

# Highway Drainage—Importance and Methods

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Although the writer has been engaged in the design of farm drainage systems and in teaching farm drainage at Ohio State University for 37 years, he is not a specialist in highway drainage. But in traveling 20,000 to 25,000 miles per year over our public roads, he has developed a keen interest in the problems of highway drainage.

The same basic principles govern the movement of water over the surface of land or through the soil whether the problem is on the farm, an airport, a railway right of way, or a public highway. The necessary packing of the subgrade, the heavy subsoil in cuts, and the impervious character of highway surfaces add stubborn complications to highway drainage, but do not alter the fundamental nature of the problem.

## DRAINAGE IS BIG BUSINESS

During the past century, Ohio farmers have spent \$36,000,000 for the construction of 25,000 miles of public outlet ditches. (Indiana has about the same mileage.) They have spent more than \$200,000,000 for private drainage on their own land. In 1951 alone they installed 9,200 miles of tile drains on their farms. One 400-acre farm in Huron County has 800,000 feet of tile drains. Wood County, Ohio, has enough private tile lines to reach one-tenth the distance to the moon. Farmers do not hesitate to spend from 100 to 150 dollars per acre for the drainage of wet fertile land. They are doing this for purely economic reasons. Improved highway drainage should be an economic advantage to the taxpayer in lower maintenance costs, less wear and tear to traffic vehicles and in increased safety.

## IMPROVED TRANSPORTATION— A PRIMARY BENEFIT

Improved transportation is one of the primary benefits of agricultural drainage. The farmer must be able to transport his tillage,

seeding and harvesting machinery over all of his land at the earliest possible date in the spring and as quickly as possible after summer rains.

The large amount of corn commonly left unharvested until April or May is the result of the inability of the farmer to transport his corn picker and wagon through his fields. The action of frost in poorly drained soil will lift the roots of his winter wheat and his deep rooted legumes by the same forces that too frequently cause the highway pavement to fail.

The value of non-agricultural drainage is recognized more and more each year. Professor Quincy Ayres, of the College of Engineering, Ames, Iowa, says: "It is known that the bearing power of soils of all kinds is greatly reduced by the presence of excess moisture. Diversion of surface water and drainage of ground water in non-agricultural projects is one of the most important services rendered by drainage." Highway engineers encounter some of the most interesting and sometimes the most baffling of all drainage problems.

#### MOVEMENT OF SOIL MOISTURE

Soil is a complicated material made up of solid particles and various sizes of pores. Water that enters it either remains in it or percolates through it. Water retention and movement constitute the two important phases of soil moisture relationships.

Movement of soil water in liquid stage takes place through the soil pore space. This movement takes place by the action of gravity or capillarity or by a combination of the two.

Coarse textured soils have a rapid initial rate of capillary movement but finer textured soils will eventually have the highest rise. Capillary conductivity becomes less as the moisture content of the soil is reduced. It will take place in any direction but is most rapid in the direction of the force of gravity. In general, extremely loosely or extremely tightly packed soils will have lower capillary conductivity than medium packed soils. Thus, for greatest capillary flow, the soil pore size must be neither too large nor too small.

Keen has shown that under the most favorable conditions, capillary action would lower the water table 34 inches in six or seven months. Beyond this, the capillary movement was exceedingly slow. Alway and McDole of Nebraska found that the capillary movement of water from more than 12 inches was very slow after the soil moisture content was reduced to field capacity or lower. This is the condition that prevails above the free water table.

Since the surface of highway soils are almost completely sealed by the pavement, the rising capillary moisture is trapped just beneath this surface where it accumulates. In agricultural soils this water may be removed by direct evaporation or by transpiration from the leaves of growing plants.

The relatively low insulating qualities of most highway pavements and their ability to absorb and lose heat rapidly makes possible rather sudden changes in the soil temperature beneath them. Low soil temperatures will increase the rate of rise of capillary moisture.

The problem is a complicated one, but the above facts suggest that where it is possible to maintain a low water table by subsurface drainage, less water will accumulate directly under the pavement as a result of capillary rise of moisture.

#### SUBSURFACE DRAINAGE WILL REDUCE SOIL MOISTURE IN TWO WAYS

Subsurface drainage will improve soil moisture relationship in two ways in most situations. First, it will keep the zone of saturation well beneath the paved surface. Second, it will reduce the rate of concentration of capillary moisture directly beneath the highway surface.

Tile drains will remove that water which is free to move through the non-capillary pore spaces by the force of gravity. Since the flow is induced by the force of gravity, the level of free soil water will be higher with increased distance from the drain. This will be a steep curve for tightly packed clay soils and relatively flat for sand and gravel subsoils. Thus, the more impervious the soil the closer must be the spacing of the drains to keep the water table near the level of the drain. For a given spacing, the deeper the drains, the greater will be the minimum distance from ground surface to surface of water table midway between drains.

In farm drainage, the problem is complicated by the fact that the soil profile is seldom homogenous. In highway drainage, the problem is further complicated by the thorough packing of the subgrade. This reduces the non-capillary pore space through which gravitational water can move.

#### DEEP DRAINS ARE MORE EFFECTIVE THAN SHALLOW ONES

There is increasing evidence that deep drains are more effective than shallow ones in maintaining low water table. This is true in heavy clay soils as well as in the more permeable sands. Four feet

below the surface of the pavement is none too deep. This will place the drain below most of the effect of subgrade packing. Filling the trench with crushed stone will facilitate the movement of water to the drain. Thin impervious layers above the grade line of the tile may result in a shallow zone of saturation above the drain. Porous backfill will permit this perched water to flow laterally to the tile. This does not imply that porous backfill is always necessary.

### LOCATION OF DRAINS

In many cases highway drains are placed directly below the main surface channel, well to the side of the edge of the pavement. This may place the tile lines too far apart for effective control of the water table directly under the pavement in impervious soils. A better location under these conditions may be just inside the edge of the pavement. Such location will bring the tile lines close together and will protect the porous backfill.

As previously stated, properly placed subsurface drains will maintain a low water table and thereby retard the upward movement of capillary moisture under the pavement. In some soils, subsurface drains will not completely eliminate this upward movement of water. Some method may be necessary to remove this capillary water as fast as it accumulates under the pavement. Several inches of granular fill directly under the pavement and extending to the porous backfill over each tile drain would seem to offer possibilities under such conditions. Railroad engineers have furnished a precedent for this in placing 15 to 18 inches of ballast under the ties. In the course of years, this ballast becomes impervious due to the inclusion of cinders and ashes. Serious drainage problems result. To overcome this, the railroad companies have developed complicated and expensive equipment to automatically remove, screen, and replace the ballast. This should not be a problem with ballast under highway pavements.

Seepage water entering the highway from the sides of cuts may cause serious damage. In solving such problems, intelligent use must be made of both surface and sub-surface drains. Seepage water creeping along under pavements on steep or even moderate grades may be the cause of much trouble. On new construction, a careful study of the soil profile should be made to detect conditions likely to cause such seepage.

### ADEQUATE SURFACE DRAINAGE IS FIRST STEP

Adequate surface drainage is the first step in providing good internal soil drainage. Most new highways have surface channels of

adequate capacity. For safety reasons they are placed well to the side of the pavement, but the critical point is just at the edge of the pavement.

The total runoff from the paved surface is nearly equal to the rain falling on it. There is frequently a small channel just at the edge of the pavement formed by vehicles driving over the edge. Part of the runoff is trapped here. Some of it finds its way directly beneath the road surface. This problem is sometimes solved by constructing a small gutter or ridge at the edge of the pavement. Frequent side channels carry the water to the main roadside waterway. Subsurface drains placed under the edge of the pavement or in the berm nearby can be made to collect much of this runoff.

On many roads not enough attention is given to the prompt removal of surface water from the right of way. There are many cases where water is standing within 12 to 24 inches vertically of the highway surface. These are the places where the highways have taken the worst beating. Perfect control of surface water is often the most important step in providing adequate internal drainage. The subgrade drainage problem is often aggravated by surface water getting through cracks and holes in the pavement. Keeping surface water out is one of the most important contributions to good internal soil drainage. A leaky pavement is to a highway what a bad roof is to a house.

Where adequate soil drainage exists naturally the problem of highway design is greatly simplified. But wherever roads must be constructed on flat, heavy soils, serious attention must be given to both surface and subgrade drainage if our highways are to stand up against the terrific beating such as they have received during the past few months.

#### HIGHWAY DESIGN CRITERIA FOR AGRICULTURAL DRAINAGE

Newly located highways passing through farmland already having or in need of intensive agricultural drainage, present a problem to the highway engineer. These new highways will disrupt existing farm drainage and may limit the opportunity for future improvements.

Many have assumed that the highway department has fulfilled its obligation when it has taken care of all existing tile drains, at existing grade, and present capacity. It is probable that there is much wet farm land along the route still needing drainage. The most significant trend in farm drainage today is toward deeper laterals. This necessitates deeper mains and outlet ditches. Farmers are de-

manding mains and outlet ditches of greater capacity than was formerly considered adequate.

Engineers for the Ohio Turnpike Commission, have developed supplementary design criteria for agricultural drainage for the Ohio turnpike. These criteria were officially adopted by the Turnpike Commission. This is an excellent guide for readjusting land drainage interrupted by highway construction. Fundamentally it gives the land-owners about the same opportunity for making future drainage improvements they would have had if the turnpike had not been constructed. Many of our prominent real estate appraisers, lawyers, and engineers believe that the saving in cost of land acquisition will more than pay for the extra cost involved in meeting these criteria. This work requires the services of an engineer experienced in planning farm drainage.

#### SUGGESTED AS GOOD INVESTMENT

The suggestions contained in this paper are based largely on the writer's extensive experience with farm drainage. They are only suggestions. It would seem to him that there is crying need for a lot of research on this subject.

Efficient internal drainage of wet highway soils will probably always be expensive. Farmers on wet land in Indiana and Ohio do not hesitate to invest from one-fourth to one-half the total value of their farms in improved drainage. There would be little or no agriculture in many of these areas if they were unwilling to make this investment. Adequate highway drainage can certainly be secured at a lower cost percentage wise than these farmers have been paying for many years. And there is more at stake. The best surface and subsurface highway drainage known will not provide perfect water control under all conditions. In extremely cold weather, some capillary moisture will reach the surface but there will be less to freeze. Well drained highways will give more years of better service at less cost.