Use of Crushed/Recycled Concrete as Drainable Base/Subbase & Possible Future Plugging of Pavement Systems

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Outline

• Background
• Material Properties and Specifications
• Impact on Pavement Systems
• Summary
Outline

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• Material Properties and Specifications
• Impact on Pavement Systems
• Summary
Aggregate Needs

• Two billion tons of aggregate are produced every year in the US
• Production is expected to increase to more than 2.5 billion tons per year by the year 2020
• Concerns are raised about
  – Availability of natural aggregates
  – Where we will find new aggregate sources

FHWA (2004)
Recycling of Concrete

• Aggregate in concrete comprise about
  – 80 to 85 percent of the mix by mass
  – 60 to 75 percent of the mix by volume

• Recycled concrete aggregate (RCA)
  – Crushed aggregate from existing concrete
  – Consists of high-quality, well-graded aggregates (usually mineral aggregates), bonded by a hardened cementitious paste

FHWA (2004)
Process of RCA productions

Unloading of crushed concrete

Crushing in primary crusher

Steel rebar stockpile

Stockpile of RCA

Vibratory feeder, sorting screen and secondary crusher

FHWA (2004)
Use of RCA

- The principal application of RCA in the US has been as a base/subbase material.
- The utilization of RCA as aggregate in PCC and HMA is not as widely accepted in the US.

FHWA (2004)
Base/Subbase

• To support and distribute heavy pavement loads to the ground
• To facilitate drainage
• To provide a stable construction platform
Base/Subbase

• A concrete pavement structure typically consists of a concrete surface and subbase(s) placed upon a prepared subgrade.

• A “base” is part of an asphalt pavement structure, while a subbase is an optional element of a concrete pavement structure.

APCA (2007)
RCA Subbase

- RCA subbase condition underneath concrete slab after coring
Sources of Moisture in Concrete Pavement

APCA (2007)
Typical Concrete Pavement Drainage Systems

Edge Drain

Daylighted

Concrete Pavement
Free-draining Subbase
Separator Layer (Geotextile)
Concrete Shoulder
Geotextile
Subgrade
Minimum offset distance of 3 ft (1 m)
Collector Pipe

Concrete Pavement
Free-draining Subbase
Concrete Shoulder
Drainable Material Reaches Daylight
Subgrade

APCA (2007)
Iowa Pavement Drainage System

Features

- Outlet pipe
- Edgedrain
- Surface Course
- Shoulder
- Permeable base
- Subbase layer
Outline

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RCA Properties

• In general, RCA has
  – Higher water absorption
  – Lower specific gravity
  – Lower density
  – Lower stiffness
RCA Properties

• Engineering properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Natural aggregate</th>
<th>Recycled concrete aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>2.6–2.6</td>
<td>2.2–2.4</td>
</tr>
<tr>
<td>Absorption (%)</td>
<td>0.5–1.6</td>
<td>4.3–5.9</td>
</tr>
<tr>
<td>Loss in L.A. abrasion test (%)</td>
<td>20–30</td>
<td>20–45</td>
</tr>
</tbody>
</table>
RCA Properties

- Measured Laboratory and Field Properties

<table>
<thead>
<tr>
<th>Test performed</th>
<th>Property</th>
<th>Crushed limestone</th>
<th>Recycled concrete aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Laboratory Tests</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sieve analysis</td>
<td>Classification</td>
<td>GP (ASTM) A-1-a (AASHTO)</td>
<td>GP-GM (ASTM) A-1-a (AASHTO)</td>
</tr>
<tr>
<td>Sieve analysis</td>
<td>Percent fines</td>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>$G_s$</td>
<td>2.75</td>
<td>2.54</td>
</tr>
<tr>
<td>Vibrating table</td>
<td>$\gamma_d \text{ max, min}$</td>
<td>$\gamma_d \text{ max} = 97 \text{ lb/ft}^3$</td>
<td>$\gamma_d \text{ max} = 88 \text{ lb/ft}^3$</td>
</tr>
<tr>
<td>Abrasion</td>
<td>Percent loss</td>
<td>15.3%</td>
<td>22.5%</td>
</tr>
<tr>
<td>CBR</td>
<td>CBR at 0.4 in. penetration</td>
<td>52%</td>
<td>22%</td>
</tr>
<tr>
<td><strong>In-situ Tests</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geogauge</td>
<td>Modulus</td>
<td>1480 ksf</td>
<td>1000 ksf</td>
</tr>
<tr>
<td>DCP</td>
<td>Penetration index (PI) CBR*</td>
<td>PI = 1.1 in./blow</td>
<td>PI = 0.95 in./blow CBR = 9%*</td>
</tr>
<tr>
<td>Clegg hammer</td>
<td>Clegg Impact Value (CIV)</td>
<td>CIV = 13</td>
<td>CIV = 13</td>
</tr>
<tr>
<td>Air Permeameter</td>
<td>Permeability</td>
<td>2.2 in/sec.</td>
<td>1.95 in/sec.</td>
</tr>
<tr>
<td>Gradation</td>
<td>% fines</td>
<td>4%-9%</td>
<td>4% - 11%</td>
</tr>
</tbody>
</table>

* estimated from DCP, ** due to breakage of particles under compaction

White et al. (2004)
RCA Properties

• RCA has different physical, chemical, and mechanical properties due to cement paste attached.

• Cement paste attached causes RCA to weigh less, increase water absorption, and lower abrasion resistance compared to conventional natural aggregate.

• Increase in fine aggregate due to the breakage of RCA particles under loading reduces the freeze-thaw resistance and permeability of pavement base and subbase.

Condition of aggregate in parent PCC

Photo courtesy of ARA, Inc. (2006)
RCA Properties

• Cement hydration also results in the formation insoluble residues of calcium carbonate (tufa formation)
RCA Material Specifications

• The first systematic guidelines for recycling concrete were developed in Japan in 1977
• British Standard BS812: aggregate soundness and crushing value
• AASHTO M 319: limitation of plastic soil, the percentage of wear by the Los Angeles abrasion test, soundness property as expedient indication of aggregate quality
• Many state DOTs have their own specifications for the use of recycled unbound pavement materials
# RCA Material Specifications

<table>
<thead>
<tr>
<th>State</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>May be used for aggregate subbase and base. Requirements not same as standard specs. If specs not incl. in Spec. Prov., contr. May request use by contacting Materials Group prior to initiating a Suppl. Agreement to allow use of salvage mat. For aggregate base and subbase.</td>
</tr>
<tr>
<td>California</td>
<td>Can be used up to 100% (Special Provisions)</td>
</tr>
<tr>
<td>Connecticut</td>
<td>Yes, Grading &quot;B&quot;, &lt;= 2% by mass asphalt cement (M.02.02)</td>
</tr>
<tr>
<td>Florida</td>
<td>Subgrade stab. (914-3.2)</td>
</tr>
<tr>
<td>Illinois</td>
<td>Coarse Aggregate (1004.04)</td>
</tr>
<tr>
<td>Indiana</td>
<td>Subgrade only, size No. 53 (207.02)</td>
</tr>
<tr>
<td>Iowa</td>
<td>Subbase (2110, 2111, 4109, 4121,4123, Material I. M. 2010)</td>
</tr>
<tr>
<td>Louisiana</td>
<td>Subbase yes</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>LA Abrasion Test &lt; 50, gradation requirements, approved stockpiles (M1.11.0)</td>
</tr>
<tr>
<td>Minnesota</td>
<td>Yes, but not near perforated pipes (3149.2)</td>
</tr>
<tr>
<td>Nebraska</td>
<td>307.02) w/ gradation requirements (1033)</td>
</tr>
<tr>
<td>New York</td>
<td>If RCA used from other than DOT project, provide documents showing that the material obtained is from NYSDEC registered or permitted C&amp;D facility; 2 alternates, at least 95% by weight of RCA (304-2.2)</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>Can be used; retained on No. 10 sieve, gradation requirements (704.01)</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>Subbase only; RCA from DOT, municipal or county projects only; other concrete can be approved showing made using materials approved by DOT (703.2)</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>Used as granular material for bedding only (M.01.02.2)</td>
</tr>
<tr>
<td>Washington</td>
<td>Yes up to 100% as base (9-03.21)</td>
</tr>
</tbody>
</table>

Celeen (2007)
## RCA Material Specifications (cont’d)

<table>
<thead>
<tr>
<th>State</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>Can be used up to 100% (Special Provisions)</td>
</tr>
<tr>
<td>Colorado</td>
<td>Conform to qual. Req. of AASHTO M147 except ratio of minus 200 sieve fraction to the minus 40 sieve fraction (M147 2.2.2)</td>
</tr>
<tr>
<td>Connecticut</td>
<td>Yes, Grading &quot;A&quot;, &lt;= 2% by mass asphalt cement (M.02.03)</td>
</tr>
<tr>
<td>Illinois</td>
<td>Coarse aggregate (1004.04)</td>
</tr>
<tr>
<td>Louisiana</td>
<td>Kept in approved, dedicated stockpiles, 100% crushed PCC or in combination w. approved stone; complies w/ specified gradation (1003.03e)</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>LA Abrasion Test &lt; 50, gradation requirements, approved stockpiles (M1.11.0)</td>
</tr>
<tr>
<td>Minnesota</td>
<td>Used singularly or w/ virgin aggregate or other RCA; special care taken where drainage layers and/or perforated pipes are installed or will be installed, SEE NOTES (3138.2)</td>
</tr>
<tr>
<td>Missouri</td>
<td>Used for any temp surface, regardless of the type or thickness of aggregate shown on the plans; If option is exercised, contractor shall notify engineer at least 2 weeks prior to using the recycled concrete. And shall identify location from where concrete will be removed; recycled concrete shall be placed in max 4-in lifts and each lift shall be compacted by a min of 3 passes w/ 10-ton roller (304.3.5)</td>
</tr>
<tr>
<td>New Jersey</td>
<td>Used as Dense-graded aggregate conforms with gradation and plasticity requirements (901.08)</td>
</tr>
<tr>
<td>North Dakota</td>
<td>Remixed at plant; coarse aggregate consist of min 20% coarse virgin one (560.04)</td>
</tr>
<tr>
<td>South Carolina</td>
<td>Yes; source shall be inspected, sampled and tested, and approved by the Engineer before material is used. Min 4 weeks should be allowed for this sampling (305.02)</td>
</tr>
<tr>
<td>Washington</td>
<td>Yes up to 100% as base (9-03.21)</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>&gt;= 90% crushed concrete that is free of steel reinforcement. And include &lt;10% asphaltic pavement or surfacing, base or a combination of asphaltic pavement, surfacing and base (301.2.3.2)</td>
</tr>
</tbody>
</table>

*Celeeh (2007)*
RCA Material Specifications: A glance at Iowa DOT Specifications

• Iowa DOT GS-12004 (April 15, 2014)
  – Section 4121 “Granular Subbase Material” and 4123 “Modified Subbase Material”

  • Aggregate requirements
    – Specified gradation
    – Aggregate quality (see below tables)

Granular Subbase Materials

<table>
<thead>
<tr>
<th>Coarse Aggregate Quality</th>
<th>Maximum Percent Allowed</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrasion</td>
<td>50</td>
<td>AASHTO T 96</td>
</tr>
<tr>
<td>A, Freeze</td>
<td>26</td>
<td>Office of Materials Test Method No. Iowa 211, Method A</td>
</tr>
</tbody>
</table>

[^1]: If the Alumina value fails, determine the A, Freeze value for specification compliance. Office of Materials Test Method No. Iowa 222 does not apply to gravel.

Modified Subbase Materials

<table>
<thead>
<tr>
<th>Aggregate Quality</th>
<th>Maximum Percent Allowed</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrasion[^2]</td>
<td>45</td>
<td>AASHTO T 96</td>
</tr>
<tr>
<td>C, Freeze</td>
<td>15</td>
<td>Office of Materials Test Method No. Iowa 211, Method C</td>
</tr>
</tbody>
</table>

[^2]: Virgin material with Al₂O₃ not exceeding 0.7 (+4) or A, Freeze not exceeding 10 may have an abrasion maximum of 55.
[^3]: For gravel or gravel/non-gravel blend, have a plasticity index not exceeding 7 for each source.
RCA Material Specifications: A glance at Iowa DOT Specifications

• Iowa DOT GS-12004 (April 15, 2014)
  – Section 4121 “Granular Subbase Material” and 4123 “Modified Subbase Material”
• RCA
  – Crushed PCC pavement meeting the requirements of Materials I.M. 210
RCA Material Specifications: A glance at Iowa DOT Specifications

- **Iowa DOT Materials I.M 210** “Production of Certified Aggregate from Reclaimed Roadways” (April 15, 2014)
  - Modified Subbase and Granular Subbase
  - “Recycled crushed PCC pavement, crushed composite pavement (CCP), and salvaged HMA (RAP) can be reclaimed from an Interstate or Primary roadway pavement under the jurisdiction of the contracting authority and shall be certified based on gradation testing”
  - “Recycled PCC roadway pavement or recycled composite roadway pavement obtained from secondary roads or municipal streets may be used if the source of the aggregate is known and the PCC coarse aggregate durability is Class 2 or better and shall be certified based on gradation testing. The producer shall be responsible for documentation of the pavement source”
  - “When the source or quality of the material from the secondary or municipal pavement is unknown, the material shall be certified based on quality requirements identified in the Standard Specifications for crushed stone for the aggregate being produced and gradation requirements for the aggregate product”
  - “On secondary and municipal projects, recycled material can also be reclaimed from roadway pavement under the jurisdiction of the contracting authority and shall be certified based on gradation testing”
Outline

• Background
• Material Properties and Specifications
• Impact on Pavement Systems
• Summary
Concrete Pavement Performance: PCI and IRI

<table>
<thead>
<tr>
<th>Statistic Variable</th>
<th>PCI (%)</th>
<th>IRI (m/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RCA</td>
<td>Natural</td>
</tr>
<tr>
<td>Average</td>
<td>82</td>
<td>74</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>Maximum</td>
<td>99</td>
<td>93</td>
</tr>
<tr>
<td>Minimum</td>
<td>55</td>
<td>55</td>
</tr>
</tbody>
</table>

Overall, the average Pavement Condition Index (PCI) and the International Roughness Index (IRI) values of RCA sections are a little higher than those values of natural aggregate sections but these difference are not statistically significant.

However...... (See next slides)
Surface Distress

- RCA subbase section on I-35 in Hamilton (M.P. 140.75 to 140.80)
  - More joint related distress

Spalling of transverse joint

Spalling of longitudinal joint

#2 #3 #4 #5 #6 #7 #8
Shoulder Distress

RCC subbase section of I-80 in Cedar County (M. P. 269.30 to 269.40)
- Lane to shoulder separation

RCC subbase section of I-35 in Hamilton County (M. P. 131.40 to 131.45)
- Shoulder drop off
Subsurface Drainage

• Typical subsurface drainage outlet conditions in Iowa

No Blockage (I-35/S/MP 127.90)

Tufa Blockage (I-80/W/MP 56.72)

Sediment Blockage (IA-5/E/MP 86.50)

Soil Blockage (IA-5/E/MP140.35)
Subsurface Drainage

• Subsurface drainage outlet conditions
  – with respect to Iowa JPCP subbase aggregate type

![Bar chart showing frequency of different subbase aggregate types by type of blockage]
Subsurface Drainage

• Free water flowing under blocked subsurface drainage outlet
Subsurface Drainage

- Shoulder distresses (shoulder drop or cracking) were observed nearby several blocked drainage outlet spots

I-80/W/MP 48.30
Shoulder drop/cracking
Blocked outlets

I-29/N/MP 70.84
Shoulder drop/cracking
Blocked and damaged outlets
Subsurface Drainage

• Effects of RCA base on concrete pavement drainage
  – The use of RCA in PCC base/subbase, irrespective of gradation, produces precipitate (tufa)
    • The amount of precipitate appears to be directly related to the quantity of RCA fines (# 4-minus)
  – Although selective grading (to eliminate fines) or blending with virgin aggregates will significantly reduce the precipitation potential, they will not completely eliminate it
  – The potential for accumulation of fine material deposits in and around pavement drainage systems can be reduced by washing the RCA before using them in pavement foundation layers

Snyder and Bruinsma (1996)
Subsurface Drainage

- Lesser tufa formation from RPCC base was observed at plastic outlet pipe without the use of rodent guards

I-35/N/MP 143.50
Subsurface Drainage

• Few instances of tufa blocked drainage outlet condition was observed in JPCP having blended RPCC and virgin aggregate materials.

<table>
<thead>
<tr>
<th>No Block</th>
<th>Soil Block</th>
<th>Sediment Block</th>
</tr>
</thead>
<tbody>
<tr>
<td>(US-151/S/MP 63.60)</td>
<td>(US-151/S/MP 64.50)</td>
<td>(US-151/S/MP 67.10)</td>
</tr>
</tbody>
</table>

US-151/S/MP 62.57 to MP 67.57 (10 spots) and US-151/N/MP 62.57 to MP 67.48 (9 spots):
Construction year: 2003/ AADTT: 1,101/ PCC thick: 9.5 inch
Subsurface Drainage

- NCHRP synthesis 239: Pavement subsurface drainage systems
  “Pavement subsurface drainage is a major factor in extending the life of a pavement”

- NCHRP 1-34 studies: Effects of subsurface drainage on pavement performance
  “The presence of subsurface pavement drainage did not improve any aspect of the behavior or performance of the AC and PCC pavements”

Contradictory findings?
No Subsurface Drainage

• However, what if there is no subsurface drainage in pavement system?
No Subsurface Drainage
No Subsurface Drainage
No Subsurface Drainage
No Subsurface Drainage
No Subsurface Drainage
No Subsurface Drainage
Subsurface Drainage

Moisture Related Damage nearby ‘No Drainage’ Outlet

I-80/W/MP 35.10/Pottawattamie County
- Pavement type: JPCP (11.5 in PCC/10.0 in subbase)
- Subbase aggregate type: RCA
- Construction year: 2005
- Transverse cracking with water coming out

I-80/W/MP 34.70/Pottawattamie County
- Pavement type: JPCP (11.0 in PCC/8.0 in subbase)
- Subbase aggregate type: Virgin
- Construction year: 1986
- Faulting with water coming out
Outline

• Background
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Summary: Conclusions

• The use of RCA has great benefits especially considering the environmental and economical advantages

• The national trend: use of RCA as base and sub-base materials
  – The use of RCA in the rehabilitation of major PCC pavements cannot be overlooked
Summary: Conclusions

- Use of RCA as subbase materials results in tufa blockage

- The pavement surface condition of RCA subbase sections in Iowa is comparable to that of natural aggregate subbase sections in terms of the Pavement Condition Index (PCI) and the International Roughness Index (IRI)

- The featured distresses on RCA subbase sections are shoulder distresses (shoulder drop or cracking)
Summary: Conclusions

• Few pavement surface distresses observed in RCA subbase sections in Iowa do not lead to the conclusion that:
  – Tufa from RCA materials do not need to be mitigated or removed through any alternative solutions such as RCA material quality control, outlet design and maintenance, etc.

• Pavement failures in Iowa have been reported on roadways without any subdrain system
Summary: Conclusions

• Lesser tufa formation from RCA base is observed with:
  – Use of plastic (PVC) outlet pipe without the use of rodent guards
  – Use of blended RCA and virgin aggregate materials
  – However, further investigations are needed to validate these solutions
Summary: Recommendations for Future Research

• Prevention of tufa formation while using RCA as base/subbase materials
  – Objectives
    • To determine optimized ratio of RCA to virgin aggregate to prevent tufa formation
    • To evaluate RCA properties in tufa formation
    • To develop recommendation of RCA properties required to prevent tufa formation
Summary: Recommendations for Future Research

• Long-term monitoring of the subsurface drainage performance
  – Objectives
    • To identify when subsurface drainage performance becomes non-functional
    • To investigate what triggers tufa formation and how long does it take to form from the time of construction
    • To recommend minimized maintenance activity frequency to keep subsurface drainage functional
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http://www.CPTechCenter.org/
http://www.InTrans.iastate.edu/
Thank You!

Questions?
Comments?
Performance Evaluation of Concrete Pavement Granular Subbase

Investigators: White, D. J., Ceylan, H., Suleiman, M. T., Jahren, C. T., and Cackler, T

**Duration**
February 1, 2006 – July 31, 2007

**Goal**
Determine if recycled PCC pavement subbase is performing adequately compared to virgin aggregate subbase sections.

**Approach**
Evaluate the structural condition of existing recycled PCC pavements subbase across Iowa through laboratory and field tests.

**Sponsor**
Iowa DOT ($150,000)
Phase I Research

• Transverse cracking was observed nearby several culvert spots (not drainage outlet spots)
Phase II Research

- Cracking/patching is observed nearby culvert only/culvert with drainage outlet
Phase II Research: I-35/N/MP143.50

- **Site information**
  - Route/Dir./MP/County: I-35/N/MP143.50 Hamilton County
  - Traffic (AADTT): 3,984
  - Pavement type: JPCP (11.5 in PCC/10.2 in Subbase)
  - Outside shoulder type: HMA
  - Subbase aggregate type: RPCC
  - Construction year: 2003
  - Construction project number: IM-35-6(94)140--13-40

- **Inspection location Information**
  - Inspection location number: No. 2
  - Date of inspection: June/5/2013
  - MP/GPS coordinate: MP143.50/N42(D)27(M)45(S) and W93(D)34(M)7(S)

- **Subdrain observation information**
  - Number of outlet pipe: 2
  - Type of outlet pipe: Corrugated plastic
  - Size of outlet pipe: 4 inch
  - Condition of outlet pipe: 100% blockage (Tufa Block)
  - Water present inside outlet pipe: Yes (standing)
  - Type of rodent guard: Gate
  - Tufa/Dead zone (due to tufa) present: Yes
  - Embankment slop condition: Less than 30 degree
  - Slope Condition at outlet: Downhill

- **Pavement distress condition on inspection location**
  - No distress observed

- **Note**
  - Water flowing block due to gate screen

Water backup in pipe

No pavement distress

Water flowing block due to gate screen
Phase II Research: I-80/W/MP102.00

- **Site information**
  - Route/Dir./MP/County: I-80/W/MP 102.00 Dallas County
  - Traffic (AADTT): 7,940
  - Pavement type: JPCP(12 in PCC/9.0 in Subbase)
  - Outside shoulder type: HMA
  - Subbase aggregate type: RPCC
  - Construction year: 1991
  - Construction project number: IR-80-2(131)99

- **Inspection location Information**
  - Inspection location number: No. 2
  - Date of inspection: June/13/2013
  - MP/GPS coordinate: MP 102.00/N41(D)31(M)4(S) and W94(D)9(M)47(S)

- **Subdrain observation information**
  - Number of outlet pipe: 2
  - Type of outlet pipe: Corrugated Steel
  - Size of outlet pipe: 6 inch
  - Condition of outlet pipe: 80% Tufa Blockage/ Damaged
  - Water present inside outlet pipe: Yes (free flowing)
  - Type of rodent guard: N/A
  - Tufa/Dead zone(due to tufa) present: Yes
  - Embankment slop condition: More than 30 degree
  - Slope Condition at Outlet: Downhill

- **Pavement distress condition on inspection location**
  - No distress observed

- **Note**
  - Steel pipe with plastic pipe inside
Phase II Research: IA-163/W/MP21.26

• Site information
  – Route/Dir./MP/County: IA-163/W/MP 21.26 Jasper County
  – Traffic (AADTT): 1,262
  – Pavement type: JPCP(10 in PCC/10 in Subbase)
  – Outside shoulder type: HMA
  – Subbase aggregate type: Virgin
  – Construction year: 1998
  – Construction project number: NHSN-163-2(15)--2R-50

• Inspection location Information
  – Inspection location number: No. 1
  – Date of inspection: June/11/2013
  – MP/GPS coordinate: MP 21.26/N41(D)35(M)15(S) and W93(D)11(M)40(S)

• Subdrain observation information
  – Number of outlet pipe: 1
  – Type of outlet pipe: Corrugated Plastic
  – Size of outlet pipe: 4 inch
  – Condition of outlet pipe: 100% Soil Blockage
  – Water present inside outlet pipe: No
  – Type of rodent guard: Gate screen
  – Tufa/Dead zone(due to tufa) present: No
  – Embankment slop condition: More than 30 degree
  – Slope Condition at Outlet: Uphill

• Pavement distress condition on inspection location
  – No distress observed

• Note
  – Had to dig to find outlet (Uphill)

Had to dig to find outlet

No pavement distress

Had to dig to find outlet (Uphill)
Phase II Research: I-80/E/MP154.27

- **Site information**
  - Route/Dir./MP/County: I-80/E/MP 154.27 Jasper County
  - Traffic (AADTT): 8,582
  - Pavement type: JPCP(12 in PCC/9.0 in Subbase)
  - Outside shoulder type: HMA
  - Subbase aggregate type: RPCC
  - Construction year: 1993
  - Construction project number: IM-80-5(164)154--13-50

- **Inspection location Information**
  - Inspection location number: No. 3
  - Date of inspection: June/19/2013
  - MP/GPS coordinate: MP 154.27/N41(D)41(M)17(S) and W93(D)15(M)52(S)

- **Subdrain observation information**
  - Number of outlet pipe: 2
  - Type of outlet pipe: Corrugated Steel
  - Size of outlet pipe: 6 inch
  - Condition of outlet pipe: 100% Tufa Blockage
  - Water present inside outlet pipe: Yes (standing)
  - Type of rodent guard: Gate screen
  - Tufa/Dead zone(due to tufa) present: Yes
  - Embankment slop condition: Less than 30 degree
  - Slope Condition at Outlet: downhill

- **Pavement distress condition on inspection location**
  - Transverse cracking/patching nearby bridge abutment

- **Note**
  - Poked hole in tufa and then water flowed out
Phase II Research: I-80/E/MP80.17

- **Site information**
  - Route/Dir./MP/County: I-80/E/MP 80.17 Adair County
  - Traffic (AADTT): 7,810
  - Pavement type: JPCP(11.4 in PCC/10.0 in Subbase)
  - Outside shoulder type: HMA
  - Subbase aggregate type: RPCC
  - Construction year: 2000
  - Construction project number: IM-80-2(156)73--13-01

- **Inspection location Information**
  - Inspection location number: No. 3
  - Date of inspection: June/13/2013
  - MP/GPS coordinate: MP 80.17/N41(D)29(M)48(S) and W94(D)34(M)12(S)

- **Subdrain observation information**
  - Number of outlet pipe: 1
  - Type of outlet pipe: Corrugated Steel
  - Size of outlet pipe: 6 inch
  - Condition of outlet pipe: 100% soil block
  - Water present inside outlet pipe: Yes (standing)
  - Type of rodent guard: Gate screen
  - Tufa/Dead zone(due to tufa) present: No
  - Embankment slop condition: More than 30 degree
  - Slope Condition at Outlet: uphill

- **Pavement distress condition on inspection location**
  - Dowel bar retrofit nearby culvert

- **Note**
  - One of dowel bar retrofit spots on I-80 JPCP, Adair County
Phase II Research: IA-9/E/MP233.50

- **Site information**
  - Route/Dir./MP/County: IA-9/E/MP 233.50 Howard County
  - Traffic (AADTT): N/A
  - Pavement type: HMA over JPCP (9.0 in HMA/8.0 in JPCP)
  - Outside shoulder type: Gravel
  - Subbase aggregate type: Virgin
  - Construction year: 2006 (overlay)/1974 (existing pavement)
  - Construction project number: STPN-009-7(27)--2J-45 (overlay)/FN-9-7(6)—21-45(existing pavement)

- **Inspection location Information**
  - Inspection location number: No. 3
  - Date of inspection: July/11/2013
  - MP/GPS coordinate: MP 233.50/N43(D)22(M)15(S) and W92(D)14(M)17(S)

- **Subdrain observation information**
  - Number of outlet pipe: 1
  - Type of outlet pipe: Corrugated Steel
  - Size of outlet pipe: 6 inch
  - Condition of outlet pipe: 20% sediment block
  - Water present inside outlet pipe: Yes (free flowing)
  - Type of rodent guard: Fork
  - Tufa/Dead zone(due to tufa) present: No
  - Embankment slop condition: Less than 30 degree
  - Slope Condition at Outlet: Parallel

- **Pavement distress condition on inspection location**
  - Longitudinal/transverse patching

- **Note**
  - Composite pavement site recommended by District 2 Engineer for inspection
  - Relative low number of drainage outlet (about 1 outlet per a mile)

- Soil blockage with water flowing
- Longitudinal/transverse patching
Forensic Testing and Evaluation: I-35/N/MP141.30

• Site information
  – Route/Dir/MP/County: I-35/1(North)/MP.140.19 to MP.142.07/Hamilton
  – Traffic (AADTT): 4,945
  – Pavement type: JPCP(11.5 in PCC/10.2 in Subbase)
  – Outside shoulder type: HMA
  – Subbase aggregate type: RPCC
  – Construction year: 2003
  – Construction project number: IM-35-6(94)140-13-40

• Inspection location Information
  – Inspection location number: No. 5
  – Date of inspection: Oct/10/2012
  – MP/GPS coordinate: MP 141.30/N42(D)25(M)50(S) and W93(D)34(M)12(S)

• Subdrain observation information
  – Number of outlet pipe: 1
  – Type of outlet pipe: Corrugated steel
  – Size of outlet pipe: 6 inch
  – Condition of outlet pipe: 100% of blockage(due to tufa/damaged)
  – Water present inside outlet pipe: Yes(standing)
  – Type of rodent guard: Gate screen
  – Tufa/Dead zone(due to tufa) present: Yes
  – Embankment slop condition: Less than 30 degree
Forensic Testing and Evaluation: I-35/N/MP141.30 (Cont’d)

• Pavement distress condition on inspection location
  – No distress

• PMIS pavement distress records for site
  – IRI(ft/mile): 90.0
  – PCI(%): 91
  – Faulting(inch): 0.30
  – Transverse crack(number/mile): 2
  – Longitudinal crack(ft/mile): 8.0
Forensic Testing and Evaluation: IA-163/W/MP18.82

- **Site information**
  - Route/Dir/MP/County: IA-163/2(West)/MP. 16.93 to MP. 21.44/Jasper
  - Traffic (AADTT): 1,262
  - Pavement type: JPCP (10.0 in PCC/10.0 in Subbase)
  - Outside shoulder type: HMA
  - Subbase aggregate type: Virgin Aggregate
  - Construction year: 1998
  - Construction project number: NHSN-163-2(15)--2R-50

- **Inspection location Information**
  - Inspection location number: No.3
  - Date of inspection: Oct/24/2012
  - MP/GPS coordinate: MP18.82/N41(D)35(M)24(S) and W93(D)14(M)30(S)

- **Subdrain observation information**
  - Number of outlet pipe: 2
  - Type of outlet pipe: Corrugated plastic
  - Size of outlet pipe: 4 inch
  - Condition of outlet pipe: 90% of blockage(due to sediment)
  - Water present inside outlet pipe: Yes(standing)
  - Type of rodent guard: Gate screen
  - Tufa/Dead zone(due to tufa) present: No
  - Embankment slop condition: Less than 30 degree
Forensic Testing and Evaluation: IA-163/W/MP18.82(Cont’d)

- Pavement distress condition on inspection location
  - No distress

- PMIS pavement distress records for site
  - IRI(ft/mile): 83.6
  - PCI(%): 95.0
  - Faulting(inch): 0.0
  - Transverse crack(number/mile): 12.9
  - Longitudinal crack(ft/mile): 29.0