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Concrete Pavement Recycling-Project Selection and Scoping

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"Moving Advancements into Practice"

MAP Brief September 2017

Best practices and promising technologies that can be used now to enhance concrete paving

Concrete Pavement Recycling—Project Selection and Scoping

Introduction

Most concrete pavement projects can and should be considered candidates for recycling. Characteristics that make a project a good candidate for recycling are driven by specification requirements, production options, regulations, and the cost of virgin materials, among other considerations. This MAP Brief includes guidance on:

- determining whether concrete recycling is an option for a particular project,
- identifying which type of recycled material could be produced and where this recycled material could be utilized,
- pavement crushing and specification expectations that drive project scoping,
- economic considerations, and
- other factors impacting and guiding the identification of candidate projects and uses.

All projects are unique, and there are many appropriate and proven approaches to project selection and scoping for concrete recycling. A flowchart that shows one generalized approach to project selection and scoping is presented in Figure 1, and subsequent sections of this MAP Brief describe the approach in a similar order to that shown in the flowchart.

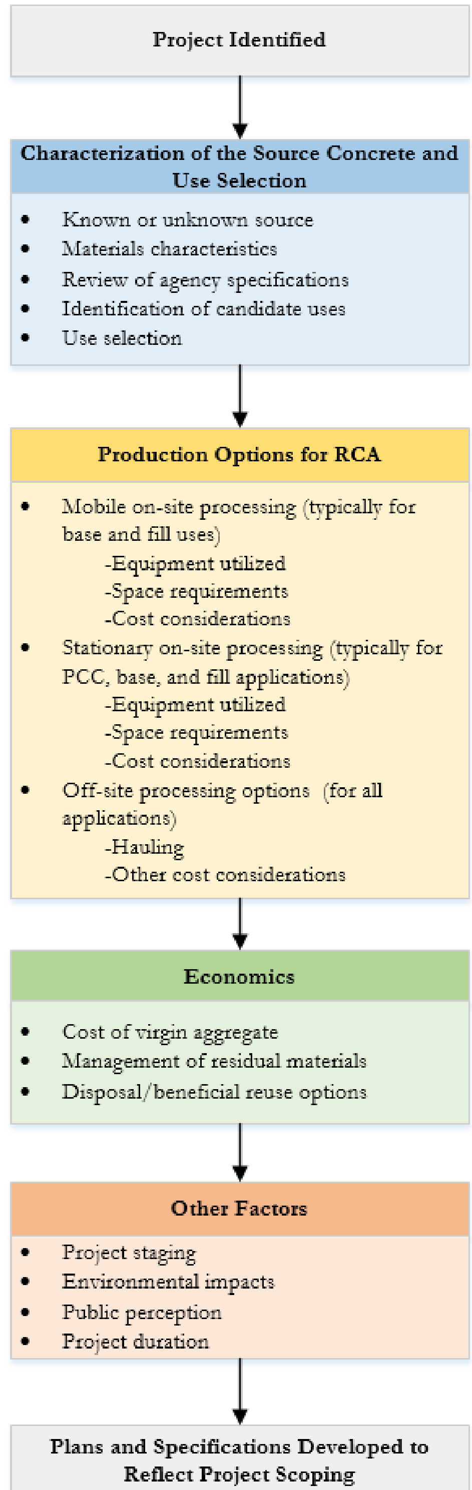

Figure 1. Project selection and scoping considerations flowchart

Characterization of the source concrete and use selection

Material characteristics

Most concrete on a project can be recycled if properly matched to the quality of material needed for a specific application. Typically, concrete sourced from agency infrastructure is of known (and often good) quality, having met previous QA/QC requirements. For concrete of unknown quality or sourced from non-agency projects, testing to determine characteristics such as compressive strength, abrasion resistance, and susceptibility to materials-related distress (such as alkali-aggregate reactivity [AAR] and D-cracking) is recommended. Some successful recycling of AAR and D-cracked pavements into new concrete applications has been performed (Snyder 2017), but mitigating provisions (such as the use of fly ash or slag cement and reduced water to cementitious materials [w/cm] ratio) are typically incorporated into the new concrete mixture.

In almost every paving application, the source concrete should be clean—i.e., free of significant amounts of undesirable material that could impact the quality of the end product (Snyder and Cavalline 2016, AASHTO 2010). The Agency should review the specifications for typical aggregate products in the context of potential use of RCA and align the material requirements with the potential application and source of the RCA. If RCA is to be used for new PCC applications, additional QA/QC measures are typically implemented.

Identification of candidate uses

Once the material characteristics of the source concrete from a project have been confirmed, candidate uses for the RCA can be identified. These uses in highway applications generally include the following:

- Concrete pavement (single- and two-lift)
- Asphalt pavement
- Base material (unbound and stabilized)
- Fill or embankment material (along the pavement or elsewhere on project)
- Filter material around drainage structures
- Drainage layer

The contractor should be given as much flexibility as possible in selecting the specific applications for which RCA can be used on a project. From a sustainability perspective, concrete should be recycled into the highest grade use practical, which contributes to a zero waste highway construction stream (Van Dam et al. 2015). However, recycling in any use is still preferable to disposal. In cases of source material of marginal or varying quality, use as fill material and/or unbound base material may be better applications than as aggregate for new concrete mixtures.

Agency specifications

To promote concrete recycling, agency specifications should be modified to remove barriers to RCA use and to maximize the usable portion of RCA produced. Existing specifications may include language that implicitly (or explicitly) restricts the use of recycled materials through unnecessary restrictions on aggregate mechanical properties, gradation, or durability. Raising specification limits for allowable abrasion loss, widening gradation requirements, or using other specification modifications has been shown to successfully encourage the use of RCA (Snyder et al. 1994, Fick 2017). Alternatively, some state agencies have successfully modified existing specifications to apply to both natural and recycled aggregates (Prieve and Niculae 2016).

Use selection

Once the source material characteristics are known, one or more uses for RCA can be targeted by an agency or other stakeholders. As stated previously, sustainability principles encourage material reuse at the highest grade possible (Van Dam et al. 2015). However, site conditions, contractor experience, economic considerations, and agency preferences each play a role in use selection. Many laboratory and field studies, as well as successful in-service performance, have supported the development of a wealth of technical guidance for use of RCA in bound and pavement applications, as well as lower-grade uses such as fill material. A reference guide on RCA production and use prepared by the American Concrete Pavement Association (ACPA 2008) has been utilized by state agencies and other stakeholders for many years. Additional guidance for concrete pavement recycling, in the format of a practitioners' manual has recently been developed (Snyder et al. 2017).

Production options for RCA

RCA can be produced in several ways, and feasible alternatives vary with site location, project characteristics, and market factors. One key difference in production options is whether they are performed on-site or off-site. On-site processing can be performed using conventional stationary crushing and grading facilities set up at one or more locations on or near the project site or using mobile on-grade processing equipment. Urban areas often have permanent aggregate processing and recycling facilities that can be used, and this option may be enticing when on-site space is limited.

The decision to use a mobile crusher or a stationary plant requires consideration of technical, financial, and environmental aspects of a project, including hauling costs, transport distances, plant production capacities, and economy of scale (Zhao et al. 2010). The economic and environmental benefits of selecting RCA over virgin aggregates are highly linked to transportation costs. In both on-site and off-site production, hauling should be minimized. On-site processing of RCA provides the advantages of reduced hauling distances, resulting in reduced emissions and the potential for reduced construction duration (Braga 2015, Van Dam et al. 2015). The location of the source concrete and the use(s) of recycled material must also be considered.

Production of RCA requires equipment for breaking, excavating, removing steel and other undesirable materials, crushing, screening, and hauling. Equipment must be provided to prepare the existing concrete pavement for recycling, including cutting tooth plows or high-pressure water jets to remove joint sealants, and (if necessary) excavators for removal of asphalt patches and milling machines to remove overlays. Pavement breakers and drop hammers are often used to break the existing pavement into pieces of manageable size for excavation using backhoes, end loaders and other suitable equipment.

Mobile on-site processing for base and fill uses

On-site processing for unbound RCA base is often performed using on-grade (or near-grade) crushing. In the on-grade process, crushing, screening, and grading are performed sequentially as the equipment passes over the existing pavement. After pavement breaking, a hydraulic hammer may be used to break oversized rubble pieces. An excavator feeds the mobile crushing equipment (shown in Figure 2), which includes crusher(s), magnet belts to remove metals from crushed pieces, and sizing screens. The finished RCA is transferred to conveyors, which windrow the material alongside the roadway. Very few hauling trucks are required, since the excavator feeds the crusher. Space on one side of the roadway is required for the windrows of RCA and crusher fines.

Figure 2. Mobile on-site crushing equipment (photo courtesy of Kevin Merryman, Iowa DOT)

Stationary on-site processing for PCC, base, and fill applications

On-site stationary processing of RCA (shown in Figure 3) requires space and equipment to support crushing, screening, and stockpiling at a central location. Site selection should minimize impact on private property and impacts to local communities. The land required to support a stationary on-site recycling operation will depend on a number of factors, including required production capacity, the number of crushers and screens, size of equipment, stockpile area required, roadway area to support truck traffic, and other considerations. However, on-site RCA production facilities have been reported on sites as small as ½ acre (DETR 2010). Ramp interchange areas (e.g., inside the loops of a cloverleaf or the areas between ramps and the mainline pavement) are often ideal, and tend to be easier to permit from an environmental standpoint (Fick 2017). For larger projects, on-site production is sometimes relocated during various project stages to help optimize hauling efficiency and to support construction staging.

Figure 3. Crushing and sizing of source concrete at on-site stationary plant (photo courtesy of Gary Fick, Trinity Construction Management)

Off-site processing options

Recycling at stationary plants tends to be more economical in urban markets, where transportation costs can be kept low (Goonan 2000). These recycling facilities often accept construction and demolition (C&D) debris (including materials other than concrete) from multiple sites, and typically charge tipping and/or processing fees. These fees may be offset by the potentially greater production capacity of some stationary plants, since larger recycling plants tend to have lower RCA production costs and higher operational efficiencies (Zhao et al. 2010).

An advantage of stationary recycling plants is the additional capacity that many have over mobile plants, resulting in production of stockpiles of different qualities of materials for use in different applications (Silva et al. 2017). Since stationary plants often process and handle C&D waste from a variety of sources, contamination may be an issue, particularly if RCA is to be used for PCC mixtures. However, stationary plant technologies and practices have progressed to the point where the quantity of contaminants introduced to the RCA can be minimized and high quality RCA can be produced for a variety of applications (Silva et al. 2017).

General Considerations for RCA Processing

For both on-site and off-site RCA processing, production rates, availability of material during different stages of a project, hauling distance, and equipment all need to be considered. Crushing and screening equipment for RCA is generally identical to the equipment used for producing virgin aggregate at a quarry. However, the types and sizes of the crushers is important, as the crushing mechanism will influence the gradation of RCA produced and quantity of fines generated, and the size of crusher will affect production rates. Impact crushers tend to crush both mortar and aggregate, resulting in the production of more fines (O'Mahony 1990). If fines production is to be limited, use of a jaw crusher may be warranted. Depending on the selected end use and specification requirements, a combination of primary and secondary crushers may be required to achieve the desired final product.

Conveyers and screens need to be sized for the appropriate production rates and material to be produced to meet specifications. If the RCA must be fractionated to meet project specifications, additional screening equipment and space for separate stockpiles may also be required. RCA for new PCC mixtures will likely need to be held to higher QA/QC standards than RCA for base or fill applications.

Economic Considerations

Cost of Virgin Aggregate

Although concrete recycling promotes a more sustainable highway infrastructure, the decision to recycle or use RCA is largely driven by the relative cost of using virgin aggregates (Fick 2017). There are construction commonalities between RCA and virgin aggregate, including a number of construction processes. However, when considering costs, there are certain features associated with RCA and virgin aggregate that need to be compared. When comparing costs, the cost of recycled aggregate production and hauling must be weighed against the purchase and hauling costs for virgin aggregates (and disposal of unrecycled concrete). Market prices for both virgin aggregates and RCA produced by off-site recyclers vary over time, by geographic location, and by quality and gradation. Since it is often very difficult to accurately predict market prices during the design phase, this cost comparison is easier to do during the construction phase. One factor to include in this cost comparison is that RCA typically has a lower specific gravity, providing more material by volume, and allowing RCA to "go a longer way" for any given weight of material (Van Dam et al. 2015).

RCA typically provides comparable performance to virgin aggregates (ACPA 2010). Therefore, life cycle cost analyses (LCCA) for pavements containing RCA should produce similar results to those produced for the same pavements containing virgin aggregates, if the initial costs of the aggregates are similar. If the RCA is less expensive than the natural aggregates, a lower life-cycle cost could be anticipated.

Residuals management

Residual material from RCA production may include solids and/or liquids (slurries). Specifications typically dictate the size fractions of RCA that can be used, and conversely, the fractions that may be unusable for any given application. Specifications for material sizes larger than the No. 4 sieve are generally easy to meet, while requirements for the size fractions passing sieves smaller than No. 4 are more difficult to meet (Fick 2017). This may result in a portion of finer RCA becoming waste. The quantity of fine material allowed in RCA is dependent on the application (e.g., drainable base specifications typically allow fewer fines than the specifications for dense-graded granular base, and specifications for coarse RCA used in concrete typically allow fewer fines than RCA used in bases).

Implementing measures to reduce the quantities of residuals will reduce associated costs. Ultimately, residual materials can be either disposed of or reused in various applications at the project site. Disposal of RCA solids or slurries is generally not desirable. Beneficial reuse options include use as fill material, unbound base (if gradation requirements allow) and other applications such as a less-costly alternative for subgrade stabilization (Lindeman and Varilek 2016) and in new concrete paving mixtures (Naranjo 2016). Cost savings associated with these beneficial reuse applications should be considered. Stakeholder flexibility in design and construction choices will help to optimize the production and use of RCA and minimization of residuals.

Other Factors

Project Staging

Project staging plays a key role in the availability of source concrete material for RCA, timing of its availability, stockpile and storage needs (Figure 4), and what applications (and areas within a project site) are potential candidates for use of the RCA. For example, contractors may need to supplement RCA with virgin material to have adequate material to accomplish the project scope when widening is performed. During the initial stages of a project, RCA produced from on-site material may not be available for use. In such cases, virgin aggregate or RCA from other sources will be needed until RCA is available from demolition of the existing pavement.

Another issue associated with project staging is that if all concrete pavement on a site is recycled as RCA, other materials sometimes remain and must be accommodated (Fick 2017). Identifying alternative uses for RCA will aid in optimizing the use of RCA and reducing the amount of surplus material at the end of a project.

Other factors affecting project selection and scoping are those associated with environmental or societal impacts. Environmental requirements in sensitive areas may restrict recycling operations. Public perception increasingly favors concrete recycling, since

Figure 4. On-site crushing operation (photo courtesy of Gary Fick, Trinity Construction Management Services)

reuse of existing infrastructure is generally seen as a prudent decision. Project duration may also provide limitations to (or potentially support) the decision to recycle.

Weighing Factors and Making Decisions

Consideration of the factors listed above, and potentially others, will drive project selection and scoping. A checklist of considerations for different uses is summarized in Table 1. In order to weigh factors, agency preferences and allowable uses should be clearly articulated through specifications, special provisions, preconstruction conferences, and other means. With available options clearly evident from the beginning project planning and development, the decision to recycle, as well as decisions on how and where to use the recycled material, can be made in a manner that maximizes benefits to involved parties.

Table 1. Checklist of considerations for use of RCA in different applications

RCA use	Materials considerations	Production considerations	Other considerations
New RCA concrete and stabilized base materials	• Source concrete is suitable for RCA production • RCA can meet agency specifications for concrete or stabilized base aggregates • New RCA concrete and/or stabilized base materials can meet agency specifications	• Processing options (on-site vs. off-site) • Hauling • Crusher types • Required production rates • QA/QC may be more stringent than for unbound uses • Residuals production, management, and disposal/beneficial reuse	• Staging allows for availability of RCA in appropriate quantities at appropriate time • Cost of virgin aggregate • Environmental considerations and permitting • Public perception
Unbound bases and drainage layers	• Source concrete is suitable for RCA production • RCA can meet agency specifications	• Processing options (on-site vs. off-site) • Hauling • For on-site production, stationary or on-grade • Crusher types • Required production rates • Residuals production, management, and disposal/beneficial reuse	• Staging allows for availability of RCA in appropriate quantities at appropriate time • Cost of virgin aggregate • Environmental considerations and permitting • Public perception
Filter material around drainage structures	• RCA can meet agency specifications	• Processing options (on-site vs. off-site) • Hauling • Crusher types	• Staging allows for availability of RCA in appropriate quantities at appropriate time • Temporary stockpile/storage area • Cost of virgin aggregate • Environmental considerations and permitting • Public perception
Fill (beneficial reuse of fines) not in pavement structure	• Meets agency specifications	• Solids/slurry management techniques • Temporary stockpile/storage area • Hauling	• Proximity to receiving waters • Other environmental considerations and permitting • Public perception

Summary

Existing concrete pavement structures are agency assets that can be used beneficially to support a more sustainable highway infrastructure. Agencies should provide guidance for allowable and desirable uses of RCA, as well as specifications that reflect agency objectives (cost, sustainability, quality, etc.). The decision to mandate or specify RCA for certain uses should be weighed against the approach of allowing the contractor (market) to determine the most efficient use(s) of RCA.

To maximize the benefits of recycling, project scoping and selection should engage all key project stakeholders. The owner-agency will gain the best value from recycling when specifications, RCA material requirements, and the contractual framework allow flexibility in choosing the most appropriate RCA applications on the project. Practical guidance and accumulated experience should provide agencies with the confidence that RCA can be successfully utilized in a number of applications. Publicizing the resulting benefits from recycling will also aid in promoting recycling in future projects (DETR 2000).

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