of State Highway Officials the pre-qualification of bidders on public construction work. The report of the committee was then referred to the executive committee which, in turn, authorized the taking of a letter ballot on the approval of the report and recommendations of its provisions for pre-qualifications.

In commenting on the legality of pre-qualification, the Committee on Cooperation with Contractors said, "Nothing in the way of a court decision has yet been found by either of the committees. The nearest approach to it is a decision of the Comptroller General of the United States. He tacitly sustained the Supervising Architect in his refusal of plans to a bidder who had failed to qualify in accordance with the advertisement. A further indication of legality is the fact that the Bureau of Public Roads and the State Highway Departments of Wisconsin and Iowa have been pre-qualifying bidders for some time. Since a determination of responsibility is definitely required by law, and since the same bidder should receive the award irrespective of when the determination is made, there seems to be no real question of law involved. The courts have shown themselves very reluctant to interfere with the discretionary acts of administrative officers when they are performed in public interest."

This subject could be discussed at much greater length, setting out more in detail the advantages of the two plans suggested herein, designed as they are to regulate, if not eliminate, the unqualified contractor; but there has been enough said to indicate the trend of the industry concerning the matter. We are desirous only of setting up such standards in the construction industry as will insure prompt and quality performance of a given contract, at a reasonable profit to the contractor. If, as, and when this is accomplished, it can not be, in our opinion, other than in the best interests of the public and the construction industry alike.

HIGHWAY DRAINAGE PROBLEMS

By C. C. Wiley,
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Mark Twain once remarked that we had been talking about the weather for more than 2,000 years but so far no one had done anything about it. Road drainage is also a perennial topic of discussion, especially at road meetings, and sometimes it would almost seem that no one had done anything about it, either.

Possibly there is some excuse for this condition. Drainage is far from an exact science, for many miles of road are controlled by men who have had little opportunity to study the problem, and even the most expert highway drainage engineer is likely to make a mistake or to overlook something while engrossed in the details of some new feature of pavement design and construction.

The road builders are therefore wise in discussing and rediscussing the problems even at the expense of considerable repetition so as to fix clearly in their minds the fundamental objects and purposes of road drainage which are so essential to good design, proper construction, efficient maintenance, and safe and convenient operation of our highways.

All soils become muddy when wet and hence unstable for road subgrades or surfaces. Excess water in any highway structure is a source of trouble, while free water on the road surface is a hindrance to traffic and if combined with freezing and thawing, the damage done may be considerable and travel of the road fraught with danger. It is therefore necessary to remove or prevent the entrance of excess water into all parts of a highway, and consequently road drainage may be defined as the process of excluding or removing excess water from the road.

The source of the water to be drained away is the precipitation on the earth's surface in the form of rain, snow and sleet, of which rain is the most important. Part of this water enters the soil and tends to percolate away, while part of it flows away over the surface. Since road drainage must keep excess water from all parts of the road, the drainage system must take care of both surface water and water in the soil. Road drainage therefore is naturally divided into two great parts, surface drainage and underdrainage or subdrainage.

Snow is next in importance to rainfall. Since snow is about eight times as bulky as water and also more cohesive, its first effect is resistance to traffic; hence our big snow removal programs are primarily for the purpose of preventing the snow from obstructing traffic. Snow removal does, however, affect the road drainage. When the snow melts it becomes free water on the surface and drains away in the same manner as rain.

Run Off

The part of the water which flows away over the surface is termed the run off. The amount of the run off depends on the intensity of the rainfall, the porosity of the soil, and grades. Heavy rainfall increases the run off because in proportion to the total amount of water there is less time for any of it to enter the soil.

Porous soils obviously will take up water faster than dense soils and hence decrease the run off. Anything, such as pavements and roofs, that increases the average imperviousness of an area also increases the run off. Steep grades cause greater run off by carrying the water away before it has time to enter the soil.

Run off may be nearly zero on sandy soils but nearly 100% on solid rock. On fairly level cultivated farm lands it will amount to from 10 to 30%. Ordinary residential sections of a city may show a run off of from 30 to 50% while in built-up business districts it may be as high as 90%.

Since the run off increases with the rate of rainfall, and since it is necessary to drain the water away almost as fast as it falls to prevent flooding, the rate of rainfall becomes of primary importance in designing a drainage system.

Storms vary greatly in severity. The extremely severe storm of maximum rainfall occurs only at long intervals of time, while the less severe storm of moderate rainfall may occur much more frequently. The more permanent the drainage structures, the greater the land values, and the greater the potential loss caused by floods the greater is the need to make the drainage system capable of handling the more severe storms of less frequency. Thus a high-priced storm sewer in a city should properly have a capacity to handle the storms of high rainfall occurring perhaps once in 20 to 30 years, while an open ditch system for secondary country roads may resonably be made to care for the more gentle storms occurring once in 8 to 10 years. It is well, however, to point out that if this rural territory develops into urban property the drainage system needs a corresponding change.

Various books on hydrology and drainage give methods for estimating the rainfall and run off and also methods for determining the size of tile or open ditch. These methods are not nearly so complicated as many think, and consequently it is not difficult for any road engineer to determine with fair accuracy the necessary sizes of ditches and tile, instead of merely guessing at them.

The Crown

The first device for the surface drainage of a road is the crown, which is exactly analagous to the roof slope of a building. Good drainage calls for considerable crown, but traffic prefers little or none. Hard, smooth, impervious surfaces such as brick, concrete, and asphalt, require but little slope for good drainage, and hence the needs of both drainage and traffic are easily met. The softer and rougher surfaces require more crown, but the amount is limited by the needs of traffic and the fact that erosion during heavy storms may cause cross-washing. Taking all factors into consideration, earth roads should be crowned about 3/4 of an inch to the foot. Less than 1/2 inch per foot does not give good drainage, especially when the surface is cut a little by traffic, while with more than 1 inch per foot the side thrusts of traffic soon cuts or wears the surface into ruts which hold water that further softens the soil. In a similar way, gravel and macadam are best with about $3/8$ inch per foot, while the hard surfaces work well at $1/8$ inch per foot or even less.

On city pavements the water from the crown is collected by the gutter and discharged through inlets into an underground drain or storm sewer. Water from the parkways, sidewalks, and adjoining land may also reach the gutter. It is essential that the gutter have sufficient capacity and grade to carry the water quickly to the inlets, and that the inlets be frequent enough in number and of sufficient capacity to discharge the water promptly into the sewer so as to prevent flooding. Obviously the underground system must have ample capacity. Gutter grades are usually fairly good. The underground system is often guessed at instead of designed, or else is built piecemeal without regard to coordinating the various parts, and hence is more or less inadequate; but by far the most common fault is a totally inadequate number of well located inlets of proper size. No single item in city pavement work needs more care than fixing the location and dimensions of the inlets.

Size and Shape of Side Ditches

Present construction on rural roads provides side ditches to collect the water from both the roadway and the adjoining land and carry it to the natural outlets. If the distance the water must be carried is short, the ordinary ditch section is sufficient; but if the distance is long or a large amount of side land contributes water to the ditch, the size should be increased to meet the needs. Failure to provide ample ditch capacity is, perhaps, one of the most common defects in ordinary road construction. Since it is not a difficult matter to estimate the required capacity and to design a ditch accordingly, there is little real excuse for not doing so.

If grades are steep or the volume of water large, the ditch is likely to be eroded, and special provision may be necessary to prevent this. In some cases the ditch may be paved or lined with stone, brick, or concrete. With steeper grades, baffle walls with discharge weirs and aprons may be built, but perhaps the most effective and possibly the cheapest method in the long run is to lay a tile and provide frequent inlets into it.

Frequently road officials desire to connect their road ditches to adjacent farm tile. The landowners almost as frequently object, usually on the grounds that the tile is not big enough to carry both the road water and the ground water. In point of fact the surface water is in and away before the seepage flow of the same storm begins to reach the tile. Consequently the greatest danger is that of clogging the tile. Farm tile are usually small in size and laid to irregular grade and alignment without manholes and hence may be easily clogged with sticks or silt. The danger can be largely overcome by introducing the water into the tile through a catch basin provided with a gooseneck or trap between it and the tile. A reasonably good catch basin can be made of 30 inch tile set on end with a grating cover and with a 6 or 8 inch elbow with its mouth turned downward projecting through the side at the proper depth for the outlet.

The side ditches must have adequate outlets. They should connect to the streams so that the water will run out of them and be carried away from the road. All too frequently obstructions are to be found where the side ditch meets a stream. Often too the blade grader is so operated that the ditch goes up over the bridge and culverts instead of down into the streams.

Of course the ditch must have sufficient grade. 0.1% will do for open ditches but twice as much is better, while the maximum is governed by the tendency of the soil to erode. If the road grade is made level, except on fills, the ditch must become deeper as it proceeds and thus becomes a menace to traffic. In cuts, however, the ditch may start with a very shallow depth at the crest and then deepen as required, often without attaining objectionable depth.

On embankments the grade of the road may be level, since the water drains away laterally to a lower level. Side ditches may not be required at the toe of the embankment, depending on the nature of the adjacent ground. Often, however, the fill is made from borrow pits and these should be carefully located and constructed so as to form drainage channels to the streams.

The cross section of the ditch should be such as can be easily constructed and maintained with the ordinary road machinery. The outlets, however, may require some other method. A V-shaped ditch or one with a narrow bottom such as can be made with a blade grader is perhaps the best. Naturally such ditches will have a rather flat side slope next to the roadway and this is highly desirable on account of safety to traffic. The deep, steep-sided ditch is a menace to traffic and many a life has been lost in such a ditch.

A close relative to the side ditch is the intercepting ditch. If a cut traverses a hillside where a large amount of land drains toward the road it may be necessary to protect the slope of the cut and the side ditch from destruction by water flowing down the hillside. This is accomplished by constructing an intercepting ditch a short distance back from the edge of the cut. It is imperative that this ditch have ample capacity so that it will not overflow and cut a channel into the cut. It should be well constructed and provided with a good outlet.

Bridges and Culverts

The third item in surface drainage has to do with the natural streams or outlets. Culverts and bridges must be provided to carry the road across these streams, and the effectiveness of the entire drainage system may be affected by the manner in which this is done. It is not commonly considered that an embankment is a drainage structure but in reality that is what it is. With a grade line well above high water, the surface water drains away quickly, or it is possible to provide side ditches that function at all times and also to secure reasonable subdrainage. But with a low grade line the road is not only flooded but all the usual drainage structures are also rendered inoperative during high water.

Each bridge and culvert must provide ample waterway so as to prevent flooding of the lands by holding back the water. It is not always possible to know how much waterway is necessary, but the attempt to determine it should never be slighted. It is by no means infrequent to find the smaller culverts and bridges, especially on the township roads, grossly inadequate. This may be due to the fact that many officials do not sufficiently understand stream flow to estimate the size needed or it may be due to a lack of funds or to a penurious policy on the part of the officials. On the other hand, many structures are often entirely too large. While excess size does not interfere with the drainage, it does use up funds that would give better returns if spent elsewhere.

There is one kind of culvert that presents many problems. This is the farm entrance culvert. Its purpose is to provide a driveway from the road over the side ditch into private property. In so doing it must provide ample waterway for the side ditch or it will cause flooding and possibly erosion of the roadway. It is therefore not sufficient to make a single standard farm entrance and use it indiscriminately. At each location the size of the opening should be studied and a culvert of ample capacity provided. However, the minimum size should be such as to avoid the danger of the opening becoming obstructed by sticks, stalks, and floating debris. A minimum size of about 12 inches seems desirable.

Entrance culverts should be placed at proper grade. There is often a tendency to place them too high and adjust the side ditch to them or to place them too low to be effective. The grade of the ditch should be established and the culvert made to conform to it.

Corrugated iron pipe, cast iron pipe, common tile, sewer pipe, precast sectional concrete culverts, and built-in-place culverts of concrete or masonry may be used at entrances.

There are some men who contend that all entrance culverts should be of the highest type of structure, just as cross culverts are. There are others who seem to be content with any old thing. A choice somewhere between these two extremes, or perhaps a judicious use of all types, is the proper answer to the problem.

Let us take for example the main entrance to the farm. Here are located the house and other buildings. The location is permanent and the improvements are definite. This is the place to build a high type of structure. Such a culvert will be worth the added cost in appearance and harmony with its surroundings if nothing more. Let us now see what should be used for a field entrance at some distance from the house. Here there are no improvements and the traffic over the culvert is infrequent. In this location the high type culvert is out of place. It costs too much for the service to be rendered. The location may not be fixed; a few years and the farmer wishes to enter his field at some other point. Consequently a culvert of simple corrugated pipe, tile, or possibly precast units is entirely suitable if properly installed. It can be made of sufficient capacity. Its looks are satisfactory, and in case of necessity it can be easily taken up and moved to another point.

There are also those who contend that all entrance culverts should have headwalls, but again this is not always necessary. The conditions of flow are somewhat different from those in a stream crossing the road, and advantage can be taken of the fact. If the side slopes of the driveway fill are made the same as the side slopes of the ditch and the culvert barrel lengthened accordingly, no headwall is necessary. Furthermore, a continuous row of white headwalls along the road is not especially attractive in appearance, and these hard structures have often proved dangerous and destructive to vehicles accidentally running into the ditch.

The length of an entrance culvert should be sufficient to provide driveway of sufficient width and accommodate any side slopes that may be given the fill. A field drive should be at least 8 feet wide and preferably 10. Entrances at houses should be at least 12 feet because, being used more frequently, they should be wide enough to be easily turned into. If headwalls are used, this should be the distance between headwalls. If headwalls are omitted, the culvert barrel must be longer. For example, if a ditch is 2 feet deep below the road crown and has the side slope of 2½:1, then 5 feet is required on each end for the slopes, making the minimum length of pipe 22 feet.

In a number of instances old corrugated pipe, tile, and even sectional culverts have been dug out during the reconstruction of a road and reemployed as entrance culverts, adapting the different types and sizes to suitable locations. Whenever these old structures are suitable for reuse, they effect a real saving.

Subdrainage

As stated previously, part of the water falling on the surface does not run off but enters the soil and becomes known as ground water. Part of the ground water is retained by capillary action, part of it is taken up by vegetation, and the remainder percolates through the soil under the action of gravity as free water.

The amount of capillary water in a given soil tends to remain constant; hence capillary action will draw water a considerable distance above free water level. Capillary water itself rarely causes trouble in a road, but the amount of it in the soil may be so near the critical point at which the soil quickly softens that only a small amount of additional water is necessary to make the soil unstable. Saturation occurs when the voids in the soil are filled with free water.

At some distance below the surface, ground water constantly saturates the soil. The top of this saturated portion is called the ground water level or the water table. The water table constantly fluctuates, rising in periods of rainfall, often entirely to the surface, and falling again when the rain stops. Interference with the natural outlet of the ground water will cause the water table to rise, while a clear outlet will cause it to fall.

Underdrainage does not drain off capillary water; but since the amount of capillary water decreases with the height above free water, a low water table reduces the amount of capillary water at the surface and provides a greater head for water entering the soil to percolate to the ground water level. In this way a small rainfall causes less complete saturation of the surface, and after a heavy rainfall the excess water quickly descends and the surface quickly dries out to normal.

Underdrainage may be accomplished by means of open ditches, blind drains, and tile or some other form of pipe.

Open ditches are suitable for subdrains only in localities where it is safe to make a ditch deep enough to tap the ground water level and where freezing is of rare occurrence. The open ditch is dependent on seepage through its sides for its success, and if the banks freeze, the ditch becomes inoperative. As this is likely to occur in the spring when the ground is frozen or covered with ice, the soil full of water, the ditches flooded, and the sun thawing the road surface, the open ditch loses its effectiveness right at the season when it is most needed.

Blind drains consist of a trench more or less completely filled with some kind of porous materials, such as sand, gravel, cinders, or broken stone. Obviously it may prove quite effective in collecting ground water, but since the water must flow away by percolation through the porous filling, it is equally obvious that the carrying capacity of a blind drain is not large. It is therefore suitable only to carry small quantities of water short distances or to collect the water more quickly into some other form of main drain. Blind drains that work well at first sometimes lose their value because of silt getting into and clogging the porous filling.

The best subdrain is the tile, either concrete or clay. When the tile is unglazed, water will filter into it throughout its entire length and circumference and hence it collects the water quickly. If greater collecting capacity is needed, blind drain laterals and porous backfilling are effective.

Vitrified clay pipe and dense concrete pipe can collect water only through the joints, but they are used for subdrains where the soil is not silty. Perforated metal pipe is also used and often proves effective. It is a question, however, whether the steel or iron pipe is economical except in temporary locations, for no matter how excellent the metal, it will rust out long before the clay or concrete pipe disintegrates. The metal pipe, however, does have one advantage in that it is less liable to disruption by earth movements and may therefore be desirable in installations for controlling land slides.

The ordinary earth road in flat farm lands presents some interesting drainage problems. In the first place, surface drainage is likely to be sluggish and flooding of the road consequently frequent. The crown should, therefore, tend towards the maximum permissible, the side ditches should be of ample size, and the outlets the best conditions afford. The side ditches will act somewhat as underdrains in the summer but not in winter when frozen or during periods of heavy rainfall when they are full of water.

If the farm lands are tiled, no additional underdrains may be necessary in the road and yet they may be desirable. Ordinarily one line of tile placed under the side ditch on the side from which ground water approaches will serve. As indicated previously, this underdrain will not prevent the road from becoming muddy, but it lowers the water table so that the excess water from rains quickly descends and the road soon dries out. Experiments by the Illinois Division of Highways on clay and loam soils showed distinctly that such drains materially reduced the time of drying but did not prevent saturation.

In the winter time the freezing of stream banks, the freezing of the streams themselves, and high water in the streams offers obstruction to the outlet for the ground water, and the water table rises. When the road thaws out, the thawing takes place from the top down and the bottom up. The water released on the surface must escape by evaporation or by percolating to the sides, with the result that a surface layer of mud develops. If the water table is high, the thawing from below merely transforms the layer of ice into mud; and when the ice sheet finally breaks through, a few inches below the surface, mud meets mud and the "bottom falls out" of the road. (See Fig. 1.)

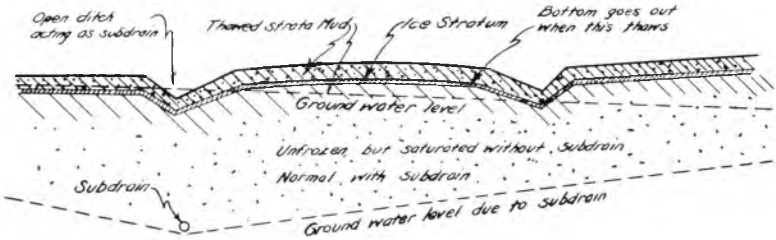

Fig. 1. Effect of high water table.

A tile drain placed below the frost line and provided with a free outlet will greatly improve conditions. Although surface thaw will still act as before, giving a muddy surface, the drain will take away the water released by the thawing below so that when the ice sheet breaks the ground below is reasonably firm and hence does not go to pieces; and just as soon as it breaks through, the water in the surface will descend and the top dry quickly. Of course, if the road authorities have been wide awake and have dragged the surface several times while it is thawing, much of the top water will have been worked out and disposed of and the road will dry up smooth and firm.

Another interesting condition is presented by the road on a fill several feet in height (Fig. 2). It has often been ob-

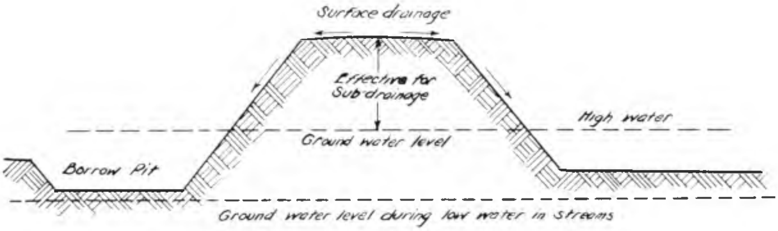

Fig. 2. Road built on fill.

served that such roads even across swamps are normally in excellent condition as compared with nearby roads on ordinary ground or in cuts. This is altogether a matter of drainage. If the road surface is kept well crowned and free from depressions, the surface water quickly drains off, since the distance is short and the fall is large so that there is little chance for the water to enter the soil. At the same time the road is above the adjacent land so that water does not flow onto it from elsewhere. The road therefore enjoys the best of surface drainage.

Likewise the subdrainage is of the best. Since the roadway is raised above the surrounding land and consequently above the normal water table, any water entering the soil of the roadway quickly descends. Even when the ground is frozen and the general water table rises, it will not rise above the level of the free water adjacent to the embankment; hence at all times the soil is low in capillary water, and any water that may enter or be released by thawing speedily percolates away.

Drainage in Cuts

In contrast to the fill is the adjacent cut (Fig. 3). Here the conditions are almost exactly reversed. The road is de-

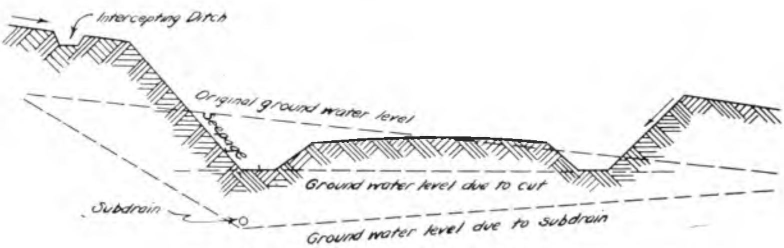

Fig. 3. Effect of adjacent cut.

pressed below the adjacent lands so that the water from them tends to reach the road. Water from the road itself must be collected in the cut and, with the water from other land, be carried longitudinally out of the cut, thus giving maximum opportunity for percolation into soil and requiring the maximum provision for handling surface water.

In addition, the ground strata are cut, and water percolating in any of them is thus tapped and discharged into the road. If these water-bearing layers outcrop in the roadway itself, springy places result that are difficult to cure and that often disrupt even the best types of pavements.

For surface drainage of such a cut the side ditches must be adequate, and intercepting ditches along the edges of one or both sides of the cut may be needed. If springy places show, either in the roadway or in the sides of the cut, underdrains will be necessary. If the ground water comes in from the side, increasing the capacity of the side ditch may be a sufficient remedy. If it enters near the road level, a subdrain placed under the ditch on that side may intercept it. Of course, if an impervious stratum underlies the one carrying the water, a tile placed below the former will do little good. This error sometimes has been made.

If the ground water flow is essentially parallel to the road and is tapped by the road slope, the only effective method is to place underdrains in the resulting springy place in the road. Blind drains leading to the side ditches are often used but are of questionable efficiency. If a hard surface is to be placed on the road, it is much better and but little more expensive to place tile drains 1½ to 2 feet below the crown of the road, backfill the trenches with gravel or stone, and connect these laterals to a main tile along the roadside leading to an adequate outlet. These tiles should be not less than 4-inch and perhaps better 6-inch and should be of good quality so that freezing will not disintegrate them.

An interesting example of underdrainage was brought to the speaker's attention a few years ago. (Fig. 4.) A gravel

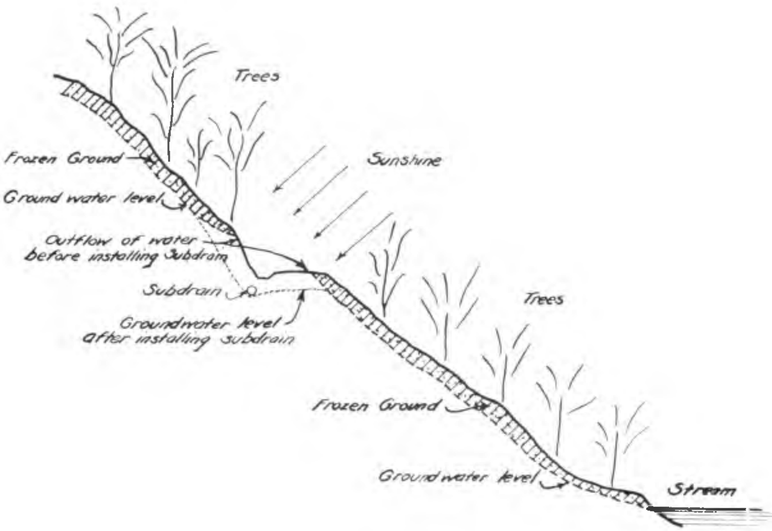

Fig. 4. Road built on side of hill.

road wound down around the shoulder of the hill. Early in the spring and sometimes during winter thaws water would break out onto the road at one place for a distance of several hundred feet, and the entire road would become a mudhole. Many attempts were made to remedy the trouble, including the making of a bigger ditch and the driving of sheet piling as a cutoff wall, but to no avail. It was finally observed that at this point the timber had been cleared off so that the sun got a clear opening to the road, while the remainder of the hillside and the stream in the valley were still largely in shadow. This suggested that the sun shining on the exposed section of the road thawed it out before the rest of the hillside thawed, with the result that the pent-up ground water flowed out onto the road. A large tile was therefore placed a few feet below the ditch on the uphill side of the road and the trouble was cured. At the times when the road had formerly broken up this tile discharged a large amount of water but was entirely dry in the summer.

Another important use of underdrains is in the controlling and preventing of land slides. Many, if not most, of these slides are due to unbalanced earth strata which under the action of water tend to move. Hence, the movement can be prevented by suitable drainage. Many examples of this could be cited, but time does not permit. Mr. Geo. E. Ladd of the U. S. Bureau of Public Roads has been making a study of these conditions and presents some valuable discussion of them in *Roads and Streets* for November, 1928.

THE COLLECTION AND DISTRIBUTION OF GASOLINE TAX

By A. N. Bobbitt,
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In the study of the collection, distribution, and uses of gasoline tax, it might be interesting to give some consideration to the history and development of the gasoline tax.

The first proposal for a tax on gasoline that was given any serious consideration was made by President Wilson in his address to congress on December 7, 1915. At that time he estimated that a tax of one cent per gallon on gasoline and naphtha would yield a revenue of $10,000,000 per year.

The World War was then in progress in Europe and it was a question as to how much revenue the tariff would produce. The gasoline tax was considered as a ready means for making up the deficiency which was expected to occur in the revenue derived from the tariff.

This recommendation of the President was not taken seriously. It did, however, provoke some interesting comment from a few newspapers. The *Horseless Age,* the oldest automobile magazine in America, said in its editorial comment, "What gasoline is to automobiles, oats are to horses, so let's tax oats too, and see what revenue we can get from that source. A levy of three cents per bushel on oats would be equivalent ad valorem to one cent per gallon on gasoline. As the production of oats amounts to above 1,153,000,000 bushels per year, according to the Department of Agriculture, the revenue to be derived from the tax we propose would amount to $34,590,000.00, quite a tidy little sum and more than three times what the president hopes to get from his tax on gaso-