Recycling Asphalt Pavements: Past, Present and Future

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Recycling Asphalt Pavements

- Presentation will provide brief overview of the Recycled Materials Resource Center
- Where have we been, where are we now and where are we going?
- Present a life-cycle costing and impact assessment tool developed specifically for highways
  - Asphalt paving example
RMRC Overview

- The Recycled Materials Resource Center is a National Center in Partnership with FHWA
- Established in TEA-21 in 1998

MISSION

To reduce barriers to the appropriate use of recycled materials in the highway environment

- Research
- Outreach

www.rmrc.unh.edu
RMRC RAP-Asphalt Projects

- Project 9 - Properties of Asphalt Mixtures Containing RAP
- Project 15 - Determination of $N_{\text{design}}$ for CIR Mixture Design Using the SGC
- Project 16 - Laboratory Foamed Asphalt Producing Plant
- Project 17 - Development of a Rational and Practical Mix Design System for Full Depth Reclamation (FDR)
RMRC RAP-Asphalt Projects Cont.

• Project 22 - Overcoming the Barriers to Asphalt Shingle Recycling (Phase Three)
• Project 26 - Determination of Structural Layer Coefficient for Roadway Recycling Using Foamed Asphalt
• Other projects in progress on RMRC website
RAP: Where have we been?
Asphalt Pavement Recycling

- Began as early as the 1900’s
- Oil embargo increased recycling in the 1970’s
- Began with hot mix
- Became the most recycled material in the United States
Categories of Recycling

- Hot In-place Recycling (HIP)
  - Surface recycling
  - Remixing
  - Repaving
- Cold Recycling
  - Cold In-place Recycling (CIR)
  - Cold Central Plant Recycling (CCPR)
- Full Depth Reclamation
  - Pulverization
  - Mechanical stabilization
  - Bituminous stabilization
  - Chemical stabilization
RAP: Where are we now?
Approach:

- RMRC Project 9 results showed RAP affects volumetrics, which offsets increased stiffness due to RAP binder in dynamic modulus measurements - effect on field performance not well defined

- AASHTO Design Guide predicts pavement performance, Level 3 uses binder properties – what are the appropriate binder properties to input for RAP mixtures?

- Perform Level 3 analysis using combinations of virgin & RAP binder properties – dovetails with NETC 04-4: Determining effective PG grade of RAP mixtures

- Products include recommendation on how to handle RAP mixtures within the framework of the M-E Pavement Design Guide
Project 41 - Determination of Moisture Damage (Stripping) Potential of HMA With Recycled Materials Using Accelerated Loading Equipment

**Principal Investigator:** Dr. Jo Sias Daniel, UNH

**Approach:**
- There is potential for stripping in recycled mixes (water in RAP, poor blending, etc.)

- Use Model Mobile Load Simulator (MMLS3) for APT of RAP mixtures

- Test control (no RAP), 2-3 RAP percentages & sources for field density, rut depth vs # load applications, ITS before & after wet loading

- Provide method of identifying recycled mixtures that are susceptible to moisture damage, applicable to materials other than RAP as well as a better method for simulation of field conditions
Project 41 - Determination of Moisture Damage (Stripping) Potential of HMA With Recycled Materials Using Accelerated Loading Equipment
Recycled Materials Use Survey

RMRC is currently conducting a national survey of state use of recycled materials.
RAP: Where are we going?

Green Highways and Sustainability – “buzz words”
How can sustainability be applied to road construction?

- Roads can be constructed in a more sustainable manner
- Roads can be sustainable (materials can be recovered and reused/recycled)
- Tools are available to evaluate environmental burdens and trade-offs of various options
- Present a life-cycle costing and impact assessment tool developed specifically for highways
  - Asphalt paving example
Pavement Life-cycle Assessment Tool for Environmental and Economic Effects (PaLATE)

Developed by Arpad Horvath (UC Berkeley) for the Recycled Materials Resource Center

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Questions that can be answered:

- For a particular roadway, which material is better environmentally, economically: e.g., recycled or virgin?
- Will changing the recycled material content in a particular pavement affect its environmental performance?
- Does sending demolished portions of a road to a processing plant or to a landfill make more environmental and economic sense?
- Which maintenance options will minimize environmental and economic effects? For example, should full depth reclamation be performed instead of more frequent, smaller maintenance procedures?
Factors that are considered:

- Design of the roadway
- Construction materials, material transportation distances and modes
- Technology choices – e.g., on-site construction and maintenance equipment (e.g., asphalt paver), and off-site processing equipment (e.g., rock crusher)
- Life-cycle economic costs
<table>
<thead>
<tr>
<th>Material</th>
<th>Density [tons/cy]</th>
<th>New Asphalt Pavement</th>
<th>New Concrete Pavement</th>
<th>New Subbase &amp; Embankment Construction</th>
<th>Transportation</th>
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</thead>
<tbody>
<tr>
<td>Virgin Aggregate</td>
<td>1.25</td>
<td>1123</td>
<td>0</td>
<td></td>
<td>100</td>
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<tr>
<td>Bitumen</td>
<td>0.84</td>
<td>50</td>
<td>0</td>
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<td>Cement</td>
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<td>Concrete Additives</td>
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<td>RAP transportation</td>
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<tr>
<td>RCM transportation</td>
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<tr>
<td>Coal Fly Ash</td>
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<td>Coal Bottom Ash</td>
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<td>0</td>
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<td>Foundry Sand</td>
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<td>Recycled Tires/ Crumb Rubber</td>
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<td>Glass Cullet</td>
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<td>Water</td>
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<td>Steel Reinforcing Bars</td>
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<td>Total: Asphalt mix to site</td>
<td>1.23</td>
<td>1173</td>
<td>0</td>
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<td>Total: Ready-mix concrete mix to site</td>
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<tr>
<td>RCM from site to LF</td>
<td>1.88</td>
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## Equipment Data

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<tr>
<th>ACTIVITY</th>
<th>Equipment</th>
<th>Brand/Model</th>
<th>Eng Cap</th>
<th>Productivity</th>
<th>Fuel Consumption</th>
<th>Fuel Type</th>
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<tbody>
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<td>Concrete Paving</td>
<td>Slipform paver</td>
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<td>106 hp</td>
<td>564 tons/h</td>
<td>19.7 l/h</td>
<td>diesel</td>
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<td>Texture curing</td>
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<td>70 hp</td>
<td>187 tons/h</td>
<td>20.2 l/h</td>
<td>diesel</td>
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<tr>
<td></td>
<td>machine</td>
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<td></td>
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<td>Asphalt Paving</td>
<td>Paver</td>
<td>4</td>
<td>196 hp</td>
<td>2,400 tons/h</td>
<td>49.1 l/h</td>
<td>diesel</td>
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<td></td>
<td>Pneumatic roller</td>
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<td>100 hp</td>
<td>668 tons/h</td>
<td>26.1 l/h</td>
<td>diesel</td>
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<td></td>
<td>Tandem roller</td>
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<td>125 hp</td>
<td>285 tons/h</td>
<td>32.7 l/h</td>
<td>diesel</td>
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</table>

- Equipment type utilized for each activity: Concrete & asphalt paving, CIR & HIPR, FDR, rubblization, milling, concrete demolition, excavation, placing, compaction, tire & glass recycling, HMA production
Case Study

• NH DOT Construction Project in central NH
• Portion of project will utilize rubblization of an existing concrete roadway
• Investigate alternative materials and compare life-cycle costs and life cycle impacts (environmental effects)
• Data from DOT engineers put into PaLATE – small investment in time
NH DOT Case Study

• Initial Construction

  ➢ Option 1
  - Mill off the existing Pavement
  - Rubblize (Recycle) Concrete / Cover with (Recycled) Pavement Millings
  - Widen with Virgin Materials
  - Pave with 3.5” on New Hot Mix Asphalt

  ➢ Option 2
  - Remove Concrete Slab and landfill
  - Construct 12” of Gravel & Crushed Gravel full width
  - Pave with 5.5” of New Hot Mix Asphalt
NH DOT Case Study (cont)

- **Maintenance Option 1**
  - Years 4 & 8: Crack Seal
  - Year 12: Resurface – 1” Wearing Course
  - Years 16 & 20: Crack Seal
  - Year 24: Resurface – 1” Wearing Course

- **Maintenance Option 2**
  - Year 1-11: nothing
  - Year 12: Hot In-Place Recycling (HIPR)
  - Year 13-23: nothing
  - Year 24: HIPR
Initial Construction cost for rubblization is about half that of using virgin materials.

Maintenance cost of crack sealing & resurfacing is about half that of HIPR.
Initial Construction: Recycling uses 3.5M MJ less energy than use of virgin materials (reduced materials production)

Maintenance: HIPR uses 1.5M MJ less than crack sealing & resurfacing.

HIPR - equipment processes
Crack seal & resurfacing - materials production
Case Study Results: Water Consumption (Mg)

Initial Construction: Rubblization uses 700 Mg less (reduced materials production)
Maintenance: HIPR uses 400+ Mg less (reduced materials production)
Case Study Results: CO₂ / GWP (Mg)

Initial Construction: Rubblization generates ~200 Mg less of CO₂ emissions (reduced materials production)

Maintenance: HIPR generates ~75Mg less of CO₂ emissions (reduced materials production)
Case Study Results: NO\textsubscript{x} Emissions (kg)

Initial Construction: Rubblization generates \(~1000\)kg less NO\textsubscript{x} emissions (reduced emissions from all sections)

Maintenance: HIPR generates \(~700\)kg less NO\textsubscript{x} emissions (no material production or transportation)
Case Study Results: PM$_{10}$ Emissions (kg)

- Initial Construction: Rubblization generates ~2000kg less PM$_{10}$ emissions (reduced materials production)
- Maintenance: HIPR generates ~300kg less PM$_{10}$ emissions (no material production or transportation)
Case Study Results: SO$_2$ Emissions (kg)

Initial Construction: Rubblization generates ~25K kg less SO$_2$ emissions (reduced materials production)

Maintenance: HIPR generates ~20K kg less SO$_2$ emissions (no materials production)
Case Study Results: CO Emissions (kg)

Initial Construction: Rubblization generates ~500kg less CO emissions (reduced materials production)

Maintenance: HIPR generates ~250kg less CO emissions (no materials production or transportation)
Decision-making

• So how does one make a decision with so many performance metrics?
• It’s not trivial, but it needs to be done transparently and rigorously to defend the sustainability of a highway design
Conclusions

• The future of utilizing recycled materials, including RAP, may include an assessment of sustainability and life cycle impacts

• There are tools available to specifically address the life cycle impacts of roadway construction, and recycling

• Recycling and recycled materials use are two important components of sustainability in highways

• The RMRC has
  - conducted some 43 research projects nationwide
  - conducted training for DOT/EPA personnel in 39 states
  - developed specifications and recommended practices adopted by AASHTO
  - developed important tools for evaluating the sustainability and life cycle impacts of highway construction and maintenance
Caveats

• Use of recycled materials is **VERY** site specific. Just because it worked at one site does not mean it will work at your site, and vice versa.

• Recycled materials must be considered at the very beginning of the project, not in middle of the project.

• Include all stake holders (including public) at the beginning of the project to avoid surprises at the end.
Acknowledgements

- Dr. Kevin Gardner, Director RMRC
- Dr. Jenna Jambeck, RMRC
- Alberta Carpenter, PhD Student
Questions?

Further information available on RMRC website:

www.rmrc.unh.edu