PennDOT RECYCLING MATERIAL BRIEF

Recycled Concrete Aggregate Fact Sheet

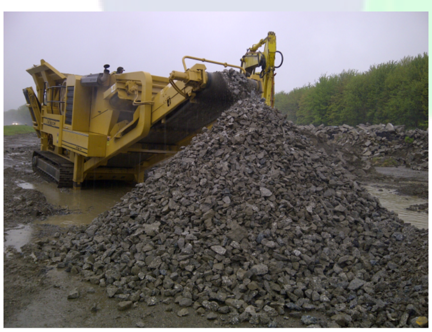
Background and Origin

With growing stress on our transportation systems juxtaposed with rising costs of materials and disposal necessary to carry out these projects, the need for creative solutions to help offset the cost of highway and bridge repairs is essential. Over the last decade, one solution that has gained momentum throughout the United States is the use of Recycled Concrete Aggregate (RCA) in civil engineering applications.

The reuse of concrete in roadway infrastructure dates back to the 1940s; specifically, the first documented use of recycled concrete in a transportation projects in the United States was a section of Route 66 in Illinois. Since its first documented use and with a growing stress on transportation systems, interest to increase the use of RCA has grown exponentially. Many entities such as the United States Environmental Protection Agency (U.S. EPA), United States Department of Transportation (U.S. DOT), State DOTs, and the Federal Highway Administration (FHWA) perform/support research efforts and create guidelines/Specifications for the use of RCA in various applications.

According to the U.S. EPA, in 2016 and 2017 over 560 million tons of construction and demolition (C&D) wastes were generated in the U.S. Specifically, concrete is the largest waste stream generated by PennDOT operations annually. If captured, portions of this “waste” material can potentially supply the highway and construction industries with a vast resource of aggregate material that when realized will benefit the Commonwealth fiscally as well as increase the much needed landfill space statewide.

Recycling of concrete is a relatively simple process. It involves breaking, removing, and crushing existing concrete from roads, buildings, and other structures (i.e. sidewalks, bridges, utility excavations, demolition operations, cleanup operations associated with natural disasters, structural failures, etc.) to generate a strong durable aggregate that has many uses. Once the concrete is recycled, the resulting RCA contains not only the original aggregates, but also hydrated cement paste (otherwise referred to as fines). Laboratory studies conducted by state DOTs, as well as federal agencies, have found that the use of RCA will produce strong durable concrete suitable for pavements and other industrial uses in all areas of the United States. According to these studies the mixture produced by utilizing coarse aggregate has no significant effect on mixture proportions or workability when compared with control mixtures made with conventional aggregates. Although there are limitations to using recycled fine aggregates, these drawbacks can be generally overcome by limiting a mixture to a specified percent of RCA. Recycled aggregates have exhibited good particle shape, high absorptions, and low specific gravity compared with conventional mineral aggregates. Additionally, a number of agencies have found through their research that using RCA has shown an increase in freeze-thaw resistance and improved durability.



Example of concrete crushing and processing operations

As of 2007 major urban highways were being constructed using RCA. Such projects have enlisted the use of RCA in concrete aggregates, sub-base materials, rip-rap or slope protection, embankment burrow, and aggregate base coarse. Cost savings as high as 65%+ have been realized.

This fact sheet provides information on the recycling of concrete pavement including the resultant aggregate properties, engineering parameters, and applications for the Pennsylvania Department of Transportation (PennDOT) approved uses in civil engineering applications.

Material Properties

All aggregates have different material properties that make them suitable for specific applications. The two primary material properties of RCA that deem them appropriate for civil engineering applications are the aggregates coarse and angular shape and the available fines.

There are many material properties that are evaluated when determining if a specific material can be used in civil engineering settings. Most of these properties and their standard testing methods are listed below.

Property	Standard Testing Methods
Deleterious Components	ASTM C40, ASTM 295, ASTM C142 ASTM D2419
Fines	AASHTO M80
Specific Gravity	ASTM C127, AASHTO T85; Fine Particles: ASTM C128, AASHTO T84
Density	ASTM C127, AASHTO T85; Fine Particles: ASTM C128, AASHTO T84
Absorption	ASTM C127, AASHTO T85; Fine Particles: ASTM C128, AASHTO T84
Los Angeles Abrasion Test	ASTM C131, ASTM C33, AASHTO T96-681, ASTM C535
Sulfate Soundness	ASTM C88, ASTM C33, Fine Particles: AASHTO T104
Alkali-Silica or Alkali-Carbonate Reactivity	AASHTO T299, AASHTO T303, ASTM C295, ASTM 289, ASTM C342, ASTM C441, ASTM C589, ASTM C666 and ASTM C856
D-Cracking	ASTM C 666
Compressive strength	ASTM C39

Additional material properties that must be quantified prior to a material being used as an aggregate include; chloride content, alkalinity, tufa formations, flexural and tensile strength, the modulus of elasticity (E), durability, and gradation.

General Practices

Mix designs should be based on the measured density of the RCA aggregates. The same sand to aggregate ratio used for conventional mixes applies when using RCA aggregates. If fine aggregates are used they should be limited to 30% of the sand portion. Water content should also be monitored during the mixing process.

When stockpiling RCA stone, in process segregation should be avoided. This will help when blending operations are considered. Stockpile moisture content should also be monitored. Installing a sprinkler system to periodically wet RCA stockpiles has proven to help minimize the potential for RCA aggregates to absorb moisture from the concrete mix. Finally, location is particularly important due to pH considerations. Storage locations that minimize impact to stormwater runoff should be selected.

Quality control procedures used for conventional concretes are recommended during placement, mixing, and stockpiling of RCA. The slump, air content, and temperature should all be considered during placement.

Unresolved Issues

The formation of tufa (a calcium carbonate precipitate) has been a long observed issue when using RCA in roadway applications. Specifically, many projects have experienced clogging of underdrains and stormwater runoff with initial high pH values. Additionally, due to the presence of mortar on the surface of the aggregate it is more porous and absorptive than many natural aggregates. This can sometimes result in increased shrinkage and creep of the new concrete containing RCA. State DOTs have and continue to perform research and testing to address these qualitative concerns, so that quantitatively RCA can be utilized to its maximum potential.

Applications

RCA has good particle shape, high absorptions, and low specific gravity. Because of these properties, improvements to substandard geometrics, subgrade conditions, and vertical clearance at bridges and drainage are recognized. Although not all of the below listed applications are approved for PennDOT use, RCA has been successfully used in the following civil engineering applications:

- Sub-base
- New Concrete
- Backfill
- Retaining walls
- Shoulder back-ups
- Drainage Applications
- Embankment Fill Material

Specifications

In PennDOT's Publication 408 – Construction Specifications (Publication 408) Section 703, RCA is approved for use as 2A aggregate with the exception of subbase. Historically, PennDOT's Publication 408 permitted the use of RCA as a sub-base material. However, in 2020 due to the formation of Tufa which resulted in high pH concentrations in stormwater runoff at specific project locations, the specification that allowed RCA's use as subbase material was temporarily suspended. The PennDOT lab is currently assessing the best way to address pH issues, once this is determined it is anticipated that RCA will once again be an approved subbase material. With the exception of subbase, the following table is a listing of all Publication 408 – approved uses for 2A aggregate:

Section	Application
203	Embankment and Fill
221	MSE Walls
601	Sides of Trenches, Above Pipes, and Conduits
605	Endwalls, Inlets, Manholes, and Spring Boxes
738	Geogrids
1085	Precast Reinforced Concrete Box Culverts
1086	Sound Barriers

Special Provisions

The below table provides a listing of Special Provisions that have been approved for RCA usage, copies of these Special Provisions are available on PennDOT's Engineering and Construction Management Website (ECMS).

Special Provision Number	Use
Removed	RPCC Aggregate for Miscellaneous Drainage
Removed	RPCC Aggregate for Rock Lining, Class R Modified
c00335	Recycled Concrete Shoulder
Removed	Subbase (No. 2A), Recycled Concrete

Conclusions

The use of RCA remains an emerging market with a significant amount of research still being conducted. RCA offers many benefits such as cost effectiveness, diversion of non-recyclable products from disposal in landfills, and materials conservation. From a chemical and physical standpoint, aggregate generated from RCA is not significantly different from conventional aggregates. Although the research and uses of RCA have greatly matured since it's initial uses, there are still challenges (i.e. decreased workability, Tufa formations, the presence of deleterious materials, and negative perceptions) to overcome before it can be used freely as an aggregate substitution. As new Specifications for RCA applications are approved by PennDOT, Publication 408 will be updated.

If a previously unexplored use application for RCA has been identified, contact the PennDOT Strategic Recycling Program (SRP) at PennDOTSRP@pa.gov to discuss a path forward.