2016 Municipal Street Seminar
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# Recycling Concrete Pavement

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# 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!***

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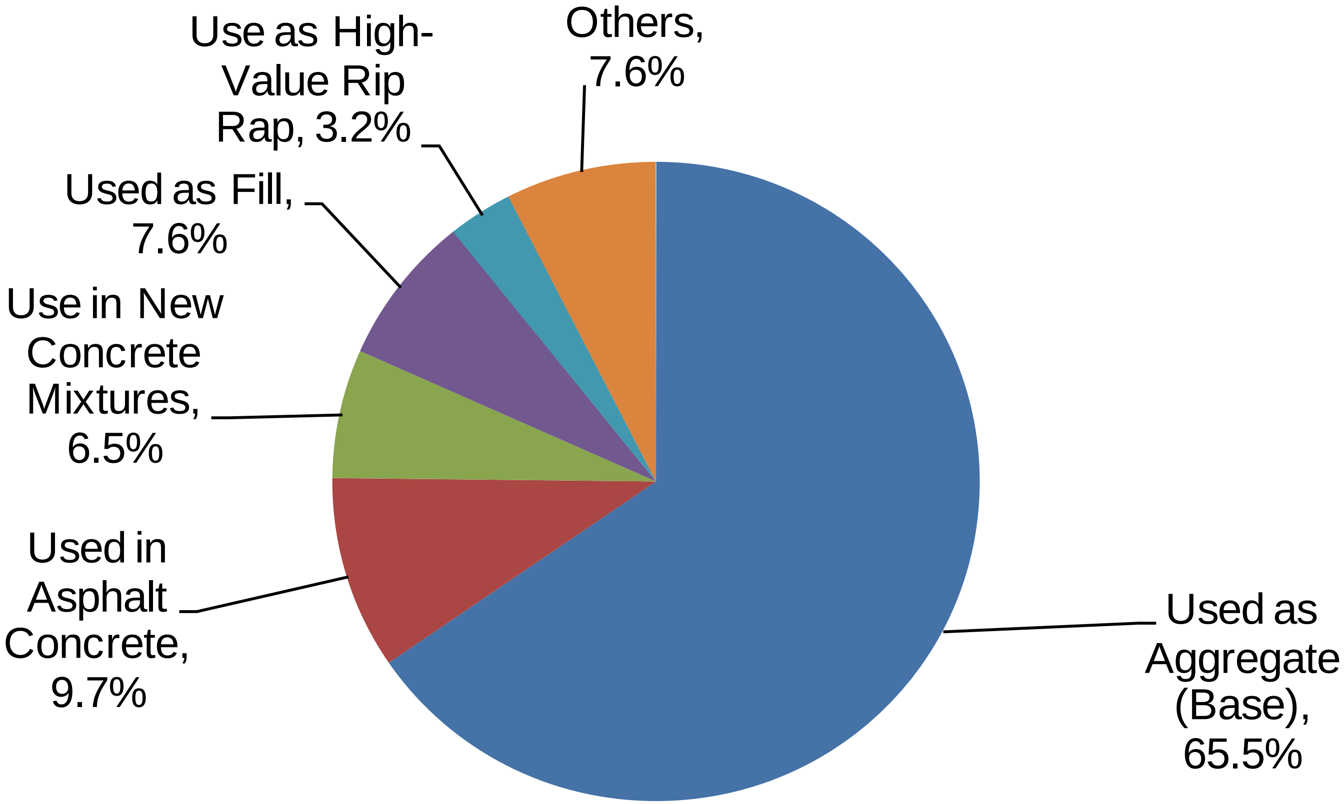
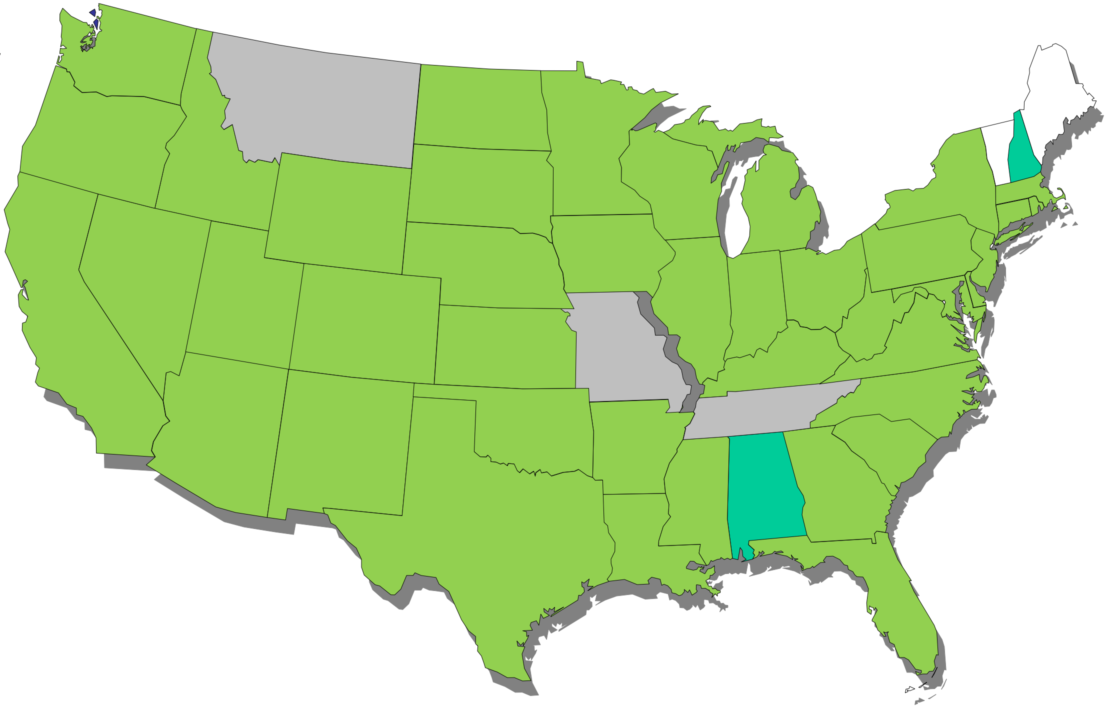
# Uses of Recycled Concrete Aggregate Nationally



# Concrete Recycling:
# A Proven Technology!

At least 44!

- ~~41~~ of 50 states allow use of RCA in various applications (FHWA, 2004)



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# Why Recycle? Sustainability!

Triple Bottom Line

- Social
  - ➢ Conservation of Resources
  - ➢ Reduction in Greenhoues 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

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# 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!

Illinois Tollway

Move Illinois

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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

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# 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


2007 Photo

No Virgin Aggregates Used for New Concrete:
*100% RCA (Coarse & Fine)*

8" CRCP
6" CSB
Original

14" CRCP
3" ASB
6" LTS

11" CRCP
1" BB

Reconstruct and Unbonded Overlay

# 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**

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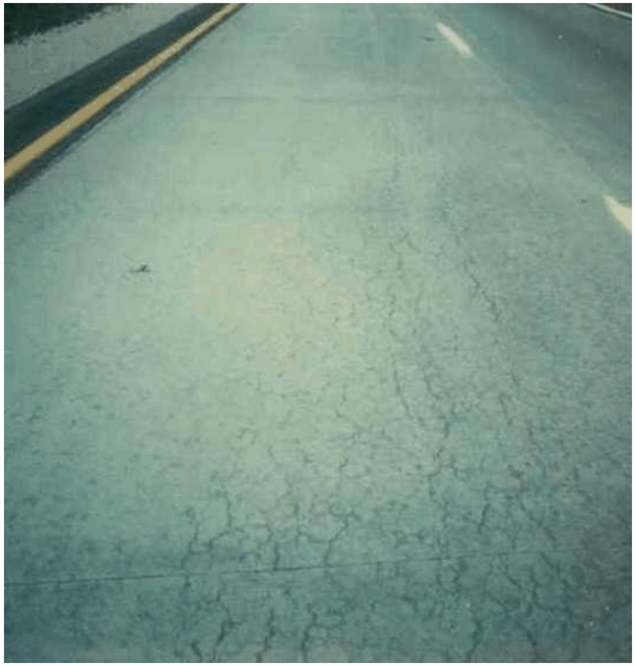
MnDOT estimated savings of 27% total project costs and 150,000 gallons of fuel.

# 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.**



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# 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

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# 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??***
  - $CaO \xrightarrow{H_20} Ca(OH)_2 \xrightarrow{CO_2} CaCO_3 + H_2O$

# Rodent Guard – Tufa Buildup

***Effect of screened fines 2 inch layer?***

# Maintenance Issue

# Production of RCA

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

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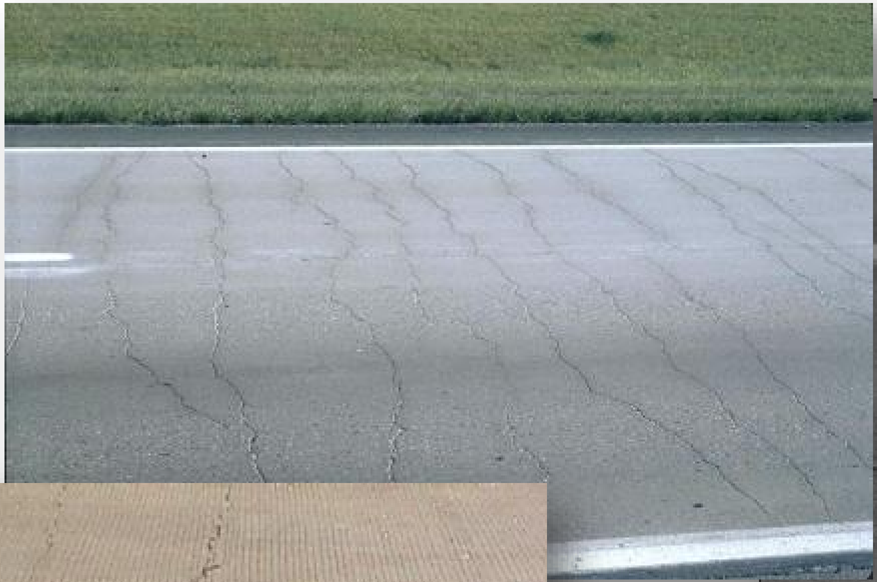
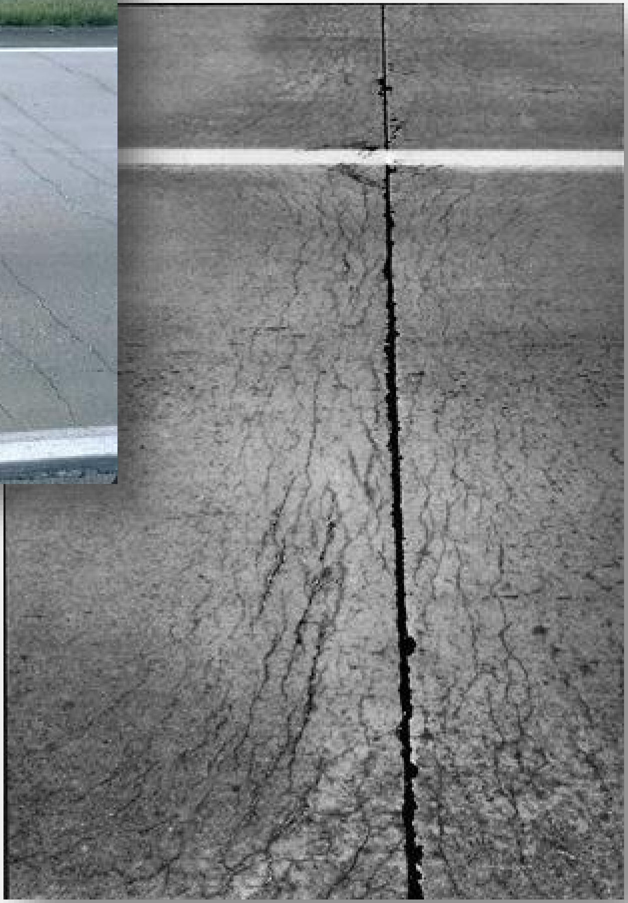
# Evaluation of Source Concrete





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

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# 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+ $yd^2$/hr

# Pavement Breaking and Removal

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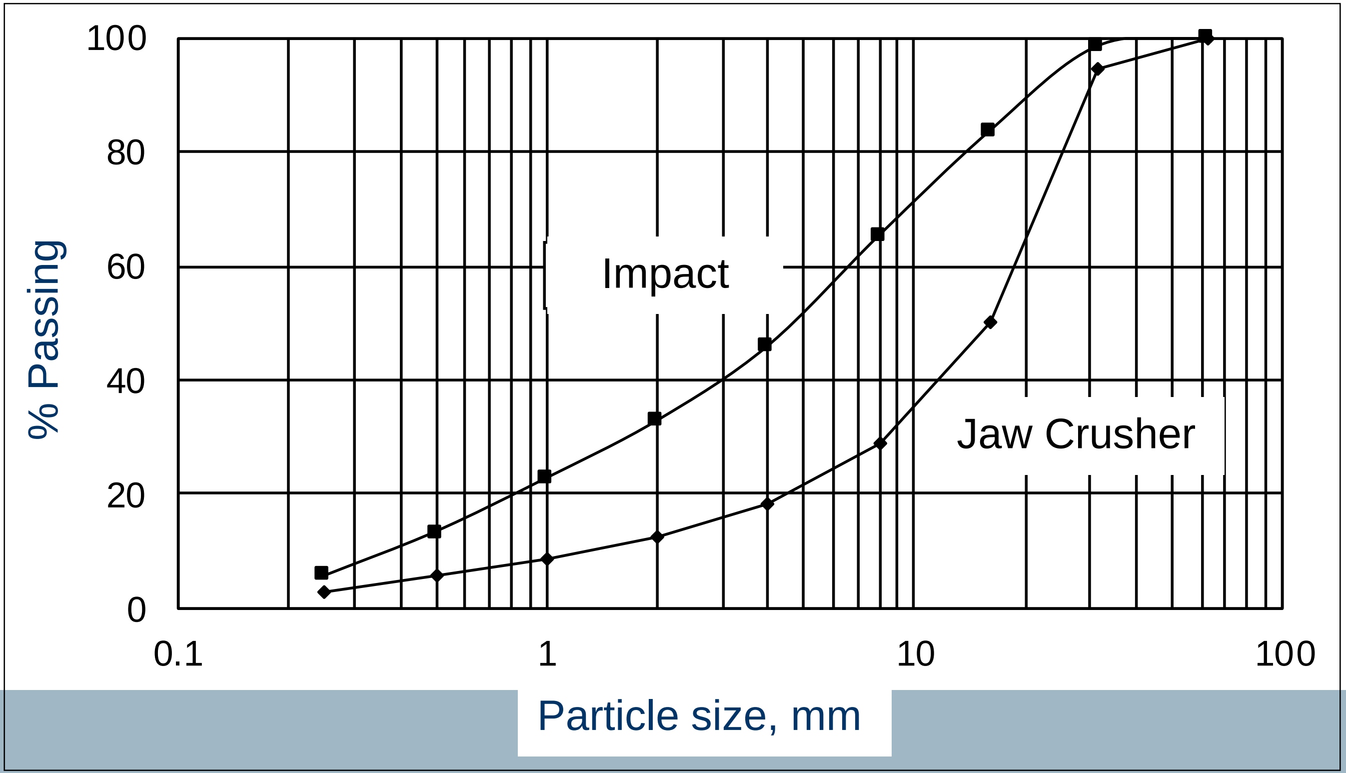
# Removal of Embedded Steel

- 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.

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# 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

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# 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 $lb/yd^3$ |

# 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 |

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# Hardened 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 |

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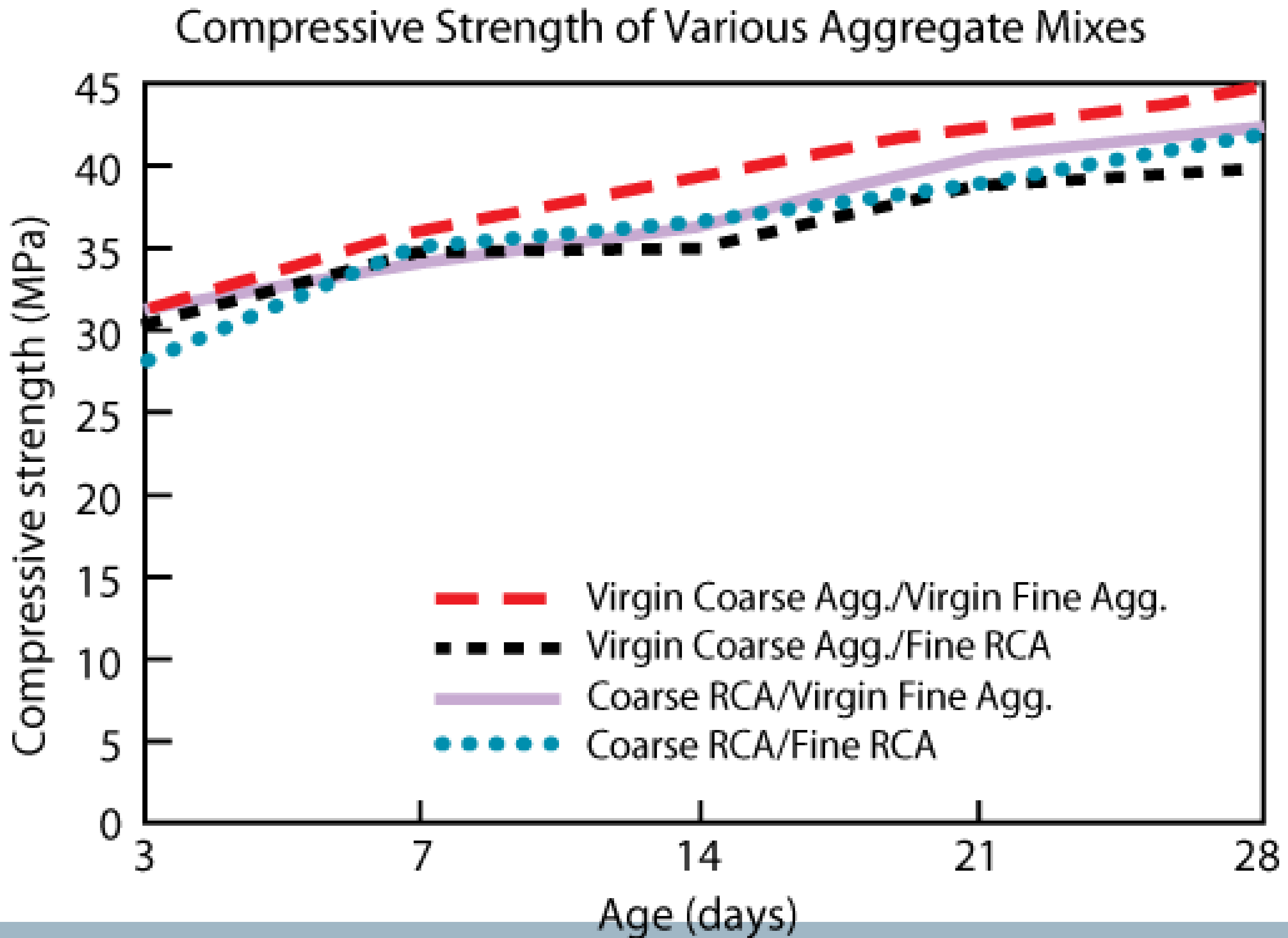
# Hardened Properties



# 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.

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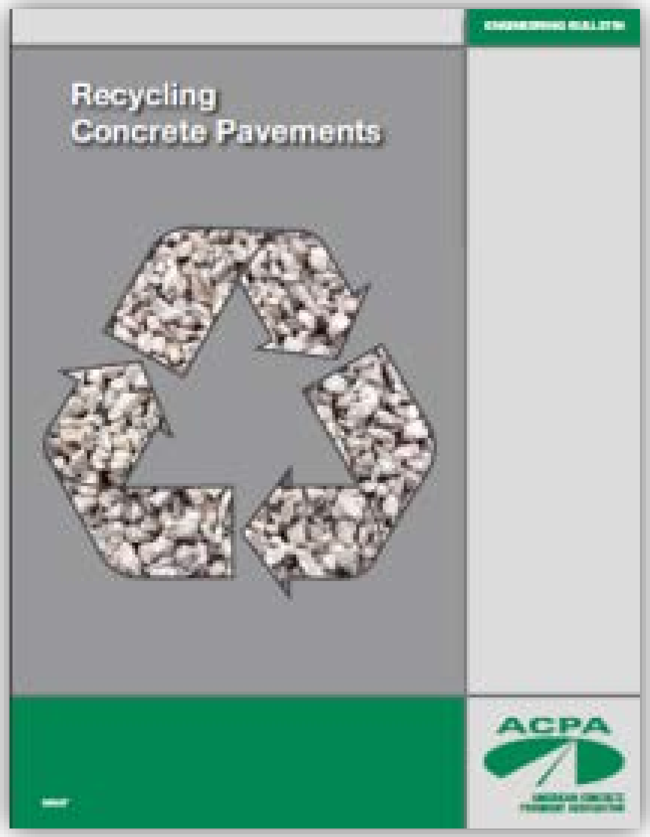
# Resources: ACPA EB043P

- 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

- American Concrete Pavement Association
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# Questions and Discussion

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