2012-35TS
Published April 2013

TRANSPORTATION POOLED FUND PROGRAM

TECHNICAL SUMMARY

**MnDOT Technical Liaison:**
John Siekmeier
John.Siekmeier@state.mn.us

**MnDOT Project Coordinator:**
Nelson Cruz
Nelson.Cruz@state.mn.us

**Principal Investigator:**
Tuncer Edil, University of Wisconsin–Madison

PROJECT COST:
$465,000

MnDOT CONTRIBUTIONS:
$60,000

PARTICIPATING STATES:
CA, MI, MN, OH, TX, WI

Researchers tested the modulus of recycled pavement material and other materials using a large-scale model experiment.

RESEARCH SERVICES

OFFICE OF POLICY ANALYSIS, RESEARCH & INNOVATION

# Pooling Our Research: Using Recycled Materials in Road Foundations

## Why a Pooled Fund Study?

The pavement layer of a road is supported by layers of aggregate materials consisting of gravel, crushed rock and sand. With these materials being depleted in Minnesota and the United States, the use of recycled materials from pavements that have reached the end of their service lives, such as recycled asphalt pavement (RAP) and recycled concrete aggregate (RCA), is becoming increasingly common. While Minnesota specifications currently allow the use of recycled materials in road foundations, it is not well understood how their properties—including strength, stiffness and sensitivity to climate—will affect performance.

***TPF-5(129): Recycled Unbound Pavement Materials.*** *Better understanding of the properties of recycled materials will help MnDOT in using mechanistic design procedures to predict pavement performance, leading to more cost-effective use of resources.*

Current design procedures assume that recycled materials have very similar properties to those of typical virgin aggregates, referred to in Minnesota as Class 5. Better understanding of these properties will help in using mechanistic design procedures to predict pavement performance using computer models and ensure that recycled materials are environmentally safe. In 2008 MnDOT took the lead on a pooled fund study to help establish the properties of these materials.

## What Was the Pooled Fund Study's Goal?

The objective of this study was to determine how the material properties of recycled materials used in aggregate base layers of roads affect pavement performance by conducting laboratory tests and monitoring newly constructed MnROAD test sections.

## What Did We Do?

Researchers conducted a literature review and a survey of states on the use of RCA and RAP as aggregate base courses. Then they obtained and tested samples from eight geographically diverse states. As a control, they used a conventional Class 5 gradation base course from MnDOT. Researchers conducted numerous laboratory tests on these samples and field tests of test sections to investigate the following (for both RCA and RAP, unless specified):

- Grain size distribution, fines content, asphalt content (RAP only), mortar content (RCA only), specific gravity, absorption and impurities.
- Proctor test compaction characteristics, plastic deformation, resilient modulus and the effects on resilient modulus of varying effort of compaction and freeze-thaw cycling. Moduli back-calculated from the cyclical loading of MnROAD test sections were compared to laboratory and field (falling weight deflectometer) measurements.
- Hydraulic properties for both materials and for RCA, pH and metal leaching characteristics.
- Mechanical properties under different climatic conditions as well as the effects of wet-dry cycling on particle degradation.
- The deflection of various MnROAD aggregate base course materials from 2009 to 2013 via falling weight deflectometer tests, from which moduli were back-calculated.

*continued*

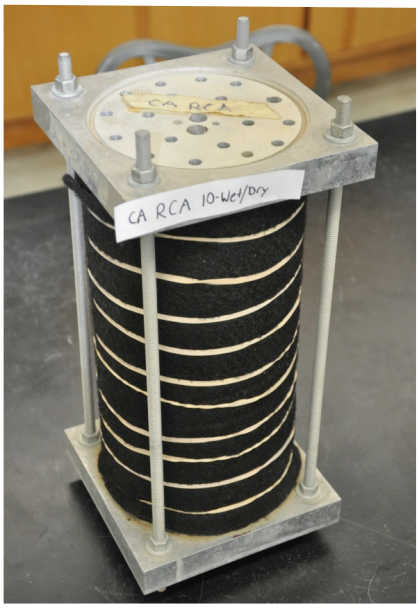
*"As the use of recycled materials increases, it's important to move beyond traditional specifications toward material testing procedures that more accurately predict performance based on mechanical properties."*

**—John Siekmeier,**
Research Engineer,
MnDOT Office of
Materials

*"The use of recycled materials has huge benefits beyond remedying the increasing scarcity of virgin materials, including saving on the energy expenditures and associated environmental costs of manufacturing and transporting virgin materials."*

**—Tuncer Edil,**
Professor, University
of Wisconsin–Madison
Department of Civil
and Environmental
Engineering

**Produced by CTC & Associates for:**
Minnesota Department
of Transportation Research Services
MS 330, First Floor
395 John Ireland Blvd.
St. Paul, MN 55155-1899
(651) 366-3780
www.dot.state.mn.us/research




Researchers tested the effects of wet-dry cycles on particle degradation in aggregates with recycled materials by compacting them in a mold and placing them in an apparatus allowing the passage of water.

## What Did We Learn?

Results show that RCA and RAP are suitable for unbound aggregate base course applications. They show equal or better performance characteristics compared to natural aggregates in terms of stiffness, freeze-thaw and wet-dry durability, and toughness. Selected findings of specific experiments follow:

- Samples from different states had similar properties, with 50 percent mortar content for RCAs and 5 percent asphalt content for RAP. Average impurities were 1 percent for RCA and 0.2 percent for RAP by weight, indicating that the recycling industry has developed sufficient controls.
- RAP had the highest resilient modulus, followed by RCA and then Class 5 aggregate. Brick content of up to 30 percent in RCA did not affect resilient modulus.
- A decrease in compaction effort resulted in a lower resilient modulus for all materials, and resilient modulus decreased with an increase in moisture content for RAP and RCA.
- The plastic deformation of RAP was much greater than that of natural aggregate, while that of RCA was smaller. (In general, flexible pavement design should take into account that some RAP is sensitive to temperature change that may lead to rutting.) Both materials had a greater resilient modulus than Class 5 aggregate, regardless of the number of freeze-thaw cycles.
- Changes in temperature did not affect the resilient modulus and strain rate of RCA and natural aggregate but caused a decrease in two of three RAPs tested. Wet-dry cycling did not affect particle degradation.
- All materials had high drainage capacities, with RAP having the highest followed by natural aggregate and RCA.
- MnROAD leachate slightly exceeded Environmental Protection Agency drinking water maximum contaminant levels on only a few occasions for all materials. These measurements are for the base layer; metal levels would be expected to fall before reaching groundwater.

## What's Next?

MnDOT is reviewing the recommendations in this report with a view toward updating department materials specifications. It will also organize webinars to communicate results within MnDOT and to other departments of transportation.

*This Technical Summary pertains to Report 2012-35, "Recycled Unbound Materials," published November 2012 and funded through pooled fund study TPF-5(129). The full report can be found at* http://www.lrrb.org/PDF/201235.pdf *and pooled fund study information at* http://www.pooledfund.org/Details/Study/361.