Use of H2Ri to Dehydrate Road Embankments for Better Performance

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Outline

- Introduction
- Test Section Construction & Sensor Installations
- Field Monitoring Results
- Discussions and Conclusions
- Other On-going Projects
Evaporation

RH = 50%

RH = 100%
Water Flow under Gravity
Water Flow due to Suction

RH = 50%

RH = 99%

RH = 100%

RH = 99.99%
Moisture Distribution in Road Embankment

Suction > 140 MPa (RH < 90%)

Air-dry

suction = $\gamma wh$

Infiltration

Ponding water

Suction > 140 MPa (RH < 90%)

Air-dry
Road Embankment with Conventional Drainage

Suction $> 140$ MPa (RH $< 90\%$)

Air-dry

Suction $= 10$ kPa

Suction $> 140$ MPa (RH $< 90\%$)

suction $= \gamma_w h$

Infiltration

Ponding water

Suction $> 140$ MPa (RH $< 90\%$)

Air-dry

Infiltration

Ponding water
Resilient Modulus at Varying Moisture Contents

Southeast Region, Alaska

Confining pressure (psi)

Resilient modulus (ksi).

MC = 6%
MC = 5.3%
MC = 3.3%

FC = 3.15%
Resilient Modulus at Varying Moisture Contents

Southeast Region, Alaska  FC=10%
Frost Heave and Thaw Weakening
Material: H2Ri

Zero Horizontal Gradient Test
Laboratory Rainfall Infiltration Tests

Fig. 12. Average moisture distribution for silt water infiltration test

- Moisture content (%)
- Height (in.)

One Directional Water Flow

Plastic mold containing saturated material

Remained wet after 3 days
Dried out in one day

40.14%
42.09%
43.35%
43.54%
Initially saturated silt/sand

RH = 50%

Impermeable Membrane

Initially saturated geosynthetic
Laboratory Rainfall Infiltration Tests

- RH = 50%
- Impermeable Membrane
- Initially saturated silt/sand
- Initially saturated Mirafi Nylon Wicking Fabric
Use of H2Ri to Dehydrate Road Embankment

- Suction = 10 kPa
- Suction > 140 MPa (RH < 90%)

Wicking Fabric
Relatively dry
Asphalt Concrete
Air-dry

Suction profile
Dalton Highway and Oil Pipeline
Beaver Slide
Final Design
Installation

4 ft
Installation

3 ft
1 ft
Sensor Installation

CS107L Temp. Probe

CR1000 +
2 AM16/32

CS616-L Moist. Probe
Road conditions On May 24, 2011 (After Treatment)

-3.6 ft - 9 ft
Grain Size Distribution

Percent passing by weight (%) vs. Grain Size (mm) graph showing different particle sizes from Gravel to Fines. A significant 6% is highlighted on the graph.
Road Conditions (May 24, 2011)
Comparison in Road Conditions

May 12, 2010

May 24, 2011
Temperature and Moisture Profile

Temperature contour
6/16/2011 5:00:00 AM

Moisture contour
Temperature Profile (Layer 1: -2ft)

- Date Range: 08/18/10 to 08/23/12
- Temperature Range: -40°C to 30°C
- Key Dates:
  - 09/23/10, 04/26/11, 05/10/11, 09/24/11, 04/16/12, 05/07/12
- Key Events:
  - 08/21/11, 11/21/11, 02/21/12, 05/23/12
- Legend:
  - Air
  - Layer 3
  - Layer 7
  - Layer 10
  - Layer 14
  - Layer 17
Temperature Profile (Layer 2: -3ft)

Date

08/18/10  09/23/10  11/18/10  02/18/11  04/26/11  05/18/11  08/21/11  09/24/11  11/21/11  02/21/12  04/16/12  05/23/12  08/23/12

Temperature (°C)

-40 -30 -20 -10  0  10  20  30

Legend:
- Air
- 1
- 4
- 8
- 11
- 15
- 18

Depth (ft)

-3.61

Distance (ft)

0 20 40 60 80

West  East

Note: The graph shows temperature profiles for different dates with specific markers for significant events or measurements.
Temperature Profile (Layer 3: -4ft)
Moisture Profile (Layer 1: -2ft)
Moisture Profile (Layer 2: -3ft)

Date

Volumetric Moisture Content (%)
Moisture Profile (Layer 3: -4ft)
Moisture Profile (Layer 4)
Two Mechanisms of Frost Boils/Soft Spots

Frost Heave and Subsequent Thaw Weakening

Pressurized Ground Water Flow after Lengthy Rains

Frozen Soils
Relative Humidity in the Air
Total Suction in the Air

Suction (kPa)

Date

08/18/10 11/18/10 02/18/11 05/21/11 08/21/11 11/21/11 02/21/12 05/23/12 08/23/12
Working Mechanism of Wicking Fabric

Suction < 1,000 kPa

Suction > 10,000 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 four years. It can be used for a longer monitoring period if needed.