Overview of Minnesota Road Pavement Structure Research Project

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The Minnesota Road (Mn/ROAD) research project test facility by design and location supports cold regions pavement research for both low- and high-volume roads. The facility is one of a kind and is impressive in terms of size and automation. However, the real payoff for the $25 million investment lies in the results from research conducted there. The facility was completed and opened to traffic in June 1994. Research activities are under way. Extensive materials testing and baseline readings of sensors have been completed, yielding preliminary results as well as additional questions. Unique and leading-edge engineering tools used or developed on this research project are being implemented for the operational needs of Minnesota pavement and materials engineers. For more long-term results, a pavement structure research program for Mn/ROAD is in place. Besides performing research with in-house staff, the Minnesota Department of Transportation has substantial cooperative research agreements with the University of Minnesota, FHWA, the U.S. Army Engineer Cold Regions Research and Engineering Laboratory, and the Finnish National Road Administration. The general objectives of Mn/ROAD research are to evaluate electronic sensors and other pavement characterization tools, verify existing pavement design and analysis models, investigate factors that affect pavement response and performance, and develop new and improved pavement design and analysis models.

The purpose of this technical note is to give an overview of the background, direction, and content of the pavement structure research program at the Minnesota Road (Mn/ROAD) research project facility. Mn/ROAD is a full-scale outdoor pavement research laboratory operated by the Minnesota Department of Transportation (Mn/DOT) in the city of Otsego, Minnesota.

The facility is designed to provide pavement researchers with data on traffic loadings, environmental conditions, construction material characteristics, pavement response, and pavement performance throughout the next 20 years. The purpose of the Mn/ROAD research program is to coordinate and organize research activities and results from a multitude of active and proposed projects to achieve the goal of Mn/ROAD through a series of appropriate and implementable steps. The goal of Mn/ROAD is to make the design, construction, and maintenance of pavements more effective and efficient in cold regions through the development of improved pavement analysis and design procedures.

Background

The last major full-scale road laboratory in the United States was the AASHO road test facility constructed in Illinois in the late 1950s. The results from the AASHO experiment form the basis for most pavement structure designs today. Since that experiment there have been a number of significant changes:

1. There is a greater awareness of the effects of weather and climate on the performance of pavement structures.
2. There is a greater awareness of the effects of variability on the reliability of pavement models.
3. Electronic instrumentation has emerged as a reliable method for monitoring the responses of pavement structures.
4. There is now a strong interest in developing reliable, mechanistic-based pavement models.
5. The characteristics and economics of available pavement materials have changed.
6. Pavement construction methods and equipment have changed.
7. Traffic demands have increased and load characteristics have changed.
8. The Strategic Highway Research Program (SHRP) Long-Term Pavement Performance (LTPP) program was initiated and continues under FHWA's direction
9. An era dominated by new highway construction has ended and an era of highway rehabilitation and reconstruction has begun.

Furthermore, in describing the role of SHRP, SHRP Executive Director Damian Kulash pointed out that despite the fact that over 20,000 pavement research papers were catalogued during the past 10 years by TRB, there were no major improvements in pavement life or durability during that period (*1*). This last statement is debatable, but it does highlight a desire for breakthrough changes in pavement engineering. All the above points dictate that a new pavement structure experiment is needed.

Direction

Frank McCullough of the University of Texas at Austin describes an approach for developing and verifying pavement models (2). It calls for increasing levels of model verification in terms of cost and confidence, ranging from laboratory materials characterization tests to accelerated pavement structure testing and finally to long-term, full-scale road experiments. Results at each level are fed back into the model to refine it. Mn/ROAD offers key components in this approach to developing reliable mechanistic-based pavement design procedures for cold regions.

Since the design and construction of the Mn/ROAD facility were initiated and accomplished primarily with Mn/DOT resources with strong support from the University of Minnesota (UM) and the Minnesota Local Road Research Board, the vision for Mn/ROAD research appropriately focuses on the benefits for the citizens of Minnesota. This vision is as follows:

> . . . to develop the expertise and the tools that will confront and solve the pavement structure engineering and economic problems of Minnesota in the 21st century. (*3*)

However, it has never been the intention of Mn/DOT to restrict the benefits of Mn/ROAD to Minnesota. On the contrary, Mn/DOT perceives the success of Mn/ROAD research as directly proportional to the amount of support it offers to other transportation agencies, educational institutions, and organizations interested in pavements. Of particular importance are nearby states and other areas with conditions similar to those in Minnesota.

FHWA has provided substantial financial support for Mn/ROAD construction and research. Other federal agencies of the United States and foreign countries support the project. Several state transportation departments and universities have supported work or visited Mn/ROAD. As the project has developed, more people and organizations have become involved. The design of the facility reflects the input of over 100 individuals serving on 10 committees.

The Mn/ROAD facility includes 40 test sections, each about 150 m (500 ft) long. Each test section is made up of a different combination of material layers. Surface layers include asphalt concrete (22 sections), portland cement concrete (14 sections), aggregate (2 sections), and chip-sealed (2 sections).

The Mn/ROAD test sections do not constitute a full factorial experiment. Rather, test sections represent diverse cells in the large factor matrix associated with Mn/ROAD. For example, asphalt concrete section design factors are as follows:

- Seven pavement thicknesses (76 to 273 mm);
- Two subgrade soils (R = 12, 70);
- Fifteen subbases (various materials and thicknesses);
- Two drain states (drained, undrained);
- Two pavement viscosity numbers (PVNs)—low, high; and
- Four lab compactions (low, medium, high, very high).

Portland cement concrete section design factors are as follows:

- Four pavement thicknesses (152 to 241 mm);
- Two subgrade soils (R = 12, 80);

- Five base type combinations;
- Two drain states (drained, undrained);
- Four dowel diameters (0 to 38 mm);
- Four panel lengths (3.7 to 7.6 m);
- Three pavement widths (7.6 to 12.2 m); and
- Two supplemental steel states (added, not added).

There are actually 80 test sections at Mn/ROAD, since each test area has two lanes that will experience different loadings. An extensive testing and instrumentation program at Mn/ROAD further defines the spatial and temporal variability of project characteristics.

During construction approximately 4,700 material samples were collected for research purposes. Mn/DOT, UM, and Braun Intertec laboratories have completed thousands of routine material characterization tests, from gradation to M_r. The remaining samples are stored for future testing.

Mn/ROAD staff installed 4,572 electronic sensors, including 22 different sensor types, throughout the pavement structure to measure static and dynamic responses to environmental and traffic conditions. Some sensors are monitored automatically on a regular basis and others are monitored intermittently as needed for specific research work. The following measurements are made throughout the pavement structures:

- Static and dynamic strains,
- Static and dynamic pressures,
- Surface and subsurface deflections,
- Vertical accelerations at joints,
- Slab tilts,
- Temperature profiles,
- Total moisture content profiles,
- Unfrozen moisture content profiles,
- Soil suction profiles,
- Frost front locations,
- Water table locations, and
- Subsurface drainage outflows.

An automated weather station at the site regularly collects various weather data, which will be collected with nondestructive equipment during the life of the pavement structures:

- Falling-weight deflections,
- Roughness profiles,
- Cross-section profiles,
- Distress surveys,
- Visual images, and
- Skid resistance.

Approximately 40 gigabytes of data will be collected each year. A relational data base structure and graphical user interface support the researchers performing the analyses.

Twenty-three of the 40 test sections are loaded with westbound traffic on Interstate Highway 94; 14 of these 23 Interstate sections are expected to have about a 10-year life, and the remaining sections should last 5 years. An automated weigh-in-motion scale monitors these loadings. An average of 7,000 heavy commercial axles are westbound on a daily basis. Seventeen of the 40 test sections are in a closed loop and are loaded with calibrated trucks. One lane will be loaded 4 days a week with a maximum legally loaded truck at 356 kN (80,000 lb). The other is loaded 1 day a week at 498 kN (112,000 lb). Equivalent single-axle load (ESAL) accumulation rates are approximately equal for the two lanes. These thinner, low-volume sections are expected to last about 3 years.

In light of the importance of research on pavement rehabilitation and reconstruction, committee work began in this area over a year before the Mn/ROAD facility was opened to traffic.

Content

The content and quality of the Mn/ROAD research program are dictated to a large degree by the capabilities of the facility and the quality of the generated data. Therefore the first research objective was to build the project well. For this reason researchers were heavily involved in the design and construction of the facility, particularly in the area of electronic sensors and materials testing. Such intimate knowledge of the facility from a research perspective is of great value to all future research work.

The variety and quantity of data generated by the Mn/ROAD facility can be used for a vast number of research projects, many of which may not have been conceived yet. Unlike the SHRP LTPP test sections, the Mn/ROAD facility is geared to provide pavement researchers with continuous or nearly continuous dynamic and static pavement response data, as well as performance data. It allows the detailed analysis of daily or even hourly pavement structure events.

Of course, the primary objectives of the Mn/ROAD research program relate to conducting research projects that contribute to the realization of the vision for Mn/ROAD research. In order to bring some structure to the program, projects are classified as those that verify existing pavement models, those that contribute to understanding factors affecting pavement response and performance, and those that develop design procedures with improved mechanistic and statistical functionality. What follows is a description of some of the significant components of the Mn/ROAD research program in each of these classifications.

An important component of any research project evaluating a new method is a comparison with the current method, or control method. Similarly, the Mn/ROAD research program includes studies that evaluate current models for designing pavement structures. Although current design tools are beginning to include some aspects of mechanistic design, they are primarily empirical in nature and base their predictions of pavement life on the results of the 40-year old AASHO road test. Of primary interest in this area are the evaluation of the Minnesota pavement design method and the AASHTO Guide for Design of Pavement Structures. Two recent TRB papers highlight significant concerns with the flexible pavement design methods of the AASHTO guide (*4,5*).

Another key component of any research project is simply learning through analysis. What is learned is then correlated and consolidated in the research project findings. On a parallel track, many of the Mn/ROAD research projects are designed to uncover specific types of information that are woven together and fed into other projects. Some of these "building-block" projects are short-term projects that address pavement response questions and long-term projects that address pavement performance (life) questions, whereas some attempt to develop relationships between the response and performance. Some projects develop mechanistic material parameters indirectly through field testing and backcalculation, whereas others measure these parameters directly with laboratory tests. Still others describe and predict the state of various pavement structure components under a variety of conditions. Two major (and a few minor) building-block projects address seasonal changes and various truck loading configurations

NCHRP Project 1-26, developed primarily at the University of Illinois, describes in general terms the types of models, relationships, and input needed for the development and calibration of a mechanistic pavement design procedure (*6*). This report also highlights the need for a closed-loop approach to validate the procedure. The NCHRP approach is the basis for pulling the Mn/ROAD research findings together into a mechanistic-based design procedure and calibrating it for conditions similar to Mn/ROAD's.

The nature of a mechanistic design procedure based on Mn/ROAD research will depend on the distress experienced by the Mn/ROAD test sections and the basic relationships uncovered under the research program. The research program will start with simpler pavement load response models and build toward more complex ones. For instance, static load models will be addressed before dynamic models. Elastic-, inelastic-, and viscoelastic-based models will be evaluated. Analytical models such as VESYS as well as numerical models such as finite-element models will be evaluated. Climatic effects models such as FHWA's integrated model are also an important part of a mechanistic design procedure and will be evaluated and calibrated also.

Two key (difficult) components of such a design procedure are variability and the transfer functions. To understand the effects of variability on the reliability of a design procedure, it is important to have a good understanding of the variability of all the data and findings that feed into the procedure. Transfer functions ultimately relate information from field measurements about pavement distress and performance to model predictions. For a mechanistic-based model, the transfer function converts an accumulation of short-term pavement responses to longer-term pavement distress or performance. Such links have historically been the weak point of pavement design procedures.

Finally, to counteract the popular myth that the research is done when the report is written, two other Mn/ROAD objectives are to support the implementation of the research findings throughout the life of the project and to support the education of a new generation of pavement experts. Although the Mn/ROAD research program is expected to last 20 years, preliminary findings and even final reports will be forthcoming throughout the life of the project. This means that the development of pavement engineering expertise through education and information exchange, as well as implementation of tools for pavement structure practitioners, will be an ongoing process in the Mn/ROAD research program.

This is a broad overview of the Mn/ROAD facility, its design and purpose, the data that will be generated there, and its potential for supporting significant pavement research. More detailed information and data are available by visiting the Mn/ROAD site and through a number of available handouts, summaries, and reports.

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