Performance Data from Field-Deployed Prototype Scour Monitoring Systems

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Overview of Concept

Bio-Inspired Scour Sensor Post Solution
Magnetostrictive whisker sensors for detection of flow

Operating Principle of MS Flow Sensor

- Patent pending concept developed under grants from the Dept. of Defense for aerospace applications
- Biologically inspired cantilevered beams (whiskers) vibrate and are stressed by fluid flow
- Movement of the whisker changes the magnetic field at field reader and motion is detected
- Magnetic properties makes it very robust and well suited for subsurface environment
Sensor post concept

- 2.4 GHz antenna
- Data processing board
- NiMH battery pack: 10-year design lifespan
- Magnetostrictive flow sensor whiskers
- Pull-out prevention measures
- Flanges to protect sensors during installation
Scour Application

Plan View

Base Station:
- Cellular data link to DOT
- Solar-powered rechargeable battery

High-power cellular link

Dynamic readings from free sensor
Static sensor buried in riverbed

Low-power Zigbee link

Smart Scour Sensor Post

Section A-A
Lateral Riverbed Migration Applications

- Erosion-Sensitive Roadway
- Bank Top
- Smart Scour Sensor Posts
- Bank Toe
Mock whisker sensor post demo
Progress with enhancing whisker mechanical properties
Progress with enhancing whisker mechanical properties
1st prototype test site

Bacon Ridge Branch at MD450-Defense Highway:

Batthy Boat Derived Depth Values

Values in Feet:
- ≤ 2
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5

Legend:
- Gray: ≤ 2
- Yellow: 2.0 - 2.5
- Orange: 2.5 - 3.0
- Light Green: 3.0 - 3.5
- Dark Green: 3.5 - 4.0
- Green: 4.0 - 4.5
- Brown: 4.5 - 5.0
- Red: > 5

North Arrow

0 50 100 Feet
0 25 50 Meters
Tidal site selected to increase chances of seeing movement of soils. Drawback is fairly low flow velocities.
Magnetic seaweed sensors for detection of flow

- Patent pending concept developed under grant from the NSF & DOT for scour applications.
- Biologically inspired flexible cantilevered beams and membranes (seaweeds) deflect and are put in motion by fluid flow.
- Movement of the seaweed sensor changes the magnetic field at field reader and motion is detected.
- Magnetic properties makes it very robust and well suited for subsurface environment.
Prototype of seaweed sensor
1st prototype test site

- Bacon ridge branch bridge is a tidal site (near Annapolis, MD)
Draft installation plan for wired scour detection system

Conical base plug

Hollow stem auger or ~3” dia. pile driven casing

Not to scale
Draft installation plan for wired scour detection system

- Sensors
- Base of post
- Conical base plug

Hollow stem auger or ~3” dia. pile driven casing
Draft installation plan for wired scour detection system

- Sensors
- Base of post
- Conical base plug

Top of sensor at X% critical scour depth as desired warning notification

Not to scale
Draft installation plan for wired scour detection system

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Top of sensor at X% critical scour depth as desired warning notification

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Alarm sent when scour reaches depth selected for alarm

Not to scale
30 foot long (six 5 ft long sections), 10 inch inner diameter hollow stem auger

Shaft for connection to motor
Disposable wooden end plug not shown
Cutter
North post sensor configuration

Sensor 2 positioned 9 inches from end of post.

Sensor 1 & 3 positioned 3 inches from end of post.

Sensor 4 positioned 15 inches from end of post.
Typical Response – Sensors 2 & 4 Buried

North Post - Sensor 1
10/23/13 05:43

North Post - Sensor 2
10/23/13 05:43

North Post - Sensor 3
10/23/13 05:43

North Post - Sensor 4
10/23/13 05:43

River Bank
Low tide 10/23/13 - 02:07
High tide 10/23/13 - 07:09

Sensor at -3 inch

Sensor at -9 inch

Sensor at -15 inch
Low tide 10/23/13 - 12:43
High tide 10/23/13 - 19:55

Sensor at -3 inch

Sensor at -9 inch

Sensor at -15 inch
Lateral Riverbed migration site: Bennett Creek, near MD 355
Constraints led to a January installation
Horizontal drilling used. Started ~30 ft from exposed bank
Install Site #2 Sensor Posts
Install Site #2 Underwater Response
Install Site #2 In Air Response

Sensor: 1-1

Sensor: 2-1

Sensor: 3-1

Sensor: 4-1

Sensor: 5-1

River Bank
Photo of whiskers installed at the end of the in-air and in-water posts
Whisker Response

In Air

Time Response

Frequency Domain Response

In Water
Comparison of in-air and in-water time domain data
Comparison of in-air and in-water frequency domain data
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The views, opinions, findings, and conclusions reflected in this presentation are the responsibility of the authors only and do not represent the official policy or position of the USDOT/OST-R, MDOT, MDSHA, or any other entity.
Hall sensor measures change in magnetization due to stress

Permanent magnet to provide initial magnetization