Recycling Concrete Pavement

Presented by: Tom Cackler
CP Tech Center Representative
Concrete Pavement Reuse and Recycling – Proven Technologies!
Treat RCA As An ENGINEERED Material
PERFORMANCE CAN EQUAL OR EVEN EXCEED VIRGIN MATERIALS
What is Concrete Recycling?

• Breaking, removing and crushing hardened concrete from an acceptable source to produce aggregate.
• Old concrete pavements often are excellent sources of material for producing RCA.
• **Concrete pavements are 100% recyclable!**
Uses of Recycled Concrete Aggregate Nationally

- Used as Aggregate (Base), 65.5%
- Used in Asphalt Concrete, 9.7%
- Use in New Concrete Mixtures, 6.5%
- Used as Fill, 7.6%
- Use as High-Value Rip Rap, 3.2%
- Others, 7.6%
Concrete Recycling: A Proven Technology!

At least 44!

41 of 50 states allow use of RCA in various applications (FHWA, 2004)
Why Recycle? Sustainability!

Triple Bottom Line

- **Social**
  - Conservation of Resources
  - Reduction in Greenhouse Gases (GHGs)

- **Environmental**
  - Energy savings
  - Landfill reduction
    - 50,000 U.S. landfills accepting PCC in 1980
    - 5,000 U.S. landfills accepting PCC in 2000

- **Economic**
  - Capture the “Equity” in existing pavement
  - Can allow contractor to lower projects costs
Additional Benefits: Potential Performance Improvements

- Can provide for more efficient project execution.
- Foundation stability; angular, rough texture and secondary cementing action.
- Concrete strength; partial substitution of RCA for virgin fine aggregate may increase concrete compressive strength.
Key RCA Use: Unstabilized Subbases/Backfill

- Most common RCA application in U.S.
- Application used by 38 of 41 states using RCA in U.S. (FHWA 2004)
  - Some believe it outperforms virgin aggregate as an unstabilized subbase!
- Some level of contaminants is tolerable.
RCA Subbase Example: Illinois Tollway

- Congestion Relief and Move Illinois Programs (2008 – 2016)
  - 3.4M tons of recycled concrete aggregate used in base
    - RCA material cost savings: $20,530,000
    - Hauling cost saved (@$7.50/ton): $25,500,00
    - Reduced haul fuel consumption: 529,000 gals
    - 12,258,000 lbs of CO$_2$ not emitted!

Source: Steve Gillen (Illinois Tollway) from 2016 Internal Tollway Document
Key RCA Use: Concrete Mixtures

- Used in the U.S. concrete mixtures for many applications since the 1940s
- RCA can be (and has been) incorporated as the primary or sole aggregate source in new concrete pavements.
- Use in two-lift construction is common in Europe, growing in U.S.
  - Austrian standard practice for 30+ years
  - U.S. Demo projects and Illinois Tollway
Reconstruction Example: Texas I-10

- Houston, TX between I-45 & Loop 610W
- 1995 Reconstruction – 6 CL miles
- Original CRCP built in 1968
- 10 Lanes + HOV

No Virgin Aggregates Used for New Concrete:

100% RCA (Coarse & Fine)

Original

<table>
<thead>
<tr>
<th>CRCP</th>
<th>CSB</th>
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<tbody>
<tr>
<td>8&quot;</td>
<td>6&quot;</td>
</tr>
</tbody>
</table>

Reconstruct and Unbonded Overlay

<table>
<thead>
<tr>
<th>CRCP</th>
<th>ASB</th>
<th>LTS</th>
<th>BB</th>
</tr>
</thead>
<tbody>
<tr>
<td>14&quot;</td>
<td>3&quot;</td>
<td>6&quot;</td>
<td>1&quot;</td>
</tr>
</tbody>
</table>

2007 Photo
D-Crack Reconstruction Example: US 59, Worthington, MN

- 1st major recycle of “D-cracked” concrete into new concrete
- Original 1955 pavement – 16 centerline miles reconstructed in 1980
  - 100% coarse RCA (3/4-in top size) used in new pavement
  - Fines used for 1-in cap on subbase
  - Edge drains added
  - 3000+ vpd, ~8 percent heavy commercial

- Rehabilitated in 2000 – DBR, grind, reseal joints
- **No recurring D-cracking**

MnDOT estimated savings of 27% total project costs and 150,000 gallons of fuel.
ASR Reconstruction Example:
I-80, Pine Bluffs, Wyoming

• 1985 Reconstruction:
  • 65 percent coarse RCA, 22% fine RCA
  • Low-alkali (<0.5%) cement, 30% Class F flyash, w/c = 0.44
  • 4400 ADT in 1985 (30 - 40% heavy)

• 2004 Rehabilitation:
  • DBR, grind, joint reseal

• 2006 ADT: 8000 vpd (30-40% heavy)

  • No significant evidence of recurring ASR until recently.
Iowa RCA Uses

- Coarse aggregate in Pavement
- Base materials
  - Granular Sub base (GSB)
  - Modified Sub base
  - Special Backfill
- Rip Rap
Recycled PCC as Aggregate - 1977

- US 75 Lyon Co.
- IA 2 Taylor Co.
- I-680 Pott.
Recycled PCC in Pavement

US 75 Lyon County – Resurfaced 2008
Recycled PCC in Pavement

IA 2 Taylor County – Resurfaced 2011
Recycled PCC in Pavement

I-680 Pott County Resurfaced 1997  Rebuilt 2011
Recycled PCC as Subbase
Stationary Crushing Prior to 1993

- Rubblized pavement hauled to plant site, crushed, then hauled back to construction site
- Safety Issues
- Haul road damage
Mobile Crushing (Paradigm)

- Concrete broken, crushed, and recycled in same spot
- In 1995 Estimated over $800,000 saved on a single 14 mile project
History Granular Sub Base for PCC

- 2006: Eliminated screened fines (15% passing #200) from PCC crushing process 2 inch layer at the bottom.
  - *What is Tufa??*
    - \( \text{H}_2\text{O} \) \( \text{CO}_2 \)
    - \( \text{CaO} \Rightarrow \text{Ca(OH)}_2 \Rightarrow \text{CaCO}_3 + \text{H}_2\text{O} \)
Effect of screened fines 2 inch layer?
Production of RCA

• Typical steps:
  - Evaluation of source concrete.
  - Pavement preparation.
  - Pavement breaking and removal.
  - Removal of embedded steel.
  - Crushing and sizing.
  - Beneficiation.
  - Stockpiling.
Evaluation of Source Concrete

Known sources vs. unknown sources?
Iowa DOT & Sudas Requirements

Materials Issues - Approval

• Reclaimed from Interstate or Primary roadway pavement - certified based on gradation testing
• Secondary roads or municipal may be used if aggregate source is Class 2 or better durability - certified based on gradation testing
• Unknown secondary or municipal source - certified based on quality requirements for crushed stone and gradation requirements
Pavement Preparation

RCA for concrete mixtures might require more pavement preparation than for other uses.

- Removal of joint sealant:
  - Cutting tooth sealant plow
  - Removal during production

- Removal of asphalt patches, overlays and shoulders?
  - Some European countries allow up to 30% RAP in new concrete paving mixtures (two-lift construction).
  - IL Tollway use of FRAP in two-lift paving
Pavement Breaking

- Main purpose: size material for ease of handling, transport – typically 18 – 24 inches, max dimension
- Also aids in debonding concrete and any reinforcing steel.
- “Impact breaker” is most common breaking method.
- Production: 1,000+ yd²/hr
Pavement Breaking and Removal
Removal of Embedded Steel

• Typically during break-and-remove
• Can also follow crushing operations
  – Electromagnets
  – Manual removal
• Standard crushing, sizing and stockpiling equipment.
• Yield loss = 0 – 10% (varies with many factors).
• Three main crusher types: jaw, cone, and impact.
  – Tell contractor desired gradation/result
  – Contractor to select crushing process for desired gradation and material properties.
Environmental Challenges from Crushing Concrete

- Silica dust (concrete)
- Asbestos (demolition debris – not paving PCC)

Example concrete crushing dust suppression system (photo courtesy of Duit Construction).
Beneficiation

• “The treatment of any raw material to improve its physical or chemical properties prior to further processing or use.”
  - Examples: removal of organic material, excessive dust, or other contaminants from RCA prior to use.

• Example beneficiation techniques:
  - Change crushing processes
  - Washing, wet or dry screening, etc.
  - Air blowing
  - Water floating or “heavy media separation” techniques.

• Degree of beneficiation required depends upon condition/composition of RCA and its intended use.
Stockpiling

- Stockpile coarse RCA using same equipment, techniques as for virgin material.
- Protect fine RCA stockpiles from moisture
  - Secondary cementing
- RCA stockpile runoff is initially highly alkaline
  - Leaching of calcium hydroxide
  - Runoff alkalinity rapidly decreases
### Properties of RCA

<table>
<thead>
<tr>
<th>Property</th>
<th>Virgin Agg.</th>
<th>RCA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shape and Texture</strong></td>
<td>Well-rounded; smooth to angular/rough</td>
<td>Angular with rough surface</td>
</tr>
<tr>
<td><strong>Absorption Capacity</strong></td>
<td>0.8% – 3.7%</td>
<td>3.7% – 8.7%</td>
</tr>
<tr>
<td><strong>Specific Gravity</strong></td>
<td>2.4 – 2.9</td>
<td>2.1 – 2.4</td>
</tr>
<tr>
<td><strong>L.A Abrasion</strong></td>
<td>15% – 30%</td>
<td>20% – 45%</td>
</tr>
<tr>
<td><strong>Chloride Content</strong></td>
<td>0 – 2 lb/yd³</td>
<td>1 – 12 lb/yd³</td>
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# Fresh (Plastic) Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Coarse RCA, Natural Fines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workability</td>
<td>Similar to slightly lower</td>
</tr>
<tr>
<td>Finishability</td>
<td>Similar to more difficult</td>
</tr>
<tr>
<td>Water bleeding</td>
<td>Slightly less</td>
</tr>
<tr>
<td>Water demand</td>
<td>Greater</td>
</tr>
<tr>
<td>Air content</td>
<td>Slightly higher</td>
</tr>
</tbody>
</table>
# Hardened Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Coarse RCA, Natural Fines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength</td>
<td>0% to 24% less</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>0% to 10% less</td>
</tr>
<tr>
<td>Strength variation</td>
<td>Slightly greater</td>
</tr>
<tr>
<td>Modulus of elasticity</td>
<td>10% to 33% less</td>
</tr>
<tr>
<td>CTE</td>
<td>0% to 30% greater</td>
</tr>
<tr>
<td>Drying shrinkage</td>
<td>20% to 50% greater</td>
</tr>
<tr>
<td>Permeability</td>
<td>0% to 500% greater</td>
</tr>
</tbody>
</table>
Hardened Properties

Compressive Strength of Various Aggregate Mixes

- Virgin Coarse Agg./Virgin Fine Agg.
- Virgin Coarse Agg./Fine RCA
- Coarse RCA/Virgin Fine Agg.
- Coarse RCA/Fine RCA

Compressive strength (MPa) vs. Age (days)
## Durability and Other Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Coarse RCA, Natural Fines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeze-thaw durability</td>
<td>Depends on air voids</td>
</tr>
<tr>
<td>Sulfate resistance</td>
<td>Depends on mixture</td>
</tr>
<tr>
<td>ASR</td>
<td>Less susceptible</td>
</tr>
<tr>
<td>Carbonization</td>
<td>Up to 65% greater</td>
</tr>
<tr>
<td>Corrosion rate</td>
<td>May be faster</td>
</tr>
</tbody>
</table>
Summary

- Concrete recycling is a proven, sustainable technology for producing aggregate.
- **Consider RCA an “engineered material”; test thoroughly.**
- Consider adjustments to pavement design and/or concrete mixture design, as needed.
- **Performance of pavements constructed using RCA is generally good.**
Resources: ACPA EB043P

- Production of RCA
- Properties and Characteristics of RCA
- Uses of RCA
- Properties of Concrete Containing RCA
- Performance of Concrete Pavements Constructed Using RCA
- Recommendations for Using RCA
- Appendices
Resources – CP Tech Center

- Recycling Concrete Pavement Materials, A Practitioners Reference Guide
- Tech Briefs
  - Introduction to RCA
  - Environmental Considerations
- Webinar Series
  - Introduction to Recycling
  - Environmental considerations
  - Construction considerations
  - Case Study Experience
- Website
Acknowledgments

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Questions and Discussion