INNOVATIVE AND SUSTAINABLE SOLUTIONS TO PREVENT FROST HEAVE AND ROAD PAVEMENT DAMAGES

March 23, 2023

MACCAFERRI

WEBINAR AGENDA

5’ *Introduction*

10’ *How MacDrain™ Arctic Blanket works against frost heave*

10’ *Benefits and sustainability*

Live Q&A Session

Speaker: Settimo De Cario

Civil Engineer and Maccaferri Corporate Manager

Cold temperatures and snow can cause significant impacts on road conditions, affecting also people who are using the infrastructure


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Rainwater and snow infiltrate the soil through the cracks in the road, while groundwater is drawn up into the soil above by capillary action


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When the moisture gets frozen under the road pavement, it expands causing failure in pavements


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Cracks and potholes can cause damages to cars and endanger people’s life. Therefore, every time this happens, prompt maintenance is necessary


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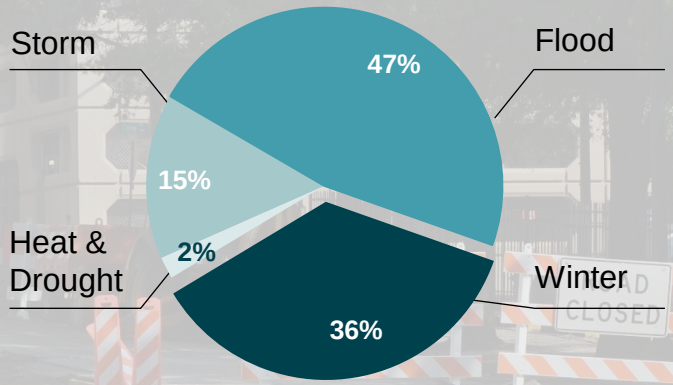
Winter extreme events have a big impact on total annual cost in road maintenance.
ROAD CLOSED
ROAD CLOSED
DETOUR
ROAD CLOSED
DO NOT ENTER

Share of extreme weather events on total road maintainance costs



Source: Vulnerability of transport systems. Main report 7th framework program of the European Commission

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Winter extreme events have a big impact on total annual cost in road maintenance.

Share of extreme weather events on total road maintainance costs

Source: Vulnerability of transport systems. Main report 7th framework program of the European Commission

In Europe, one-third of the year budget on winter maintenance is allocated to the rehabilitation of roads due to the negative impact of frost.

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Winter extreme events have a big impact on total annual cost in road maintenance.

Infrastructure owners are asking for more safety for users with less maintenance costs


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THE FROST HEAVE EFFECT


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FROST HEAVE EFFECT

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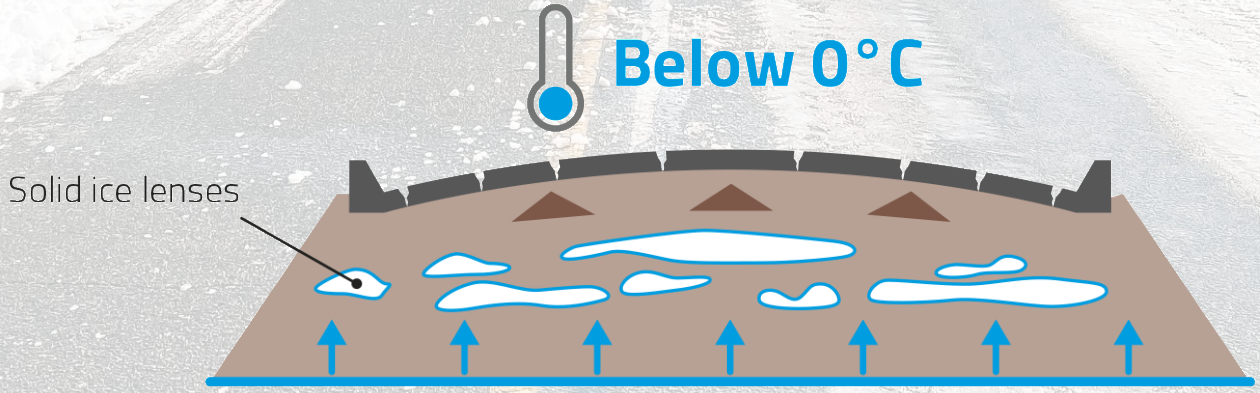
1 FROST HEAVE DEFORMATION AND CRACKING OF SURFACE ROAD LAYERS

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FROST HEAVE EFFECT

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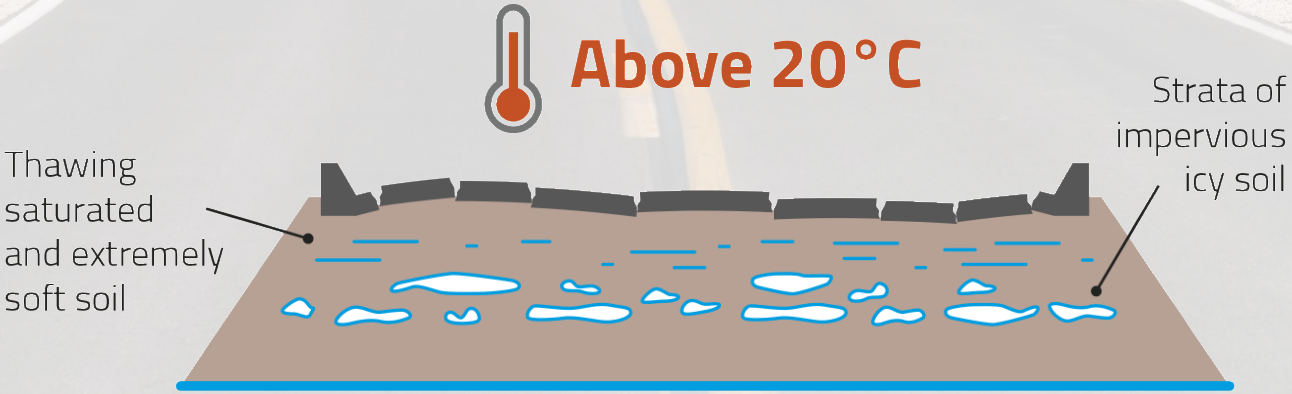
2 SURFACE ROAD DESTRUCTION DUE TO TRAFFIC AND THAWING



OUR RESPONSE TO THESE PHENOMENA?

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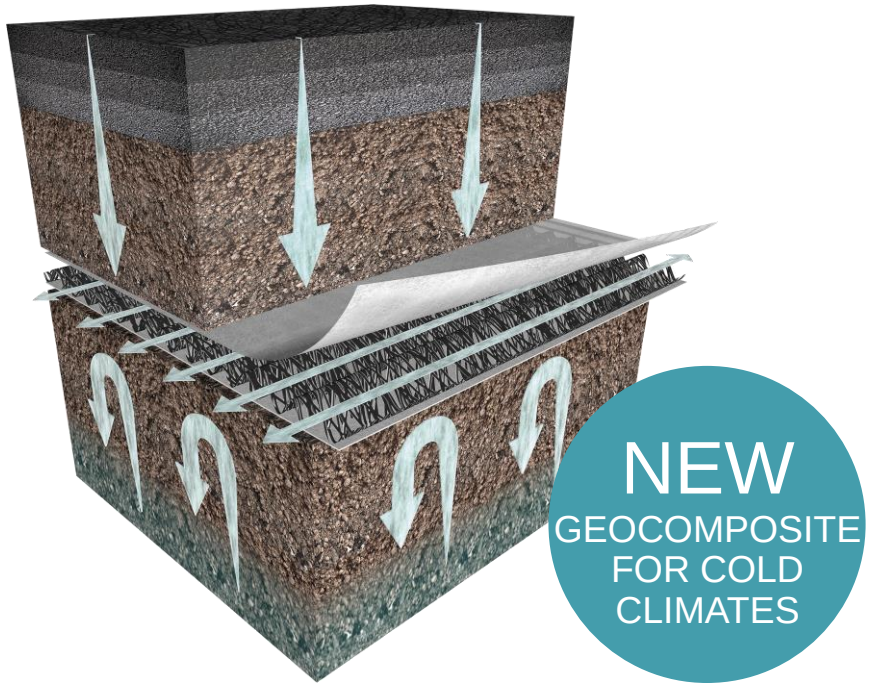
MacDrain™
ARCTIC BLANKET



NEW
GEOCOMPOSITE FOR COLD CLIMATES

OUR RESPONSE TO THESE PHENOMENA?

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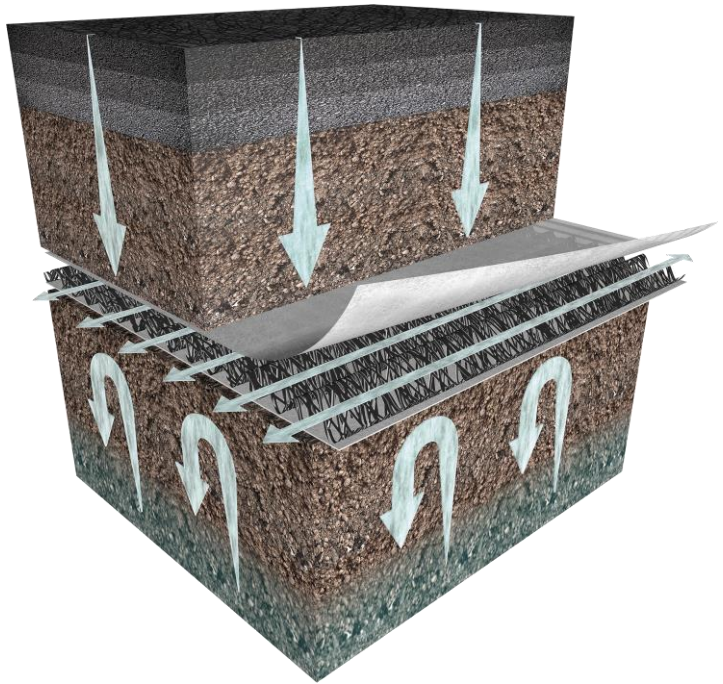
MacDrain™ ARCTIC BLANKET



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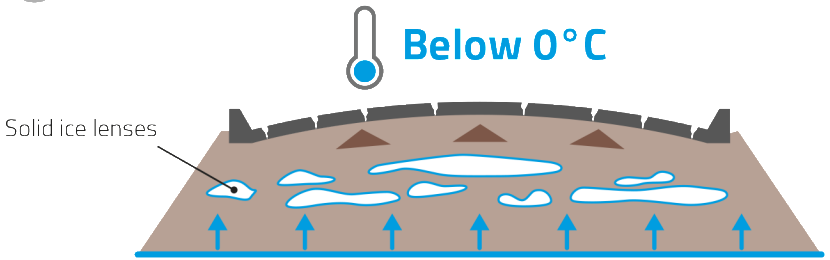

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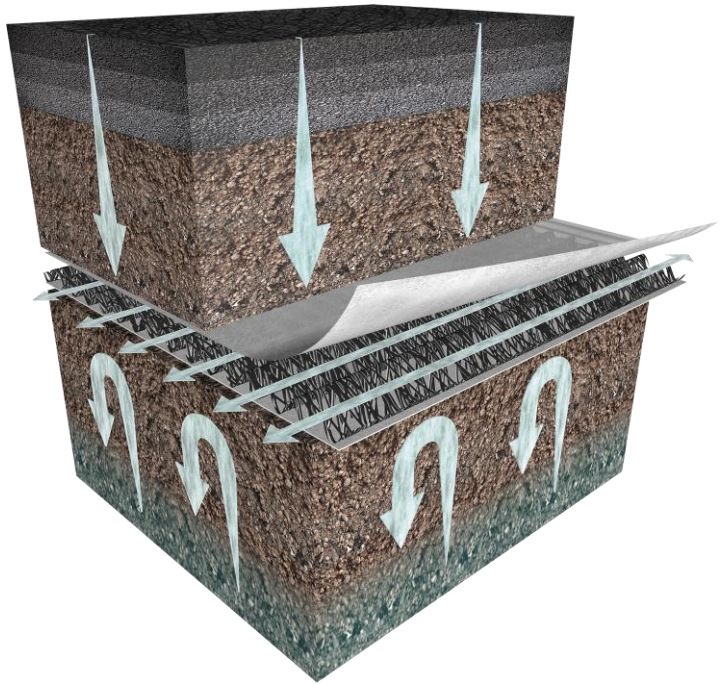

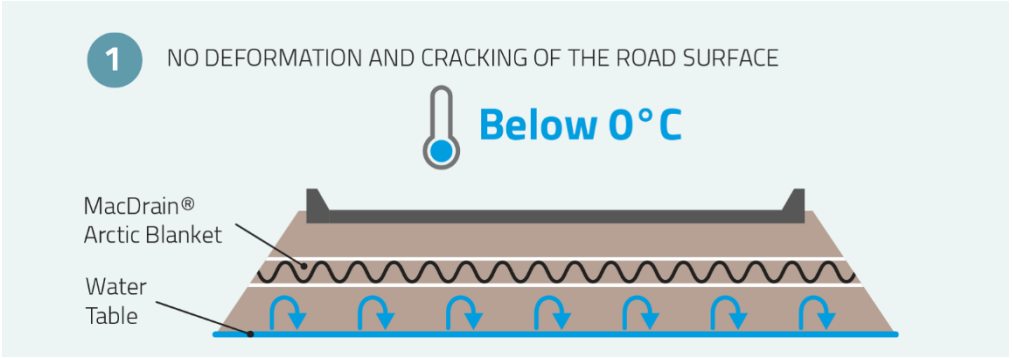

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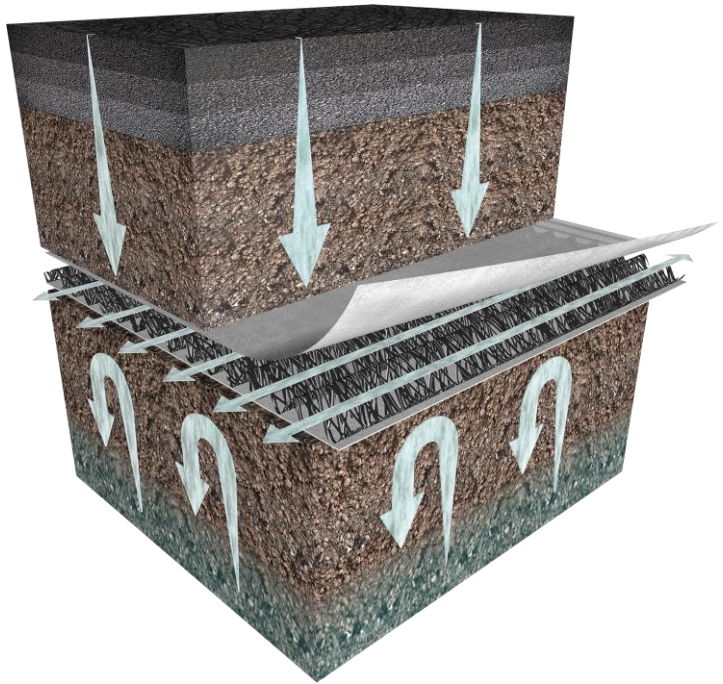
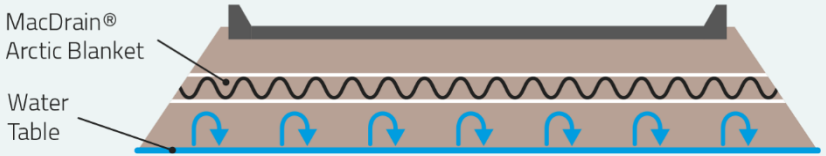


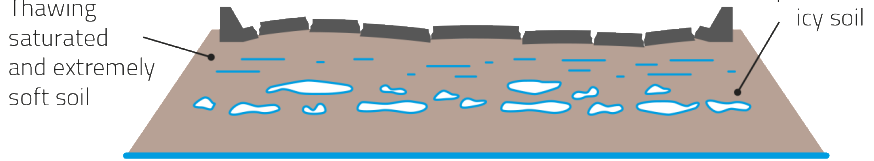
1 NO DEFORMATION AND CRACKING OF THE ROAD SURFACE

Below 0°C



2 SURFACE ROAD DESTRUCTION DUE TO TRAFFIC AND THAWING

Above 20°C



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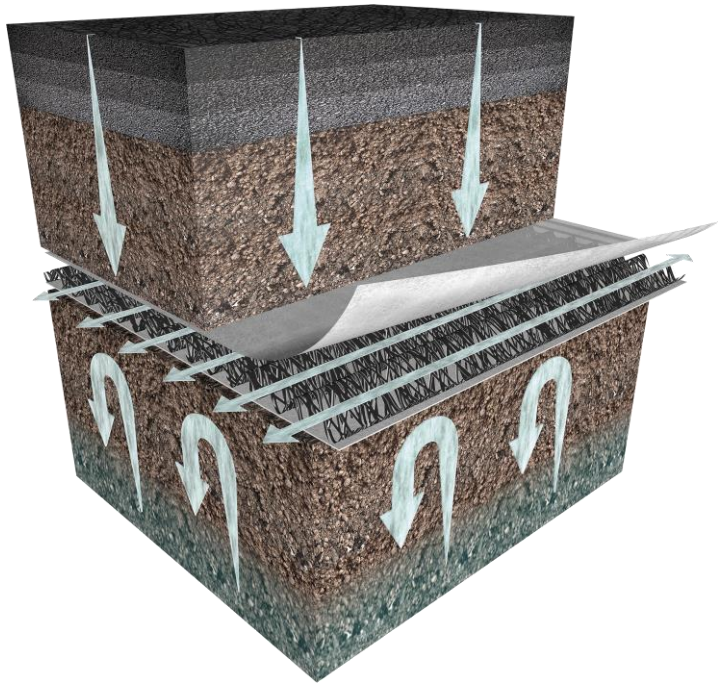

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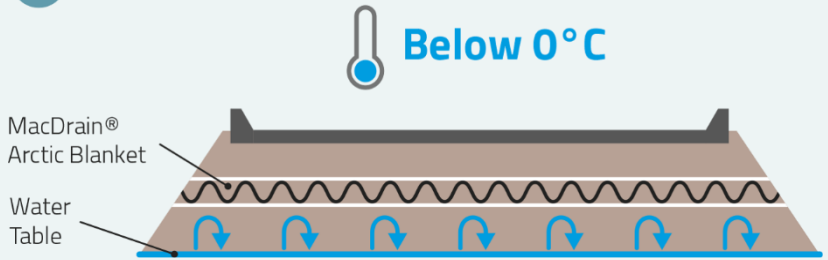
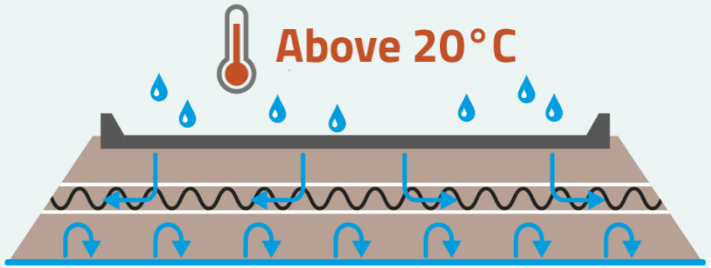
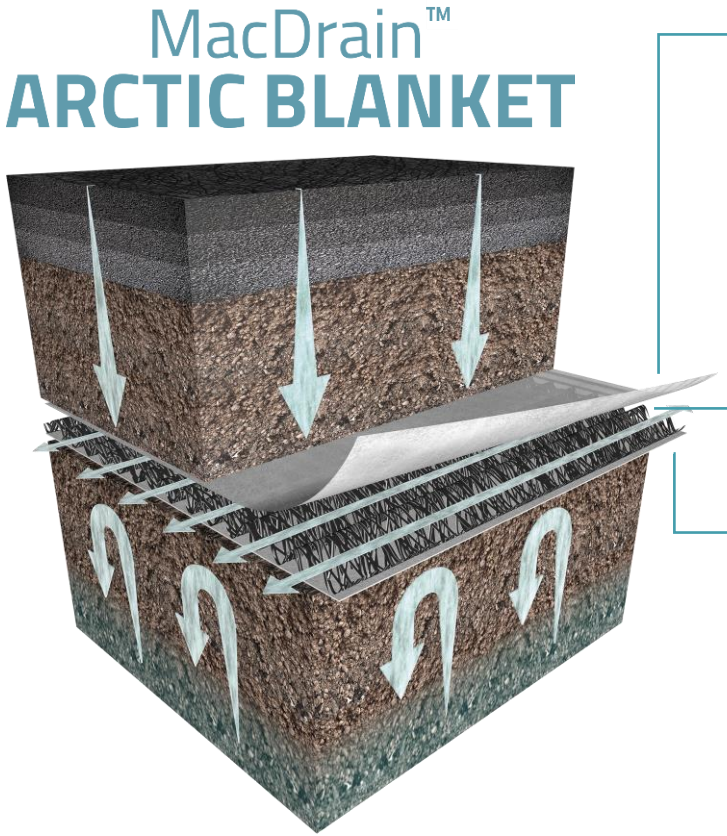


2 NO ACCUMULATION OF WATER IN THE ROAD SUB-BASE LAYER



HOW MACDRAIN™ ARCTIC BLANKET WORKS



Nonwoven geotextile

Selected to meet the highest standard of resistance during the loading and compaction phase in the overhead structure. The top layer acts as a filter allowing water from the overlying soil to enter the drainage core below, enhancing drainage along the plane of the geosynethetic and providing enchanced soil stabilization performance.

GeoMat with W-shape

Developed to provide drainage characteristics with high resistance to compressive loads and high flow rate thus minimizing compressive creep.

Nonwoven geotextile with hydrophobic polymer enhancement

Designed to prevent the upward capillary rise of groundwater whilst remaining permeable to downward flow.

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MACDRAIN™ ARCTIC BLANKET: TEST CAMPAIGN

TEST CAMPAIGN MACDRAIN™ ARCTIC BLANKET

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Outstanding performance

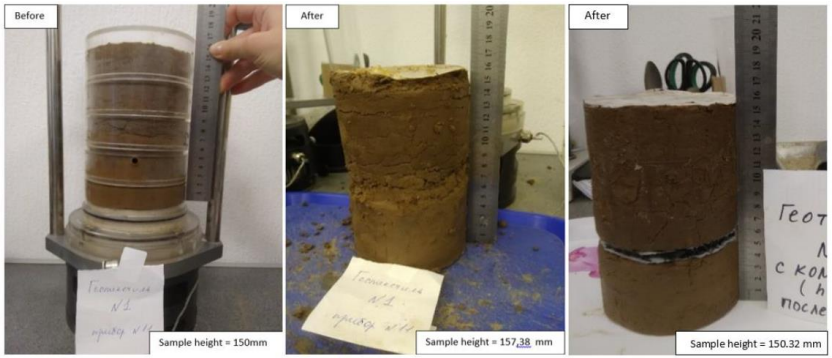
Engineered to resist to compressive loads and high traffic flow preventing periodical maintenance

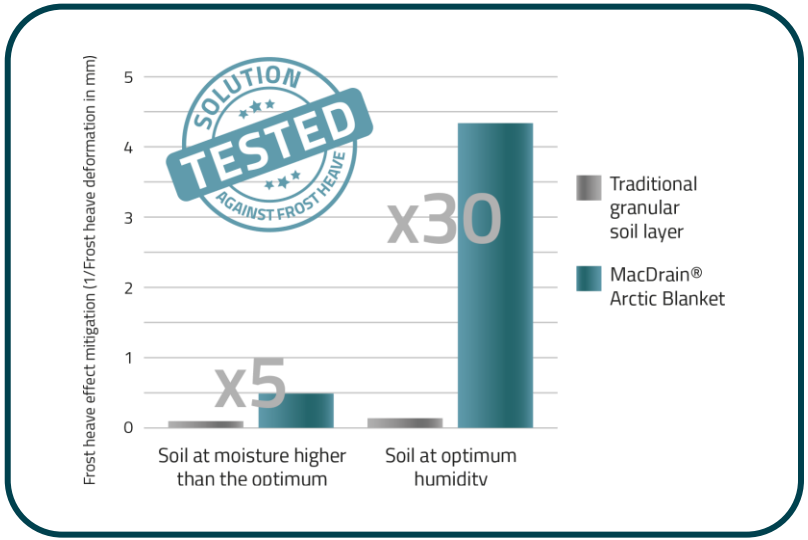
FROST HEAVE TEST

Laboratory test according to the GOST 28622-2012

- Tests have been performed both with an optimum and a higher humidity for compaction.
- Measurement are made at intervals over a period of 96 hours.
- The samples used are 150 mm high with the geocomposite located at 100 mm.

Results have shown that placing **MacDrain™ Arctic Blanket** in the soil mixture reduces drastically the frost heave phenomenon.





MacDrain™ Arctic Blanket, placed in soil mixture, showed a reduction of the soil deformation up to over **30 times** in road base layer.

TEST CAMPAIGN MACDRAIN™ ARCTIC BLANKET

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FROST HEAVE TEST

Laboratory test in CELTEST laboratory (UK) according to the BS812: Part 124:2009

- The tests have been performed with a non frost susceptible soil at Maximum Dry Density (1.8 Mg/m^3) and Optimal Water Content (16.6%).
- Measurement are made at intervals over a period of 96 hours.

Results have shown that placing **MacDrain™ Arctic Blanket** in the soil mixture reduce the mean frost heave **from 9.8 mm to 2.2 mm**

Test Specimen - Maximum Heave Observed in 96 hours (mm)			
Test Specimen 1		10.5	*(nearest 0.5mm)*
Test Specimen 2		10.0	*(nearest 0.5mm)*
Test Specimen 3		9.0	*(nearest 0.5mm)*
Range of Test Specimens Maximum Heave		1.5	*(should not exceed 6mm)*
Mean Frost Heave		**9.8**	*(nearest 0.1mm)*

Test Specimen - Maximum Heave Observed in 96 hours (mm)			
Test Specimen 1		1.5	*(nearest 0.5mm)*
Test Specimen 2		2.5	*(nearest 0.5mm)*
Test Specimen 3		2.5	*(nearest 0.5mm)*
Range of Test Specimens Maximum Heave		1.0	*(should not exceed 6mm)*
Mean Frost Heave		**2.2**	*(nearest 0.1mm)*

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Technology for a better society
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TEST on damage during installation at low temperatures

SINTEF ROUGH project - Site test in Kemi (Finland)

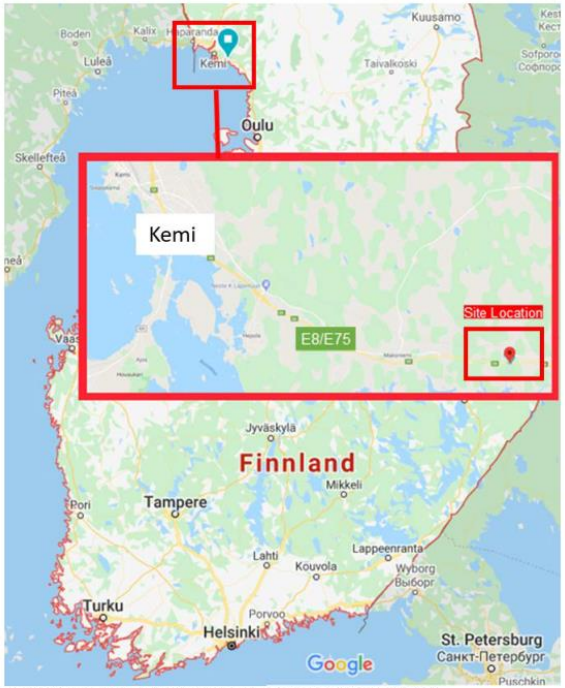

Figure 1: Location of the field tests (Screenshot Google Maps)

TEST CAMPAIGN MACDRAIN™ ARCTIC BLANKET

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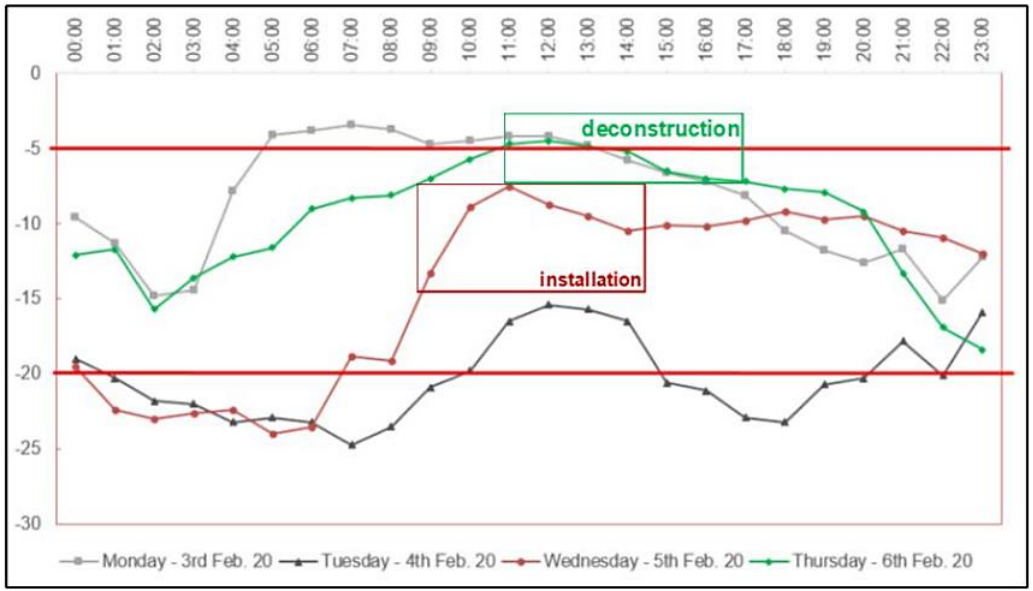
SINTEF ROUGH project - Site test in Kemi (Finland)

- Tests was performed at -12°C as subgrade temperature;



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TEST CAMPAIGN MACDRAIN™ ARCTIC BLANKET

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TEST on damage during installation at low temperatures

SINTEF ROUGH project - Site test in Kemi (Finland)

- Tests was performed at -12°C as subgrade temperature;
- The **MacDrain™ Arctic Blanket** was placed directly on frozen soil;

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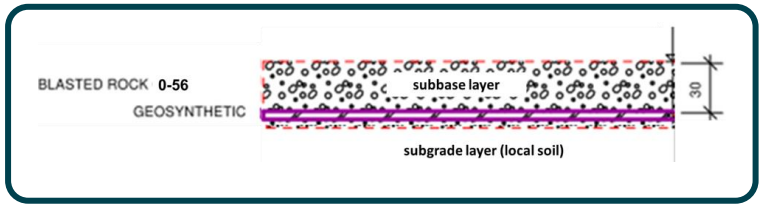
- Subbase layer of 30 cm crushed rock was placed;



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- The **MacDrain™ Arctic Blanket** was placed directly on frozen soil;
- Subbase layer of 30 cm crushed rock was placed;
- Five passes with 12.6 t dynamic roller were performed;

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- Tests was performed at -12°C as subgrade temperature;
- The **MacDrain™ Arctic Blanket** was placed directly on frozen soil;
- Subbase layer of 30 cm crushed rock was placed;
- Five passes with 12.6 t dynamic roller were performed;
- The sub-base layer was removed and the damaged sample was recovered.

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TEST CAMPAIGN MACDRAIN™ ARCTIC BLANKET

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TEST on damage during installation at low temperatures

SINTEF ROUGH project - Site test in Kemi (Finland)

- Samples damaged during the installation was checked in accordance with EN ISO 10319, EN ISO 25619-2 and EN ISO 12958.
- On undamaged samples EN ISO 25619-2 tests were carried out at 4 different temperatures (20°C, 0°C, -10°C and -20°C).

	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)	undisturbed	X	X	X	X

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TEST on damage during installation at low temperatures

SINTEF ROUGH project - Site test in Kemi (Finland)

- Evolution of **tensile strength** and strain when the products are exposed to installation under crushed rock at a temperature of – 10 °C

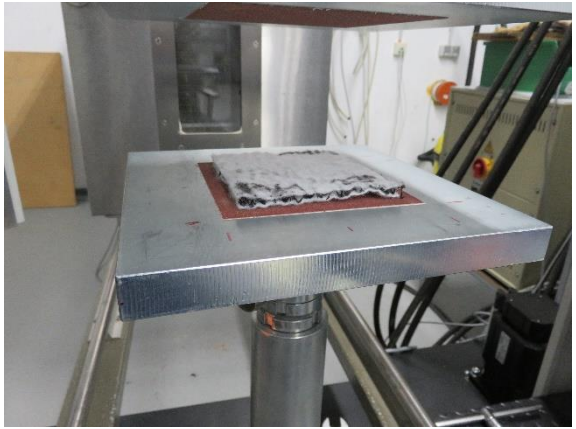
  The product shows a fairly similar behaviour when exposed to the Kemi installation conditions:

  - a reasonable reduction in tensile strength (between ~ 25% to ~ 30 %)
  - a slightly higher (but still reasonable) reduction in tensile strain (between ~ 30% to ~ 40%)

- Evolution of the **compressive strength and strain** when the products are exposed to installation under crushed rock at a temperature of – 10 °C

  - The product is more rigid at low temperatures! (residual strain compression 124%)
  - No reduction in compressive strength

- Transmissivity results are within the product tolerance



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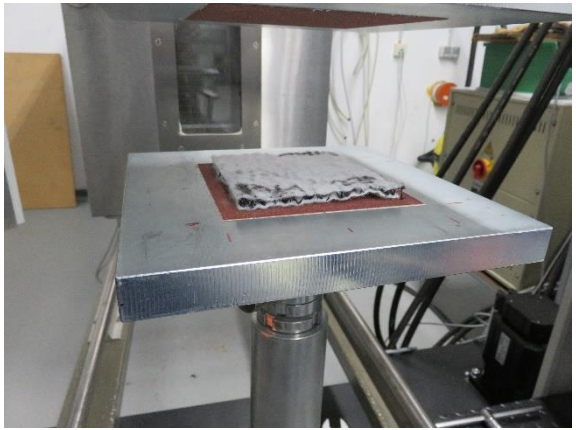
		MACDRAIN ARCTIC BLANKET			
	Unit	20°C	0°C	-10°C	-20°C
Compression strength acc. EN ISO 25619-2					
Residual strength	%	-	170.7	169.2	231.3
Compression strain acc. EN ISO 25619-2					
Residual strain	%	-	103.6	126.2	112.5
Strain at 1.0 MPa acc. EN ISO 25619-2					
Residual strain	%	-	93.1	95.8	89.6



Test results laboratory temperature tests MacDrain Arctic Blanket

MacDrain™ Arctic Blanket is suitable for the installation over frozen soil

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TEST CAMPAIGN MACDRAIN™ ARCTIC BLANKET

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Outstanding performance

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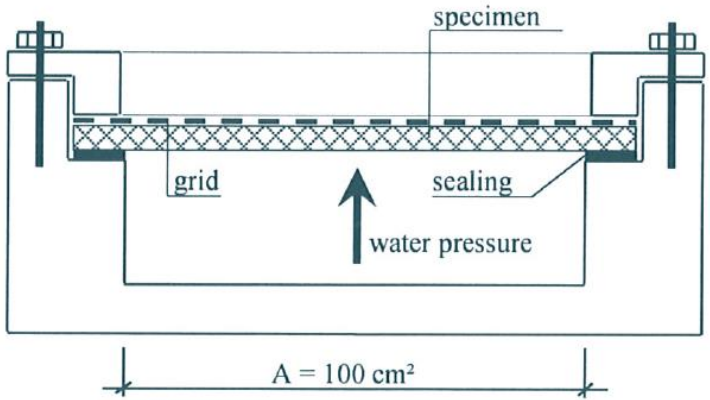
Determination of resistance to penetration by water

Hydrostatic pressure test with Kiwa GmbH – Laboratory test according DIN EN 13562:2000-07



Test parameters	
Temperature	21 °C
Humidity	50%
Diameter of specimen	140 mm
Exposed specimen area	100 cm^2
Water type	de-ionized
Water temperature	21,4 °C
Speed gradient of hydraulic pressure	100 ± 5 mm/min

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Determination of resistance to penetration by water

Hydrostatic pressure test with Kiwa GmbH – Laboratory test according DIN EN 13562:2000-07

Results

Material	Water head (mean)
Standard PP nonwoven 140 g/m^2	1 mm
Standard PP nonwoven 150 g/m^2	3 mm
Hydrophobic GTX nonwoven 140 g/m^2	54 mm
Hydrophobic GTX nonwoven 150 g/m^2	**77 mm**

HydroFabric TI300 PP nonwoven 150 g/m2										
Specimen	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
Water head	97 mm	78 mm	**110 mm**	**40 mm**	55 mm	68 mm	79 mm	76 mm	72 mm	98 mm

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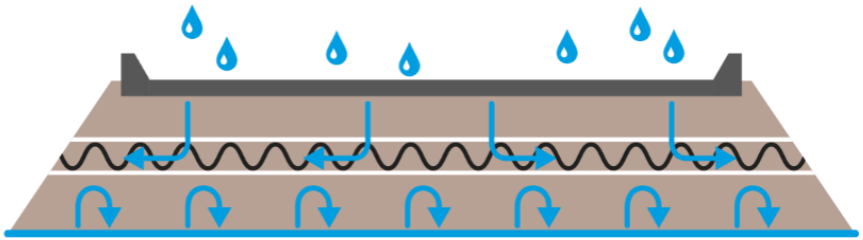
Hydrophobic GTX nonwoven 140 g/m^2	54 mm
Hydrophobic GTX nonwoven 150 g/m^2	**77 mm**

Also, when the water head above the MacDrain™ Arctic Blanket is very high, it **prevents water from seeping into the subsoil**



This hydrophobic nonwoven geotextile **stops the upward movement of water** as the bottom layer of MacDrain™ Arctic Blanket

MACDRAIN™ ARCTIC BLANKET: BENEFITS

MACDRAIN™ ARCTIC BLANKET BENEFITS

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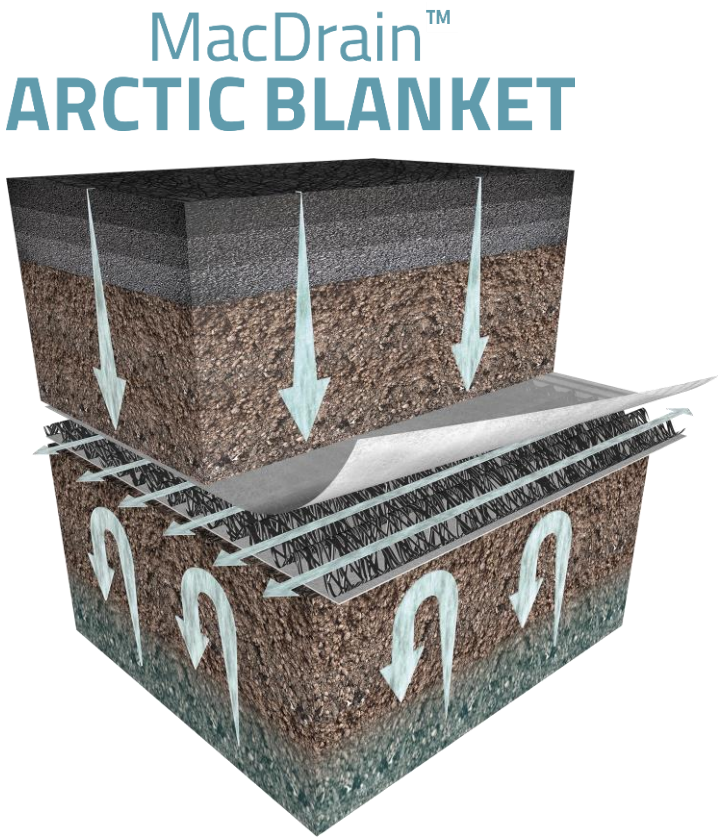

- MATERIAL SAVINGS
- FASTER INSTALLATION
- OUTSTANDING PERFORMANCE
- COST REDUCTION
- ENVIRONMENTAL SUSTAINABILITY

MACDRAIN™ ARCTIC BLANKET BENEFITS

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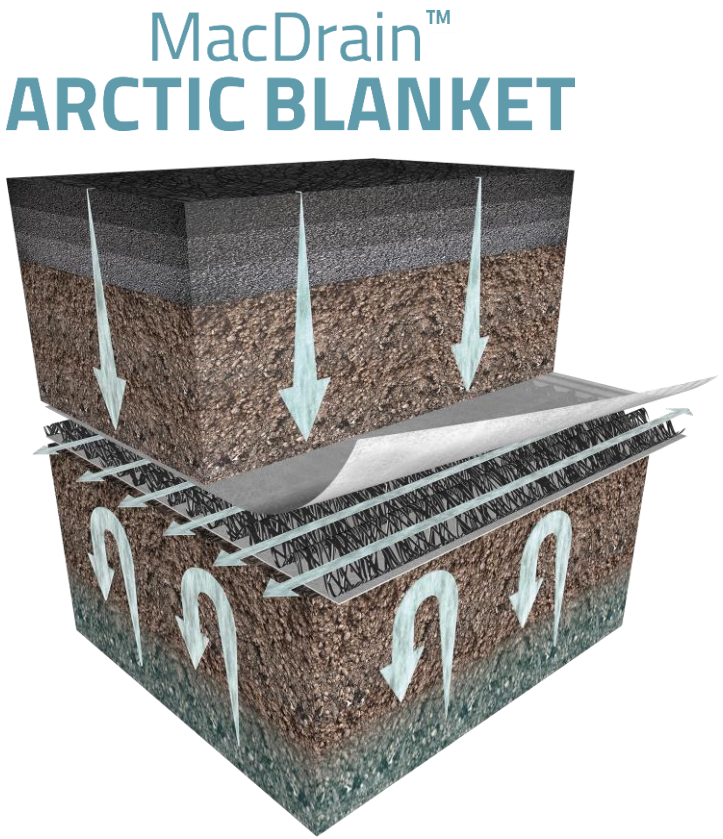

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MACDRAIN™ ARCTIC BLANKET BENEFITS

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Material savings

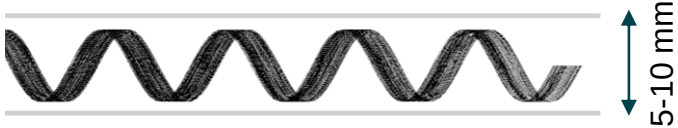
MacDrain™ Arctic Blanket allows a reduction up to **80%** of traditional layer thickness.

without MACDRAIN™ ARCTIC BLANKET

30-50 cm of granular soil is needed to mitigate the effect of Frost Heave

with MACDRAIN™ ARCTIC BLANKET

5-10 mm thick MacDrain™ Arctic Blanket ensure a long-lasting road protection against Frost Heave



MACDRAIN™ ARCTIC BLANKET BENEFITS

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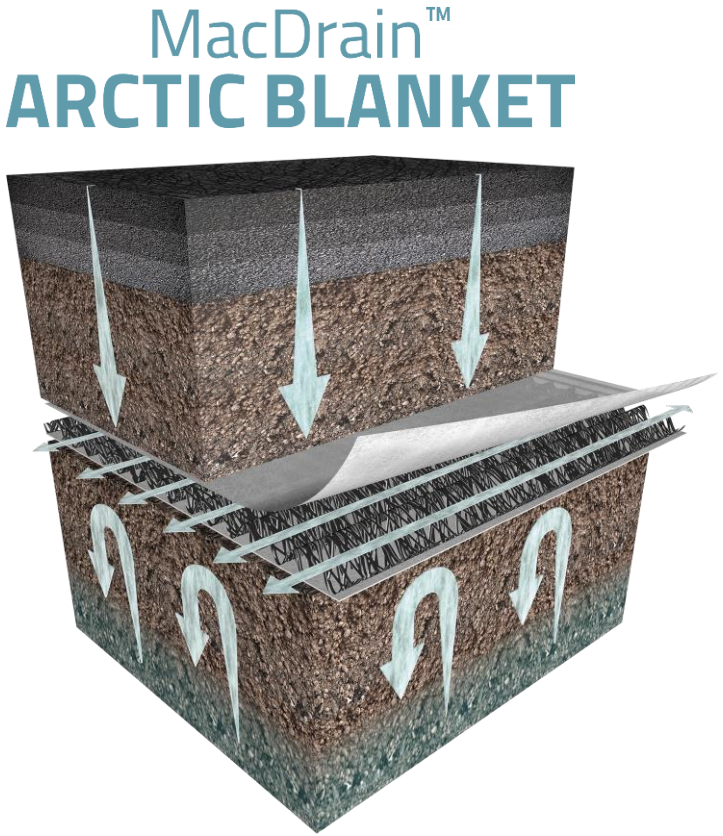

- MATERIAL SAVINGS
- **FASTER INSTALLATION**
- OUTSTANDING PERFORMANCE
- COST REDUCTION
- ENVIRONMENTAL SUSTAINABILITY

MACDRAIN™ ARCTIC BLANKET BENEFITS

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Fast installation

MacDrain™ Arctic Blanket can be **easily unrolled** without requiring special equipment and operations

without MACDRAIN™ ARCTIC BLANKET

with MACDRAIN™ ARCTIC BLANKET

MACDRAIN™ ARCTIC BLANKET BENEFITS

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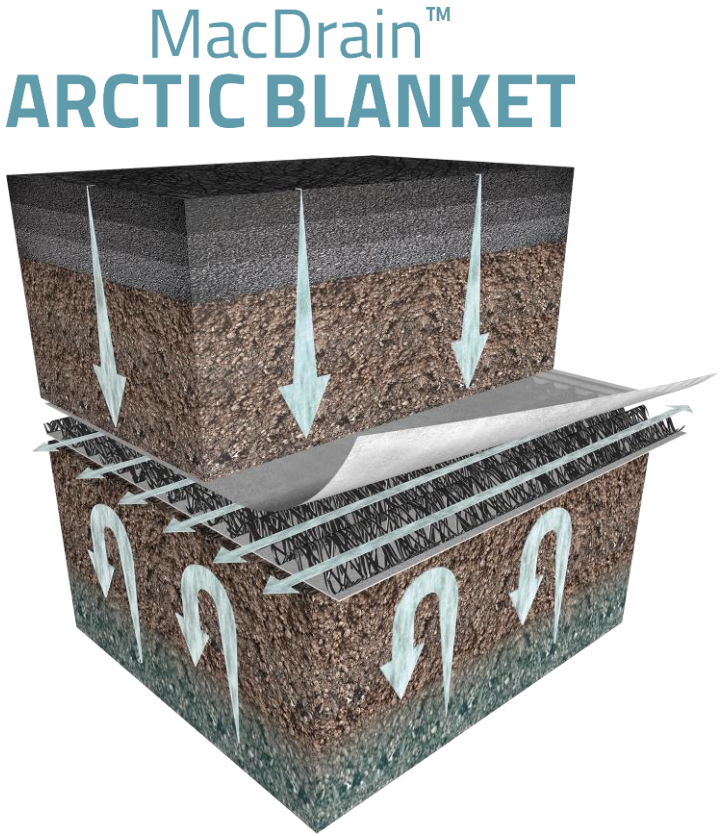

MATERIAL SAVINGS

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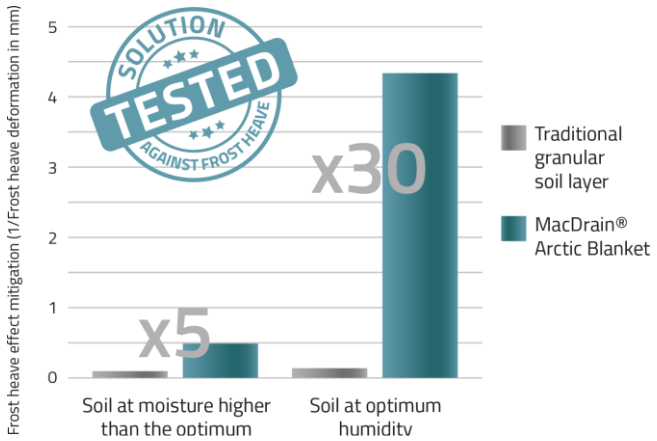
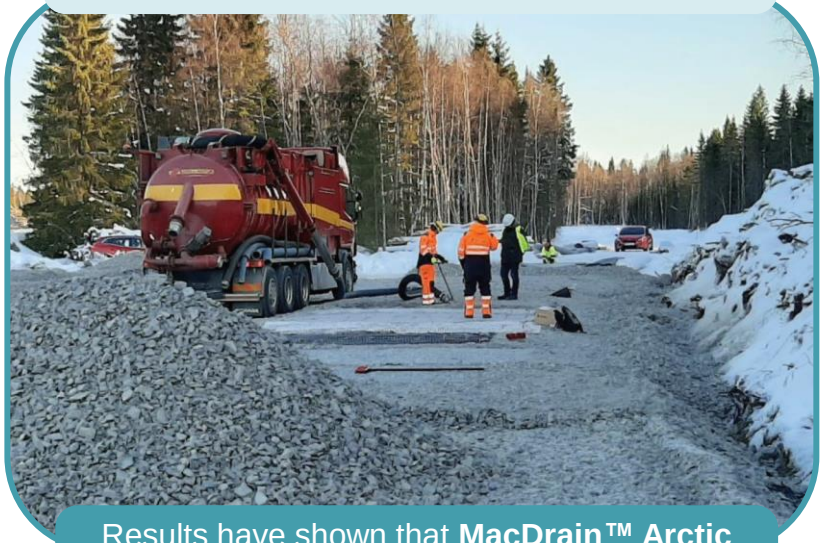
Tests have been performed both with an optimum and a higher humidity for compaction.



Results have shown that placing **MacDrain™ Arctic Blanket** in the soil mixture reduces drastically the frost heave phenomenon.

Tests on damage during installation at low temperatures (at -12°C)



Results have shown that **MacDrain™ Arctic Blanket** is suitable for the installation over frozen soil.

MACDRAIN™ ARCTIC BLANKET BENEFITS

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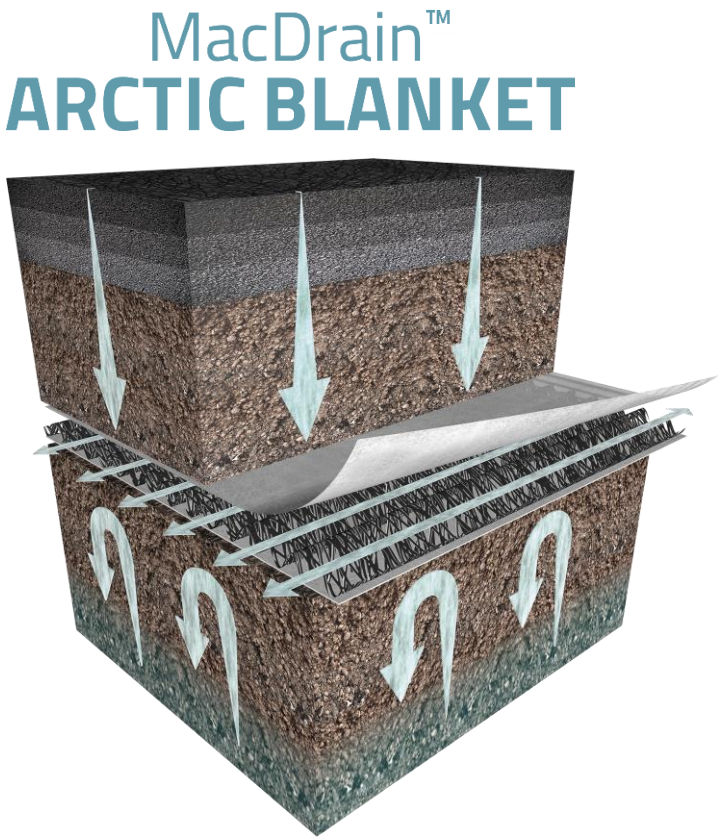

MATERIAL SAVINGS

FASTER INSTALLATION

OUTSTANDING PERFORMANCE

COST REDUCTION

ENVIRONMENTAL SUSTAINABILITY

MACDRAIN™ ARCTIC BLANKET BENEFITS

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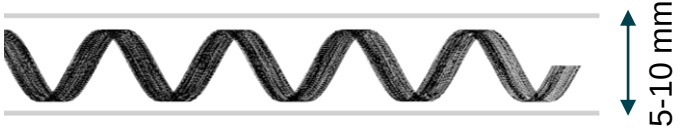
Cost Reduction

MacDrain™ Arctic Blanket can be quickly installed onsite with reduced cost and **no need for maintenance** compared to a layer of clean granular soil

without MACDRAIN™ ARCTIC BLANKET

with MACDRAIN™ ARCTIC BLANKET

MacDrain™ Arctic Blanket dramatically cut the installation time to granular soil



If properly laid, MacDrain™ Arctic Blanket is maintenance free

MACDRAIN™ ARCTIC BLANKET BENEFITS

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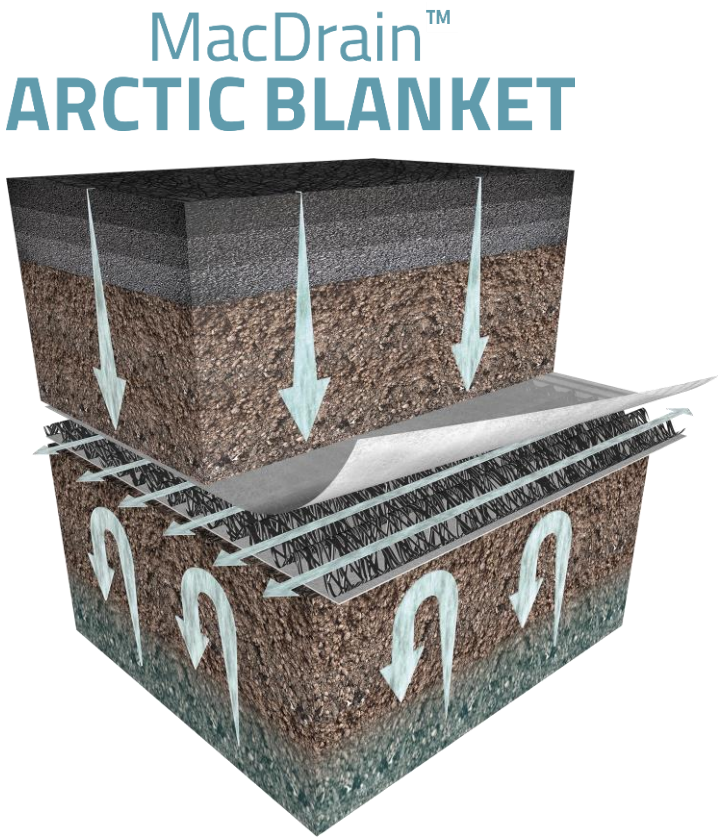

- MATERIAL SAVINGS
- FASTER INSTALLATION
- OUTSTANDING PERFORMANCE
- COST REDUCTION
- **ENVIRONMENTAL SUSTAINABILITY**

MACDRAIN™ ARCTIC BLANKET BENEFITS

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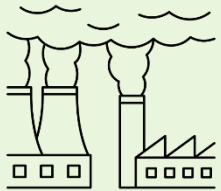
Environmental Sustainability

- MATERIAL SAVINGS
- OUTSTANDING PERFORMANCE
- FASTER INSTALLATION

- LESS QUARRYING
- LESS TRANSPORTATION
- LESS WASTE MATERIAL
- LESS DISRUPTION
- PROMOTING SAFE AND DECENT WORK



REDUCING EMISSIONS

MACDRAIN™ ARCTIC BLANKET BENEFITS

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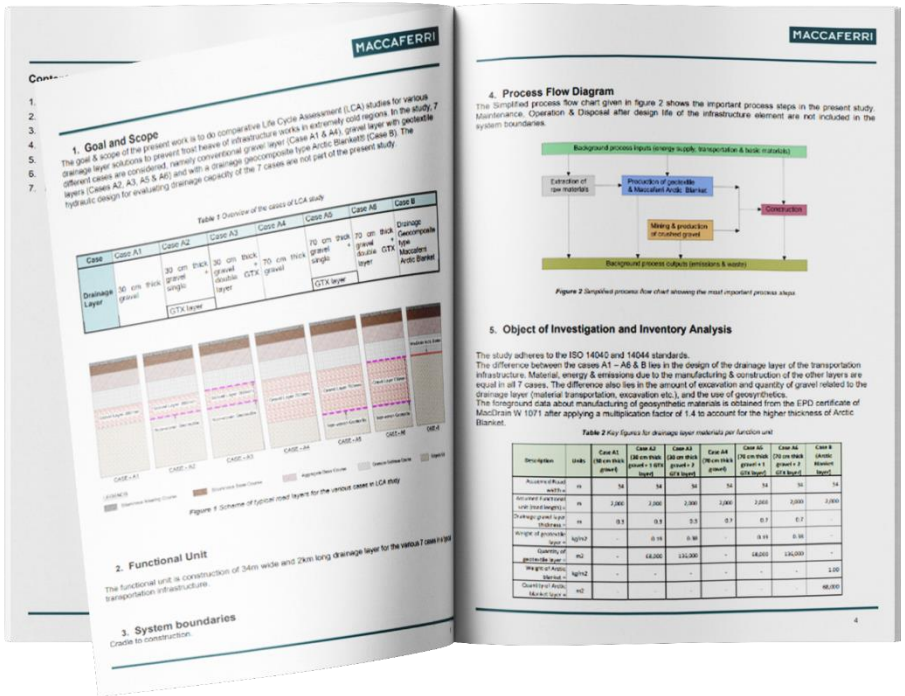
Environmental Sustainability

- MATERIAL SAVINGS
- OUTSTANDING PERFORMANCE
- FASTER INSTALLATION

MACDRAIN™ ARCTIC BLANKET BENEFITS

Environmental Sustainability – Life Cycle Assessment

Comparative Life Cycle Assessment (LCA) studies for various drainage layer solutions to prevent frost heave of infrastructure works in extremely cold regions.



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1. Goal and Scope

The goal & scope of the present work is to do comparative Life Cycle Assessment (LCA) studies for various drainage layer solutions to prevent frost heave of infrastructure works in extremely cold regions. In the study, 7 different cases are considered, namely conventional gravel layer (Case A1 & A4), gravel layer with geotextile layers (Cases A2, A3, A5 & A6) and with a drainage geocomposite type Arctic Blanket® (Case B). The hydraulic design for evaluating drainage capacity of the 7 cases are not part of the present study.

Table 1 Overview of the cases of LCA study

Case	Case A1	Case A2	Case A3	Case A4	Case A5	Case A6	Case B
Drainage Layer	30 cm thick gravel single	30 cm thick gravel single + GTX layer	30 cm thick gravel double layer + GTX	70 cm thick gravel	70 cm thick gravel single + GTX layer	70 cm thick gravel double layer + GTX	Drainage Geocomposite type Maccaferri Arctic Blanket

Figure 1 Scheme of typical road layers for the various cases in LCA study

2. Functional Unit

The functional unit is construction of 34m wide and 2km long drainage layer for the various 7 cases in the transportation infrastructure.

3. System boundaries

Cradle to construction.

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4. Process Flow Diagram

The Simplified process flow chart given in figure 2 shows the important process steps in the present study. Maintenance, Operation & Disposal after design life of the infrastructure element are not included in the system boundaries.

Figure 2 Simplified process flow chart showing the most important process steps

5. Object of Investigation and Inventory Analysis

The study adheres to the ISO 14040 and 14044 standards.
The difference between the cases A1 – A6 & B lies in the design of the drainage layer of the transportation infrastructure. Material, energy & emissions due to the manufacturing & construction of the other layers are equal in all 7 cases. The difference also lies in the amount of excavation and quantity of gravel related to the drainage layer (material transportation, excavation etc.), and the use of geosynthetics.
The foreground data about manufacturing of geosynthetic materials is obtained from the EPD certificate of MacDrain W 1071 after applying a multiplication factor of 1.4 to account for the higher thickness of Arctic Blanket.

Table 2 Key figures for drainage layer materials per function unit

Description	Units	Case A1 (30 cm thick gravel)	Case A2 (30 cm thick gravel + 1 GTX layer)	Case A3 (30 cm thick gravel + 2 GTX layer)	Case A4 (70 cm thick gravel)	Case A5 (70 cm thick gravel + 1 GTX layer)	Case A6 (70 cm thick gravel + 2 GTX layer)	Case B (Arctic Blanket layer)
Number of Road width	m	34	34	34	34	34	34	34
Assumed Functional unit (road length) =	m	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Drainage gravel layer thickness =	m	0.3	0.3	0.3	0.7	0.7	0.7	
Weight of geotextile layer =	kg/m2	-	0.19	0.38	-	0.19	0.38	
Quantity of geotextile layer =	m2	-	68,000	136,000	-	68,000	136,000	-
Weight of Arctic Blanket =	kg/m2	-	-	-	-	-	-	1.00
Quantity of Arctic Blanket layer =	m2							68,000

4

MACDRAIN™ ARCTIC BLANKET BENEFITS

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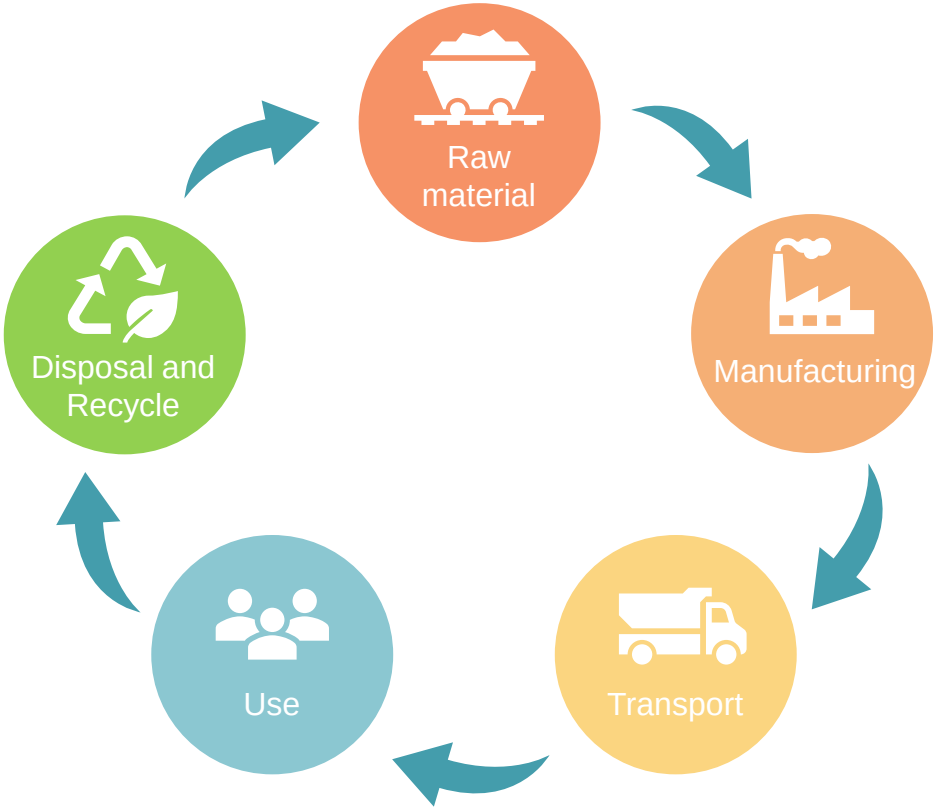
Environmental Sustainability – Life Cycle Assessment



Life Cycle Assessment

An LCA study involves a thorough inventory of the energy and materials that are required across the industry value chain of the product, process or service, and calculates the corresponding emissions to the environment. LCA thus assesses cumulative potential environmental impacts. The aim is to document and improve the overall environmental profile of the product.

LIFE CYCLE ASSESSMENT

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Impact Category

The **environmental performance** is assessed with reference to the below listed seven **midpoint impact category indicators**.

Abiotic Depletion (ADP-M & ADP-F) is an indicator that is related to the extraction of minerals and fossil fuels for any activity.

Global warming potential (GWP) is a measure of how much heat a greenhouse gas traps in the atmosphere up to a specific time horizon, relative to CO_2.

Acidification Potential (AP) provides a measure of the decrease in the pH-value of rainwater and fog, which has the effect of ecosystem damage.

Eutrophication Potential (EP) provides a measure of nutrient enrichment in aquatic or terrestrial environments, which leads to ecosystem damage.

Photochemical Oxidation (PCO) is a chemical reaction that is a major contributor to the formation of smog and air pollution in urban areas.

Ozone Layer Depletion (ODP) provides a measure of the depletion of stratospheric ozone layer caused by different gases.

LIFE CYCLE ASSESSMENT

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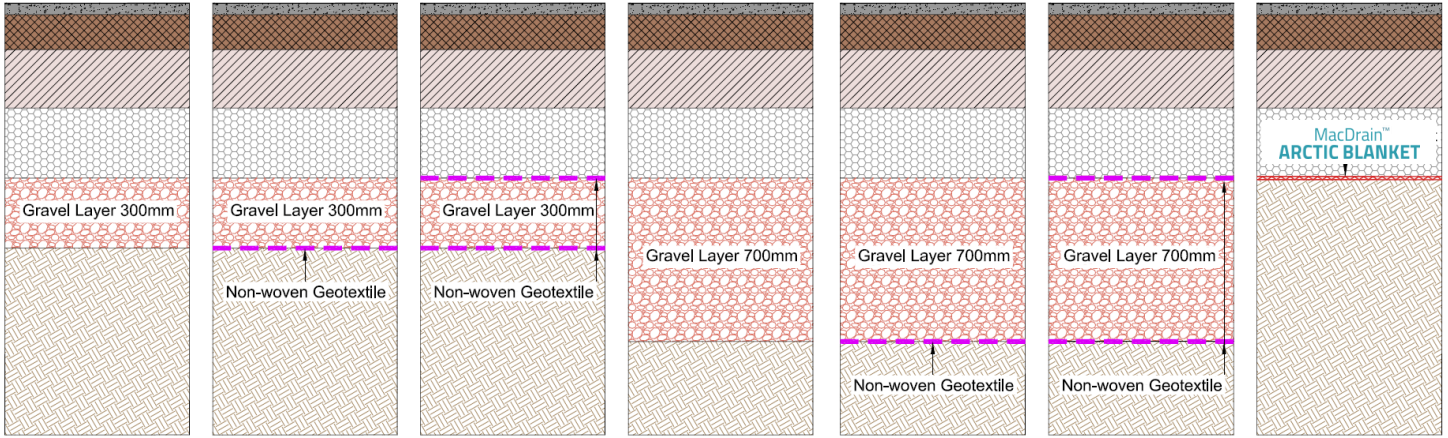
A comparison between 7 different cases

The study compares **7 different cases**, namely conventional gravel layer (Case A1 & A4), gravel layer with geotextile layers (Cases A2, A3, A5 & A6) and with a **drainage geocomposite type MacDrain™ Arctic Blanket** (Case B).

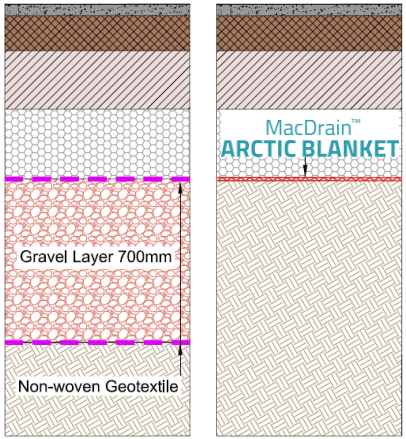


CASE - A1	CASE - A2	CASE - A3	CASE - A4	CASE - A5	CASE - A6	CASE - B
30 cm of thick gravel	30 cm of thick gravel + Single GTX Layer	30 cm of thick gravel + Double GTX Layer	70 cm of thick gravel	70 cm of thick gravel + Single GTX Layer	70 cm of thick gravel + Double GTX Layer	**Single layer of Maccaferri MacDrain™ Arctic Blanket**

*The hydraulic design for evaluating drainage capacity of the 7 cases are not part of the present study.

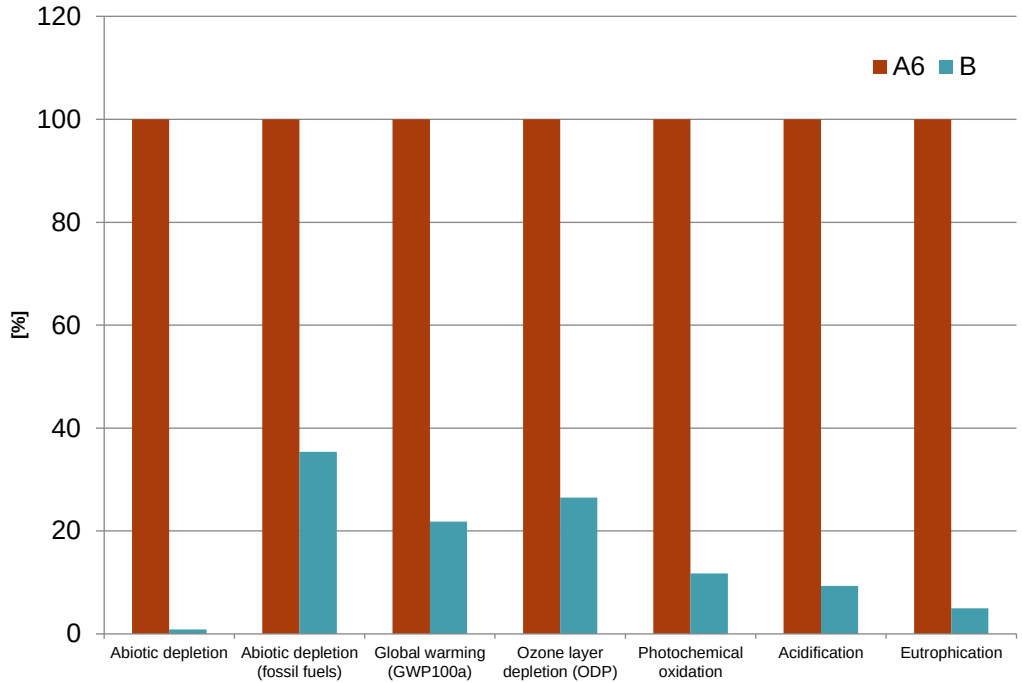
LIFE CYCLE ASSESSMENT

MacDrain™ Arctic Blanket vs 70 cm of gravel and double GTX layer



70 cm of thick gravel + Double GTX Layer

Single layer of Maccaferri MacDrain™ Arctic Blanket



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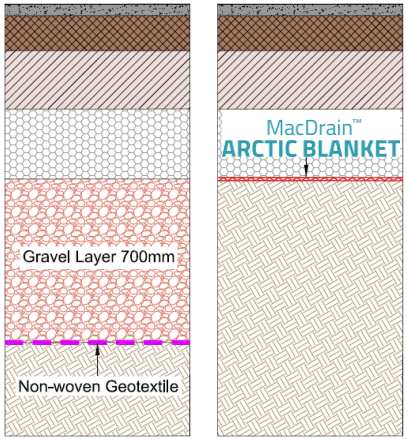
LIFE CYCLE ASSESSMENT

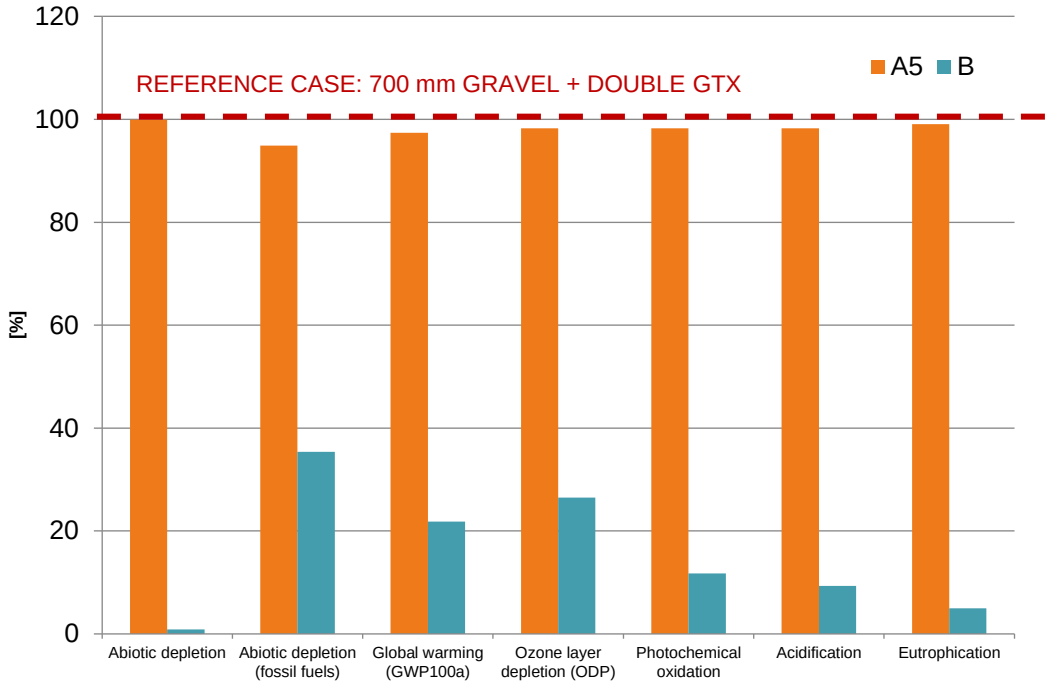
MACCAFERRI

MacDrain™ Arctic Blanket vs 70 cm of gravel and single GTX layer



70 cm of thick gravel + Single GTX Layer

Single layer of Maccaferri MacDrain™ Arctic Blanket



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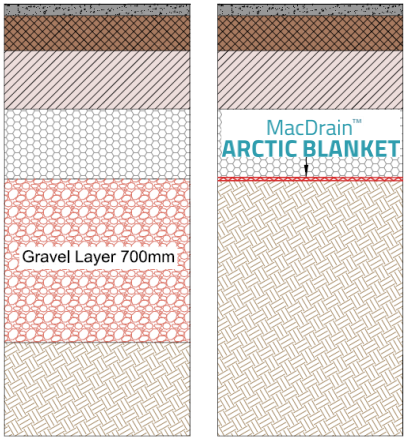
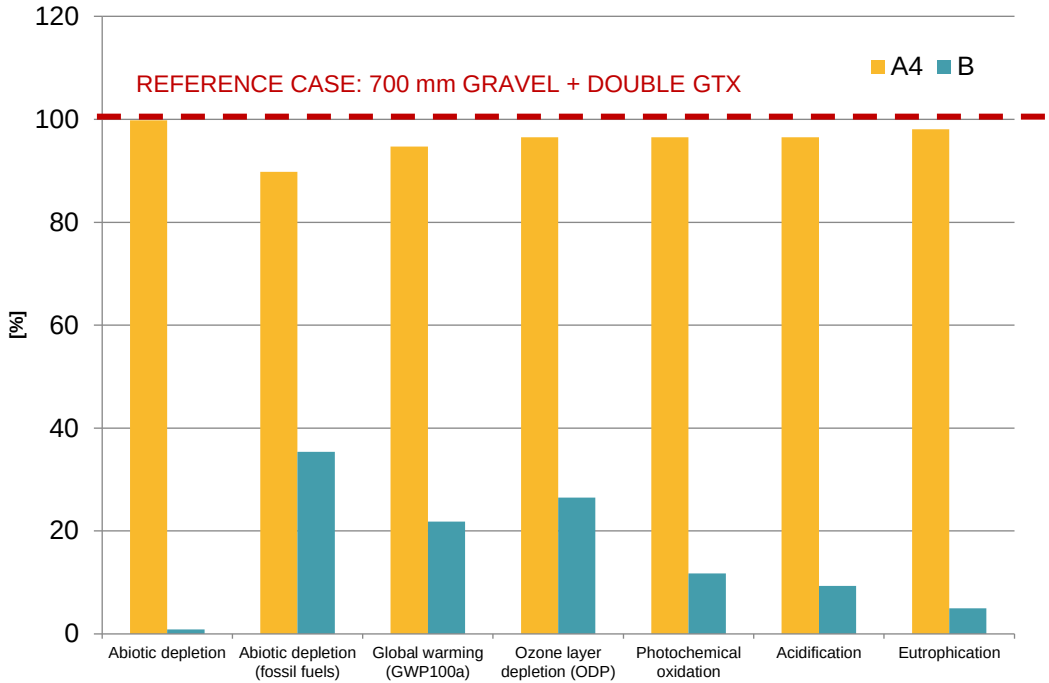
LIFE CYCLE ASSESSMENT

MacDrain™ Arctic Blanket vs 70 cm of gravel



70 cm of thick gravel

Single layer of Maccaferri MacDrain™ Arctic Blanket



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LIFE CYCLE ASSESSMENT

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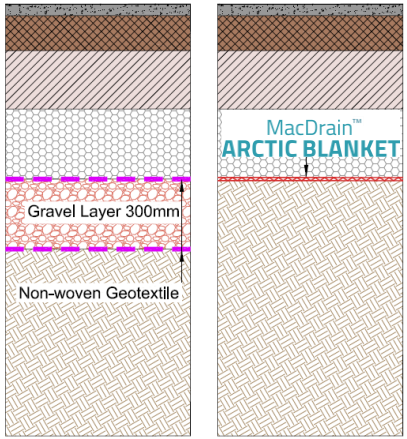
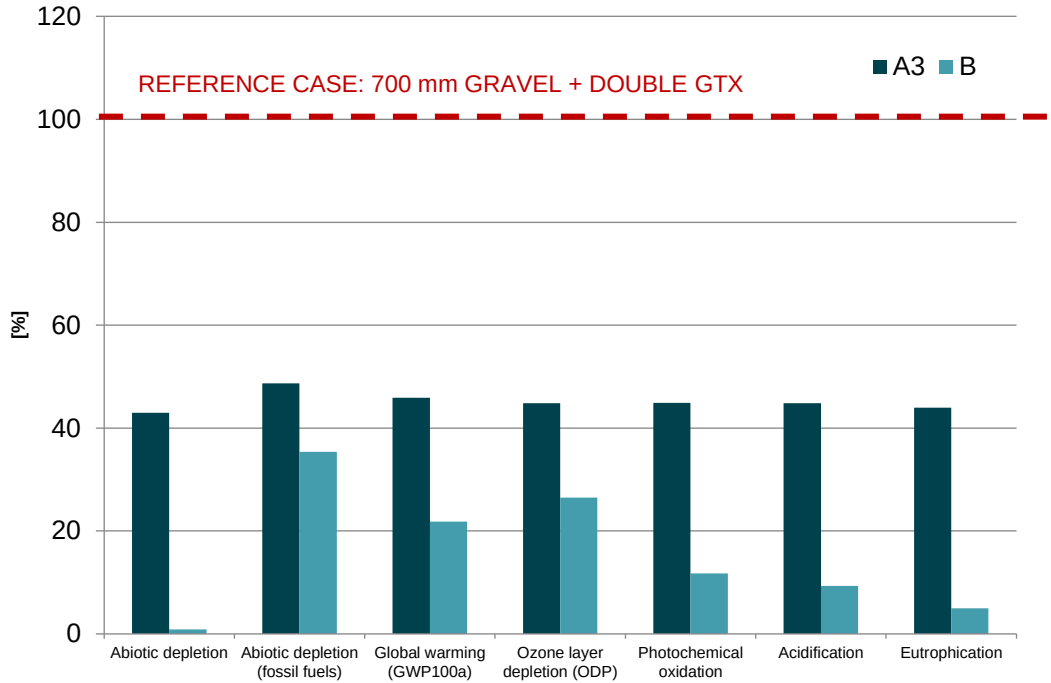
MacDrain™ Arctic Blanket vs 30 cm of gravel and double GTX layer



30 cm of thick gravel + Double GTX Layer

Single layer of Maccaferri MacDrain™ Arctic Blanket



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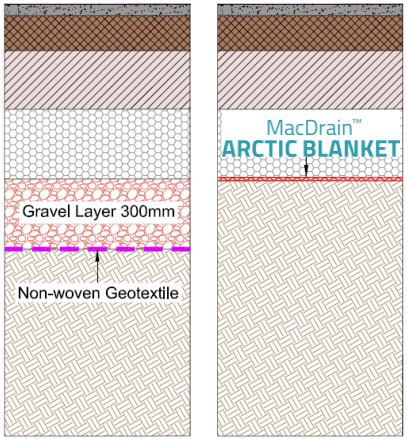
LIFE CYCLE ASSESSMENT

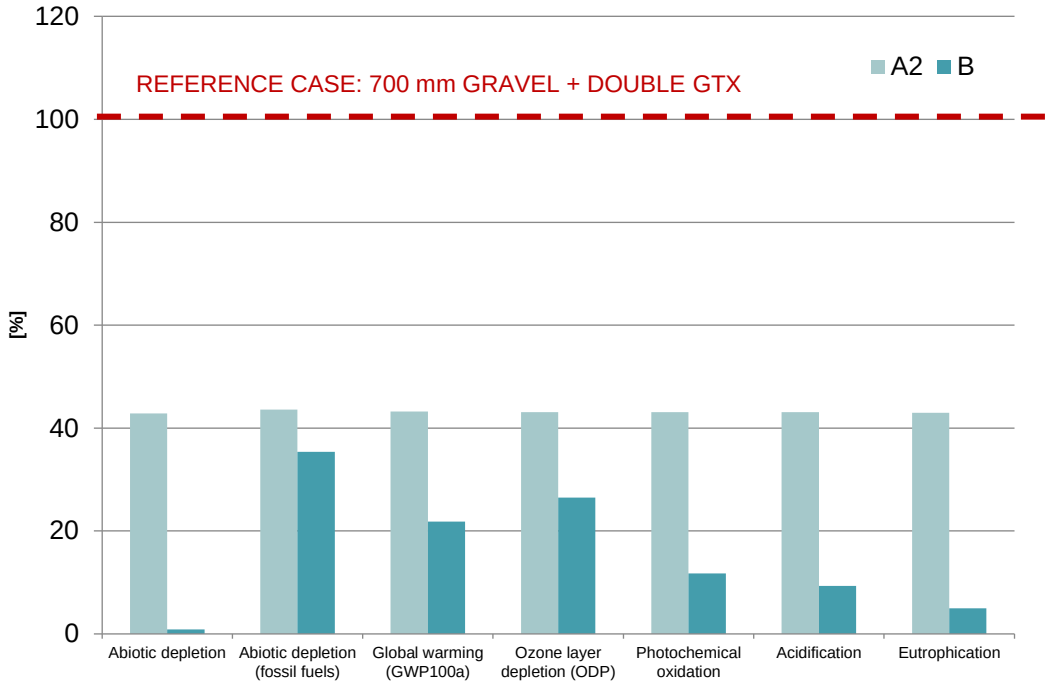
MACCAFERRI

MacDrain™ Arctic Blanket vs 30 cm of gravel and single GTX layer



30 cm of thick gravel + Single GTX Layer

Single layer of Maccaferri MacDrain™ Arctic Blanket



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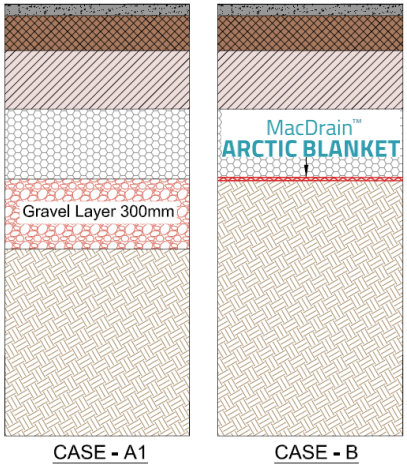
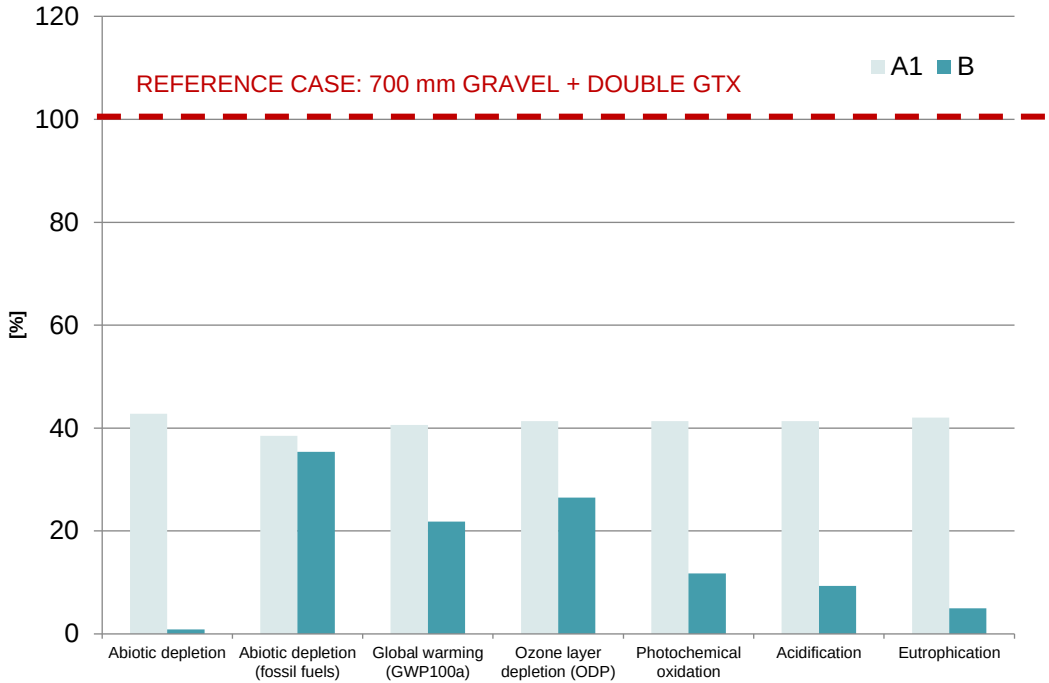
LIFE CYCLE ASSESSMENT

MacDrain™ Arctic Blanket vs 30 cm of gravel



30 cm of thick gravel

Single layer of Maccaferri MacDrain™ Arctic Blanket



*The hydraulic design for evaluating drainage capacity of the 7 cases are not part of the present study.

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MacDrain™
ARCTIC BLANKET

A DRAINAGE SYSTEM TO PREVENT GROUNDWATER CAPILLARY RISE AND FROST HEAVE