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EXPERIENCES OF INSTALLATION DAMAGE ON GEOSYNTHETICS BASED ON FULL SCALE TESTING IN KEMI (ROUGH PROJECT)

ARNSTEIN WATN, NTNU/WATNCONSULT/SINTEF

Philippe Delmas

ROUGH – background and goal

Extensive use of geosynthetics

Common Nordic system for specification and certification (NorGeoSpec) since 2002

Challenging conditions (low temperature, snow, freeze/thaw, soft subsoil)

Guidelines for installation and construction og gsy are general

Construction activity restricted in winter conditions

Experiences revealed possible damage related to installation and construction at low temparature

Investigate survivability of gsy during installation and construction at low temperatures

Prepare guidelines for installation and construction in "Rough Nordic Conditions"

Basis for evaluation of "fit for purpose"

Basis for specification and certification

ROUGH Project - RecOmmendations for the Use of GeosyntHetics in Nordic conditions

- Nordic Authorities
  - Finnish Transport Infrastructure Agency (Finland),
  - Statens vegvesen (Norwegian Public Roads Administration, Norway), and Trafikverket
  - (Swedish Transport Administration - Sweden)
- Research Institutes
  - SINTEF

- Manufacturers/Suppliers
  - BontexGeo
  - CETCO
  - DUPONT
  - Fibertex Nonwovens
  - HUESKER Synthetic
  - MACCAFERRI
  - Naue
  - Solmax
  - Tensar International
  - Thrace
  - ViaCon

The second part of the ROUGH project on sealing was realised with the important contribution of Eric Blond Consultant Inc. (Canada) and Tutkimuskeskus Terra (Tampereen yliopisto, Finland).

The coordination and the interpretation were realised by Sintef with WatnConsult AS

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ROUGH (**R**ec**O**mmendations for the **U**se of **G**eosynt**H**etics in Nordic conditions)

The ROUGH project was realised with the contribution of the Finnish Transport Infrastructure Agency (Finland), Statens vegvesen (Norwegian Public Roads Administration, Norway), and Trafikverket (Swedish Transport Administration - Sweden)

and the participation of the following Manufacturers:
BontexGeo, Cetco, DuPont, Fibertex, Huesker, Maccaferri, Naue, Solmax, Tensar, Thrace, Viacon.
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ROUGH (**R**ec**O**mmendations for the **U**se of **G**eosynt**H**etics in Nordic conditions)

Project background

Existing NorGeoSpec (certification and specification for geosynthetics) **does not include** regulations and requirements for geosynthetics for specific conditions

- regarding **low temperatures, installation conditions aggregates and soft subsoils common in the Nordic countries.**

This has even been in the past the topic of some court cases related to the evaluation of "fitness for purpose" of geosynthetics for Nordic conditions.

Based on discussion with different traffic authorities it was therefore proposed to establish a development project (ROUGH) addressing which special requirements must be placed on geosynthetics to ensure technically and economically optimal solutions in Nordic countries.

ROUGH (**R**ec**O**mmendations for the **U**se of **G**eosynt**H**etics in Nordic conditions)

Scope:

Nordic conditions (sub-zero temperatures, soil types and working conditions: drop height, compaction, etc.).

Geosynthetics

applications

roads, railways, reservoir dams, rivers, waste disposal, sport fields

function(s)

reinforcement/stabilisation, filtration, drainage, or sealing

ROUGH (**R**ec**O**mmendations for the **U**se of **G**eosynt**H**etics in Nordic conditions)

ROUGH Content

1- **full-scale on-site experiment in Kemi** (Northern Finland) on installation under Nordic conditions for applications with functions reinforcement / stabilisation, filtration, drainage

2- **literature study & a synthesis state of the art** for sealing; *considering the difficulty of realisation of on-site experiment for sealing applications*

ROUGH (RecOmmendations for the Use of GeosyntHetics in Nordic conditions)

ROUGH Kemi field tests

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ROUGH (RecOmmendations for the Use of GeosyntHetics in Nordic conditions)

ROUGH Kemi field tests

Main Requirements

Temperature: mild cold – 5°C > θ > - 20 °C

Snow: take away the snow (before installation)

Granular material: blasted rock gravel (0-58mm)

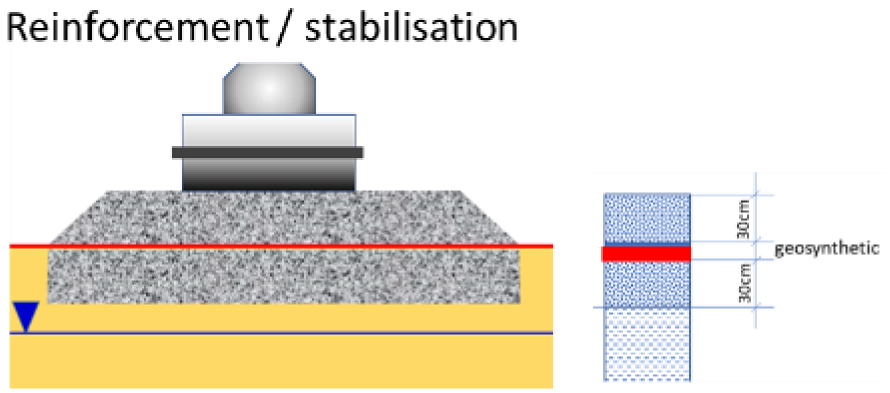
Compaction level: according the Finish guidelines

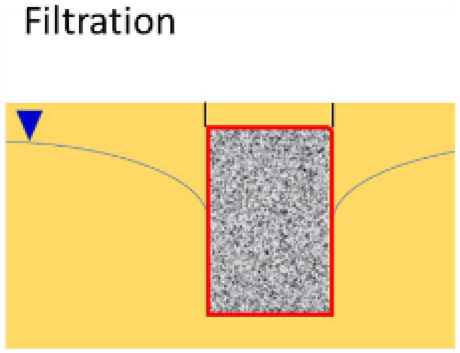
All GSY tested under same conditions:

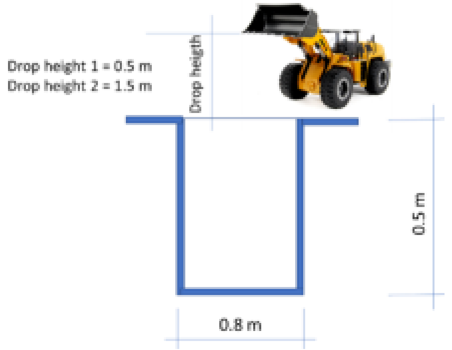
- installed and compacted at the same day.
- excavated at the same day. (not be the same day of installation).

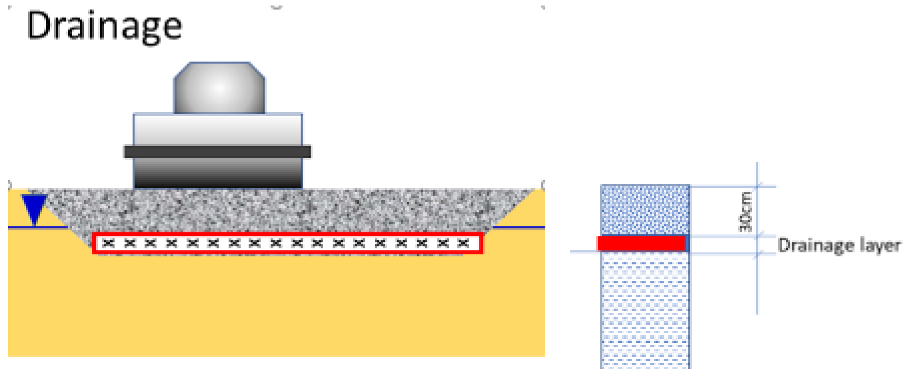
Excavation:

- upper layer shall be carefully removed, first "cm" the excavator can be used, for the last "cm" (up to the GTX surface) the vacuum cleaner shall be used









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In-situ soil

Reinforcement /stabilisation

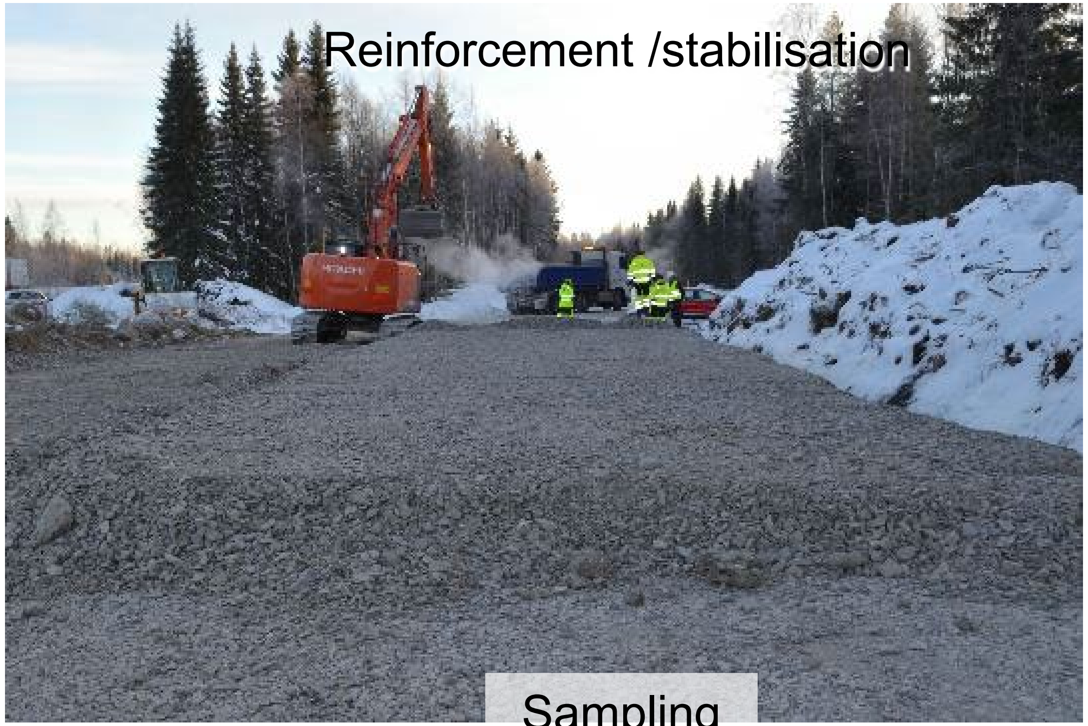
Drainage

Filtration

Granular soil

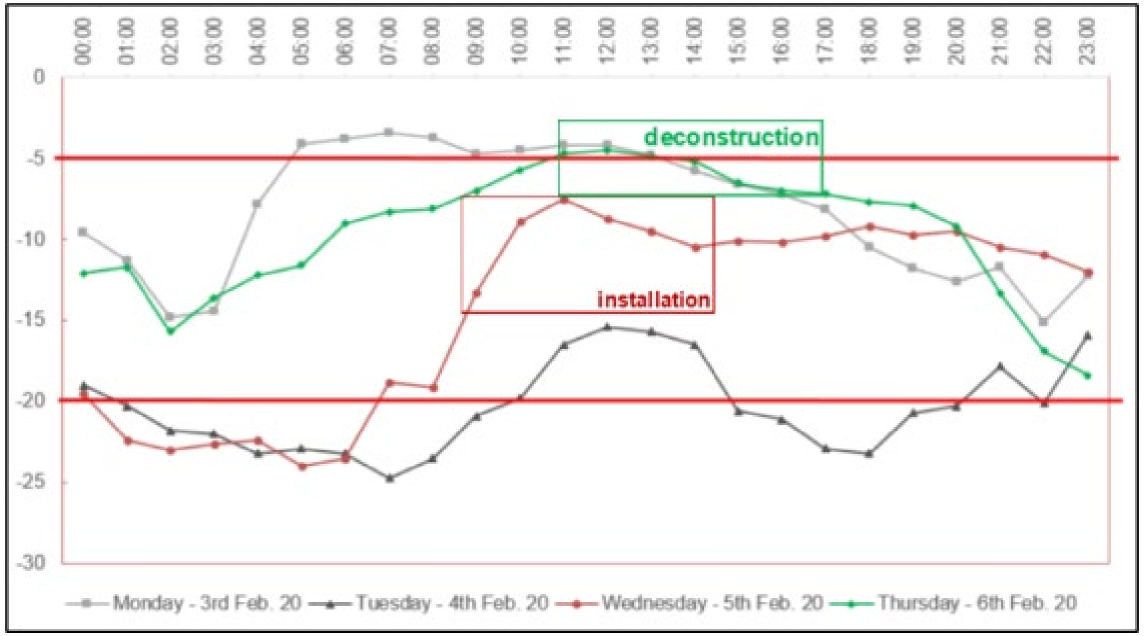
Crashed rock gravel

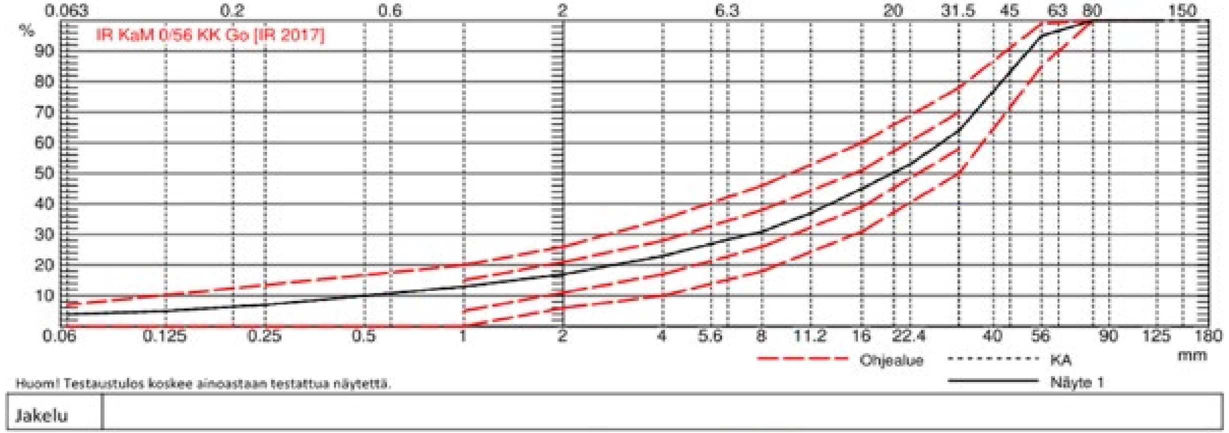
- 7.8 °C



Preparation, compaction and testing of granular layers

Reinforcement Stabilisation & Drainage





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Geosynthetics

Storage & preparation

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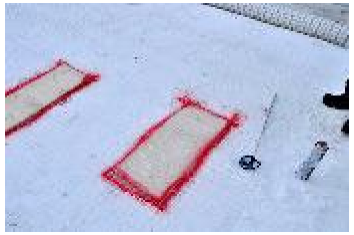
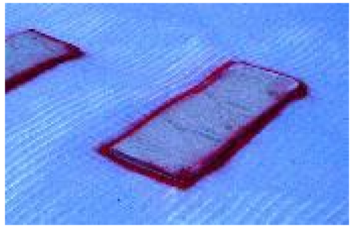
ROUGH Kemi field tests

Pre-marking of the test specimens for lab testing for Reinforcement Stabilisation & Drainage





Reinforcement /stabilisation

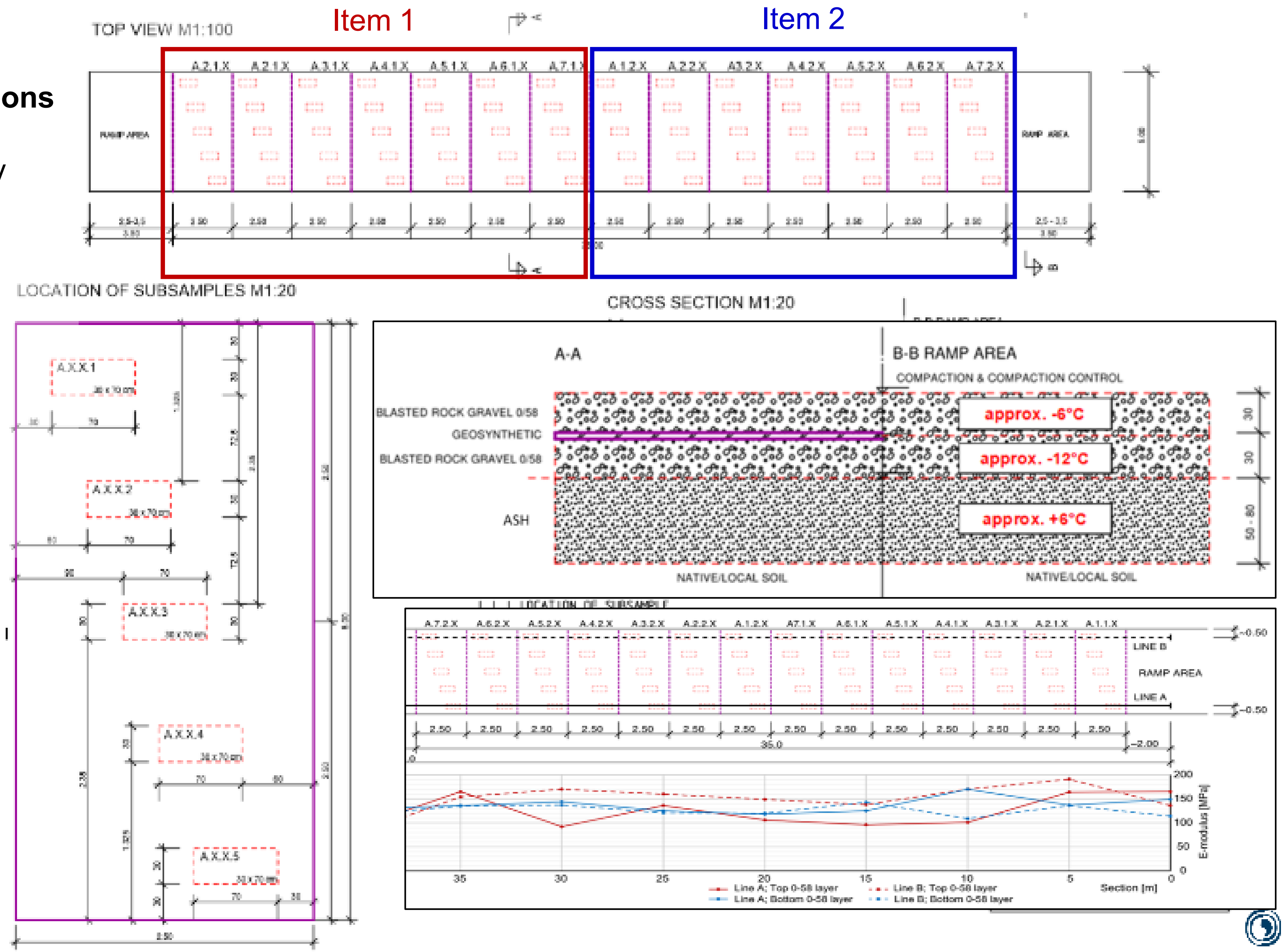
All products installed under same conditions

- same range of temperature
- installed and compacted at the same day

All products excavated at the same day

Two items for each product

7 Products tested



Preparation of sub-base layer and placement of Geosynthetics

Placement of 30 cm crushed rock gravel layer and compaction

Control of drop height

Removal technique for upper crushed rock gravel layer

Vacuum cleaner with specific suction head

Removal of the upper crushed rock gravel layer for Reinforcement / stabilisation area





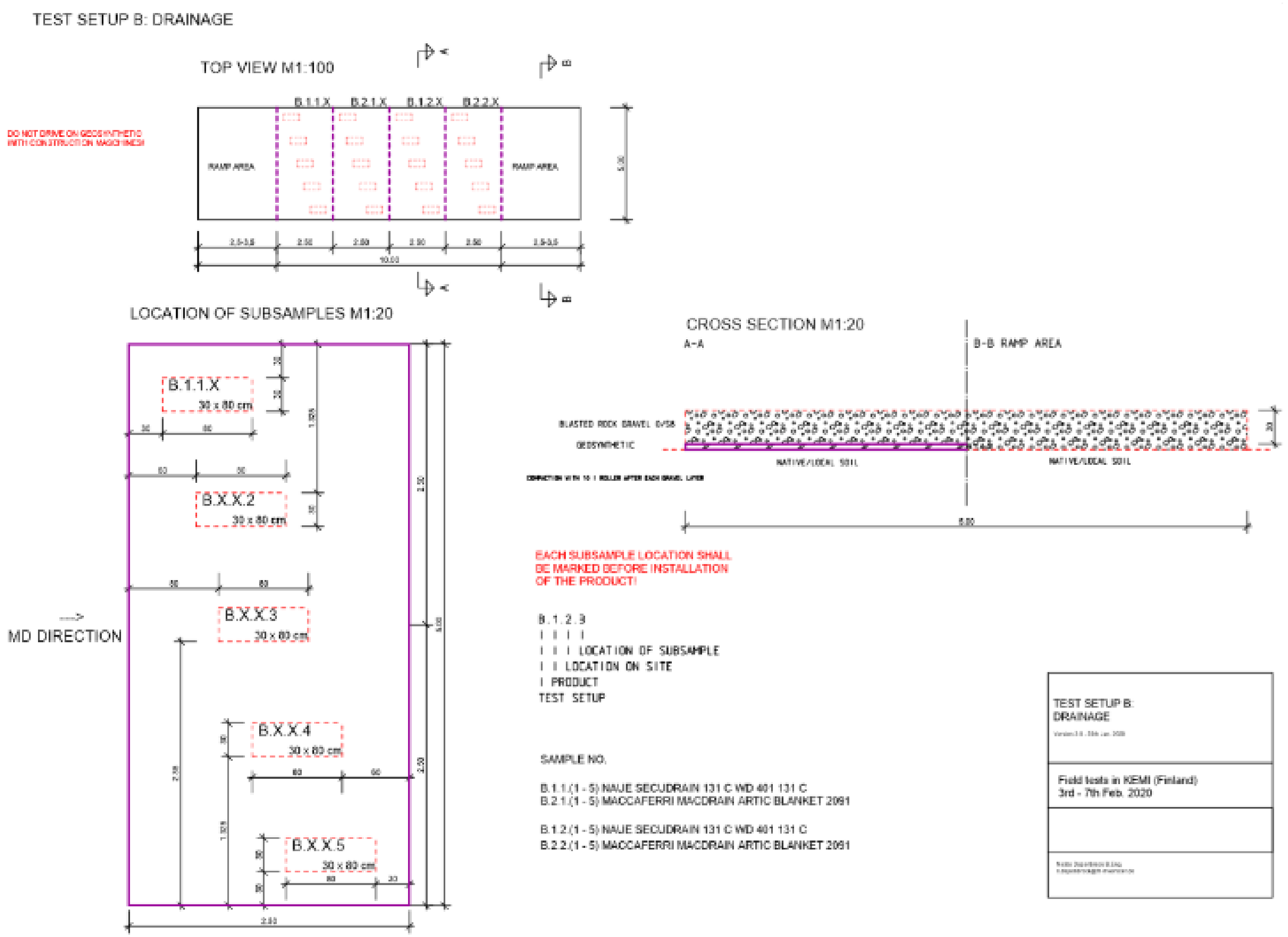

Drainage

All products installed under same conditions
- same range of temperature
- installed and compacted at the same day

All products excavated at the same day

Two items for each product

2 Products tested



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Existing on-site sub-base layer

Placement of Geosynthetics

placement of 30 cm crushed rock gravel layer and compaction

Removal of the upper crushed rock gravel layer for Drainage area and removal of geosynthetics

Filtration

All products installed under same conditions

- same range of temperature
- installed and compacted at the same day

All products excavated at the same day

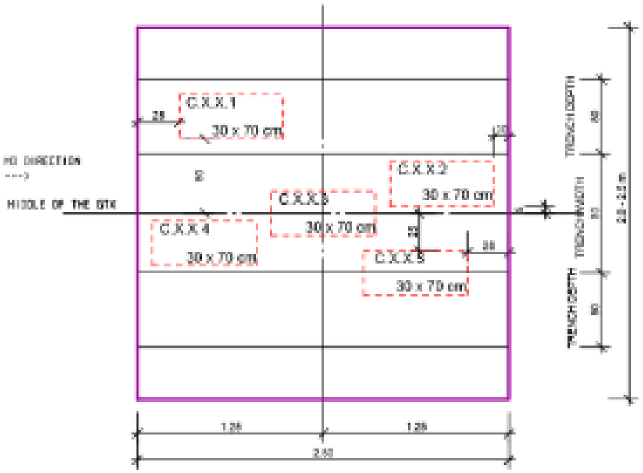
Two items for each product for each drop height

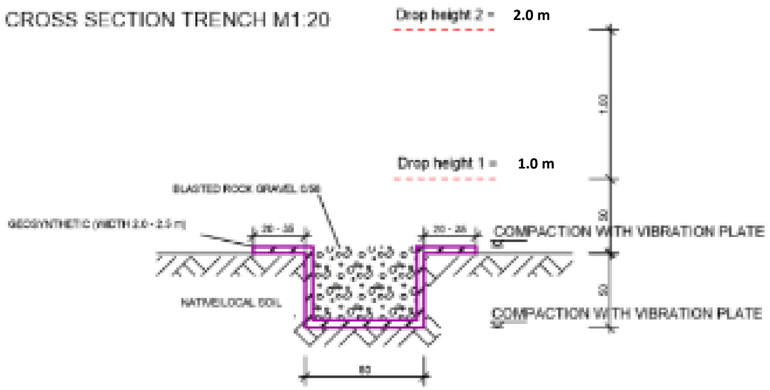
Drop height measured above soil level

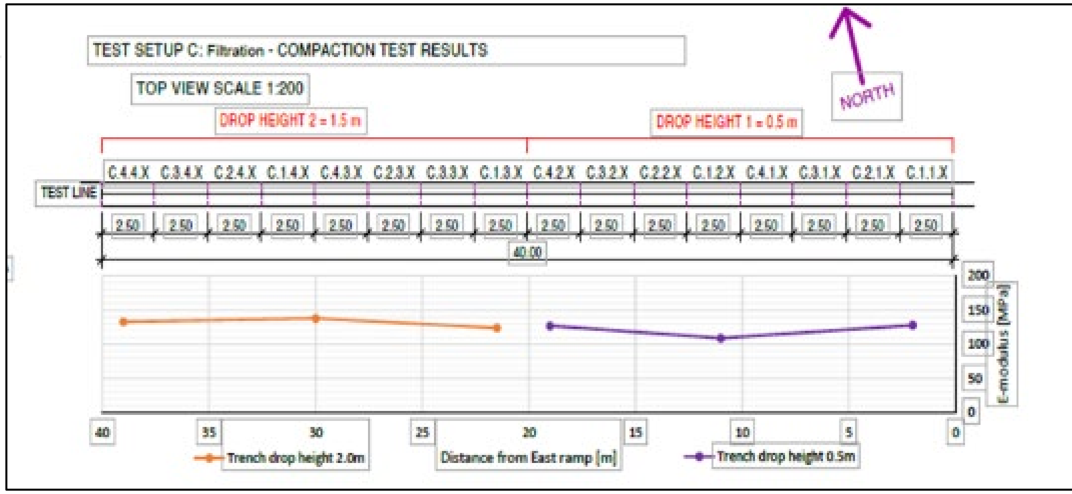
trench depth : 0.5 m

2 drop heights : 0.5 m & 1.5 m

4 Products tested







Existing on-site sub-base layer,

Creation of the trench
trench depth : 0.5 m

Placement of geosynthetics
- avoiding heavy irregularities (rock)
- pre-marking of trench limits (top & bottom) to allow same location of tests specimens
- light anchorage at the top of trench

Filling of trench with crushed rock gravel

Control of drop heights



Levelling of crushed rock gravel and compaction

Excavation of the core of the trench

Removal of the crush rock gravel remaining in the trench using the Vacuum cleaner

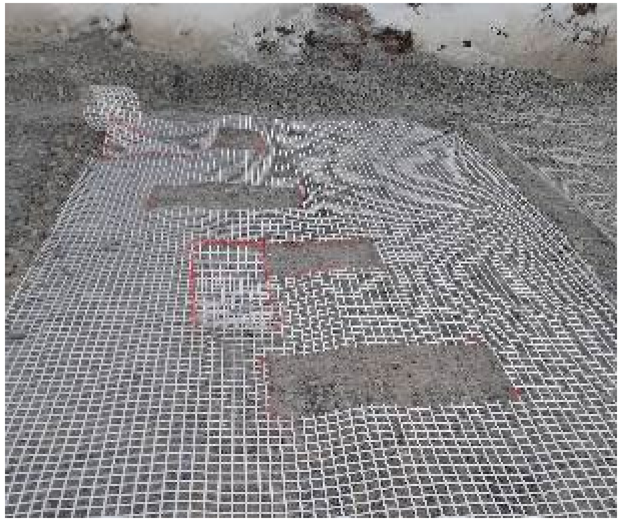





Preparation of the tests specimen “Reinforcement / stabilisation” & “Drainage” for the transport







Synthesis of the ROUGH laboratory tests

Function reinforcement / stabilisation & drainage

Stress-strain characteristics at -20°C, -10°C, 0°C and +20°C.

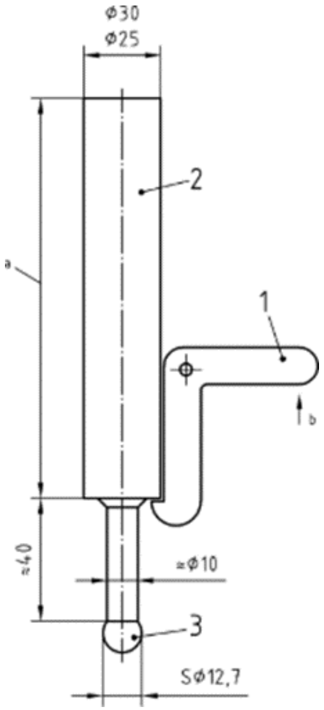
- *specimens cooled down at least one hour before testing;*
- *after closing door of cooling chamber, tensile testing started when the temperature reached the required temperature*

For the reinforcement/stabilisation products, tests carried out on single strands according EN ISO 10319.

For the drainage products, tests carried out on 100 x 100 mm specimens according EN ISO 25619-2.

The tests were carried out at the SKZ (Germany).

Synthesis of the ROUGH laboratory tests



Function reinforcement / stabilisation

Dynamic impact testing at different temperatures

Effect of brittleness of geosynthetics' on vulnerability to damages due to dynamic impacts

- falling weight (1000 ± 5g)
- with a round fall head
- height of 50 cm
- inside a 35 x 35 mm square pipe.
- impact energy in accordance to EN ISO 13433 - (cone drop test): E = 4.91 J
- bedding of product = 300 mm x 300 mm x 3 mm plate (acc. EN 12691): *Flexible sheets for waterproofing — Bitumen, plastic and rubber sheets for roof waterproofing — Determination of resistance to impact.*

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Reinforcement Stabilisation

	characteristic(s)	sample tested	Temperature			
			- 20 °C	- 10 °C	0 °C	20 °C
Kemi	tensile test (20 cm)	damage (in situ) (test)		X		(X)
		reference				X
Laboratory	tensile test (rib & junction)	damage (dynamic impact)	X	X	X	X
		virgin	X	X	X	X

Test of damage product realised at +20°C

Filtration

	characteristic(s)	sample tested		Temperature			
				- 20 °C	- 10 °C	0 °C	20 °C
Kemi	tensile test (20 cm) opening size O_{90}	damage (in situ) (test)	Drop height **1,0 m**		X		(X)
			Drop height **2,0 m**		X		(X)
		reference					X

Use of DoP data:

- Energy Index
- Water permeability V_{H50}

Drainage

	characteristic(s)	sample tested	Temperature			
			- 20 °C	- 10 °C	0 °C	20 °C
Kemi	tensile test (20 cm) compression strength/strain waterflow capacity	damage (in situ) (test)		X		(X)
		reference				X
Laboratory	compression strength/strain & compression strain (1 MPa)	virgin	X	X	X	X

Specific requirements on the products

Filtration

Norwegian guidelines for construction works (N200 Vegbygging, 2021) give a good basis for requirements for the use of geotextiles in filtration in Nordic areas.

They include requirements for geotextile to ensure functionality of product during intended service lifetime.

Firstly, the geotextiles shall be conformed to the **General Requirements**

Additionally specific requirements need to be added:
based on (N200 Vegbygging, 2021) they include

- ✓ a robustness factor (EI) basically intended to ensure the geotextile is not damaged during the installation

- ✓ and construction; to an extent this may prevent the filter functionality during the service lifetime.

ROUGH (RecOmmendations for the Use of GeosyntHetics in Nordic conditions)

EI 2	EI 3	EI 4	EI 5
EI ≥ 2,1 kN/m	EI ≥ 3,2 kN/m	EI ≥ 4,5 kN/m	EI ≥ 6,5 kN/m

Maximum grain size against filter geosynthetic	D_{max} ≤ 100mm		D_{max} > 100mm	
Material in drain ditch	Natural gravel (rounded)	Crushed rock (sharp edged)	Natural gravel (rounded)	Crushed rock (sharp edged)
In-situ soil mechanical class				
Very soft (soft clay and silt) $c_u < 25$ kPa	EI 3	EI 4	EI 4	EI 5
Medium (medium firm clay and silt) 25 kPa ≤ $c_u < 50$ kPa	EI 2	EI 3	EI 4	EI 5
Firm (very firm clay, sand and gravel) $c_u > 50$ kPa	EI 2	EI 3	EI 3	EI 4

ROUGH (RecOmmendations for the Use of GeosyntHetics in Nordic conditions)

Based on Kemi experiment:

If geosynthetics **correctly designed and prove that they perform correctly** for positive temperature (e.g., + 20 °C) for defined geotechnical conditions of installation
(type of soils, drop height, compaction, etc.),

- no additional installation damage is observed on **Tensile strength / Robustness Factor** if products are installed under same conditions at **-10°C**

  Note: For a low drop height, Robustness Factor (EI) may be relevant parameter to assist in designing against installation damage; nevertheless, for a greater drop height, no specific increase of damage with an increase in drop height is observed.

- no influence on **Opening size** is observed when products tested are exposed to installation at **-10°C** in a trench with crushed rock under a drop height of 1.0 m & 2.0 m.

<u>Requirements advice</u>

For applications using geosynthetics for filtration in ditches, installed under following Nordic conditions:

Temperature:	**- 10°C**
Backfill:	crushed rock 0/56, layer ~ 30 cm
Drop height:	~ 1.0 m to 2.0 m maximum
Compaction:	acc. to Finnish road construction guidelines (InfraRYL Table T1) or similar.

Vulnerability Ratio to be considered:

VI (T / EI) (20°C / - 10°C) = 1 (*)

VI (Opening size) (20°C / - 10°C) = 1 (*)

(*) valid only for the products tested in the ROUGH project (or similar products). For other products, realisation of specific experimental full-scale test, is strongly recommended.

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Specific requirements on the products

Drainage

Based on Kemi experiment:

2 geosynthetics tested during ROUGH project, when the products are installed under crushed rock and compacted under normal conditions at - **10°C**, reduction in both **tensile strength and strain** remain in a reasonable range (≤ ~ - 40 %)

If product is **correctly designed** for positive temperature (e.g., + 20 °C) for the defined geotechnical conditions of installation (type of soils, drop height, compaction, etc.),

- no extra installation damage due to negative temperature **(- 10°C)** was observed on the tensile strength and strain.

Compression strain at 1 MPa enables comparison of behaviour at different temperatures under same geotechnical conditions.

- laboratory tests show almost no influence of strain at 1 MPa at different temperatures (≤ 4% at – 10°C)

On samples in Kemi (- 10°C, crushed rock, compaction), compression strain increase seems related to similar reduction in water flow capacity.

➔ can be expected that decrease of water flow capacity linked to low temperature (e.g. – 10°C) should be reduced by only (~ - 4 % to – 5%).

➔ effect of negative temperature (- 10°C) on further hydraulic capacity of geosynthetic drainage composites appears to be negligeable.

ROUGH (RecOmmendations for the Use of GeosyntHetics in Nordic conditions)

Specific requirements on the products

Drainage

<u>Requirements advice</u>

As only 2 drainage geosynthetics have been tested during the ROUGH project, it is difficult to draw some general requirements advice.

For the 2 drainage composites installed under following Nordic conditions:

Temperature:	**- 10°C**
Backfill:	crushed rock 0/56, layer ~ 30 cm
Drop height:	~ 1.0 m to 2.0 m maximum
Compaction:	acc. Finnish road construction guidelines (InfraRYL Table T1) or similar.

Vulnerability Ratio to be considered:

VI (tensile strength/strain) (20°C / - 10°C) = 1 (*)
VI (hydraulic capacity) (20°C / - 10°C) = 1 (*)

(*) valid only for the products tested in the ROUGH project (or similar products). For other products, realisation of specific experimental full-scale test, is strongly recommended

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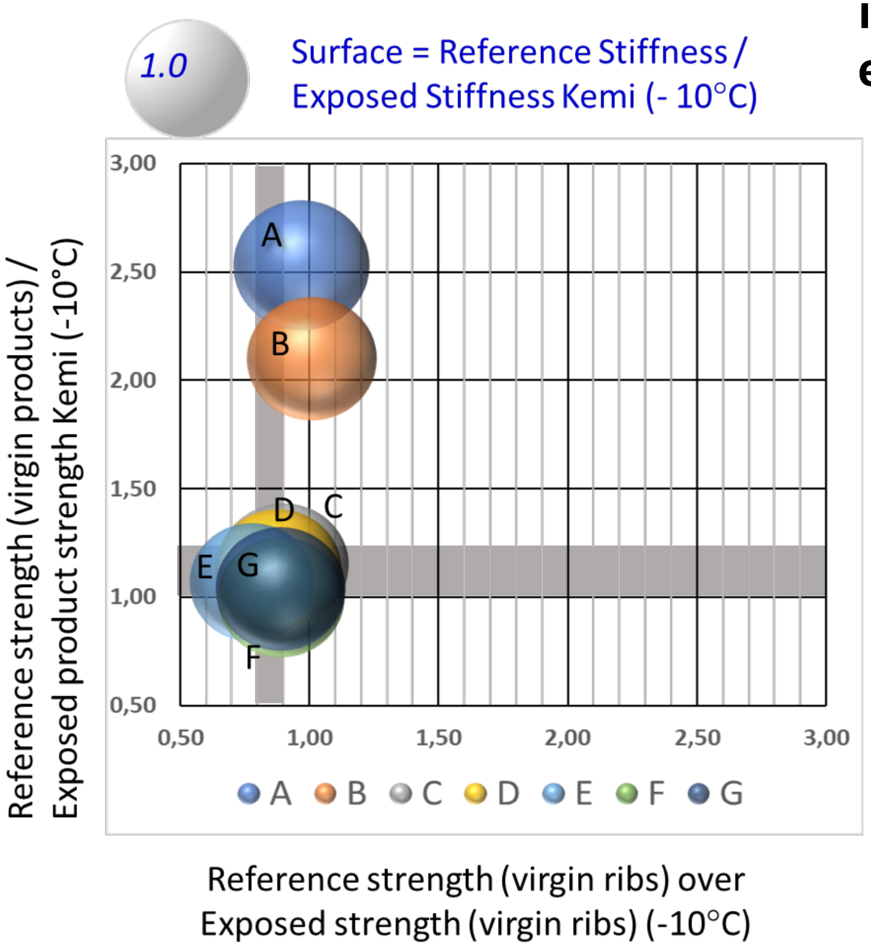
ROUGH (RecOmmendations for the Use of GeosyntHetics in Nordic conditions)

Some results of the Kemi experiment

Reinforcement / Stabilisation



Comparison evolution of strength products exposed to Kemi installation (-10°C) with evolution of strength virgin products exposed to (-10°C)

2 products (A & B) ➔clear reduction in strength (- 50 % to – 60 %) for the Kemi samples
analysis installation damage tests similar conditions (+ 20°C) show observed reduction of strength in Kemi is similar to the one at + 20°C.

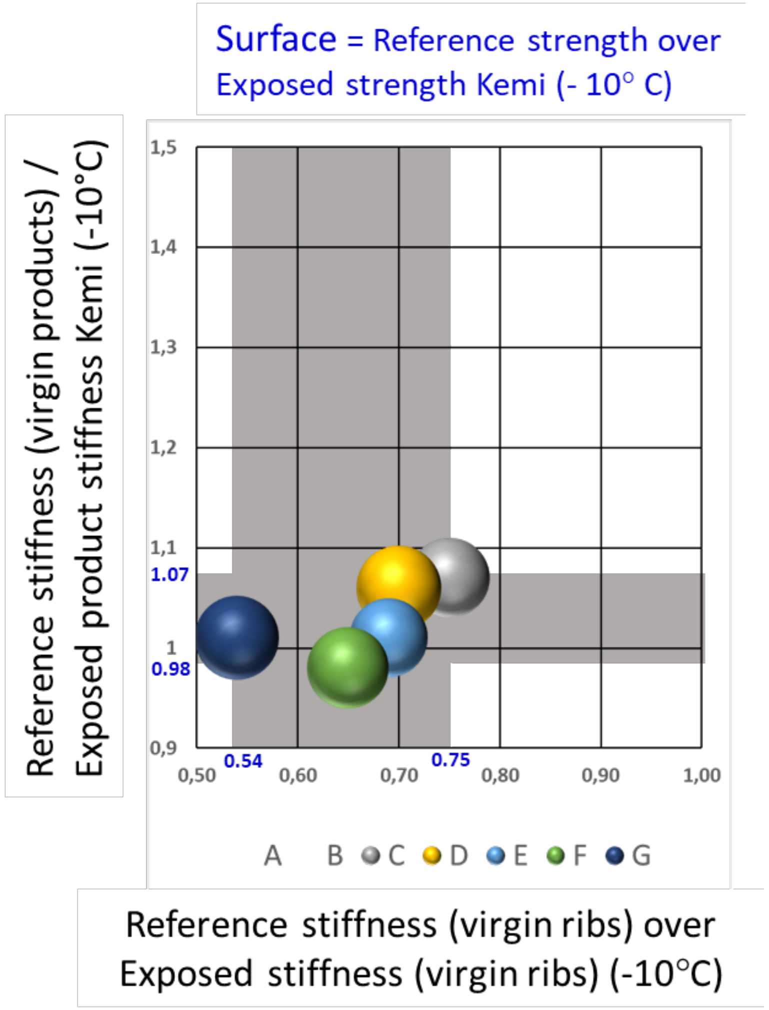
5 other products grouped (C, D, E, F, G) show:

- a small reduction of strength on the "Kemi" samples (≤ 13%)
- where a small increase in strength is observed on the virgin rib in lab (≤ 13%)

ROUGH (RecOmmendations for the Use of GeosyntHetics in Nordic conditions)

Some results of the Kemi experiment

Reinforcement / Stabilisation



Comparison evolution of stiffness (at 3% strain) of products exposed to Kemi installation (-10°C) with evolution of stiffness (at 3% strain) of virgin products exposed to (-10°C)

5 other products grouped (C, D, E, F, G) show:

- a very small of stiffness on the "Kemi" samples (≤ 7%)
- where a large increase in stiffness is observed on the virgin rib in lab (33% to 85%)

Note: the strength stiffness is significantly increased by a reduction in temperature (0°C to - 20°C) when tested in the laboratory: e.g., with a reduction in temperature from + 20°C to - 10°C, the average of all products tested ≥ + 40 %; it shall be noted that this is also the case for the surrounding soil.

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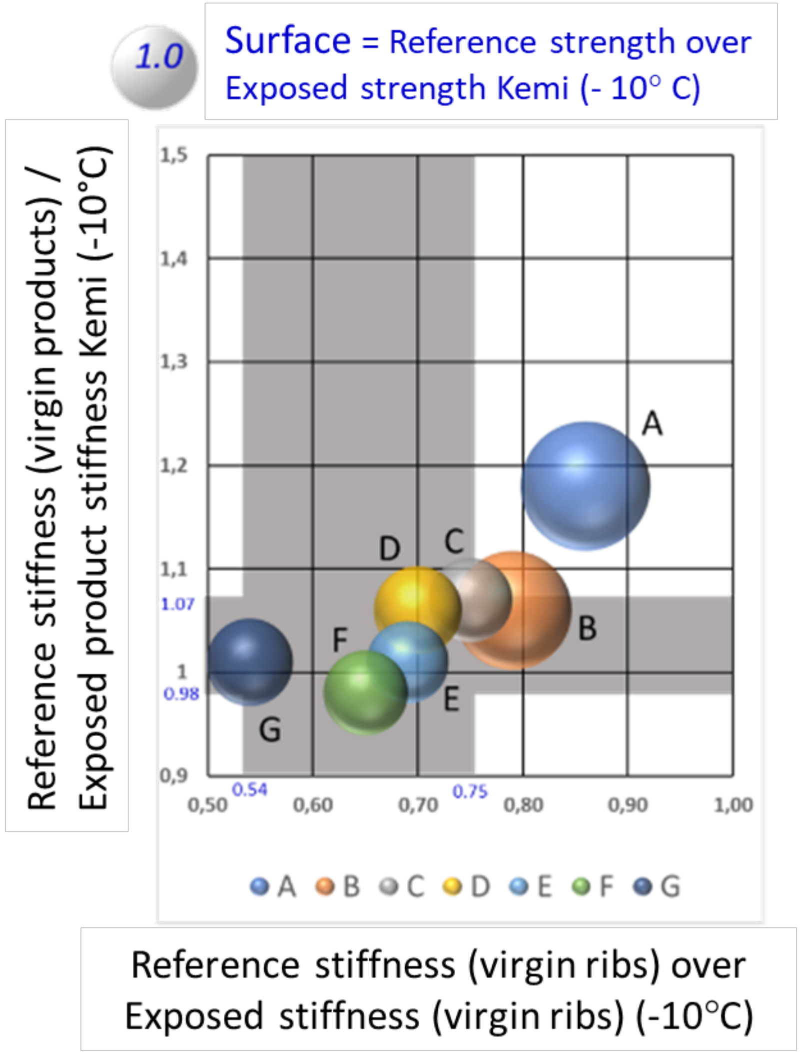
ROUGH (RecOmmendations for the Use of GeosyntHetics in Nordic conditions)

Some results of the Kemi experiment

Reinforcement / Stabilisation



Comparison evolution of stiffness (at 3% strain) of products exposed to Kemi installation (-10°C) with evolution of stiffness (at 3% strain) of virgin products exposed to (-10°C)

5 other products grouped (C, D, E, F, G) show:

- a very small of stiffness on the "Kemi" samples (≤ 7%)
- where a large increase in stiffness is observed on the virgin rib in lab (33% to 85%)

Note: the strength stiffness is significantly increased by a reduction in temperature (0°C to - 20°C) when tested in the laboratory: e.g., with a reduction in temperature from + 20°C to - 10°C, the average of all products tested ≥ + 40 %; it shall be noted that this is also the case for the surrounding soil.

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ROUGH (RecOmmendations for the Use of GeosyntHetics in Nordic conditions)

Specific requirements on the products

Reinforcement / Stabilisation

Based on Kemi experiment:

If geosynthetics are **correctly designed** for positive temperature (e.g., + 20 °C) for defined geotechnical conditions of installation

- no additional installation damage observed on **strength** when products are installed under same conditions at **- 10°C**

- no additional installation damage observed on **stiffness** if products are installed at **- 10°C**

- nevertheless, stiffness of geosynthetic is significantly increased at - 10°C compared to + 20°C,
  also the case for surrounding soil at – 10°C.

Note: the strength stiffness is significantly increased by a reduction in temperature (0°C to - 20°C) when tested in the laboratory: e.g., with a reduction in temperature from + 20°C to - 10°C, the average of all products tested ≥ + 40 %; it shall be noted that this is also the case for the surrounding soil.

ROUGH (RecOmmendations for the Use of GeosyntHetics in Nordic conditions)

Specific requirements on the products

Reinforcement / Stabilisation

<u>Requirements advice</u>

For applications using geosynthetics for reinforcement stabilisation, installed under following Nordic conditions:

Temperature:	**- 10°C**
Backfill:	crushed rock 0/56, layer ~ 30 cm
Drop height:	~ 1.0 m maximum
Compaction:	acc. to Finnish road construction guidelines (InfraRYL Table T1) or similar.

The Vulnerability Ratio to be considered is:

VI (tensile strength) (20°C / - 10°C) = 1 (*)
VI (tensile stiffness) (20°C / - 10°C) = 1 (*)

(*) valid only for the products tested in the ROUGH project (or similar products). For other products, realisation of specific experimental full-scale test, is strongly recommended.

Note: the "Vulnerability Ratio" (VR) on Tensile strength is same as RF_{ID} (ISO/TR 20432)

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Overall results

- No additional installation damage is observed on the essential characteristics when the products are installed under the same conditions at -10°C as if on conventional installation (+20 °C)
  - Tensile strength and tensile stiffness for reinforcement/stabilisation
  - Robustness factor and characteristic opening size for filtration
  - Water flow capacity for geosynthetic drainage composites
- Damage on geogrid junctions as previously experienced when installed at low temperatures was not revealed at the field test
  - This type of damage is likely to be heavily influenced by the polymer type and additives and the production procedure.
- If gsy are properly designed for "conventional conditions" they can also be installed in a challenging conditions with tempertures down to -10°C

ROUGH (RecOmmendations for the Use of GeosyntHetics in Nordic conditions)

Dissemination


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2022:00635- Restricted

Report – part 1

Tests on damage during installation at low temperatures

Kemi (Finland) 05.-06.02.2020

Function: reinforcement / stabilisation, filtration, drainage

Author(s)
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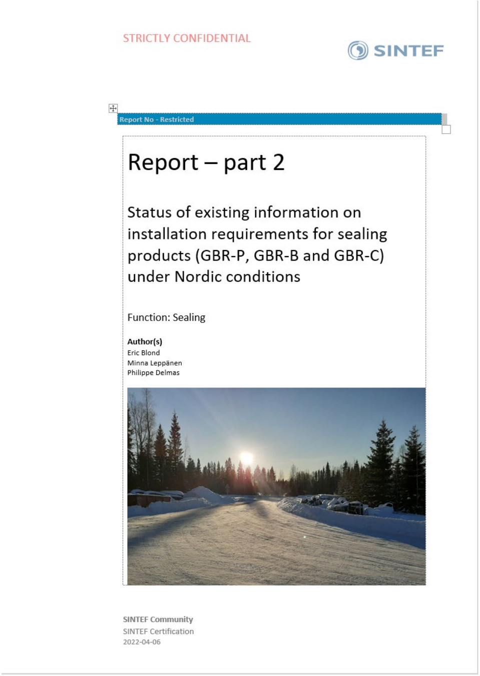
Arnstein Watn
Christian Recker

SINTEF Community
SINTEF Certification
2023-08-07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Report No - Restricted

Report – part 2

Status of existing information on installation requirements for sealing products (GBR-P, GBR-B and GBR-C) under Nordic conditions

Function: Sealing

Author(s)
Eric Blond
Minna Leppänen
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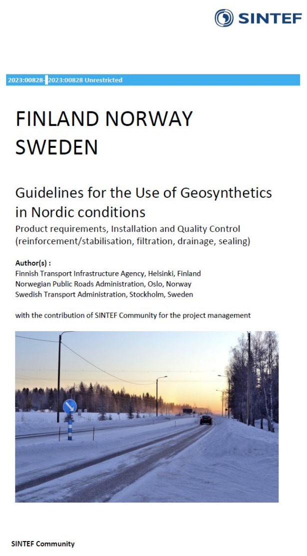
SINTEF Community
SINTEF Certification
2022-04-06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2023:00828 2023:00828 Unrestricted

FINLAND NORWAY SWEDEN

Guidelines for the Use of Geosynthetics in Nordic conditions

Product requirements, Installation and Quality Control (reinforcement/stabilisation, filtration, drainage, sealing)

Author(s) :
Finnish Transport Infrastructure Agency, Helsinki, Finland
Norwegian Public Roads Administration, Oslo, Norway
Swedish Transport Administration, Stockholm, Sweden

with the contribution of SINTEF Community for the project management

SINTEF Community

- Results will be basis for implementation in national specification and recommendations

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