TOPSOIL, SAND-CLAY AND GRADED MIX ROADS IN SOUTHEASTERN UNITED STATES

By L. D. Hicks, *Assistant Engineer of Materials and Tests, North Carolina State Highway and Public Works Commission,*

W. F. Abercrombie, *Assistant Engineer of Materials and Tests, Georgia State Highway Department,*

and J. L. Land, *Materials Engineer, Albama State Highway Department*

Arranged by E. A. Willis, *Associate Highway Engineer, U. S. Bureau of Public Roads*

MATERIALS

Hicks: Soil materials suitable for the construction of both base and surface courses are found in many sections of Southeastern United States. In general the soils of this region belong to the Red and Yellow great group of soils. These soils, while not laterites are lateritic, and are more stable than soils of other groups, excepting laterites. The clays of these soils do not possess the expansive properties that are characteristic of the so-called silica clays.

Soil materials utilized in road construction may be classified according to local designations as follows: topsoil, sand-clay, sand-clay-gravel, chert, pebble soil, disintegrated granite, float and lime-rock.

Topsoil

Abercrombie: Topsoil is a residual formation covering the upper surface of fields and woods, varying in depth from a fraction of an inch to some two or three feet, and consists of quartz fragments varying in size from fine sand to stones of several inches, together with clay and decayed vegetable matter. It occurs primarily in the Piedmont Plateau region.

Hicks: In North Carolina the topsoils are the "A" horizons of granitic soils, generally typed as Cecil, Durham, and Appling sandy loams.

Sand-Clay and Sand-Clay-Gravel

Land: Sand-clay is found in natural strata ranging from 5 to 20 ft. in depth and is generally located in the south central, coastal plains and low hilly regions. This material is easily loaded and certain varieties make excellent surfacing and base courses. The natural sand-clays have a wide range in gradation of sand and percentage of clay and for this reason only a very small percentage of it as found in its natural state is suitable for use. Artificial mixtures of sand-clay are made where no natural deposits occur if suitable separate deposits of sand and clay do occur.

Sand-clay-gravel is a sedimentary material consisting of a natural mixture of siliceous gravel, sand and clay. It is found in the hilly sections just to the north and west of the so-called sand-clay regions. The two materials are often found together. In reality, sand-clay-gravel is a sand-clay material containing more than 25 percent of gravel retained on a No. 10 sieve.

Chert

Abercrombie and Land: Chert is a sedimentary deposit consisting of a rocky amorphous silica and fine material composed of dust of fracture and clay. It occurs in hilly or mountainous regions. Cherts vary widely in the quality and quantity of clay, coarser particles and natural cementation value in the stone itself. The clay ranges from a medium to a high percentage in quantity and from a low to a high plastic quality.

Pebble Soil

Abercrombie: Pebble soil is a sedimentary deposit of a natural mixture of topsoil and rounded iron oxide pebbles varying from a fraction of an inch to several inches in diameter. The surface usually consists of a grayish-brown to yellowish-brown loam grading into a yellow sandy loam which extends down into a bright to deep yellow friable sandy-clay. The soil ranges in depth from a few inches to four or five feet.

Disintegrated Granite

Hicks: Disintegrated granite is found quite extensively in certain sections of the Piedmont Plateau. This material occurs as the "C" horizon of the Cecil, Durham, and Appling series. Depending upon the degree of the weathering of the feldspar, the material has all degrees of plasticity. Pedalogically, disintegrated granite is not a soil, but a soil material. It has been formed by decomposition or alteration of granite which is composed mainly of quartz, feldspar, and mica. The feldspar is in process of decomposition, forming a clay-like substance, and the quartz and mica are unaltered. Topsoil is the result of a complete or almost complete process. The decomposed feldspar has been leached out to a great extent, leaving the quartz and mica. Some of the best topsoils are found as the upper strata of disintegrated granite pits. An examination of this material shows quartz, very little mica, no altered feldspar, and grains of altered granite.

Float

Land: Float consists of hard granular material varying in particle size from a No. 200 sieve to 3 in. and resembles talus with the exception that it has been washed into drifts, mixed with sand, silt, clay and sometimes organic matter. Float occurs in the creek and river valley lands of the extreme hilly and mountainous sections of Alabama. The portion which passes a No. 10 sieve resembles topsoil but frequently has a poorer gradation. The larger material sometimes has a coating of plastic clay. The nature of this material facilitates stabilization and it makes most excellent base courses or wearing surfaces.

Limerock

Abercrombie: Limerock is a sedimentary deposit of shells occurring in depths of from 5 to 50 ft. These shells from aging and pressure have partially disintegrated and become somewhat cemented. There are two types of deposits; the primary contains whole shells and fossils, while the secondary deposits from their chalky appearance and a majority of broken bits, appear to have been transported from the primary deposits and redeposited.

Characteristics of Materials

Hicks: Soil materials suitable for the construction of road bases or surfaces must meet certain requirements for gradation and physical characteristics. The gradation should be from coarse to fine in order that a dense mass may be obtained with as low porosity as possible. Such a mass prevents the absorption of moisture in detrimental amount. Soils having high liquid limits should be avoided or corrected as high liquid limits are indicative of detrimental capillarity. Soils with high plasticity indexes become unstable when wet and undergo considerable volume changes with changes in moisture content.

Specifications of the North Carolina State Highway and Public Works Commission require soil materials used in earth type base and surface construction to meet the following limits for grading and physical characteristics:

The Course Aggregate Type (soils) shall contain more than 40 percent of aggregate retained on the No. 10 mesh sieve and shall conform to the following grading requirements:

Total Passing U. S. Standard Sieves	Percent
1 inch	100
No. 10	30–60
No. 40	20–45
No. 200	8–25

The fraction passing the No. 200 mesh sieve shall be less than one-half the fraction passing the No. 40 sieve for base course material. This ratio shall be less than ⅔ for surface course material. When tested in accordance with the methods of the American Association of State Highway Officials the fraction passing the No. 40 sieve shall have a plasticity index not to exceed 6 and have a liquid limit of not more than 25 for base course material and shall have a plasticity index between 3 and 10 and a liquid limit not to exceed 35 for surface course material.

A tolerance of 10 percent of aggregate retained on the 1-in. sieve shall be permitted provided the maximum size does not exceed 1½ in.

The Fine Aggregate Type (*soils*) shall not contain more than 40 percent of aggregate passing the 1-in. and retained on the number 10 sieve, and the soil mortar (material passing the number 10 sieve) shall conform to the following grading requirements:

Total Passing U. S. Standard Sieves	Percent
No. 10	100
No. 40	40–70
No. 200	5–35

The fraction passing the No. 200 mesh sieve shall be less than one-half the fraction passing the No. 40 mesh sieve for base course material. For surfacing materials this ratio may be 2/3. The fraction passing the No. 40 mesh sieve shall have a plasticity index not to exceed 4 and have a liquid limit of not more than 25 when tested in accordance with the methods of the A.A.S.H.O. for base courses and shall have a plasticity index not to exceed 6 and a liquid limit of not more than 35 for surface course materials.

The Fine Aggregate Type (*soil*) shall contain no aggregate larger than 1 in. except that a tolerance of 10 percent of aggregate retained on the 1-in. sieve will be permitted, provided the maximum size does not exceed 1½ inches.

Many of the topsoils of the Cecil, Durham, and Appling series meet the above requirements without admixtures, and some of the sand-clays of the Ruston and Norfolk series will also meet them. However, in many instances where the topsoils are derived from fine-grained igneous rocks, the materials do not meet these specifications due to deficiencies in coarse sand or excesses in silt and clay. Stabilizer aggregate of crushed stone, crushed or uncrushed gravel or crushed slag is mixed with nonplastic to feebly plastic topsoils of this type to produce mixtures conforming to the requirements for Coarse Aggregate Type soil. Loamy topsoils derived from basic igneous rocks and volcanic slates are generally plastic and may be stabilized with coarse sand to produce mixtures meeting the requirements for Fine Aggregate Type soil. Sand-clays containing excess clay have plasticity indexes and liquid limits in excess of the specifications and are more abundant than sand-clays meeting the specifications. Sand admixtures are used to reduce the clay enough to lower the high plasticity indexes and liquid limits.

The upper layer of the sand-clay gravel deposits in North Carolina contains material meeting the specifications for Coarse Aggregate Type soil, but the lower strata, in most cases, contain gravelly material with excess clay. Sand admixtures are necessary with this type of material, and in many cases it is necessary to add so much sand to reduce the plasticity index that a Fine Aggregate Type soil is produced.

Sand-clay bases and surfaces have been constructed by mixing creek sand with the clay subgrade. The clay must be friable and the sand incorporated when the clay is fairly dry. Only a very small amount of the clay subgrade is needed as it generally contains about 50 percent pure clay. This kind of work has been done only with State forces as it requires good weather and careful proportioning and mixing.

Prior to 1934 a material called disintegrated granite had been used quite extensively in certain sections of the Piedmont Plateau region. As long as it was used as a surface course the material served very well, but as soon as a bituminous surface treatment was placed on it failure occurred. Investigation by the soils laboratory revealed that the disintegrated granite had a high liquid limit and a high field moisture equivalent. These test values indicated capillarity in detrimental amount. When surface evaporation was prevented by the impervious bituminous surface mat, the base absorbed sufficient moisture to become unstable and failed. Results of admixtures during the spring and summer of 1936. It was suggested that lime or limestone screenings be used as admixtures, but limestone is not very abundant in North Carolina and the cost of importing these materials would have been excessive. Limestone screenings would probably have had to be used with nonplastic materials, but results of laboratory tests made on mixtures of plastic disintegrated granite materials

TABLE 1

TEST RESULTS OF TYPICAL DISINTEGRATED GRANITE MATERIALS FROM NORTH CAROLINA

Mechanical analysis

Sample		Coarse aggregate particles larger than 2.0 mm. Ret. No. 10	Particles smaller than 2 mm. (percent by weight)					
			Soil mortar—100%				Colloids smaller than 0.001 mm.	Passing No. 40 sieve
County	Laboratory number		Coarse sand 2.0 to 0 25 mm.	Fine sand 0.25 to 0.05 mm.	Silt 0.05 to 0.005 mm.	Clay smaller than 0.005 mm.		
Orange	560	64	52	19	19	10	3	59
Ashe	1233	64	40	36	22	2	1	66
Guilford	2022	37	45	25	19	11	6	64
Stokes	2214	38	59	30	9	2	1	55
Davidson	3601	43	67	21	5	7	5	44

Physical characteristics of material passing No. 40 sieve

Sample		Liquid limit	Plasticity index	Shrinkage		Moisture equivalent
County	Laboratory number			Limit	Ratio	Field
Orange	560	38	5	22	1.6	25
Ashe	1233	32	0	20	1.7	35
Guilford	2022	30	3	19	1.7	25
Stokes	2214	30	0	21	1.7	30
Davidson	3601	25	1	20	1.7	26

tests made on samples of typical disintegrated granite materials are given in Table 1. These results are within the limits of the specifications, except for the values of the liquid limit. The test values of the field moisture equivalent are 25 or greater.

The majority of the bases that were constructed of disintegrated granite failed or showed signs of failure after the winter of 1935 and 1936. Many were reconditioned by sand or stone screenings and sand indicated that combinations of these materials were satisfactory. The bases reconditioned with sand or stone screenings have served satisfactorily to date. No new bases have been constructed using disintegrated granite materials with sand or stone screenings admixtures, as suitable topsoils have been found near enough to warrant their use instead.

Table 2 gives test results on typical base course materials used in North

Carolina. These bases are surfaced with a bituminous treatment mat consisting of a prime coat of tar or asphalt, a second application of hot asphalt and stone, followed by a seal coat of stone or sand and cut-back asphalt. It will be noted that the porosites of these well graded materials when compacted by the Proctor test are low, ranging from 22.3 percent to 26.0 percent. The column headed "Potential Absorption" gives theoretical absorption values of the materials at their respective porosites or the percentages of moisture that these compacted masses will contain when all of the voids are filled with water.

The values of porosity and potential absorption were computed from the formulae:

$$\text{Porosity} = \left[\frac{(62.355 \times \text{Sp. Gr.}) - \text{Wt. per cu. ft.}}{62.355 \times \text{Sp. Gr.}}\right] \times 100$$

$$\text{Potential Absorption} = \left[\frac{62.355}{\text{Wt. per cu. ft.}} - \frac{1}{\text{Sp. Gr.}}\right] \times 100$$

These factors are believed to be important when used in connection with the physical test constants since they depict the condition of stability of the soil when saturated.

Abercrombie: The soil mixtures used as base course materials in Georgia are selected or designed on the basis of the gradation of the soil mortar or that fraction passing the No. 10 sieve. The fractions determined are:

(1) Coarse sand, between the No. 10 and the No. 60 sieves, (2) fine sand, between the No. 60 and the No. 200 sieves, (3) silt, the material passing the No. 200 sieve not removed by elutriation, and (4) clay or binder, that part removed by elutriation.

The studies of the individual particles going to make up the mixtures are essentially, whether or not: the sand grains are hard, sharp and durable particles, preferably siliceous; the character of the clay or binder is suitable for getting the desired results; and the coarse aggregate or plus 10 mesh material consists of hard, tough and durable particles.

The requirements of the Georgia High-

TABLE 2

Tests of Typical North Carolina Base Course Materials

Material	County	Coarse Aggregate	Analysis of fraction passing No. 10 sieve: Sand	Silt	Clay	Colloids	Passing No. 40	Soil Constants: Liquid limit	Plasticity index	Shrinkage limit	Shrinkage ratio	Field moisture equivalent	Optimum moisture content	Maximum density	Porosity	Potential absorption	Grouping
		%	%	%	%	%	%						%	lb. per cu. ft.	%	%	
Natural sand clay	Bladen	0	87	7	6	5	62	15	0	21	1.7	18	9.7	121.3	25.8	13.2	A-2
do do	do	0	85	7	8	4	63	13	0	15	1.9	15	9.6	122.8	25.1	12.8	A-2
do topsoil	Davidson	4	72	15	13	6	69	16	0	17	1.8	19	10.4	122.0	24.7	12.6	A-2
do do	do	3	75	14	11	5	66	21	0	18	1.8	18	10.7	120.4	25.7	13.3	A-2
Artificial sand clay	Hoke	0	83	6	11	8	65	17	0	14	1.9	18	10.0	125.0	23.4	11.6	A-2
do do	do	0	82	3	15	13	57	25	7	16	1.8	20	10.6	123.0	23.7	11.9	A-2
Natural topsoil, sand admixture	Rowan	8	71	18	11		67	20	2	16	1.9	16	9.8	125.7	23.3	11.6	A-2
do	do	15	77	13	10		65	15	0	17	1.8	15	9.2	127.0	22.3	10.9	A-2

way Department for soil type base course materials are given in Table 3.

A clause is included in the Georgia specifications governing topsoil, sand-clay and pebble soil to cover the material found in some individual deposits which may not conform to the master gradations given in Table 3, but which, because of the character of the material, will make a firm stable base. This clause states that a reduction or increase in the silt or clay, or an increase in the sand retained on the No. 60 sieve may be authorized, provided the material used binds satisfactorily and shows no signs of instability.

No. 10 sieve in the top four inches of the base. If the natural soil does not carry this amount, then sufficient crushed stone, gravel or slag, grading of from ¾ in. to ¼ in. is added.

In general the material removed by elutriation in chert may be classified as dust of fracture (amorphous silica). However, when clay binder occurs then the 50 percent maximum clay is excessive and careful selections are made so as to eliminate such excessive clay.

Topsoil or sand-clay bound macadam base construction consists of a broken stone base bound with topsoil or sand-clay.

TABLE 3

REQUIREMENTS OF GEORGIA HIGHWAY DEPARTMENT FOR SOIL TYPE BASE COURSE MATERIALS

Material	Gradation of total material Percentage passing			Gradation of fraction passing No. 10 sieve			
	2-in. sieve	1½-in. sieve	No. 10 sieve	Clay	Silt	Total sand	Coarse sand
	percent	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*
Topsoil and sand-clay				9–18	5–15	65–80	45–60
Pebble soil	100	80–100	25–80	11–25	0–15	55–90	30–85
Sand-clay-gravel	100	80–100	25–70	7–25	0–15	55–90	30–85
Chert	100	80–100	20–40	15–50	5–25	25–80	15–80

No special amount of material retained on the No. 10 sieve is required in the natural topsoil and sand-clay deposits, but the presence of coarse material is welcomed. No stones larger than 1½ in. are allowed to remain in the mixture after placing on the roadway.

A further gradation requirement in the material retained on the No. 10 sieve may be applied to the topsoil or sand-clay depending upon the importance of the road. If the particular project is to be on an ordinary farm to market highway no coarse material will be required; but if the project is on a rather important route and is expected to carry considerable traffic then coarse material, locally called "Mineral Stabilizer" will be required. The design is to get approximately 25 percent retained on the

The gradation of the broken stone is as follows:

	Percent
Passing 2½-in. sieve	100
Passing 2-in sieve	95 to 100
Passing 1-in. sieve	35 to 70
Passing ½-in. sieve	0 to 10
Passing ⅜-in. sieve	0 to 2

The gradation of the top soil or sand-clay mortar is as follows:

	Percent
Clay	9 to 25
Silt	5 to 20
Total sand	50 to 80
Sand retained on No. 60 sieve.	30 to 60

The construction consists as the name suggests of placing a sufficient amount of broken stone to give the full compacted thickness of base desired and filling the voids with the topsoil or sand-clay mortar.

In many instances if a local natural mixture of topsoil or sand-clay cannot be secured, a deposit of suitable clay is selected and mixed with stone screenings or sand in the proper proportions to secure the required gradation. The mixing is done prior to placing on the roadway.

Although for a number of years various kinds of tests have been conducted on limerock in an effort to determine the difference between that which would set up and give a satisfactory base from that which could not be used, the only test that proved satisfactory was to build a test road section. This practice is still continued and has shown that the primary deposits are the only ones suitable for base construction. In the last two years grading tests have been made on several hundred samples and it is found that, although it is a quarried and crushed product, the gradations run rather uniform. It appears at present from what work has been done that a limerock mortar containing less than 35 percent material passing the 200-mesh sieve is a satisfactory material, while that containing more than 35 percent is of doubtful quality or unsatisfactory. However, it is felt an insufficient amount of work has been done at this time to establish a gradation specification.

Land: Alabama's low cost road construction program was inaugurated with the sole idea that soil is present and must be used either as a substructure, subgrade, or base course supporting a wearing surface; that where inferior soil is encountered, a stable transition material of known high quality must be used as a sub-base or base of sufficient depth to assure load distribution and prevent distortion; and that the best and most economical result can be obtained by the proper use of carefully selected materials common to the vicinity and which have stood the test of nature.

The essential requirement for economic and sound low cost road construction is an alert, trained and diligent road building material prospecting division supported by a carefully operated testing laboratory. To the officials of this division knowledge of soil sciences must be paramount if the best usage of local materials is to be employed in design and construction of roads.

Sand clays, clay gravels, and cherts were used as patching materials for mud holes and bad places on rural trail roads long before graded or modern road construction was begun. Topsoil and floats came into use at a much later date and the lack of better or more easily secured material in certain vicinities aided in promoting their usage. The procedure established by early settlers and engineers of using materials which the test of weather and use of roadways had shown to be stable and nearest to a given project has been more or less followed by us in later years.

Our whole system of testing, specifications, etc. grew out of the comparisons of materials carefully selected by experienced inspectors on or near proposed projects with those that had proved satisfactory over a period of years. This system of selection of satisfactory materials by comparison and elimination has proved economical and satisfactory. It has helped considerably in developing the idea that suitable material is near most projects and that one must go find it and then select the best for use. It also assisted in the development of local material throughout the State and in proving that many times the best materials were outside the limits of modern standard specifications. Many sand-clays and clay-gravels containing large amounts of coarse sand with only a small percentage of soil fines frequently having extremely high liquid limits and plasticity indices have proved the best of road building materials.

Typical analyses of samples from roads

that have given completely satisfactory service in Alabama for a period of four years or more are given in Table 4.

CONSTRUCTION AND CONTROL METHODS

Hicks: The construction of topsoil, sand-clay, and graded road mix bases and surfaces in North Carolina is done under specifications for soil type base courses or soil type surface courses. These specifications do not allow the use of any material that has not been tested and approved by the soils laboratory. For the past two years, artificial compaction of soil type bases has been required, using moisture and sheepsfoot or pneumatic tired rollers. Investigation of the densities of these artificially compacted bases has shown them to be from 95 to 102 percent of the densities obtained by the Proctor test, and to be fairly uniform. They are also equal to the densities of soil surfaces which have been compacted by traffic for years, according to density tests made on old soil surfaces. This artificial compaction requirement permits the construction of the soil type base and bituminous surface treatment in the same contract and eliminates the loss of material from the base during the period required for traffic to compact it.

TABLE 4

TESTS OF TYPICAL ALABAMA BASE COURSE MATERIALS

Material	Top soil	Top soil	Sand clay	Sand clay	Sand clay gravel	Chert	Float
Mechanical Analysis of Whole Sample—% Passing:							
2-in. sieve	100.0					100.0	100.0
1½-in. "	82.3				100.0	98.0	98.1
1-in. "					91.7	95.5	88.4
¾-in. "					84.5	88.8	74.0
No. 4 "	68.1				53.5	50.7	43.2
No. 10 "	65.8	96.8	98.8	91.7	40.9	38.3	32.9
Mechanical Analysis of Material passing No. 10 sieve:							
Passing No. 20 sieve, %			91.7	58.3			
" No. 40 " , %		59.7	54.1	25.9	37.3	68.6	61.4
" No. 80 " , %			12.7	20.0			
" No. 200 " , %	27.1	22.3	10.0	17.0	14.0	39.6	38.3
Sand retained on No. 60, %	51.7	60.5	83.4	78.4	83.7	42.7	50.0
Total sand, %	72.9	77.7	89.5	78.9	86.0	60.4	61.7
Silt, %	12.9	8.5	0.0	2.3	1.0	13.6	15.3
Clay, %	14.2	13.8	10.5	18.8	13.0	26.0	23.0
Soil Constants of Fraction passing No. 40 sieve:							
Liquid limit		16.4	23.7	52.1	47.9	20.8	26.7
Plastic limit		13.8	24.1	24.1	23.5	16.5	19.8
Plasticity index		2.6	0.0	18.0	24.4	4.3	6.9
Shrinkage limit		12.2	17.6	20.8	21.3	13.2	16.8
Volumetric change, %		5.0	8.3	67.1	30.0	12.6	17.7
Field moisture equivalent		12.1	22.3	34.1	23.2	15.4	20.1
Lineal shrinkage, %		Nominal	0.3	8.0	1.1	1.4	1.9

Since the latter part of 1934, all soil type base and surface construction in North Carolina has been done under laboratory control. Prior to drawing up the plans and contract, a preliminary soil survey is made by the soils laboratory to locate suitable materials. At the same time the materials that will be encountered during grading operations are examined and the presence and location of undesirable subgrade soils are noted. Material pits, if available, are staked out and samples taken for tests. Based on results of tests, a material report is made which includes a sketch showing the location of material pits containing satisfactory materials, the amounts of admixtures necessary, recommended thickness of base or surface course and subgrade treatment when necessary, and any other recommendations that are pertinent to the quality of the subgrade and base or surface course. During construction, the resident engineer makes wash tests of samples of the base or surface course taken at intervals of 500 ft. and sends a report to the soils laboratory. When taking these samples, enough material is obtained to send the soils laboratory a sample for every 1000 ft. of the project for check tests. In this way close control is maintained of the quality of the material used.

There have been several formulas suggested for calculating the amount of sand admixture needed to reduce the plasticity index of soil. The writer has found that they are fairly accurate when both materials have plasticity indexes, but when a plastic material is mixed with a cohesionless material such as sand, a much lower plasticity index will be obtained than calculated. This is sometimes corrected by assuming that the sand has a "minus" plasticity index, but this "minus" value varies with the soil. Most of the soil work in North Carolina is base construction for bituminous surface treatment and low plasticity indexes are desired. It has been found that, within the grading limits of the specifications, plasticity indexes of from 0 to 4 will be obtained when the clay content of the mixture is reduced to about 10 percent.

The use of well graded topsoil and sand-clay materials having good physical characteristics, when available locally, permits the construction of an excellent road at low cost. When no suitable material is available, the use of commercial sand-clay, gravel and crushed stone must be resorted to, at considerable increase in cost. The advent of stabilization with portland cement and bituminous materials is proving to be a boon to localities far from sources of good materials in that the available unsuitable materials may be rendered stable at a cost lower than the importation of commercial sand-clay gravel and crushed stone. It is possible that stabilization with these materials may even produce bases superior to those constructed of topsoils and sand-clays; however, time alone will give this information.

Abercrombie: The desired condition of the base for receiving the surface treatment is for the material to be set up and well bonded. This is accomplished by thoroughly mixing the materials, after they are placed on the roadway, by means of plows and harrows, then compacting into a solid unyielding slab, either by pneumatic tired rollers, sheepsfoot rollers, traffic or a combination. If insufficient moisture for compaction is present more is added.

After the material has set the surface is thoroughly cleaned by means of brooms and blowers; then a prime coat of bituminous material is applied. After this prime coat has cured under a few days traffic the surface treatment is placed.

In Georgia the basis of design is the mortar passing the No. 10 sieve. The gradations given in Table 3 are used as specifications, but for individual deposits of each type of material the grading is controlled to even closer limits within the broader master grading specification in order to obtain the best results.

To insure positive control of the material going into the roadway the following procedure is observed.

When a project is contemplated for construction a survey of the natural existing local materials is made. After likely looking deposits are located, the material is examined by digging test holes and judging the quality by appearance and feel. If the materials in the deposits are judged worth further investigation based on quality and quantity representative samples of the material are taken and tested in the general laboratory.

After a deposit has been proved satisfactory for both quality and quantity, some time before the removing of the material is begun, the deposit is checkered off by test holes spaced at from 50 to 100 foot intervals, so as to gather an idea of the depth and extent of the deposit. Samples are taken from each of the test holes and tested, in a field laboratory, to determine the percentage of each ingredient.

In deposits which may contain a top layer of sandy material underlaid by a clayey material, if the first samples prove to be low or high in some ingredient, a new sample is taken going not so deep or deeper, as the case may be, into the lower layer and then retested. After the correct depth is established, for each hole, to give the desired mixture, then a stake is driven beside the hole with the cut depth marked as a guide for excavation.

During excavation operations an inspector is present at all times observing that the materials are mixed in the proper proportions and frequently testing samples as a check.

After the material has been placed on the roadway further samples are taken at intervals of not over 500 ft. and sent to the general laboratory for analysis.

If upon examination of these samples it is found that some sections contain a higher or lower percentage of some ingredient that is desired, corrections are made for these sections by adding the correct amount of the deficient ingredient.

Land: At first Alabama used only materials from natural deposits which possessed satisfactory qualities. Later it was found that two or three materials, each of which was not suitable within itself, could be easily combined in certain proportions to give as good results as materials mixed by nature. Projects are studied individually with respect to requirements, local materials, haul distances, etc. If deposits of naturally usable materials are not found within an economical haul, then other materials available are given consideration for mixing or stabilization. Concentrates are avoided. Mixtures slightly high in clay are preferred to friables since stabilization is accomplished more easily and more satisfactorily by the addition of angular material rather than clay. Materials proposed for stabilization use are carefully analyzed, proportions for mixtures worked up and various experimental samples made in the laboratory until a combination is found which has sufficiently wide limits to permit economical mixing on construction and easy field control.

Topsoils are usually passed up as unsatisfactory when they require stabilizing but it is a common practice to add metal to the top three inches of base courses to strengthen their surface.

Sand-clay, clay-gravels, and floats frequently have irregular gradations and slightly high clay content in the 10-mesh material or binder. This deficiency is usually corrected by the addition of local sand of proper gradation.

Chert usually has plastic clay and poor gradation in its natural state. To offset this irregularity, we employ sand-clay, sand, limestone screenings, and limestone dust, individually or collectively, as necessary to produce satisfactory results.

Whenever stabilization becomes necessary, standard requirements are generally met, because known results can be had as cheaply as doubtful ones.

The material to be stabilized is spread

on the roadway in layers of uniform depth and covered evenly by the stabilizer. Then the two are uniformly mixed by harrowing, plowing or disking, and machining until uniformity is secured. This method has given good results but is not entirely satisfactory and it is believed that plants, either stationary or traveling, will supplant our present method with economy and better results.

After trying the various tests proposed by the Bureau of Public Roads and several States, we finally accepted the elutriation 8-minute suspension for clay determination. This method is the simplest one which will give results sufficiently correct to assure accuracy, volume production and complete coordination between the field laboratory and the central laboratory.

Only the simplest equipment and operations are used and the difference between the field and main laboratory is in the arrangement of equipment for volume production. The co-ordination between the field and main laboratory work is usually so close and the actual operations so nearly the same that if a difference arises in the results obtained by the inspector in the field and the testing laboratory the error should be determined by testing a check sample brought from the field by the inspector. By this operation accurate results are secured and the character of materials is known for each section in the roadway.

Field laboratories are equipped with kits containing the necessary appliances for the determination of clay and silt, gradation of metal, liquid limits and plasticity indices.

Roadway inspectors are responsible for the placing, mixing, watering, and shaping of the material on the roadway. After all operations are completed and well in advance of pavement operations, samples are taken from the roadway at 5-station intervals. The inspector who performs this sampling is one other than on construction. These samples give a cross section of the material on the roadway (residue).

Alabama's experience in working with and testing soils has led to the belief that standard specifications, although they are necessary, if rigidly enforced would seriously affect economy in the use of local material on low cost road construction, but if used as a guide, the routine tests they require are invaluable in the selection of suitable and elimination of dangerous material; i.e., a good grade of material with low percentages of soil fines, low volume change and small lineal shrinkage limit need not be rejected because of nominal high L.L. and P.I., but chert with a high percentage of soil fines, large volume change, large lineal shrinkage limit, high L. L. and P.I. must be rejected as unfit for use.