Evaluation of Recycled Concrete as Aggregate in New Concrete Pavements

From the WSDOT Research Office
May 2014

Disclaimer: The contents of this report reflect the views of the author(s), who is (are) responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Washington State Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration. This report does not constitute a standard, specification or regulation.

The Problem
The Washington State Department of Transportation (WSDOT) manages 2,400 lane-miles of concrete roadway, most constructed in the 1950s and 1960s. The Federal Highway Administration and WSDOT are interested in alternatives that promote cheaper and more sustainable pavement construction practices. One alternative is to incorporate recycled concrete as aggregate in new Portland cement concrete pavements. The dwindling supplies of high-quality natural aggregate, increasingly limited landfill space, swelling disposal costs, emphasis on the conservation of natural resources, and reduced construction costs are important reasons to consider the using recycled concrete aggregate (RCA).

What We Did
This research was conducted to evaluate the suitability of incorporating RCA, produced from demolished concrete pavements in Washington State, as an aggregate in new Portland cement concrete pavements (PCCP). This study investigated the properties of RCA and evaluated its effects on concrete properties relating to the performance of new PCCP. Demolished concrete pavements from western, eastern and central Washington were used as the sources investigated in this study. All three RCA sources were produced from demolished pavements containing high-quality original materials.

The variables investigated included levels for replacing coarse natural aggregate with coarse RCA (0%, 15%, 30% and 45%), the source of the RCA used, and percent replacement of Portland cement with fly ash (0% or 20%). In total, twenty concrete batches were produced. For each batch, fresh concrete samples were tested for slump, air content, and density. Hardened concrete samples were tested for compressive strength, modulus of rupture, coefficient of thermal expansion, drying shrinkage,
and freeze-thaw durability. Additional tests were performed on RCA from each of the three sources to determine specific gravity, absorption capacity, Los Angeles abrasion loss, degradation values, and alkali-silica reactivity.

Five tests were used to characterize RCA properties including specific gravity, absorption capacity, Los Angeles abrasion loss, degradation value in various conditions, and alkali-silica reactivity. The conditions for which the degradation value was determined included the as-delivered unprocessed RCA, the processed RCA, and processed RCA mixed with natural aggregate at rates of 15%, 30%, and 45%. Overall, tests showed that RCA had a lower specific gravity, greater absorption capacity, and meets the WSDOT requirements for Los Angeles abrasion loss and degradation value once processed. Additional tests may need to be performed to evaluate potential deleterious expansion due to alkali-silica reactivity.

Three tests were used to determine if RCA had any effects on the properties of fresh concrete including slump, air content by the pressure method, and density. Slump and air content were controlled parameters in the batching process, with targets specified by WSDOT of 1-3 inches for slump and 4-7% for air content. It was a goal during the mix process to make concrete mixtures within the low end of each of those ranges. Slump was controlled by withholding mix water or adding water-reducing admixture (WRA), and air content was controlled by the amount of air entraining admixture used in the batch. RCA was found to decrease the slump and density of fresh concrete. RCA had no significant effect on air content.

Five tests were used to determine the effects of RCA on hardened concrete properties including compressive strength, modulus of rupture, coefficient of thermal expansion, drying shrinkage, and freeze-thaw durability. Test results showed that up to a 45% replacement of coarse natural aggregate with RCA had no significant effect on any of the hardened concrete properties tested. In addition, all samples tested met WSDOT minimum strength requirements for use in concrete pavements. It should be emphasized that these results were obtained...
using RCA from demolished pavements incorporating high-quality original materials.

What We Learned
The results of this study indicate that RCAs of similar quality to those incorporated in this research would be viable for use in new concrete pavements. RCA had no significant effects on the compressive strength, modulus of rupture, coefficient of thermal expansion, drying shrinkage, or freeze-thaw durability of hardened concrete for up to a 45% replacement of coarse RCA for natural coarse aggregate. In addition, all results from tests on the RCA from the three sources and results from the concrete incorporating this RCA at up to 45% replacement met WSDOT requirements for use in new concrete pavements.

What the Researchers Recommend
Properties of the RCA can be characterized by several factors including resistance to abrasion and the amount of adhered mortar. Water-reducing admixtures and fly ash can be used to negate the effects of RCA on fresh concrete workability. To address performance concerns related to the alkali-silica reactivity of RCA, it is recommended that each RCA source be tested for alkali-silica reactivity following the crushing process and mitigated as necessary. Construction of a test section incorporating RCA is recommended to gain experience with real-world applications. Experience with the test section will be beneficial in developing implementation criteria and specifications related to the use of RCA in pavements. Additional research
is recommended to explore the performance of PCCP incorporating substitution rates greater than 45%, and to establish minimum performance criteria for RCA properties.

**Implementation**

Based upon the findings of this research, WSDOT recommends identifying future PCCP construction projects to implement test sections to gain experience using RCA. From the test sections WSDOT will develop lessons learned, performance criteria and specifications related to the use of RCA in concrete pavements. WSDOT will work with the American Concrete Pavement Association (ACPA) to determine the appropriate level of RCA to use in a test project.

**Contact Information**

**Report Number and Title**
Evaluation of Recycled Concrete as Aggregate in New Concrete Pavements, WA-RD 826.1

**Researchers**
Haifang Wen and David McLean, Professors Spencer Boyle, Tim Spry, and Danny Mjelde, former graduate students Washington State University 509-335-2513, haifang_wen@wsu.edu 970-491-3366 david.mclean@colostate.edu

**Research Manager**
Kim Willoughby, Research Manager for Construction, Materials, Maintenance, Bridges and Structures WSDOT Engineering Policy and Innovation Division 360-705-7978, WillouK@wsdot.wa.gov

**Technical Monitors**
Kurt R. Williams, WSDOT State Materials Engineer 360-709-5410, WilliKR@wsdot.wa.gov
Jeff Uhlmeyer, WSDOT State Pavement Engineer 360-709-5485 UhlmeyJ@wsdot.wa.gov
Dave Erickson, WSDOT State Roadway Construction Engineer 360-705-7829, EricksD@wsdot.wa.gov

**Funding**
$60,000 WSDOT Research Office (80% Federal, 20% State)
$90,000 WSDOT Construction Office (State)
$60,000 PacTrans, University Transportation Center (WSU)

**Americans with Disabilities Act (ADA) Information:** Materials can be provided in alternative formats for people with disabilities by calling Shawn Munniks at 360-705-7097 or munniks@wsdot.wa.gov. Persons who are deaf or hard of hearing may contact Office of Equal Opportunity through the Washington Relay Service at 7-1-1.

**Title VI Statement to Public:** WSDOT ensures full compliance with Title VI of the Civil Rights Act of 1964 by prohibiting discrimination against any person on the basis of race, color, national origin or sex in the provision of benefits and services resulting from its federally assisted programs and activities. For questions regarding WSDOT’s Title VI Program contact Jonté Sulton at 360-705-7082 or SultonJ@wsdot.wa.gov.