



TECHNICAL SUMMARY

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PROJECT COST:

\$155,225



Researchers collected recycled concrete from a stockpile managed by the city of Minneapolis.



RESEARCH
SERVICES SECTION

Strength and Drainage in Aggregates Mixed with Recycled Materials

What Was the Need?

The performance of pavements depends critically on the stiffness and strength of the foundation that supports them. The base and subbase layers of this foundation are constructed using large volumes of aggregates such as crushed stone, gravel and sand. Because of the high cost of purchasing and transporting aggregate, Minnesota transportation agencies are interested in replacing a portion of it with recycled construction and industrial materials when constructing new pavements. These materials include asphalt shingle, fly ash, municipal solid waste bottom ash, shredded tires, and concrete or asphalt reclaimed during the reconstruction of existing pavements. Using these materials also benefits the environment by enabling productive use of materials that might otherwise be sent to landfills.

However, there is limited information about how the addition of recycled materials to aggregates affects their mechanical, hydraulic and environmental properties. Mechanical properties include strength and stiffness, which are important for preventing pavement rutting and cracking. Hydraulic properties measure how materials retain or drain water; it is important that pavements drain well to avoid heaving during winter. Environmental properties are measured to assess whether materials leach inorganic chemicals—such as heavy metals—into the groundwater in concentrations higher than allowed levels.

What Was Our Goal?

The goal of this study was to compare the suitability of four recycled materials to that of virgin aggregates for use in the construction of road base and subbase layers. These materials included reclaimed asphalt pavement, reclaimed concrete material, fly ash and foundry sand.

What Did We Do?

Researchers began by collecting recycled materials from various locations in Minnesota. Then they mixed these materials in various proportions and combinations with virgin aggregate, creating 17 samples. They evaluated the hydraulic, mechanical and environmental properties of these samples as well as one sample of 100 percent virgin aggregate by measuring:

- Particle size distribution by repeatedly sieving samples and then calculating the ratio of the remaining to original material.
- Optimum water content corresponding to maximum dry density by packing moist samples at various water contents in a gyratory compactor.
- Water retention—a measure of the pore size distribution—by desaturating the compacted specimens in pressure plate chambers and measuring the amount of water retained in the specimens under various conditions.
- Hydraulic conductivity—the rate at which water flows through a material—measured at both the point of saturation and a little lower than this during the leaching test.
- Resilient modulus—a measure of material stiffness—by applying cycles of axial stress to cylindrical specimens in a triaxial cell at and slightly below its optimum water content.
- Shear strength—a measure of material cohesion—by applying a small contact load to a specimen and increasing it until the specimen fails to support it.
- Leaching characteristics, or the likely concentrations of heavy metals and other in-

continued

“Using recycled materials in road construction will not only produce substantial cost savings, but will also allow us to save energy and employ sustainable construction processes.”

–**Satish Gupta**,
Professor, University of Minnesota Department of Soil, Water, and Climate

“This report builds on the conclusions of previous studies that show that recycled materials can be used very effectively to produce durable roads when appropriate due diligence is conducted, including screening the source of waste and conducting the appropriate environmental testing.”

–**John Siekmeier**,
Mn/DOT Senior Research Engineer

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To evaluate hydraulic, mechanical and leaching characteristics, researchers used a gyratory compactor to prepare specimens at maximum density, which more realistically approximates real-world pavements than specimens prepared using more common methods.

organic chemicals expected to leach from recycled materials into the groundwater, using laboratory tests that simulate this action.

What Did We Learn?

With the exception of foundry sand, recycled material mixtures were similar to virgin aggregates in drainage characteristics, stiffness, strength and environmental impact, and so are expected to be good substitutes for them as base and subbase materials in road construction.

Except for some RAP-aggregate mixtures with slightly higher fine contents, the particle size distribution of recycled materials was similar to that of virgin aggregates, and their hydraulic conductivities were higher, suggesting equal or better water retention and drainage. With the exception of foundry sand, the addition of recycled materials to aggregates increased their resilient modulus, and fly ash also improved their shear strength.

Environmental testing did not demonstrate that adding RAP, RCM and fly ash to virgin aggregates will lead to substantial leaching of toxic chemicals into the surrounding environment. With some exceptions, heavy metal concentrations in the leachate were generally less than those allowed by EPA drinking water standards. For some RCM mixtures and all fly ash mixtures, the leachate concentrations of some heavy metals were higher than allowed, but these concentrations are expected to fall below U.S. Environmental Protection Agency limits before reaching the groundwater by filtering through soils below the road foundation layers.

What's Next?

This project is part of an ongoing effort to determine the design, performance and economic characteristics of materials used in unbound pavement layers. The quantification of these characteristics is critical to the eventual movement by Minnesota's pavement designers to mechanistic-empirical pavement design.

This Technical Summary pertains to the LRRB-produced Report 2009-32, “Hydraulic and Mechanical Properties of Recycled Materials,” published October 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200932.pdf>.