Concrete Pavement Recycling Series

PROTECTING THE ENVIRONMENT DURING CONSTRUCTION

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Introduction

Concrete recycling provides many environmental and economic benefits, and reuse of pavement materials in new highway applications has been shown to be one of the most effective ways to increase pavement sustainability (Van Dam et al. 2015). Similar to almost all types of other construction activities, some impacts to the environment (including water quality, air quality, waste generation, noise, and other local effects) are possible during concrete recycling activities and should be addressed.

However, the potential negative environmental impacts of concrete recycling have consistently been shown to be readily mitigated through planning and design considerations, use of conventional stormwater best management practices (BMPs), and through readily implementable construction controls.

A summary of the potential environmental impacts of concrete recycling that can occur during *construction*, along with a summary of planning, layout, and construction controls, is presented in this technical brief. A summary of the potential environmental impacts of concrete recycling that can be addressed during project *planning and design*—along with mitigation strategies—is presented in a separate technical brief (Cavalline 2018).

Environmental Concerns Requiring Consideration During Construction

Water Quality

As reported by Steffes (1999) and Sadecki et al. (1996), recycled concrete aggregate (RCA) stockpile runoff and drainage (leachate) from RCA in situ can or may:

- Be highly alkaline (i.e., high pH due to dissolved calcium hydroxide)
- Contain chemical contaminants
- Potentially cause formation of deposits of suspended solids or precipitates in drainage systems or other downstream features

High-pH leachate from stockpiles and subsurface drains can negatively impact receiving natural waters, vegetation, and zinc-coated and aluminum pipe (through corrosion), until diluted with rainfall and other surface waters. Typically, these concerns are restricted to small areas surrounding the stockpile location or drainage outlets, since adequate dilution typically takes place within several feet of the point of discharge (ACPA 2008). The high-pH runoff is also often neutralized by infiltration and exposure to soils and rock.

Placing drains away from receiving waters, along with the use of conventional stormwater BMPs such as bioswales, as discussed in the *planning and design* technical brief (Cavalline 2018), have been shown to mitigate issues with high pH.

RCA leachate and runoff will also typically include small amounts of pollutant materials, including "heavy" metals such as vanadium, chromium, and lead (Sadecki et al. 1996, Chen et al. 2012, Edil et al. 2012). **Although these pollutants can occasionally be present in quantities higher than permissible limits for drinking water, dilution of the runoff and leachate, as well as capture or uptake into environmental systems like bioswales, have been consistently shown to mitigate the impact on receiving waters, particularly when adequate separation and/or BMPs are provided** (Snyder et al. 2018).

Air Quality

Air quality concerns associated with concrete recycling activities include fugitive dust and emissions from equipment used in production and hauling, similar to air quality concerns associated with most other types of construction activities. In addition to impacting the environment, air pollutants from any construction activity can be a nuisance to the local community.

Use of virgin aggregates is also associated with air quality impacts from similar sources, but emissions from virgin aggregate production and use may be even greater due to hauling distances from off-site quarrying operations.

Air quality impacts of concrete recycling are heavily driven by hauling distances, dust suppression efforts, and methods used for source concrete removal and the production of RCA. Emissions due to hauling and transport are often reduced by performing recycling operations on-site (or nearby). The highest contribution of dust is from vehicular sources and wind effects (DETR 2000), and efforts focused on mitigating these factors (see Table 1) are effective in reducing the overall impacts of recycling operations.

Table 1. Construction controls to protect the environment

	Mitigation Strategies			
Consideration	**Location**	**Site Layout and Controls**	**Process Controls**	**Operations**
Air quality (emissions and dust)	• Consider prevailing wind conditions in site selection • Use natural topography, roadway features, buildings, or vegetation as wind screen	• Minimize haul distances • Reduce vehicle movements • Maintain haul roads (surfacing, chemical stabilization of surfaces, application of water) • Provide wind screens for processing operations and stockpiles	• Application of water (misters, spray rigs/nozzles for prewetting and crushing operations) • Maintain vehicles and plant equipment – Maximize fuel efficiency, utilize emissions checks – Avoid leaving plant equipment and/or vehicles operating unnecessarily	• Work during periods of low wind velocities if mitigation techniques are not effective • Reduce vehicle speeds • Shrouds or tarps on haul trucks • Vehicle wheel and chassis washes • Limit stockpile height and minimize disturbance • Cover stockpiles or provide a wind barrier • Comply with OSHA's crystalline silica rule (OSHA 2016, 2017)
Water quality	• Select processing and stockpile locations away from receiving waters	• Construct runoff collection trenches around stockpiles and processing equipment • Use enhanced or redundant BMPs around perimeter of stockpiles and processing equipment (EPA 2017)	• Utilize conventional stormwater BMPs, such as berms, straw bales, and grass/filter channels around stockpiles and processing equipment (EPA 2017) • Trap runoff and sediment, preventing discharge of wash water to open stormwater inlets or receiving waters	• Cover stockpiles and maintain perimeter BMPs • Monitor and maintain BMPs around stockpiles and processing equipment • Mitigate pH and solids content of runoff as needed using localized treatment such as mechanical catchments and floc/pH logs
Waste generation	• Identify appropriate locations for washing equipment • Identify appropriate on-site locations for beneficial reuse of waste material (if allowed)	• Capture wash water using approved methods	• Use evaporative techniques in appropriate areas to reduce wash water volume	• Optimize crushing operations to minimize fines • Promote beneficial reuses of waste in pavement or fill applications
Community impacts	• Use on-site or nearby recycling (to reduce impact of haul and transport vehicles) • Locate away from sensitive areas, businesses, or homes	• Encourage two-way transport to reduce trips • Provide noise attenuation barriers	• Use chutes/conveyors to reduce noise	• Minimize drop height of material • For off-site recycling using public roadways, reduce trips during peak hours

Noise and Other Local Impacts

Like other construction operations and stationary industry activities, recycled aggregate operations can be viewed as unfriendly to local communities due to lighting, noise, vibration, dust, and traffic impacts (DETR 2000). The selection of on-site vs. off-site recycling will heavily influence local impacts, which may be most pronounced when operations occur in urban settings.

The nature of concrete recycling operations, however, is such that noise and vibration cannot entirely be eliminated (O'Mahony 1990). Planning considerations and the construction controls presented in this technical brief have been proven to successfully mitigate noise and other impacts to local communities.

Waste Generation – Concrete Residuals

Production of RCA can also result in the generation of solid waste and wastewater (slurries) that need to be managed and ultimately disposed of or used beneficially. Solid waste associated with concrete recycling can include crusher fines (generated during concrete processing to produce RCA) and other unused materials from the source concrete, such as sealants, reinforcing steel, and repair materials. Wastewater may be created from equipment washing operations and stockpile runoff. The quantity and nature of residuals produced varies by concrete source, techniques utilized for crushing and beneficiation, and wash-off frequency and methods.

To improve sustainability of the overall highway system, options for beneficial reuse of concrete residuals are becoming increasingly common and should be promoted. Several beneficial reuse strategies for residuals from concrete recycling are discussed next.

Construction Strategies and Controls to Mitigate Environmental Concerns

Table 1 presents environmental concerns associated with concrete recycling that should be considered during the construction phase. It also summarizes mitigation strategies that can be implemented in different construction focus areas. Note that many of these construction controls are the same as best practices commonly utilized for other types of construction activities.

Further discussion of strategies to minimize the job-site footprint, mitigate impacts associated with RCA production and handling, implement waste product reduction and management, and comply with water and air quality regulations are included in the following sections.

Project Site Controls to Mitigate Environmental Impacts

The decision to perform crushing and grading operations on-site vs. off-site is a key factor in determining the types of environmental impacts that should be addressed during the construction phase. On-site (or near-site) recycling generally reduces the impacts associated with RCA transport, such as noise, dust, emissions, and traffic issues.

When selecting sites for recycling operations (particularly in urban settings), stakeholders should avoid "sensitive receptors," which include populations, facilities, certain ecosystems, and any nearby entities that could be adversely impacted by the presence of a material crushing and grading facility and associated hauling equipment (DETR 2000).

Provisions to control dust and emissions can be incorporated into site location, layout, process controls, and operations, similar to air quality measures that can be incorporated into other construction activities. For example, dust control strategies should account for prevailing wind conditions and utilize the natural topography or vegetation. Existing features, such as elevated roadways or roadway depressions, can be used to shelter operations from wind and rain, and can provide some runoff control (see Figures 1 and 2).

Dwayne Stenlund/MnDOT

Figure 1. Well-implemented on-site material crushing program in urban area

Dwayne Stenlund/MnDOT

Figure 2. Demolished material stockpiled beneath bridge prior to crushing with silt fence and vegetative buffer

Local community impacts can be mitigated by encouraging two-way transport (to reduce haul vehicle trips) and by reducing noise through use of chutes, conveyors, and attenuation barriers. For off-site recycling, hauling during off-peak hours may reduce traffic issues on local roadways.

Emission reductions can be achieved by minimizing haul distances and vehicle movements, as well as by encouraging proper maintenance of plant equipment and vehicles. Simple changes in site geometry and vehicle movement controls can have significant impacts. For example, one study found that reducing vehicle speeds from 30 to 20 mph reduced dust by 22% (BCPH 2017). Reducing idle time, maximizing fuel efficiency, and utilizing emissions checks provide additional ways to minimize the impacts of greenhouse gases and other emissions associated with job-site activities.

Site controls, such as applying water to ground surfaces and equipment (Figure 3) and misting the surrounding air (Figure 4) can be very effective in mitigating job-site dust.

Dwayne Stenlund/MnDOT

Figure 3. Spray nozzle for dust control on aggregate conveyor

Dwayne Stenlund/MnDOT

Figure 4. Job-site dust suppression (misting) equipment

The use of water spray bars near crushing operations has been shown to significantly reduce dust problems. One research study showed that the use of spray bars resulted in a nearly 50% reduction of dust emissions measured at a distance of 33 ft (10 m) from the crusher (DETR 2000).

Other situations that cannot be directly controlled by site personnel (e.g., dust blowing due to windy weather) can be addressed with operational controls, such as suspending demolition when wind speeds exceed certain thresholds (MnDOT 2017). Provisions to mitigate dust should be included in a dust control plan.

Mitigating Impacts from RCA Production and Handling

On-site RCA production and handling should be managed in a manner that protects nearby receiving waters, reduces dust, and complies with applicable agency regulations. Strategies for mitigating these impacts for concrete recycling projects differ very little from those utilized for natural aggregate processing/handling or for conventional construction projects.

Implementing conventional stormwater BMPs around stockpiles (such as berms, straw bales, or grass/filter channels) and selecting stockpile sites away from surface waters have mitigated the impacts of alkaline runoff, sediments, and other water pollutants on receiving streams (Sadeki et al. 1996). Many agencies have adopted these traditional stormwater BMPs around RCA stockpiles and other concrete recycling operations and have reported success in compliance with regulations (Stenlund 2017, Wagner 2017).

In addition to the stormwater BMPs listed previously, constructed erosion control methods—including silt fences and seeding/slope control—and other physical and natural methods should be used to control and treat runoff. Strategic placement of operations and stockpiles to take advantage of existing site features can aid in the effectiveness of these BMPs.

Drainage from recycled aggregate processing operations and stockpile areas can be directed to a maintained sediment trap or a bioswale for capture of sediments and treatment of runoff if warranted. Nearby stormwater inlets, taken off line, have been successfully utilized as traps for runoff and sediment. An example of this approach is shown in Figure 5, where stockpiles of concrete are set inside a roadway depression where stormwater inlets are taken off line.

When working close to receiving waterways, enhanced perimeter controls to prevent unacceptable discharge can include concrete blocks (Figure 6) or Jersey barriers (Figure 7) wrapped in geotextile fabric.

Crushed concrete can be used as a filter berm, and some state agencies allow use of the RCA as part of the BMP along with geotextile-wrapped barriers (Stenlund 2017).

As with conventional or natural aggregate, different gradations of RCA should be stored in separate stockpiles, as should RCA products from different concrete sources. Practices to keep materials "clean" (such as removal or non-inclusion of visibly contaminated material prior to the crushing operation) and to reduce segregation (limiting stockpile heights and implementing appropriate stockpiling and loading techniques) should be required. Measures must also be taken to prevent contamination or mixing of additional fines or subgrade material.

Best practices for stockpile management to mitigate air quality impacts include controlling stockpile height and minimizing the production of fines to prevent dust. For example, Washington State Department of Transportation (WSDOT) specifications limit stockpile height to 24 ft and require stockpile construction in layers less than 4 ft thick for stockpiles that will contain more than 200 cy of material (WSDOT 2017). Stockpile areas should be misted with water for dust control when materials are being added to or taken from the stockpiles (see Figure 3).

To reduce dust and impacts of stockpile runoff on the water quality of nearby receiving waters, consideration should be given to tarping or covering RCA stockpiles (see Figure 8).

Dwayne Stenlund/MnDOT

Figure 6. High-performance perimeter control using concrete blocks wrapped in geotextile fabric

Dwayne Stenlund/MnDOT

Figure 7. Perimeter control at waterway near demolition and concrete crushing operations with RCA filter berm on inside of geotextile-wrapped Jersey barrier

Dwayne Stenlund/MnDOT

Figure 5. Concrete stockpiles set inside of roadway depression with stormwater inlets taken off line

Dwayne Stenlund/MnDOT

Figure 8. RCA stockpile tarped with plastic and bounded by perimeter berm of wrapped RCA

Other provisions, such as placing stockpiles beneath elevated roadways (shown in Figure 2), can also be effective. Agencies often require redundant perimeter controls, such as an enhanced silt fence with vegetative barrier (also shown in Figure 2) or other types of BMPs in sensitive areas.

The redundant perimeter control for the tarped stockpile in Figure 8 consists of RCA wrapped in a geotextile fabric "burrito" (which acts as a sediment filter and perimeter berm for stockpile runoff) in combination with a bioswale, which provides natural capture and treatment mechanisms for the runoff. Trenches around RCA stockpiles are also effective in controlling runoff (Sadecki et al. 1996).

Some soils may be more effective at neutralizing leachate pH than others, with clayey soils having some ability to neutralize alkaline runoff (Townsend et al. 2016). Research supporting development of soil-based BMPs for RCA leachate and runoff is currently ongoing (Ginder-Vogel 2017). Treatment of RCA stockpile runoff (or early-age leachate from drains for unbound RCA bases) may be required in some situations (but very infrequently).

Suspended and dissolved solids from both stockpile runoff and RCA leachate at pavement subdrains can be reduced using bioswales (as shown in Figure 8), mechanical catchments (see Figure 9), and chemical methods such as floc logs (polyacrylamide products that flocculate/chelate suspended and dissolved solids) (see Figure 10).

Methods of treating runoff to adjust pH include CO_2 bubblers, chemical addition, and products such as pH or "shock" logs.

Water quality monitoring and testing should be performed in accordance with the agency's National Pollutant Discharge Elimination System (NPDES) permit; the project's Stormwater Pollution Prevention Plan (SWPPP) (EPA 2007); and in compliance with applicable federal, state, and local regulations. Special provisions utilized with RCA should provide guidance on the water quality characteristics that should be monitored, required test methods, and frequency of testing. All structural BMP features should be inspected and maintained regularly, and runoff pH management and removal of accumulated materials should be performed as needed or required.

Minimizing Waste Generation and Promoting Beneficial Reuse of Fines

The type(s) of crushers(s) utilized will affect the final product gradation and the production of fines—a solid waste product that must be disposed of or beneficially reused (Embacher 2001). To reduce production of fines, jaw crushers are often used for primary crushing operations because they can handle larger slab fragments and produce fewer fines than cone and impact crushers (Snyder and Cavalline 2016, Yrjanson 1989, O'Mahony 1990).

Many disposal and reuse options exist for waste materials associated with the production and use of RCA, including disposal at a landfill, on-site burial, beneficial reuses such as RCA in new concrete (Naranjo 2016, Rowden 2016), soil stabilization (Lindemann and Varilek 2016), and as pipe bedding (Prieve and Niculae 2016). To promote concrete recycling, agencies should consider approaching projects in a manner that gives the contractor options for the use of RCA so that beneficial reuses of recycling waste products can be considered during the bidding process.

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Figure 9. Localized mitigation of high-pH leachate from drain near receiving waters using pH log and bioswale

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Figure 10. Floc log tied to wooden stake in outflow path

Slurries and wash water can result from washing equipment, vehicles, and tools used for concrete recycling, as well as from other on-site activities. NPDES construction permits often require concrete wash-off management to prevent discharge of liquids and solids to soils/waters (unless in defined designated areas) using BMPs. Designated areas for wash-off, discharge, and disposal need to be maintained and recorded on the SWPPP, with such activities restricted from sensitive areas. Best wash-water practices utilized by the Minnesota Department of Transportation (MnDOT 2009), for example, include the following:

- Perform wash operations and wash-water disposal at designated areas of open subgrade or along shoulder
- Wash at designated areas on a closed surface; then subsequent disposal
- Work area isolation, with subsequent capture and disposal
- Sump manhole isolation trap and vacuum removal

Wastewater and slurries can also be captured in lined ponds, fractionation tanks (or frac tanks), and closed stormwater inlets. Some agencies allow ponding in approved areas, where evaporation can be utilized to help reduce the volume of the waste material. Solids can then be subsequently disposed of or beneficially reused. In all situations, stakeholders should comply with applicable regulations.

Air Quality – Respirable Crystalline Silica

The Occupational Safety and Health Administration's (OSHA's) new crystalline silica rule, aimed at protecting workers from harm from respirable crystalline silica, was effective September 23, 2017 for construction and is currently scheduled to become effective, in general, on June 23, 2018. OSHA's Construction Standard (with Table 1) provides guidance for engineering and work practice control methods and required respiratory protection and minimum assigned protection factors for a variety of equipment and tasks (OSHA 2017).

Best practices for dust protection for concrete recycling activities include use of spray bars and other water suppression systems at the points of dust generation, protecting operators with ventilated enclosures when possible, and restricting access to work areas to limit exposure of non-essential personnel. Required respiratory protection differs by duration of operating shift as well as utilization venue (i.e., indoors vs. outdoors).

Hand-held equipment and equipment operated without protective enclosures for operators tend to have more stringent respiratory protection requirements than larger equipment and machinery. Project personnel should be sure to consult applicable OSHA regulations for guidance in preparing this plan and otherwise ensuring compliance with the rule (OSHA 2016 and 2017). The American Concrete Paving Association (ACPA) also published a Technical Bulletin, *Understanding OSHA's Crystalline Silica Rule*, to provide guidance for stakeholders in the concrete pavement industry (ACPA 2016).

Summary

Concrete recycling is a sustainable practice providing many environmental and economic benefits. However, similar to other construction activities, concrete recycling activities should be approached in a manner that mitigates potential adverse environmental impacts.

Strategies for addressing environmental concerns during concrete recycling construction projects are very similar to those regularly used in highway projects without concrete recycling. Proactive pre-construction decisions regarding the location(s) and site layout of recycling operations, along with implementation of conventional process controls and operational practices at the construction site, can be used to reduce negative impacts to air and water qualities and the local community.

Concrete recycling has been successfully performed on many highway projects without adversely affecting the environment or local communities. Use of appropriate controls during planning and design (Cavalline 2018) and during construction (as discussed in this technical brief) to mitigate environmental impact are simply steps in treating RCA as an engineered material, ensuring a more sustainable highway infrastructure.

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