Research Note

Evaluation of Recycled Concrete as Aggregate in New Concrete Pavements

From the WSDOT Research Office
May 2014

Recycled Concrete Aggregate

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,

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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.

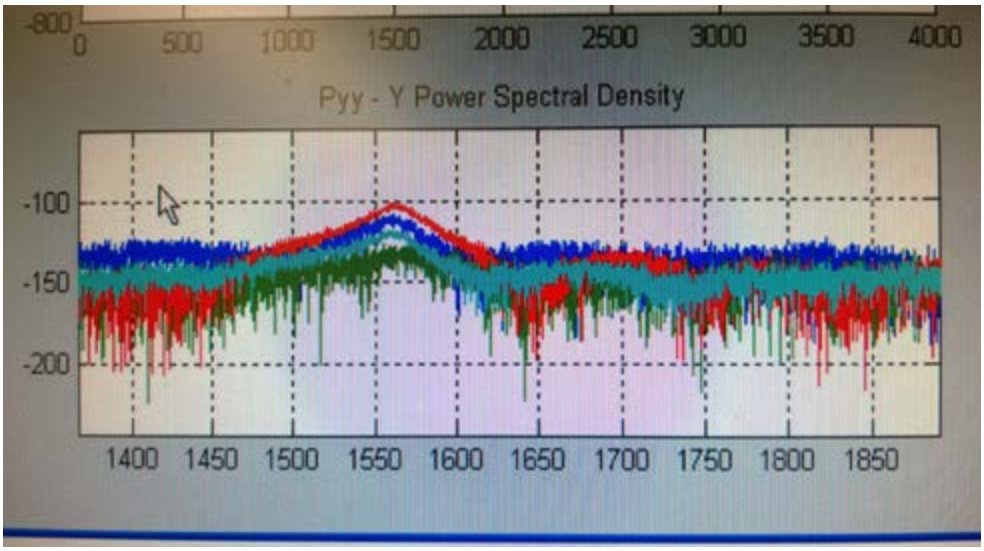
Five tests were used to determine the effects of RCA on hardened concrete properties including compressive strength, modulus of rupture, coefficient of thermal expansion, drying shrinkage, and freeze-thaw durability. Test results showed that up to a 45% replacement of coarse natural aggregate with RCA 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

Nonstandard flexural modulus with third point loading test setup

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.



Test setup for freeze-thaw modal test and visualized computer output

What the Researchers Recommend

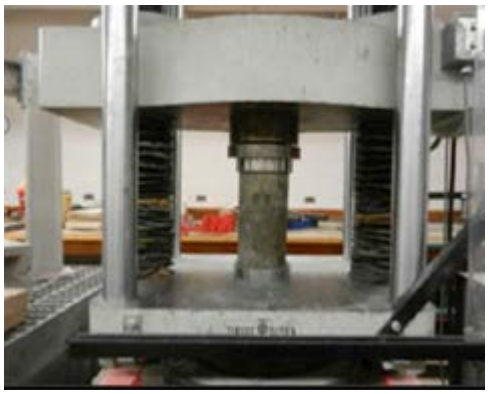
Properties of the RCA can be characterized by several factors including resistance to abrasion and the amount of adhered mortar. Water-reducing admixtures and fly ash can be used to negate the effects of RCA on fresh concrete workability. To address performance concerns related to the alkali-silica reactivity 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.

Batching test mixes



Testing for the compressive strength of the concrete cylinder

Testing for the modulus of rupture of the concrete

Contact Information

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