

Concrete Pavement Recycling Series

CONCRETE PAVEMENT RECYCLING AND THE USE OF RECYCLED CONCRETE AGGREGATE (RCA) IN CONCRETE PAVING MIXTURES

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Background

Concrete recycling is the breaking, removal, crushing, and processing of hardened concrete to produce recycled concrete aggregate (RCA), a granular material that is generally suitable for use as a substitute for virgin aggregate in various (generally construction-related) applications (ACPA 2009).

Concrete recycling has been used extensively in Europe since the 1940s and in the US since the 1970s (Darter et al. 1998). At least 43 states now perform concrete recycling for paving applications. Annual production of RCA in the US from all sources (both pavements and demolition debris) was recently reported at about 140 million tons (CDRA 2014).

The recycling of paving materials (including concrete pavement) into new paving applications is supported by the Federal Highway Administration (FHWA), which states that “reusing the material used to build the original highway system makes sound economic, environmental, and engineering sense” (FHWA 2002).

Reasons for Concrete Pavement Recycling

Good reasons to recycle concrete pavement include increased demand for quality aggregates in the face of limited resources, reduced availability of landfill space, and adoption of sustainable construction practices. Economics is one component of sustainability, and concrete recycling offers the potential for major savings

in the cost of aggregate, which comprises 20% to 30% of the cost of pavement construction materials and supplies (Halm 1980) and 10% to 15% of total construction costs (excluding engineering and right-of-way acquisition).

Concrete pavement recycling is a smart and environmentally sustainable choice that conserves aggregate and other resources, reduces unnecessary use of limited landfill space, saves energy, and may reduce greenhouse gas emissions. Concrete recycling can eliminate the need for mining or extracting new virgin aggregates and can reduce haul distances and fuel consumption associated with both aggregate supply and concrete slab disposal.

Uses of RCA

RCA has been successfully used in many paving applications, including new concrete paving mixtures for single- or two-lift concrete pavements, hot-mix asphalt (HMA) paving mixtures, bound and unbound subbase applications (e.g., cement-treated and granular bases), drainage layers, fill material, and more.

Foundation layer and fill applications are the most common uses for RCA produced from concrete pavements. They offer the ease and resulting cost savings of processing the materials on site, as well as tolerance for minor contaminants (e.g., sealant materials, residual steel, and subgrade soils) in these applications. Additionally, RCA typically provides a strong, stable subbase through the angular nature of

particles and a degree of secondary cementing that takes place in the presence of moisture over time.

The drive for more sustainable pavements demands that consideration be given to using recycled materials to the highest degree possible when it is feasible to do so (Van Dam et al. 2015). For example, RCA is commonly used in subbase and fill applications, but a particular RCA may be of sufficient quality for use in producing a durable concrete paving mixture that might otherwise require the use of a more expensive local aggregate or the transport of a high-quality, non-local aggregate. In these situations, a lower-quality local aggregate source can be used in lieu of RCA in subbase and fill applications; however, the cost-effectiveness of this approach must include consideration of the costs of material handling, preparation for use, and transportation (from both monetary and environmental perspectives).

Life-cycle cost analyses (LCCA) and life-cycle assessment (LCA) tools can help to determine the highest or “optimized” use of recycled materials (Van Dam et al. 2015).

RCA has been successfully used in concrete mixtures in the US for roadway surfaces, shoulders, median barriers, sidewalks, curbs and gutters, building and bridge foundations, and even structural concrete. RCA has been used in the construction of hundreds of concrete pavement construction projects in the US and around the world. Figure 1 presents a summary of the states that have used RCA in concrete paving mixtures.

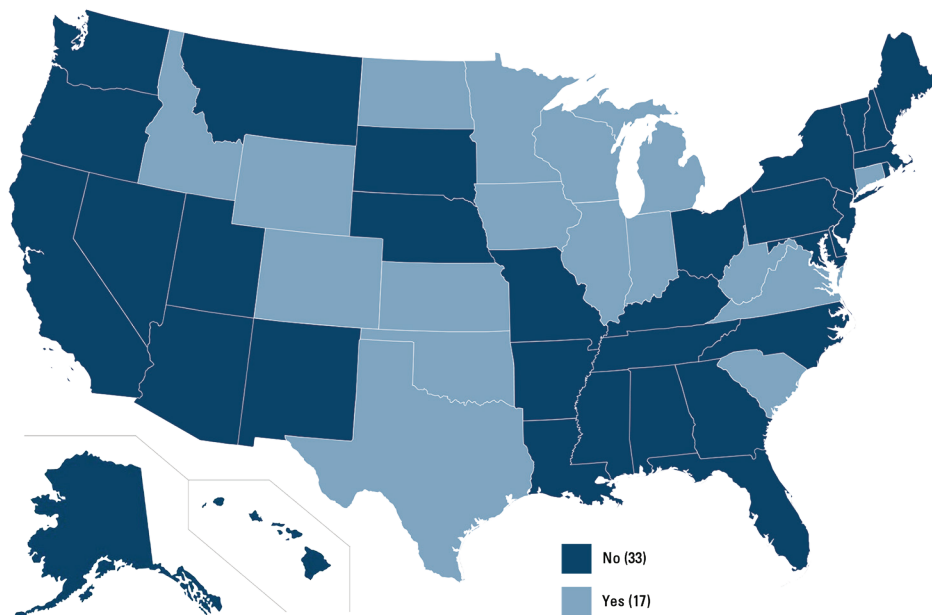
RCA concrete paving projects have included relatively low-volume roads (e.g., US 75 in Iowa) and some very

heavily traveled urban freeways (e.g., I-10 near Houston, Texas). They also have included the use of RCA produced from pavements that were severely damaged by D-cracking (e.g., US 59 in Minnesota) and alkali-silica reactivity (ASR) (e.g., I-80 in Wyoming) to produce new concrete pavement mixtures.

The use of RCA in the lower lift of two-lift concrete paving is common in some European countries (e.g., Austria) and is increasingly allowed in the US (e.g., the more recent Illinois Tollway reconstruction of I-90) (Kreen and Stinglhammer 1994, Gillen and Vavrik 2016).

RCA intended for use in concrete paving mixtures must be treated as an engineered material, with due consideration given to differences in physical and mechanical properties, such as absorption capacity and coefficient of thermal expansion, and the impact that these differences have on the plastic and hardened properties of the resulting concrete. Consideration of these properties may result in the need to modify the concrete mix design through the use of chemical and/or mineral admixtures, different mix component proportions, and/or aggregate blending.

These factors may also require the consideration of different pavement structural characteristics (e.g., thickness, panel dimensions, or reinforcing). The need for mixture adjustments and design modifications is discussed briefly in this Tech Brief and extensively by the American Concrete Pavement Association (ACPA 2009) and Snyder et al. (2018).



Sources: FHWA 2004, Tunison et al. 1993

Figure 1. States that have used RCA for new concrete pavement

Performance of RCA Concrete Mixtures

Snyder et al. (1994) and Reza and Wilde (2017) have identified more than 100 projects in the US that were constructed using RCA as part of the concrete paving mixture, including several where D-cracked or ASR-damaged pavements were recycled. Cuttell et al. (1997) evaluated the performance of nine of these projects with ages ranging from 6 to 15 years in 1995. Gress et al. (2009) re-evaluated these nine projects and two others in 2006.

Most of these projects, and the others built since then, have performed well and were considered successes. Some projects, however, have failed prematurely and have provided lessons in the design and construction of RCA concrete pavement details or have led to RCA concrete mixture design modifications to produce concrete properties and pavement performances similar to (and, in some cases, superior to) those of conventional concrete materials and pavements.

For example, RCA concrete pavements constructed with longer (>20 ft) mesh-reinforced panels have often developed mid-panel transverse cracks that deteriorate rapidly because the coarse RCA provides relatively little aggregate interlock across the crack. For similar reasons, undoweled RCA concrete pavements have sometimes developed faulting more quickly than their natural aggregate counterparts. Various RCA concrete paving projects that have failed prematurely were studied and presented in detail in Cuttell et al. (1997), FHWA (2004), and Gress et al. (2009).

Summaries of a few interesting and successful RCA concrete paving projects are presented here.

RCA from Composite Pavements Used in Two-Lift Pavements

US 75, Iowa – 1976

The Iowa Department of Transportation (DOT) reconstructed a portion of US 75 near Rock Rapids, Iowa using two-lift paving in 1976, incorporating about 60% recycled concrete aggregate and 40% recycled asphalt pavement (from the original pavement) in the 7-in. lower lift and all virgin materials in the 4-in. top lift. Many of the 20-ft-long reinforced panels developed transverse cracks, which faulted due to failure of the reinforcing steel, but the pavement was otherwise in good condition in 2006 (see Figure 2).

The pavement was overlaid with HMA in 2008 after 42 years of service. The project is particularly noteworthy because of the use of a significant quantity of recycled

HMA (typically considered a contaminant in RCA concrete mixtures) in the lower paving lift.



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Figure 2. US 75 near Rock Rapids, Iowa, in 2006 after 40 years of service and some rehabilitation

Austria – 1980s to present

The Austrian Salzburg-Vienna A-1 concrete motorway was reconstructed in the late 1980s and used two-lift construction with recycled concrete and HMA aggregate in the lower lift. The success of this project led to the adoption of two-lift paving using recycled materials in the lower lift as standard practice in Austria (Kreen and Stinglhammer 1994) and an increase in the use of this construction technique in other European countries.

Illinois Tollway – Circa 2014 through 2017

The Illinois Tollway encourages the recycling of 100% of all existing pavement materials within the limits of its reconstruction projects. For example, specifications for the reconstruction of I-90 between Rockford and Chicago, Illinois, allowed for the use of both crushed concrete products and fractionated recycled asphalt pavement (FRAP) in the lower lift of two-lift concrete pavement (Gillen and Vavrik 2016).

I-10 near Houston, Texas, CRCP Using 100% RCA (Both Coarse and Fine) – 1995

A 30-year-old section of I-10 continuously reinforced concrete pavement (CRCP) was crushed to produce RCA that was used to provide 100% of the coarse and fine aggregate for the new CRCP mixture (Won 2007). The RCA was required to meet Texas DOT (TxDOT) standards for concrete paving aggregate. Experience with this project contributed to TxDOT's 1999 decision to limit the use of fine RCA to less than 20% replacement of the total fine aggregate on future projects (Won 2007).

The contractor initially had difficulty in producing consistently workable concrete due to inadequate moisture

control of the RCA stockpiles, but this problem was remedied with the installation of improved stockpile sprinkler systems. There were also some problems with variability of strength, generally due to occasional low test results. The contractor on this job was required to modify the mix design to produce higher average strengths.

The relatively low elastic modulus of the RCA concrete is considered a key factor in the excellent performance of this project to date (see Figure 3).



Moon Won, Texas Tech University

Figure 3. I-10 near Houston, Texas in 2006 after 11 years of service

RCA from Pavements with Materials-Related Distress (MRD)

The following projects are noteworthy as two of the first major projects to recycle D-cracked or ASR-damaged concrete into new concrete pavement.

Both of these pavement projects demonstrate that concrete mixtures containing RCA can result in long-lasting, good-performing concrete pavements, even when the RCA is produced from concrete with significant MRD, provided appropriate steps are taken in the mixture design and proportioning and materials processing.

US 59 near Worthington, Minnesota – 1980

This 16-mile-long Minnesota project used coarse RCA (3/4 in. top size) from the original severely D-cracked pavement to produce concrete for a new 8-in. jointed plain concrete pavement (JPCP) with edge drains and a 13-16-14-19 ft skewed transverse joint pattern. The longer panels eventually developed transverse cracks and the undoweled joints faulted badly (both problems were addressed in a 2004 pavement rehabilitation project), but D-cracking has not reoccurred (see Figure 4).

I-80 near Pine Bluff, Wyoming – 1985

By 1985, portions of I-80 in eastern Wyoming had developed severe ASR damage. Concrete pavement recycling was determined to be a feasible and economical



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Figure 4. US 59 near Worthington, Minnesota in 2006, after 26 years of service and 2004 rehabilitation

rehabilitation solution for this pavement, so RCA was produced for use in a new 10-in. JPCP concrete surface (with “randomly” spaced and undoweled skewed joints).

Extensive testing was performed to determine the following strategy for preventing the reoccurrence of ASR: 1) the use of a low-alkali Type II cement, 2) blending the coarse and fine RCA with high-quality virgin aggregates, and 3) using a Class F fly ash.

There was little evidence of recurrent ASR in 2006 when a major pavement rehabilitation (dowel bar retrofit, diamond grinding, and joint resealing) was performed to address joint faulting that had developed. However, some materials-related distress (that may include ASR) was reported by Rothwell (2017) after approximately 30 years of service.

Production of RCA

Following are the major steps in concrete pavement recycling:

1. Evaluation of the source concrete to determine its suitability for various potential applications
2. Preparation of the slab (removal and separate recycling of asphaltic materials, joint sealants, etc., as necessary for the intended application)
3. Breaking and removing the concrete
4. Removal of any steel mesh, reinforcing steel bars, and/or dowels
5. Crushing the concrete and sizing the RCA
6. Treating the RCA to remove any additional contaminants (a process commonly known as beneficiation), if necessary
7. Stockpiling the RCA



Gary Fick, Trinity Construction Management Services, Inc.

Figure 5. Typical concrete pavement crushing and stockpiling operation

The same basic equipment used to process virgin aggregates also can be used to crush, size, and stockpile RCA (see Figure 5). However, the selection of crushing processes can affect the amount of mortar that clings to the recycled aggregate particles and, therefore, the properties of the RCA (as described below).

Jaw crushers generally are more effective at producing higher quantities of coarse recycled aggregate, but the resulting RCA particles often contain relatively high amounts of reclaimed mortar, which usually increases aggregate absorption capacity. Impact crushers are more effective at removing mortar from natural aggregate particles, resulting in coarse RCA with properties that are more similar to virgin aggregate, but also resulting in the production of lower amounts of coarse RCA from any given volume of processed concrete.

Stockpiles of RCA constructed in or near environmentally sensitive areas should be protected from precipitation or provisions should be made to capture and treat the runoff, which is initially highly alkaline due to the leaching of calcium hydroxide (a product of cement hydration) from the freshly crushed material. Runoff alkalinity usually decreases rapidly with time as the exposed calcium hydroxide is depleted. Exposure to precipitation may also result in some secondary cementation of previously unhydrated cement grains, which can cause the RCA particles to agglomerate, particularly for fine aggregate stockpiles.

Properties of RCA

RCA particles are comprised of reclaimed virgin aggregate, reclaimed mortar, or both. Concrete crushing processes generally produce relatively angular, rough-textured particles. The properties of a specific RCA depend on many factors, including the properties of the original concrete and the amount of reclaimed mortar in the RCA. Higher amounts of reclaimed mortar typically result in increasingly higher absorption, lower specific gravity, lower particle strength, and lower abrasion resistance than would be present if the mortar fraction was removed to leave only the natural aggregate portion of the RCAs.

RCA must generally meet the same requirements as virgin aggregate for the target application (e.g., concrete mixture, subbase layer). With proper care and process control, RCA generally can be produced to meet standard aggregate quality and grading requirements. Typical properties of natural aggregate and RCA are presented and compared in Table 1.

Sulfate soundness tests do not provide reliable tests for RCA (Hansen 1986) and are typically waived in favor of freeze-thaw testing using AASHTO T 103 (2008), AASHTO T 161 (2017), or various state-specific tests (e.g., New York State DOT [NYSDOT] Test Method 703-08 and Ontario Ministry of Transportation [MOT] Test Method LS-614).

Recycled concrete aggregate should be considered an engineered material for which the properties must be

Table 1. Typical properties of natural and recycled concrete aggregate

Property	Natural Aggregate	RCA
Absorption Capacity (%)	0.8–3.7	3.7–8.7
Specific Gravity	2.4–2.9	2.1–2.4
L.A. Abrasion Test Mass Loss (%)	15–30	20–45
Sodium Sulfate Soundness Test Mass Loss (%)	7–21	18–59
Magnesium Sulfate Soundness Test Mass Loss (%)	4–7	1–9
Chloride Content (lb/yd ³)	0–2	1–12

Source: After Snyder et al. 1994

determined prior to use so that appropriate mixture design or construction adjustments can be made as required.

As noted in Table 1, high levels of chlorides have been found in RCA (especially in RCA with high reclaimed mortar content) produced from sources with long-term exposure to deicing chemicals. When RCA from such sources is used in concrete pavements and the chloride levels are high enough to be of concern, epoxy-coated steel or other corrosion-resistant/non-corroding materials should be considered for use as tie bars and slab reinforcing (for jointed and continuously reinforced concrete pavements).

Using RCA in Concrete Paving Mixtures

Properties of Concrete with RCA

When RCA is used to produce new concrete mixtures, its effect on the properties of those mixtures can range from minimal to significant, depending on the nature, composition, and gradation of the RCA. Changes in mixture design and admixture usage can reduce (and sometimes eliminate) many differences in the properties of RCA concrete mixtures (ACPA 2009).

Fresh (Plastic) RCA Concrete Properties

RCA particles tend to be angular and rough-textured, which can increase the harshness of fresh concrete mixtures. The shape and texture of coarse RCA particles generally do not cause significant workability problems, but the higher absorption capacity of RCA (especially fine RCA) can lead to a rapid loss of workability. These effects and others are noted in Table 2.

Workability, finishing, and water bleeding characteristics can be successfully addressed, at least in part, by washing or wetting the aggregate and maintaining it in a moist condition until batching, or by limiting fine RCA content to 30% or less replacement of natural sand. The use of

Table 2. Effects of RCA on fresh concrete properties

Property	Range of expected changes from similar mixtures using virgin aggregates	
	Coarse RCA Only	Coarse and Fine RCA
Water demand	Greater	Much greater
Finishability	Slightly more difficult	More difficult
Bleeding	Slightly less	Less
Air void system	Similar	Increased*
Setting time	May be accelerated	May be accelerated

*Reported air content will include the air in the source concrete paste
Sources: After FHWA 2007, ACI 2001

pozzolanic and chemical admixtures can also improve mixture workability.

Another note is that setting times of mixtures made with RCA may be 45 to 60 minutes shorter than those of control mixtures, likely due to a chemical effect of the hydrated cement and calcium hydroxide in the RCA, especially in mixtures with more fines (Obla et al. 2007).

Hardened RCA Concrete Properties

Table 3 provides a summary of the ranges of typical changes in concrete properties that result from the use of RCA as a replacement for natural aggregate while holding all other factors constant (i.e., no compensating mixture adjustments are made).

Mixture design modifications (e.g., those listed in the far right column of Table 3) can partially offset or eliminate many of these differences (e.g., reducing the water-to-cementitious-material [w/cm] ratio to offset reductions in strength or using fly ash in the mixture to decrease concrete permeability). Other differences (e.g., coefficient of thermal expansion and shrinkage) can be accounted for in the pavement structural design (e.g., modifications of panel dimensions and reinforcing).

It should be emphasized that concrete with adequate levels of compressive and flexural strength for paving and other applications can be produced even when virgin aggregates are completely replaced by RCA products. Concrete with RCA can be highly durable, provided the mixture proportioning (including the use of chemical and mineral admixtures) is done properly and the construction (including concrete curing) is of good quality, even when the RCA is produced from concrete with D-cracking or ASR problems.

D-cracked pavements have been successfully recycled into new concrete layers since at least the early 1980s by producing RCA coarse aggregate with a maximum size of

Table 3. Typical properties of RCA concrete compared to similar mixtures comprising all natural aggregate

Property	Coarse RCA Only	Coarse and Fine RCA	Potential Adjustments
Compressive Strength	0–24% lower	15–40% lower	Reduce w/cm ratio
Tensile Strength	0–10% lower	10–20% lower	Reduce w/cm ratio
Variability of Strength	Slightly greater	Slightly greater	Increase average strength compared to specified strength
Modulus of Elasticity	10–33% lower	25–40% lower	This may be considered a benefit with regard to cracking of slabs on grade
Coefficient of Thermal Expansion/Contraction	0–30% higher	0–30% higher	Reduce panel sizes
Drying Shrinkage	20–50% higher	70–100% higher	Reduce panel sizes
Permeability	0–500% higher	0–500% higher	Reduce w/cm ratio
Specific Gravity	0–10% lower	5–15% lower	—

Sources: After ACI 2001, FHWA 2007, and Hansen 1986

3/4 in. or less (ACPA 2009). ASR-damaged pavement has also been successfully recycled into new concrete pavement through the use of Class F fly ash and/or slag cement, admixtures (e.g., lithium nitrate), and aggregate blending (i.e., limited or partial substitution for natural aggregate).

Developing Concrete Mix Designs Using RCA

Qualification Testing

It has been recommended that RCA used to construct new concrete pavements should meet the same quality requirements as virgin aggregate (FHWA 2007), but it may be more effective to properly characterize and control the variability of the physical and mechanical properties of the RCA and consider them in the mixture design. Other recommendations include the following:

- Magnesium and sodium sulfate soundness tests may be waived because they may be unreliable in predicting RCA durability (ACPA 2009)
- Attention must be paid to sources known to be subject to ASR and D-cracking (ACPA 2009) by testing the materials in accordance with AASHTO R 80 (AASHTO 2017)
- Contaminants should be limited as follows (ACPA 2009):
 - » Asphalt: 1% by volume (although significantly higher asphalt content has been included in the lower lift of some two-lift concrete pavement systems)
 - » Gypsum: 0.5% by weight
 - » Glass: 0
 - » Chlorides: 0.06 lb/yd³
- RCA washing, air blowing, or other mitigation techniques should be considered to remove dust from

crushing and handling operations that might otherwise increase water demand or reduce paste-aggregate bond, resulting in reduced concrete strength

Proportioning

The fundamental principles of mixture proportioning for RCA concrete are the same as those for conventional concrete. Some changes may be needed to accommodate differences in the properties of the RCA (FHWA 2007, ACPA 2009):

- W/cm ratio may need to be decreased to achieve the desired hardened properties
- Fine RCA should be limited to less than 30% by mass of fine aggregate
- Gradation of the combined aggregate system should be assessed using tools such as the tarantula curve, Shilstone workability plot, or power 45 curve
- Paste content may need to be increased to maintain workability, particularly if fine RCA is used
- The mixture should be designed correctly for yield with consideration of the lower specific gravity (SG) of RCA

Fathifazl et al. (2009) developed a concrete mixture proportioning method specifically for use with RCA. Known as the equivalent mortar volume (EMV) method, this method is based on fixing the total amount of mortar in the RCA concrete mixture (including the residual mortar content on the RCA) to be equal to the mortar content of an equivalent conventional mixture. Mixtures produced using this proportioning method tend to be harsh and rocky, especially when the RCA contains higher amounts of residual mortar.

Construction

Better monitoring of stockpile moisture content and batch quantity adjustments is required to ensure that the final required w/cm ratio is achieved.

Sustainable Aspects of Concrete Recycling

The use of RCA can save money and time and reduce the environmental impact of concrete paving. Its use can potentially shorten project completion time as a result of expedited construction schedules due to reduced haul times. The potential for increased material transportation savings is even greater when there is no locally available aggregate and aggregate has to be trucked in from farther away.

Expedited construction schedules result in fewer lane closures, which improves public safety. Public safety is also enhanced if processing of the aggregate is in close proximity to the project and there are fewer commercial vehicle-miles required for transport.

Using RCA in new construction benefits the environment because it reduces the amount of material typically disposed of in landfills and conserves resources related to mining virgin aggregates.

Recommendations for Using RCA

Production Recommendations

- Jaw crushers are effective at removing any embedded steel reinforcing or dowels and also tend to produce fewer fines than other types of crushers, which boosts the yield of coarse RCA. Impact and cone crushers are more effective at removing mortar to produce coarse RCA with properties that are similar to those of the original concrete aggregate (ACPA 2009).
- “Closed system” aggregate processing plants are preferred because they allow greater control over the aggregate particle size distribution and provide a more uniform finished material.
- Moisture control of stockpiles is essential in ensuring the production of uniform RCA concrete.

Concrete Pavement Mixture Recommendations

- In general, RCA products intended for use in new concrete pavements should meet the same quality requirements as virgin aggregate. RCA for use in high-quality concrete should be free of potentially harmful components.
- More than 90% of the material should be cement paste and aggregate. Small amounts of joint sealant material, motor oil, and other pavement surface contaminants

have not been found to cause problems in RCA used in concrete mixtures (FHWA 2007). Washing the RCA prior to batching is not generally required (except as needed to meet specification requirements limiting minus #200 material) but may be beneficial in reducing moisture absorption and associated workability problems and in enhancing the paste-aggregate bond.

- Evaluate and test suspected ASR-affected and D-cracked sources to ensure that selected mitigation measures will effectively prevent recurrent problems.

Techniques that may be effective in preventing recurrent ASR include the following (ACPA 2009, Van Dam 2002):

- » Use Class F fly ash and/or slag cement in place of a portion of the cement
- » Limit the use of fine RCA
- » Reduce concrete permeability through lower water content
- » Use admixtures such as lithium nitrate
- » Reduce slab exposure to moisture (e.g., sealed joints, drainable base, and subdrainage systems)

Recurrent D-cracking may be prevented by reducing coarse RCA top size to 3/4 in. (19 mm) or less and by reducing slab exposure to moisture through the same techniques described above (ACPA 2009).

- The basic proportioning of concrete containing RCA can be accomplished using the same procedures recommended for proportioning concrete containing only virgin aggregate.
- To achieve similar workability to a conventional concrete mixture, 5% to 15% more water and/or a water-reducing admixture and/or the use of fly ash (substitution for Portland cement) may be required (FHWA 2007).
- Additional cementitious material may be necessary to produce the required strength (FHWA 2007).
- FHWA (2007) recommends a w/cm ratio of 0.45 or less. However, many highway agencies are currently limiting the w/cm ratio to 0.42 or less for all concrete paving mixtures to provide a less permeable and more durable pavement.
- The use of fine RCA should be limited to 30% of the total fine aggregate to avoid the production of a harsh mix.
- There are no general limits on the use of coarse RCA in concrete paving mixtures, and 100% coarse RCA

has been successfully used in many projects, often with chemical and/or mineral admixtures or other mix proportioning adjustments to address potential workability issues. Limits on coarse RCA use have been imposed on some projects when the source concrete exhibited MRD (e.g., D-cracking or ASR) (Snyder et al. 1994).

- RCA substitutions for natural aggregate should be done volumetrically (rather than by weight) because of the generally lower specific gravity of RCA.

Pavement Structural Design Recommendations

- Determine and consider the physical and mechanical properties of RCA concrete in the development of RCA concrete pavement design details.
- Increased shrinkage and thermal response of concrete containing RCA can cause larger joint movements, requiring different sealant materials or reduced panel dimensions.
- Reduced potential for aggregate interlock at transverse cracks in jointed, mesh-reinforced RCA concrete pavement may need to be offset with higher amounts of reinforcing.
- Lower RCA concrete strength and elastic modulus may result in slightly increased pavement thickness requirements and different reinforcement requirements for continuously reinforced pavement.
- ACPA (2009) provides additional structural design guidelines and recommendations.

RCA User Resources

The following resources provide guide specifications and detailed information concerning the production of RCA and its use in new concrete paving mixtures.

AASHTO. 2013. *Standard Specification for Reclaimed Concrete Aggregate for Use as Coarse Aggregate in Hydraulic Cement Concrete*. AASHTO MP 16-13. American Association of State and Highway Transportation Officials, Washington, DC.

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The mission of the National Concrete Pavement Technology Center is to unite key transportation stakeholders around the central goal of advancing concrete pavement technology through research, tech transfer, and technology implementation.

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