

Reduce. Reuse. Recycle.

Transportation and its supporting infrastructure have significant economic, social, and environmental impacts. Using more sustainable methods to design, construct, and preserve roads will better protect the environment and meet our ongoing needs.

Mn/DOT and our partners in government, industry, and academia have been researching and implementing ways to make our roads greener, while maintaining or improving roadway quality.

MnROAD is conducting research on several “green” pavement technologies that reduce environmental impacts, reuse roadway materials, or use recycled materials in pavement applications:

REDUCE

- Warm mix asphalt – reduce energy costs
- Pavement noise – reduce roadway noise pollution
- Porous pavements – reduce storm water runoff

REUSE

- Full depth reclamation – reuse in-place roadway materials
- Taconite aggregates – reuse high quality aggregate

RECYCLE

- Asphalt pavements – recycle old roadways in hot mix asphalt
- Base materials – recycle old concrete and asphalt roadways
- Shingles – recycle both tear off and manufactured shingles

Green pavement technology needs to maintain or improve the performance of existing pavement technologies. This ensures the green product will be market-driven, cost-effective and sustainable.

The following pavement techniques were analyzed at MnROAD to determine their potential to improve the quality and cost-effectiveness of pavements, while providing environmental benefits.

Warm Mix Asphalt

Warm mix asphalt (WMA) technologies allow asphalt to be produced and placed at lower temperatures. Typical warm mix is heated to 250°F, which reduces temperatures by 50 to 100°F compared to typical Hot Mix Asphalt (HMA) temperatures of 330°F. Such drastic reductions cut fuel consumption and decrease the production of greenhouse gases and fumes. Potential engineering benefits include better compaction, less thermal cracking, and the ability to pave in colder weather.

In 2008, MnROAD constructed six 500’ test roadway segments to demonstrate WMA’s constructability and evaluate its long-term performance. The mixes contained a PG 58-34 asphalt binder with 20% recycled asphalt pavement to produce the wear and nonwear layers. The asphalt mixture was designed for high volume traffic. A chemical additive (Evotherm 3G) was added to the binder to accommodate lower production temperatures.



Observations during construction confirmed WMA handled like HMA, had comparatively low energy costs, and noticeably reduced asphalt fumes. In addition, density was achieved with faster roller speed, less vibration, and less passes.

Mn/DOT is working closely with industry decision-makers to implement new WMA projects in 2009. As the technology matures in future years and producers and contractors become comfortable with it, expect to see even more projects being constructed using WMA.

Pavement Noise

Pavement surfaces need a balance of texture and smoothness to be safe in diverse weather conditions and provide a smooth, quiet ride. Researchers have been developing improved surface textures for new and rehabilitated pavements and methods to monitor in-place pavement performance as it relates to ride quality, friction, quietness, and texture.

At typical freeway speeds, tire-pavement noise is the dominant traffic noise source. In 2007, MnROAD commenced On-Board Sound Intensity (OBSI) testing—a method to measure tire-pavement noise using sophisticated microphones mounted on a vehicle's rear wheel



near the pavement surface. Minnesota is one of only five states that adopted this technology.

MnROAD partnered with other states, industry, academia, and the FHWA to develop and test different methods of creating concrete roadway surface textures. A pooled fund study, *PCC Surface Characteristics – Rehabilitation*, analyzed ways to surface grind roadways.

Laboratory and small scale testing at Purdue University developed an innovative grind surface that optimizes ride quality, quietness, concrete durability, and safety from hydroplaning and splash and spray.

In 2007, MnROAD's Low Volume Road was used as an initial test bed for three 18" grinding patterns (traditional, innovative 1 pass, and innovative 2 pass). After monitoring the test beds, three Mainline (I-94) test sections were ground later that summer and in 2009. OBSI testing on the innovative grind section revealed that this was the quietest concrete pavement surface in North America.

An in-house Mn/DOT study, *PCC Surface Characteristics – Construction*, was developed to improve methods to finish the texture of new concrete roads. MnROAD built six distinct concrete surface textures in 2008 for the purpose of monitoring them over time. The surfaces include transverse broom, longitudinal broom, longitudinal tine, astroturf drag, and pervious concrete.

Another in-house study, *HMA Surface Characteristics*, monitored the different surface characteristics of hot mix asphalt test sections and their effects on noise. It studied new and old surfaces including Novachip, 4.75-mm Superpave, and porous HMA.

Pervious Pavements



As housing and retail development progresses, the increase in impervious surfaces has been an issue of concern for every community. Run-off from impervious surfaces has been known to negatively impact streams, wetlands, and other water resources.

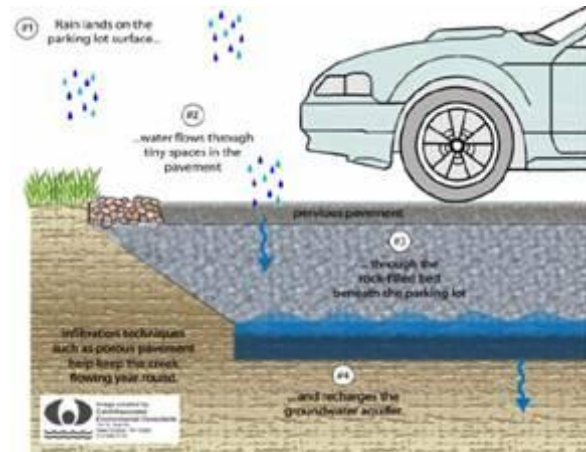
Metro area communities have made various attempts to encourage infiltration by constructing pervious pavement on porous bases. Pervious pavements can be made from either asphalt or concrete. Additional benefits of pervious pavements include noise and splash and spray reduction.

It is important to determine if these types of pavements perform well in northern climates that experience cold winters and hot summers. By adequately evaluating pervious pavements in this climate, changes in porosity and infiltration can be monitored over time under measurable traffic loads, environmental conditions, and deicing operations.

The Local Road Research Board (LRRB) funded two pervious pavement projects at MnROAD—one on porous asphalt and one on pervious concrete. To support this research, MnROAD constructed a sand subgrade porous HMA test section and a clay subgrade test section. This type of pavement construction was a first for both Mn/DOT and the contractor.

At the same time, MnROAD started working with the Aggregate Ready Mix Association of Minnesota in 2005 to develop pervious concrete technology for northern climates. The partnership resulted in the construction of a pervious concrete pavement in a parking lot at MnROAD in 2005 and a pedestrian walkway in 2006.

Lessons learned from the parking lot and the sidewalk helped develop test sections on the



Low Volume Road in 2008. This included 7" of pervious concrete on a sand subgrade, 7" of pervious concrete on a clay subgrade, and a non-pervious control section. The project focused on identifying the right asphalt and concrete mix designs for our climate.

Each of the pervious test sections were constructed with curb and gutter and transverse drains to measure storm water runoff if and when they clog. These sections will be monitored for long-term pavement performance, as well as their ability to reduce runoff.

MnROAD also worked with Iowa State University to build a pervious concrete overlay over a jointed concrete pavement. This technology allows water to flow through the pervious overlay laterally to the shoulders. It is also expected to reduce noise while providing a smooth, safe driving surface.

Full Depth Reclamation



Full depth reclamation (FDR) is a technique in which the full asphalt pavement section and a predetermined portion of the underlying base materials are uniformly crushed, pulverized, or blended, resulting in a stabilized base course.

Pavements that experience base failures or high amounts of cracking are considered ideal candidates for FDR. Further stabilization may be obtained for these roads through available additives, including cement, fly ash, lime, foamed asphalt, and asphalt emulsions.

A new surface course is then placed on the recompacted base. The advantage of this construction method is that an agency can reuse all of the in-place materials without having to haul in new granular materials, saving material and trucking costs.

MnROAD has constructed a number of test sections studying this technology. In 2000, a 6" HMA test section on the Low Volume Road was reclaimed. We learned any work that blends clay subgrade material during the FDR process needs to be further stabilized with an additional additive.

In 2007, three full depth reclamation test sections were constructed on the LVR under the auspices of a fly ash stabilization study. Many coal power plants in the United States are eagerly looking for ways to use their fly ash (a

byproduct of electricity production) to avoid landfilling. Fly ash contains cementitious properties and is frequently used to enhance mixtures of Portland cement concrete. While High Carbon Fly Ash cannot be used in the concrete paving industry, laboratory testing has shown it to be a viable stabilizing agent for unbound materials.

MnROAD constructed three test sections consisting of a 4" HMA over 8" of a fly ash treated FDR, non-treated FDR, and a class 6 crushed stone base as the control. This work was completed for Phase II of the fly ash stabilization project sponsored by the U.S. Department of Energy and performed by Bloom Consultants, LLC.

In 2008, MnROAD constructed three FDR test sections on the Mainline in partnership with SemMaterials to demonstrate alternate contracting methods and to evaluate the properties and performance of FDR using asphalt emulsion stabilization. SemMaterials provided all of the materials and labor.

This project was conducted to determine the optimal percentage blend of HMA and aggregate base for full depth reclamation with engineered emulsion. The three blends of HMA and aggregate base were at 50/50, 75/25, and 100/0. Researchers also evaluated how to best rehabilitate full depth HMA on clay pavements.

Recycled Unbound Base Materials

Minnesota has a long history of using recycled materials in pavement construction. They have been used in all layers of the pavement, from the surface down to the unbound supporting layers. Mn/DOT's current Class 7 specification allows salvaged or recycled HMA, PCC, and glass to be used as part of the granular base materials. However, their material properties (strength, stiffness, unsaturated properties, etc.) are not well understood. New pavement design procedures require more detailed material properties to accurately predict pavement performance.

Mn/DOT initiated a pooled fund study to construct several test sections at MnROAD using recycled materials in the granular base layers. The material properties were monitored during construction and throughout the pavement life to determine their effects on pavement performance. The properties will be used to verify mechanistic-empirical design inputs, especially their variation with changing seasons



and moisture regimes. Each of the test sections for this effort had 5" warm mix asphalt, 12" recycled base (see below), and 7" select granular over clay subgrade.

The four test sections consisted of:

- Recycled concrete base (Cell 16)
- 50% recycled concrete + 50% class 5 granular base (Cell 17)
- Recycled asphalt pavement (RAP) base (Cell 18)
- Class 5 aggregate base (control – Mn/DOT standard base) (Cell 19)

Taconite Aggregate

MnROAD has developed a number of partnerships since 2004 to research the use of taconite materials in roadways.

An initial partnership helped construct two test sections (asphalt and concrete) using taconite aggregates at MnROAD. The most recent partnership uses federal funds from the Economic Development Administration (EDA) of the U.S. Department of Commerce to research Iron Range aggregate materials in transportation applications. The goal is to assess available aggregate resources that could potentially supply an abundant, high-quality, low-cost aggregate for roadway use.

Currently aggregate material from the Iron Range is considered "waste product." However, it has high potential for use in our roadways. This effort will help pave the way to use this material in the near future, especially in areas where aggregates are becoming scarce.

Using fine to coarse taconite aggregate materials in hot mix asphalt, concrete pavement, and aggregate base layers is being studied. Laboratory work on taconite aggregates is also being carried out in parallel at Mn/DOT and the University of Minnesota.

In 2008, MnROAD built one test section on the Mainline (I-94) to compare permeable large stone base materials to traditional finer non-permeable aggregate base materials. It will allow researchers to demonstrate:

- The benefits of a higher quality, stronger base layer
- Its effect on hot mix asphalt pavement performance
- How to account for these materials during design



We constructed a second Mainline section to demonstrate the use of a 4.75-mm Superpave HMA pavement using two different sources of taconite tailings (MinTac and Ispat) and a locally available manufactured sand.

This mixture, made with sand-size aggregate particles, makes a durable pavement surface, as well as provides superior surface characteristics such as friction, noise abatement, texture, ride quality, and splash and spray reduction.

Recycled Asphalt Pavements

Using reclaimed asphalt pavement (RAP) in new asphalt mixtures has numerous advantages to the environment, owner agencies, and contractors.

Environmental benefits include:

- A reduction of the product's carbon footprint and any of its end uses
- Conservation of natural resources
- Conservation of landfill space



From an economic standpoint, the reuse of materials provides an opportunity to stabilize material prices, which fluctuate as the economy and demand for raw materials change. The

technology for using increased amounts of RAP in asphalt mixtures has improved significantly in terms of mix design and material processing and handling.

In 2008, MnROAD built three test sections designed around recycled asphalt pavements, including a number of control sections. Each test section consisted of a 5" HMA layer, 12" class 5 base, and 7" select granular over clay. The RAP used in this project was recycled from the MnROAD Mainline, crushed to size, and reincorporated into the new HMA pavement.

Test sections consisted of:

- 30% Non-Fractionated RAP (PG 58-28 wear and nonwear) – (Cell 20)
- 30% Fractionated RAP (PG 58-28, 20% Fine RAP, 10% Coarse RAP, wear and nonwear) (Cell 21)
- 30% Fractionated RAP (PG 58-34, 20% Fine RAP, 10% Coarse RAP, wear and nonwear) (Cell 22)

Shingles

Manufacturer waste shingles (MW) and tear-off shingles (TO) from homes are being used nationwide as beneficial additions to asphalt pavements.

MW shingles are obtained from a shingle manufacturing facility as scrap. They contain approximately 20% asphalt cement by weight. Shingle asphalt cement is significantly harder than paving grades of asphalt.

TO shingles are old shingles that have been removed from a roof. Granules are often lost; therefore TO shingles contain approximately 25% aged hardened asphalt, which is lower quality than MW asphalt. Current Mn/DOT Standard Specifications allow the use of manufacturer waste shingles, and may soon include tear off shingles.

Mn/DOT is working closely with regulatory agencies and industry recyclers to develop quality control measures so shingles can be incorporated into asphalt mixes in an environmentally-sound fashion without impacting the quality or service life of the pavement. Recycling these shingle materials into pavements will dramatically reduce the amount of shingles that are landfilled every year. Some local



companies are exploring ways to process the recycled shingles to create an even better HMA paving product.

In 2008, MnROAD used both manufactured waste and tear-off shingles on the Mainline. Tear off shingles were used on the shoulders on 10 different test sections (Cells 15-23 and on the eastern transition with I-94). The mix included 5% tear off shingles with no other recycled asphalt pavement (RAP), using a PG 58-28 binder. The manufactured shingles were used on the shoulders for 5 test sections (Cells 5, 6, 13, 14 and on the western transition with I-94). The mix included 5% manufactured shingles with no other RAP, using a PG 58-28 binder.

Preliminary results from a concurrent laboratory study show that at 3% shingles there was no significant difference in mixture stiffness between tearoff and manufactured waste shingles, while at 5% shingles differences do appear in terms of mixture stiffness and optimum binder content.

For more information:

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