Concrete Pavement Recycling Series

USING RECYCLED CONCRETE AGGREGATE (RCA) IN UNBOUND AGGREGATE SHOULDERS

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Introduction

Recycled concrete aggregate (RCA) can be—and has been—successfully used in unbound aggregate shoulder surface applications (see Figure 1).

Nine of 13 states responding to a survey conducted by the National Concrete Pavement Technology (CP Tech) Center (2017) stated that RCA was allowed for use as shoulder surfacing by their agency. The FHWA (2004) reported that the Michigan DOT (MDOT) also allows the use of dense-graded RCA in shoulder surfacing applications.

While the use of RCA in unbound shouldering is allowed in many states, its use is not common. This is likely because roadways with recyclable concrete mainline pavements typically have asphalt- or concrete-surfaced shoulders and little or no need for aggregate shoulder surfacing. Additionally, it is far more common and broadly accepted to use RCA in unbound base applications beneath travel lanes and shoulders.

This Tech Brief describes qualification requirements, design techniques, and construction considerations for unbound RCA shouldering materials.

Qualification Requirements

Gradation

Many highway agencies require only gradation control when recycling concrete pavements from known sources (i.e., their own networks) and require more extensive testing only for the processing of materials from other sources.

The gradation of unbound aggregate shoulder surface materials is critical to the stability of the material under service. Good dense-graded unbound base materials are typically required to have a plasticity index (PI) of 6.0 or less, with no more than 12% to 15% passing the No. 200 sieve (ACPA 2008, ASTM 2015). Similar requirements are probably appropriate for state DOT shoulder surfacing materials; some relaxation of these requirements may be possible for lower volume roads (i.e., some county and other rural roads).

Iowa DOT

Figure 1. RCA aggregate shoulder (50% blend with natural aggregate) on US 34 east of Fairfield, Iowa

Table 1. Reported RCA grading requirements for shoulder surface applications: 1.5-inch aggregate top sizes

	Percent Passing (by mass)										
State	**1.5 in.**	**1 in.**	**3/4 in.**	**1/2 in.**	**3/8 in.**	**#4**	**#10**	**#16**	**#60**	**#100**	**#200**
GA	97–100		60–95				25–45		10–30		2–11
IL	100	90–100		60–80		30–56		10–40			4–12
NC	100			55–95		35–74					
TN	100	85–100	60–95		50–80	45–65		20–40		5–18	

Tables 1–4 summarize aggregate grading requirements for RCA shouldering material, as reported by respondents to the National CP Tech Center survey (2017).

Table 2. Reported RCA grading requirements for shoulder surface applications: 1.25-inch aggregate top sizes

	Percent Passing (by mass)				
State	**1.25 in.**	**5/8 in.**	**#4**	**#40**	**#200**
WA	99–100	80–100	35–45	3–18	0–7.5

Table 3. Reported RCA grading requirements for shoulder surface applications: 1-inch aggregate top sizes

	Percent Passing (by mass)							
State	**1 in.**	**3/4 in.**	**1/2 in.**	**3/8 in.**	**#4**	**#8**	**#30**	**#200**
IA	100	95–100	70–90		30–55	15–40		6–16
OH	100	60–90		35–75	30–60		9–33	0–15

Table 4. Reported RCA grading requirements for shoulder surface applications: 3/4-inch aggregate top sizes

	Percent Passing (by mass)						
State	**3/4 in.**	**3/8 in.**	**#4**	**#8**	**#10**	**#40**	**#200**
MN	100	65–95	40–85		25–70	10–45	5–15
SD	100		50–78	37–67		13–35	4–15

Figure 2 presents a plot of the gradations for the four states (also listed in Table 1) that reported using 1.5-in. top-size material and shows that the specified ranges are fairly well graded and plot near the 0.45 power curve. Similar plots can be produced for the other top-size gradations.

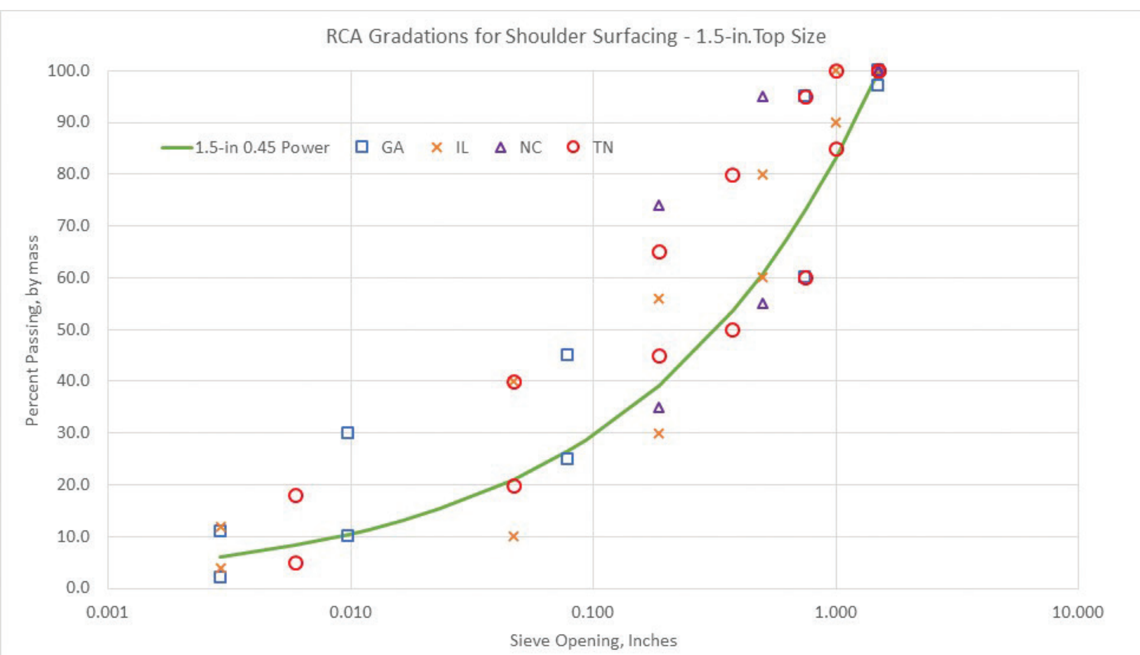

Figure 2. Specified RCA gradation ranges for states that responded to the National CP Tech Center survey and use 1.5-in. top-size material

Durability

When additional testing is required, RCA materials are generally required to meet the same quality requirements as conventional aggregate shouldering materials. An exception is typically made for sulfate soundness testing because RCA is often susceptible to sulfate attack when tested using sodium or magnesium sulfate materials. This susceptibility may make the results of tests like AASHTO T 104 unreliable.

AASHTO M 319 describes alternative soundness testing approaches, including AASHTO T 103, a freeze-thaw procedure conducted in water with 25 cycles of freezing and thawing and a maximum allowable loss of 20%. Other listed alternates are the New York State DOT (NYSDOT) Test Method NY 703-08 and Ontario Ministry of Transportation Test Method LS-614, both of which involve freeze-thaw cycles in a sodium chloride brine solution with a maximum allowable mass loss of 20%.

Other Qualification Tests

RCA materials may be subject to some qualification tests not generally applied to natural aggregates (e.g., limits on certain potentially deleterious substances, such as asphalt concrete, brick, plaster, gypsum board, and hazardous materials). Other than asphalt concrete, these substances are typically found in RCA from building demolition and are not common in RCA from pavement sources.

Typical limitations on potentially deleterious substances include the following:

- AASHTO M 319 limits bituminous concrete material to 5% or less, by mass, of the RCA, but allows higher percentages with validation testing using the California bearing ratio test (AASHTO T 193), the resilient modulus test (AASHTO T 307), construction of a test strip, or historical data.
- AASHTO M 319 limits the inclusion of plastic soils such that the liquid limit (AASHTO T 89) of materials passing the No. 40 sieve is 30 or less and the plasticity index (AASHTO T 90) of the same material is less than 4. Alternatively, the sand equivalent test (AASHTO T 176) value of the same material must be a minimum of 25%.
- RCA should be "substantially free" of other potentially deleterious materials, such as wood, gypsum, metals, plaster, etc. (i.e., each less than 0.1% by mass). These limits can be adjusted if it is determined that the adjustments will not negatively impact the performance of the product.

Blending with Natural Aggregate

RCA can be blended with natural aggregate for use in unbound shoulder surface applications. The decision to blend often depends on the relative quantities of required material and available RCA product (e.g., if the required volume of shouldering material is less than the expected RCA production volume), as well as other project-specific or agency requirements.

An example of the latter is that the Iowa DOT limits RCA content in shouldering material because shoulders made from 100% RCA initially were not sufficiently stable for heavy trucks. The Iowa DOT now limits RCA content to 30% of new shoulder material and 50% of material added to existing aggregate shoulders (Iowa DOT 2015).

No other agency responding to the recent CP Tech Center survey (2017) indicated a requirement for blending with natural aggregate, although they may allow it.

Guidelines for Producing RCA Shoulder Material

Guidelines specific to the use of crushed concrete from existing pavements in unbound bases are available in Appendix B of the American Concrete Pavement Association's (ACPA's) *Recycling Concrete Pavements* (2009). This guidance is also generally applicable to the use of RCA in unbound shoulder surfaces. Key points from this document are summarized as follows:

- "RCA material … should be free of all materials that are considered to be solid waste or hazardous materials…" "The quality control (QC) plan … will also describe methods to be used to ensure that RCA materials are not contaminated with unacceptable amounts of deleterious materials."
- "If … combinations of RCA and other approved virgin aggregate materials are to be used … proposed percentages of combined materials should be established [for approval]. Revised density acceptance criteria are recommended when percentages or sources of material change because RCA specific gravity and absorption characteristics are different from those of natural aggregate and may vary significantly between sources."
- "If RCA is blended with other approved aggregates, blending should be accomplished using a method that ensures uniform blending and prevents segregation."

RCA Shoulder Design and Construction Considerations

Design of unbound RCA shoulders should be performed using the same tools used for conventional unbound aggregate shoulders and should result in shoulders with similar thickness.

Placement and Compaction Equipment

RCA shoulders can be placed using standard equipment and techniques. However, excessive handling and movement of the RCA during placement and compaction should be avoided. These activities can produce additional fine material through abrasion and particle fracture, resulting in a changed particle size distribution that could lead to reduced shoulder stability.

There are differing opinions concerning the type of compaction equipment that should be used. The more broadly accepted line of thinking recommends the use of rubber-tired compactors because steel-wheeled compaction equipment may produce more RCA particle breakage and degradation. However, some agencies recommend using steel-wheeled compaction equipment when the RCA may contain embedded steel fragments that could damage rubber-tired rollers, even though RCA processing should remove any steel that would be hazardous to either compaction equipment or vehicles that might use the shoulder in service conditions.

Moisture and Density Control

RCA (and blends of RCA and natural aggregate) should be placed close to the optimum moisture content to ensure that compaction efforts are efficient. Optimum moisture content for RCA is typically significantly higher than for natural aggregate because of the higher absorption capacity of typical RCA. Placement at suboptimal moisture contents may cause segregation and requires additional compaction effort, which may result in unnecessary degradation of the RCA and creation of fines that change the drainage and stability characteristics of the material.

Compaction density control is typically accomplished by performing a standard proctor test (AASHTO T 99 or ASTM D698) and requiring a minimum in-place density of no less than 95% of standard proctor. When the desired density cannot be achieved without crushing the base material during compaction, it may be preferable to slightly relax the compaction requirement and/or adopt a procedural standard of compaction (i.e., require a specified number of compaction passes to achieve adequate density, based on agency experience). Appendix X1 of AASHTO M 319 provides a detailed description of an alternative field control method that involves the use of variable acceptance criteria for compaction based on tests performed on each designated lot and sublot on the project.

Potential Economic Benefits

The economic benefits of using RCA in aggregate shoulder surfacing depend mainly on the difference in cost between using virgin material and using recycled concrete aggregate. These costs typically include the following:

Virgin material:

- Material costs
- Haul virgin material
- Place and compact virgin material
- Haul out demolished concrete (to disposal)
- Dispose of concrete

Recycled concrete:

- Haul demolished concrete (to crusher, unless recycled in-place)
- Material and haul costs for virgin blending material (optional)
- Crush and screen RCA
- Place and compact RCA

Note that the cost of breaking and removing the existing concrete pavement is required for both operations and can, therefore, be included in or eliminated from both calculations without affecting the difference in costs. The differences in these costs are highly project-specific and generally (but not always) favor concrete recycling. Use of on-site or mobile crushing equipment for RCA may provide cost savings.

An additional economic benefit to recycling into aggregate shoulder surfacing or unbound aggregate base rather than into higher-type applications (e.g., aggregate for asphalt or concrete mixtures) is the reduced need to eliminate typical contaminants (e.g., asphalt concrete, joint sealant materials, reinforcing steel fragments, etc.) and crusher dust from the recycling stream prior to use of the RCA. This provides contractors with flexibility in production and construction and generally results in lower unit material costs.

Furthermore, shoulder surface aggregates are generally somewhat densely graded (for stability under traffic loads), so a greater proportion of the crushed concrete can be reused, resulting in a higher reclamation efficiency than for most other RCA applications.

Environmental Considerations

Water passing over and percolating through RCA materials can produce runoff and effluent that initially is highly alkaline, often with pH values of 11 or 12. This is an effect that generally diminishes with service time as the calcium hydroxide near the exposed RCA surfaces is dissolved and removed from the system. This high pH effluent is generally not considered to be an environmental concern because it is effectively diluted at a very short distance from the source with much greater quantities of surface runoff (especially for unbound RCA shoulders, which typically are not drained and do not have drainage outlets or other point sources).

Consideration of the sensitivity of local soils, surface waters, and groundwater to the presence of alkaline effluent may necessitate setting limits on the proximity of RCA placement to sensitive areas. Chapter 7 of *Recycling Concrete Pavement Materials: A Practitioner's Reference Guide* (Snyder et al. 2018 in press) provides additional information and guidance on mitigating environmental impacts such as elevated pH effluent.

Other potential negative impacts of concrete recycling are the noise and dust produced by the concrete breaking, hauling, and crushing operations, particularly for off-site crushing. These impacts can be managed by using mobile crushing units, judiciously selecting crushing sites, using dust and noise suppression systems, restricting site operation hours, etc.

Potential negative impacts typically are completely offset by reductions in impacts that would result from the use of natural aggregates, such as consumption of natural aggregate resources, energy consumed, and emissions produced in aggregate production and hauling, consumption of landfill space for demolished concrete, etc.

Summary

RCA is allowed for use in aggregate shoulder surface applications in at least 10 states. It has been used successfully in many instances, although at least one state requires blending with 50% to 70% natural aggregate to ensure adequate stability immediately after construction.

Many highway agencies require only gradation control for RCA base/subbase and shouldering materials when the source concrete is from their own network. Other source materials may be required to meet the same quality requirements as conventional aggregate materials. RCA grading requirements typically call for a maximum particle size of 3/4 to 1.5 in. and a relatively dense gradation with some material (but no more than 12% to 15%) passing the No. 200 sieve to aid in achieving compaction and density.

Standard equipment and techniques can be used to construct RCA shoulders, although steps should be taken to minimize the potential for producing additional fines through abrasion and other mechanisms. A key step is to place and compact the RCA at optimum moisture content, which is typically higher than for natural aggregate materials.

The potential economic benefits of using RCA in shoulder surfaces are often large, but vary among projects, mainly due to the cost and proximity of suitable natural aggregate sources. The potential for negative environmental impacts with RCA shoulder surfaces is relatively small and is associated with diffuse high pH surface runoff and noise/dust from production operations. These negative impacts are generally offset by reductions in impacts that would result from the use of natural aggregates.

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