



## TECHNICAL SUMMARY

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### PROJECT COST:

\$92,397



A triaxial pressure chamber was used to determine the resilient modulus of specimens by measuring their compaction under various loads.



**RESEARCH**  
SERVICES SECTION

# The Effect of RAP on the Structural Capacity of Pavement Base Layers

## What Was the Need?

To reduce costs of construction and disposal of used pavement materials, Minnesota is increasingly recycling these materials when reconstructing highways. One of these materials, recycled asphalt pavement, is often used in the base course as a substitute for a portion of virgin aggregate.

However, unlike virgin aggregates, which are not bound together, RAP aggregates are coated with aged asphalt binder. Little research is available on whether moisture or freeze-thaw conditions affect the RAP binder in a way that causes the aggregate in the RAP to behave differently from typical unbound aggregates and how this might affect the structural capacities of base layers containing RAP.

## What Was Our Goal?

The objective of this study was to evaluate the effect of freeze-thaw cycles and severe moisture conditions on the structural capacity of RAP base layers, where structural capacity is defined as the combination of stiffness—measured as resilient modulus—and shear strength.

## What Did We Do?

Researchers began by conducting a literature review on the material properties, testing methodologies and nature of moisture damage for RAP in base materials. Then they compiled RAP material test results from Mn/DOT databases and collected pavement samples from several highways in Minnesota, including one source of 100 percent RAP, one of Minnesota Class 5 virgin aggregate, and three Class 7 mixtures of RAP and virgin aggregate being used as a base layer. The 100 percent RAP, taken from Minnesota Trunk Highway 10, was blended with virgin aggregate at 50 percent and 75 percent RAP content.

Researchers then evaluated these samples in the laboratory for:

- Gradation, or the coarseness of the aggregate, using dry sieve analysis; gradation is an important material property affecting the stability of the base layer
- Asphalt content, or the percentage of aggregate consisting of RAP, using an asphalt extraction apparatus
- Moisture density, using the standard Proctor test and the Superpave gyratory compactor
- Aggregate RAP resistance to abrasion and degradation, using the Micro-Deval test
- The structural capacity of RAP as compared to virgin aggregate, using the resilient modulus test and following the National Cooperative Highway Research Program 1-28A test protocol
- Objective dry density, by compacting resilient modulus samples in a gyratory compactor
- Shear strength, using the triaxial shear test for resilient modulus samples compacted at optimum moisture content and maximum dry density at two confining pressures
- The effect of freeze-thaw on the resilient modulus and the shear strength of RAP as compared to virgin aggregate, by subjecting one set of samples to two freeze-thaw cycles

*“This is the first time Minnesota has performed freeze-thaw laboratory tests on recycled bases containing RAP. These tests indicate that there is no decrease in resilient modulus or degradation over time.”*

–Tim Andersen,  
Grading and Base  
Engineer, Mn/DOT  
Office of Materials

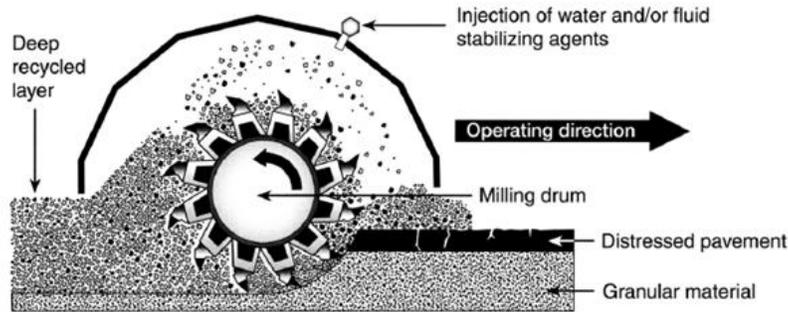
*“This project clearly answered the question of how RAP affects the structure of base layers and shows that it is a viable alternative to virgin aggregate. The research will be useful not just to Minnesota but also nationally.”*

–Magdy Abdelrahman,  
Assistant Professor, North  
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A typical full depth reclamation involves ripping and breaking up the pavement and base with a reclaiming machine, saving construction costs and eliminating the issue of disposal.

### What Did We Learn?

Researchers found that RAP had a higher resilient modulus and equivalent shear strength to Mn/DOT Class 5 virgin aggregate, and the effect of freeze-thaw cycles was negligible. While RAP gradation was coarser than virgin aggregate, it fell within Mn/DOT Class 5 gradation limits, and there was no clear difference in the friction angle and cohesion between RAP-aggregate blends, RAP-aggregate field samples and virgin aggregate.

Additional significant findings included:

- The maximum dry densities for RAP and RAP-aggregate blends were lower than for virgin aggregate, but there were conflicting measurements for moisture content. According to gyratory compactor testing at 50 gyrations, the optimum moisture content for RAP-aggregate blends was lower than for virgin aggregate, but according to the Proctor test the optimum moisture content for the RAP-aggregate blend was higher.
- Freeze-thaw of RAP-aggregate blends at low confining pressures reduced their shear strength, but this effect was unclear at higher confining pressures.
- The resilient modulus for all RAP material was higher than that of Class 5 aggregate. In general, the resilient modulus of RAP material was found to be dependent on confining pressure, and decreasing the moisture content increased the resilient modulus of RAP material.

### What's Next?

Using RAP produced during pavement rehabilitation will reduce the amount of virgin aggregate needed, construction costs and lane closure times, as well as help agencies avoid the costs of disposing of used asphalt material recovered during pavement rehabilitation. The results of this research will help Mn/DOT to further evaluate the effectiveness of using RAP as a base layer. To determine whether there is additional degradation over time, researchers recommend further resilient modulus tests on field projects in five to 10 years. In the near future, researchers plan further evaluations of RAP in various road construction applications.

*This Technical Summary pertains to the LRRB-produced Report 2009-05, “Investigation of Stripping in Minnesota Class 7 (RAP) and Full-Depth Reclamation Base Materials,” published January 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200905.pdf>.*