It is interesting to compare Design and Construction Practices before and after World War II.

Design and construction practices since World War II have changed many old methods, to try and accommodate today's volume and kind of traffic. These changes have resulted in better alignment, greater sight distance, wider and thicker pavements, wider right of way. The use of the third lane of traffic on hills is proving very satisfactory. The increased use of flumes and paved ditches, seeding and grassing of cut and fill slopes on new construction prevents erosion and adds to the appearance of the road.

The use of thicker insulation courses under high type surfaces is a partial solution to pumping of concrete surfaces and to base failures on bituminous concrete surfaces. Some of our neighbor states have had success on heavily traveled roads by using a 10 to 15 inch sand gravel cushion from shoulder to shoulder under pavements.

During the 1920's and the early 1930's the greater portion of our roads were constructed with one idea in mind; "connect each and every county seat and provide all year around travel". Many miles of this early construction had poor visibility, sharp curves, both horizontal and vertical, steep grades, one-way and low capacity bridges, narrow and light pavements. This was in the days before high speed automobiles and heavy trucks were so numerous.

Many years ago a prominent highway engineer was asked to name the three most important features pertaining to the construction and maintenance of a highway. His reply was, "The first one is drainage, the second one is drainage, and the third one is more drainage."

We know this is a true statement, because water is the arch enemy of road builders. Drainage properly installed and maintained is the only effective means of combating this enemy. "An ounce of prevention is worth a pound of cure."

Kentucky is so located geographically that we have more miles of rivers, creeks and branches than any other state in the Union. It naturally follows that we have more bridges, large box culverts, small box culverts and pipe culverts per mile of maintenance than any other state.
We have all seen sections of well drained roads, with little or no surfacing that were so well compacted that they showed no displacement by very heavy traffic. This should indicate to us that the proper design of a drainage system and pavement section of any road is a compromise between spending more money for adequate drainage, or spending more for thicker pavement surfaces.

Maintenance men spend a great portion of their time and effort correcting the effects rather than the cause of bad drainage. Opening up pipes and culverts that have become stopped up, opening outlet ditches, installing french drains, paving ditches, replacing headwalls that have been undermined and have fallen off. "A culvert that is stopped up is as useless as a glass eye at a keyhole."

Pipe culverts are more numerous than any other type of drainage structure, and if properly located, installed and maintained is an integral part of the entire drainage system. Unlike bridges and box culverts, they may become stopped up and the road is not immediately damaged, however if left in this condition the base of the road will become water-logged and the surface will fail.

Selecting the Proper Type and Size Pipe Culvert

The Division of Design has found that certain types of pipe culvert are not suited to certain sections of the state, due to the presence of salt water, mine water or industrial waste water, or sewage, as the acid usually present in such drainage is injurious to metal, and sometimes concrete. At this time certain types of pipe culverts are restricted in certain sections of the state for the reason given above.

I find that the proper location of a pipe culvert is very important. An improperly located pipe can be a liability rather than an asset. The pipe should be so located that all the water to be carried by the pipe can get into it quickly and easily. The pipe should be self cleaning.

The maintenance engineer finds that many pipe culverts are not properly installed. If a pipe culvert is not properly installed it will not function as intended. The flow of water it is installed to carry should be uninterrupted. To accomplish this, the following factors should be considered:

1. The inlet should be placed in such a position that the water can enter the pipe without any interference.

2. The pipe should be placed as nearly as possible in line with the average flow direction of the water. *This does not apply to pipe culverts installed for ditch relief on grades. These should be installed askew instead of at right angles to the center line of the road and on a
grade not less than the grade of the road. The pipe should have an ell headwall on the inlet end.

*NOTE:* Twenty years ago while serving as resident engineer on KY-80, between London and Somerset, I had the contractor install all pipe culverts for ditch relief, on askew. This lengthened each pipe from six to nine feet, however, it allowed each pipe to have a grade equal to the grade of the road. These pipe culverts have never stopped up. This would be a good time and place to tell what happened to me about fifteen (15) years ago while serving as maintenance engineer in District 7. A pipe culvert under US-23 south of Paintsville would stop up at each rain. The water would overflow the road and it was necessary to open the pipe by hand. This pipe was installed at right angles to the center line of the road and ditch water had to make a right angle turn to get into the pipe, then the outlet ditch was parallel to the road and at right angles to the pipe, it stopped up at each rain due to the pipe being too low. Once while opening the pipe an old man living near the inlet end of the pipe approached me and said, “Young man do you know why that pipe stops up every time it rains?” “Well”, he said, “If you don’t know, I’ll tell you, IT AIN’T GOT NO SUCK.” That has stuck with me until this day. If a pipe stops up, the chances are “IT AIN’T GOT NO SUCK.”

3. A pipe installed with sufficient fall will be self-cleaning, and no sediment or debris will lodge in the pipe.

4. The flow line should be a straight grade, if possible, and in no instance should a grade of the flow line change from a steep grade to a flatter grade. There is no objection to changing from a flat grade to a steeper grade.

5. The grade of the outlet or tail ditch should be equal to, or greater than, the grade of the pipe. Otherwise the outlet ditch will be filled with sediment. A paved spillway or flume is needed at the outlet end of many pipe culverts to protect the fill slope and prevent undermining of headwalls. The same applies to cut slopes at inlet end when the water runs straight down the slope to the pipe.

6. The grade of the inlet ditch should be the same as the inlet end of the pipe, this will aid the water in getting into the pipe.

7. The grade of the flow line of pipe culverts, except in cut sections, should conform with the average old ground line, or the average channel grade, otherwise erosion or sedimentation will result.

8. A pipe culvert should not be installed at a point in a cut of fill section where there is any indication of slides, slips or settlements, because only a slight movement will pull the joints apart, permitting
water to leak into and thus accelerate the movement of the soil, thereby causing a surface failure in the road.

9. All pipe culverts should have some type of headwall, at least at the inlet end and preferably at both ends. Headwalls prevent under-scour at the ends of the pipe, facilitate water getting into and out of the pipe, show the location of the inlet and outlet of the pipe.

**Box Culverts**

Box culverts rank second in number to pipe culverts in use on the highway system. Box culverts usually carry more water than pipe culverts and in most instances cost more. Failure of a box culvert to function is likely to result in great damage to the road. Box culverts, like pipe culverts, must be of the proper type and size, and must be properly located, installed and maintained, if they are to furnish effective and continuous service. Multiple box culverts are not satisfactory where we have a quick runoff, as they tend to catch drift and in many cases the water runs over the road. A single span structure is preferred.

**Pumping**

Prior to 1940 the term “Pumping Pavements” was seldom heard. However, during World War II, load restrictions were eased to aid in the movement of war material. This was the beginning of serious pavement pumping. Our roads were not designed to carry this heavy traffic.

Why do surfaces fail?

There should be no doubt about the cause: poor foundations, which may be due to lack of adequate base or lack of proper drainage — or both.

Highway engineers agree that the majority of pavement failures are due directly or indirectly to excessive subgrade moisture. “Get the water out and keep it out”.

Design and construction engineers will be open to criticism for poor design and construction practices until adequate drainage and good foundations are built into our roads.

At present we have approximately 15,000 miles of roads under state maintainence and 4,059 bridges. 679 of these bridges are sub-standard. *(Vertical clearance less than 14'. Horizontal clearance less than 18'. Less than 15 ton capacity.)* To adequately maintain this mileage and these bridges would require double the amount of funds now available for maintenance.

Our roads are wearing out faster than we are rebuilding them. What are we going to do about it? Two things are certain: 1. We must spend more to get the kind of roads we need, 2. We must see to it that the money is spent wisely.