MnROAD Research Facility

Three Decades of Collaboration, Studies, Innovation, and Deployments

Photo: Minnesota DOT

GLENN ENGSTROM, BERNARD I. IZEVBEKHAI, BENJAMIN WOREL, JEFF BRUNNER, AND LAUREN DAO

Engstrom is the director of the Office of Materials and Road Research, Izevbekhai is a research operations engineer, Worel is the MnROAD operations engineer, Brunner is a research manager, and Dao is the communications coordinator at the Minnesota Department of Transportation in Maplewood.

Above: An aerial view of MnROAD from eastbound I-94 shows the test track loops. The real-life pavement testing scenario has aided Minnesota DOT—and transportation agencies nationwide—in developing technologies and techniques for better, longer-lasting, more environmentally friendly roads.

In the 1980s, a group of visionary engineers at the Minnesota Department of Transportation (DOT) explored the idea of building a Cold Regions Pavement Research Test Facility. This led to a task force composed of Minnesota DOT engineers and officials, along with administrators, industry representatives, and university experts from FHWA and the first Strategic Highway Research Program (SHRP).

The task force identified the need to test pavement types in Minnesota's cold-weather climate—and its pavement-relevant freezing and thawing patterns—to develop the most economical pavement systems for the region. Testing pavement concepts in a real-life scenario would help Minnesota DOT understand how to build the best roads for the state's budget. The initial goal was to evaluate pavement performance under actual, existing conditions to improve pavement design methods and increase pavement performance.

Construction of the MnROAD research facility took place from 1989 through 1993 and cost $25 million. Funding for the Interstate portion was approved by FHWA through the standard federal aid process; the low-volume, closed-loop test section was paid for with Minnesota state funds. A partnership between Minnesota DOT and the Minnesota Local Road Research Board (LRRB) provided much of the operational funding in the facility's first decade. Today, funding comes from a combination of LRRB, federal and state sources, and industry and other private partners.

MnROAD has three main functions:

1. **Operations** including testing and monitoring test cells; adding traffic to the low-volume road (LVR) test track; and maintaining the site, instrumentation, and data systems;
2. **Research projects** funded by the National Road Research Alliance (NRRA), LRRB, Minnesota DOT, FHWA, other states (via pooled funds), the National Cooperative Highway

Research Program (NCHRP), industry, and SHRP; and

3. **Construction**, including the design, manufacture, and instrumentation of test cells.

MnROAD has flourished over the past three decades—in collaboration with the Transportation Research Board (TRB)—as a research site for many ideas conceived by TRB standing committees in their triennial strategic plans and research needs statements (RNSs). One example is the newly completed unbonded overlay pooled fund study, led by MnROAD staff, that was initiated by a TRB standing committee RNS in 2010.

MnROAD has maintained this symbiotic relationship with TRB, with many Minnesota DOT and MnROAD staff serving on TRB standing committtees and providing guidance to committees on transitioning RNSs to actual research. Many prospective bidders for NCHRP projects request collaboration with MnROAD to facilitate the research process.

Technical Accomplishments

Located 40 miles northwest of Saint Paul, the MnROAD research facility consists of three test tracks: 1) The Mainline, a two-lane, 3.5-mile stretch of I-94 parallel to 2) an Old Westbound route (OWB), to which live traffic is occasionally diverted to facilitate periodic testing, and 3) a two-lane, 2.5-mile LVR test track.

MnROAD researchers have continuously incorporated pavement instrumentation not previously used for civil engineering structures under live traffic, including test cell instrumentation technology with automated data storage and retrieval that facilitate quick responses to data requests. Sensor types now include vibrating wire strain gauges, moisture sensors, trees with watermarks and thermocouples, clip gauges for joint movements, concrete maturity data loggers, and fiber-optic sensors.

A wide range of test cell pavement designs and pavement textures also are available within the test track's closed low-volume track and interchangeable sections of I-94. In 2010 and 2011, researchers from Virginia Transportation Research Council performed initial testing and validation of various friction devices, including the grip tester and the continuous friction device. These tests facilitated better understanding of the sensitivity of grip testers when measuring friction in curves and superelevations.

A pooled fund study with FHWA, Minnesota DOT, and Texas DOT retained the Technical University of Gdansk (TUG), Poland, to measure rolling resistance of MnROAD test cells in 2011 and 2014 (*1*). Rolling resistance is an important predictor of fuel economization, as it measures pavement–tire interaction. The study brought the Mark 4 TUG Device—the only internationally approved equipment for rolling resistance—to MnROAD and measured all the test cells in a continuum.

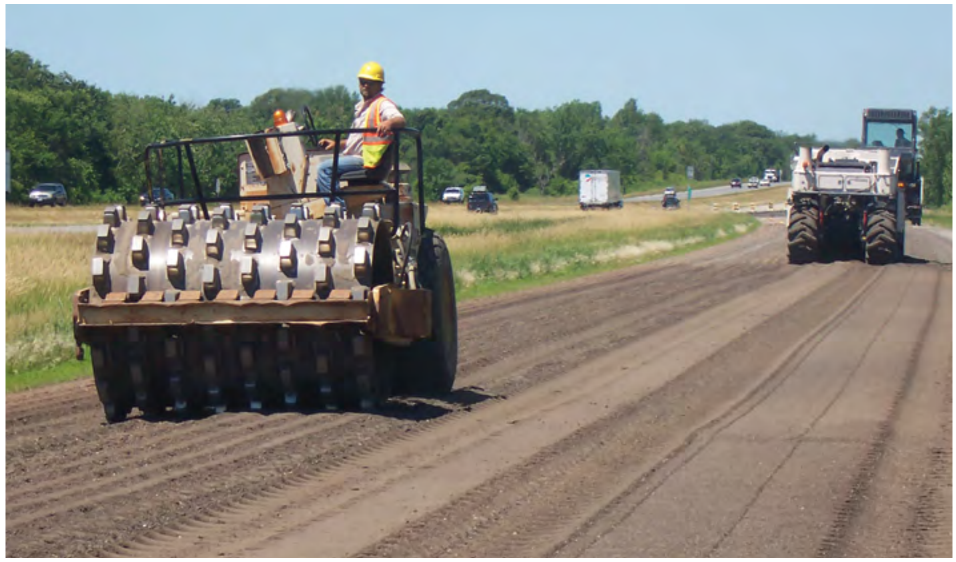

Photo: Minnesota DOT

Putting wheels—and a sheepsfoot roller—to the road, MnROAD built stabilized full-depth asphalt on Cells 2 through 4 of the Mainline in 2008.

Developing Asphalt Pavement Design and Construction Practices

A significant result of Phase I was the development of ROADENT M-E, a mechanistic–empirical (ME) pavement design software. This later evolved into Minnesota's Pavement Design Program, MnPAVE, a damage response software that saved the state millions of dollars in construction costs.

MnROAD also contributed significantly to the development of the original *Mechanistic–Empirical Design Guide* (MEPDG), which eventually became the implemented AASHTOWare Pavement ME Design software (*2*). Test Cells 33, 34, and 35 were designed at the facility to evaluate three binders from the original Superpave® program. These test cells demonstrated the immense benefit of using a polymer-modified performance grade (PG) 58-34 binder instead of the unmodified PG 58-28 binder in the top four inches of hot-mix asphalt (HMA) in Minnesota. Superpave test cells exhibited much less transverse cracking than conventional mixes. Although low-temperature asphalt pavement cracking is discussed in the context of seasonal effects, these MnROAD research findings significantly enhanced the predictability of asphalt pavement performance (*3*).

Innovations in Concrete Pavement Design, Construction, and Technology

MnROAD data from 23 test sections contributed to many design improvements for concrete overlays on both asphalt pavement and existing concrete pavement. Consequently, state, local, and national agencies can build these overlays economically and sustainably with confidence.

MnROAD studies also helped refine optimization of concrete pavement thickness. These studies showed that test cells designed with older AASHTO-based concrete pavement designs were quite conservative. Though Cells 7 through 9 on The Mainline were designed in 1992 for a five-year service life, they continue to carry Interstate traffic after more than 28 years—at a thickness of only 7.5 inches.

Cells 113 through 513—also known as "how thin can you go?"—demonstrated that, although a five-inch-thick concrete pavement can withstand nearly five years of Interstate traffic, pavement six inches thick is the minimum required for a sufficient built-in safety factor to resist distresses caused by nonuniform support from aggregate base layers and local damage (*4*).

A recently completed study challenged the long-held belief that a minimum concrete strength of 250 psi flexural strength was needed before opening a new pavement to traffic. Results suggest that—under certain conditions—the minimum strength needed to open for traffic could be reduced to 170 psi without the conventionally expected reduction in service life, leading to a potential reduction of construction and user costs (*5*). Test cells were subjected to various degrees of early load repetitions. Periodic examination of the test sections using a falling weight deflectometer, petrographic analysis, and ride measurements revealed minimal strain or distress levels similar to the control segments that received no early loading. The research team also developed a software for practitioners to compute the expected service life associated with early opening to traffic.

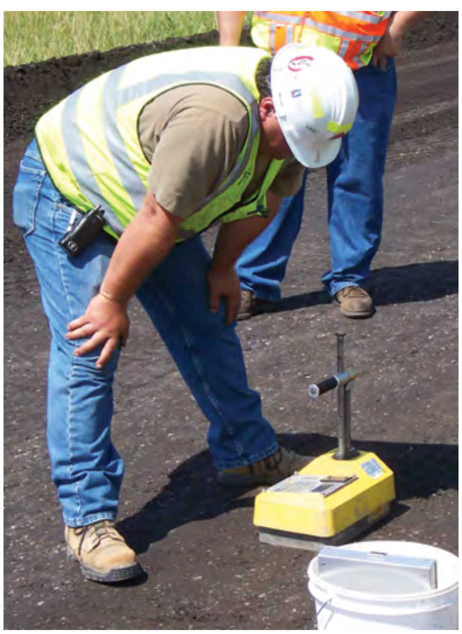

Photo: Minnesota DOT

MnROAD workers measure nuclear density after full-depth asphalt paving.

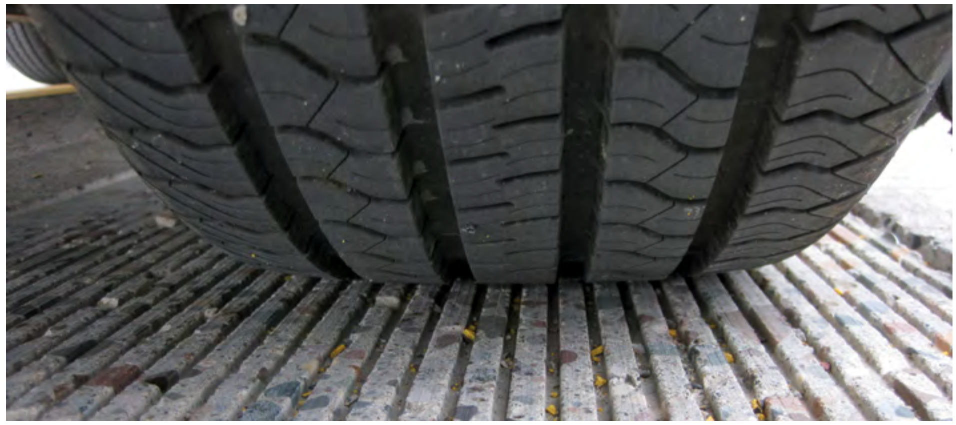

Photo: Minnesota DOT

A close-up of grooved pavement shows an innovative concrete grind developed from MnROAD surface grinding research.

Studies on pavement surface characteristics have helped researchers and practitioners understand the factors that enhance pavement friction and pavement acoustics. In collaboration with the American Concrete Paving Association and the International Grinding and Grooving Association, various quiet grinding configurations were tested in 2007, 2008, and 2009. This led to the 2010 Next-Generation Concrete Surface (NGCS). The quietest concrete surface in the world, NGCS measures less than 98 dB in the "A" weighted scale, compared with 105 dB for a transversely tined surface or 101 dB for a broom-dragged surface texture (*6*). NGCS has been implemented nationwide, as well as in some European countries and Australia.

Subsurface Design and Drainage

The first tests of scouring—that is, water pumping out through pavement joints as vehicles pass over—in concrete pavement bases made at MnROAD was observed in nondrainable bases and underscored how subsurface drainage extends pavement life (*7*). MnROAD studies have documented that nondrainable bases cause HMA cracks to deteriorate prematurely from the bottom up. Research work on geocomposite barrier drains showed effective removal of excess water even when used with nondrainable materials. Such drainability minimized pavement damage.

In 1996, a pooled fund study demonstrated that, in certain portland cement concrete (PCC) test cell failures, the cells lacking drainable bases displayed a peculiar scouring phenomenon evident of cavitation and hysteresis. As a result, the geocomposite joint drain (GJD) was devised. The three-layer system of nonwoven geofabric sandwiches a geonet placed under transverse joints in concrete. This has successfully improved subsurface drainage through lateral transmissivity, moving the water that enters the joint to the daylighted shoulder without the added thickness that would be required if a drainable aggregate base layer was used.

GJD has been implemented in new construction throughout the state and is gaining national popularity. Many studies of different subsurface drainage designs and pavement performance at MnROAD have proved that subsurface drainage is indispensable to pavement longevity.

Intelligent Construction Technology in Quality Management

In 2017, NRRA and Ingios Geotechnics studied a geogrid-reinforced aggregate base performance specification on MnROAD test sections LVR 328, 428, 528, and 628. Researchers conducted automated plate load testing and validated intelligent compaction monitoring. Light weight deflectometers also were deployed to document the construction process and validate pavement design inputs. Itasca Consulting was retained by Minnesota DOT to enhance its commercially available distinct-element software, Particle Flow Code 3D, to estimate the increased stiffness of geogrid-reinforced aggregate base for use in MnPAVE-Flexible, which is now available at no cost to all state DOTs (*8*).

Environmental Factors in Design and Preservation

MnROAD studies have shown the impact of environmental factors in overall pavement performance. For example, studies and analysis of pavements on the LVR test track highlighted some degradation in the outer lane, where environmental factors are the primary stresses (no traffic loadings). This analysis led to better designs protecting against traffic and environmental factors.

MnROAD research also facilitated the implementation of seasonal load limits, also known in Minnesota as spring load restrictions (*9–10*). Test sections built in 1993 (the LVR and Mainline 10-year sections) were added to the testing cycle along with the first batch of MnROAD bituminous sections (Mainline five-year test sections). The initiative first included a verification of the suitability of various sensors for documenting pavement response and then studied seasonal changes. As the section sample size grew, along with the length of performance, a knowledge base of freezing and thawing characteristics and their corresponding load capacity developed. This provided Minnesota DOT the information the agency needed to implement seasonal load limits for asphalt pavements and extended the limits for aggregate-surfaced roads.

Additionally, some published reports have accentuated MnROAD's technical contributions to pavement design, construction, and maintenance, as well as profiler certification and equipment validation outlined in various other published reports (*11–13*).

Benefits to Date

The nearly 30 years of extensive research associated with MnROAD have benefited the state of Minnesota and its partners in quantifiable and invaluable ways, for drivers and for the pavement engineering industry. MnROAD has consistently been able to show calculated benefits that have been greater than the cost of research. These numbers do not include the additional benefits of educating future pavement engineers, learning what not to do, and demonstrating and highlighting technologies road owners can use today. Engineers have benefited from open communication to solve real world problems though the NRRA, the National Center for Asphalt Technology (NCAT), and other MnROAD partners in shared research efforts. This means research partnerships across state DOTs and industry drive successful implementation. Some of the benefits of MnROAD initiatives over the years are detailed in the following sections.

PHASE I

The calculated Phase I (1994–2006) benefits have made positive impacts within Minnesota and the nation at large. Increases in performance and pavement life resulted in a reduction in costs for maintenance, repairs, user delays, and congestion. MnROAD studies have been estimated to save the state of Minnesota $33 million per year—and many other states and organizations have benefited, as well (Table 1).

TABLE 1 Calculated Savings Based on Phase I Research

Benefits	Savings/Year
Spring load restriction policy	$14,000,000
Winter load increase policy	$7,000,000
Low-temperature cracking reduction	$5,700,000
ME flexible design method	$4,000,000
ME rigid design method	$1,200,000
Sealing pavement/shoulder joints	$1,200,000

NOTE: ME = mechanistic–empirical.

PHASE II

During Phase II (2007–2016), MnROAD test cells were designed around studies developed by partners representing local,

National Road Research Alliance

The National Road Research Alliance (NRRA) is a pooled fund with the goal of improving the future sustainability of roads via research and a commitment to cooperative implementation. The alliance sponsors research at the MnROAD test track, one of the most sophisticated cold-weather pavement facilities in existence, as well as at other locations.

NRRA's membership currently includes 11 state agencies and DOTs, 21 academic programs, six associations, and 41 industry partners. Together, five technical teams covering asphalt, concrete, geotechnics, intelligent construction technologies, and preventive maintenance share expertise and learn about new tools and methods to improve and expand transportation systems nationally.

For more information, visit mndot.gov/mnroad/nrra.

state, national, and international interests, including several pooled fund studies. The test cells included new construction and rehabilitation along with various asphalt and concrete pavement surfaces.

Construction of Phase II test cells began in 2007 and continued with projects in 2008, 2010, and 2011. Almost 40 test cells were reconstructed on the LVR and Mainline test tracks, representing more than 20 research projects. This second phase resulted in further positive impacts within the state of Minnesota and across the nation. With more insights from the research, Minnesota was estimated to have saved $10.3 million per year (Table 2).

TABLE 2 Calculated Savings Based on Phase II Research

Benefits	Savings/Year
Investigation of low-temperature cracking in asphalt pavements (Phase II): TPF-5(132)	$14,000,000
Development of an open-graded aggregate base (stable and drainable)	$7,000,000
Thin and ultrathin concrete overlays of existing asphalt pavements: TPF-5(165)	$5,700,000
Development of design guide for recycled unbound pavement materials: TPF-5(129)	$4,000,000
Full-depth reclamation stabilized with engineered emulsion	$1,200,000
Field investigation of highway base material stabilized with high carbon fly ash	$1,200,000

Photo: Minnesota DOT

MnROAD workers take subgrade samples on which to conduct testing.

PHASE III

Now in Phase III (2016–present), research efforts are nearing completion and the benefits will be calculated as the research is finalized and implemented. This will include data, analysis, and implementation from more than 40 NRRA projects. A partnership between MnROAD and NCAT for cracking studies and pavement preservation has studied built test cells at MnROAD; test track on Lee Road in Auburn, Alabama; and test sections in Pease, Minnesota, since 2016 (Table 3). This collaboration is expected to provide quantifiable advantages of preservation treatments and better understanding of low-temperature cracking.

A great many researchers from around the nation and the world have utilized MnROAD facilities and data. With nearly 30 years of detailed data, including weather, traffic, pavement performance, environmental and dynamic instrumentation, and supporting research reports on hundreds of test sections and experiments, MnROAD developed an online database for researchers. This data is now part of FHWA's InfoPAVE.[1]

Another critical benefit offered by MnROAD is its contribution to education. It has been used as a staging facility for a variety of demonstrations, technology transfer, and verification testing for all members

[1] For more on InfoPave, visit https://infopave.fhwa.dot.gov/mnroad/index.

TABLE 3 Research Projects to Provide Future Benefits

Phase III Expected Future Benefits
Use of mix-and-spray HMA rejuvenators
Development of PCC patching materials guide
Flooded road assessment tool
Use of recycled base aggregates
Better understanding of PCC overlay designs
Low-cement PCC mixtures performance
Early loading of PCC pavements
Best practices for HMA overlays of PCC
Pavement preservation (Minnesota DOT/NCAT) to determine life-extending benefit curves
Veta software implementation by states
Intelligent construction technology projects

NOTE: HMA = hot-mix asphalt; PCC = portland cement concrete; DOT = Department of Transportation; NCAT = National Center for Asphalt Technology.

of the pavement community. Although the facility itself provides the data, its true legacy is in the careers of graduate engineers. MnROAD has been excellent training for many engineers who have gone on to other positions in pavement engineering and who have cited their time at MnROAD as a key experience. The facility's extensive database and archive of well-documented research ensures that MnROAD will continue to educate pavement engineers far into the future.

Future Efforts

Every few years, test cells of completed projects go through a construction overhaul. MnROAD teams and partners are deep into the planning, approval, and sourcing of funds for the 2022 construction phase. The current primary partners of the test track are NRRA, LRRB, and NCAT.

Near-future research is focused on current high-priority topics of sustainability, alternative materials, and intelligent construction technologies for asphalt and concrete pavement construction and maintenance. As the global sustainability landscape shifts to an emphasis on study and precautions for reduced environmental impact, MnROAD seeks to lead the industry in that direction.

Proposed projects in line with this initiative will test ideas for new materials in pavements and seeing their impact on the surrounding ecology. Ideally, revised pavement material recycling techniques and use of technology will reduce dependence on virgin materials throughout the pavement structure and limit waste products. Industry and academia partners could learn from these new test sections, implementing new technology and construction methods that maximize productivity and reduce user delays.

The list of MnROAD research partners continues to expand. The future promises even more quality research through the cooperative efforts of state agencies, academia, industry, manufacturers, and consultants.

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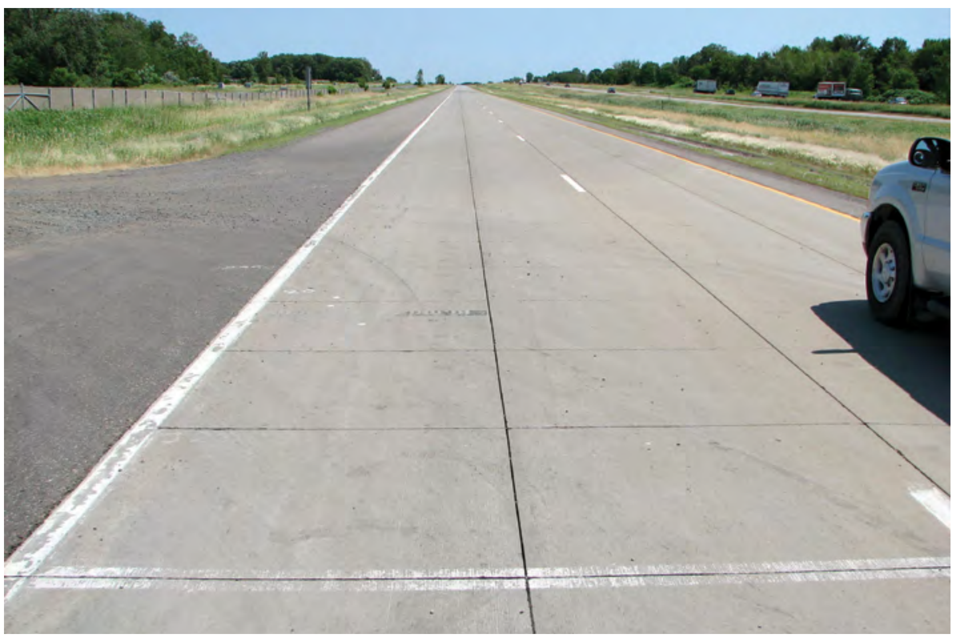

Photo: Minnesota DOT

Post-construction research in 2008 tested whitetopping—covering asphalt pavement with a top layer of PCC—on Cell 60 on the I-94 Mainline.

Minnesota Local Road Research Board

Established in 1959 through state legislation, the Local Road Research Board (LRRB) has sponsored more than 200 individual research projects over the past 15 years. Current LRRB-funded research falls primarily into the following categories: design, construction, maintenance and operations, environmental compatibility, administration, and implementation.

The transportation practitioners who are responsible for county highways and city streets best understand the problems and challenges in providing safe, efficient roadways. LRRB makes it easy for them to participate in setting the research agenda. Transportation practitioners submit ideas to the LRRB, which selects and approves proposals. The Minnesota Department of Transportation (DOT) provides administrative support and technical assistance. Researchers from Minnesota DOT, universities, and consulting firms conduct the research, and LRRB monitors the progress.

Research sponsored by LRRB helps improve the quality of Minnesota's transportation systems. The impact of this research multiplies as more and more engineers see potential applications through the technology transfer efforts of LRRB's Research Implementation Committee. Past LRRB research projects include exploring better methods to inspect and maintain timber bridges, identifying best design practices when applying Complete Streets principles, and evaluating the impacts of implements of husbandry on Minnesota roads and bridges.

For more information, visit www.lrrb.org.

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VOLUNTEER VOICES

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Product Manager
Geneva Pipe and Precast, Orem, Utah