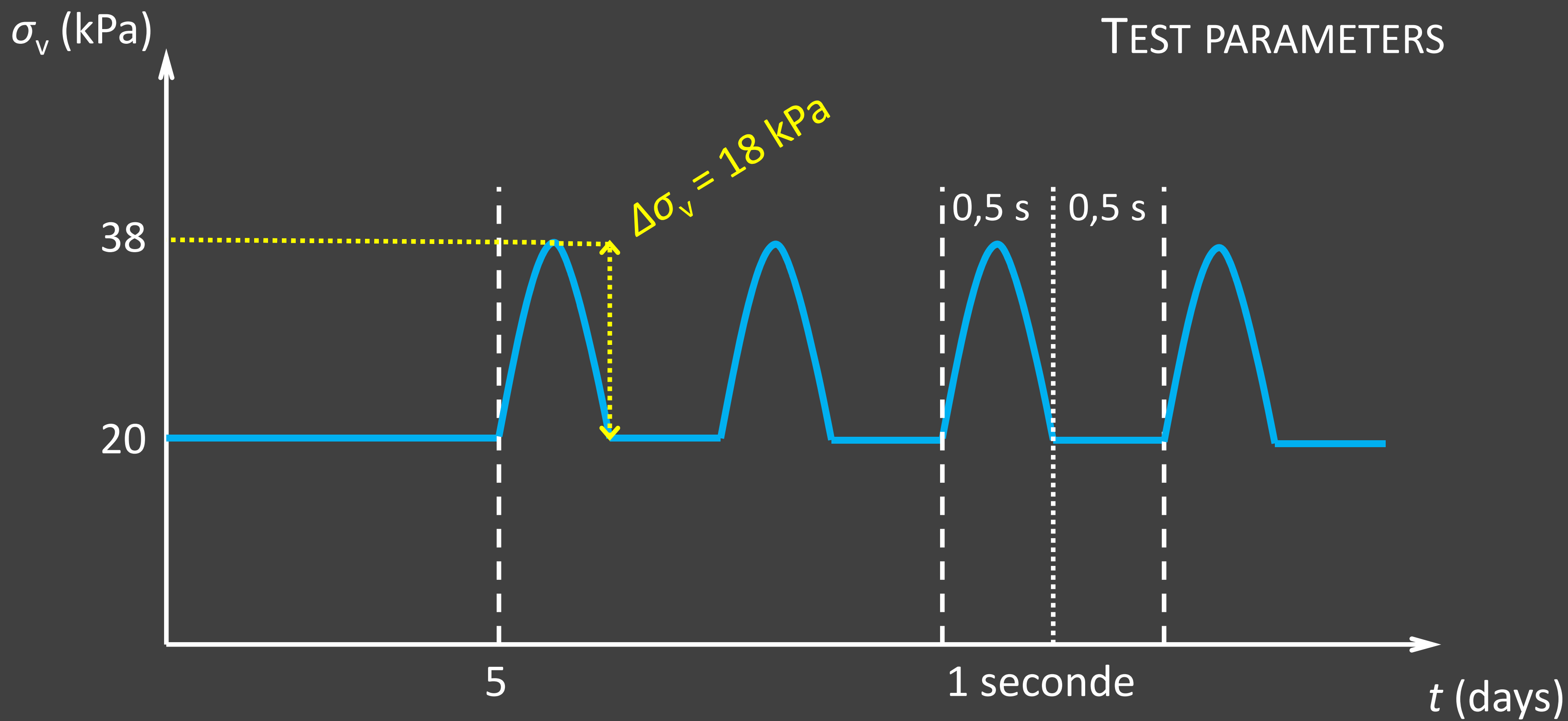
$a = 150$ mm

Dynamic Load

$\Delta\sigma v = 18$ kPa

METHODOLOGY

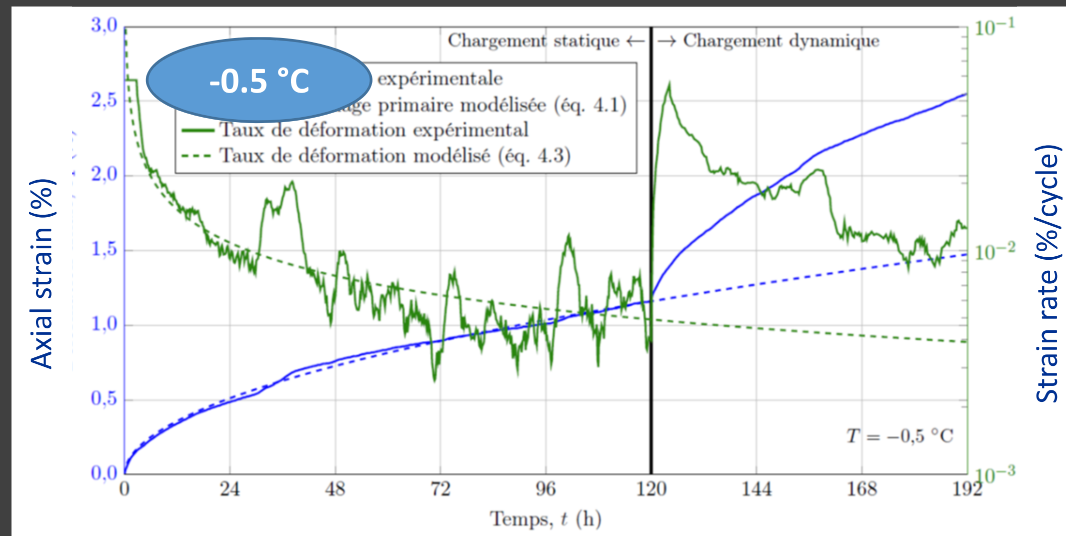
TEST PARAMETERS

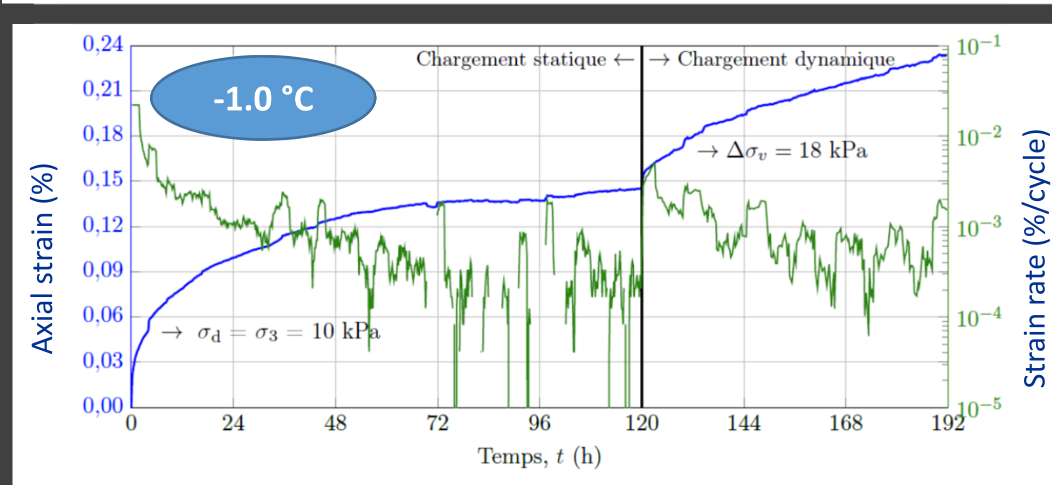


Results

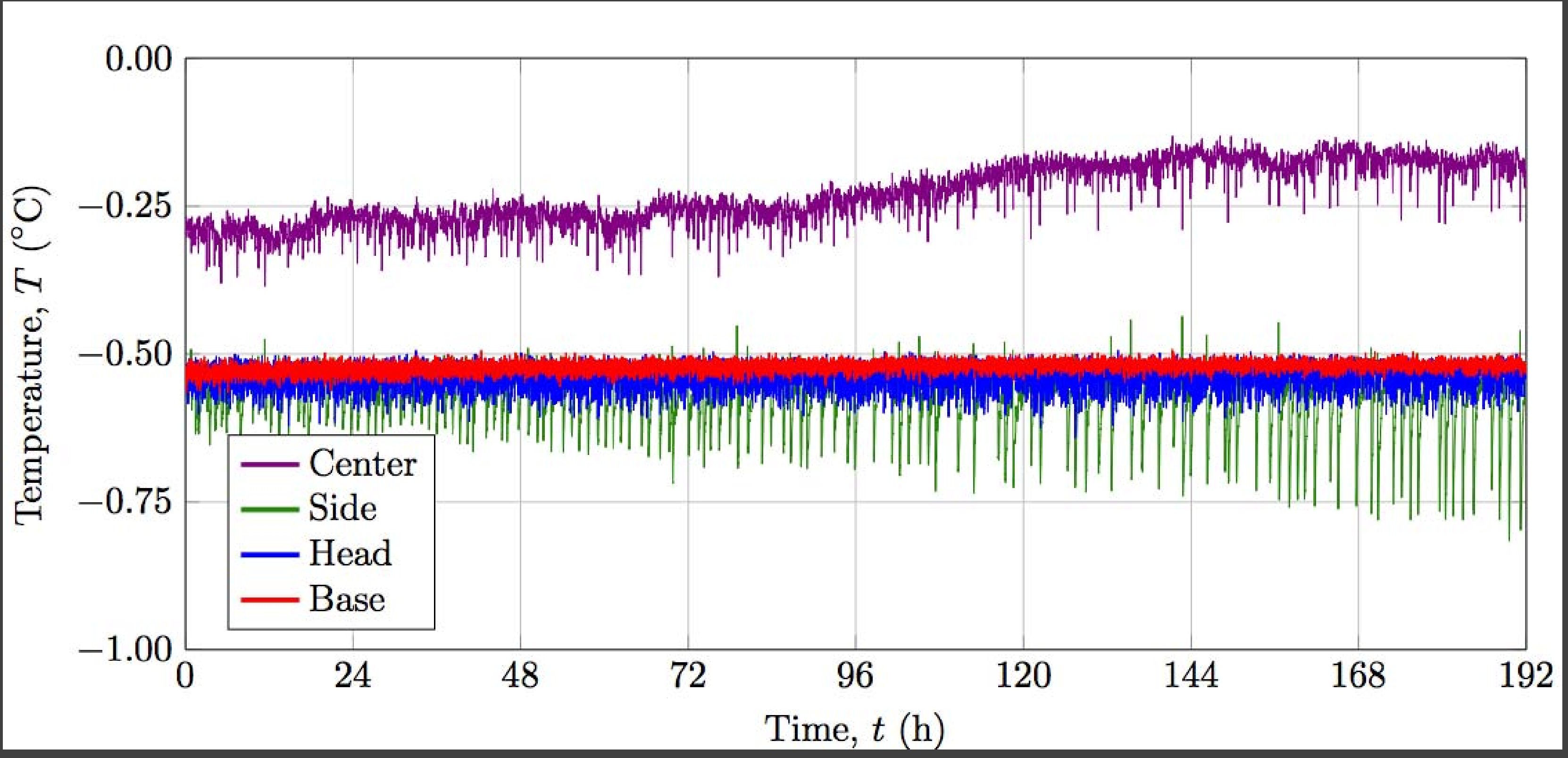
$$\varepsilon_e^{(c)} = \left(\frac{\sigma_d}{\sigma_{c\theta}}\right)^n \left(\frac{\dot{\varepsilon}_c t}{b}\right)^b$$

$$\sigma_{c\theta} = \sigma_{c0}\left(1+\frac{\theta}{\theta_c}\right)^w$$





RESULTS



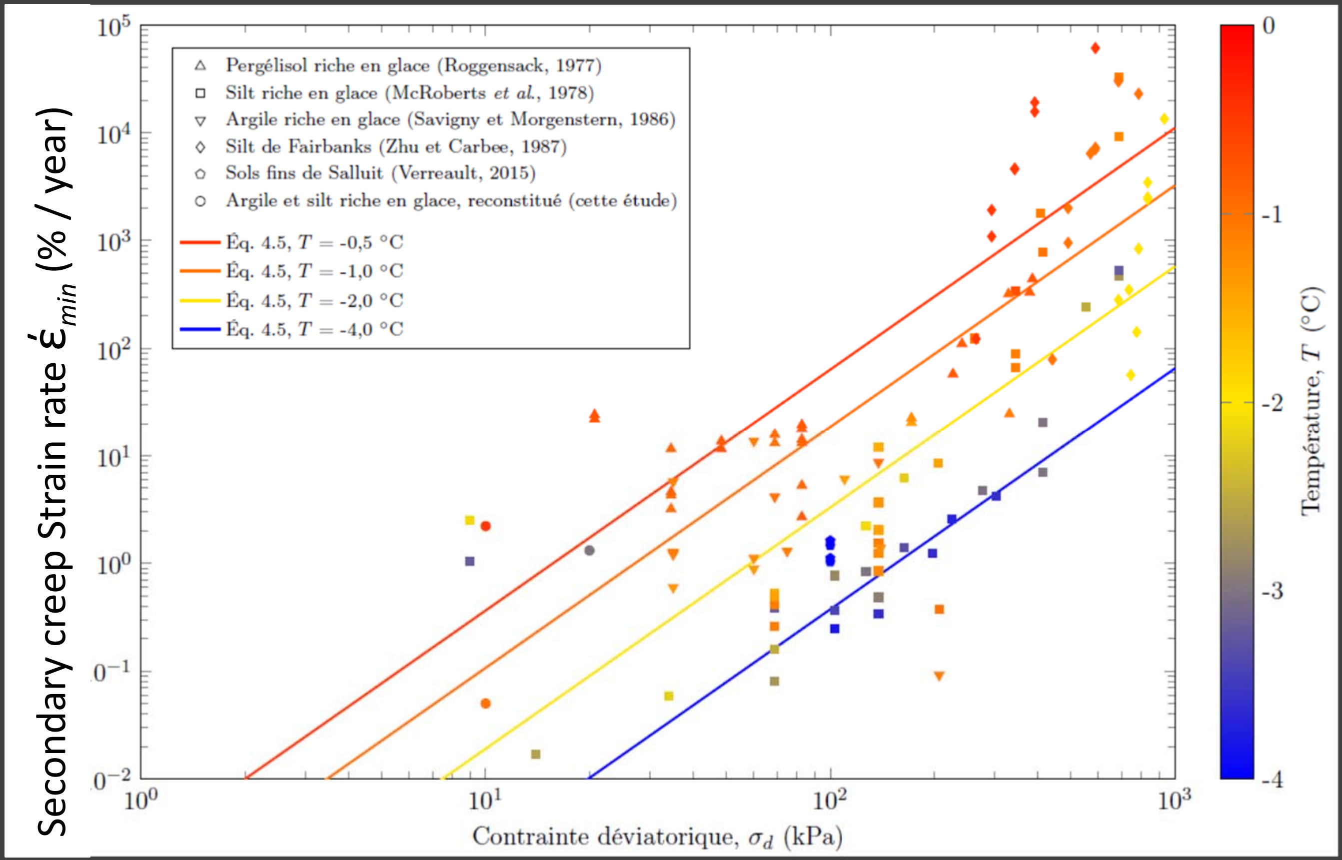
0.00
−0.25
−0.50
−0.75
−1.00
Temperature, T (°C)
0
24
48
72
96
120
144
168
192
Time, t (h)
Center
Side
Head
Base

RESULTS

Static creep interpretation

Combination of experimental results with data from literature

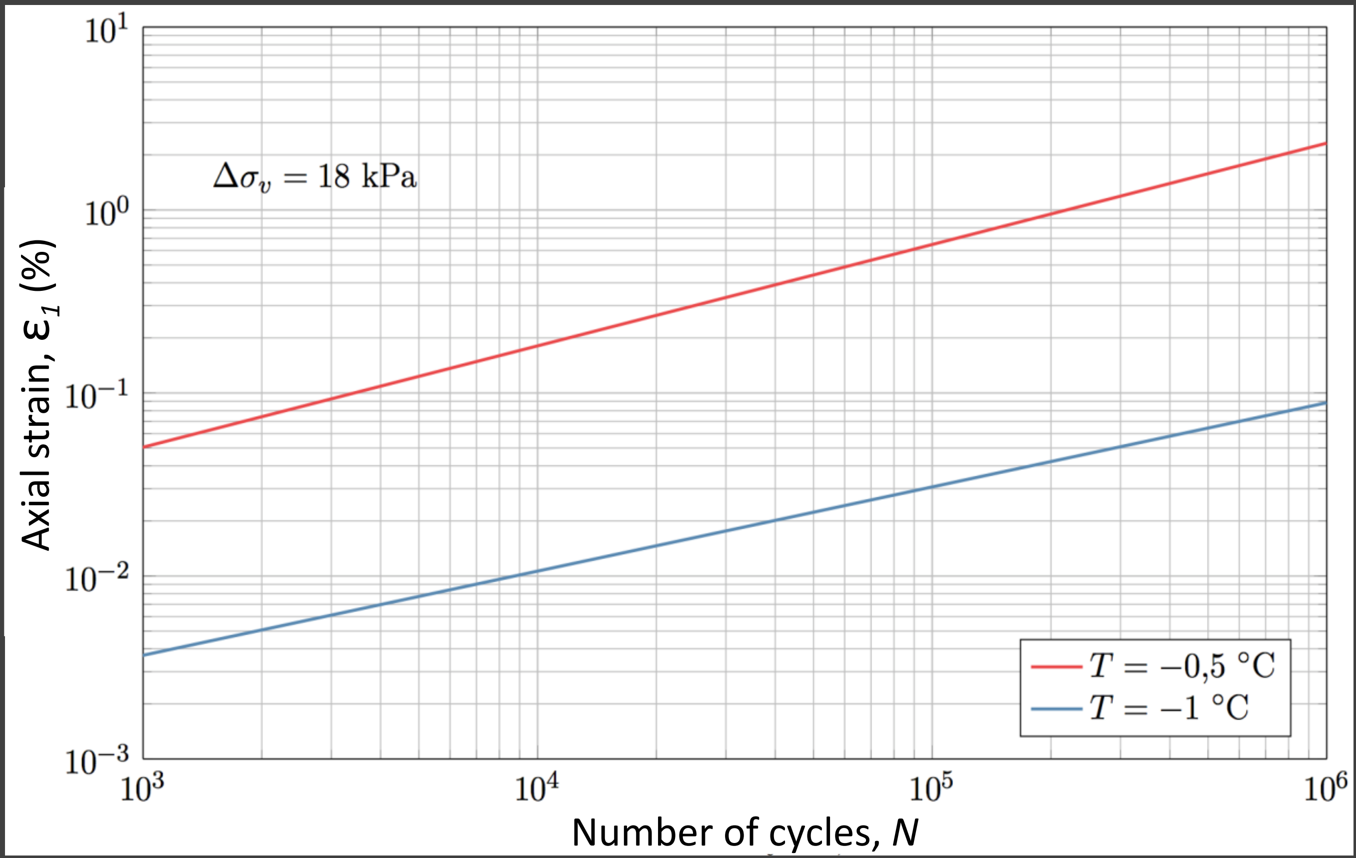
(warm T / low stress)



Results

Dynamic creep interpretation

- Dynamic creep component extracted from substracting the extrapolation of the static creep



RESULTS

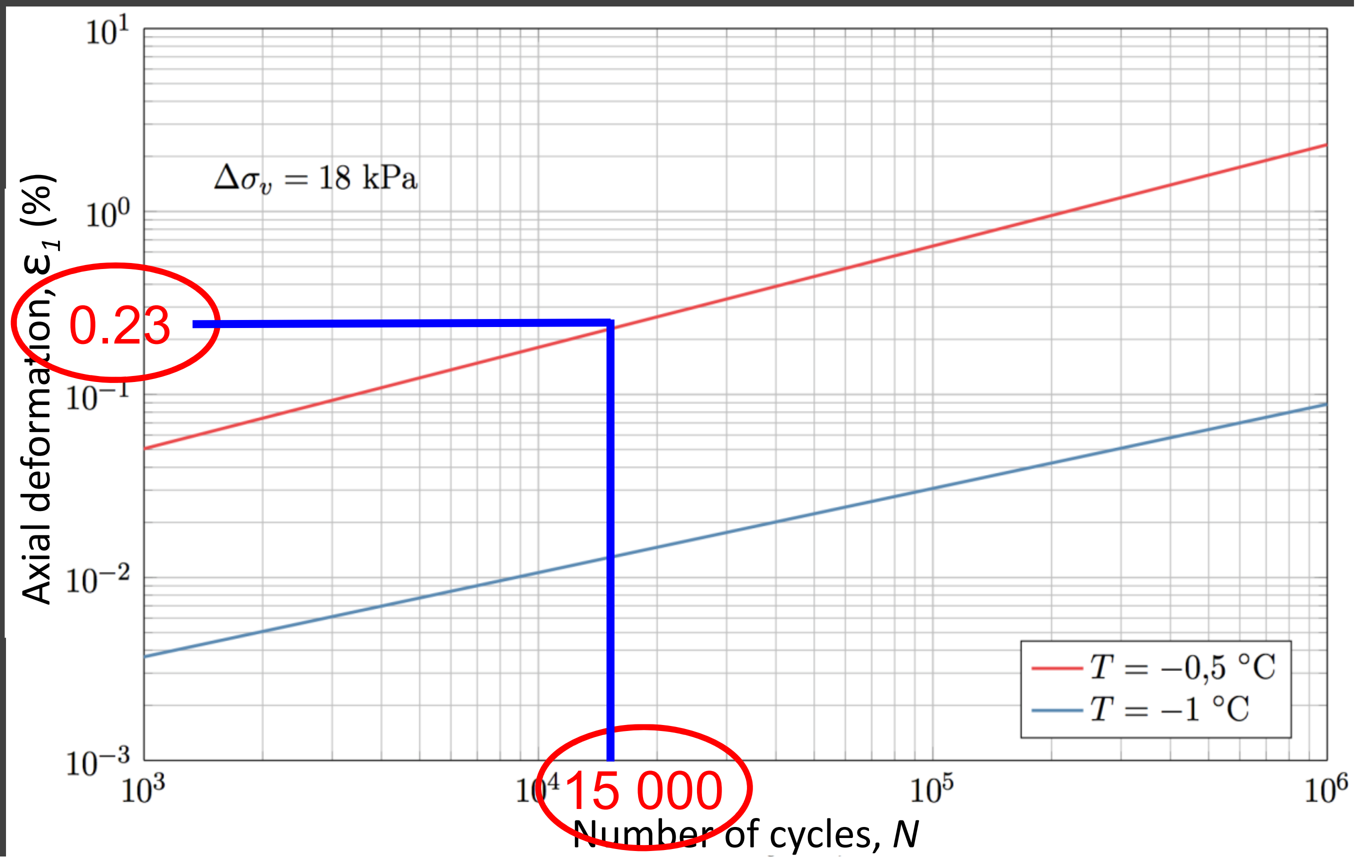
Dynamic creep interpretation

Marginally frozen layer

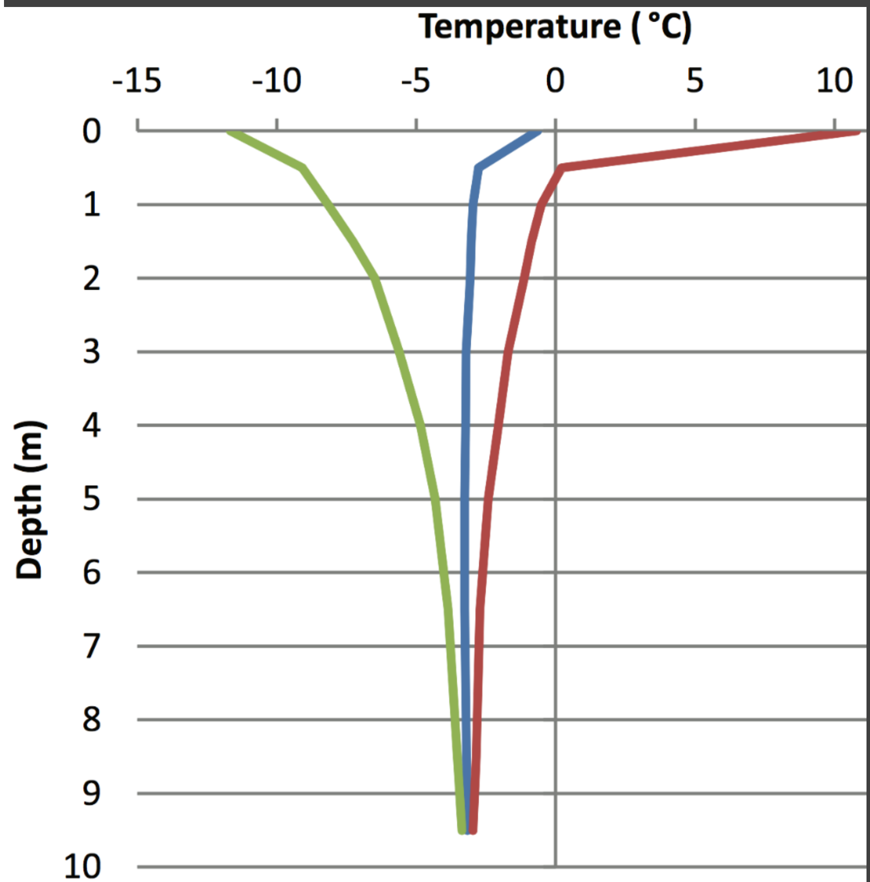
Tav. = -0.5 °C
Δz = 1 m

Number of loading cycles N

N = 50 trucks/day * 100 days * 3 axles/truck
N = 15 000



EXAMPLE OF APPLICATION



Embankment built on sensitive permafrost

thickness = 1 m
summer = 100 days
traffic = 50 trucks / day

Static creep settlement = 1.1 mm
Dynamic creep settlement = 2.3 mm

Total settlement is
3 times more important
when considering dynamic solicitation

CONCLUSION

The relative contribution of dynamic load is responsible for approximately 70 % of total settlement in conditions tested.

Total annual settlements are low but do not consider :

- primary creep
- thawing – consolidation in permafrost
- settlement in the embankment

Heavy trucks passage shall be considered on thin embankment to minimize creeping of thaw-sensitive permafrost

Benefits

New methodology to conduct drained triaxial creep test with accurate temperature control.

Adaptation and recalibration of existing static creep models to quantify static settlement.

ARQULUK

Permafrost engineering research program
Programme de recherche en ingénierie du pergélisol

THANK YOU TO OUR RESEARCH PARTNERS

?

Université Laval
Kryotek
Kativik
Transports, Mobilité durable et Électrification des transports Québec
GHD
Yukon Research Centre Yukon College
Cold Climate Innovation Yukon Research Centre • Yukon College
Université de Montréal
CRSNG NSERC
Tetra Tech
WSP
Colas
Nippo
Yukon Highways and Public Works
Ouranos
Centre d'études nordiques