Transverse Pipe Underdrains for Highway Groundwater Control: A Case History

JOHN O. HURD AND HERBERT DUNCHACK

Longitudinal pipe underdrains and transverse pipe underdrains spaced at approximately 60-ft intervals were used to provide groundwater control on one section of the Kirtland-Chardon Road highway project in Lake County, Ohio. This area was designated spring area by the geotechnical consultant because of extremely severe groundwater problems in the subgrade. Normal practice is to provide aggregate drains spaced at 50-ft intervals on uncurbed flexible pavements, but the severe groundwater problems on this section warranted additional drainage. Aggregate drains were placed on the remaining uncurbed sections of the project per normal practice. Four years after construction, the pavement in the spring area, where the improved drainage system was provided, is in excellent condition. Severe distress has been observed in the areas with standard drainage that abut the spring area.

Kirtland-Chardon Road is an urban collector that connects the city of Kirtland in Lake County, Ohio, with the village of Chardon in Geauga County, Ohio. The location of highway project LAK-Kirtland/Chardon Road, IX-1A79(1), is shown in Figures 1 and 2. The maximum design year average daily traffic (ADT) for the 4.25-mi section in Lake County is 4,130 vehicles per day. The vehicles are predominantly automobiles and light-duty trucks. Only 1.35 percent of the traffic is heavy-duty vehicles. The current and design year ADTs for the various sections of Kirtland-Chardon Road in Lake County are shown in Figure 3.

THE PROBLEM

The existing 6-in-thick pavement in 1982 was composed of a buildup of seal and chip applications or thin asphaltic concrete overlays, or both. Approximately 75 percent of this pavement rested on a 6-in-thick gravel base and the remainder was on a 8-in-thick portland cement concrete (PCC) base. This information was obtained from 49 borings taken throughout the 4.25-mi highway section. No subsurface drainage had been provided. The typical section of the existing pavement structure is shown in Figure 4.

Despite the fact that the traffic loads on the highway were relatively light, the pavement and base had deteriorated to the point that complete replacement of the pavement structure was required on approximately 75 percent of the roadway length in Lake County (Figure 5). The remaining 25 percent needed salvage construction requiring spot repair, leveling, and a surface overlay. The locations of the replacement and salvage sections are shown in Figure 6. All salvage areas were located outside those sections of highway with the highest traffic volumes.

The subgrade soils in the borings were found to be generally clayey silt, silty clay, and clayey silty sand. At many boring locations, the subgrade soil was moist to wet. Groundwater was observed flowing into the test borings at several locations. One particular steep 1,500-ft section of the highway was designated "spring area" in the foundation consultant's report (*1*). Water had been observed percolating up through the pavement surface at several locations along this section. The spring area is indicated in Figure 6; Figure 7 shows the steep topography of that section.

Additional borings were taken in the spring area and monitor pipes were installed for more detailed groundwater monitoring. Test results of borings in the spring area indicated the presence of shallow bedrock from 3 to 6 ft below the pavement surface. Sandstone bedrock was observed overlying shale bedrock and water was coming from the sandstone-shale interface and cracks in the sandstone.

The severe deterioration of the pavement was attributed in part to the groundwater problems observed (*2*). Groundwater

FIGURE 1 Location of Kirtland-Chardon Road project in Ohio.

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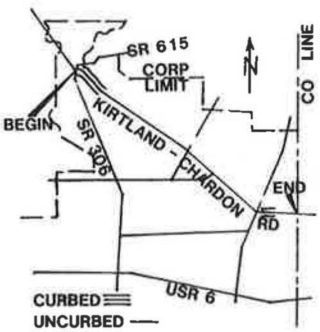


FIGURE 2 Site location map of Kirtland-Chardon Road project.

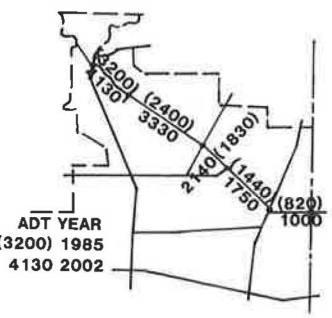


FIGURE 3 Kirtland-Chardon Road average daily traffic.

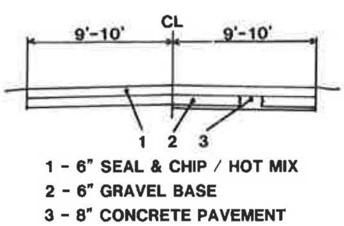


FIGURE 4 Existing pavement buildup.

FIGURE 5 Pavement condition before construction.

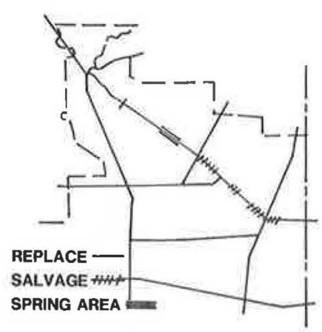


FIGURE 6 Location of salvage sections, replacement sections, and spring area.

near the surface indicates the potential for frost damage within the paving section. In addition, freezing water in cracks or porous seams of the paving section worsens pavement distress. In the warmer months, during periods when the ground is saturated, the subgrade and base are weakened, thereby reducing pavement support.

THE SOLUTION

The new-pavement buildup for the sections in which the pavement was completely replaced was composed of a 3-in asphaltic concrete surface course, a 4-in bituminous aggregate base course, and a 4-in. aggregate base course (Figures 8–10). This relatively light design was all that was required for the design traffic loads. The pavement design for the salvage and overlay sections is shown in Figures 11 and 12.

For groundwater control, 6-in longitudinal pipe underdrains were provided in curbed sections and in the uncurbed spring area (Figures 8, 10, and 11). Aggregate drains were provided on the other uncurbed sections at 50-ft intervals shown in Figures 9 and 12. (Locations of curbed and uncurbed sections are shown in Figure 2.) Normal practice has been to provide longitudinal pipe underdrains on curb sections and aggregate drains spaced at 50-ft intervals on uncurbed sections for this type of highway (*3*). In addition, 4-in transverse pipe underdrains were provided in the spring area (Figure 10). The transverse underdrains were spaced such that the top of the trench for each installation was no lower than the flow-line elevation of the next transverse underdrain upstream. Because of the relatively steep highway grades (approximately 4 to 8 percent), transverse drains were required at approximately 50-ft

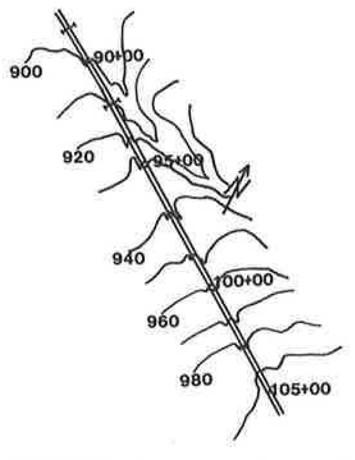
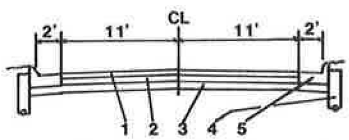
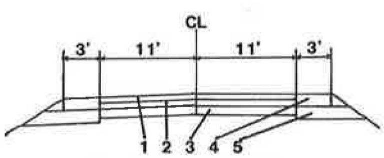


FIGURE 7 Spring area topography.



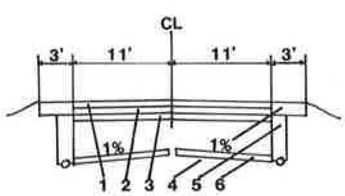
1 - 6" ASPH SURFACE
2 - 4" BIT AGG BASE
3 - 4" AGGREGATE BASE
4 - 6" PIPE UD (#8 AGG)
5 - CURB & GUTTER

FIGURE 8 Typical section, curbed replacement.



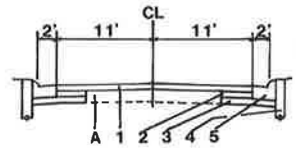
1 - 3" ASPH SURFACE
2 - 4" BIT AGG BASE
3 - 4" AGGREGATE BASE
4 - 8" AGGREGATE SHOULDER
5 - #8 AGGREGATE DRAINS

FIGURE 9 Typical section, uncurbed replacement.



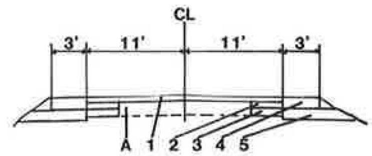
1 - 3" ASPH SURFACE
2 - 4" BIT AGG BASE
3 - 4" AGGREGATE BASE
4 - 8" AGGREGATE SHOULDER
5 - 6" PIPE UD (#8 AGG)
6 - 4" PIPE UD (#8 AGG)

FIGURE 10 Typical section, spring area.



A - EXISTING PAVEMENT
1 - 3" ASPH SURFACE
2 - 4" BIT AGG BASE
3 - 4" AGGREGATE BASE
4 - 6" PIPE UD (#8 AGG)
5 - CURB & GUTTER

FIGURE 11 Typical section, curbed salvage.



A - EXISTING PAVEMENT
1 - 3" ASPH SURFACE
2 - 4" BIT AGG BASE
3 - 4" AGGREGATE BASE
4 - 8" AGGREGATE SHOULDER
5 - #8 AGGREGATE DRAINS

FIGURE 12 Typical section, uncurbed salvage.

intervals. It was anticipated that nearly all seepage lenses would be intercepted in the spring area by this transverse underdrain design.

THE COST

The highest project contract was let in September 1985 and completed in December 1986. The unit prices bid for each type of subsurface drain are shown in Table 1. All bids were within acceptable limits above or below the engineer's estimate. Bidder 1 was the low bidder for the project. The cost of the subsurface drainage in relation to the cost of the pavement is shown in Table 2. The cost of pavement includes the cost of subgrade compaction, subbase, base, surface course, and curb or shoulder. The values shown are based on the successful bidder's unit prices bid for the drainage and pavement items.

It should be noted that the cost of the spring area drainage system per foot of pavement on this project is inflated compared with the same system on a similar project with normal, flatter grades. As a result of the steep slopes in the spring

TABLE 1 UNIT COSTS OF SUBSURFACE DRAINAGE ITEMS

	6-in. Pipe Underdrain			
Bidder	30 in. Deep	50 in. Deep	4-in. Pipe Underdrain	Aggregate Drain
1	4.90	6.75	7.00	4.00
2	4.50	6.00	5.00	3.25
3	5.50	9.00	11.00	4.00
Engineer's estimate	7.00	7.25	7.10	4.50

NOTE: Costs are in U.S. dollars per foot.

TABLE 2 COMPARISON OF SUBSURFACE DRAINAGE SYSTEM COSTS AND PAVEMENT COSTS

	Subdrainage System Cost ($/ft of pavement)	Pavement Cost ($/ft of pavement)	Cost of Pavement for Drainage (%)
Curbed section	9.80	63.60	15
Uncurbed section	0.93	43.90	2
Spring area	17.41	43.90	40

area, very close spacing of the transverse underdrains was required to guarantee complete groundwater interception.

The cost of the pipe underdrain subsurface drainage system compared with that of the pavement would at first glance appear excessive. However, it must be noted that the proposed pavement section is only 22 ft wide and relatively thin. The comparative cost of the pipe underdrain system would be considerably less for a state or federal highway project with a wider and thicker pavement section. The same cannot be said for the comparative cost of the aggregate drain system. Grading requirements on a state highway project would require a greater length of aggregate drain than those specified on this project. Thus, both the aggregate drain cost and the pavement cost would increase in proportion on state or federal highway projects.

PERFORMANCE

The project has been visually monitored periodically for signs of pavement distress since its construction in 1985 and 1986. As of May 1990, the following observations had been made regarding pavement performance.

No significant pavement distress had been observed on the curbed sections. Only a few thin longitudinal cracks or cracked spots were observed (Figure 13). The longitudinal underdrains appeared to have provided adequate subsurface drainage.

Significant distress, including alligator cracking, rutting, or both, had been observed on the typical uncurbed section west of the spring area (Figure 14). Repair of the pavement had been required immediately west of the spring area. This distress was indicative of possible subsurface drainage problems. It was apparent that the aggregate drains had not provided adequate subsurface drainage throughout this area.

FIGURE 14 Condition of pavement on typical uncurbed section west of spring area.

No pavement distress had been observed in the spring area (Figure 15). The inspections indicated (in retrospect) that the spring area subsurface drainage system should have been extended in a somewhat westerly direction outside the delineated spring area. There was little doubt that the spring area drainage system had provided adequate subsurface drainage. Figure 16 indicates subsurface flows through the outlet pipes under relatively dry conditions. Detailed monitoring of subsurface drainage discharge was beyond the scope of this project.

No significant pavement distress had been observed on the typical uncurbed section east of the spring area. Its condition (Figure 17) was similar to that of the typical curbed section. The aggregate drains appeared to have provided adequate drainage. It should be noted that most of this area was composed of salvage sections that were in fair condition before construction.

Whether application of the longitudinal pipe underdrain with or without transverse underdrains on this entire project

FIGURE 13 Condition of pavement on typical curbed section.

FIGURE 15 Condition of pavement in spring area.

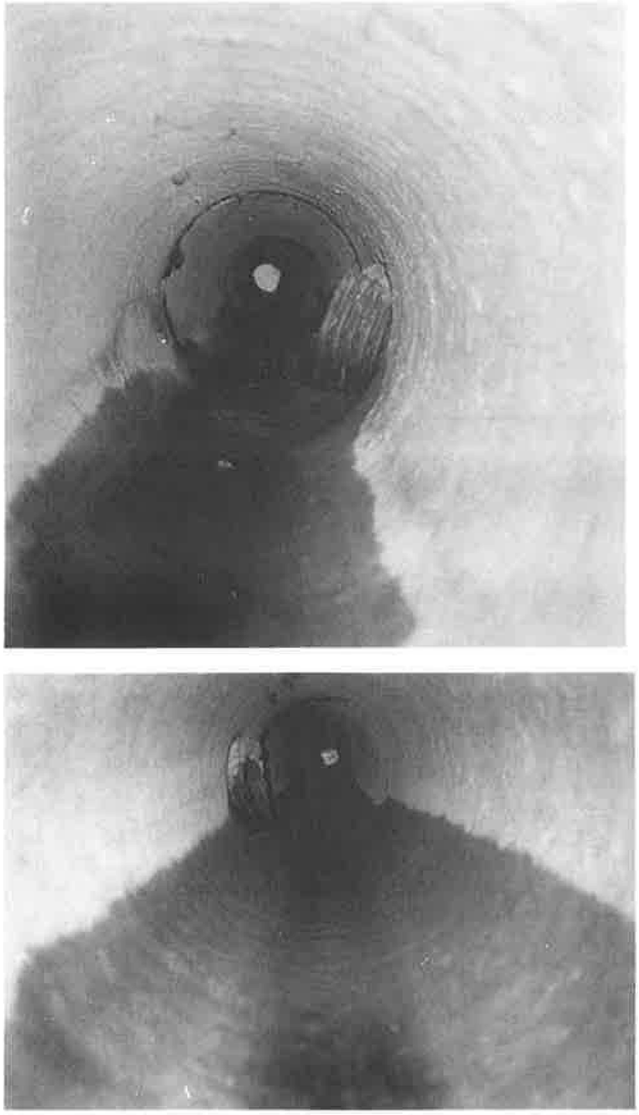


FIGURE 16 Dry-weather flow in outlet pipes, two views.

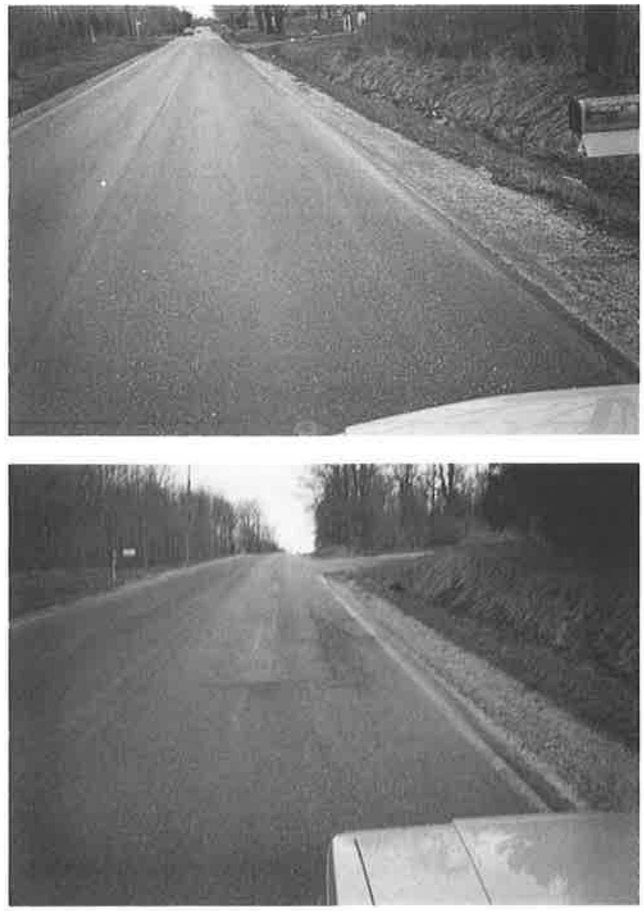


FIGURE 17 Condition of pavement on typical uncurbed section east of spring area, two views.

would have been justified will require long-term investigation and examination of maintenance costs, which are beyond the scope of this paper. There is no doubt that the pipe underdrain system would have been justified on those sections that have required repair to date. The benefit of subsurface drainage would be greater on thicker high strength or wider pavements with higher traffic volumes. In these cases, the comparative cost of the drainage system and the cost of the pavement would be much less.

RECOMMENDATIONS

Where subsurface drainage is required on uncurbed asphalt pavement sections, longitudinal pipe underdrains should be used in lieu of aggregate drains. Where severe subsurface drainage problems exist, transverse underdrains should be provided in conjunction with longitudinal underdrains to provide adequate and thorough drainage of the subgrade.

ACKNOWLEDGMENTS

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REFERENCES

1. *Pavement and Subgrade Investigation Report: Kirtland-Chardon Road.* Triggs and Associates, Inc., Willoughby Hills, Ohio, Feb. 1982.
2. *Line-Grade-Typical Section Submission Report: Kirtland-Chardon Road.* Frank A. Thomas and Associates, Inc., Willoughby Hills, Ohio, April 1982.
3. *Ohio Department of Transportation Location and Design Manual.* Ohio Department of Transportation, Columbus, May 1983.

The findings and opinions are those of the authors and do not constitute a standard or specification.