SOILS, THEIR CLASSIFICATION, AND SOME OF THEIR RELATIONS TO HIGHWAY CONSTRUCTION

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When we refer to soils in highway construction, we include all material encountered in construction excavation exclusive of coal, rock and all types of shale.

The textural classification of soils are noted as clays, silts, loams, sands, silty clays, silty loams, silty sands, clay loams, sandy loams, silty clay loams and sand clay loams.

The sand, silt, and loam classification usually indicates the better soils while the clay classification usually indicates a bad soil. The sands, silts and loams with a clay combination classification may be either a fairly good soil or a very poor soil. If the soil contains enough plastic clay to cause detrimental lubrication when exposed to water, then the soil will be bad.

The textural classification of soils is based entirely on gradation so it is easy to see how soils of the same gradation may vary much as to their suitability for roadway construction. An extreme example would be where one soil had its derivation from a silica sand and another soil of the same gradation had its derivation from a soapy shale. The origin of the larger soil particles is a very important factor in subgrade samples where the actual subgrade is composed of soil mixed with pulverized rock and shale from adjacent cut sections. It is apparent that gradation alone is not an accurate test for evaluating soils as to their suitability for highway construction.

A second classification of soils we use in known as group classification. This group classification is noted as an A-1 through A-7 with soil having a tendency to decrease in construction value as the number increases. There is also a number in parenthesis which shows the tendency of a soil in a given group to decrease in value as the number in parenthesis increases. For example an A-6 (4) soil should be better than an A-6 (12) soil. In this group classification, an A-1 (0) soil should be the best and an A-7 (20) soil should be the worst. The Bureau of Public Roads had a large part in developing this group classification and it is surely a step forward over the old P.R.A. classification. The factors that control the group classification are gradation, liquid limit, plastic limit and plasticity index of soils.
We have developed a modified CBR test of soil that is used in connection with other standard tests and we believe the combined information furnishes enough data on soils to make an intelligent evaluation as to the suitability of said soils for construction purposes.

The C.B.R. test is made by compacting a sample of soil at optimum moisture with a hydraulic press. The compacted sample is then immersed in water with enough lead plates and weights on the sample so that said weight in water will equal the approximate weight of a standard concrete pavement in air. The sample remains immersed in water until it does not swell more than three thousandths (0.003) of an inch in a twenty-four (24) hour period. All samples have a minimum swelling period of seventy-two (72) hours even though it does not show a three thousandth (0.003) of an inch swell. We have found that many of the heavy clay soils will require a swelling period of eighteen (18) or twenty (20) days while many of the sand and silty soils will swell all the would ever swell before the three (3) day swelling period is up.

After the sample has swelled as outlined above, it is taken out of the water and a penetration is run with a steel pin having an end area of three (3) square inches. The amount of pressure in pounds required to cause the steel pin to penetrate the soaked sample is recorded for 0.1, 0.2, 0.3, 0.4 and 0.5 of an inch. The readings are then reduced to pounds per square inch for each of the above penetrations. These readings are then compared to a standard for each penetration. The standards used are the ones worked out by California and reported in the Highway Research Board Publication of 1942. The standard for the respective penetrations of 0.1, 0.2, 0.3, 0.4 and 0.5 of an inch are 1000 pounds, 1500 pounds, 1900 pounds, 2300 pounds, and 2600 pounds per square inch. The CBR for any penetration is the percentage of the actual pounds required per square inch to make the penetration based on its respective standard. For example, if it required 100 pounds per square inch to penetrate a sample 0.1 of an inch, then 100 divided by 1000 would give 10 per cent. The CBR at 0.1 penetration would be 10.0.

It is very seldom that the CBR will be the same for each of the five (5) penetrations made on a soaked sample. The question then arises which CBR should be used for an evaluation. It is the opinion of the soil department at Frankfort that the trend shown by the five penetrations should determine the evaluated CBR. If a soil shows an increase in its CBR value from the 0.1 penetration to the 0.5 penetration, then the soil should be given its greatest CBR value which would be at the 0.5 penetration. If a soil shows a decrease in its CBR value from the
0.1 penetration to the 0.5 penetration, then the soil should be given its smallest CBR values which would also be at its 0.5 penetration. If the CBR values vary slightly up and down from the 0.1 penetration to the 0.5 penetration, then give the soil the average CBR value. Often the CBR for the 0.1 penetration will be considerably different from the other penetrations and the four penetrations will be reasonably close together and in this condition we would average the four CBR values. We consider this condition a leveling off trend. Sometimes this leveling off trend will be based on the last three CBR values. We believe there is sound reasoning for using the trend in selecting the CBR value. If a CBR value increases as the penetration and load increases we feel this is a strong indication that the soil builds up resistance when the load is increased, due probably to internal friction. If a CBR value decreases as the penetration and load increases, we believe this is a strong indication that much of the bearing value of the soil is due to its cohesion and heavy loads are detrimental to such cohesive forces.

The question that probably arises at this time is what CBR value constitutes a good subgrade. A soil with a CBR value of eight (8) should have enough bearing value to carry the loads transmitted to it under our standard concrete pavement or under a flexible pavement with a total thickness of eleven or twelve inches provided the nature of the soil is such that all the water that collects or condenses at subgrade elevation will drain through the subgrade and not have any slight ponding of water at subgrade elevation. The amount and type of clay in the subgrade soil are the factors that will determine this drainage condition provided the water table is low enough to permit such drainage.

When the clay plus P.I. content of a subgrade soil is less than 45, it is believed that said subgrade soil will permit all the water that collects or condenses to drain through it under a well constructed pavement and subgrade. A subgrade soil with a CBR value of eight (8) and a clay plus P.I. content of 36 would very probably be better than a subgrade soil with a CBR value of twelve (12) and a clay plus P.I. of 55. There are two principal reasons why the soil with the CBR value of eight would be better than the soil with a CBR value of twelve mentioned above. The first reason is that the subgrade moisture would drain through this eight CBR soil much better and the second reason is that this eight CBR soil would have a better rebound and would have a tendency to stay in contact with the pavement better than this twelve CBR soil. Any one who has watched and studied compaction operations in the field would surely concur in this fact, that as the clay plus P.I. content of a soil increases, the less rebound the soil will
have. An extreme example that shows the rebound characteristics of a soil is well known by most construction engineers, and that is the ease with which heavy clay soils take compaction and the way silts and sands resist compaction by being springy and showing much rebound.

There is a range in CBR values where the clay plus P.I. in the subgrade soil plays an important part in the performance of a subgrade under a pavement. This range of CBR values is between eight and fifteen. Soils within this CBR range with a clay plus P.I. content under 45 will not pump under our standard concrete pavement when subjected to any of Kentucky's heavier traveled roads provided said pavement is placed on a well constructed subgrade of such soils. Soils within this CBR range and a clay plus P.I. content over 45 should have a two (2) inch course of crushed limestone or its equivalent placed under our standard concrete pavement. In this range, two (2) inches of flexible thickness should be added for the clay plus P.I. content.

For soil subgrades with a CBR value of fifteen (15) or greater the clay plus P.I. content is not such an important factor. First, because there will be only a small percentage of soils in this CBR range that will have a clay plus P.I. content greater than 45. The second reason is that a well constructed subgrade with a CBR value of 15 or greater should have enough bearing value to carry any of Kentucky's heavy traffic when under our standard concrete pavement with out having any detrimental deflection when subjected to said heavy loads.

A large portion of soils with a CBR value under eight will have a clay plus P.I. content over 45 and will hold subgrade water when deflections are made in said subgrade due to heavy loads. There will be a few subgrade soils with CBR values under eight and have a low clay plus P.I. content. These soils usually contain a shiny substance called mica. Often these mica subgrade soils will permit a concrete pavement to break up considerably and never show much sign of pumping. These mica soil subgrades would need an insulation course under a concrete pavement to give added subgrade support rather than to prevent pumping. Our real bad pumping soils will usually have a CBR of five (5) and under. The soils that contain a detrimental amount of mica and have a low clay plus P.I. content will usually have a CBR value between five (5) and seven (7).

Suppose we had some soils on a project with a CBR value of three (3) or four (4) and other soils on the same project with CBR values of eight (8) or ten (10) with clay plus P.I. contents under 45. What would it be worth to get the better soils at subgrade elevation? If we were designing for Kentucky's heavy traffic a soil with a CBR value of three (3) or four (4) should have five (5) inches of compacted lime-
stone under a standard concrete pavement. For a flexible pavement, there should be a total thickness of sixteen (16) or seventeen (17) inches. For the better soils mentioned, a standard concrete pavement without any insulation could be used and for the flexible pavement, a total thickness of eleven (11) or twelve (12) inches should be adequate. This shows the problem to be decided on each project or section of a project. Which will cost less, to plan for additional surface material or utilize the better soil at subgrade elevation?

Most sedimentary soils that are found in their natural position will usually occur in three (3) horizons. The top horizon is referred to as top soil, the second horizon as transition soil and the third horizon as parent soil. The parent soil that lays over limestone rock or shale will usually be a plastic clay and a bad pumping soil. For such sedimentary soils, the first two horizons will always be the best material for subgrade construction. Sometimes, the top soil will contain too much vegetation to be satisfactory for subgrade construction. The thickness of the soil horizons may vary considerably from cut to cut but usually in each cut, the horizons will be fairly uniform and be approximately parallel to the original ground line. In some cuts the plastic clay parent soil will dominate the earth construction while in other cuts the plastic clay parent soil may not be more than six (6) inches thick. Soils that lay over sandstone will usually make from fair to good subgrade material. The stream deposited soils or wind blown soils do not necessarily conform to the horizon pattern mentioned above.

With a very little practice, field engineers and grade inspectors could learn to distinguish which soils on their project would make the better subgrade material. The simple test of rubbing the soil between the thumb and fingers would tell which of two soils is better if there is an appreciable difference. The soil that will make a slick ribbon or have a slick soapy feel will make a bad subgrade soil. The soil that will have a silty or floury feel on to a sandy feel will make the better subgrade. While thinking on bad subgrade soils, we should mention that coal bloom, fire clay, pulverized soapy shale and pulverized dark colored shales all make bad subgrade material. If there is very much difference in the value of two soils, it is easy to determine by this feel test which of the two soils is the better for subgrade construction. This feel test is so simple that it is hard to produce confidence in field engineers, and grade inspectors that they can judge the better of two soils by such a simple procedure. As an example as to how practical this simple feel test is, a trained personnel can estimate very closely the actual CBR value of a soil within the range of three (3) to twelve (12).

If we are to get the expected results of designed pavements based
on soil tests, there are a few vital construction problems that must be met satisfactorily. Three construction problems that cause many surface failures shall be considered here. The first one is the subgrade must have adequate density to expect a designed pavement to give satisfactory results. The second problem is proper drainage in rock cuts. The third problem is the water table.

In order to have adequate density, all embankment construction should start at the toe of the slope and proceed in horizontal layer construction until subgrade elevation is reached. If the embankment is made with rock, each layer of construction should be kept reason­ably smooth and all void well filled. It is very probable that rock embankment can be kept in good condition with a bull dozer. Rock embankment should never be constructed in layers thicker than three (3) feet. Often rock embankment can be placed in layers of eighteen (18) inches without causing any hardship on the contractor. Rock embankment should always be placed in as thin a layer as practical without causing undue hardship on the contractor but do not be too concerned about a slight hardship on the contractor because it is a very important construction problem and procedure.

If an embankment construction is made of earth, each layer should be satisfactorily rolled before placing another layer. You cannot satisfactorily roll an embankment section without having some systematic plan for placing and rolling. Just because you have a sheepsfoot roller going on a job does not mean you are getting satisfactory rolling. You can never be sure of getting satisfactory rolling when you are placing the material and rolling it at the same time and in the same lane. It would not be practical to show all the plans for placing and rolling an embankment section but a simple example will be given that shows the principal involved that is necessary to be sure of good compaction. Suppose you had a full roadway width of embankment construction. Begin placing the material on one side and continue with one strip or lane for the full length of embankment to be placed then continue with succeeding strips until the entire embankment width has been covered. After one or more strips have been placed, start the sheepsfoot roller on the first strip that was placed and roll said section until the roller walks out or is satisfactorily rolled. By the time the hauling equipment has the full roadway width covered, the sheepsfoot roller should have the first half of the roadway width satisfactorily rolled and ready for the next layer of construction to start. Proceed in like manner for each layer of construction. This plan shows that the material is being placed and rolled in separate sections at the same time and it is the simple principal involved which will let a grade inspector know if he is getting adequate compaction.
If the feet on a sheepsfoot roller has the proper end area and the roller has proper weight and the soil is at approximately optimum moisture satisfactory density will be obtained when the roller walks out. When these conditions are met, the inspector can just watch the roller in operation and tell when satisfactory compaction has been obtained. The size of the feet and weight of the roller may be obtained from our specifications. The question that would probably arise here is how may I tell optimum moisture. Our experience in the soil department has been that optimum moisture is a little drier than most engineers and inspectors think. If you will squeeze tightly a handful of soil it should form a slightly friable ball and discolor your hand only slightly. The feel of optimum moisture is very similar for all soils. The optimum moisture for sands and gravel will feel considerably wetter.

It is very seldom that any trouble is encountered in getting satisfactory density with the heavy clay soils that make such poor subgrade material. It is also very seldom that we fail to have trouble getting satisfactory density with many of our better subgrade soils. The optimum moisture content for compacting good soils is very definite and critical. It is very seldom that any trouble is encountered in getting satisfactory density with the heavy clay soils that make such poor subgrade material. It is also very seldom that we fail to have trouble getting satisfactory density with many of our better subgrade soils. The optimum moisture content for compacting good soils is very definite and critical. If many of our good soils are compacted at slightly above optimum moisture said soil will not have enough bearing value to carry the heavy hauling equipment the contractors use today so the density of the previously compacted layer will be broken and the soil will develop a springy, spongy nature. Most clay soils that will make a bad subgrade under a pavement will have a better bearing value at its optimum moisture than our good subgrade soils. This fact explains why the clay soils will carry the contractors heavy equipment well during construction while the good soils have a tendency to get springy. This difference in bearing value of soils during construction is much more pronounced when compaction is undertaken while the soils are above optimum moisture. The difference in the way soils react to a contractor's heavy equipment makes it hard for most all contractors and some engineers to believe the soil department's evaluation of soils. Generally speaking, most soils that are easy for the contractor to compact will make a poor subgrade and the soils that are hard to compact are good subgrade soils. Whenever an embankment grade gets springy and spongy it is almost a sure sign that the soil is good and that you are trying to compact it above optimum moisture. After an embankment section gets springy and spongy, it is very difficult to get satisfactory density on the succeeding layers because you are trying to compact against a spongy base. If there is room one or two layers of clay construction will usually correct a spongy base to where satisfactory
density can be obtained on the good soil on to subgrade elevation. Clay subgrade soils that have a good bearing value during construction will eventually get wet under a pavement and have a very low bearing value to a probable depth of six (6) to nine (9) inches. Clay soils will absorb the subgrade moisture to the approximate depth stated above while good soils will permit the subgrade moisture to drain through it and its bearing value under a pavement will be almost as good as its optimum moisture bearing value or practically as good a bearing value as it has during construction.

Often road failures occur in rock cuts due to the rock subgrade or rock side ditches. Provision should always be made for water to drain from a rock subgrade toward the side ditches. It is realized that it would not be practical to require all rock pockets to be kept out of a rock subgrade but wherever such pockets occur, a trench should be cut to permit that pocket to drain toward the side ditch. Rock ditches should be so constructed that water will not be turned into the subgrade through shattered rock caused by shooting. If rock pockets are shot in the ditch line then said pockets should be made to drain along the ditch line and do not permit the water to drain under the roadway section. It is not adequate to just fill these rock pockets with refill material without provision being made to drain such pockets. Eventually, the undrained rock pockets will be filled with free water and all soils with the probable exception of sand will lose much of their expected stability under such conditions.

There are certain sections where the water table is an important factor in the stabilization of a soil subgrade. It is realized in such sections it will not always be practical to get the desired separation between the bottom of a ditch that will drain and the finished roadway grade but the following are some separations that should be met wherever practical.

Between 0.0% and 0.25% grade, the separation should be 6 feet.
Between 0.25% and 0.50% grade, the separation should be 5 feet.
Between 0.50% and 0.75% grade, the separation should be 4 feet.
Between 0.75% and 1.00% grade, the separation should be 3 feet.
1.00 or above our standard 2 foot ditch should be adequate.

A considerable portion of roadway construction over areas where the water table is a problem will consist of two or three feet of embankment to be made from side ditches. In such cases, the original ground will often be soft and the material to be excavated will be wet. On construction, these places should be spotted early and the contractor should be required to construct some temporary ditches that would
lower the water table and give the section time to drain before any embankment construction is started in said sections. This procedure will actually be beneficial to the contractor in that it will make his construction operations much easier and the State will get a much better subgrade on which to build a designed pavement. When an earth embankment is made over any section where water is at or near ground elevation, the water table should be lowered if at all practical before any embankment is placed. If rock of shale excavation is available, then these soft swampy sections can be easily stabilized.

Flat grades in cut sections often feed excessive water to the subgrade under a pavement and has the effect similar to a high water table. This condition is very noticeable if the cut is composed of a silt or loess soil. In silt or loess soil cuts on a flat grade, it would be very beneficial to the subgrade if the ditches were constructed on a special grade.