

Drainage and Pavement Performance

MnROAD Lessons Learned – December 2006

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1 Abstract

One of the more difficult aspects of a pavement system for the engineer to study is the system's response to moisture. Along with the dynamic (load response) sensors installed during the construction of MnROAD, engineers at MnROAD also installed a variety of sensors to monitor the environmental effects that the pavement systems experience. Furthermore, MnROAD engineers conduct a variety of environmental measurements to monitor the test pavements. After ten years of operation, MnROAD engineers have collected a long history of data for analysis. Furthermore, thanks to the reconstruction of some test cells, MnROAD engineers have been able to develop full-scale experiments to test various hypotheses about pavement drainage. This brief will detail some analysis and experiments using MnROAD data and/or the MnROAD facility.

2 Background

While many environmental factors help to deteriorate a pavement system, excess moisture is the primary cause of deterioration and is responsible for reduced strength in the system and reduced moduli in the pavement layers. Because of the relative difficulty of building an equivalent system in a laboratory to monitor and subject to moisture, much of an understanding of drainage in pavement systems has been developed from in-field experience with existing pavements and moisture.

The difficulty with observing in-field pavements is the need to develop a controlled environment for observation. This difficulty is no concern at the MnROAD test facility, and for this very reason, MnROAD is one of the most, if not the most, ambitious test tracks in the world in its continuous collection of environmental data. The ability to control traffic and work in an uninterrupted facility allows researchers the opportunity to install sensors and acquire data without any need to protect against disturbances or damage to the equipment involved.

While engineers at MnROAD have collected a large amount of environmental data, they have also been able to construct full-scale experiments to evaluate the effects of certain variables on pavement systems. MnROAD's controlled live traffic allows researchers a safe test facility in which they can build and modify experiments. Some of these experiments in drainage took place during MnROAD's first ten years of operation and are detailed below.

3 MnROAD Experiences in Drainage

In "Drainage of Pavement Base Material: Design and Construction Issues," a paper prepared for the annual meeting of the Transportation Research Board, Ruth Roberson of MnDOT and Bjorn Birgisson of the University of Florida use the MnROAD facility and its data to study pavement drainage and use this study to design and construct two

drainage configurations. For this study, the authors designed two edge drain configurations and installed these in two rigid pavement test cells with edge drains at MnROAD. The first design (Figure 1) was composed of dense graded granular base material to resemble a retrofitted jointed concrete pavement (JCP) over a dense graded base with edge drains. The second design (Figure 2) consisted of a blanket of asphalt stabilized base material (PASB) to resemble a typical edge drain design.

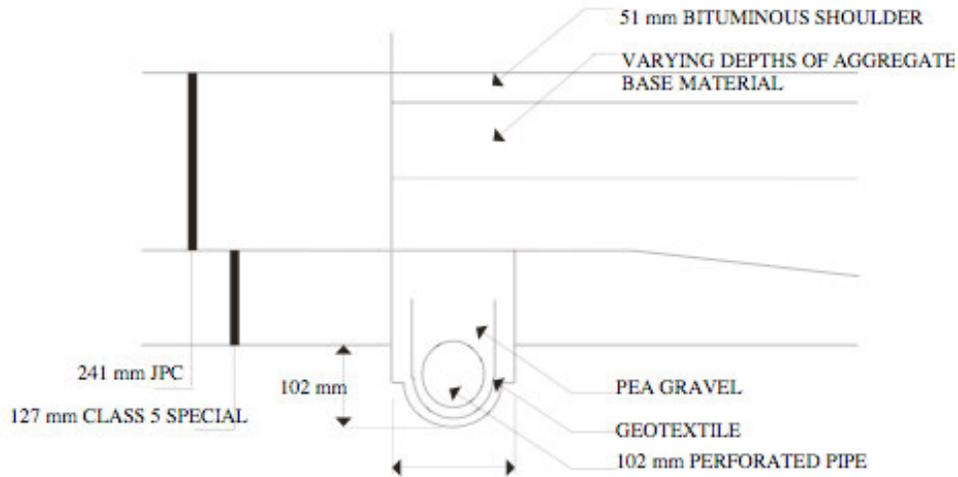


Figure 1. Edge drain configuration to simulate retrofitting a JCP overlying a dense graded base with edge drains (Roberson & Birgisson 2000)

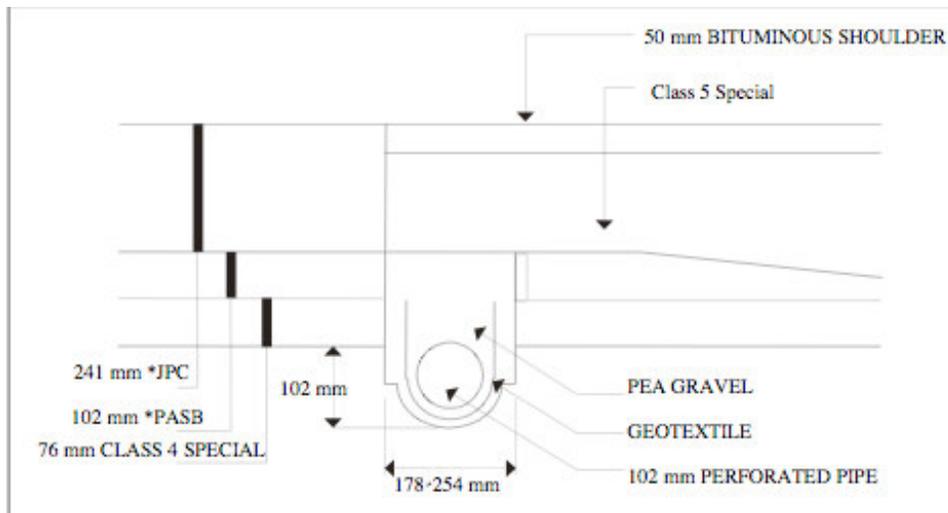


Figure 2. Typical edge drain configuration with edge drains (Roberson & Birgisson 2000)

The authors also developed an automated field-instrumentation monitoring plan to be used in conjunction with the edge drain study. This plan consisted of a battery of time domain reflectometry (TDR) probes and tipping buckets to monitor the moisture in the pavement system. The paper details the frequency of measurement and more specifics on the monitoring plan.

While the authors initially intended to compare the two edge drains, they found that this comparison was made difficult by the fact that both schemes drained the systems in a limited capacity. In each case, the results suggested that more important than a comparison of different edge drain configurations was the question of edge drain feasibility: do they assist the flow of water through pavement systems? What variables should be considered to make certain that the water flow through the layers in the pavement system is unobstructed? For instance, in the second case, a crack between the shoulder and the pavement was suspected and partially confirmed by the authors to have been the source of a great deal of water in the pavement system—this discovery, as the authors note, suggest that the control of factors contributing to moisture in the pavement system are as important as the construction of edge drain systems.

The authors found that edge drains for dense graded bases (the first case) may not assist the flow of water through the pavement system in a significant manner. For this reason, the authors recommend that the practice of retrofitting existing pavements with drainage schemes be reconsidered. For the second case (the typical configuration), the authors propose that the drain may have been affected by inadequate compaction of the soil over the edge drain. The authors conclude by noting that their experience emphasizes the need to review the use of edge drains and to scrutinize the materials and techniques that go into the construction of edge drains.

MnDOT Report 2002-30, “Evaluation of Water Flow through Pavement Systems,” aims to describe unsaturated water flow through the layers of a pavement system using the SEEP-W and DRIP software. (Incidentally, this report is another testament to the influence of MnROAD throughout the pavement community: Birgisson, formerly of the University of Minnesota and a recipient of much MnROAD experience, co-authored this project with a his student, Paola Ariza, at the University of Florida.) The study described within this report used data from MnROAD cells 33, 34, and 35 for analysis by this software. More specifically, these researchers used the measured moisture contents in the base courses (as measured by time domain reflectometry [TDR] probes) to back-calculate the likely infiltration and response to rain of the pavement systems for the cells.

These researchers then evaluated the movement of moisture through the layers of each cell’s pavement system using their knowledge of the system’s modeled response to moisture. Furthermore, the models attempt to determine the amount of time a pavement system retains moisture, the influence of the material properties of the pavement system on the retention of moisture in the pavement system, and the effects of different structures (water table, shoulder construction, edge drains, etc.) in a given pavement system on the moisture conditions in the system.

MnDOT Report 2003-26, “Edge-Joint Sealing as a Preventative Maintenance Practice,” describes a simple experiment that highlights an excellent use of MnROAD’s full-scale dimensions, accessibility, and array of environmental sensors. In this experiment, the researchers (MnDOT’s Roger Olson and Ruth Roberson) examined two similar concrete test sections with bituminous shoulders and edge drains. One of these sections acted as a control and did not have its longitudinal edge joint (the joint between the shoulder and

the pavement) sealed. The second section was, therefore, the test. Before sealing the test section, the two sections were monitored and found to have no significant differences in the volume of water drained. The test section was then sealed and both sections were again closely monitored. The effect of the sealed edge joint is best described in Figure 3, wherein the test section is at the foreground and the control section in the rear.

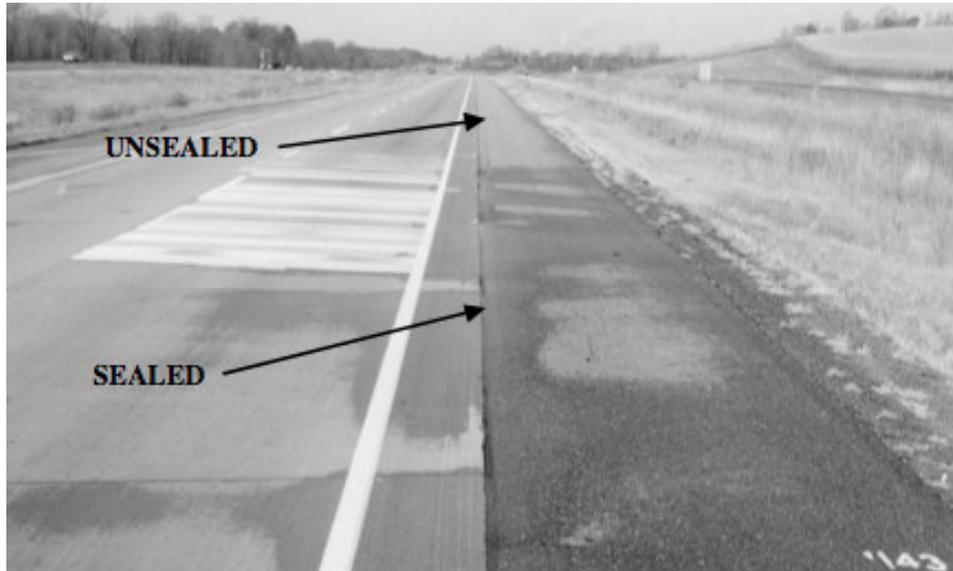


Figure 3. Two concrete test sections after rain (Olson & Roberson 2003).

It is clear from Figure 3 that the moisture still lingering on the test section had already drained through the edge joint in the control. Collected data supported this observation: the total volume of water entering the pavement system for a rain event was reduced by as much as 85% through the use of an edge seal. For this reason, the authors held that the edge-joint seal should become standard practice in preventative maintenance for pavements. Other points raised by this study will be discussed in Section 4.

4 MnROAD Contributions to Pavements in Drainage Research

MnDOT Report 2002-30 emphasized the need to model drainage using unsaturated flow theory and the dependency of the predictions on a detailed knowledge of field conditions. The report also recommended key locations of TDRs to aid in understanding unsaturated flow through flexible pavements. By applying the SEEP-W model, the report confirmed this tool as being useful in modeling the effects of moisture on pavement.

MnROAD has established itself as a significant site of environmental data collection. An example of MnROAD's expertise in environmental sensors is evident in the monitoring plan proposed by Roberson and Birgisson. This plan has been available for other engineers who need to determine water flow through a pavement system. MnROAD's second phase will be highlighted by more innovations in environmental sensor installation, implementation, and maintenance.

MnROAD Report 2003-26 describes an obvious contribution to pavements in that it explicitly states the benefits of sealing the edge joint with a simple, elegant experiment and analysis. As the report notes, this seal reduces the amount of moisture in the pavement system by hundreds to thousands of liters. For this reason, the seal has the potential to be a major component of any preventative maintenance program.

MnROAD has also raised valid questions about the efficacy of edge drains relative to the moisture in the pavement system. In two of the reports detailed above, MnROAD engineers have been highly critical of the edge drain and the common assumption that edge drains provide positive drainage to the pavement system. As early as 1998, MnROAD engineers discovered, as an aside to another study, that this assumption was not always valid. Later studies such as MnROAD Report 2003-26 bring that assumption to the forefront and find that “the edge drain is not draining the pavement system but rather it is draining the edge joint.” While other researchers have made similar claims, few have made it with the wealth of data at MnROAD’s disposal to support this statement.

Furthermore, professionals in the pavement industry, particularly those in sealant products, have promoted the work in edge-joint sealing done at MnROAD. MnDOT engineers have also reported that they have been approached by out-of-state districts interested in applying MnDOT Report 2003-26 to the maintenance practices of their roadways.

5 Recommendations

The only recommendation moving forward for MnROAD is to promote its research and data in drainage more actively. One of the difficulties of understanding MnROAD’s work in drainage is finding documents to study. Many of these documents are pointed to by a myriad of links online that are known only to the people creating the documents and logging the data.

An overall recommendation of the Lessons Learned project is for MnROAD to centralize and catalogue MnROAD-related research and data. Adding the drainage documents and data to this process would both aid researchers and bolster the MnROAD catalog.

6 References

1. Birgisson, B and R. Roberson. Drainage of Pavement Base Material: Design and Construction Issues. In *TRB 79th Annual Meeting Compendium of Papers*. CD-ROM. Report 00-0938. Transportation Research Board, Washington, D.C., 2000.
2. Clyne, T. R., V. R. Voller, and B. Birgisson. *Evaluation of a Field Permeameter to Measure Saturated Hydraulic Conductivity of Base/Subgrade Materials*. Report MN-RC-2001-19. Minnesota Department of Transportation, 2001.
3. Ariza, P. and B. Birgisson. *Evaluation of Water Flow through Pavement Systems*. Report MN-RC-2002-30. Minnesota Department of Transportation, 2002.

4. Olson, R. and R. Roberson. *Edge-Joint Sealing as a Preventative Maintenance Practice*. Report MN-RC-2003-26. Minnesota Department of Transportation, 2003.
5. Wang, D. and J. Baker. *MnROAD TDR Evaluation and Data Analysis*. Report MN-RC-2004-15. Minnesota Department of Transportation, 2004.
6. Gupta, S., Singh, A., and A. Ranaivoson. *Moisture Retention Characteristics of Base and Sub-base Materials*. Report MN-RC-2005-06. Minnesota Department of Transportation, 2004.
7. News Page. CrafcO, Inc. Accessed on 31 July 2006.
http://www.crafcO.com/News_Library/News_page.htm