Recycled Materials in Roadways: Improving Sustainability, Quality, and Service Life

Why is Sustainability Important?

- Nexus of major issues caused by rapidly growing global economy:
  - Global warming
  - Energy constraints
  - Resource availability (metals, cement, oil etc.)
- World population is 6 billion (B) → 12 B projected by 2100. US at 0.5B by 2050.
- US and EU (combined population = 0.75 B) consume most of world resources. China catching up fast.
- Remaining 5.25 B want everything we have. Not enough to go around if we do business as usual.

How Can We Make Infrastructure Construction More Sustainable?

1. Reduce energy consumed in construction and rehabilitation.
2. Reduce emissions emitted in construction and rehabilitation.
3. Reduce consumption of natural resources.
4. Increase service life.

How Do Recycled Materials Fit In?

1. Avoid energy and emissions associated with mining and processing construction materials. Energy has already been expended in first life of recycled material.
2. Avoid use of a natural resource (sand and gravel, limestone, oil).
Recycled Materials Resource Center

- Promote safe and wise use of recycled materials in construction of transportation infrastructure through education, technology transfer, and applied research.
- Wise ... ensure that recycled material is suitable for highway environment and provide procedures for appropriate use.
- Safe ... ensure material will not adversely impact environment or users.

Stabilizing RPM with Off-Spec Cementitious Fly Ash at MnROAD

MnROAD is a full-scale highway test facility operated by Minnesota DOT
Tuncer B. Edil, RMRC, PI
US DoE & RMRC

Two Byproducts → Useful Construction Products

RPM + High Carbon Fly Ash = high modulus and durable base

MnROAD Test Sections

Riverside 8 Fly Ash from Xcel Energy, 14.6% LOI and 22% CaO
Non-compliant with MCPA requirements.
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Placement of RPM and Fly Ash

Mixing & Compaction

Safe and Wise: Pavement Performance - Modulus

Construction Life Cycle Analysis – Energy Usage

- Most energy: Conventional construction material.
- Least energy: recycled pavement in place of crushed aggregate.

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Construction Life Cycle Analysis – GHGs

Most emissions: Conventional construction material
Least emissions: recycled pavement in place of crushed aggregate

Safe and Wise: Environmental Impact

Geomembrane installation
Sump welding
Collection tank installation
Drainage layer installation

Environmental Data – Mercury Emitted to Ground Water

Hg is well below MCL. No difference between conventional and recycled materials.

WiscLEACH Model

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HMA Paving

BE³ST in Highways Sustainability Assessment

BE³ST Highway Sustainability Rating System
- Life cycle analysis (LCA) to assess variety of sustainability metrics (energy, GHG emissions, water use, hazardous waste generation, etc.) – PALATE model
- Life cycle cost analysis (LCCA) – evaluate life cycle cost of design alternatives.
- Quantitative and auditable metrics – provide perception & financial incentives for owners and contractors to incorporate sustainability principles in designs

Sustainable Use of Recycled Asphalt in Construction
Which has higher “value”:
- Reintroduction into hot mix asphalt?
- Use as granular base?
Comparison of Alternatives using BE²ST
- HMA = hot mix asphalt
- RAP – reintroducing reclaimed asphalt into new hot mix asphalt
- RPM – using RAP as granular base
- SPRM – using RAP + fly ash binder as base.

<table>
<thead>
<tr>
<th>Design</th>
<th>Mr of Base Layer (MPa)</th>
<th>Base Layer Coefficient</th>
<th>Service Life (yr)</th>
<th>No. of Rehabilitations for 50-yr Period</th>
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<tbody>
<tr>
<td>HMA</td>
<td>206</td>
<td>0.14</td>
<td>13</td>
<td>3</td>
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<tr>
<td>HMA-RAP</td>
<td>249</td>
<td>0.14</td>
<td>14</td>
<td>3</td>
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<tr>
<td>HMA-RPM</td>
<td>846</td>
<td>0.30</td>
<td>18</td>
<td>2</td>
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</tbody>
</table>

Most energy: reintroducing reclaimed asphalt into HMA (federal policy)
Least energy: using stabilized reclaimed asphalt in base and RAP in HMA
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**GHG Emissions**

Most emissions: introducing reclaimed asphalt into HMA (federal policy)

Least emissions: using stabilized reclaimed asphalt in base & RAP in HMA

**Life Cycle Cost**

Least expensive: using stabilized reclaimed asphalt (SRPM) in base and RAP in HMA

Most expensive: reclaimed asphalt in hot mix asphalt (HMA)

**Some Take Home Messages**

- Sustainability benefits of recycled materials: reduce energy, resource consumption, emissions, & cost.
- Create longer lasting infrastructure (not a linear landfill). Ensure equivalent or improved with field performance data.
- Perception & reality can be different: conduct quantitative analysis to assess alternatives for recycled materials. Green is not necessarily green, & brown is not necessarily brown.

**Applied Research**

Focus on both mechanical and environmental aspects... information and tools for the roadway designer, the contractor, and the environmental compliance officer.

Provide designer with methodology to use recycled materials in place of conventional materials. For example, developed method for MnDOT to design low volume roads with recycled pavement material (RPM). Validated with full-scale test sections.

Computer tools: PaLate for life cycle assessment and WiscLEACH for environmental suitability.
History of RMRC

• 1st RMRC Center, Univ. of NH, funded by FHWA
• 2nd RMRC, UW-Madison and UNH, pooled fund administered by FHWA
• RMRC-3G - 3rd Generation of RMRC Center
  - Home is UW-Madison
  - Pooled fund by State DOTs and other entities
  - Administered by WisDOT

Who is RMRC?

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Craig H. Benson
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What does the RMRC do?

- Applied research and development - turn concepts into field applications
- Continuing education/technical training on using recycled materials in roadway construction
  - face-to-face workshops
  - webinars
- Clearinghouse for technical information (see www.rmrc.wisc.edu)
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Current Research

Project 47

Stabilization of Reclaimed Pavement Material and Road Surface Gravel with Coal Combustion Project

Conducted by UW, this project is sponsored by the Minnesota Local Roads Research Board (LRRB), with support from the RMRC. This project is evaluating the stabilization of reclaimed pavement materials (RPM) and RAP with CCPs.

- Final Report
  - Rated in Current Research

Project 46

Engineering Properties of RAP and RCA for Unbound Base Course Applications

Conducted by UW, this project will receive $31,000 from the Federal Highway Administration (FHWA). The project will evaluate the properties of unbound materials (RAP and RCA) used as base course and to assess how these materials behave in the field.

- Rated in Current Research

Project 45

Tools

- RAP Hamburger
- RAP KEBAB
- User Guidelines
  - General
  - Materials
  - Quality
  - Notes

Materials

- RAP Hamburger
- RAP KEBAB
- User Guidelines
  - General
  - Notes
Examples of Completed RMRC Projects

ASTM D18.14 Standard Development Activities
- D7762 Design of Stabilization of Soil and Soil-Like Materials with Self-Cementing Fly Ash
- D7760 Method for Measurement of Hydraulic Conductivity of Tire Derived Aggregates Using a Rigid Wall Permeameter
- D7765 Use of Foundry Sand in Structural Fill and Embankments

Updated Beneficial User Guidelines:
- Fly Ash
- Bottom Ash
- Flue Gas Desulphurization (FGD)
- Foundry Sand

Examples of Completed RMRC Projects

- Evaluation of Testing Protocols for the Environmental Assessment of Fly Ash Stabilized Subgrade Materials
- Synthesis of the Use of Crumb Rubber in Hot-Mix Asphalt
- Design System for HMA Containing a High Percentage of RAS Material
- Recycled Asphalt Shingles as Structural Fill
- Cementously Stabilized Layers in Pavement Design and Analysis
- Specifications for Recycled Materials Used as Unbound Base Course

RMRC-3G Partners – FY13

- Colorado
- Georgia
- Illinois
- Minnesota
- Pennsylvania
- Virginia
- Wisconsin
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RMRC-3G

- Currently soliciting research ideas
- TRB – you are welcome to join our welcome reception at TRB!
  - 6:00pm, Marriott Hotel
- For more information, contact:
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Industry Wide Analysis: Coal Combustion Products as Construction Materials

- Coal combustion products: fly ash, bottom ash, flue gas desulphurization (FGD) gypsum
- Construction applications: concrete (fly ash), geotechnical (fly ash, bottom ash), wall board (FGD)
- Considered benefits by offsetting conventional materials and eliminating disposal.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Annual Savings</th>
<th>Equivalent to</th>
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<tbody>
<tr>
<td>Energy (trillion Btu)</td>
<td>159</td>
<td>Annual energy use for 1.7 million households</td>
</tr>
<tr>
<td>Water (billion gal)</td>
<td>32</td>
<td>31% of domestic water withdrawals of CA</td>
</tr>
<tr>
<td>CO₂e (million ton)</td>
<td>11</td>
<td>Removal of 1.9 million passenger cars per year from roadways</td>
</tr>
<tr>
<td>Financial (US $B)</td>
<td>5.1-9.7</td>
<td>Annual full-time salary ($39.5k/yr) of 130,000–240,000 average Americans</td>
</tr>
</tbody>
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