ARCTIC TECHNOLOGY CENTRE

DTU

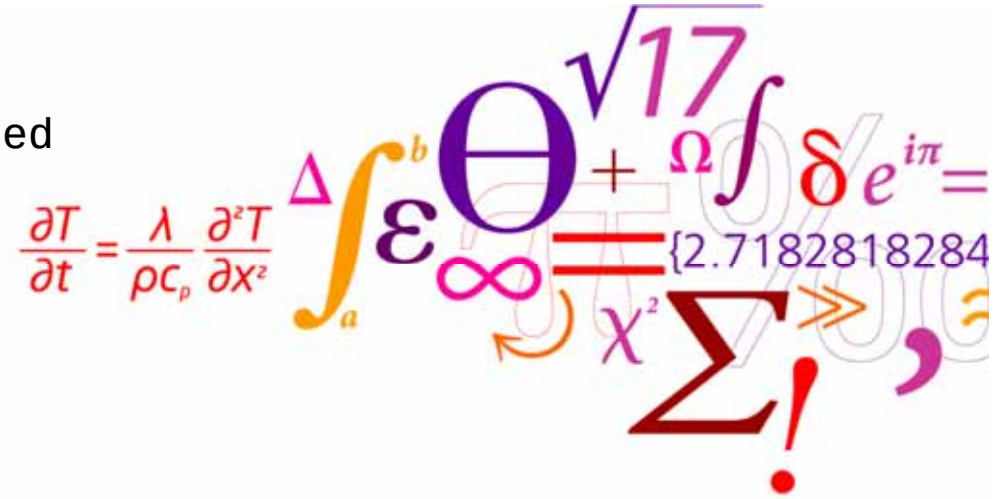
Suggested best practic for geotechnical characterisation of permafrost in the Nordic countries

Nordic Geotechnical Meeting 2012

Frederik Ancker Agergaard
PhD student, Arctic Technology Centre

together with

Thomas Ingeman-Nielsen & Niels Foged



DTU Civil Engineering
Department of Civil Engineering

Agenda

- Intro to frozen soils & permafrost
- Perspectives & motivation
- Characteristic properties
- Conclusions

Frozen soil

Soil matrix components:

- Soil grains
- Air
- Unfrozen water
- Ice

Ice forms

- Pore ice
- Ice veins
- Ice lenses
- Particle ice coat
- Ice

(Form dent)

Most engineering challenges in frozen soil/permafrost pertains to the ICE component !

River bank permafrost exposure, Kangerlussuaq, Greenland

Motivation

- Experience of different approaches
- Possibility of misunderstanding
- No European codes of practice on frozen soil characterisation for geotechnical purposes
- Need for clear distinction of soil properties in own research

Perspectives

In an Arctic setting:

- Infrastructure
- Mine tailing dams

In more everyday geotechnics:

- Frost heave/frost sensitivity
- Artificial freezing

Bulk density

Frozen sample

- Geometric
- Sand equivalent
- Archimedes' princip.

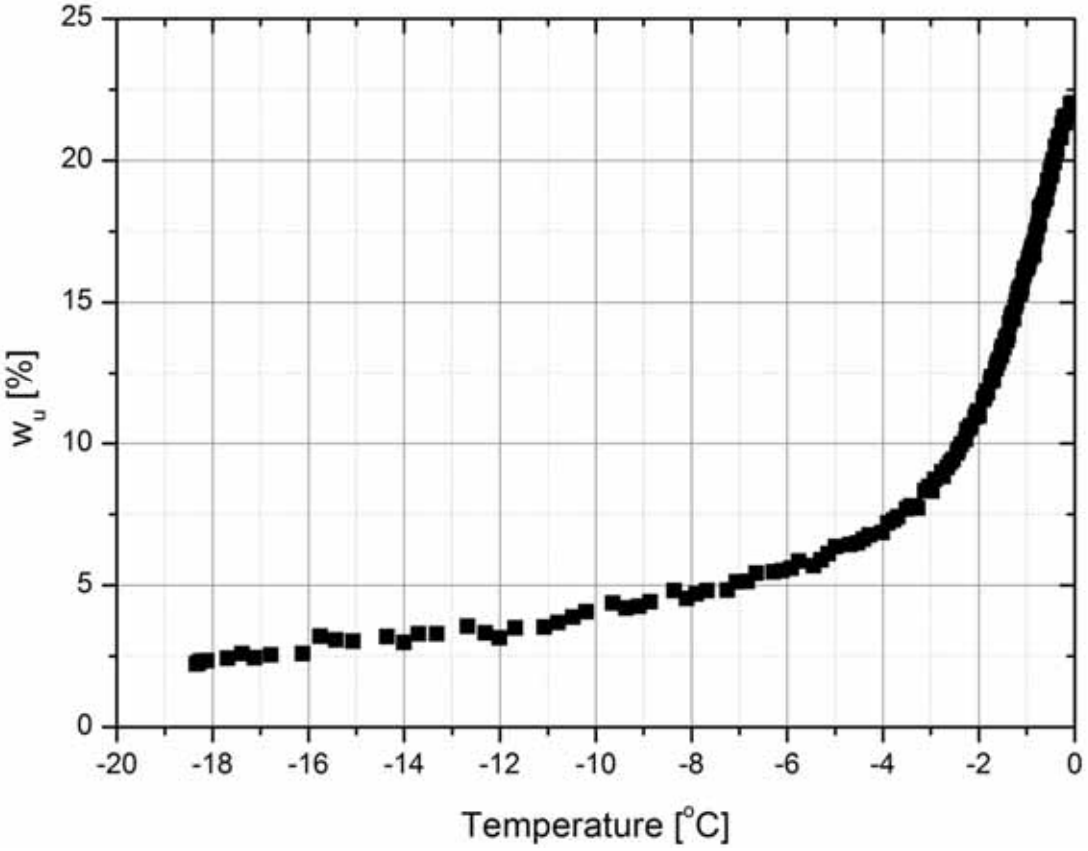
Info of solids vs. ice

Unfrozen water content & pore water chemistry

Frozen sample

- Only in fine-grained deposits
- Up to 10% @ -10° C
- Reflects residual salinity (from thawed sample)
- Freezing point depression

Can be correllated with Casagrande properties and undrained shear strength.

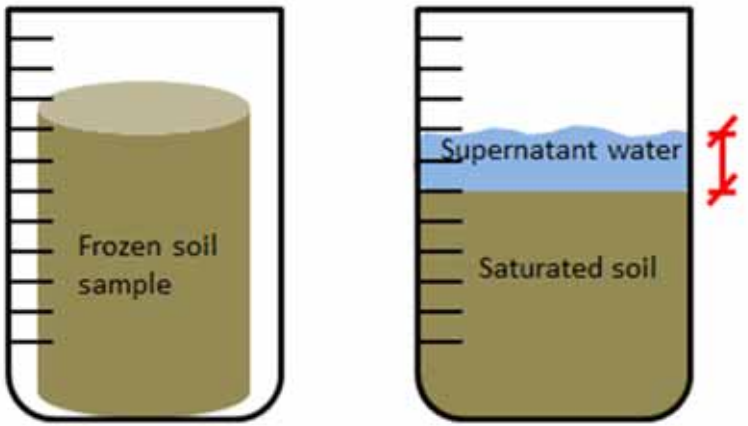


Excess ice content

Thawing the sample

- Gravimetric total water content
- ASTM – super natant water
- Volume fraction of frozen sample

Latent heat of ice acts as buffer for temp. changes.



Parameter	Value
Sample mass: m_{tot}	328.0 g
Sample volume, f: $V_{tot,f}$	196.3 cm^3
Excess ice volume, t: $V_{w,i}$	53.0 cm^3
Unfrozen water content: w_u	5 %
Ice content:	
Gravimetric ice content: w_i	42 %
Volumetric ice content, t: $w_{i,vol,t}$	37 %
Volumetric ice content, f: $w_{i,vol,f}$	27 %

Thermal properties

- Thermal conductivity
- Heat capacity

In-situ frozen, frozen & thawed state

Necessary for climate effects on soil temperature & for soil-structure thermal regime

Strength & deformation props.

Frozen sample

For example:

- Triaxial test
- UCS

- UCC
- Oedometer

Test temperature & no. of tests decided by in-situ soil temp.

”Warm” vs. ”cold” PF

Conclusions

Permafrost/frozen soil characterisation is suggested to comprise:

- Grain size distribution
- Atterberg limits
- Natural water content (after drainage of ice)

In addition to -------->

Frozen soil tests
- Bulk density from Archimedes' principle volumes
- Volumetric excess ice content
- Unfrozen water content
- 4 or more strength and deformation tests covering the soil temperature range relevant for the duration of the service lifetime
- Thermal conductivity and heat capacity
Thawed soil tests
- Undrained and remoulded shear strength
- Natural water content
- Consistency limits
- Residual salinity
- 4 or more strength and deformation tests covering the soil temperature range relevant for the duration of the service lifetime
- Thermal conductivity and heat capacity

Thank you for your attention !