Field Monitoring Performance of H2Ri at the Beaver Slide Test Section

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Outline

- Introduction
- Test Section Construction & Sensor Installations
- Field Monitoring Results
- Discussions and Conclusions
Water Flow under Gravity
Evaporation

RH = 50%

RH = 100%
Water Flow due to Suction

RH = 50%

RH = 99%

RH = 100%

RH = 99.99%
Water Content, Soil Suction, Relative Humidity and......

Dry Soil

Plant Available Water

Drainable Water

<table>
<thead>
<tr>
<th>Soil Suction (kPa)</th>
<th>10000000</th>
<th>1500</th>
<th>500</th>
<th>40</th>
<th>&lt;10</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Humidity (%)</td>
<td>0</td>
<td>98.9</td>
<td>99.6</td>
<td>99.97</td>
<td>99.992</td>
<td>100</td>
</tr>
<tr>
<td>Water Content (%)</td>
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<td>4</td>
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<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Water Permeability</td>
<td>~0</td>
<td>~0</td>
<td>medium</td>
<td>high</td>
<td></td>
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Solid Phase

Water Phase
Water Content, Soil Suction, Relative Humidity and......

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Dry Soil ↔ Plant Available Water ↔ Drainable Water

Solid Phase ↔ Water Phase
Water Content, Soil Suction, Relative Humidity and……

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<th>Water Permeability</th>
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<tbody>
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<td>1000000 - 1500</td>
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<td>0 - ~0</td>
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<td>high</td>
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Water Content, Soil Suction, Relative Humidity and……
Road Embankment with Conventional Drainage

RH = 50%

RH = 98.9%

RH = 99.99%

RH = 100%
Road Embankment with Conventional Drainage

(FC=3.15%, Southeast Region)
Frost Heave and Thaw Weakening

Water in large void space freezes into ice crystals along plane of freezing temperature.

Ice crystals attract water from adjacent voids, which freezes on contact and forms larger crystals.

Crystals continue to grow and join, ice mostly by capillary water, forming ice lens. Vertical pressure exerted by ice lens heaves surface.
Material: H2Ri

Zero Horizontal Gradient Test
Laboratory Rainfall Infiltration Tests

Fig. 12: Average moisture distribution for salt water infiltration test

- Mirafi Nylon Wicking Fabric
- Mirafi® HP570
- Mirafi® FW402
- Mirafi® G-Series Drainage Composites

Moisture content (%)

Height (m.)

One Directional Water Flow

Remained wet after 3 days

Plastic mold containing saturated material

Dried out in one day

Saturated Silt

Impermeable Membrane

Plastic Mold

Mirafi Nylon Wicking Fabric
Beaver Slide (May 12, 2010)

Arctic Circle

11%
Design Concept

RH = 50%

RH = 99.9%

RH = 99.99%

RH = 100%

RH = 98.9%

RH = 50%
Final Design
Installation

4ft
Installation
Sensor Installation

CS107L Temp. Probe

CS616-L Moist. Probe

CR1000 + 2 AM16/32
Road conditions On May 24, 2011 (After Treatment)

-3.6 ft -9 ft
Grain Size Distribution

6%
Comparison in Road Conditions

May 12, 2010

May 24, 2011
Road Conditions (May 24, 2011)
Temperature and Moisture Profile

Temperature contour
9/24/2010 12:00:00 PM

Moisture contour
Temperature Profile (Layer 3: -3.5ft)
Temperature Profile (Layer 4: -6.5ft)
Moisture Profile (Layer 2: -2.5ft)
Moisture Profile (Layer 3: -3.5 ft)

[Graph showing temperature and volumetric moisture content over time with specific dates and values marked.]

Date: 05/30/11, 05/30/12

Temperatures and Volumetric Moisture Content (%) are plotted against time with distinct markers for key dates and values.
Moisture Profile (Layer 4 - 6.5 ft)
Freezing Process
During a Rainfall Event

(a) 09/04/2010

(b) 09/06/2010

(c) 09/13/2010

(d) 09/17/2010

(e) 09/20/2010

(f) 09/22/2010
Thawing Process

5/15/2011 12:00:00 PM

Temperature contour

5/22/2011 12:00:00 PM

Temperature contour

5/29/2011 12:00:00 PM

Temperature contour

5/30/2011 12:00:00 PM

Temperature contour

Moisture contour

Moisture contour

Moisture contour

Moisture contour
Thawing Process

Temperature contour
7/1/2011 12:00:00 PM

Moisture contour

Temperature contour
7/5/2011 12:00:00 PM

Moisture contour

Temperature contour
7/21/2011 12:00:00 PM

Moisture contour

Thawing Process
Two Mechanisms of Frost Boils/Soft Spots
Relative Humidity in the Air
Total Suction in the Air

Date

08/18/10
11/18/10
02/18/11
05/21/11
08/21/11
11/21/11
03/21/12
05/23/12
08/23/12

Suction (kPa)

100000
10000
1000
100
10

40
Working Mechanism of Wicking Fabric

Suction $< 1,000 \text{kPa}$

Suction $> 10,000 \text{kPa}$
Conclusions

1. Two mechanisms for the “frost boils/soft spots”:(a) frost heave and subsequent thaw weakening - early spring, and (b) upward pressurized water flow during lengthy rainy period - mid-summer and fall.

2. H2Ri was able to eliminate the damages caused by both mechanisms. The test section has performed very well in the past two years. No soft spot or frost boil occurred in the test section treated with H2Ri while the soft spots or frost boils were observed during early springs or a particularly rainy period on both the upper and lower ends of the test section in the past two years. The M&O personnel claimed they can clearly see whether the road is treated with H2Ri or not based upon the pavement surface performance.
3. The animation of the change in volumetric water content indicated that the water was flowing along the direction of the wicking fabric to the shoulder of the pavement. Field observation indicated that the soil at the shoulder was damp.

4. The H2Ri successfully eliminated the frost heave and thaw weakening in the first -4 ft below the pavement surface (Below the second layer of H2Ri). The observed volumetric moisture contents indicated that the soils had never reach saturation. It is an indication of no frost heave at all. However, for soils at the -7 feet below the centerline of the pavement surface which is beyond the treated zone, there was an indication of excess water due to frost heave. However, it was too deep to cause damages the pavement structure.
Conclusions

5. The H2Ri is a good material for draining water out of the pavement structure if properly used. The material itself has (a) high ability to absorb water for surrounding soils and (b) high ability to transport water under negative water pressure (unsaturated). The pressure difference can be generated by exposing the H2Ri to the atmosphere.

6. The obtained data indicates that the instrumented sensors functioned very well and the data were consistent with each other. The whole data acquisition system functioned very well in the past two years. It can be used for a longer monitoring period if needed.
Cautions

- Make sure you know which direction you want the moisture to flow. Water will always go from wet to dry.
- Don’t allow the exposed fabric to be wetter than the soil. It will cause water to flow in the wrong direction.
- Make sure the exposed fabric is exposed to the air. Covering it may eliminate evaporation.
Acknowledgement

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Thank You!