SUB-SECTION VIII e

INVESTIGATIONS ON FAILURES, DRAINAGE AND FROST ACTION

SUBDRAINAGE PROBLEMS IN HIGHWAY CONSTRUCTION AS RELATED TO GEOLOGY AND SOIL MECHANICS

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Nearly ten years ago the engineering geology section of the Kansas State Highway Commission began a study of the movement of subsurface water as related to highway engineering problems. Much of this work was done in the process of making engineering-geoligical surveys for proposed highways 2), but several special studies have been made by various members of the section. None of the individual reports have as yet been published, but the drainage system described here is an outgrowth of the information obtained.

Mr. Seward E. Horner, Chief Geologist, was instrumental in planning the investigations and in developing the subdrainage system now used. Most of the subdrainage designs and the subdrainage specifications for Kansas highways are the work of Mr. Horner and Mr. G.O.McDonald, Road Engineer for the Commission.

Since 1936, an engineering-geological survey, as described by Martin and Horner 2), has been made in Kansas for every proposed highway improvement. From the information of this survey, a structural contour map is constructed for each project along with an accurate and detailed geological cross-section along the centerline of the proposed improvement. The geological report for each project discusses the engineering significance of all geologic features including the sub-surface hydrology. Specific recommendations for classification and use of materials and for design are included. Similar reports, maps, and profiles or cross-sections have been prepared as a preliminary to special investigations of sub-surface water problems.

Very early in the study it became evident from resurveys of old alignments that many road failures occurred near the intersection by grade line of certain limestone and sandstone formations. In several such cases no seeps at these locations had been detected either during the original engineering survey or during construction, and the natural tendency was to attribute the failure to a change in material. However, study of the physical character of these formations in their weathered and unweathered states, a knowledge of their water-bearing characteristics in other nearby localities, observation of vegetative indications of seepage, and the use of other established geologic principles enabled the geologist to determine that these formations do carry water, at least seasonally.

Perhaps half of our drainage installations are designed for seasonal or intermittent seepage. This type of seep may flow for only a matter of hours after heavy rains or may flow for a month of two after the spring rainy season and not be affected by individual rains. The character of the flow is determined largely by the size of the catchment area and the properties of the water-carrying zone. Even those horizons which carry water for only a few hours after rains may introduce enough water into the road structure to produce failures. Seasonal seeps may issue from horizons in either the bed rock or the mantle rock. Seasonal seepage from bed rock horizons ordinarily indicates that water is carried only in the fractured and weathered, near-surface portion of the formation. Such formations usually furnish little or no water to wells far back of the outcrop where the fractures are closed and little weathering has taken place.

Limestone and sandstones are not the only formations carrying water into Kansas subgrades. Any bed of coal should be considered a possible aquifer under Kansas conditions. Coal beds usually have only a seasonal flow and that only in the weathered part near the outcrop. However, persistent coal seams even less than one inch thick may carry large volumes of water during wet seasons. Many shale horizons carry large amounts of water into the road structure. Any black fissile or platy shale should be examined carefully as a possible aquifer. Lensing sandy shales often have a slow movement of water through them. This movement is often so slow that all of the water is removed by evaporation at the outcrop on natural exposures. It is always a good practice to check such horizons early in the morning when the evaporation rate is low. Thin calcareous zones in shales should also be considered as possible seasonal aquifers. Even seemingly tight clay shales may carry large quantities of water along bedding planes and through joint fractures. During dry seasons when no flow exists, evidence of the water-bearing property can usually be found in the staining and weathering along fractures and bedding planes. It is often advisable to mark such zones for later study during a wetter season.

Some of the original surveys had plotted seep areas on the original ground downgrade from the location of the failure which later developed and well below the outcrops of the offending formation. In several cases chevron drains of standard design and based on agricultural or drawdown principles had been installed in the wet area and were assumed to have been effective in as much as the failure on the constructed road had not occurred directly over them but at some point up the grade. In many such cases the original soft area was the result of seepage from the same formation that later caused the higher failure. Water leaving the aquifer had entered the mantle x) and flowed through a permeable zone to a lower level where supercharging of the mantle, decreasing permeability, or other factors forced it to the surface. Removal of the mantle during excavation altered the flow of water and stopped the addition of further water to the former seepy area. Failures, however, simply moved up grade to the new exposure of the aquifer.

Further investigation disclosed that many zones in the mantle rock may serve as seasonal

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x) Mantle is here defined to include all the unconsolidated material above bed rock. All soils are considered as a part of the mantle rock.

or year-round aquifers. Space does not permit a full discussion of the occurrence of free subsurface water in the mantle; but, in general, any zone inclined to the horizontal, and slightly more impermeable than overlying material may serve as the base of an aquifer. All that is required to start a lateral movement along the top of such a layer is for water to be delivered to the zone from above at a rate faster than the rate at which it can pass vertically through the more impermeable layer. In this connection it must be kept in mind that permeability is a relative term and that it may result from either textural or structural arrangements. This principle of subsurface flow was based upon actual field observations and has been used in many of our subdrainage investigations. It is in complete agreement with the findings of Coleman and Bodman 1) in their laboratory investigations of infiltration into moist, layered soils.

Some actual examples of zones which have been observed to be the base of aquifers in the mantle are:

1. Tight B horizons.
2. The contact between weathered parent material (C horizon) and unaltered parent material.
3. The contact between glacial drift or loess and underlying shales or buried soils.
4. Zones of heavy structureless clay underlying zones of equally heavy clay which, however, exhibit pronounced blocky or prismatic structures.

Unsaturated permeable horizons exist below most of the aquifers discussed previously. In several localities ground water investigations made in connection with water-supply problems have described the water table at a level well below that of bed rock aquifers for which we have had to provide drainage.

Thus for the most part we are not dealing with true water table conditions in Kansas;nor do our conditions fit exactly the generally accepted picture of perched water tables which shows a rather stagnant body of water held at some point above the true zone of saturation. Too close an adherence to the concepts of ground water, water table, perched water table and other terms which were developed in connection with water-supply problems, even when technically correct, may lead to false conclusions in connection with subsurface water problems on highways. For Kansas conditions it is believed that a better understanding is obtained if the water in the aquifers described above be considered as water in the zone of aeration.

True water table conditions are usually encountered in Kansas highways only in valley sections and in most valleys the water table is too low to affect the road structure. Where the water table is near the surface, a change in grade or alignment is usually more economical than subdrainage.

The fact that most of our subsurface water problems on highways result from water having a strong directional flow in well defined and usually thin zones in either the mantle rock or bed rock gave rise to the system of interception drainage which is used in Kansas. By interception drainage we mean that, effectively, all water is intercepted before it can enter the road structure. To accomplish this end, the following conditions must be known:

1. The source of the water. This includes knowing not only the exact horizon carrying the water but its topographic and structural relation to the road structure. It also includes a knowledge of the catchment area from which the aquifer feeds. As has been pointed out, the surface expression of seepage is not always directly related to the true source.
2. The amount of water involved and its direction of flow. This of course depends on the catchment area and on the dip of the horizon or its attitude in relation to the road structure.

The Kansas Highway System uses two general types of interceptor drains. The pipe underdrain (Plate I) is used where **relatively** thin aquifers are to be intercepted. It consists of a trench cut entirely through the water carrying zone and well into the relatively impermeable material beneath. Perforated pipe is installed in the bottom of the trench with the perforations down and the trench is backfilled with material expecially designed to prevent silting. Unless otherwise specified, backfill material meeting the specifications described by the Vicksburg, Experiment Station 3) is used. The geologist making the field study recommends changes in the filter material when such change is warranted. The minimum width of the trench shown is one foot and the minimum depth of cut into impermeable material is also one foot. Experience has shown that this width and depth of trench will give full interception for most conditions of moderate flow. The cost of backfill

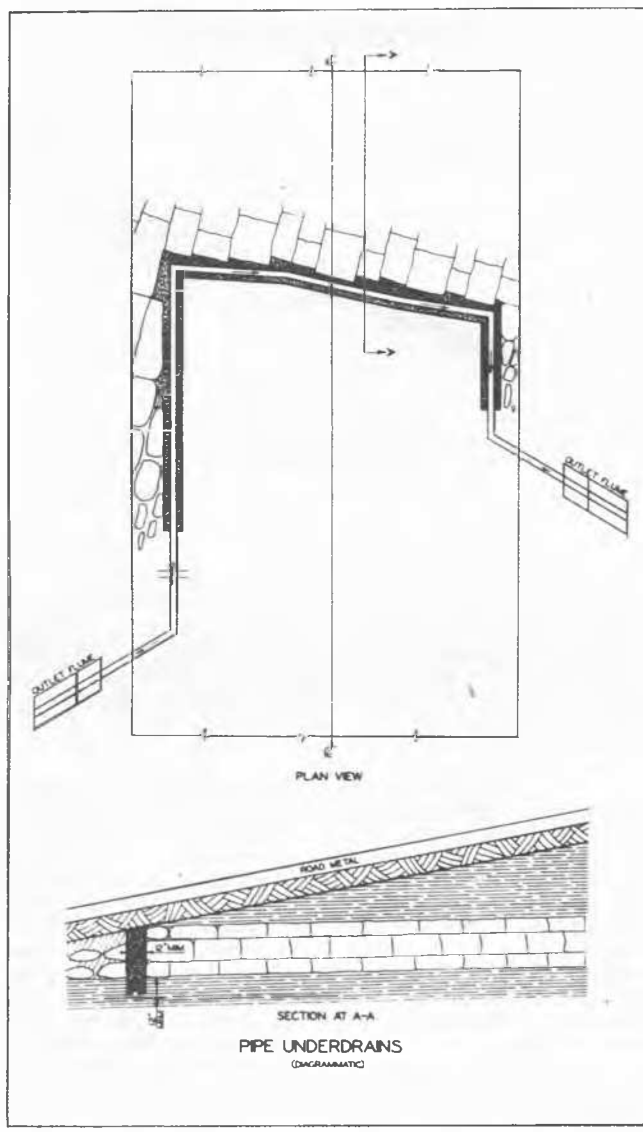

Plate 1

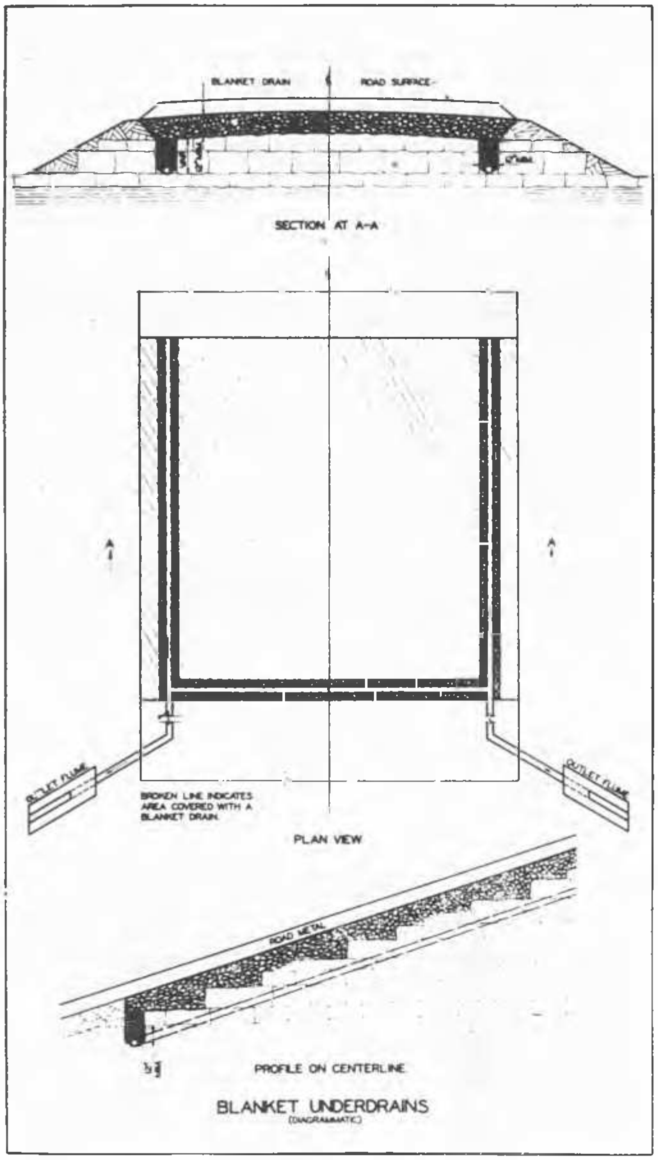

Plate 2

material encourages the use of narrow trenches but the figure given is only a minimum. The geologist recommends additional width or depth to conform to varying amounts and rates of flow. All pipe is installed on a 1 per cent grade. This grade is again based on experience but has been satisfactory for preventing silting in every case studied.

For thick aquifers such as limestone formations carrying water along several thin shale partings (Profile view, Plate II), we use the blanket interceptor illustrated by the diagrammatic views of Plate II. For this drain the face of the outcrop is cleared of all clay and soft shale and covered with a layer of crushed stone. This layer is a minimum of twelve inches thick and has, in addition to high permeability, a strength approaching that of a stabilized base course. Underdrain pipe is used to carry the water from the blanket aggregate. The common installation requires a pipe installed longitudinally on either side with a lateral pipe underdrain at the lower end of the blanket. This end lateral is set either into impermeable material beneath the aquifer or at such a depth that water cannot escape past it to cause a failure at some point downgrade.

The standard subdrainage sheet is only a general guide to subdrainage and is supplemented in every case by detailed plan and profile views of the geology (including that of the mantle rock) of each particular subdrainage area. The resident engineer is especially instructed that the position of the drain relative to the geology of the location is to be the final guide to correct installation.

The chief advantage of interception drainage either by pipe or blanket underdrain is its effectiveness and its natural approach. The record of drawdown or agricultural type drains formerly used by the Kansas Highway Commission was anything but satisfactory. Failures developed over many such drains in the first season after construction Failures were also common at nearby, related locations. We have had no failures or related failures where interceptor drainage has been used.

The poor performance of agricultural type subdrains often results from the failure to recognize that the surface expression of seepage may be changed as a result of construction of the road. The correct solution is interception of subsurface water at the source. Furthermore, in drawdown subdrainage, some variations in the free water surface is inevitable and capillarity is a factor which makes adequate subdrain design difficult. Since interceptor drains prevent essentially all subsurface water from entering the road structure, the ideal of a low constant subgrade moisture content is more nearly obtained. In any event, time consuming, costly, and sometimes misleading field and laboratory studies which are an absolute necessity for successful drawdown subdrainage are largely eliminated by interception. The information required for interception can be obtained during routine, engineering geological surveys.

CONCLUSIONS

While the subsurface water conditions encountered on Kansas highways may differ in varying degree from those of other regions, the following two general principles followed in Kansas Highway subdrainage are universally applicable:

1. The geologic features in every seepy area must be determined fully before any system of subdrainage is employed. Studies which include only the characteristics of the area of surface expression of subsurface water are very often misleading.
2. In most locations subsurface water can be prevented from entering the road structure by interception subdrainage. Where interception is possible, it is the most effective system to use.

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