Mn/ROAD

Minnesota Road Research Project

NELRAE M. SUCCIO

In pursuit of more economical, longer-lasting highways, engineers are currently making preparations for tests on 40 sections of pavement in one of the most challenging road research projects since the American Association of State Highway Officials (AASHO) Road Test in the 1950s and 1960s.

In June 1990 the Minnesota Department of Transportation (Mn/DOT) began construction of the Minnesota Road Research Project (Mn/ROAD), a new roadway technology test facility. This $19.5 million project will provide researchers with the opportunity to study the effects of cold weather and heavy commercial traffic on roadway materials including soil, base, subbase, and pavement types. An important feature of the project will be a computer-monitored network of nearly 4,500 sensors placed throughout the 40 test sections.

Located on I-94 in Otsego, approximately 40 miles northwest of the Minneapolis-St. Paul metropolitan area, the project will include a 3-mile, two-lane roadway for high-volume research and a 2.5-mile, two-lane low-volume closed-loop roadway.

Westbound Interstate Highway 94 traffic will be diverted over 23 high-volume test sections to provide "live" load data. Although the average daily traffic count rises considerably during the summer months, approximately 23,000 vehicles use the road each day. Ten- and 15-ton single-axle loadings will be applied on the low-volume test sections with a specially equipped vehicle.

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Why Minnesota?

Mn/DOT has taken the lead because of the need for cost containment at the same time that emphasis is shifting from Interstate construction to system rehabilitation.

Much of the information and most of the design methods used today are based on research conducted 30 years ago for the AASHO Road Test. The technology used at Mn/ROAD includes new sensors that were not previously available, enabling researchers to conduct tests that are crucial to today's needs. The result will be to reduce the costs of future maintenance, rehabilitation, and reconstruction by development of new methods of design.

Many states do not need to be concerned with the effects of frost on pavements. However, Minnesota's cold-region climate adds to the normal wear and tear and accelerates pavement damage resulting from the freezing and thawing process and heavy truck traffic. Consequently, Mn/DOT has been working closely with the Federal Highway Administration (FHWA) and the U.S. Army Corps of Engineers researchers at the Cold Regions Research and Engineering Laboratory (CRREL) in developing plans for Mn/ROAD.

The Mn/ROAD project is a cooperative effort with the University of Minnesota. The Center for Transportation Studies, Civil and Mineral Engineering Department, Computer Sciences Department, and Agricultural Engineering Schools are all active participants.

Mn/DOT is also developing partnerships with Nordic countries, the Canadian provinces, and other cold-climate states to address this problem.

Technology transfer and implementation of research results are major emphases of the project. The exchange of knowledge is expected to add to the project's value for Mn/DOT, the University of Minnesota, and all participants.

Reflecting the rapidly expanding level of activity, the 4th International Conference on the Bearing Capacity of Roads and Airfields in 1994 and the 6th International Conference on Low-Volume Roads in 1995 will be held in Minnesota, each attracting 300 to 500 experts. Mn/ROAD will be highlighted at both conferences with tours, papers, and presentations.

Construction

Two roadways with a total of 40 pavement test sections are under construction. Each section is approximately 500 feet long, separated by transition sections. Various thicknesses and compositions have been used in designing the test sections to obtain various service lives.

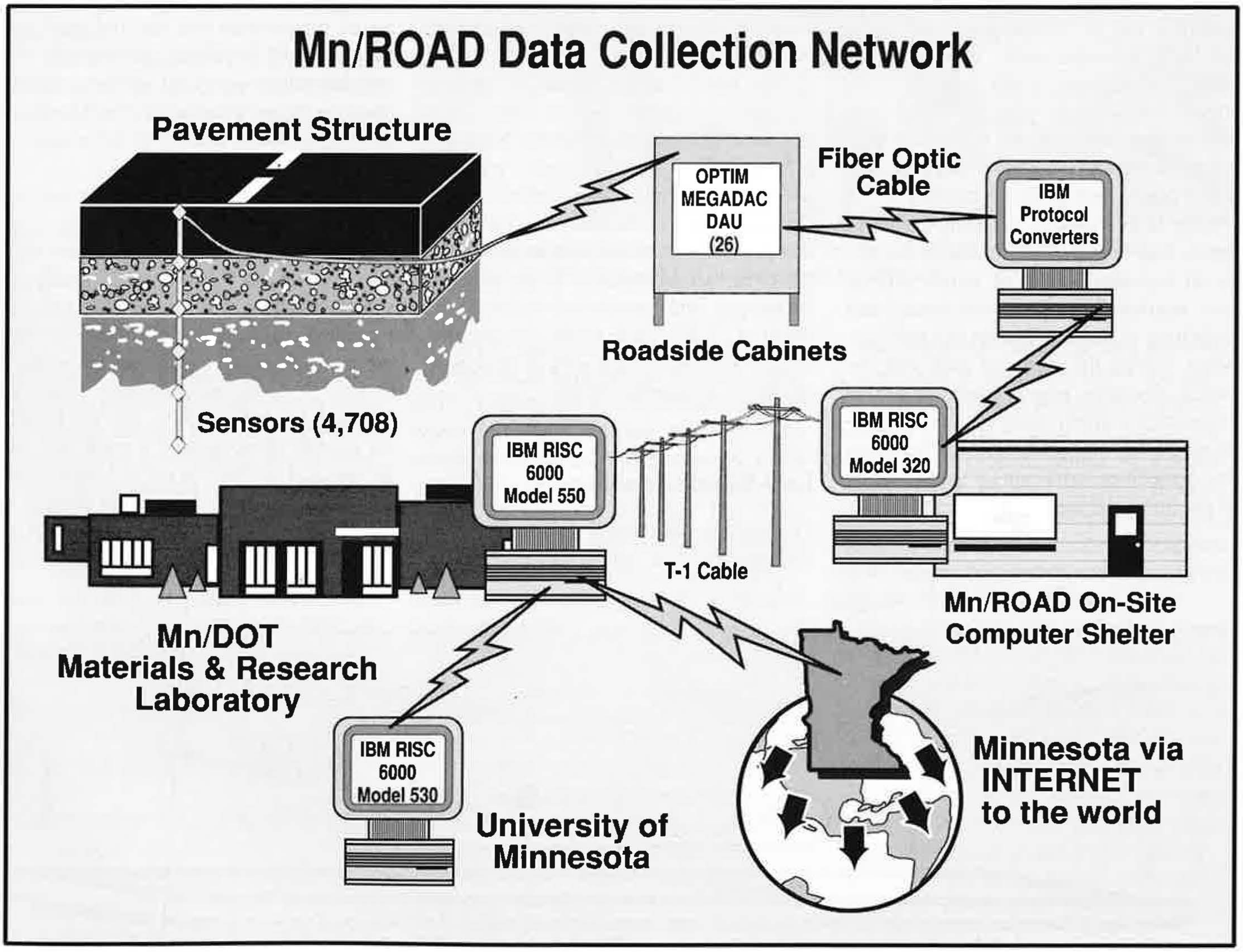
The 23 sections in the mainline test road are composed of 14 asphalt- and 9 concrete-surfaced sections. The designed service lives of these sections are 5 and 10 years. A midpoint crossover on the mainline test road will allow traffic to continue using the 10-year sections once the 5-year sections have failed. Because there will be no slowdowns or detours onto or on the new road, the experiment will have little effect on everyday traffic patterns.

Parallel and adjacent to the mainline test road is a separate two-lane road with an oval racetrack-like configuration. This road will be used to research low-volume road designs and contains 17 test sections: 8 asphalt-, 5 concrete-, and 4 aggregate-surfaced sections, designed for a 3-year service life. Research will focus on pavement designs of interest to counties and cities.

Although Phase I of the study is set up over a 10-year period, some information gained from the 3- and 5-year failures will be put into practice before this phase is completed.

The project site encompasses 197 acres, mostly agricultural. Although Mn/ROAD construction required removal of wetlands, the wetland losses are mitigated onsite. The creation of eight new ponds amounts to approximately 22 acres of wetland replacement. The new ponds incorporate beneficial features such as irregular shorelines, gentle slopes, varying bottom contours, and wildlife islands. Mn/DOT has worked with the Minnesota Department of Natural Resources and the U.S. Fish and Wildlife Service to maximize the environmental value of the project. The new ponds will also provide a place for future research on roadway effects on the environment.

Stage I construction began on the project in June 1990 and was completed in the spring of 1992. State and federal monies were used to fund the Stage I contract. Work completed under this contract consisted of test roadway grading, swamp excavation, and backfill. More than 1,000,000



ISBERG, MnDOT

Mn/ROAD's sensor and data-collection network shows route of data from pavement sensors to Minnesota researchers and throughout world.

cubic yards of material was moved to complete this first stage of construction.

Above-average rainfall in the 1990 and 1991 construction seasons significantly slowed progress on the project. One consideration in choosing the proper location for the work was the availability of subgrade materials with desired physical characteristics. The native loam material on the site is highly reactive to moisture. As a result, the unusually high amount of precipitation recorded in 1990 and 1991, coupled with the reactive nature of the material, caused a delay in completion of the first stage of construction.

A contract for instrumentation and paving, Stage 2 construction, was let in 1991. Following completion of grading the mainline test roadway, the 5-year segment of the mainline will be instrumented and paved in 1992. Interstate traffic will be routed onto this segment in fall 1993 or early 1994. The 10-year portion of the low-volume roadway will be completed with instrumentation and paving in 1993, with traffic placed on it in the fall of 1993.

After both roadways are completed and before they are opened to traffic, there will be an extensive period of sensor calibration, nondestructive pavement testing, and evaluation of baseline data for research purposes. During the spring of each year, research objectives require intensive testing procedures on both roadways to gather appropriate data for analysis. This period is one of the most significant for study relating to pavement damage.

Automated Weather Station and Weigh-in-Motion Scale

An automated weather station (AWS) and weigh-in-motion (WIM) scale were constructed in 1989 and are located at the east end of the project. The WIM scale is in the existing westbound roadway just before the area where the transition onto the new mainline test road is established. The scale will provide the baseline traffic information for the mainline test sections. Each truck, as it travels over the scale, will have its speed, length, individual axle weight, and spacing, classification, and total vehicle weight recorded. Vehicle weight parameters include left- and right-side measurements of each axle, including the total weight of each axle. Data gathered by the WIM scale will be used in future pavement performance evaluations.

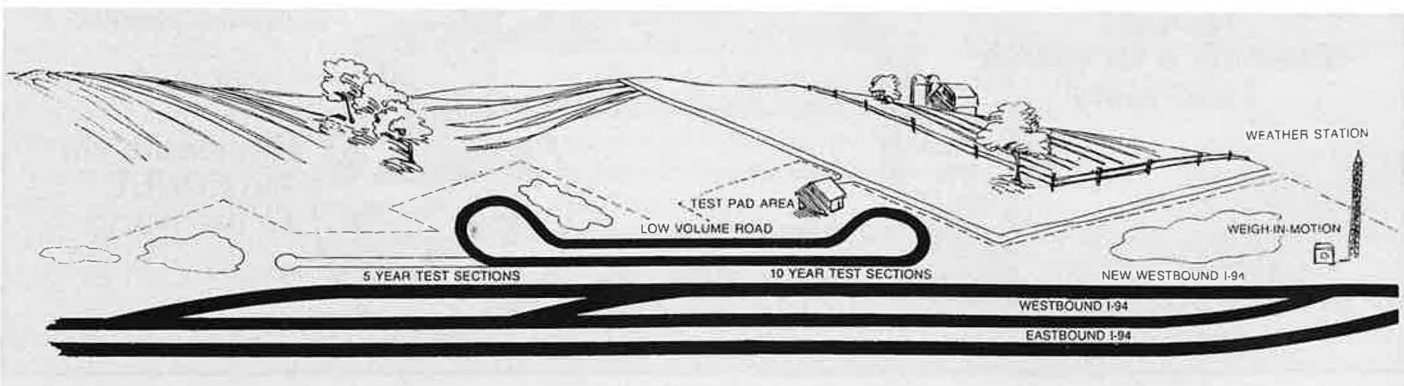
The AWS output includes general weather information such as wind speed and direction, air temperature, humidity, precipitation, and barometric pressure. Special sensors monitor pavement surface conditions such as the presence of ice, dew, and chemicals. Five temperature probes are placed at various locations in the inslopes, backslopes, and westbound roadway to a depth of 12 feet. Each probe uses thermocouples and thermistors with 21 measuring points to correlate the results.

Low-Volume Loadings

The mainline test loads will be provided with existing "live" traffic, and loads on the low-volume road will be provided by calibrated test trucks. Test conditions on the trucks running this track will be constant (air pressure of tires, axle configuration, etc.). However, a 10-ton single-axle loading will be used in one lane and a 15-ton single axle loading will be applied to the other. The 10-ton configuration will generate 3 equivalent single-axle loads (ESALs) per pass and the 15-ton configuration will generate 18 ESALs per pass. It is estimated that up to 150,000 ESALs must be applied to the low-volume road before there is significant distress in the test pavements. The two trucks must be driven about 146,000 miles to apply these 150,000 ESALs.

It is anticipated that MnDOT will conduct specialized testing using varying axle configurations and loads. For these experiments, tire pressure and size and gear configuration will be varied. Additionally, the vehicles will be equipped with instrumentation to record the way in which suspension in the truck affects the dynamics on the roadway.

To reduce labor costs for the low-volume road (LVR) load-application process, Mn/ROAD researchers are joining forces with the Minnesota Guidestar [intelligent vehicle-highway systems (IVHS)] and department maintenance personnel to develop an automated driverless truck control system. A cooperative Strategic Highway Research Program (SHRP)—Mn/DOT project recently demonstrated a truck that can be operated remotely at up to 5 mph. That technology will be advanced to provide a vehicle capable of traveling on the LVR at speeds of up to 30 mph. Mn/ROAD engi-



GUSTAFSON/MnDOT

Schematic drawing of completed Mn/ROAD project site.

neers and researchers are interested in working with the trucking industry, truck manufacturers, and technology developers and vendors to address common concerns.

To protect the electronic instruments on the test site, the driverless truck must operate and navigate in a typical highway environment that does not include such things as guide wires or radio control signals. The truck must have multiple fail-safe features and be able to communicate information on its operational state to a remote site.

The option of using a human driver is less costly, but a number of factors favor the driverless option:

- Safety is a concern for the human driver because of fatigue;
- More funding options for innovation are available;
- The driverless option builds on the technology of the SHRP and Mn/DOT remotely driven maintenance shadow vehicle; and
- The driverless option provides a springboard for further, more advanced IVHS prototypes and research.

KVEBERG/MnDOT

John Hippchen and Carol Isberg, Mn/ROAD personnel, display sensors and data acquisition at 1992 Minnesota Transportation Conference.

Research Objectives

The major research objectives for Phase I of this project include verifying existing pavement design models, analyzing factors that affect pavement performance, and developing new design models.

Mn/ROAD and the University of Minnesota have developed a plan to investigate 14 major pavement research objectives. These objectives are based on consultant work performed by Matthew W. Witczak, a renowned pavement expert and a professor at the University of Maryland. Each objective considers the effects of design procedures, materials, traffic loadings, and climatic conditions on pavement performance.

Although Phase I research is expected to last a minimum of 10 years, the facility lends itself to research that could continue for more than 20 years. Examples of areas of research include validation of pavement design rehabilitation techniques, environmental projects, and new product design. The facility could also be used for research in cooperation with private industry, other DOTs, FHWA, and as a facility where other types of Mn/DOT research can occur. The existing westbound and eastbound roadways can be used for future research purposes and for carrying traffic. The westbound road is concrete and the eastbound road is bituminous, providing the opportunity for a variety of research to be performed at the site.

Sensor Network

An extensive network of sensors located within each pavement structure layer will monitor the various roadway materials through a central data base system. A task force of experts from several engineering and scientific disciplines, various governmental agencies, academia, and private industry have guided the project design through development.

The Mn/ROAD data-collection network is composed of approximately 4,500 sensors directly cabled to 26 roadside cabinets. Conduits of various sizes will protect the cabling. Each cabinet, similar to a signal control cabinet, houses two pieces of data-acquisition equipment and will be environmentally controlled. An Optim Megadac 3008 collects static data and an Optim Megadac 5017 collects dynamic data.

These Megadac data-acquisition units will convert the sensor response from an analog to a digital signal for researchers' use. To run the entire system, a network consisting of five industrial protocol converters will be installed in five of the cabinets. Each cabinet and protocol converter will be connected using fiber-optic cable and fiber-optic modems. This entire network will be fiber-optically connected using an onsite computer housed in a computer shelter.

An IBM RISC 6000 Model 320 will check, verify, compress, temporarily store, and send the data to the Maplewood Materials Research and Engineering Laboratory via a dedicated T-1 transmission line. WIM and AWS will also send information to the onsite computer for temporary storage and transmission. Up to 100 megabytes of data will be moved from Mn/ROAD to the Maplewood office each day.

The computer data base at the laboratory consists of an IBM RISC 6000 Model 550 loaded with Oracle software. Once the data are stored in the main data base, they can be sent directly to the University of Minnesota researchers, or those dedicated to the project in other parts of the world, using INTERNET.

The main data base will not only house information received from the sensors, it will also consist of information regarding all of the materials testing, sensor placement, sensor identification, surveying data, asphalt and concrete tests, WIM and AWS data, and other information related to the development and construction of the facility.

Approximately 30,000 feet of power cable will provide power to the cabinets and sensors. In conjunction with this, approximately 52,500 feet of fiber-optic cable will be installed to run the network and transfer data to the onsite computer shelter.

Partnerships

Many individuals and organizations are working together to ensure the success of the project. The Minnesota Department of Transportation (Mn/DOT) has designated funding for planning, construction, research, and staffing since 1986.

David Newcomb is the technical director of Mn/ROAD at the University of Minnesota's Civil and Mineral Engineering Department. Funding is also provided by the University of Minnesota's Center for Transportation Studies for research and development.

The Federal Highway Administration has helped with project development by providing representation and expertise on key committees and is funding portions of the construction and purchasing sensors, data-acquisition equipment, and computers.

The Minnesota Local Road Research Board, which includes engineers from Minnesota counties and municipalities and representation from Mn/DOT, has funded research contracts for the Mn/ROAD project.

How Does Mn/ROAD Relate to SHRP?

Although Mn/ROAD is not an initiative of the Strategic Highway Research Program (SHRP), information from the pavement research facility will be incorporated into SHRP's Long-Term Pavement Performance (LTPP) and Asphalt programs. The researchers from both programs have been working closely together and, as a result, SHRP was able to use the preliminary work for Mn/ROAD instrumentation in preparing plans for instrumentation of the LTPP sections.

Data collected from the high-volume traffic test sections will become part of the General Pavement Studies (GPS) sections for the LTPP experiment in SHRP. The existing number of GPS sections will be increased by 9 portland cement concrete and 14 asphalt cement concrete test sections. SHRP researchers will monitor these test sections in the same way they do for other GPS pavements.

A SHRP contractor will test and evaluate asphalt cement, aggregates, and asphalt mixture samples that will be used in Mn/ROAD's flexible pavement sections.

Mn/ROAD and SHRP personnel have worked closely with data base development for the Minnesota project. Although the Mn/ROAD data base will have much more information than will the other GPS sections, common data will be stored in the same format as it is at other LTPP sites.

SHRP's approach to pavement research is global, whereas Mn/ROAD is a centralized facility for conducting detailed studies. Both approaches are necessary in defining and resolving problems concerning pavement design, construction, and performance.

SHRP has given Mn/ROAD engineers direction on testing methods and materials testing. Mn/ROAD sections are included in the Long-Term Pavement Performance General Pavement Studies. The Mn/ROAD data base is being developed with compatible data base software. Collaboration with SHRP efforts enables Mn/ROAD researchers to accelerate progress and correlate the use of Mn/ROAD results with SHRP.

CRREL of the U.S. Army Corps of Engineers has two cooperative contracts for analyzing materials and incorporating the results in the CRREL Mechanistic Pavement Design Procedures.

The Federal Aviation Administration is funding a contract for Mn/ROAD research at the University of Minnesota through David Newcomb for soils and pavement testing.

Steps are being taken to work cooperatively with other players in the private transportation sector. The Minnesota Asphalt Pavers Association, and the Concrete Paving Association of Minnesota have been cooperatively involved in the development of the project and serve on key committees.

In 1991 representatives from the Finnish National Road Research Administration and Technical Research Centre of Finland visited Minnesota and engineers from the project were able to return the visit to Finland for a cooperative exchange of technical information. As a result of these visits, an agreement was implemented for cooperative research on the project.

Costs

The Mn/ROAD facility is expected to be vital and active during the foreseeable 20 to 50 years. Much of the early expense involves development of the site infrastructure needed to support future research phases. The planned instrumentation and communications system will be crucial to keeping costs of data collection manageable while enabling researchers to obtain data not previously available.

In financial terms, when amortized annually, the initial cost is a relatively small

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