Concrete Pavement Reuse and Recycling – Proven Technologies!

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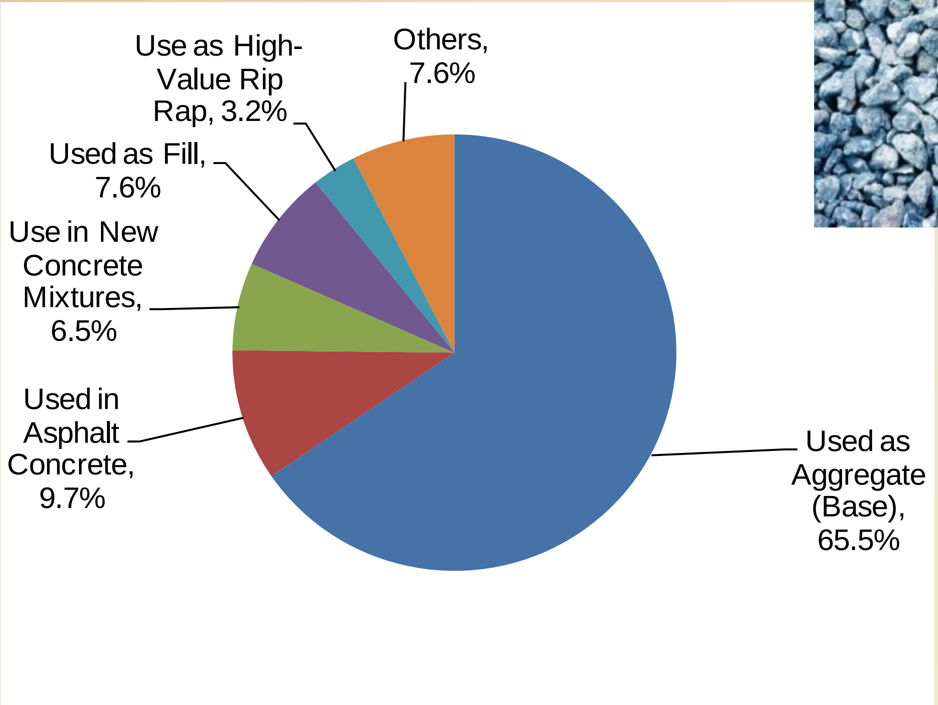
What is Concrete Recycling?

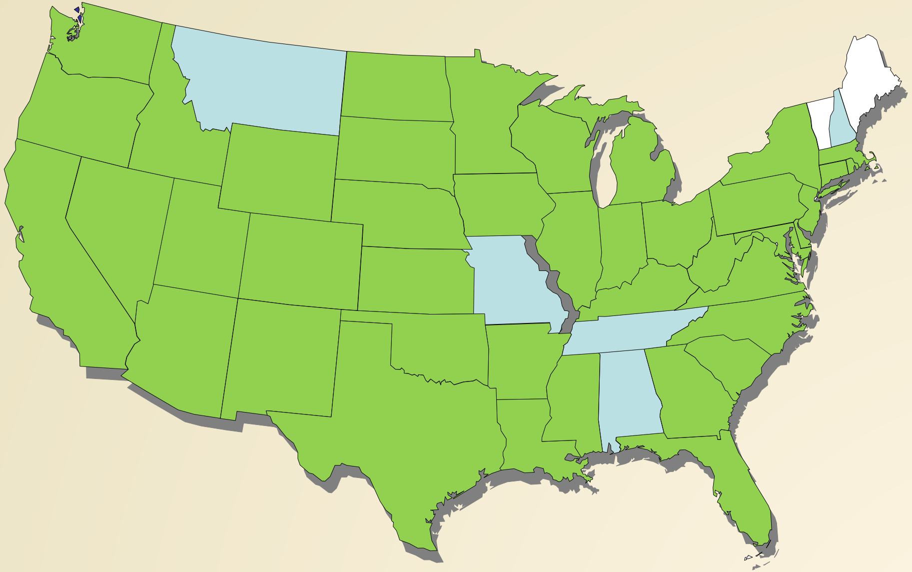
- Breaking, removing and crushing hardened concrete from an acceptable source to produce aggregate.
- Old concrete pavements often are excellent sources of material for producing RCA.
- ***Concrete pavements are 100% recyclable!***

Uses of Recycled Concrete Aggregate



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

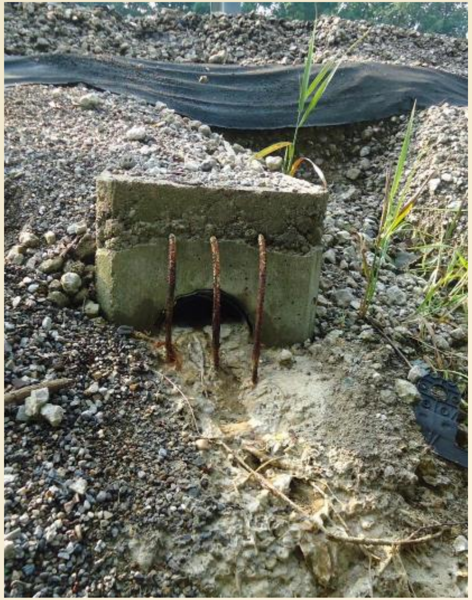
- AASHTO M319
- Quality requirements (Saeed and Hammons, 2008)
  - Micro-Deval, Tube Suction, Tri-axial and Resilient Modulus tests
  - Criteria vary with design traffic, climate and moisture
- Grade according to subbase function
  - Free-draining? Dense-graded?
  - See ACPA EB204P

Recommendations: Pavement Structural Design

- RCA Subbase:
  - Consider possible stiffening of RCA subbase and adjust panel length, thickness as required.
  - *<u>No structural problems have been reported with the use of RCA in foundation layers.</u>*

Potential Impacts on Drainage Systems

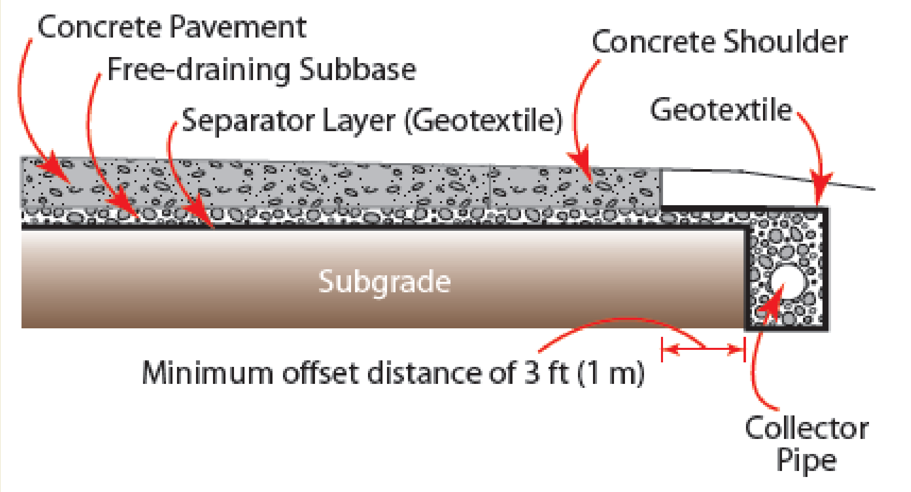
Photo credits: Iowa DOT and PennDOT



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 ….

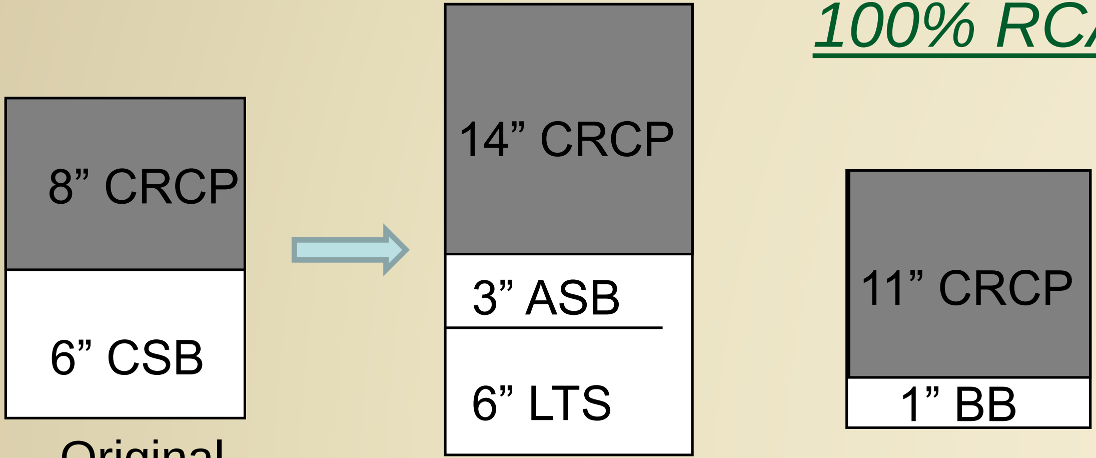
- Deterioration of mid-panel cracks in JRCP
- Design issues (undoweled joints, panel length, foundation type, etc.)

…. *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

Reconstruct and Unbonded Overlay

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 CO_2 not emitted!

Illinois Tollway

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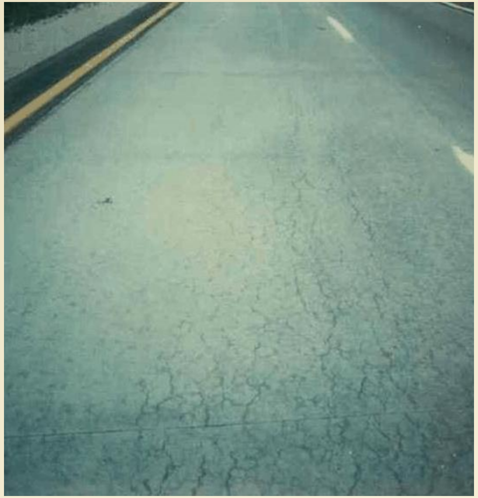
D-Crack Reconstruction Example: US 59, Worthington, MN

- 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)

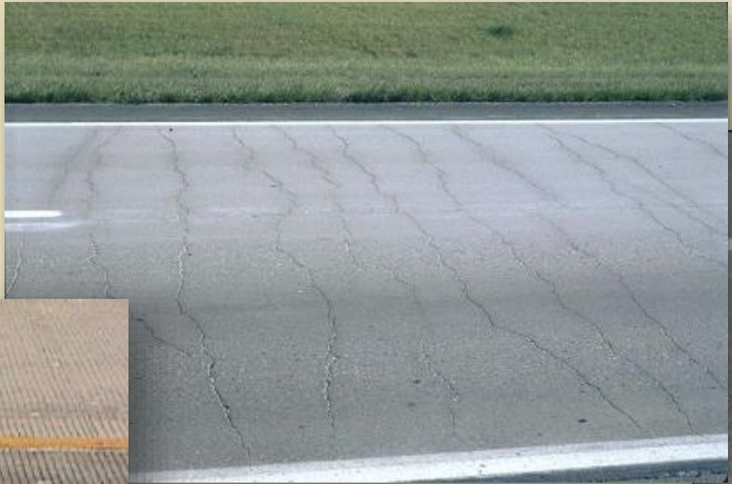
No significant evidence of recurring ASR (until recently).

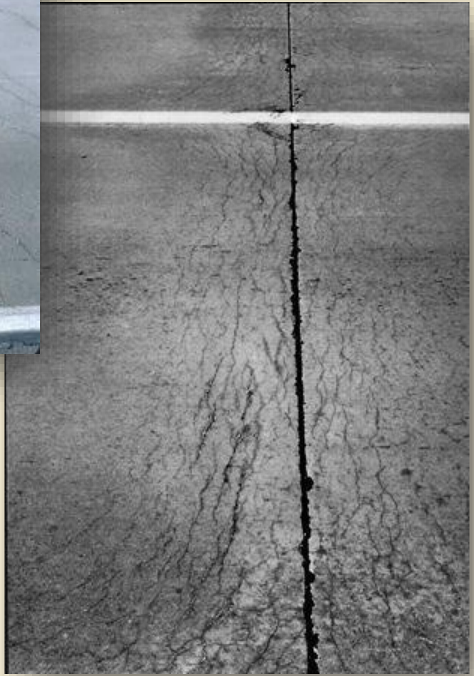
Production of RCA – Typical Steps

Typical steps:

- Evaluation of source concrete.
- Pavement preparation.
- Pavement breaking and removal.
- Removal of embedded steel.
- Crushing and sizing.
- Beneficiation.
- Stockpiling.

Evaluation of Source Concrete





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

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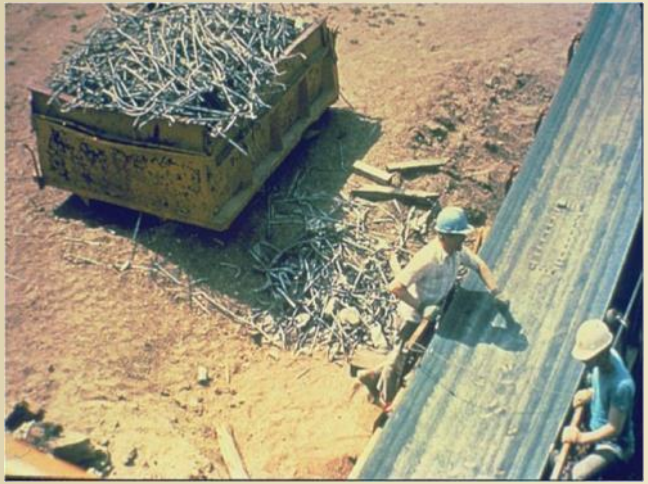
Pavement Breaking

- 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+ yd^2/hr

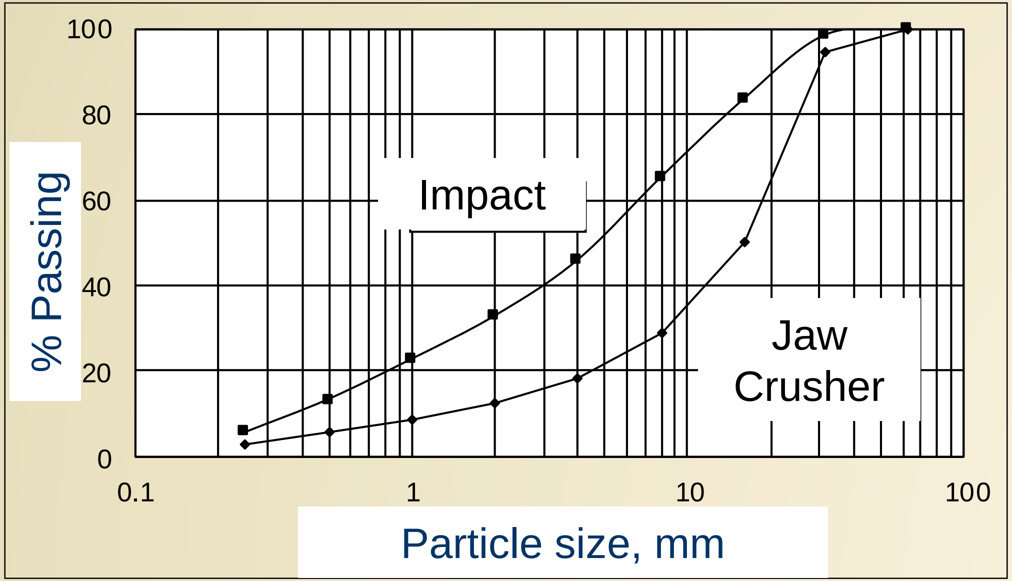
Pavement Breaking and Removal

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

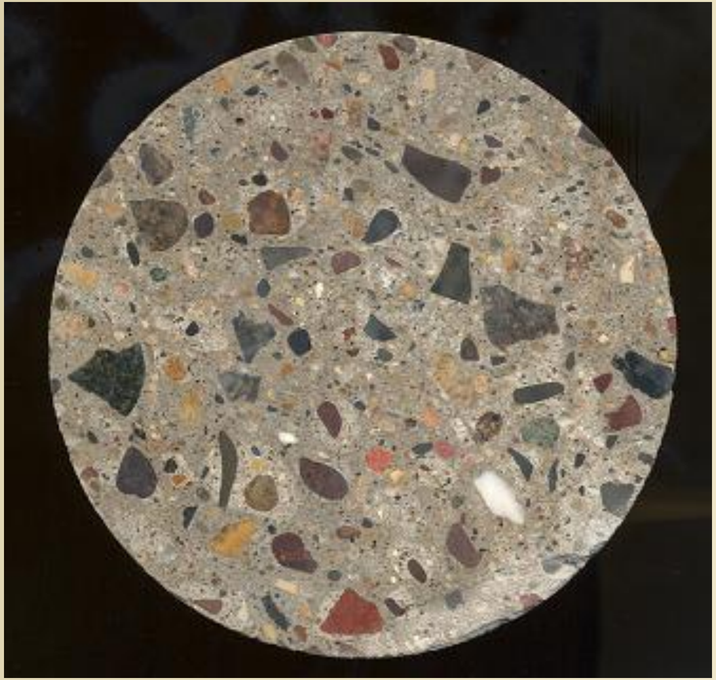
- Stockpile coarse RCA using same equipment, techniques as for virgin material.
- Protect fine RCA stockpiles from moisture
  - Secondary cementing
- RCA stockpile runoff is initially highly alkaline
  - Leaching of calcium hydroxide
  - Runoff alkalinity rapidly decreases

Properties of RCA

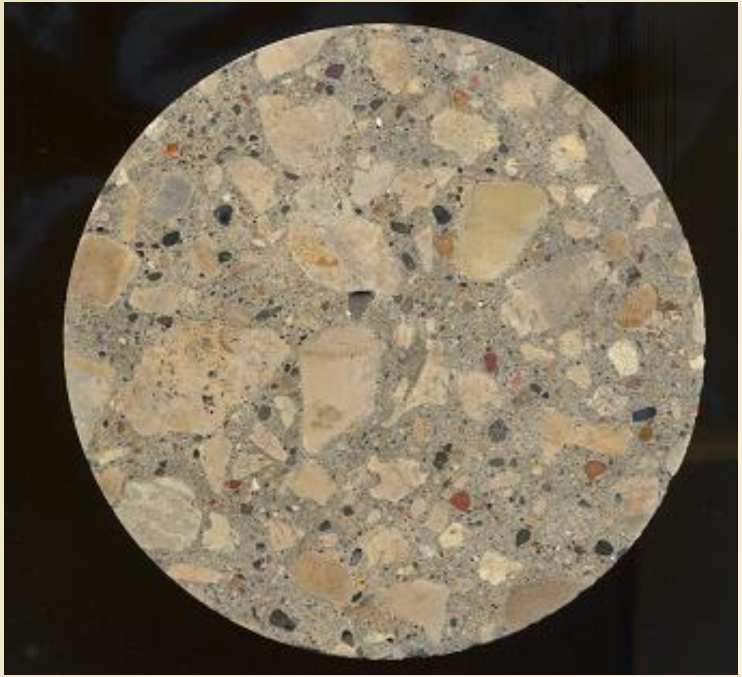
Property	Virgin Agg.	RCA
Shape and Texture	Well–rounded; smooth to angular/rough	Angular with rough surface
Absorption Capacity	0.8% – 3.7%	3.7% – 8.7%
Specific Gravity	2.4 – 2.9	2.1 – 2.4
L.A Abrasion	15% – 30%	20% – 45%
Chloride Content	0 – 2 lb/yd^3	1 – 12 lb/yd^3

Properties of Concrete with RCA

(Hint: it’s all about the mortar …)



Recycled



Control

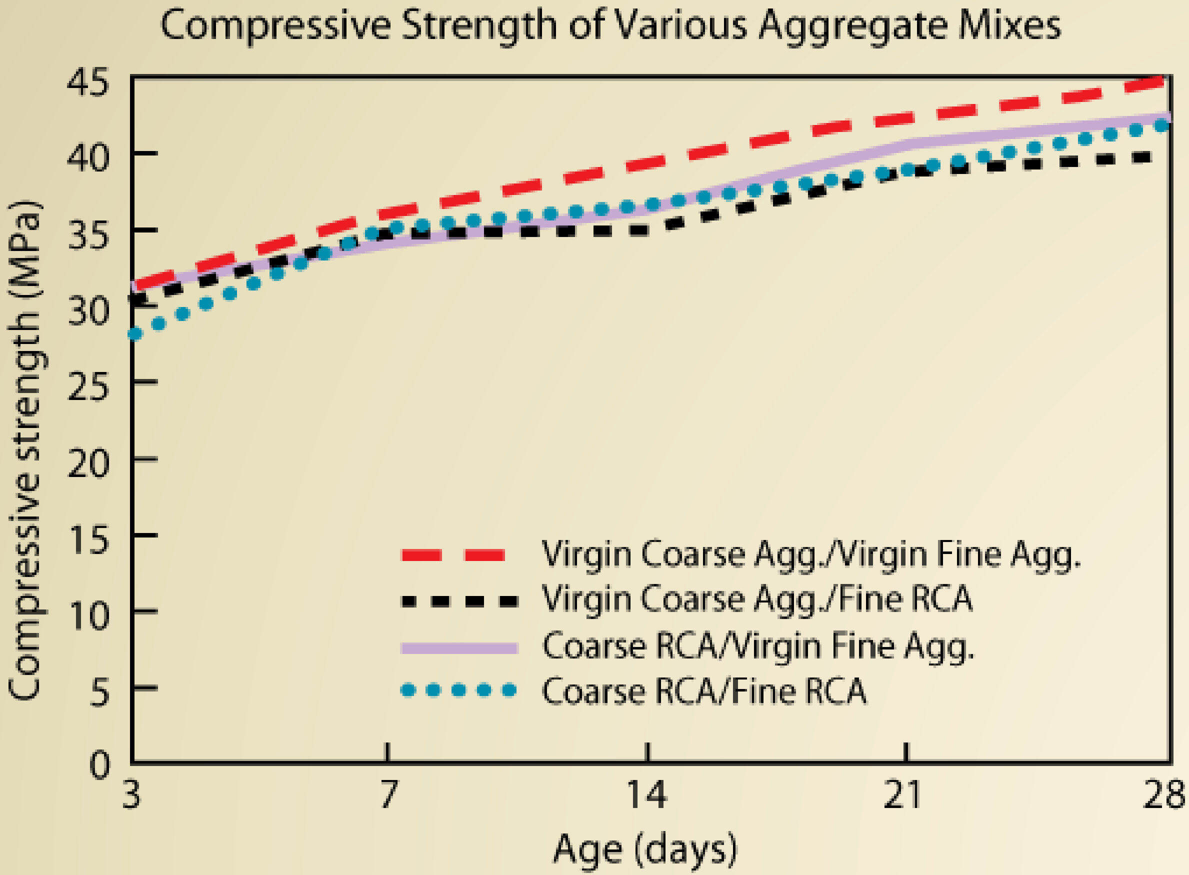
Fresh (Plastic) Properties

Property	Coarse RCA, Natural Fines
Workability	Similar to slightly lower
Finishability	Similar to more difficult
Water bleeding	Slightly less
Water demand	Greater
Air content	Slightly higher

Hardened PCC Properties

Property	Coarse RCA, Natural Fines
Compressive strength	0% to 24% less
Tensile strength	0% to 10% less
Strength variation	Slightly greater
Modulus of elasticity	10% to 33% less
CTE	0% to 30% greater
Drying shrinkage	20% to 50% greater
Permeability	0% to 500% greater

Hardened PCC Properties



Durability and Other Properties

Property	Coarse RCA, Natural Fines
Freeze-thaw durability	Depends on air voids
Sulfate resistance	Depends on mixture
ASR	Less susceptible
Carbonization	Up to 65% greater
Corrosion rate	May be faster

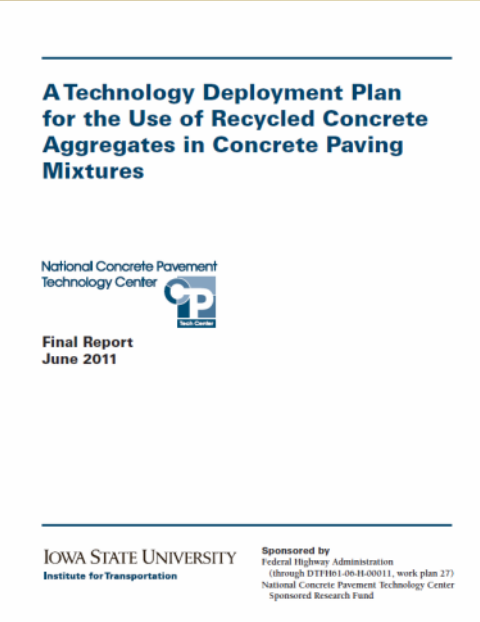
Summary

- 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



A Technology Deployment Plan for the Use of Recycled Concrete Aggregates in Concrete Paving Mixtures

National Concrete Pavement Technology Center

Final Report
June 2011

Iowa State University
Institute for Transportation

Sponsored by
Federal Highway Administration
(through DTFH61-06-H-00011, work plan 27)
National Concrete Pavement Technology Center
Sponsored Research Fund

- Describes barriers to implementation (perceptions, lack of experience, risk, etc.)
- Recommends approaches to overcoming them.
- Report available at: http://www.intrans.iastate.edu/reports/RCA%20Draft%20Report_final-ssc.pdf

- **Also: FHWA Technical Advisory TT 5040.37: Use of Recycled Concrete Pavement as Aggregate in Hydraulic-Cement Concrete Pavement**

Acknowledgments

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