

# Life Cycle Benefits of Using Recycled Materials

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NRRA Conference - February 18, 2016

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## Recycled Materials Resource Center RMRC-3G

- **Recycled Materials in Roadways:  
Improving Sustainability, Quality, and Service Life**
- 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 performs as good or better than natural material.
- **safe** ... ensure material will not adversely impact the **environment or users**.

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## Current RMRC Projects

- ▶ Life Cycle Assessment & Life Cycle Cost Analysis
- ▶ Recycled Materials as Back Fill for Mechanically Stabilized Earth Walls
- ▶ Recycled Material Web Map: Connecting Consumers with Producers
- ▶ RCA Leachate - is this a problem?

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## Two Byproducts → Useful Construction Materials



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

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## Stabilizing RPM with Off-Spec Cementitious Fly Ash at MnROAD

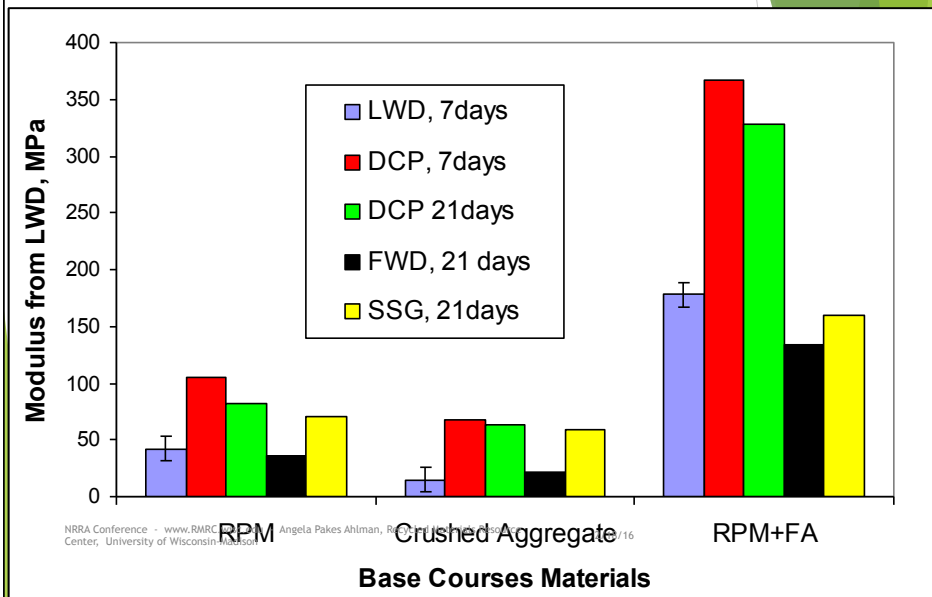


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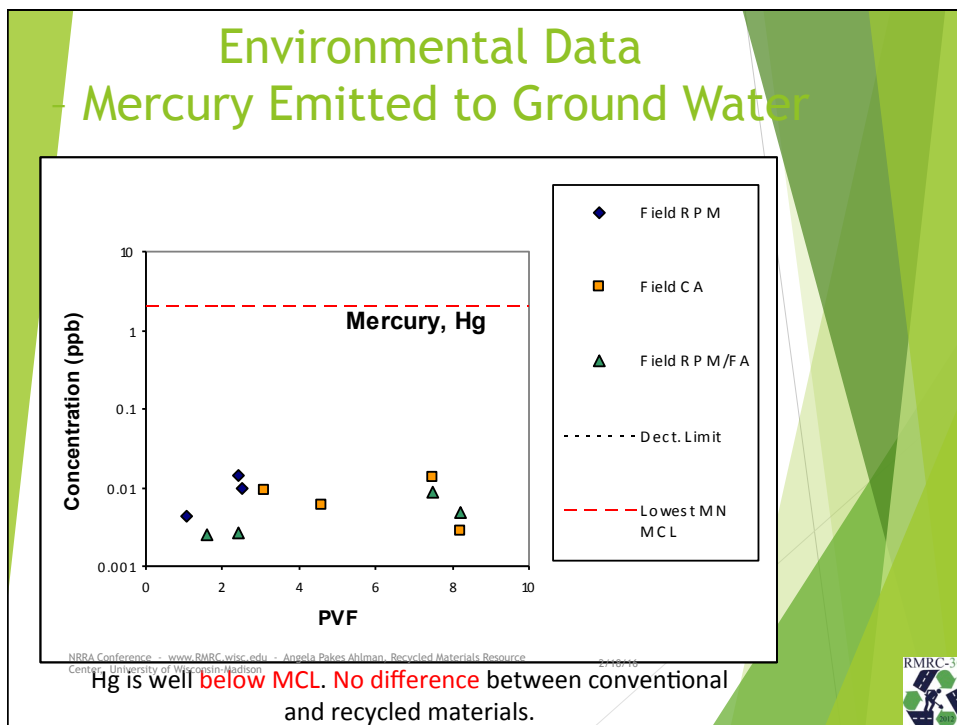


## Safe and Wise: Pavement Performance - Modulus

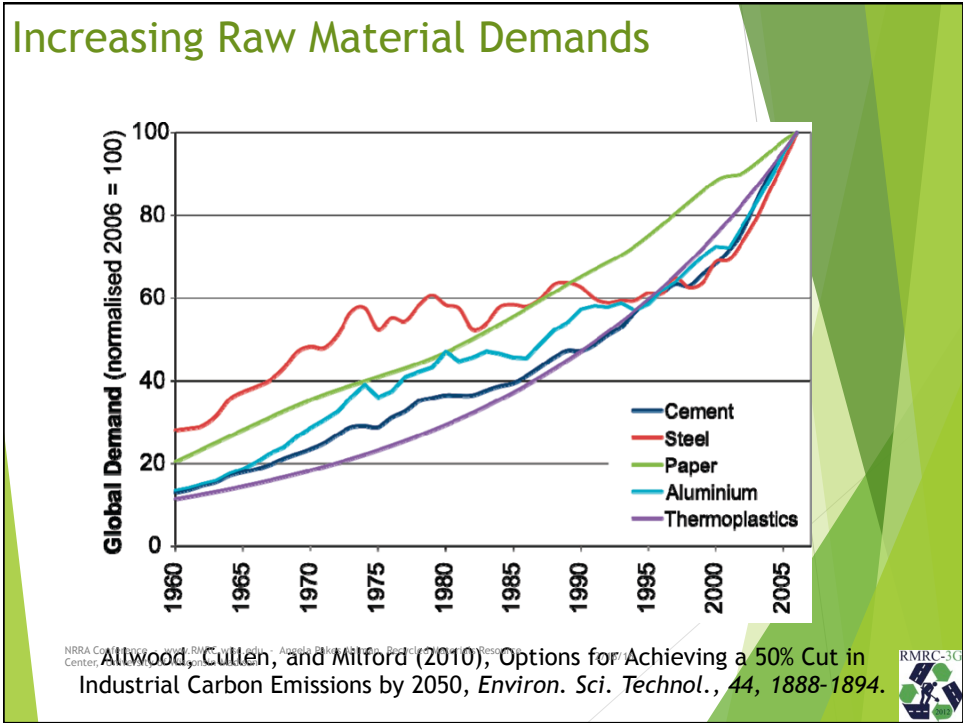


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# Rare Earth Elements

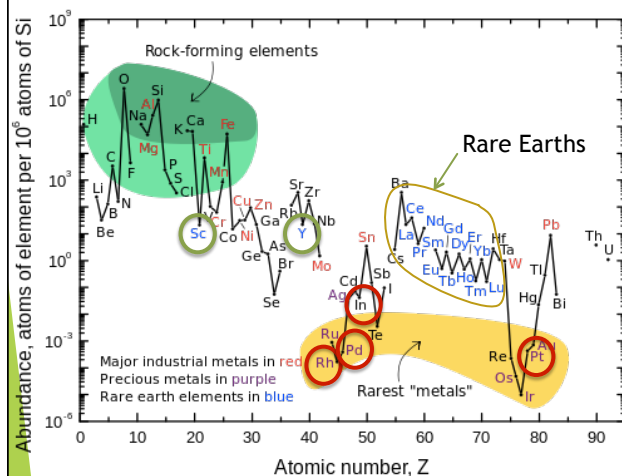
**Periodic Table of the Elements**

Lanthanides - Atomic number between 57-71  
Scandium & Yttrium

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## Why "Rare" Earth Elements



- ▶ Not rare, but not abundant
- ▶ Usually not concentrated in ore, making mining uneconomical in most applications
- ▶ Lack of concentrated sources led to name "rare"
- ▶ Other important rare elements

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## Sustainability & “Rare” Earths

- ▶ Scandium: aluminum alloys for aircraft
- ▶ **Yttrium**: high-temp superconductors, energy-efficient light bulbs
- ▶ **Samarium**: rare-earth magnets (small & powerful - used in hybrids, turbines), lasers
- ▶ Europium: red & blue phosphors, lasers, fluorescent lamps
- ▶ **Dysprosium**: rare-earth magnets (hybrids, wind turbines)
- ▶ **Cerium**: catalytic convertors

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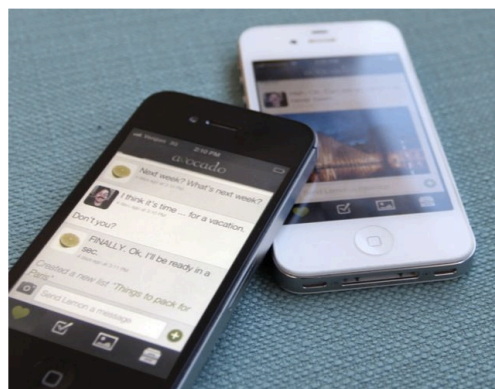


## Other Rare Elements We Use: Smart Phones & Touch Screens

Supply Of The iPhone's Touch Sensitive Coating Is Running Out

Buster Hein (11:42 am PDT, Jul 12th 2013)

f Like (70) t Tweet (76) p 29



- ▶ Indium tin oxide - colorless and electrical conductive coating.
- ▶ Other uses - light emitting diodes, solar cells
- ▶ Charge on skin transmitted to phone, which is recorded & interpreted by circuitry

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**Indium supply expected to be exhausted by 2020**



## Sustainability & Security

- ▶ National security - today we focus on terrorism
- ▶ What are the security issues of the future?
  - ▶ Energy (oil, gas, biofuels, nuclear)
  - ▶ Mined resources (metals, rare earths, etc.)
  - ▶ Climate
- ▶ Why national security?

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## National Security & the State of Maritime Piracy

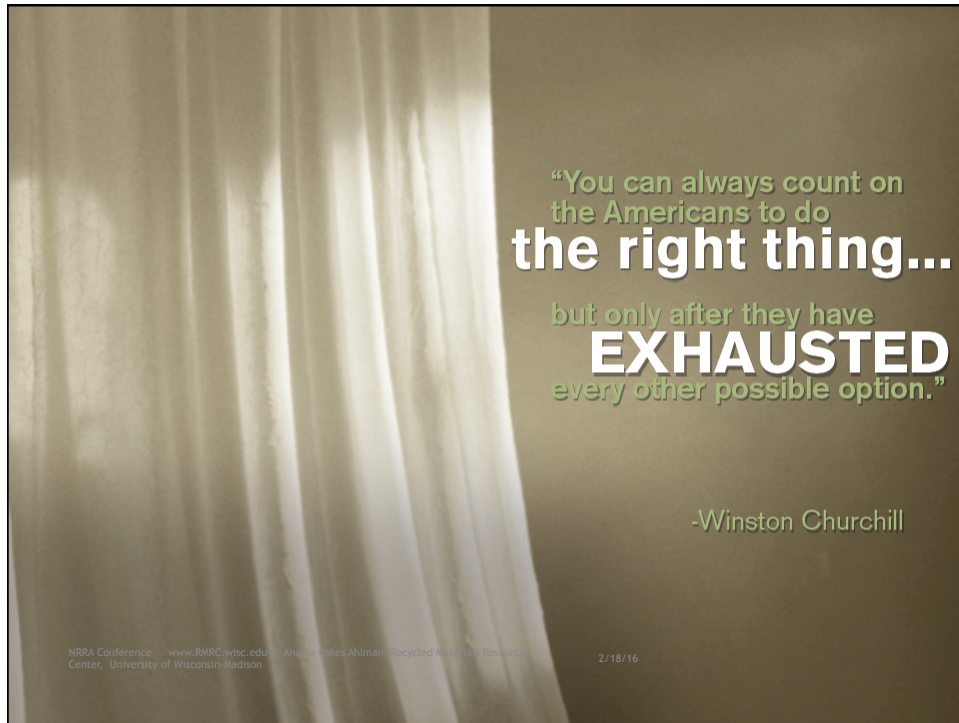
\$500B/year for Persian Gulf patrols  
20% of oil supply - *Stern*, 2010



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## Sustainable Development

- ▶ "Development that meets the needs of the present without compromising the ability of the future generations to meet their own needs."

▶ *Our Common Future*, 1987

## Sustainable Pavement

- ▶ "minimizes the use of energy and renewable resources, while generating a minimum of pollutants, in the most cost-effective manner, while maximizing the benefits to the society."

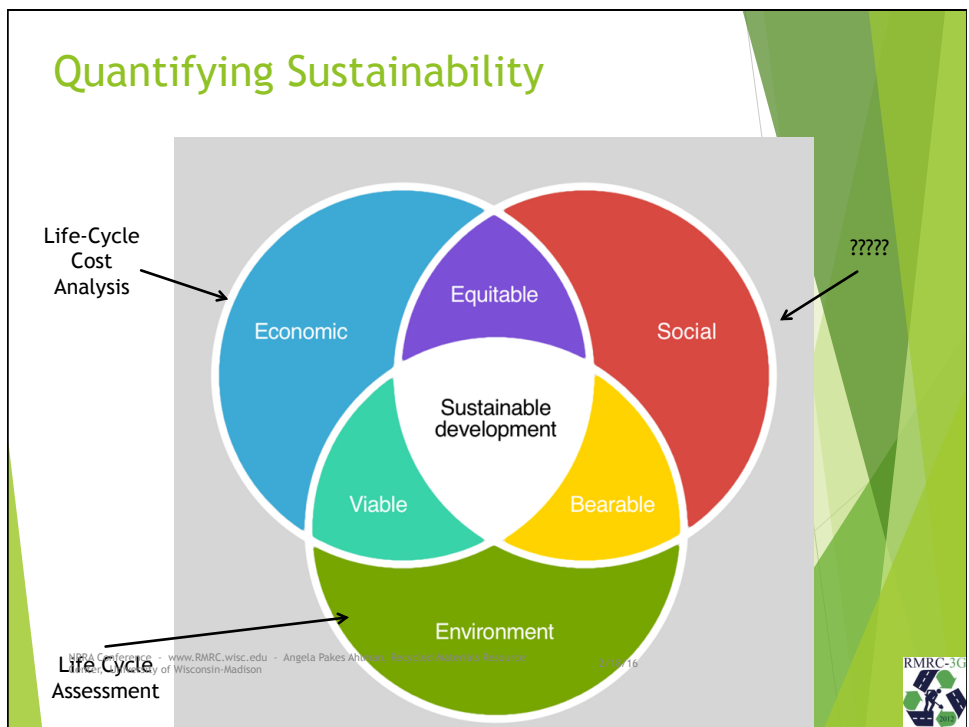
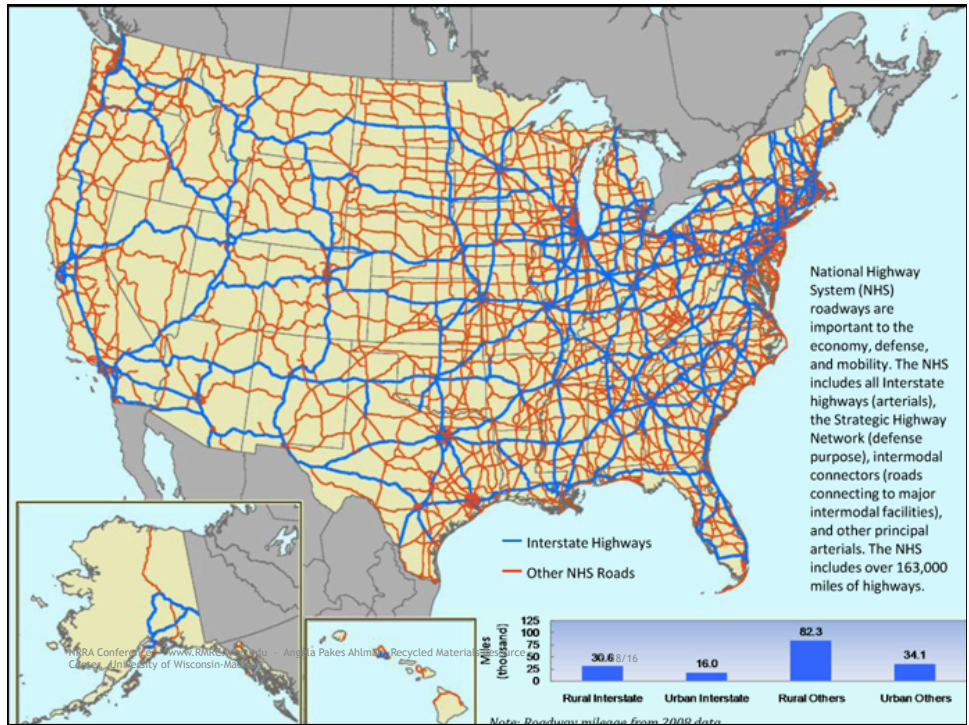
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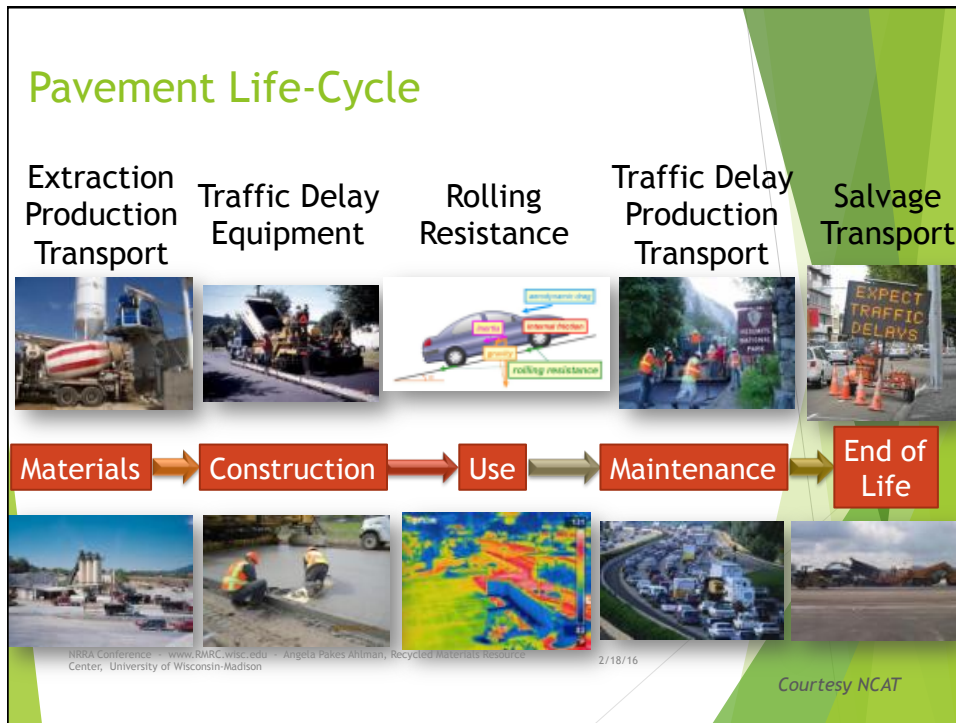
▶ P. Taylor, 2008

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## Objectives

- ▶ State DOTs seeking a quantitative and transparent manner in which to clearly convey the benefits in using recycled materials.
- ▶ Adopt, improve and use a tool to calculate the life cycle benefits associated with incorporating these materials in highway construction.
- ▶ Develop fact sheets on recycled materials and industrial by-products being used in highway construction.

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## Common Recycled Materials

- ▶ Every participating state uses:
  1. Reclaimed Asphalt Pavement (RAP)
  2. Fly Ash
- ▶ Other common materials:
  1. Reclaimed Asphalt Shingles (RAS)
  2. Recycled Concrete Aggregate (RCA)
  3. Crumb Rubber
  4. Tire Derived Aggregate
  5. Bottom Ash
  6. Foundry Sand
  7. Foundry Slag
  8. Iron Slag

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## Example: Materials

- ▶ Life Cycle Analysis
  - ▶ How much energy is required to extract, process, and transport aggregate and asphalt?
  - ▶ How much CO<sub>2e</sub> is produced during this process?
  - ▶ How much energy is used and CO<sub>2e</sub> is produced at the plant?
- ▶ Life Cycle Cost Analysis
  - ▶ How much does it cost to buy the asphalt and the aggregate and produce a mixture?

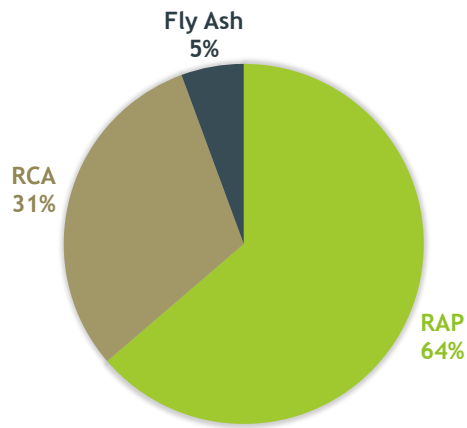
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## 2013 Statewide Data: MnDOT Recycled Material Profile

► Total tons of recycled material: 631,063



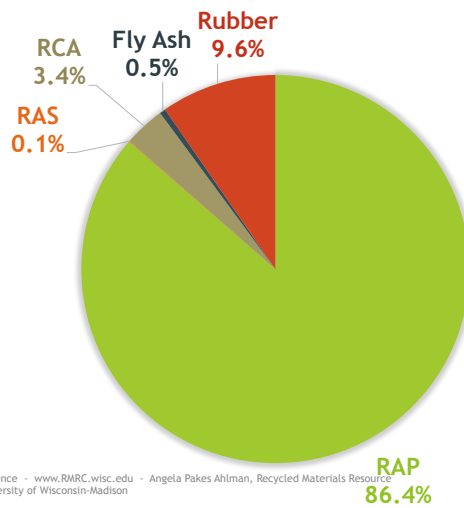
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## 2013 Statewide Data: GDOT Recycled Material Profile

► Total tons of recycled material: 1,736,094



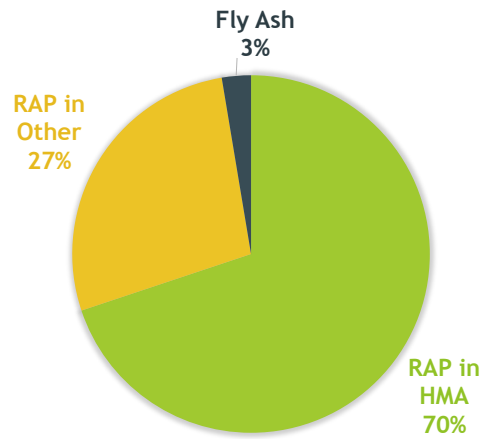
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## 2013 Statewide Data: PennDOT Recycled Material Profile

► Total tons of recycled material: 577,198



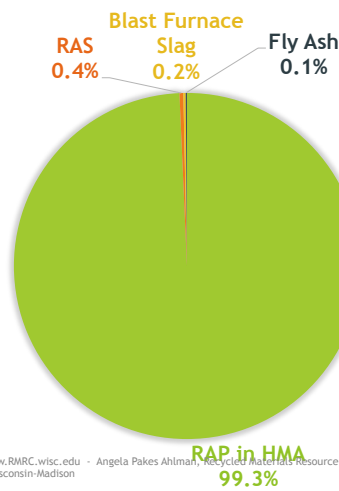
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## 2013 Statewide Data: VDOT Recycled Material Profile

► Total tons of recycled material: 1,051,339

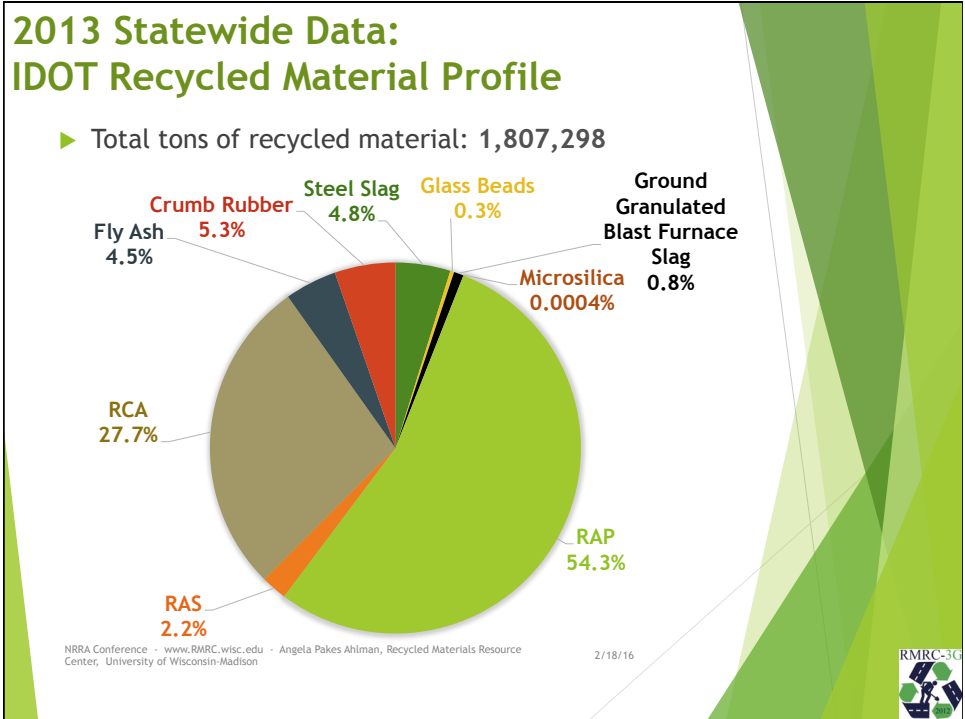
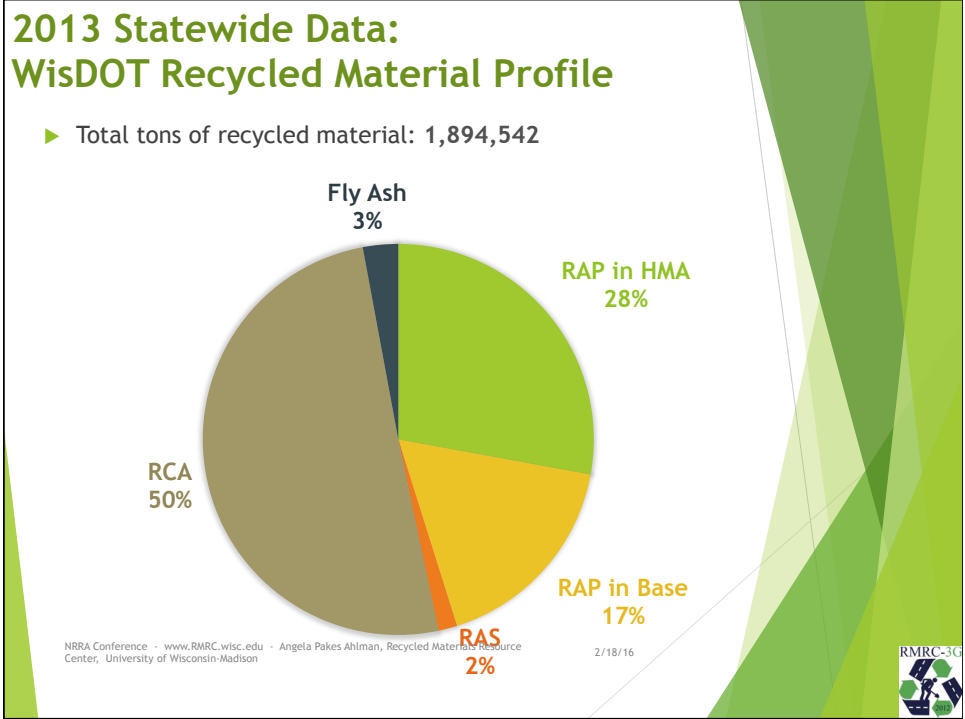


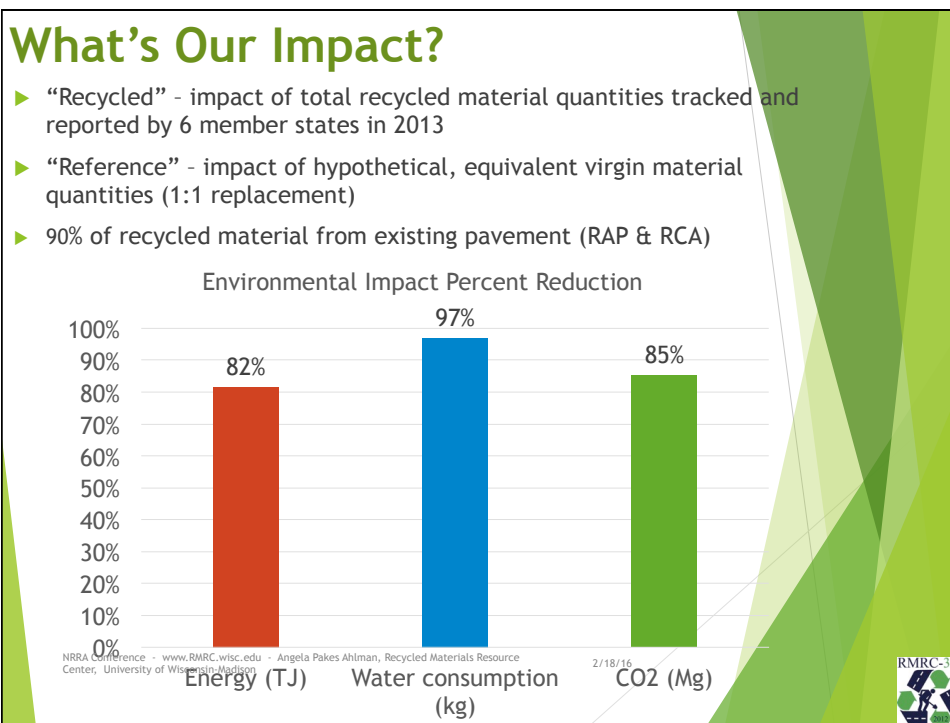
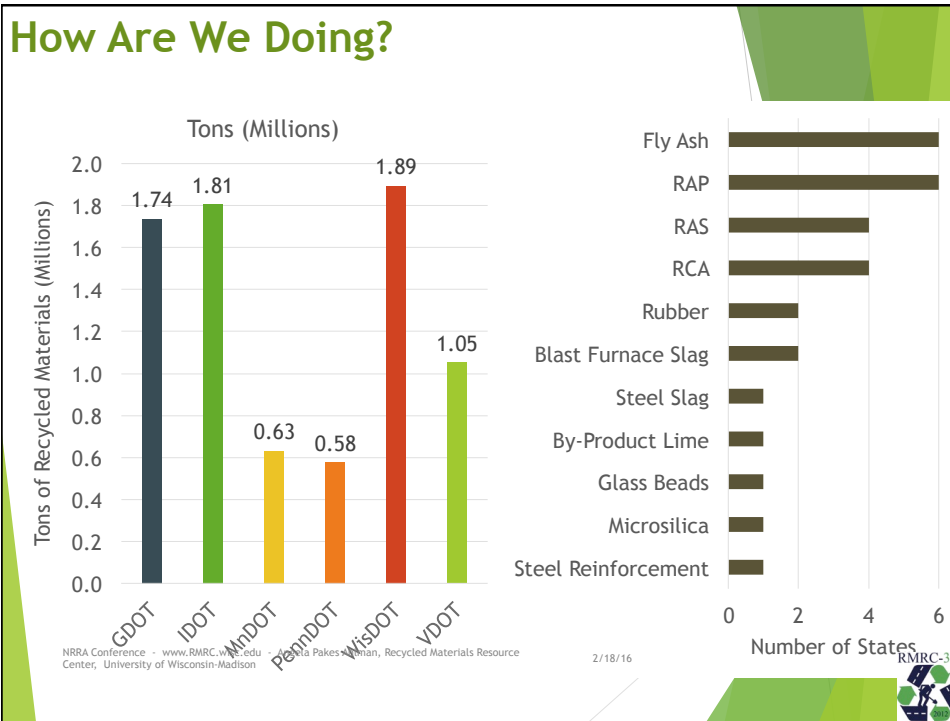
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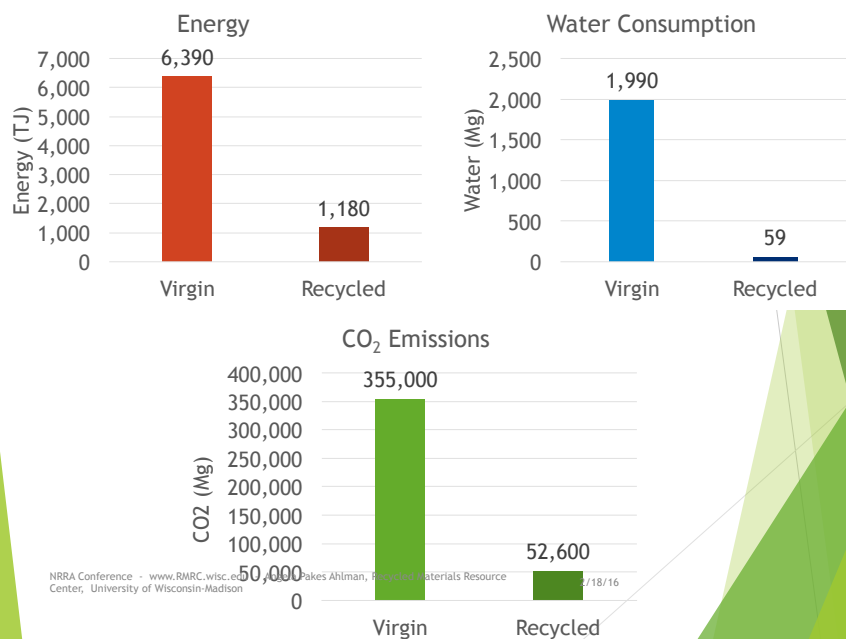








## Quantitative Impact



## Recycled Materials Web Map Connecting Consumers & Producers

- Develop an interactive on-line Recycled Material Web Map and supporting web site
- Producers/suppliers have a tool to ***promote material*** by entering, updating, and maintaining material source information
- Consumers have a tool to ***search for local recycled materials and specifications***

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## Recycled Material Web Map

<http://rmwm.caps.ua.edu/>

**Consumer Search**

1. Select your search options:

State:  
No State Selected

Material Types:

- Select All Material Types
- Waste glass
- Fly ash
- Slag
- Recycled base and crushed aggregate
- Coal Combustion Products
- Geo-foam
- Foundry Sand
- Scrap Tires
- FGD Sludge
- Cement Kiln Dust
- Lime Kiln Dust
- Iron Slag
- Ferrous Slag
- Ferrous Dust
- Scrap Metal

2. Search using selected state/materials

or

3. Click-left-click on the map to do a radius search within 100 miles of where I click.

Providers and Stockpiles

Provider	Contact	Phone	Email	Address	City	State	Zip
Roanoke Quarry	Gary Hubbard	(540) 774-1696		4754 Old Rocky Mount Road	Roanoke	VA	24014
Oak Creek Power Plant					Oak Creek	WI	53154
Valley Power Plant					Minwaukee	WI	53233

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## Web Map Structure

### 4 core layers

- **Providers** - contact info for stockpiles
- **Stockpiles** - material/quantities
- **Regulations/specifications** - search by state, material, and application
- **Case studies** - projects that successfully used recycled materials located on map

## Consumer Search

- 3 ways to filter:
  1. State
  2. Material
  3. Radius search
- Result grid at bottom of page displays selected providers and stockpiles
- Provider/Stockpile information displayed on click

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## Default View and Consumer Search

Recycled Materials Web Map In an admin | Manage Roles | Manage Users | Log Out

Consumer Search

1. Select your search options:

State:

Material Types:

- Select All Material Types
- Waste glass
- Fly ash
- Slag
- Recycled base and crushed aggregate
- Coal Combustion Products
- Geo-foam
- Foundry Sand
- Scrap Tires
- FGD Sludge
- Cement Kiln Dust
- Lime Kiln Dust
- Iron Slag
- Ferrous Slag
- Ferrous Dust
- Scrap Metal

2.  using selected state/materials

or

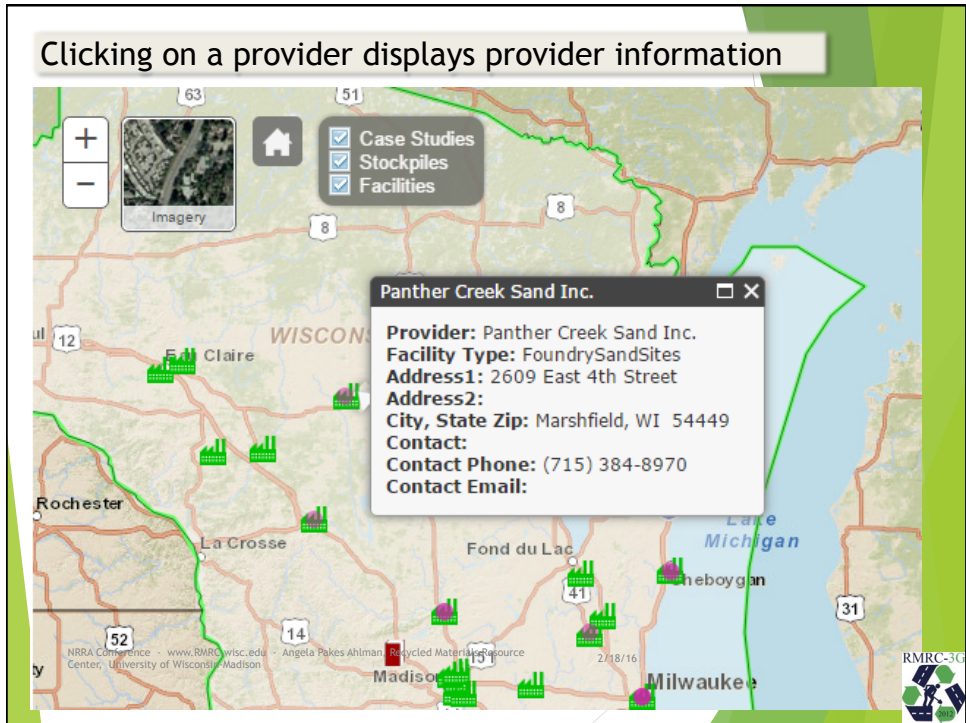
3. Ctr-Left-click on the map to do a radius search within 100 miles of where I click.

Providers and Stockpiles

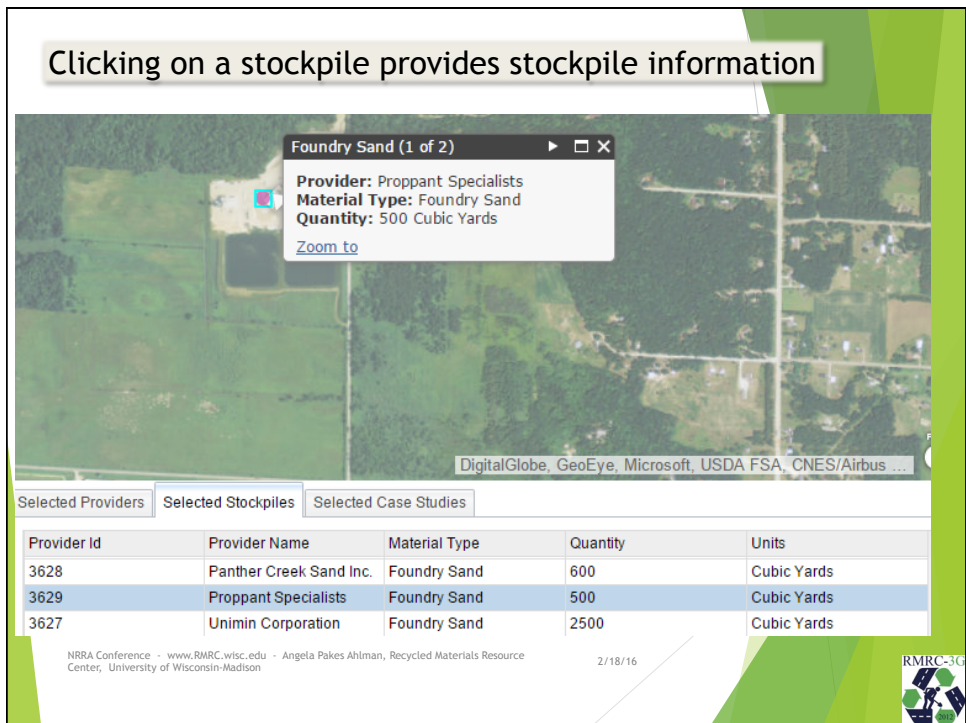
Provider	City	Phone	Email	Address	City	State	Zip	Hours
Roanoke Quarry	Roanoke	(540) 774-1696		4754 Old Rocky Mount Road	Roanoke	VA	24014	M-F 7:00AM-5:00PM
Oak Creek Power Plant	Oak Creek				Oak Creek	WI	53154	Please call RMRC-3G hours



Clicking on a provider displays provider information



Clicking on a stockpile provides stockpile information



### Stockpile Edit - Providers can edit their stockpile information

Recycled Materials Web Map

Consumer Search  
Advanced Search

Providers and Stockpiles

Select Provider  
Valley Power Plant

Add New Provider

Facility: Valley Power Plant  
Address: Milwaukee, WI  
City: Milwaukee  
State: WI  
Contact  
Contact Phone:  
Contact Email:

Find Move Edit Delete

Add New Stockpile

Coal bottom ash  
Comments:  
Quantity: 5000 Cubic Feet  
Find Move Edit Delete

Slag  
Comments:  
Quantity: 50 Tons  
Find Move Edit Delete

Coal Fly Ash  
Comments:  
Quantity: 3000 Cubic Feet  
Find Move Edit Delete

Map Specifications / Regulations Reg-Spec Editor

Case Studies  
Stockpiles  
Facilities

Map Imagery

Lawrence J. Brady Airport  
Glendale  
Whitefish Bay  
Shorewood  
Milwaukee  
West Allis  
Franklin  
Oak Creek  
Caledonia  
Frankville  
Racine  
Sturtevant  
Kenosha Rgn

Edit Stockpiles

Facility: Valley Power Plant

Material: Coal bottom ash

Comments:

Show Quantity

Quantity: 5000

Units: Cubic Feet

Cancel Save

Esri, HERE, DeLorme, IFL, USGS, EPA, RMRC-3G

### New Stockpile - Providers can add a stockpile

Consumer Search  
Advanced Search

Providers and Stockpiles

Select Provider  
Unimin Corporation

Add New Provider

Facility: Unimin Corporation  
Address: 8375 West US Hwy 51  
City: Portage  
State: WI  
Contact  
Contact Phone: (608) 742-2101  
Contact Email:

Find Move Edit Delete

Add New Stockpile

Foundry Sand  
Comments:  
Quantity: 5000 Cubic Yards  
Find Move Edit Delete

Foundry Sand  
Edit Delete  
Comments:  
Quantity: 2500 Cubic Yards

Map Specifications / Regulations Reg-Spec Editor

Case Studies  
Stockpiles  
Facilities

Map Streets

1. Single Click on the map to locate the new stockpile.  
2. Double Click to complete.

Edit Stockpiles

Facility: Unimin Corporation

Material: Foundry Sand

Comments:

Show Quantity

Quantity: 2500

Units: Cubic Yards

Cancel Save

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DigitalGlobe, GeoEye, Microsoft, USDA FSA  
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## Regulations & Specifications

- Collected environmental regulations and DOT specifications for recycled material
  - Reg/specs added for: WI, VA, MN, PA  
AASHTO, EPA, FHWA
  - Will expand to: IL and GA
- Users can search by state, material, and/or application
- Short descriptions appear on-hover
- System will check broken links and default to main website
- Material-Application matrix varies by state

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## Add/Edit Case Study

## Case Study - I-94

**I-94 Reconstruction**  
**State:** WI  
**Year:** 2013  
**Materials Used:** Coal Fly Ash, Reclaimed asphaltic material, Reclaimed concrete material, Coal bottom ash, Foundry Sand  
**Description:** With the goal of quantitatively determining the environmental benefits of using recycled material, the RMRC targeted a one-mile stretch of the Kenosha County portion of the I-94 North-South Freeway Project in Kenosha County, WI. The reconstruction included full depth reclamation of the existing three lanes, and an expansion of one additional lane on each side. In addition to the mainline construction, four ramps were reconstructed and State Highway 142 was re-paved.  
**Documents:** [I-94 SOW.pdf](#)  
[Zoom to](#)

Recycled Materials Web Map  
Consumer Search  
1. Select your search options:  
Search State: Pennsylvania  
Search within 100 miles of where I click  
Search for the following application types:  
 Encapsulated  Unencapsulated  
Search for the following applications:  
 Reclaiming walls (Unencapsulated)  
 Road base material (Unencapsulated)  
 Floating storage granules (Unencapsulated)  
 Stone and no-cement (Unencapsulated)  
 Stabilized base aggregate (Unencapsulated)  
 Structure fill (Unencapsulated)  
Search for the following material types:  
 Coal bottom ash  
 Waste glass  
 Fly ash  
 Slag  
 Recycled base and crushed aggregate  
 Foundry Sand  
2. Left-click on the map to search.

Runs on mobile devices



## Recycled Material as Backfill for Mechanically Stabilized Earth Walls

- **Cost – Effective**
- **Flexible**
- **Feasible > 30m**
- **Eliminates space and material**



### Key Properties

RCA



$$\phi' = 41^\circ$$

$$c' \sim 0 \text{ kPa}$$

$$K = 0.11-1.60 \times 10^{-4} \text{ cm/s}$$

- 140 million tons/yr
- Potential for clogging of drainage

RAP



$$\phi' = 37^\circ$$

$$c' = 55 \text{ kPa}$$

$$K = 1.0 \times 10^{-3} \text{ cm/s}$$

#### Creep behavior: bituminous coating

- 68 million tons/yr
- Engineering properties are temperature sensitive

Recycled Materials Resource





## Leaching of Alkaline Substances and Heavy Metals from RCA Used as Unbound Base Course

- ❑ Recycled Concrete Aggregate (RCA)
  - Demolition of concrete pavement, bridge structures, roadway structures, airport runways
- ❑ Uses
  - Infrastructure backfill; e.g., pavement base course
- ❑ Advantages
  - Excellent mechanical properties
  - Significant life-cycle benefits
  - Widely available and used

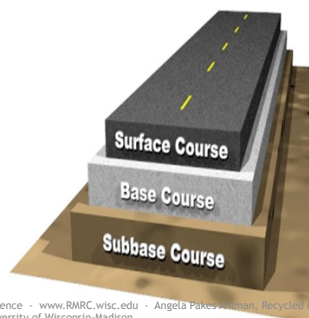


## Problem Statement

- ❑ Environmental Issues
  - High Alkaline Leachate
    - Cement-based material
    - Wide pH range (7.5 to 13) in field studies
  - Leaching of Heavy Metals



Iowa DOT (1999)



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## Problem Statement

### Objectives

- Leaching of alkaline substances and heavy metals
- Different leaching patterns from 'fresh' vs. stockpiled RCA



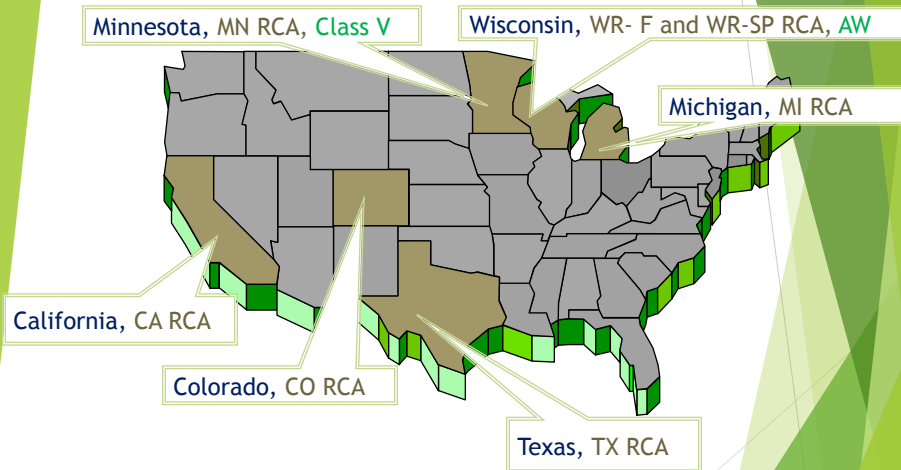
❖ RCA **recement** during stockpile period

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## Materials



• CA, CO, MI, MN and TX RCA were provided by pooled fund project.

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## Materials

Sample	Source	Stockpiled?
MI	Pavement	No
WR-F	Pavement	No
CA	Multiple sources	Yes
CO	Multiple sources	Yes
MN	Pavement	Yes
WR-SP	Building	Yes
TX	Commercial product	Unknown

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## 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.



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## Full Court Press!

- ▶ Educate!
- ▶ More rapidly implement beneficial reuse of materials
- ▶ Permissible use applications
- ▶ Update specs and regs
- ▶ Challenge ourselves with what we think we know:
  - ▶ Why don't we see RCA coming back in the mix design? In some states, has not been seen in 10 years!

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## Looking Ahead

- ▶ Executive Board is seeking new research ideas and partners with research ideas and funds for RMRC-4G!
- ▶ State-Wide Life Cycle Benefits of Recycled Materials - documentation and presentations to DOTs
- ▶ Phase II for Recycled Materials as Back Fill for Mechanically Stabilized Earth Walls - installations and field testing
- ▶ Recycled Material Web Map: Connecting Consumers with Producers - full scale launch
- ▶ Issues associated with high pH leachate from RCA and some fly ashes

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**[angela.pakes@wisc.edu](mailto:angela.pakes@wisc.edu)**

