Identifying Concrete Plant Mixing Procedures for Electrically Conductive Concrete for the Iowa City Bus Stop Enhancement Project

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Outline

• Introduction
• Methodology
• Results
• Conclusions
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Introduction:

Snow Events


Introduction: Impacts on Transportation

Heavy rain, snow, and other storms can have significant impacts on the safety, mobility, and productivity of road users. Over the last 10 years, 22 percent of all vehicle crashes were weather related. On average, these crashes resulted in nearly 6,000 deaths and more than 445,000 injuries each year. Likewise, the delays associated with adverse weather can be profound and have significant economic impacts.

Road Weather Management – Weather-Savvy Roads

https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/roadweather.cfm

Introduction: Impacts on Transportation (Cont’d)

Total Cost of Delay in the U.S. (dollars, billion)

<table>
<thead>
<tr>
<th></th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airlines</td>
<td>5.6</td>
<td>6.4</td>
<td>7.7</td>
<td>8.3</td>
</tr>
<tr>
<td>Passengers</td>
<td>13.3</td>
<td>14.8</td>
<td>16.4</td>
<td>18.1</td>
</tr>
<tr>
<td>Lost Demand</td>
<td>1.8</td>
<td>2.0</td>
<td>2.3</td>
<td>2.4</td>
</tr>
<tr>
<td>Indirect</td>
<td>3.0</td>
<td>3.4</td>
<td>3.9</td>
<td>4.2</td>
</tr>
<tr>
<td>Total</td>
<td>23.7</td>
<td>26.6</td>
<td>30.2</td>
<td>33.0</td>
</tr>
</tbody>
</table>

Thousands Of Flights Cancelled, Delayed As Storm System Wreaks Holiday Travel Havoc

https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/roadweather.cfm
Introduction: Snow Removal Traditional Method

- Photos: Whopnews- January 21, 2016
- Photos: Greenwise- February 15, 2017

Introduction: Drawbacks of Traditional Method

- Infrastructure deterioration
- Environmental pollution
- Damage to pavement

Introduction: Innovative Technologies

• The transportation authorities continuously seek innovative and smart snow removal technology to combat their annual snow removal problem
  – Hydronically-heated pavement systems (HPS)
  – Resistive cable HPS
  – Phase-change-material integrated pavement systems
  – Superhydrophobic coating techniques
  – Electrically-conductive concrete (ECON) HPS

Reference: [Rahman et al., 2022]
Introduction: ECON HPS

Reference: (Abdualla et al., 2018)

Introduction: Field Implementations

Photo: DSM International Airport (Nahvi et al., 2018)

Photo: Iowa DOT Headquarters in Ames (Malakooti et al., 2020)

Introduction: Problem Statement

• There have been discrepancies in ECON electrical resistivity between full-scale field construction and laboratory samples
  
  – The DSM International Airport ECON has an electrical resistivity eight times higher than the ECON produced in the laboratory\(^a\)
  
  – The Iowa DOT ECON HPS encountered the same problem\(^b\)

Reference: \(^a\)(Abdualla et al., 2018) \(^b\)(Malakooti et al., 2020)

Introduction: Objective

• As part of a large-scale field implementation study on using ECON HPS for bus stop enhancement construction in Iowa City, this study aims to
  
  – determine mix proportion and mixing procedure of CF-based ECON suitable for ready-mix plant production
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Methodology: Mix Proportion

<table>
<thead>
<tr>
<th>Item</th>
<th>Mix 1</th>
<th>Mix 2</th>
<th>Mix 3</th>
<th>Mix 4</th>
<th>Mix 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>cement, Kg (B)</td>
<td>408 (899)</td>
<td>408 (899)</td>
<td>408 (899)</td>
<td>408 (899)</td>
<td>408 (899)</td>
</tr>
<tr>
<td>coarse aggregate, Kg (B)</td>
<td>584 (1,287)</td>
<td>584 (1,287)</td>
<td>582 (1,284)</td>
<td>582 (1,284)</td>
<td>582 (1,284)</td>
</tr>
<tr>
<td>fine aggregate, Kg (B)</td>
<td>475 (1,047)</td>
<td>475 (1,047)</td>
<td>474 (1,044)</td>
<td>474 (1,044)</td>
<td>474 (1,044)</td>
</tr>
<tr>
<td>water, Kg (B)</td>
<td>171 (378)</td>
<td>171 (378)</td>
<td>171 (378)</td>
<td>171 (378)</td>
<td>171 (378)</td>
</tr>
<tr>
<td>w/cw</td>
<td>0.42</td>
<td>0.42</td>
<td>0.42</td>
<td>0.42</td>
<td>0.42</td>
</tr>
<tr>
<td>CT, Kg (B)</td>
<td>17 (38)</td>
<td>17 (38)</td>
<td>19 (42)</td>
<td>19 (42)</td>
<td>19 (42)</td>
</tr>
<tr>
<td>AIRALON 7000, m²/m³ (net/sf²)</td>
<td>193 (3)</td>
<td>193 (3)</td>
<td>174 (4.5)</td>
<td>233 (5.5)</td>
<td>157 (4)</td>
</tr>
<tr>
<td>ZYLA 630, m³/m² (as/asf³)</td>
<td>1,740 (45)</td>
<td>1,740 (45)</td>
<td>-</td>
<td>2,437 (63)</td>
<td>-</td>
</tr>
<tr>
<td>OpilFlo MB, m³/m² (as/asf³)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1,912 (49)</td>
<td>-</td>
</tr>
<tr>
<td>MRA 63, m³/m³ (as/asf³)</td>
<td>870 (22.5)</td>
<td>1,044 (27)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Methodology: Mix Procedures

Methodology: Trial Batches
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Results:

28-Day Electrical Resistivity

Results:

Electrical Resistivity Vs Curing Time

Results:

28-Day Electrical Resistivity Vs Mixing Time
Results: Heating Performance

![Graph showing heating performance over time and temperature](image)

Results: Heating Performance (Trial Batch 4)

![Images showing temperature distribution](image)

Results: Microstructure Evaluation

![Images showing microstructure evaluation](image)

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Conclusions

• CF begins to degrade with an increase in mixing time.

• Mixture procedure method 4 using mixture proportion-5 produced ECON with the lowest electrical resistivity and highest heating rate.

• Estimating the 28-day electrical resistivity of ECON samples is possible after at least three days of curing; before that, electrical resistivity remains unstable and increases rapidly.

Thank You!
Questions & Comments?