Recycling Concrete Pavements

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ACPA National: Who are we?

A Unified Voice for the Concrete Pavement Industry!

- Recent Refocusing Effort
- National Core Mission
- Efficient and Effective Delivery of Strategic Goals with Partners
  - Chapters
  - Agencies
  - Cement Industry
  - CPTech Center
ACPA: Re-Focused and Fine-Tuned

A Unified Voice for the Concrete Pavement Industry!
Advocating for INRASTRUCTURE INVESTMENT in Washington
Providing GUIDANCE for concrete pavement
Developing TOOLS for the betterment of the concrete pavement industry (apps.acpa.org)
Delivering TRAINING and certification programs
Guide RESEARCH and deployment

THANK YOU for your support!
Talking Points

- Introduction
- Production of RCA
- Properties of RCA
- Uses of RCA
- Properties of Concrete with RCA
Recycling Concrete Pavements

INTRODUCTION
What is Concrete Recycling?

- Breaking, removing and crushing hardened concrete from an acceptable source.
- Recycled concrete aggregate (RCA) can be produced as a substitute for virgin aggregate in almost any application.
- Old concrete pavements are excellent sources of material for producing RCA.
- Concrete pavements are 100% recyclable!
What is Concrete Recycling?

- What is the most recycled material in the US?
  - CONCRETE, according to Construction Materials Recycling Association (2008)

Did you know that 140 million tons of concrete are recycled each year in the United States alone?
Why Recycle Concrete Pavements?

Source:
U.S. Geological Survey

National aggregates production in the United States with projections to 2020, based on growth rate of 1.0% for stone and 0.5% for sand and gravel.
Aggregate costs often comprise between 20 and 30 percent of the cost of materials and supplies.

Virgin aggregate costs are increasing due to scarcity, environmental concerns, zoning, increased haul distances, etc.

Cost of concrete demolition, removal, and hauling is required whether pavement is recycled or discarded.

Some states have estimated savings of up to 60% when using RCA in lieu of virgin aggregates; a savings of about $4.00 per square yard.

CalTrans saved $5 million on just one project on I-5!
Conservation of virgin resources; EPA: “increasing the recycling and beneficial use of industrial materials” is one of the four national priorities of the Resource Conservation Challenge.

Replacing one-lane mile of 10” thick concrete pavement requires approx. 3,000 tons of aggregate; the existing 10” pavement can be recycled into approx. 4,000 tons of RCA, more than enough to satisfy the demand of the reconstruction.
Sustainability Issues (cont.)

- Landfill reduction.
- Energy savings.

- Reduction of greenhouse gases (GHGs).
Sustainability Issues (still cont.)

- Carbon sequestration through RCA carbonation.

Source:
Recycled Materials Resource Center
Pavement Performance Improvements

- Foundation stability; angular, rough texture and secondary cementing action.
- Concrete strength; substitution of RCA for virgin aggregate can potentially increase strength.
- A proven technology; 41 states allow RCA to be used in applications such as subbases, paving layers, rip-rap, embankment, etc.
FHWA’s Perspective

“…reusing the material used to build the original highway system…makes sound economic, environmental, and engineering sense…”

“The engineering feasibility of using recycled materials has been demonstrated in research, field studies, experimental projects and long-term performance testing and analysis… When appropriately used, recycled materials can effectively and safely reduce cost, save time, offer equal or, in some cases, significant improvement to performance qualities, and provide long-term environmental benefits…”
Recycling Concrete Pavements

PRODUCTION OF RCA
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
Pavement Preparation

- Intended use of RCA must be determined first.
- RCA for concrete mixtures might require more pavement preparation than for other uses.
- Joint sealant can be removed with cutting tooth sealant plow; some agencies just rely on other means of removal in the production process.
- Asphalt patches/overlays may or may not need to be removed; some European countries allow up to 30% RAP in new concrete paving mixtures.
- Deteriorated asphalt shoulders should be removed prior to breaking operations on reconstruction projects.
Pavement Preparation
Pavement Breaking and Removal

Main purpose is to size the material for ease of handling and transport to the crushing plant.
- Broken into pieces about 18 to 24 in. max.

Also should impart enough energy to maximize debonding of concrete to any reinforcing steel.

The “impact breaker” is the most common breaking method.
Pavement Breaking and Removal

1,000+ yd²/hr
Pavement Breaking and Removal

- The first step in the removal process is to loosen the concrete pieces and separate any debonded reinforcing steel.
- Where steel mesh reinforcing or rebar are present and have not been broken or separated from the concrete, a “rhino horn” is used.
Pavement Breaking and Removal

- Front-end loaders and dump trucks can easily handle removal and transport of the broken pavement fragments to the crushing site.
Removal of Embedded Steel

- Removal of reinforcing steel, tie bars and dowels can occur during several phases of the recycling process.
- Typically is accomplished during the breaking and removal operation but can follow the primary and secondary crushing operations, where electromagnets often are used to pick steel from the conveyor belts.
Crushing and Sizing

- The same basic equipment used to processes virgin aggregates also can be used to crush, size and stockpile the RCA.
- Yield depends on many factors but loss of material can be as high as 10% and may approach 0%.
- Primary crusher reduces to 3” to 4”; material then screened and anything larger than 3/8” fed to secondary crusher, which breaks to the desired RCA top size.
- Three main types of crusher: jaw, cone, and impact.
Crushing and Sizing

Jaw Crusher
- Broken concrete feed
- Jaw break plate
- Stationary jaw
- Swing jaw
- Discharge

Cone Crusher
- Broken concrete feed
- Breaking plates
- Cone
- Eccentric rotation
- Discharge

Mostly primary...
Mostly secondary...
Crushing and Sizing

Vertical Shaft Impact Crusher

- Rotor/impellers
- Broken concrete feed
- Impact break plate
- Rotation
- Crushed concrete discharge

Horizontal Shaft Impact Crusher

- Primary break plate
- Secondary break plate
- Rotor/blow bars
- Discharge
- Broken concrete feed
Crushing and Sizing
Beneficiation is the treatment of any raw material to improve its physical or chemical properties prior to further processing or use.

- Might need to remove accidentally included material such as organic material, excessive dust, or other contaminant from the RCA prior to use.
- Might change crushing processes, washing, wet or dry screening, etc. or even employ air blowing or water floating techniques.
- Degree of beneficiation required depends upon condition/composition of RCA and its intended use.
Stockpiling

- Coarse RCA can be stockpiled using the same techniques and equipment as are used with virgin coarse aggregate materials.
Fine RCA stockpiles generally need to be protected from precipitation to reduce the potential for secondary cementing due to hydration of exposed and previously unhydrated (or partially hydrated) cement grains.

The runoff from RCA stockpiles is initially highly alkaline due to the leaching of calcium hydroxide from the freshly crushed material but several studies have found that runoff alkalinity rapidly decreases, thus, there are no negative environmental effects from RCA use that would significantly offset the positive environmental effect of reduced use of virgin aggregate and landfills.
In-Place Concrete Recycling

When RCA is to be used in a subbase layer of the roadway and/or shoulders, production can be accomplished using an in-place concrete recycling train.
## Properties of RCA

<table>
<thead>
<tr>
<th>Property</th>
<th>Virgin Aggregate</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>Sodium Sulfate</td>
<td>7% – 21%</td>
<td>18% – 59%</td>
</tr>
<tr>
<td>Magnesium Sulfate</td>
<td>4% – 7%</td>
<td>1% – 9%</td>
</tr>
<tr>
<td>Chloride Content</td>
<td>0 – 2 lb/yd³</td>
<td>1 – 12 lb/yd³</td>
</tr>
</tbody>
</table>
Properties of RCA

- RCA from D-cracked concrete?
- RCA from ASR affected concrete?
- Concerns of surface dust/contaminants?
Recycling Concrete Pavements

USES OF RCA
Uses of RCA

- Unstabilized (granular) subbase/backfill
- Cement-stabilized subbase
- Concrete mixtures
- Asphalt paving mixtures and asphalt-treated subbases
- Other applications
Unstabilized Subbases/Backfill

- Unstabilized/granular subbase and backfill applications are common for RCA made from concrete pavements.
- Of the 41 states indicating their production of RCA in 2004, 38 stated that they use the material for aggregate subbase applications and some believe it outperforms virgin aggregate as an unstabilized subbase!
- Some level of contaminants is tolerable.
Cement-stabilized Subbases

- Cement-treated subbases (CTB) and lean concrete subbases (LCB) also can be constructed using RCA.
- The stabilization with additional cement/water helps prevent the migration of crusher fines and dissolution and transport of significant amounts of calcium hydroxide.
- Physical and mechanical properties of the RCA must be considered in the design and production of cement-stabilized subbases.
Concrete Mixtures

- RCA can be (and has been) incorporated as the primary or sole aggregate source in new concrete pavements.
- Used in the U.S. since the 1940’s for roadway surfaces, shoulders, median barriers, sidewalks, curbs and gutters, building/bridge foundations and even structural concrete.
- The use of RCA also is common in the lower lift of two-lift concrete pavements in Europe.
RCA in Concrete Pav’s

- ODOT allowed contractor to salvage old PCC for CA in new pavement
- 22 years after completing the work, ODOT has identified no distress associated with the RCA coarse aggregate
Concrete Mixtures (cont.)

- Techniques for batching, mixing, delivery, placement and finishing need not be significantly different than those used for concrete mixtures containing virgin aggregate.
- Concerns with water demand and premature stiffening can be addressed by limiting or eliminating fine RCA and/or presoaking RCA to maintain proper moisture.
- Contaminants can lead to air entrainment problems.
- Fresh and hardened properties might change some.
- Even ASR affected and D-cracked concrete pavements have been successfully recycled into new concrete paving mixtures.
Asphalt Mixtures/Subbases

- RCA has been used successfully in new asphalt pavement and asphalt-stabilized subbase applications.
- Typical RCA particle angularity and rough texture provide excellent potential for stability and surface friction.
- The use of asphalt to encapsulate RCA particles effectively eliminates the potential for clogging of drainage structures in subbase applications.
- Unfortunately, the more absorptive nature of typical RCA particles significantly increases asphalt binder demand, which often increases costs prohibitively.
Other Applications

- RCA is an economical and highly stable material that is well-suited for granular fill applications.
- Most states allow the use of RCA for erosion control ("rip-rap") or slope stabilization.
- Soil stabilization, pipe bedding, landscape materials, railroad ballast, agricultural soil treatment, treatment of acidic lake waters, masonry blocks, artificial reefs, etc.
PROPERTIES OF CONCRETE WITH RCA
## Fresh (Plastic) Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Coarse RCA</th>
<th>Coarse and Fine RCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workability</td>
<td>Similar to slightly lower</td>
<td>Slightly to significantly lower</td>
</tr>
<tr>
<td>Finishability</td>
<td>Similar to more difficult</td>
<td>More difficult</td>
</tr>
<tr>
<td>Water bleeding</td>
<td>Slightly less</td>
<td>Less</td>
</tr>
<tr>
<td>Water demand</td>
<td>Greater</td>
<td>Much greater</td>
</tr>
<tr>
<td>Air content</td>
<td>Slightly higher</td>
<td>Slightly higher</td>
</tr>
</tbody>
</table>
## Hardened Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Coarse RCA</th>
<th>Coarse and Fine RCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength</td>
<td>0% to 24% less</td>
<td>15% to 40% less</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>0% to 10% less</td>
<td>10% to 20% less</td>
</tr>
<tr>
<td>Strength variation</td>
<td>Slightly greater</td>
<td>Slightly greater</td>
</tr>
<tr>
<td>Modulus of elasticity</td>
<td>10% to 33% less</td>
<td>25% to 40% less</td>
</tr>
<tr>
<td>CTE</td>
<td>0% to 30% greater</td>
<td>0% to 30% greater</td>
</tr>
<tr>
<td>Drying shrinkage</td>
<td>20% to 50% greater</td>
<td>70% to 100% greater</td>
</tr>
<tr>
<td>Creep</td>
<td>30% to 60% greater</td>
<td>30% to 60% greater</td>
</tr>
<tr>
<td>Permeability</td>
<td>0% to 500% greater</td>
<td>0% to 500% greater</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>0% to 10% lower</td>
<td>5% to 15% lower</td>
</tr>
</tbody>
</table>
Hardened Properties

Compressive Strength of Various Aggregate Mixes

Age (days)

Compressive strength (MPa)

- Virgin Coarse Agg./Virgin Fine Agg.
- Virgin Coarse Agg./Fine RCA
- Coarse RCA/Virgin Fine Agg.
- Coarse RCA/Fine RCA
# Hardened Properties

<table>
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<tr>
<th>Property</th>
<th>Coarse RCA</th>
<th>Coarse and Fine RCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeze-thaw durability</td>
<td>Depends on air voids</td>
<td>Depends on air voids</td>
</tr>
<tr>
<td>Sulfate resistance</td>
<td>Depends on mixture</td>
<td>Depends on mixture</td>
</tr>
<tr>
<td>ASR</td>
<td>Less susceptible</td>
<td>Less susceptible</td>
</tr>
<tr>
<td>Carbonization</td>
<td>Up to 65% greater</td>
<td>Up to 65% greater</td>
</tr>
<tr>
<td>Corrosion rate</td>
<td>May be faster</td>
<td>May be faster</td>
</tr>
</tbody>
</table>
Additional chapters on:
- Performance of Concrete Pavements Constructed using RCA
- Recommendations for Using Recycled Concrete

Appendices: (Spec type guidelines)
- Guidelines for Removing and Crushing Existing Concrete Pavement
- Guidelines for Using RCA in Unstabilized (Granular) Subbases
- Guidelines for Using RCA in Concrete Paving Mixtures
- Relevant AASHTO/ASTM Standards
- Glossary of Terms and Index
THANK YOU!
Questions or Comments?
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