mile are governed by local conditions, climate, topography, and soil. It must be kept in mind that this processed base is then ready for any of the standard types of bituminous surfaces.

After the first mile we decided that three power graders, a multiple-blade maintainer, and a roller were all the equipment needed to build these roads. At least one of the power graders should be equipped with a windrow eliminator. The first step in operation was to scarify the road to a depth of between 4 and 6 inches. This scarified material was windrowed and turned until pulverized. Then the material was split into two windrows for more efficient mixing. One windrow was then spread out wide enough to receive an application of tar of about 0.3 gallon per sq. yd. This was bladed and mixed, and an additional shot of about 0.2 gallons was applied. After a thorough blading, this was laid out, and the second windrow was treated in the same manner. When complete, the surface was struck off with a power grader with a windrow eliminator attached. The base was compacted with a 10-ton, 3-roller followed by a multiple-blade maintainer. A light tack-coat must be applied and covered lightly with fine aggregate as soon as the rolling is completed. Under no circumstances should the application of the tack-coat be delayed.

To date, these roads have shown no failures. With one exception, they are holding much better than expected. One road was not sealed or tack-coated for some time after treatment, and this road has one bad spot near the end which will have to be repaired. On the others, there have been no signs of distress to date. These roads have a hard, smooth, non-skid surface and seem to be the answer to construction and maintenance problems of our secondary roads.

A GENERAL DISCUSSION OF ROAD STABILIZATION

W. T. Spencer,
Field Engineer of Tests,
State Highway Commission of Indiana,
Indianapolis, Indiana

We are all more or less familiar with the general character, appearance, and composition of the granular materials used in Indiana, such as limestone, sand, gravel, and slag. No doubt some of you have encountered difficult problems in the handling of these materials in various types of construction work. But let us try to visualize some of the many complex characteristics of the various soils with which you have to deal in stabilization; then you can readily see that some of the problems in soil stabilization may become somewhat involved.

Soils are of mineral origin and are formed from the disintegration of rock through the agency of wind, water, ice, frost, temperature changes, chemical action, plant growth, animal life, and decomposition. A soil may differ considerably
in chemical composition from its parent rock because of the many changes it has undergone.

A soil particle seen through a microscope may vary in form from a sphere to the small scale-like particles usually found in clay. The particle size of each grain is small. Soil may be subdivided into silt and clay particles, with a further subdivision of clay into colloidal particles. The texture of silt varies from 0.05 to 0.005 millimeters, or from 2/1,000 to 2/10,000 of an inch. Clay, which includes colloidal material, consists of particles of 0.005 millimeters, or 2/10,000 of an inch or smaller. Colloids are particles below 0.001 millimeter, or 4/100,000 of an inch. The division point between soil and fine sand is at 0.05 millimeter, or 2/1,000 of an inch. This means that in dealing with soil we have very small particle sizes with a large percentage of voids and a very large surface area. According to one authority, a clay soil having 2% coarse sand, 2.5% medium sand, 5.5% fine sand, 7.0% very fine sand, 37.0% silt, and 46.0% clay, would have a net pore space for all separates of 56, and the surface area of one cubic foot of these soil grains would total 142,000 square feet, or approximately 3.25 acres of surface.

The colloid fraction of soil is the most susceptible to shrinkage and swell. According to the U. S. Bureau of Public Roads, in a properly graded sand-clay mixture, where the colloidal fraction is only 6% of the total soil volume, its surface area is 146,000 square feet per cubic foot of mixture, and when completely saturated it is responsible for 85% of the volume change which increases 75% of the dry material.

The chemical composition of the soil affects its reaction with a stabilizing agent. Colloids high in silica adsorb thick films, and their volume undergoes great changes. Iron and alumina colloids adsorb thin films and, therefore, undergo little volume changes on wetting or drying. A change of ions on the clay and colloidal particles may alter the shrinkage, swell, and plasticity of the soil so as to alter its stability. According to the Bureau of Public Roads, potassium clay becomes the most stable, and lithium clay the most unstable.

These are only a very few of the reasons why the stabilization of some soils becomes quite a complex problem.

As pointed out by Mr. R. B. Traver in his paper on soil-aggregate stabilization with the aid of either calcium or sodium chloride as a chemical, the fact that mixtures have served satisfactorily as a road surface is no assurance that they will not soften and become unstable after surfacing if they have been constructed with a surplus of plastic soil binder. If the stabilized course is to be used as a base course, it should be constructed as such or reconstructed as necessary before surfacing.

Mr. Reagel's paper and moving pictures on bituminous stabilization were very instructive. In attempting to treat
some heavy clay soils of the A6 and A7 types with tar emulsions and cutbacks on an experimental subgrade stabilization during the summer of 1937, we found that this type of soil stabilization presents some very different problems from those of soil-aggregate stabilization.

Soil-cement stabilization, as described by Mr. Myers, also presents some interesting problems. According to its claims, the Portland Cement Association can satisfactorily treat any soil, free from organic or other objectionable matter, that has a liquid limit below 40 and a plasticity index below 20. Although the addition of cement changes the physical characteristics of the soil, the compaction in this type of stabilization is quite important.

Any of these various forms of stabilization may become somewhat complex and warrant laboratory and field studies of the materials available before the recommended method of treatment is suggested.

HIGHWAY EMBANKMENT CONSTRUCTION
PROCEDURE

K. B. Woods,
Assistant Director, Joint Highway Research Project,
Purdue University

The handling of embankments depends upon a knowledge of the material types that will be encountered in cuts or borrow and the construction control that may be exercised. This paper gives briefly a description of embankment material types which are often encountered. A method of presentation by the use of the soil profile is included. Specifications for the placing of these materials as well as tests employed in construction control are also mentioned.

Since the summer of 1935 many states have adopted specifications for the control of moisture and compaction of the soil used in embankments. Numerous failures had been occurring for several years in the higher regions where deep cuts and high fills were being used as a result of the evolution of modern grades and eliminations, and these construction requirements were intended to prevent similar failures in the future.

Such specifications have since been found to be adaptable for use in level-to-rolling country where only slight fills are necessary. Some states are even using a density specification for control of the compaction of subgrades so that new pavements may be placed on well-compacted grades.

Common materials encountered and used in embankment may be classified as soil, shale, granular material, random material, and rock. When materials are classified as such, they must be defined. The following definitions will probably suffice for them.

Soil may be considered as layers or deposits of disintegrated rock lying on or near the surface of the earth which