Realizing the benefits of knowledge
The Minnesota Department of Transportation (Mn/DOT) 1999-2000 Transportation Research Biennial Report includes research and implementation activities that have been ongoing or completed from July 1, 1998, through June 30, 2000. Eight sections highlight research accomplishments and directions in transportation modes, economic issues, maintenance, the environment, infrastructure, planning/design, and traffic management. Each section emphasizes some significant accomplishments of the Mn/DOT research program and the people who influence it.

The opening section, Realizing the Benefits of Knowledge, offers insights on the management and administration of almost $12 million in yearly funding from a variety of sources for transportation innovations. The research community within Mn/DOT is diverse in its interests and goals, yet shares a common purpose to improve Minnesota's transportation system.

This biennial report is not a complete listing of every project conducted during a two-year period. Rather, it is meant to provide a general overview of Mn/DOT's research program and tell some interesting stories about our research and research champions, the people whose investment of time pays off in many notable ways.

You can learn more about Mn/DOT and its research by visiting our web site at www.dot.state.mn.us. We welcome questions and suggestions. Please contact us at 651/282-2274 or research@dot.state.mn.us. We hope to continue learning from each other and improve our programs by sharing what we learn.
Research discovers a solution that saves millions in spring road repair

New approaches and collaborations succeed in strengthening Minnesota pavements

Spring is a most dangerous time for roads. As the temperature rises and the thaw begins, low-volume asphalt roads weaken under the weight of heavy transport, causing damage that ultimately requires repair or replacement.

Because of the wear-and-tear to many of Minnesota's roads, procedures to restrict the load on roads during the early spring have been developed. In 1999, though, thanks to the results of Mn/DOT research, the state changed the way it posts those spring load restrictions, with an estimated approximate annual savings of more than $10 million.

About four years ago, Mn/DOT's Office of Materials and Road Research wanted to explore new approaches to reducing road damage that occurs during the spring thaw. David Reitner and his colleagues Jill Ovik, John Sickmeier, David Van Deusen, and Greg Johnson began evaluating the spring load procedure and looking for improvements.

The past spring load restriction policy involved monitoring conditions that contribute to spring load damage, taking thaw depth measurements, and analyzing weather conditions and forecasts.

As a first step, researchers reviewed previous studies and practices of other states that face similar road damage caused by spring thaw. The Washington State Department of Transportation developed a thawing index equation based on air temperatures. Mn/DOT researchers adjusted the reference temperature in the equation, which improved the springshaw prediction.

Mn/DOT researchers then compared predicted and actual spring load restriction placement dates from 1986 to 1998 and discovered that typically spring load restrictions were placed a week or more later than predicted dates indicated, causing preventable damage. Further research took place at the Minnesota Road Research Facility (Mn/ROAD), Mn/DOT's pavement testing facility located on Interstate 94 near Monticello, Minn. Those results helped shape a new method for placing and removing spring load restrictions throughout the state.

Research revealed that a quick response is key to minimizing damage. "That was a big finding for us, because it tells us that the best time to take action is right away," says Glenn Engstrom, P.E., and manager of the Minnesota Road Research Section. "With most of the damage occurring early, those first few weeks can make a huge difference."

Mn/DOT's new approach addresses the timing issue. The current Mn/DOT policy uses actual and forecasted average daily temperature to determine the timing of spring load restrictions. The start of the spring load restrictions may vary from one part of the state to the next, depending on temperature. Once set, the restriction period lasts eight weeks, the time required for the pavement base and subgrade layers to regain sufficient strength to support heavy truck loads. The eight weeks also allows for various users to plan for when the restrictions will be removed. In the past, this period varied and, therefore, limited the ability to plan.

With 39,000 miles of Minnesota roads impacted by spring thaw, the implementation of this research project translates into significant savings. Researchers estimate that the more precise method of placing spring load restrictions stands to increase the life of affected roads by 10 percent, for a conservative savings estimate of $10 million annually.
In 1999, Mn/DOT first launched the new spring load restriction procedure, in cooperation with cities and counties. It drew such support that city and county officials proposed a change in state law to accommodate the new procedure.

The Minnesota Legislature approved the new policy for statewide execution and also requested the establishment of a task force to study the economic impact of spring load restrictions on Minnesota. The task force recommended further research to determine the actual costs and benefits of spring load restrictions.

As part of implementation, Mn/DOT established a toll-free phone number for cities and counties to call for information about posting spring load restrictions and also posted details on the Mn/ROAD web site.

“We continue to work closely with other maintenance departments to help make this happen at the right time,” says Engstrom. “We want to do a better job. The more precisely we can determine the pavement’s vulnerability, the better job we can do minimizing the damage to the road while keeping the roads open as long as possible.”

Use of reclaimed materials offers practical benefits

Otter Tail County wanted alternatives for its glass recycling program and began exploring the use of glass in Class 5 aggregate.

The county blended glass with virgin gravel aggregate during normal crushing operations, and then placed the mix as a new road aggregate base for county highway 74 near Amor, Minn.

Ramsey County successfully used crushed, screened glass in its Larpenteur Avenue reconstruction project. The county specified a six-inch, Class 6 aggregate base containing reclaimed glass.

Because reclaimed glass offers benefits to additional counties and cities that face the challenges of limited landfill space and the need for quality material for road construction, three agencies collaborated to explore the use of reclaimed glass in aggregate base.

Mn/DOT, the Minnesota Office of Environmental Assistance, and the Local Road Research Board undertook two important initiatives. The project team and Mn/DOT completed the writ-
ing of a new specification that includes reclaimed glass as an option for Class 7 aggregate. In addition, the Center for Transportation Studies at the University of Minnesota developed outreach and educational materials on the use of reclaimed glass in aggregate mix.

In spring 1999, Mn/DOT issued a new specification with some key new features:

- The specification includes the use of 10 percent reclaimed glass in aggregate material for road base.
- It creates a new class of aggregate materials—known as Class 7—which represents aggregate mixtures that contain salvaged/reclaimed aggregate materials.
- It allows contractors to include the use of reclaimed glass in their bid unless the purchasing government agency specifically excludes reclaimed glass in their written project specifications.

Reclaimed glass is not the only reclaimed material in the mix. For the past decade, Mn/DOT has explored the potential use of a variety of reclaimed materials including recycled asphalt, recycled concrete pavement, taconite tailings, roofing shingles, industrial ashes, and tires, among others.

Two forces drive the investigation into reclaimed materials: the cost and availability of virgin aggregate and the increasing need to reduce material in landfills.

For Mn/DOT, the research makes particular sense. "We are a larger user of aggregate for state highway construction projects, and we also develop specifications that cities and counties use," says Roger Olson, research operations engineer.

Recycled asphalt was one of the first reclaimed materials that Mn/DOT researched and began using. Many other cities and counties followed suit, resulting in less waste and cost savings. Reclaimed asphalt pavement reuses 1.5 million tons per year of asphalt that would otherwise be...
considered waste. This material is used for hot and cold mix asphalt aggregate, granular and subbase aggregate, and embankment and engineering fills. Minnesota also reuses about 300,000 tons per year of reclaimed concrete pavement.

Research is critical in determining the impact of reclaimed materials in aggregate mixes, says Olson. Mn/DOT’s process for evaluating reclaimed materials includes environmental assessment, laboratory and field testing, and review by a variety of offices.

Minnesota also learns from the practices of other countries. Gerald Rohrbach, director of the Office of Materials and Road Research, participated in a scanning tour of European countries to learn about their use of waste products in transportation projects. The Federal Highway Administration sponsored the tour and plans to share information and recommendations.

With outreach initiatives to demonstrate the use of reclaimed glass and roofing shingles, Mn/DOT continues to explore alternatives. For example, research on lightweight tire fill material resulted in its use as part of a new ramp construction in Pine City, Minn.

“We look for a variety of qualities,” says Olson. “The material needs to be environmentally sound, and the process to use the material must be economically feasible. Also of great importance is the question of does it offer equal or better engineering properties.”

Mn/DOT joins forces with other states

Minnesota is not alone in its search for solutions, and Mn/DOT recently joined forces with three other states to pool resources for research solutions that benefit all those states.

The Four-State Pavement Research Consortium was the brainchild of transportation practitioners in Washington and Minnesota, who began discussing possibilities for collaboration at a Transportation Research Board conference.

“This is a good way for us to conduct research more quickly and build upon the expertise of others,” says Glenn Engstrom, P.E., and manager of the Minnesota Road Research Section. “The states were selected because of their expertise and interest in issues that range from pavements to construction to rehabilitation to design.”

Among the leading states in the research, development, and deployment of advanced pavement technology, Minnesota, Washington, Texas, and California comprise the consortium. Consortium members began meeting in July 1999 to identify potential topics. At subsequent meetings, researchers from each state presented information about their work on specific issues.

It soon became clear that the consortium could play a significant role in advancing research in a number of areas. Washington prepared a draft charter for the consortium, including a process to select researchers and to fund and manage studies of interest.

Since its start, the consortium sponsored a South African/U.S. Pavement Technology Workshop, held in March 2000, funded a report on improved field characterization, developed software enhancements, and completed an analysis of longitudinal joint compaction in hot-mix asphalt pavement.

The consortium also agreed to fund a study on retrofitted dowel bars, as well as to develop a four-state Superpave database that can assist in the evaluation of that pavement mix. It also supported the monitoring of selected pavement projects in the four states, and the investigation of Internet-based training technology for application among the four states.

Minnesota’s contribution to the consortium includes its pavement analysis and design software and its PaveCool software, which determines asphalt concrete cooling times. Minnesota is also learning from the procedures and research conducted at other states.

Research at Mn/ROAD explores ways to extend the life of pavement, including reducing alligator cracks.
As a result of the consortium, member states have found that, despite some differences, they share much common ground, including pavement design features. In a short time, members have been able to maximize their knowledge and take that knowledge to the next level.

"Each of us have various areas that we are exploring," says Engstrom. "As we look at our common problems together, we come up with even more powerful solutions."

Drivers share their thoughts on road conditions

What winter road conditions make drivers think twice about taking to the road? Does a smooth pavement mean the same thing to a driver as it does to Mn/DOT? What do drivers think is important about the pavements that they drive everyday?

To learn about the perceptions of drivers, Mn/DOT decided to ask them. Using the tool of market research, Mn/DOT has conducted several surveys of drivers to determine their priorities when it comes to road conditions.

In one such study, researchers gathered information about snow and ice issues. "We wanted to know more about how road conditions related to snow and ice removal would affect a customer's decision to make or not make a trip," says Lee Brady, Mn/DOT's statewide market research director.

Researchers showed about 1,200 drivers videos of six different stages of actual road conditions during a snow removal event. They then asked the drivers if they would make a trip under different circumstances given the road conditions.

The research revealed that drivers make certain types of trips depending on road conditions. "If the snow wasn't completely removed, they would still go to work," says Brady. "But if the trip was an optional one, they might decide to postpone it."

The driver’s perception of the road also makes a difference in their willingness to make a trip. If drivers can see the edge and centerline, they are more likely to take their trip. The feedback from drivers provides valuable information to Mn/DOT and its maintenance crews.

"It helps maintenance to determine priorities for the level of road conditions that they should achieve for the satisfaction of their customers," says Brady. For example, bare pavement may not be necessary for most drivers to continue their plans, a piece of important information for developing plowing schedules.

In another study, market research is helping Mn/DOT define what smooth pavement means to drivers. The three-year study recorded the experiences of drivers as they conducted on-the-road ratings of pavement smoothness.

The ratings help Mn/DOT evaluate their current efforts against the perceptions of the drivers in the study. Ultimately, the ratings from the study assist Mn/DOT in making decisions about resources and in making sure that its customers are satisfied with its services.

"We can compare what they said with what we are doing," says Brady. "We can look at what customers are saying, see how they match with what we are doing, and, if necessary, make adjustments. This brings us closer to knowing that we are meeting customer needs."
Investigation of Recycled Asphalt Pavement Mixtures

Designed to extend the life of a pavement, the Superpave asphalt mixture resulted from a federal initiative to improve the performance, durability, and safety of roads. The binder specification for Superpave calls for use of virgin asphalt-aggregate mixtures, not recycled mixtures. This project will characterize typical Minnesota recycled asphalt pavement gradation and other binder properties, as well as develop a mix design methodology, using the Superpave approach, to proportion the materials in mixtures that contain recycled asphalt pavement.

Measurement of Moisture in Aggregate Stockpiles

This research aims to develop a practical and accurate field method for measuring the moisture content of aggregate stockpiles. Such measurements assist in controlling the proportions of aggregate and asphalt in the mix. Major components to the project include the following:

- Identification, assessment, and fabrication of available technologies for field measurement of moisture in particulate materials
- Development of a laboratory-based procedure for the accurate measurement of moisture in aggregates and of an experimental design methodology to calibrate aggregate moisture measurement technologies for field use
- Field testing of aggregate moisture technologies
- A field study to determine typical moisture fluctuations in the aggregate feed during a given asphalt mix production run
- Development of possible plant control strategies and guidelines

Materials Evaluation and Mix Design Procedures for Cold in-Place Recycling of Asphalt Pavements

Cold-in-place recycling (CIR) involves milling all or part of the asphalt layer, mixing with an asphalt emulsion, and recompacting. CIR offers several benefits, including reuse of resources that already exist in the roadway, strengthening of existing pavement structures, and reduction in energy that results from eliminating the transportation and heating of materials. From a practical point of view, the use of cold-in-place recycling offers an inexpensive means of providing a stabilized base for roads and for reducing pavement cracking.

This research project will evaluate the performance of cold-recycled asphalt mixtures using recycled asphalt pavement from various locations in Minnesota and a variety of additives.

Superpave Level I Mix Design at the Local Government Level

In this project, researchers will investigate the feasibility of producing high-performance, yet affordable low-volume pavements using the Superpave mix design procedure. Alternatives that will be explored include combining locally available aggregates with polymer-modified asphalts or using a less expensive unmodified binder with high-quality imported aggregates.

Field Measurement of Granular Base Drainage Characteristics

Knowledge of the in-situ drainage characteristics of pavement base and course subgrade materials at an early stage of the road design process allows the pavement designer to avoid many design-related problems. Using laboratory and field tests, this project will develop procedures for use of two drainage testing devices. Data collected from these tests will be used to establish a database and to analyze the drainage performance of the tested construction materials. Final products include a manual that explains how to use the devices and a field demonstration.

Low-Temperature Cracking of Asphalt Concrete Pavements

The ability to model the initiation and spacing of low-temperature cracks is a necessary component for the development of performance criteria that minimize the occurrence of low-temperature cracking. This project will develop performance criteria that can be used to minimize the occurrence of low-temperature cracking of asphalt concrete pavements in Minnesota. These performance criteria will be tested and calibrated with actual field data from the Mn/ROAD site.


In this project, researchers will develop a low-volume flexible pavement thickness design procedure based on the latest version of mechanistic-empirical design developed at the University of Minnesota. At the end of the project, a best practices manual will be developed to guide local agencies in the design and construction of flexible pavements.

Field Measurement of Base and Subgrade Stiffness

This project builds on past research about the in-situ drainage characteristics of pavement base and coarse subgrade materials. This project takes that work a step further by focusing on field testing devices, as well as developing and proposing a new specification for efficiently measuring the in-situ mechanical properties of grading materials during construction. New end product requirements, based on shear strength and stiffness, first will be used in conjunction with traditional compaction requirements to verify their accuracy.

Mn/PAVE: Adoption of Mechanistic-Empirical Design Method

Previous research resulted in a computer program, ROADENT, that allows designers to perform a reliability analysis for fatigue and rutting. Mn/DOT's materials laboratory is modifying and calibrating this tool to increase its accuracy and plans to produce a new version, known as Mn/PAVE, for application in the field. Training on the new Mn/PAVE tool is planned for the spring.