Evaluating Roadway Subsurface Drainage Practices - Phase II

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Abstract
Well-performing subsurface drainage systems form an important aspect of pavement design by the Iowa Department of Transportation (DOT). The recently completed Iowa Highway Research Board (IHRB) project TR-643 provided extensive insights into Iowa subsurface drainage practices and pavement subdrain outlet performance. However, the project TR-643 (Phase I) forensic testing and evaluation were carried out in a drought year and during the fall season in 2012. Based on the findings of IHRB Project TR-643, the Iowa DOT requested an expanded Phase II study to address several additional research needs: evaluate the seasonal variation effects (dry fall 2012 versus wet spring/summer 2013, etc.) on subdrain outlet condition and performance; investigate the characteristics of tufa formation in Iowa subdrain outlets; investigate the condition of composite pavement subdrain outlets; examine the effect of resurfacing/widening/rehabilitation on subdrain outlets (e.g., the effects of patching on subdrain outlet performance); and identify a suitable drain outlet protection mechanism (like a headwall) and design for Iowa subdrain outlets based on a review of practices adopted by nearby states. A detailed forensic test plan was developed and executed for inspecting the Iowa pavement subdrains in pursuit of fulfilling the Phase II study objectives. The observed outlets with blockage and the associated surface distresses in newly constructed jointed plain concrete pavements (JPCPs) were slightly higher during summer 2013 compared to fall 2012. However, these differences are not significant. Less tufa formation due to the recycled portland cement concrete (RPCC) base was observed with (a) the use of plastic outlet pipe without the gate screen–type rodent guard and (b) the use of blended RPCC and virgin aggregate materials. In hot-mix asphalt (HMA) over JPCP, moisture-related distress types (e.g., reflection cracking) were observed more near blocked drainage outlet locations than near “no blockage” outlet locations. This finding indicates that compromised drainage outlet performance could accelerate the development of moisture-related distresses in Iowa composite pavement systems.

Keywords
Drain pipe, Drainage structures, Limestone, Pavements, Portland cement concrete, Recycled Materials, Sediments, Subsurface drainage, outlets, tufa

Disciplines
Civil Engineering

Comments
This report follows on work report in "Evaluating Roadway Subsurface Drainage Practices, 2013"
Adequate subsurface drainage systems are generally believed to be beneficial to the performance of various pavement types.

**Background and Problem Statement**

The presence of subsurface drainage systems (e.g., granular bases or outlets) is generally believed to be beneficial to the performance of various pavement types. Well-performing subsurface drainage systems form an important aspect of pavement design for the Iowa Department of Transportation (DOT).

Iowa Highway Research Board (IHRB) Project TR-643 provided extensive insights into Iowa subsurface drainage practices and pavement subdrain outlet performance. However, that project's forensic testing and evaluation were carried out in a drought year and during October and November of 2012, when relatively little rainfall was recorded.

Based on the findings of IHRB Project TR-643, the Iowa DOT requested an expanded Phase II study to address several additional research needs, such as the effects of seasonal variation on subdrain outlet performance, condition of composite (HMA over JPCP) pavement subdrain outlets, and the characteristics of tufa formation.

**Project Objectives**

- Evaluate the effects of seasonal variation on subdrain outlet condition and performance
- Investigate the condition of composite pavement subdrain outlets
- Examine the effect of resurfacing/widening/rehabilitation on subdrain outlets
- Investigate the characteristics of tufa formation in Iowa subdrain outlets
- Identify a suitable drain outlet protection mechanism (such as a headwall) for Iowa based on a review of practices adopted by nearby states
Research Description
A detailed forensic test plan was developed for inspecting and evaluating Iowa pavement subdrains. The plan included site selection for inspection of drain outlets, identification of drainage components for evaluation, and inspection and evaluation methods.

The following sites were selected for forensic testing and inspection of subdrain outlets:

- 51 newly constructed jointed plain concrete pavement (JPCP) sites (231 outlet locations)
- 8 newly constructed hot-mix asphalt (HMA) sites (47 outlet locations)
- 23 HMA over JPCP sites (120 outlet locations)
- 52 outlet locations near pavement sections exhibiting high-severity moisture-related surface distress or patching, including 34 locations from 25 of the new JPCP sites and 18 locations from 11 of the HMA over JPCP sites

The rigid and flexible pavement sites constructed after 1990 were investigated during spring and summer of 2013, when about 5 inches of precipitation was recorded. Most of the composite pavement sites were investigated during late spring 2014, when the maximum recorded precipitation was 9.9 inches. The JPCP and HMA sites had been investigated in late fall 2012 during the Phase I study, when the recorded precipitation was about 3 inches.

In addition, headwall design plans and specifications adopted by other states were investigated.

Key Findings
- Moisture-related pavement surface distresses were observed in sections where no drainage outlet could be located.
- At the JPCP sites, slightly more outlets were observed with blockage and associated surface distresses in summer 2013 than in fall 2012. However, these differences are not significant.
- Tufa formation resulting from the use of recycled PCC base was observed to be lesser in quantity at locations where a plastic outlet pipe was used without a gate screen rodent guard and where blended recycled PCC and virgin aggregate materials were used.
- Shoulder distresses in JPCP were observed near blocked drainage outlet locations.
- Cracking/patching was observed near culvert-only or culvert-with-drainage outlet locations.
- More than 50 percent of HMA over JPCP outlets were blocked by sediment and soil deposits.
- Surface distresses were observed near blocked drainage outlet locations at HMA over JPCP sites.
- At HMA over JPCP sites, moisture-related distresses were observed more frequently near blocked than clear drainage outlet locations. Compromised drainage outlet performance may therefore accelerate the development of moisture-related distresses in HMA over JPCP.
Recommendations and Future Research

- Use of a gate or mesh screen rodent guard may cause outlet blockage. Because very little rodent evidence was observed during field investigations, it is highly recommended that rodent guards not be used to cover drainage outlets.
- Use of recycled PCC as base/subbase material results in tufa formation, which is the primary cause of drainage outlet blockage in JPCP. Using blended recycled PCC and virgin aggregate subbase materials seems to mitigate this problem at least partially.
- Less tufa formation due to the recycled PCC base is observed with the use of plastic outlet pipe without a gate screen rodent guard.
- Screening recycled PCC before using it in foundation layers can reduce the potential for fine material deposits to accumulate in pavement drainage systems. Studies have shown that selective grading or blending with virgin aggregates significantly reduces precipitation potential. Further research is recommended on this issue.
- Strategies to mitigate the occurrence of transverse cracking on pavements over culvert structures are needed. Further research is recommended on this topic.
- Blocked drainage outlets seem to contribute more to shoulder distresses than to pavement surface distresses. Further research is recommended for this issue.
- Rigid, slotted plastic drain pipe is more durable, offers better performance, and is better at resisting loads from construction and maintenance than other types of pipe. Flexible, lightweight subdrain pipe has been known to collapse during construction or maintenance.
- Retrofitted edgedrains are generally recommended on relatively young (<10 years old) concrete pavements that have begun to exhibit signs of early moisture-related distresses such as pumping and joint faulting but that only exhibit minimal cracking (less than 5 percent cracked slabs). However, because of the mixed historical field performance of retrofitted edgedrains as reported in the literature, the decision to install retrofitted edgedrains should be made in light of the local experience.
- Compromised drainage outlet performance may accelerate the development of moisture-related distresses in HMA over JPCP. Further research is recommended for this issue.
- Precast concrete headwalls are recommended for Iowa subdrain outlets to prevent clogging and damage from grass mowing operations. Additional research is needed to investigate the economic feasibility and field performance.

Implementation Readiness and Benefits

The recommendations and subdrain best management practices summarized above have the potential to help maintain adequate drainage systems and minimize moisture-related distresses.

Additional research is required into prevention of tufa formation while using recycled PCC as base/subbase materials, strategies to mitigate the occurrence of transverse cracking on pavements over culvert structures, the effects of blocked drainage outlets on shoulder distresses and the effects of compromised drainage outlet performance on moisture-related distresses.