Concrete Pavement Reuse and Recycling – Proven Technologies!

Presented by:
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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

- 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!

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

- Conservation of resources
- Landfill reduction
- Energy savings
- Economics

Reduction of greenhouse gases (GHGs).
Additional Benefits: Potential Performance Improvements

- 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.
Recommendations: Use in Subbases

• AASHTO M319
• Quality requirements (Saeed and Hammons, 2008)
  – Micro-Deval, Tube Suction, Tri-axial and Resilient Modulus tests
  – Criteria vary with design traffic, climate and moisture
• Grade according to subbase function
  – Free-draining? Dense-graded?
  – See ACPA EB204P
Recommendations:
Pavement Structural Design

• RCA Subbase:
  – Consider possible stiffening of RCA subbase and adjust panel length, thickness as required.
  – *No structural problems have been reported with the use of RCA in foundation layers.*
Usually not a problem when RCA is used in undrained layers or below drained layers.
Preventing Drainage Structure Clogging

- Minimize use of RCA fines.
- Crush to eliminate reclaimed mortar
- Blend RCA and virgin materials
- Use largest practical RCA particle sizes.

- Consider washing RCA to reduce insoluble residue (crusher dust) deposits.
- Use high-permittivity fabric
- Wrap trench, not pipe
- Consider daylighted subbase
Key RCA Use: Concrete Mixtures

• Many U.S. concrete mixture applications since the 1940s
• RCA can be used 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
RCA in Concrete Mixtures

• Batching, mixing, delivery, placement and finishing techniques can be conventional.

• Concerns with water demand and premature stiffening:
  – Limit or eliminate fine RCA
  – Presoak RCA
  – Chemical and mineral admixtures

• *Properties of RCA PCC may differ from conventional PCC.*
Recommendations: Pavement Structural Design

RCA Concrete Pavement:
- Consider CTE and shrinkage.
  - Adjust panel length?
  - Adjust sealant reservoir dimensions and sealant materials?
  - Higher reinforcing quantities (CRCP, JRCP)?
- Reduced aggregate interlock potential
  - Use dowels for better load transfer
- Evaluate abrasion resistance (surface friction and wear).
Recommendations: RCA in Mixture Design

• AASHTO MP16-13
• Quality Requirements and Properties
  – Generally the same as for PCC with virgin aggregate
  – Exception: sulfate soundness (unreliable for RCA)
• Materials-Related Distress
  – Alkali-silica reactivity mitigation
    • Lithium, Class F fly ash and/or slag cement, limit RCA fines
    • Reduce water access (joint sealing, drains, etc.)
  – D-cracking mitigation
    • Reduce coarse aggregate top size
    • Reduce moisture exposure
Recommendations: RCA in Mixture Design Proportioning

• Consider Specific Gravity and Absorption Capacity.
• Consider higher strength variability.
• To maintain workability, add 5 – 15% water.

OR

• Use admixtures (chemical and/or mineral).
• Verify air content requirements (adjust for air in reclaimed mortar).
• Trial mixtures are essential.
Performance of Pavements Constructed using RCA in PCC

There have been a few notable (and well-publicized) failures ....

Deterioration of mid-panel cracks in JRCP
Design issues (undoweled joints, panel length, foundation type, etc.)

.... but performance has generally been very good!
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

8” CRCP
6” CSB

14” CRCP
3” ASB
6” LTS

Reconstruct and Unbonded Overlay

11” CRCP
1” BB
RCA Subbase Example: Illinois Tollway

- 32-miles of I-88 Extension (2005)
  - Rubblized in place as base for new PCCP
  - $29.5 million savings (2015 dollars)
    - Elimination of excavation, reduced purchase and haul of natural aggregate, reduced thickness over stiffer base

- 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 CO₂ not emitted!
D-Crack Reconstruction Example:
US 59, Worthington, MN

• 1st major recycle of “D-cracked” concrete into new concrete
• 1955 pavement – 16 CL 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

• 2000 rehab: 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).
Production of RCA – Typical Steps

Typical steps:

– Evaluation of source concrete.
– Pavement preparation.
– Pavement breaking and removal.
– Removal of embedded steel.
– Crushing and sizing.
– Beneficiation.
– Stockpiling.
Known sources vs. unknown sources?
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.
• 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:
  – 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>Shape and Texture</td>
<td>Well-rounded; smooth to angular/rough</td>
<td>Angular with rough surface</td>
</tr>
<tr>
<td>Absorption Capacity</td>
<td>0.8% – 3.7%</td>
<td>3.7% – 8.7%</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>2.4 – 2.9</td>
<td>2.1 – 2.4</td>
</tr>
<tr>
<td>L.A Abrasion</td>
<td>15% – 30%</td>
<td>20% – 45%</td>
</tr>
<tr>
<td>Chloride Content</td>
<td>0 – 2 lb/yd³</td>
<td>1 – 12 lb/yd³</td>
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</tbody>
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Properties of Concrete with RCA

(Hint: it’s all about the mortar ...)

Recycled  Control
# 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>
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## Hardened PCC 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>
## 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 Deployment Plan

• Describes barriers to implementation (perceptions, lack of experience, risk, etc.)
• Recommends approaches to overcoming them.
• Also: FHWA Technical Advisory TT 5040.37: Use of Recycled Concrete Pavement as Aggregate in Hydraulic-Cement Concrete Pavement
Acknowledgments

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