

# Vertical Drains for Highway Embankments in Kansas

Paul C. Clark, Carl F. Crumpton, and William J. Gilliland, Kansas  
Department of Transportation, Topeka

In Kansas, highway fills are usually made of soil mantle and alternate layers of shale and limestone as they are removed from the cut sections. During the past several years numerous embankment slides have occurred on deep fills on older parts of Interstate 70 and other highways. Several of these embankment slides were surveyed and nine were selected for further study: Of these nine, five were chosen for detailed study and drainage (1). This abridgment discusses details of a slide that occurred in a fill on the first section of Interstate pavement completed in the nation (2). Further details about all five of the slides can be found in Clark and others (1). Conditions similar to the one described here were found in all five.

The fill conditions were determined by direct observation, aerial and ground photographs, vertical boreholes, and horizontal drilling. At some locations computer slope-stability evaluations, stadia cross sections, borehole shear, resistivity, slope indicator studies, water flow rates, dye tracer studies, clay and carbonate mineral analyses, and water analyses were made.

In the fill discussed here the downslope movement resulted from a number of small incremental slides and has been slow over a long period of time. A row of trees approximately halfway down the fill slope has acted as an anchor and prevented the slide material from moving on down the slope, but a noticeable bulge, easily seen in aerial photographs, reveals its presence.

During the drilling program, a layer of limestone blocks and fragments saturated with water was found in the fill. The water had apparently accumulated over a period of time by the movement of surface water down through joints, cracks, and rodent burrows in the fill section, especially in the median. The water in the limestone layer caused soaking of the fill slope and provided some buoyancy, and hence contributed to the resultant incremental slides.

As a corrective measure, two vertical drains were

installed from the road surface down through the top of the reinforced concrete box at the bottom of the fill (Figure 1) and successfully drained trapped water from the fill into the underlying box. One of these drains had a maximum drainage rate of  $0.00189 \text{ m}^3/\text{s}$  (1800 gal/h), and the other of  $0.000063 \text{ m}^3/\text{s}$  (60 gal/h). They have since decreased until at times they only drip. About 8 h after a rain of 2.54 cm (1 in) or more, the flow increases considerably, and they have now drained more than  $7200 \text{ m}^3$  (1.9 million gal) of water from the fill. (Even more was removed from one of the other fills.) With the trees helping to hold the slide and the drains keeping the water from building up, it is believed that this slide will not progress and that no other repair is needed.

The median at this slide location contained a large number of cracks and bowl- or funnel-shaped depressions that average 0.3 to 0.6 m (1 to 2 ft) in diameter and are about 0.3 m (1 ft) deep. Most of the holes have associated rodent burrows. Many are at junctions between the limestone blocks that were used in the construction of the fill, which are exposed at the surface. Rodents also use and enlarge these ready-made holes. Water moving along the median during rains flows into the cracks, holes, and rodent burrows.

A study of the surface drainage area that could supply water to this section of median indicated that a 2.54-cm (1-in) rain would provide approximately  $91 \text{ m}^3$  (24 000 gal) of water. If much of this water flowed into the fill via the holes in the median, it would account for the large amounts of water removed from the fill by the vertical drains.

This water inducement via the holes was investigated through dye tracer studies. Laboratory investigations had shown that concentrations of approximately 10 to 100 ppb of dye [Calcozinc Rhodamine BX (40 percent liquid by weight in acetic acid)] in water could be seen by eye and were easily detected by the use of longwave ultraviolet light. However, the Pennsylvanian age shales used in the construction of the fill, which contain large amounts of the clay mineral illite, tend to remove the dye from solution, and the dye absorbed on illite does not fluoresce under ultraviolet light. (If the dye is flushed from the clay surface the fluorescence capability is restored.) Other clays such as montmorillonite,

Figure 1. Plan and profile views of the fill.

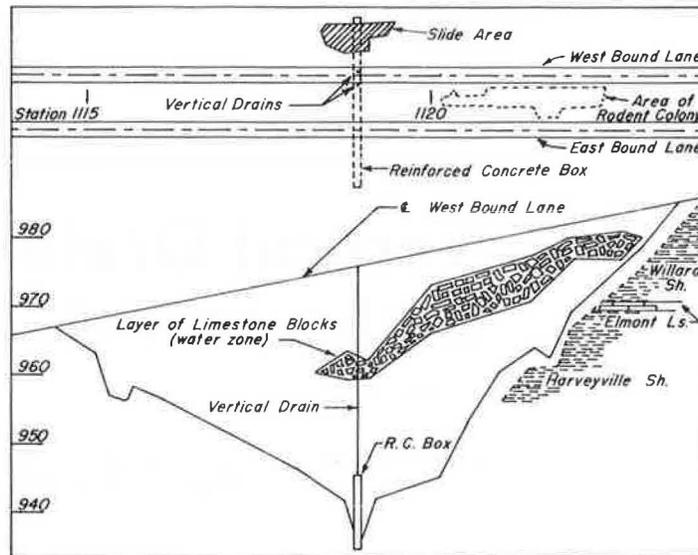
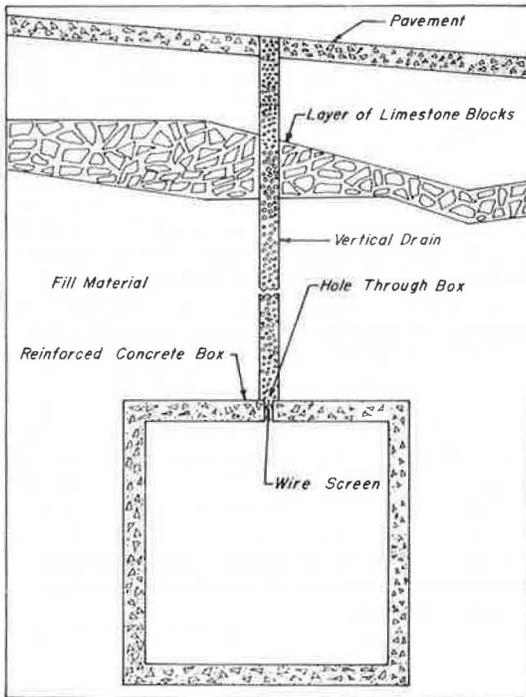


Figure 2. Generalized cross section of a vertical drain through the top of a concrete box.



kaolinite, attapulgite, and pyrophyllite also adsorbed the dye but did not kill the fluorescence.

After a period of dry weather,  $19 \text{ m}^3$  (5000 gal) of water were discharged into some of the holes in the median, about 100 m (328 ft) from the vertical drains, at an average flow rate of nearly  $0.0023 \text{ m}^3/\text{s}$  (36 gal/min). The larger holes easily took this amount of water without overflowing. The induced water was marked with the dye tracer by metering it into the outflow line of the tanker to provide a dye concentration of 30 ppm.

The flow in the drains increased in a little more than 8 h, but it was nearly 10 h before the dye became visible in the drain effluent water. The maximum measured concentration was 120 ppb of dye in the drain water at about 15 and 24 h. Inasmuch as the original concentra-

tion had been 30 000 ppb, the dye had either been diluted by water in the fill or been absorbed or adsorbed by the fill components. This probability had been provided for by the initial dye concentration as a result of the laboratory studies. The dye continued to color the water flowing from both drains for at least 16 d. This prolonged presence probably resulted from the continued flushing, by rain, of dye absorbed by the illitic clay shale.

Thus, it was verified that remote surface water was entering the layer of limestone blocks through the rodent burrows. If such induced water is not removed (i.e., by the vertical drains) then a water buildup and resultant fill instability are likely to follow. All of the fills studied in detail showed layers of limestone blocks capable of storing large quantities of water. Vertical or horizontal drains or both have been used successfully to remove much of this water (1), but attempts to drain the water downward into the original soil mantle were unsuccessful. A more permeable valley alluvium would probably make such drainage possible. Bottom hole explosions have been used successfully in Virginia to start drainage in a similar experiment (3).

Water samples were taken during the winter months to determine whether deicing salts were entering the drains. The chloride content of the water varied from 211 to 642 ppm, which is much more than in the local groundwater. During prolonged periods of cold weather, icicles formed in the box at the drain outlets. The icicles extended the full height of the box, and the largest one became about 51 cm (20 in) in diameter. A taste test of the icicles verified that deicing salts were entering the drain. The icicles formed only at this one slide location. They melt as soon as it becomes warm and have caused no problem. A deposit of calcite periodically forms at the end of a horizontal drain at another location under study (1), but it is regularly removed and has caused no problem. Water at that location is high in alkalinity as well as in chlorides.

The sodium from the rock salt used for deicing has not contributed to fill stability. It converts the normal calcium montmorillonites in the native soils and weathered shales to the more expansive sodium variety. This may be a minor contribution to the problem, but it is additive.

At one location, which has steep slopes due to a limited right-of-way, a series of slides have occurred over the years. Computer slope-stability analyses have veri-

fied that the slope is too steep to hold under the normal moisture conditions. Vertical drains have been installed, and a group of trees and shrubs were planted to help the vertical drains remove the excess water and to anchor the fill slope material. A slope indicator was also installed to see if the remedial measures were likely to be successful, but at this time the final installation is only a few months old and there is no prediction of its long-term performance.

The detrimental contribution of rodents in establishing, enlarging, and maintaining natural holes and cracks should not be overlooked. Such nonhuman users and inhabitants of Interstate roads have caused problems in areas of Arkansas (4). At one embankment slide location, maintenance forces filled the surface holes with asphalt, but the rodents soon established new burrows alongside the asphalt plugs. In some instances they burrowed directly through several inches of freshly compacted asphalt mix. In this way, they continue to maintain direct access for surface water into the interior of the fills. It is hoped that the vertical drains and the trees will continue to remove the water and maintain a stable slope.

For the vertical drain installations, a drill equipped with a 23-cm (9-in) hollow, continuous-flight auger was used to drill down through the fill section to the top of the underlying box. A 6.4-cm (2.5-in) diameter diamond core bit was then lowered inside the hollow auger to drill through the top of the concrete box. After removing the diamond bit, the wall of the larger hole was thoroughly washed while slowly rotating and moving the auger up and down in the hole. A wire hail screen (formed in the shape of a cone) was driven upward into the hole in the concrete from inside the box to prevent the drain aggregate from dropping out. The larger hole was backfilled with granular underdrain aggregate from the top of the box up to the ground or pavement surface by carefully pouring the aggregate through the center opening in the hollow auger as it was slowly removed from the hole. Only the required amount of aggregate was used to replace each 1.5-m (5-ft) section of drill stem as it was removed from the hole. Figure 2 shows a generalized drawing of a vertical drain installation.

#### REFERENCES

1. P. C. Clark, C. F. Crumpton, and W. J. Gilliland. Water Drainage From Highway Fills. State Highway Commission of Kansas and Federal Highway Administration, 1974.
2. Kansas First in Nation to Complete Road in New Program. Highway Highlights (Kansas), Vol. 17, No. 2, Nov. 1956, pp. 1, 3-6.
3. W. T. Parrott. Control of Slide by Vertical Sand Drains. HRB, Bulletin 115, 1955, pp. 51-52.
4. Rats! They're Ruining the Highways Looking for a Home. Topeka Daily Capital. July 24, 1976, p. 11.