no part of the patch will be less than one inch thick. The old concrete should be trimmed away until all loose material is removed and the surface and edges are perfectly sound. Then the edges and bottom should be made wet, taking care not to leave any water in the hole. Mix new concrete using as nearly as possible the same materials as used in the original pavement and in the same proportions except that the mixture should not be leaner than one part Portland cement, two parts sand, three parts pebbles or crushed rock. This coarse aggregate should be of maximum size corresponding to about half of the depth of the hole to be repaired. The concrete for the patch should be mixed immediately before it is to be used with just enough water to make it mix well. Place the concrete in the hole to be patched, tamping it firmly against the sides of the hole so as to leave no cavities. It should be allowed to stand for a few minutes to settle and dry, then it should be retamped. This should be kept up until it has been tamped the third time, letting it dry between each time of tamping according to the condition of the weather. It will dry much faster in hot or dry weather than at other times. The hole should be slightly over filled at first so as to take care of the extra tamping and settling of the mixture, in order that the patch may be as nearly level with the surface of the surrounding pavement as possible. After the third tamping the surface of the patch should be worked over with a wooden hand float taking special care to produce a good finish at the edges so that there will be no seam or crevice between the edges of the old and new concrete.

The berms of a concrete road should be up even with the surface of the pavement but no higher so that the water will not be held on the road but will immediately drain off to the side ditch and be carried away. It is a good idea to sow the new fresh berms with rye and later with timothy or blue grass, as the roots of these grasses will aid materially in preventing washing, and also add to the appearance of the road.

DRAINAGE OF ROADS.

By Don Heaton,
Benton County Engineer.

I know of no subject that is as much talked about, as generally agreed upon and as little practiced as road drainage. By this I do not refer to elaborately designed systems, but just the ordinary common-sense precautions that we all talk about and so often fail to carry out.
From a study of the subject it seems to me that the time spent on highway investigations and research in the last 20 years could be divided in about the following proportions: on the design of new road surfaces, 80%; on the foundations, subgrades and drainage combined, about 20%.

A few years ago, when heavy motor traffic first began to appear, many roads failed because their wearing surfaces did not have the necessary strength to withstand the demands of heavy traffic even when supported on stable foundations and subgrades. Undoubtedly the failure of the early pavement surfaces has been largely responsible for so much attention being directed in late years to developing road surfaces that would support our present day traffic. Now, however, the rather annoying regularity with which some of the strongest and best developed pavement designs have failed in very recent years would indicate that subgrades and drainage are about to receive their rightful share of attention and that the above percentages are to be changed if not actually reversed.

One of the first problems that concerns the highway designer is that of making the subgrade firm and strong enough to bear up the loads that come upon the road surface. For illustration, it is not hard to conceive of this being accomplished by the construction of a heavy foundation of such great thickness that in spite of poor drainage the road would not fail, due to the enormous effective depth from the surface of the road to the base of the foundation. On the other hand it is just as easy to conceive of the same stability being accomplished with an extremely light foundation and a subgrade kept dry by elaborate and expensive drainage works.

Between the two extremes there must be some economical half-way point, the determination of which will tell us how much money to spend for foundation and how much to spend for road drainage.

This is one of the road drainage problems that the highway research man will have to solve in the immediate future. I wish him easy sailing, though I don't know of another problem that involves more variable quantities.

Until recently, no one thought much about capillary moisture as a possible cause of subgrade failures. The usual practice in draining a road is by means of side ditches, under drains of tile and stone, or both, to remove surface and ground water. In spite of all these precautions many well designed roads have failed on account of very wet subgrades.

Repeated accounts of such failures brought on a series of experiments by the Bureau of Public Roads, to determine something about capillary moisture and methods of meeting its effects.
by road drainage. Briefly, the results of some experiments in this line conducted by the Bureau of Public Roads are: that, under favorable conditions of soil texture and temperature, capillary moisture moved a vertical distance of sixteen inches to six feet in twenty-four hours; that horizontal capillary action is much more rapid than vertical; that water has been observed to move in a horizontal direction in distances ranging from seven to thirty-three feet in twenty-four hours; and that the quantity of water and the rate at which it will move depend upon the sizes of the pore spaces between the soil particles. If the pore spaces are small, the movement of water will be relatively rapid, and the amount of water held against the attraction of gravity will be relatively great. If the pore spaces are large, the vertical or horizontal movement of water will be slow and the amount held in the soil will be small.

Even the slightest consideration of these figures and findings must leave no doubt in our minds that the natural law at work through capillarity must be faced in the design of road drainage and road subgrades. Vertical capillarity has been successfully met in many cases by placing a layer of material of low capillary power such as heavy crushed stone or coarse screened gravel, directly beneath the pavement. Attempts to stop horizontal capillarity include the design of vertical concrete cut-off walls extending about three feet below each edge of the pavement, tile drains on each side of the road and with trenches filled with broken stone, and by waterproofing ditch banks and subgrades with crude oil or tar preparations, or combinations of all three of these methods.

A mistake sometimes made in road drainage is the attempt to apply farm drainage methods to highway drainage, especially in the underdrain systems. In many respects the two call for widely different plans and considerations. There are many cases where tile drainage is a complete success in farm land, while in an adjacent highway the tile drain might be a very questionable investment. Extreme rapidity of action in farm drains is not as essential as in road drains. If a farm drain is so designed that the water table is lowered beyond the limit of capillary rise for that particular soil, the drain had better not be put in, as the one form of moisture essential for crop growth is capillary moisture. On the other hand, the ideal drain for a highway is one that eliminates capillarity completely.

Apparently the best practice in road drainage in the immediate future is going to include extensive studies of soil conditions over the route of any proposed project. Standardized methods of drainage for mile after mile of road up hill and down through cut and fill, will be replaced by adequate drainage plans to meet every condition of soil and moisture.