University of Minnesota
Center for Transportation Studies

LTAP

11th Annual
Minnesota Pavement Conference: Session Summaries

February 15, 2007

Continuing Education and Conference Center
University of Minnesota St. Paul Campus

Conference Sponsors:

Minnesota Department of Transportation (Mn/DOT)
Minnesota Local Technical Assistance Program (LTAP)
Department of Civil Engineering, University of Minnesota
City Engineers Association of Minnesota
Minnesota County Engineers Association
Minnesota Street Superintendents Association
Minnesota Public Works Association
State Aid for Local Transportation
Minnesota Local Road Research Board (LRRB)
Transportation Engineering and Road Research Alliance (TERRA)
Pavement Research Institute (PRI)

Hosted by:

Center for Transportation Studies, University of Minnesota

Facilitated by:

College of Continuing Education, University of Minnesota

Conference Objective

This one-day annual conference provides information to practitioners and others in pavement design, construction, and maintenance. The emphasis of the conference is new materials and methods that can assist decision makers in providing the most cost-effective strategies for building, repairing, and maintaining Minnesota roads.

Conference Planning Committee

Art Bolland, Minnesota Department of Transportation
Michael Darter, Pavement Research Institute, University of Minnesota
Glenn Engstrom, Minnesota Department of Transportation
Wayne Fingalson, Highway Department, Wright County
Philip Forst, Federal Highway Administration
Jerry Geib, Minnesota Department of Transportation
Lori Graven, College of Continuing Education, University of Minnesota
Jim Grothaus, Center for Transportation Studies/Minnesota LTAP, University of Minnesota
Mark Hanson, Department of Public Works, City of St. Louis Park
Patrick Hughes, Parsons Brinkerhoff
Maureen Jensen, Minnesota Department of Transportation
Gregory Kern, Minnesota Department of Transportation
Lev Khazanovich, Department of Civil Engineering, University of Minnesota
Bill Lohr, Federal Highway Administration
Erland Lukanen, Minnesota Department of Transportation
Mark Maloney, City of Shoreview, Engineering Department
Mihai Marasteanu, Department of Civil Engineering, University of Minnesota
Roger Olson, Minnesota Department of Transportation
Thomas Ravn, Minnesota Department of Transportation
Dave Rettner, American Engineering Testing
Douglas Schwartz, Minnesota Department of Transportation
Mike Sheehan, Highway Department, Olmsted County
Gene Skok, Department of Civil Engineering, University of Minnesota
Linda Taylor, Minnesota Department of Transportation
Curt Turgeon, Minnesota Department of Transportation
Teresa Washington, College of Continuing Education, University of Minnesota

Production

Minnesota LTAP
Writing: Richard Kronick (freelance), Pamela Snopl, Peter Park Nelson
Editing: Pamela Snopl
Design: Cadie Wright

The Minnesota Local Technical Assistance Program is part of the Federal Highway Administration's Local Technical Assistance Program (LTAP). LTAP is a nationwide effort designed to foster and improve information exchange among local practitioners and state and national transportation agencies. Minnesota LTAP is administered by the Center for Transportation Studies at the University of Minnesota, and cosponsored by the Minnesota Local Road Research Board and the Minnesota Department of Transportation.

Minnesota LTAP
Center for Transportation Studies
University of Minnesota
200 Transportation and Safety Building
511 Washington Avenue S.E.
Minneapolis, MN 55455
Phone: 612-626-1077
Fax: 612-625-6381
E-mail: mnltap@umn.edu
Web: www.mnltap.umn.edu

Contents

Plenary Session

Concurrent Sessions

Annual Pavement Conference Award

This year's recipient of the Gerald Rohrbach Annual Pavement Conference Award is Duane Blanck of Crow Wing County. Blanck has served as county engineer in Crow Wing County since 1975 and is a past president of the Minnesota County Engineers Association. Last year's recipient, Patrick Hughes (in back), presented the award.

"The challenges today with pavements are perhaps greater than ever, complicated by lack of long-term funding," Blanck said in accepting the award. "But we've done a heckua job."

Pat Hughes, Maureen Jensen, Duane Blanck, Lisa Freese

Plenary Session

Moderators: Maureen Jensen, Minnesota Department of Transportation, and Patrick Hughes, Parsons Brinkerhoff

Welcome

Lisa Freese, Minnesota Department of Transportation

Preserving Minnesota's aging infrastructure is a challenge for state and local governments, said Lisa Freese, Mn/DOT deputy director. Progress has been made in the past few years, "but to get ahead, we'll have to work harder to find innovations and ways to stretch our dollars." Conferences like this are an important place for sharing research and innovations and discussing the partnerships needed to make things happen more cost-effectively, she said.

Pavement Research and Minnesota Pavements

Michael Darter, Pavement Research Institute, University of Minnesota

"Our job is to grow pavement research," said Mike Darter, director of the University of Minnesota Pavement Research Institute. He used his time at the podium to share some background about the institute and its plans for the future.

The Pavement Research Institute is a resource for research in pavement techniques, materials, and technologies. It develops, promotes, and carries out pavement-related research that addresses not only state and local needs, but also regional and national needs. In addition, PRI conducts outreach and education efforts related to pavement research. (See www.pri.umn.edu.)

PRI goals for this year include improving and expanding research efforts; working with partners to reconstruct sections of the MnROAD pavement research facility; investigating partnerships for pooled-fund studies; and identifying new potential projects.

"Budgets are far less than required to maintain the pavement network at current conditions," he said. "Improved design, materials, equipment, and construction are greatly needed to reverse the trend."

Fifty Years of Interstate—North Central Region

Gene Skok, Department of Civil Engineering, University of Minnesota (retired)

Gene Skok of the University of Minnesota Department of Civil Engineering reviewed how pavement construction has changed over the years. He discussed design features and changes in areas such as slab lengths, joint orientation and layout, dowels (size, number), base type, and shoulder type.

Trends include longer design life (from 20 to 30-plus years); thicker slabs (from 9–10 inches to 11–12); more dowel bars; increased use of treated and permeable bases; and widened edges.

Other significant issues and developments include d-cracking, concrete mixture evolution, the adoption of slip-form paving, and the increased recognition of the importance of initial smoothness and surface texturing.

Hot Button Issues in Pavement Preservation

Tom Kuennen, Better Roads *Magazine*

If you haven't checked out Tom Kuennen's Web site, expresswaysonline.com, you're missing an opportunity. Kuennen provides one-stop shopping for all kinds of information about surface transportation, including history, research, current practice, the latest equipment, and politics. With all that experience behind him, Kuennen's presentation was like a state-of-the-union address on pavement preservation (PP).

Defining PP

Kuennen defined PP as a group of methods "intended to prolong pavement life, avoiding high future costs…through the expenditure of much lower amounts of money at critical points in a pavement's life." He listed crack sealing; fog, chip, and thin cold-mix seals; surface recycling; and thin hot-mix asphalt overlays as the most common PP methods. He also claimed that spending a dollar on PP "can eliminate or delay spending six to ten dollars on future rehabilitation or construction costs."

History of PP

On one hand, Kuennen explained, PP was simply the next obvious step after most interstate highway construction was completed in the 1980s. On the other hand, he pointed to the 1990 European Asphalt Study Tour as the single event that most forcefully propelled PP into the consciousness of U.S. pavement professionals. He quoted the tour's report: "By far the study team's most striking observation was that the pavements on European motorways and trunk routes are in superior condition. The extreme forms of distress that are evident in many parts of the United States…were, simply, rarely seen. Even pavements that were being rehabilitated or resurfaced were in fairly good condition by United States standards."

As a result, several organizations and programs were formed to promote PP in the United States:

- The Foundation for Pavement Preservation (formed in 1992)
- FHWA's Office of Asset Management (OAM, created in 1999)
- The Governmental Accounting Standards Board (GASB, which in 1999 issued Statement 34 requiring state and local governments to include long-lived infrastructure assets in their annual financial statements)
- The National Center for Pavement Preservation (opened in 2003)

Leaving 'worst-first' behind

Despite all of this activity, Kuennen said, PP continues to face a stubborn obstacle: the view held by many politicians and citizens that money should be spent on the worst pavements first. His suggested solution to this problem is hard data in the form of pavement inventories created via pavement management systems (PMSs).

Exemplary practices, new and old

Kuennen showcased two agencies—one large and one small—that have embraced PP practices. Necessitated by the tax cuts mandated in California's famous Proposition 13, the Los Angeles Public Works Department began a PP program, using PMS data and a proprietary rubberized slurry surfacing process. At the other end of the map, the town of Minisink, New York, has had excellent results with a proprietary surface treatment called FiberMat, in which short fibers are laid down with a polymer-modified emulsion and then covered with a sealer. Minisink claims the process has reduced reflective cracking by almost 90 percent over four years. But, citing NCHRP Synthesis Report 35-02 titled *Chip Seal Best Practices*, Kuennen also showed that the tried-and-true chip seal is still a useful PP option.

Rubberized slurry seal in Los Angeles

Minisink Township polymer-modified fiber membrane

The road ahead

Kuennen closed his presentation with a view to the future. He praised agencies that have compiled and issued PP reference material, including Mn/DOT's *Minnesota Seal Coat Handbook.* He also showed that, despite tight budgets that force agencies to direct funds toward road building, agencies are making PP progress. He cited a recent NCHRP study showing that state, county, and local agencies across the country are using hard PMS data to win dollars for pavement preservation.

MnROAD—Current Benefits and Future Direction

Ben Worel, Minnesota Department of Transportation

Ben Worel, MnROAD operations engineer with Mn/DOT, began by describing the history of the MnROAD pavement research facility (www.terraroadalliance.org/about/mnroad/index.html).

Many findings from phase 1 of MnROAD have been implemented, such as revised seasonal load limits, improved design methods (MnPAVE), and improved construction methods (dynamic cone penetrometer, intelligent compaction). Minnesota is estimated to save $33 million annually from these findings, Worel said.

Phase 2 will include reconstruction of some of the facility's test sections and additional research under the umbrella of TERRA, the Transportation Engineering Road Research Alliance. TERRA is a research governance structure formed in 2004 to foster a comprehensive road research program (www.terraroadalliance.org).

A major goal for TERRA and MnROAD is to join in more pooled-fund projects. One current example is a $665,000 contract for a study of low-temperature cracking in asphalt pavements that involves 12 partnering agencies (see related article). Mn/DOT is leading the project, which is intended to develop asphalt binder and mixture testing procedures that will ultimately lead to nationally accepted specifications (www.pooledfund.org/projectdetails.asp?id=311&status=4).

Future MnROAD research will include studies of the effects of farm implements on roadways; full-depth reclamation; binder modification; and portland cement concrete grinding.

Transportation Issues in the 2007 Legislature

Betsy Parker, Office of Government Affairs, Minnesota Department of Transportation

Betsy Parker of Mn/DOT's Office of Government Affairs discussed transportation proposals for the legislature, noting that results may not be clear until the last days of the session in early May. Key elements of the governor's budget recommendations include:

- Implementation of the constitutional amendment: The governor recommends that the voters' decision to dedicate motor vehicle sales tax (MVST) to transportation be implemented with 60 percent of the funds going to state and local highways and the remainder to transit. "The amendment helps all units of government," she said.

- Trunk highway investment: The budget includes a one-time transfer of $100 million from the general fund to the trunk highway fund to complete priority projects, and recommends that $1.7 billion be authorized for trunk highway bonding over the next 10 years. "The proposal has received a cool reception, to put it mildly, from Democrats," Parker said. The governor feels it is responsible to bond for highway construction, she explained, so that roads can be used while being paid for.

- Mileage-charge demonstration: To reduce the reliance on the gas tax as a transportation funding source, $5 million from the $100 million trunk highway fund transfer is directed toward a pilot project to demonstrate technologies that would allow a fuel-neutral mileage charge.

- Truck weight: Mn/DOT will pursue last year's proposal to allow heavier trucks if axles are added to protect pavement. These truckers would be required to obtain permits and pay permit fees.

"One burning issue at the legislature is where the money is spent," Parker said. Some people may be surprised that roughly 55 percent of state construction funding from 2003 through 2005 went to Greater Minnesota and 45 percent to the metro area. Future construction is expected to have a similar split, she said.

The biggest slice of state transportation appropriations—34 percent—is state aid to local governments. Other expenditures are state highway construction (27 percent), multimodal systems (15 percent), operations and maintenance (12 percent), infrastructure planning and investment (9 percent), and general support and electronic communications (3 percent).

Another burning issue at the legislature is how to fund transportation, Parker continued. At 34 percent, the state fuel tax makes up the largest slice of the state transportation revenue pie, followed by the motor vehicle registration tax (27 percent), federal fuel tax grants (17 percent), MVST (9 percent), federal aid to local roads (7 percent), and federal and investment income and other fees (6 percent).

The problem, Parker said, is that inflation is growing but the three key revenue resources are not. The gas tax hasn't been raised since 1988, and tab fees were actually lowered under former governor Jesse Ventura. And even though MVST revenues will grow thanks to the amendment, she said, estimates predict small growth to 2011 due to less demand for new autos as baby boomers age (which affects tab revenues as well).

In contrast, Minnesota's Construction Cost Index is estimated to have increased by around 19 percent during 2006 (final numbers were not yet available). This is significantly higher than the general inflation rate and historically at the highest level to date, Parker said.

The growth is driven by the record-level price increases in asphalt (with a producer price increase of 55.8 percent), which, in turn, are driven by the unprecedented increases in crude oil prices over the last few years. Oil price increases affect not only asphalt prices but also transportation costs, excavation costs, and machinery operations. For example, Mn/DOT experienced a 34.4 percent increase in unit cost of bituminous surfacing over the last three quarters, she said.

"When you look at declining or flat revenues on one hand and inflation on the other," Parker concluded, "there is a lot to argue about to pay for transportation."

For more information about the budget, visit the Mn/DOT Web site at www.dot.state.mn.us.

New Innovations in Recycling Asphalt

Don Brock, Astec Industries, Inc.

As CEO of ASTEC Industries, Inc. (the largest manufacturer of asphalt plants in the United States) and as the holder of approximately 90 patents, Don Brock is a bona fide expert on asphalt recycling. At the 2007 Minnesota Pavement Conference, he shared some nuggets of knowledge on the subject.

Aggregate Size in RAP	Typical Asphalt Content
3/16 x 0	7%
3/8 x 1/4	4%
1/2 x 3/8	3%

Table 1: Liquid asphalt content in recycled pavement

The times they were a-changin'

Until the 1970s, the price of asphalt had remained about the same for about half a century, Brock noted. Then several factors dramatically changed the picture. First, when OPEC manipulated oil prices in the 1970s, the cost of asphalt increased by an order of magnitude: by 1979, it was about $200 per ton. This price spike coupled with the advent of milling brought the cost of recycling below that of virgin materials.

Why not separate recycled material?

But Brock pointed out a discrepancy in the way materials are handled today. A common practice, he said, is to separate virgin material by size but to throw all RAP (reclaimed asphalt pavement) together in one bin. As shown in Table 1, he explained that this leads to mix design problems because different sizes of RAP retain different amounts of asphalt.

"So as the rock is segregated," Brock said, "it's also segregating the liquid asphalt content." This tends to limit the use of RAP in pavements to about 20 percent. But Brock explained that excellent products can be made if recycled material is separated just like virgin material.

RAP segregated in piles

RAP is worth it

Brock's next point was that paving materials obtained from RAP are a bargain compared with the virgin materials they replace. For example, in 30,000 tons of recycled pavement, there are typically about 28,200 tons of aggregate and about 70 6,000-gallon transport loads of liquid—worth roughly $1 million. The cost to reuse that RAP is only the cost of the trucking and processing, since the same material is taken out of the road and then put back into the road. He assumed this trucking/processing cost to be $6.40 per ton. He then compared that with typical prices of virgin material: rock at $9.40 per ton + asphalt at $18.00 per ton = $27.40 per ton. Thus, the savings from using recycled material would be $21.00 per ton.

Figure 1: No shoulder changes with millings

Overlay vs. inlay

Brock then compared overlays with mill-and-inlay operations: Putting an overlay on a rutted road is very likely to yield a rutted road again, but milling a pavement gets rid of the rutting. Also, the rough milled surface will interlock well enough with the inlay that a tack coat is probably unnecessary. Furthermore, Brock said, "One of the best benefits is we eliminate joint density problems. When you put down a 2-inch overlay, you put down 2½ inches, and as you try to compact it, you can't contain it on the edges, so it spreads out. As it spreads out, you create low-density areas." But with mill and inlay, the unmilled shoulder creates a dam on each side, so the material has no place to spread out.

Furthermore, with an inlay there is no need to raise either guardrails or shoulders—and no need to decrease the posted clearance under bridges or the weight limits on bridges. Finally, Brock said, if the tack coat isn't necessary and a transfer machine is used, a paver can follow 200 feet behind the milling machine, and by double hauling (mix out, milled material back), save tremendously on hauling costs.

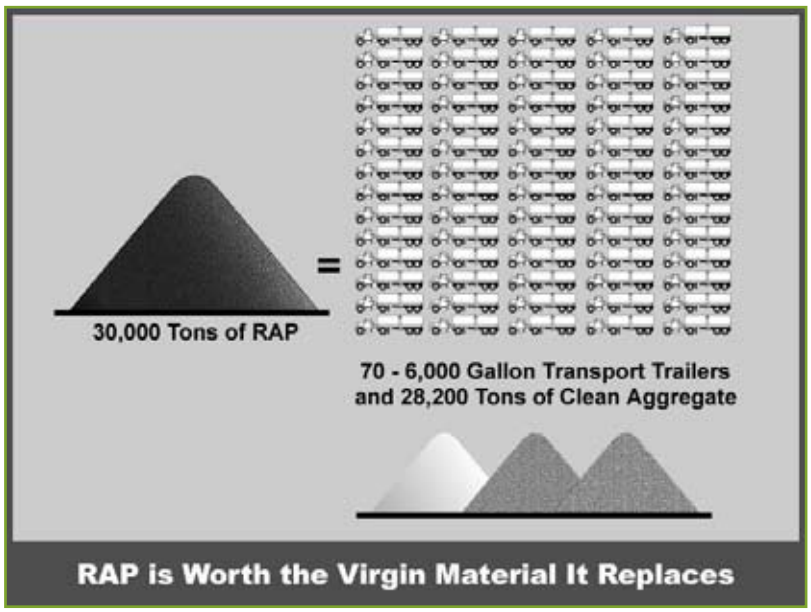

Figure 2: RAP vs. virgin material

Brock did say recyclers need to work out some problems. For example, they need to allow more mixing time to allow water to evaporate, the superheated virgin material to cool, the RAP to heat up and melt the old liquid from recycled material, then mix new liquid. By allowing that evaporation time, they will produce a product that mixes the RAP and virgin material more homogeneously. Nonetheless, Brock ended by stating confidently that, as the cost of virgin materials continues to increase—and as we become more committed to decreasing our dependency on foreign oil—he expects all agencies to turn more and more to recycling.

Concurrent Sessions

Pavement Management Can Still Save Your Asphalt

Moderators: Mark Maloney, City of Shoreview, and Wayne Fingalson, Wright County

Benefits of Pavement Management Systems

Dan Schacht and Kathy Jaschke, Ramsey County

Ramsey County began using a pavement management system (PMS) in 1984, said Kathy Jaschke. Developed in-house by Dan Schacht, the system collects data through a visual inspection performed every other year. To alleviate any subjectivity, one person does the rating using a rating guide. A spreadsheet is used to collect and analyze data.

The inventory includes road name, number, termini, length, width, municipal and commissioner district, typical section, pavement type, load limits, and construction and maintenance history.

Factors rated include smoothness, structural condition, cracking, wear and weathering, alligatoring, patching, skid resistance, uniformity, spalling, and joint condition (concrete only).

A pavement condition formula takes the factors and gives a rating: 0 for "junk" to 100 for something brand new. Citizens start to complain at 70 or below, Jaschke said. The county's goal is to maintain a rating of 90. Last year's overall rating was at 88.9, although some roads are down to the 30s or 40s.

Schacht then reviewed the benefits of a PMS. The first one, he said, is that information "is no longer just kept in the heads of the maintenance engineers," so there are no "forgotten" roads.

Another benefit is that the system "takes the political process out of project selection," he said. Priorities are based on pavement condition and traffic volumes. The system also helps develop projections for funding needs. "Our funding isn't enough to maintain at 90," Schacht said. "We are losing about a point a year."

The system allows the county to track the pavement condition and age of roads since construction or overlay, compare physical features and construction techniques, and spot problem areas. By linking the spreadsheet to a geographic information system (GIS), users can display the data on a county map.

One interesting finding came from their evaluation of maintenance practices. The county had been seal coating about a year after road construction or an overlay, but stopped seal coating in 1990. With the PMS, they learned that all roads that *weren't* seal coated had a lower condition decline than those that were. "This is not to say you shouldn't seal coat," Schacht said. "But the bottom line is, wait 7, 10, or more years, and seal coat then, and you can buy some additional time. But to seal coat right after [construction or overlay], there's no benefit and it may even make it worse."

Using an in-house system offers several advantages: it's easy to use, adaptable, and tailored for their needs. The downside of their PMS is that there is no visual record, and it's "time consuming and a little subjective," he said.

The county will share the PMS at no cost. Contact dan.schacht@co.ramsey.mn.us or kathy.jaschke@co.ramsey.mn.us.

Pavement Management Data

Dave Janisch, Minnesota Department of Transportation

Agencies are using pavement data more than ever, said Dave Janisch of Mn/DOT's Office of Materials. He presented an update on Mn/DOT's pavement testing program for county highways.

In the program, Mn/DOT State Aid and the Office of Materials are testing one-fourth of the county state-aid highway (CSAH) system each year over an eight-year period, under a joint effort with counties. Mn/DOT's Pavement Management Unit collects, analyzes, and distributes the data to counties.

The program measures roughness, rutting, and faulting in both directions. In addition, crack surveys are done on the first 500 feet of each mile. So far, 99.56 percent of the CSAH system tested has been hot-mix asphalt, Janisch said, but concrete will be tested in some upcoming counties.

Counties take turns operating the new van that was purchased for the testing. The van has three main components: three laser height sensors in the front, two scanning lasers on the back, and four digital cameras mounted on the roof. Mn/DOT has used a similar van for about 15 years and is very experienced in how it works and the data it collects, he said.

As the van drives down road, a digital photograph is taken every 25 to 50 feet. Special software allows county employees to play the video at their desks like a movie, selecting road segments of interest. "It's an extremely valuable system," he said.

Deliverables include printed reports and a spreadsheet with information on roughness, cracking, rutting, and faulting, reported for each mile and segment. Also provided is the digital video log of the county's entire CSAH system, in both directions.

Data are fed into an algorithm that calculates the international roughness index (IRI). Simulating the "golden car" traveling at 50 mph, the index measures how much movement (bouncing up and down) there would be, generated in inches/mile. The Federal Highway Administration considers an IRI less than 95 as "good," and less than 170 as "acceptable."

The average IRI on Minnesota non-interstate roads is 105, Janisch said. About 8 percent of the state highway miles have an IRI higher than 170.

Mn/DOT goes one step beyond IRI with its ride quality index, Janisch continued. This index, calculated from the IRI, uses a scale of 0 to 5. It is based on ratings assigned from a panel of 30 to 40 people taken for a drive over many different pavement sections. Mn/DOT's van follows right behind, measuring the IRI. Mn/DOT generally repairs roads when the RQI reaches 2.6, he said; 2.5 is the point where complaints begin.

Results from the county testing program's first two years (2005 and 2006) found the following: the average countywide ride quality index ranges from 2.7 to 3.6; the average surface rating (cracking index) is 3.2 to 3.8; and the average rut depth is 0.11 to 0.27. Overall, he reported, the data indicate county roads are about as smooth as the state system and have the same amount of cracking distress.

One of the uses for the data is prioritizing projects, Janisch said. In addition, multiple data points allow users to develop deterioration prediction models and monitor trends. Agencies can also enter their budget plans and determine the resulting conditions, or enter a desired condition and identify the budget needed to achieve it.

Statewide Pavement Data Collection

Rick Kjonaas, Mn/DOT; Rich Sanders, Polk County; Cameron Kruse, Braun Intertec

The pavement-testing program described by Dave Janisch (page 8) is documenting the condition of pavements on state-aid roads. But how well do the actual conditions match what was planned? A separate pilot project was conducted last year to find out.

Rick Kjonaas, deputy director of Mn/DOT's Division of State Aid, kicked off the presentation with some background about the pilot. The counties triggered the project; State Aid served as fiscal agent, issued an RFP, and chose SRF Consulting Group and Braun Intertec for the work.

Next, Rich Sanders of Polk County described the "NEEDS Report" that county engineers are required to submit to State Aid every year. The report estimates the construction cost required to improve a state-aid system to standards adequate for future traffic on a uniform basis. The data—including the year graded, year surfaced, type of surfacing, design strength, functional class, proposed section, and relative cost to improve—form the NEEDS database.

What isn't collected, however, is the actual structure in place—in other words, what was constructed (materials and thickness) versus what was planned. Other unknowns are the road users (important with increasing truck traffic) and how well the roads are performing.

For the pilot, every county engineer was asked to submit sections at three sites of 10 to 15 miles. Actual totals analyzed were 341 sites (ranging from 1 to 16 per county) over 1,297 miles. The work included a significant effort to collect site data such as termini, construction history, and traffic, said Cameron Kruse of Braun Intertec.

Testing included:

- Falling weight deflectometer, to calculate pavement strength, capacity, and remaining life
- Ground penetrating radar (GPR), to provide a picture of pavement structure and to analyze FWD data
- Coring, to calibrate GPR data
- Traffic data (volume and classification)

Coring, GPR, and traffic data were compared to reported (historical) values, and the data were used to "back calculate" pavement strength, capacity, and remaining life, Cruse said. Each county will get a report by section.

Five percent of the CSAH system was tested in the first year. Preliminary results found that the difference between cored and reported thickness in 15 percent of cases was plus or minus 3 inches. "This suggests an opportunity to improve in that area," Cruse said.

The pilot project did not include concrete, he added.

If the work becomes operational, various issues will need to be addressed, Cruse said, such as testing frequency, workload capacity, alternative analysis methods, data sharing, and seasonal traffic variation.

In closing, Kjonaas encouraged attendees to visit the improved design tools on the State Aid Web site: www.dot.state.mn.us/stateaid. (Minnesota LTAP staff assisted Mn/DOT with the development of these pages.)

Intelligent Compaction

Moderators: Glenn Engstrom and Art Bolland, Minnesota Department of Transportation

Intelligent Compaction National Pooled-Fund Project

Bob Horan, SaLUT, Inc.

Bob Horan is a speaker with an effective strategy for connecting with his audience: flatter the heck out of them! To begin his presentation at this year's Minnesota Pavement Conference, Horan, a consulting engineer on FHWA's intelligent compaction (IC) study team, complimented Minnesota profusely for taking the lead in IC research. "I know this is going to be the most knowledgeable crowd I'll talk to all year, and we're thankful for that. I think the other states are really going to benefit from Minnesota's experience."

To arrive at a definition of IC, Horan started with a dictionary definition of *intelligence*: "the ability to collect information, analyze that information, make an appropriate decision, and execute that decision." He asserted that "intelligent compaction can do all those things—and it's not pie in the sky; it's a reality today that can translate into a much better compaction process." He said FHWA defines IC as a system that measures material density and then immediately feeds the density data back into the compactor to automatically control vibration amplitude.

Horan said the first question everyone asks him is, "How does IC work?" "That's kind of a tall order," he said, "and the big reason is that I don't know how it works—totally. A lot of this technology is just now being developed. It's very competitive, so the manufacturers don't want to tell you exactly how it works."

Nonetheless, Horan went on to list the basic components of a typical IC roller system:

- An accelerometer measures the material's response to the force of compaction.
- A thermal gauge measures material temperature.
- GPS equipment constantly and precisely records roller location.
- An on-board computer processes the collected data.
- An on-board monitor displays compaction data.
- A feedback system inside the drum automatically changes compaction amplitude.

Combined, this equipment gives the operator a color-coded map showing the number of roller passes made and the amount of compaction achieved point-by-point throughout the work site. Horan said, "Eventually, this can become a QC tool. On a job near Duluth a couple years ago, I got up and rode with the operator—and he was just raving about the system! He told me how it helped him do a much better job." This led Horan to a list of the benefits he expects from further development of IC technology:

- Documented, consistent material density throughout a job site—something we can only hope for today
- On-the-job confirmation of material density rather than testing that delivers results when it is often too late to correct problems
- Greater productivity—and avoidance of overrolling—because IC lets the operator see at a glance where additional rolling is needed
- Identification of material that is uncompactable due to insufficient strength of underlying material
- Increased depth of compaction because IC allows the operator to increase vibration amplitude without overcompacting

However, Horan was quick to point out that much research is needed to achieve these results. That's why FHWA and 12 state DOTs (including Mn/DOT), with cooperation from roller manufacturers, are embarking on a three-year pooled-fund research project (Transportation Pooled Fund 5-128), with the following objectives:

- Perform side-by-side comparisons to prove IC's superiority.

- Develop QC/QA construction specifications for both granular and cohesive subgrade soils, aggregate base materials, and asphalt paving materials.
- Define standards for the precision of GPS.
- Assess operator capability to use and benefit from IC technology.

When these objectives have been achieved, Horan expects them to yield better performance by our roads, which will translate to a reduction in the cost of construction and repair. "I really believe IC has the potential to revolutionize the compaction process, and what I've seen is that people in the agencies, contractors, and roller manufacturers are all excited about this. IC is really going to develop rapidly—it's the future for the whole country!"

Intelligent Compaction Update

David White, Iowa State University

David J. White, assistant professor of civil engineering at Iowa State University, has researched soil compaction with a focus on achieving uniformity of compaction in subgrade and base soils. At the conference, he discussed his research in measuring compaction by monitoring the power needed to move a roller through soil. He said the component of machine power associated with increasing soil compaction can be isolated from the power needed to overcome gravity. White went on to show that, in both cohesive and non-cohesive soils, there is a high correlation between the machine power and material compaction, measured in terms of density, strength, and stiffness. White can be reached at djwhite@iastate.edu or 515-294-8216.

TH 64 Intelligent Compaction Experience

Graig Gilbertson, Minnesota Department of Transportation

Graig Gilbertson, Mn/DOT District 2 materials engineer, reported on the use of a Caterpillar CS-563e intelligent compaction roller to compact subgrade and base layers in reconstructing a section of Minnesota State Highway 64. Gilbertson found that the IC roller improved compaction uniformity and accurately identified variations in subgrade material. "It was like having x-ray vision of the earth!" Furthermore, he said the roller data correlated well with conventional density measurements. Gilbertson also said the roller saved money and time. "We were worried about the cost of IC, but actually the project was overbid by about 1 million dollars." Gilbertson can be reached at graig.gilbertson@dot.state.mn.us or 218-755-3807.

Hot-Mix Asphalt (HMA) Pavements

Moderators: Michael Darter, Pavement Research Institute, and Roger Olson, Mn/DOT

Cost/Benefit of Preventive Maintenance

Erland Lukanen, Minnesota Department of Transportation

We have all seen it many times: the graph showing that, if you do preventive maintenance at critical early stages in a pavement's life, the pavement remains in acceptable condition longer—and you save money over the pavement's life.

But is this truly true? Is preventive maintenance actually efficacious—and is it cost-effective? Or would we really be better off to allow a newly built pavement to deteriorate at its own rate without preventive maintenance until it is time for a major reconstruction? According to Erland Lukanen, the fact is that we have taken the value of preventive maintenance for granted; no research based on actual long-term data has either proved or disproved the preventive maintenance theory.

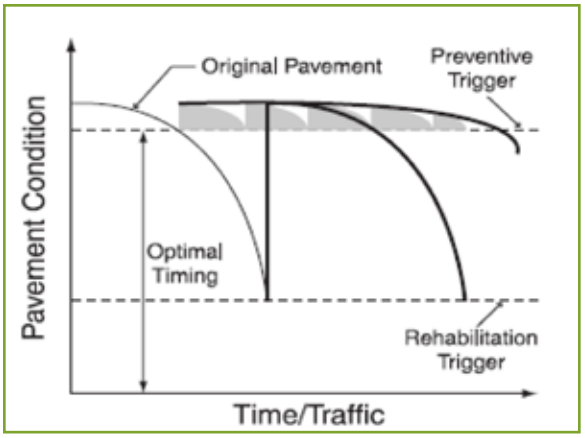

Figure 3: Preventive maintenance preserves pavement life—or does it?

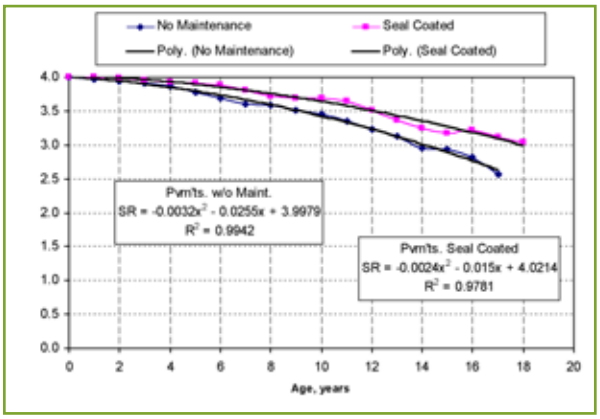

Figure 4: Pavement management data: surface condition (pavements constructed 1985–91)

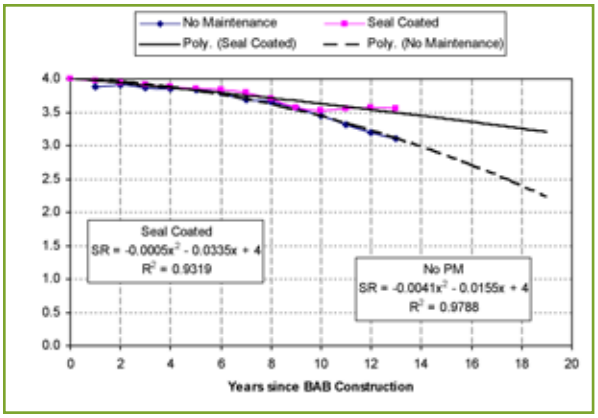

Figure 5: Pavement management data: surface condition (pavements constructed from 1992 on)

Lukanen is embarking on just such research. He is using pavement management data gathered on Minnesota roads to determine both the efficacy and cost-effectiveness of preventive maintenance. The results should be of great interest to all pavement professionals.

M-records as raw data

Lukanen explained his methodology and presented some early findings. He is using "M-records"—construction records and pavement condition data collected since 1985 on all of Minnesota's bituminous-over-aggregate interstate and collector roads. He chose 1985 as the starting date because "that's when we began doing mix design on all layers of the pavement system."

Preliminary results suggest efficacy

Lukanen showed a few snapshots of data on the efficacy of preventive maintenance: graphs comparing sections that had received various types of preventive maintenance with sections that never received preventive maintenance. Figure 4 is an example: a comparison of surface condition on sections built between 1985 and 1991 that had no subsequent preventive maintenance vs. sections built during the same period that were seal-coated and most likely also crack-sealed. (However, as Lukanen pointed out, these data say nothing about the quality of the seal coats—they just say seal coating *was* done.)

Note that the curves diverge almost from the beginning and that conditions on 18-year-old seal-coated sections were about equal to surface conditions on 14-year-old pavements that had no preventive maintenance. In other words, this one comparison begins to suggest that preventive maintenance *does* preserve pavement quality.

Then Lukanen showed Figure 5—again a comparison between seal-coated and no-maintenance sections, but this time for sections built beginning in 1992. He explained that this is an important benchmark because "that's when we got into quality management, where we were controlling the air voids and should have asphalt with greater durability."

As we might hope, the more sophisticated construction methodology appears to pay off: Non-seal-coated pavements retain their surface condition longer even without preventive maintenance—until the pavements reach about eight years in age, when seal coating apparently begins to pay off in better surface condition.

But are we getting enough bang for our buck?

These data show that preventive maintenance works. But that only addresses half of the research brief—it says nothing about the cost-effectiveness of preventive maintenance. Lukanen went on to suggest that, on this second issue, preventive maintenance may be only barely worthwhile. His

calculations showed that, if we seal-coat a pavement after about six years, we will then need to defer an overlay until the pavement is 18 years old to break even on the extra cost of the seal-coat. Overlaying any earlier would be a money-losing proposition.

Much more to be done

Lukanen cautioned that none of the preliminary data should be taken as gospel because pavements constructed at different times over the past 20 years are not completely comparable. Pavement longevity improved with the advent of quality management in the early 1990s—and improved again with Superpave in late 1990s. We can only wait for more substantial data from Lukanen.

National Sealer Rejuvenator Study

Gayle King, King and Associates

Gayle King, a chemist with extensive experience in pavement materials, discussed his work on emulsions used to seal and rejuvenate pavement. The problem is this: How can we prevent embrittlement—and how can we rejuvenate already brittle pavement? Working with FHWA and other participants, King has developed ways to identify when treatments should be done, and the materials and methods that work best. He strongly recommended fog seal for all chip seals and several other surface types. But he showed that you have to do it right to avoid losing skid resistance. Results are posted on the Web site of the National Center for Pavement Preservation: www.pavementpreservation.org.

Seal Coating—The Details Count

Tom Wood, Minnesota Department of Transportation

"When you go to Vegas and play craps, they don't give you arrowheads, and they don't give you rectangles. They give you cubes. Why? Because no matter how you roll 'em, once they land, they always stay put. It's the same with chip seal aggregate!" With that vivid metaphor, Mn/DOT researcher Tom Wood suggested the importance of single-size cubic aggregate in chip seals in a presentation at the recent Minnesota Pavement Conference.

Wood went on to use other colorful analogies to build his case for cubic aggregate. First, he dismissed "round buckshot" by asking, "Did you ever try to glue a round marble to a piece of glass? It doesn't work!" He then showed the inferiority of oblong rock. "In the wheel paths, the long stones are pushed down below the surface of the binder so you end up with bleeding. Outside the wheel paths, the rocks stand proud, so they either get knocked off by the snowplow or some four-wheel-drive pickup kicks them into the windshield of the Lexus behind. That costs $1,200!" Finally, Wood showed that dense-graded aggregate weighs and costs more than single-size material, concluding that "you can pay up to $6.30 per ton more for single-size and it costs the same per square yard as the dense-graded material."

Wood listed two other important characteristics of aggregate for chip seal: It has to be clean—less than 1% passing through a #200 screen—and it has to be durable. "The chips are where the rubber meets the road, so why would you want to use a soft chip?"

Binder is the main attraction

But Wood pointed out that the chips' only purpose is to provide traction, which is secondary to the main purpose of a chip seal: protecting the asphalt underneath. That is accomplished by the binder. "The more binder you put down," Wood said, "the longer it takes for oxidation to remove that binder and get at the underlying pavement. Furthermore, if you use more binder, you

save on chips."

He strongly recommended CRS-2p (cationic rapid set polymer modified) binder over CRS-2 because the former "develops the strength in two hours that CRS-2 develops in two days and that cut-back develops in two months. So you sweep the same day and get traffic back on the road." But to use CRS-2p, Wood said you have to lay the chips down within one minute of the binder. "The softening point of CRS-2p is 128 degrees F, compared with 108 degrees for CRS-2. That 20 degrees is huge! It makes the difference between bleeding and not bleeding. We can shoot up to 15% more CRS-2p without bleeding. That makes the chip seal more snowplow-proof, which makes it last longer."

Wood said the standard wisdom is that a chip seal will last five to seven years. "But we have CRS-2p that's been put down with single-sided aggregate. It's been there for 10 years and still looks like the day it was put down. If you have chip seal that lasts 10 to 15 years, you can stop worrying about initial material costs. That allows you to focus on the details—like how much aggregate per square yard you're putting down, the nozzle angles, and the bar height. Bar height is critical!"

New Mn/DOT design manual

Wood also introduced the latest version of Mn/DOT's *Minnesota Seal Coat Handbook*. Originally published in 1999, he explained that the new edition has three new chapters—on fog seal, chip seal for recreation trails, and an FAQ section. He then discussed the handbook's design guide. "People always ask me, 'Why should I design a chip seal?' I answer by asking: Why do you design hot mix? For performance! It's the same with a chip seal. People don't design chip seal and then they wonder why they're not getting the performance they wanted."

The design guide allows the user to calculate the amount of stone needed to cover one square yard, one stone thick. "Before we started designing chip seals, we used a standard 30 pounds of FA-3 per square yard and 3/10ths of a gallon of binder. Now with the design guide, we probably shoot 36/100ths of a gallon of CRS-2p and we're down to 16 to 17 pounds of aggregate per square foot."

To hear Tom Wood tell it, if you do chip seal right, you get lower-cost materials, longer-lasting chip seals, and longer-lasting pavements—a win-win-win for agencies and contractors alike!

Low-Temperature Cracking

Mihai Marasteanu, Department of Civil Engineering, University of Minnesota

Much has been learned about low-temperature cracking in asphalt pavements through research conducted at the MnROAD facility. Associate Professor Mihai Marasteanu of the Department of Civil Engineering shared preliminary findings from one recent project, a national pool-fund study led by Mn/DOT.

The purpose of the pooled-fund study—Investigation of Low-Temperature Cracking in Asphalt Pavements [TPF-5(080)]—is to develop asphalt binder and mixture testing procedures that will ultimately lead to nationally accepted specifications. The ultimate goal is the elimination of low-temperature cracking in both new and rehabilitated hot-mix asphalt (HMA) pavements.

Low-temperature cracking is the main cause of pavement roughness and reduced service life in northern climates. The use of performance-graded (PG) binders, especially polymer-modified binders, has gone a long way in reducing the amount of low-temperature cracking on Minnesota roadways. Mn/DOT started using these binders in 1997.

The original PG binder specifications, developed during the Strategic Highway Research Program (SHRP) in the 1990s, considered only neat binders. Engineers expect better performance if a modified PG binder is specified. For example, Mn/DOT spends an extra $5.7 million annually for modified binders, expecting better low-temperature cracking performance. It is unclear, however, if the current tests and specifications are adequate or if something better is needed.

In the pooled-fund study, the researchers discovered the important factors that affect low-temperature cracking and developed and updated testing methods. Phase 1 involved field investigation of 13 pavement sections, comprehensive laboratory study, and advanced modeling of low-temperature cracking based upon the field and lab components. Various fracture tests were conducted.

Some key findings:

- Asphalt binder testing alone does not provide sufficient reliability to predict low-temperature cracking of asphalt pavements.
  - The effect of aggregate has a significant effect on the fracture properties of similar types of mixtures made with the same asphalt binder. Granite aggregates show better low-temperature cracking performance than limestone aggregates.
  - Higher high-temperature PG grades show better performance than binders with a lower high-temperature grade.
  - The PG system provides a good starting point in the selection of asphalt binders. However, this study showed the need for further refinement of the current AASHTO M320 specification, which seems to be "blind" to improved fracture properties at low temperatures due to polymer modification.
  - Physical hardening has a significant effect on measured binder properties.
- Even at low temperatures, asphalt mixtures are significantly dependent on temperature and load rating.
  - When conducting low-temperature tests on asphalt mixtures, testing temperatures should be established relative to the expected low pavement temperature and/or relative to the low temperature Superpave PG grade for the location of interest, as opposed to the current standard of 0, -10, and -20 degrees Celsius.
  - The mixture and binder test temperatures should be matched as much as possible to better understand the contribution of the binder to the fracture properties of mixtures.

The current specifications for low-temperature cracking for both asphalt binders and mixtures do not include a fracture test. It is strongly recommended that the selection of fracture-resistant binders and mixtures be based on simple-to-perform true fracture tests.

A comprehensive report will be published later this spring.

For more about MnROAD: www.mnroad.dot.state.mn.us/research/mnresearch.asp.

(This summary was edited from pooled-fund study executive summary.)

Portland Cement Concrete (PCC) Pavements

Moderators: Doug Schwartz and Jerry Geib, Minnesota Department of Transportation

A National Study of Sealed and Unsealed Joints

Doug Schwartz, Minnesota Department of Transportation

Does joint sealing increase the lifespan of pavements? In an effort to help answer this difficult question, Doug Schwartz described a recent national study of sealed and unsealed joints. Schwartz acknowledged the role of Kathleen Hall, who delivered a presentation on the research at a March workshop in St. Cloud.

Among the issues tackled in this research were the effects of unsealed joints on long-term pavement performance, the effects of different types of sealing materials and sealing methods, and the cost-effectiveness of sealing when used with different pavement designs, in a variety of climates, and under different traffic levels.

The research, Schwartz said, grew out of a 1995 meeting; researchers realized that such an effort would require at least a decade to produce meaningful results. During the course of the project, researchers gathered a range of observations including evaluation data, deflectometer test results, and digital photographs of pavements in more than 40 paving projects of varying com-

plexity. The researchers visited 13 states in four different climate zones.

Subgrade material and traffic volumes are among the factors exerting significant effects on the effectiveness of joint sealing, Schwartz said. Highlighting the complexity of the research, Schwartz said that it would be difficult to establish a "seal/no-seal" policy without exceptions. While sealing remains popular in many areas, he continued, Wisconsin has significantly backed away from the practice.

Final FHWA review of the research results is expected to be completed in spring 2007, Schwartz said.

MnROAD Lessons Learned

Tom Burnham, Minnesota Department of Transportation

Now in its 13th year of operations, the Minnesota Road Research Facility (MnROAD) has made important contributions to the understanding of pavement design and performance. *MnROAD Lessons Learned*, a new report from the Minnesota Department of Transportation, highlights many of these contributions; MnROAD engineer Tom Burnham provided an overview of significant findings over the years.

Joint sealing, thin and ultra-thin whitetopping, and the effects of temperature on cracking and wear have proven to be among the most fruitful areas for MnROAD research. Findings in these areas continue to contribute to pavement management practices in Minnesota and beyond the state's borders.

In addition, engineers and pavement researchers working at MnROAD have gained a wealth of knowledge about how to successfully instrument and monitor pavement sections for long-term data gathering. Methods developed at MnROAD, Burnham said, have influenced pavement research projects at other facilities.

With a vital role in pavement research and support from Mn/DOT, the University of Minnesota, and pooled-fund researchers, MnROAD's future looks bright. The facility is currently preparing for significant reconstruction and upgrades that will position it to continue as a leading facility for pavement research.

Evaluation of Texture and Accident Rates on Concrete Pavement

Bernard Izevbekhai, Minnesota Department of Transportation

Where the rubber meets the road, surface texture is an important and complex issue for concrete pavements. In addition to affecting wheel noise and surface wear characteristics, texture plays an important role in safety. However, "texture is not a panacea for all safety issues," said researcher Bernhard Izevbekhai of the Mn/DOT Office of Materials.

Many methods have been used to produce desirable surface textures on portland cement concrete (PCC) pavements. One of the first was dragging wet burlap over the newly poured surface; later innovations included the use of artificial turf or brooms in place of burlap, "tining" the roadway using specialized raking tools, and more advanced approaches such as grinding the surface with diamond-coated cutting wheels.

In the late 1990s, Minnesota declared a moratorium on tining due to public concerns over excessive wheel noise caused by the deep grooves tining creates. This change spurred research to identify any safety problems that might result from abandoning tining in favor of texturing with brooms and artificial turf. Izevbekhai's research investigated safety issues, and also to aimed to create a better understanding of the effects of different surface textures in order to help design safe and quiet pavements.

The study looked at the effect of pavement texture on accident rates, noise, and measured fric-

tion levels. To examine the possible effect of pavement texture on crashes, Izevbekhai used data from crash reports, which include information on weather conditions. Crash rates were the subject of his conference presentation; the research on noise and surface friction measurement will be published in a future research report.

After cleaning the crash data to remove collisions with animals and other crash factors unrelated to surface texture, Izevbekhai looked for any changes in crash rates following reconstruction and resurfacing of concrete pavements that had previously been tined. Extensive statistical testing failed to reveal a "spike" in wet-weather crashes that would be expected if resurfacing created dangerous surface conditions.

Izevbekhai is currently involved in further research on the effects of different pavement surfacing techniques, including a federal pooled-fund study at the MnROAD pavement test facility.

Dowl Bars

Kyle Hough, Department of Civil Engineering, University of Minnesota

Kyle Hough, a master's student in the Department of Civil Engineering, presented his work with associate professor Lev Khazanovich on the effects of dowel rod misalignment in concrete pavements. This research is slated for incorporation into new guidelines for dowel alignment from the National Cooperative Highway Research Program (NCHRP).

Steel dowel bars, which link sections of concrete pavement together, are critical to the performance and long-term durability of road surfaces. Current research on dowel bar performance at the University of Minnesota dates back to the mid-1990s, Hough said, when researchers began to lab-test multiple designs using the Minnesota Accelerated Loading Facility (Minne-ALF), located in the civil engineering department.

In the lab, Hough, Khazanovich, and other researchers tested individual misaligned dowel bars to determine how alignment affected pullout strength and loading capacity. Data from these tests were then used to calibrate a computer model of dowel bar behavior. Further testing of sample slabs and monitoring of real-world pavement sections provided more data to compare with the model's predictions.

By improving engineers' ability to estimate the short-term and long-term effects of different types of dowel bar misalignment, this research has the potential to improve pavement management in Minnesota and across the country.