Tracking HMA Placement Using RFID Technology

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AASHTO Subcommittee on Construction
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The Problem

Pavement Construction

Pavement Management

Link??

AC

Lot

Distress

Milepoint
The Problem

Pavement Construction

Pavement Management

Link??

AC

Lot

Milepoint

Distress
The Concept

HMA from Plant

Encapsulated RFID Tag

Tags scanned when convenient after construction

Vehicle with RFID Reader and GPS

Haul Truck

Paver

Compaction

Finished Pavement
Radio Frequency Identification (RFID)

- **Computer**
- **RFID Reader**
- **Tag ID**
- **Power to Transmitter Antenna**
- **Tag ID from Receiver Antenna**
- **Antenna**
- **RF Power**
- **Passive RFID Tag**
- **Tag Activated by Transmitter RF**

**Diagram Description**:
- The RFID Reader sends RF power to the Transmitter Antenna, activating the Passive RFID Tag.
- The Antenna receives the RF power and transmits the Tag ID to the RFID Reader.
- The Reader processes the Tag ID and sends it to the Computer.
Radio Frequency Identification (RFID)

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- **RFID Reader**
- **Antenna**
  - Power to Transmitter Antenna
  - RF Power
  - Tag ID
  - Tag ID from Receiver Antenna
  - Passive RFID Tag
  - Tag Activated by Transmitter RF
Selected RFID Technology

- Passive UHF (~900 MHz) Tags
  - 2x2 inch Alien
  - 1x1 inch Alien
  - 1x2 inch UPM Raflatac
Tag Encapsulation

- CPVC pipes (11/16” internal diameter)
- Tags placed along inside of pipe wall
- Pipe filled with high-temperature epoxy
- Cost ~$1 each
Laboratory Evaluation

- Encapsulated tags oven-heated with HMA for 90 minutes at 165°C to simulate transport from plant to job site.
- Encapsulated tags compacted in gyratory with HMA to simulate field compaction.
- Two RFID tags per gyratory specimen.
Laboratory Evaluation

- 67% survival rate
- Some degradation over time
- Read range: ~1 meter
- Encapsulation process later improved
Field Trials: UMD Lot XX1

50 mm thick surface layer of 12.5 mm HMA mixture w/ pre-positioned RFID tags
Field Trials: UMD Lot EE

12.5 mm HMA surface, 50 mm thick
19 mm HMA base, 100 mm thick
UMD Field Trial Results

Read Success Rate

Lot EE

10” antenna height
UMD Field Trial Results

Lot EE

Detection on basis of placing method

Percentage Reads
Tag Surfacing

Tag surfacing in Lot EE:
• 1x1 tags: 20%
• 2x2 tags: 40%
(Surface lift tags only)
Hampstead Bypass Field Trial

- MD 30 NW of Baltimore
- New alignment: 4.4 miles, 2 lanes
- 2” surface lift over two 4” base lifts (19 mm)
- Staged construction
Hampstead Bypass Field Trial
November 2007

• Lower 4" base lift (19 mm)
• 40 UPM Raflatac 1x2 tags, 60 Alien 2x2 tags (10/truck)
• No MTV
- Vehicle speed: < 5 mph
- Antenna height: 3” and 12”
- Future tests to vary:
  - Vehicle speed
  - Antenna height
  - Antenna configuration
Read Success Rate

Hampstead Bypass

Percentage of Tags Read

Antenna Height

Tag Dimension

<table>
<thead>
<tr>
<th>Antenna Height</th>
<th>1x2</th>
<th>2x2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3in</td>
<td>17.5%</td>
<td>56.7%</td>
</tr>
<tr>
<td>12in</td>
<td>17.5%</td>
<td>66.7%</td>
</tr>
</tbody>
</table>
Percentage of 1x2 Tags Read in each Truck Vs Height of Antenna

<table>
<thead>
<tr>
<th>Trucks</th>
<th>Height of Antenna</th>
</tr>
</thead>
<tbody>
<tr>
<td>TruckB1-10</td>
<td>3 inch</td>
</tr>
<tr>
<td>TruckB11-20</td>
<td>12 inch</td>
</tr>
<tr>
<td>TruckB21-30</td>
<td>(3&quot; U 12&quot;)</td>
</tr>
<tr>
<td>TruckB31-40</td>
<td>12 inch</td>
</tr>
</tbody>
</table>

Tags percentage Read

- TruckB1-10: 20%
- TruckB11-20: 20%
- TruckB21-30: 40%
- TruckB31-40: 10%
Percentage of 2x2 Tags Read in each Truck Vs Height of Antenna

- Truck1-10
  - 3 inch: 60%
  - 12 inch: 60%
- Truck11-20
  - 3 inch: 40%
  - 12 inch: 80%
- Truck21-30
  - 3 inch: 60%
  - 12 inch: 60%
- Truck31-40
  - 3 inch: 70%
  - 12 inch: 70%
- Truck41-50
  - 3 inch: 60%
  - 12 inch: 80%
- Truck51-60
  - 3 inch: 50%
  - 12 inch: 50%
Tag Surfacing Rates:

- 1x2: 0%
- 2x2: 15%
Hampstead Bypass Field Trial
April 2008

• Upper 4” base lift (19 mm)
• 32 Alien 2x2 tags (8/truck)
• MTV
Tag Spatial Sequence

<table>
<thead>
<tr>
<th>Station</th>
<th>Delivery Location</th>
<th>Read Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>320</td>
<td>81-88</td>
<td>85,86</td>
</tr>
<tr>
<td>321</td>
<td>89-96</td>
<td>84,88,92,93,94,95,98</td>
</tr>
<tr>
<td>322</td>
<td>97-104</td>
<td>99,100,102</td>
</tr>
<tr>
<td>323</td>
<td>105-112</td>
<td>105,107,108,109</td>
</tr>
<tr>
<td>324</td>
<td></td>
<td>81,106,110,111</td>
</tr>
<tr>
<td>325</td>
<td></td>
<td>90,101,103,105</td>
</tr>
<tr>
<td>326</td>
<td></td>
<td></td>
</tr>
<tr>
<td>327</td>
<td></td>
<td>112</td>
</tr>
</tbody>
</table>

- Variable (unknown) spatial lag
- Mixing in MTV surge hopper
Antenna Configuration Influence

Read Success Rate

Antenna Configuration

R Outboard

R Inboard
Read Success vs. Speed

![Graph showing the relationship between vehicle speed and read success rate. The graph indicates a decreasing trend in read success as vehicle speed increases.]
Tag Longevity

2x2 Tags - Lower Base Lift (November 2007)

Read Success Rate

Read Date and Antenna Height

- Nov 07 - 3"
- Nov 07 - 12"
- Apr 08 - 3"
Conclusions

HMA production tracked successfully in field using RFID technology
- Minimal interference with paving operations
- No projection of 2x2 tags above mat surface
- Surfacing of tags needs further investigation

Adequate to good read success rate
- Range sufficient for bumper-mounted antenna array
- 2x2 tags: 60-80% read success rate or higher
- Need improvement for smaller tags
Ongoing Work

- Evaluation of surfaced tags
- Evaluation of SAW RFID technology
  - Smaller format ID tags
  - Interface for sensors (temperature, strain, cracking, moisture, others)
- Tracking of PCC placement
- Guidance on data integration
Benefit: Added Value to Data