PUBLIC ROADS

A JOURNAL OF HIGHWAY RESEARCH

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS

VOL. 10, NO. 11 ▽ JANUARY, 1930

AN EXAMPLE OF THE SURFACE OBTAINED BY SURFACE TREATING SAND-CLAY AND TOPSOIL ROADS

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - - - - - - - - - See page 2 of cover for price

PUBLIC ROADS

A JOURNAL OF HIGHWAY RESEARCH

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

CERTIFICATE: By direction of the Secretary of Agriculture, the matter contained herein is published as administrative information and is required for the proper transaction of the public business

The reports of research published in this magazine are necessarily qualified by the conditions of the tests from which the data are obtained. Whenever it is deemed possible to do so, generalizations are drawn from the results of the tests; and, unless this is done, the conclusions formulated must be considered as specifically pertinent only to the described conditions

VOL. 10, No. 11 JANUARY, 1930 R. E. ROYALL, Editor

TABLE OF CONTENTS

THE BUREAU OF PUBLIC ROADS
Willard Building, Washington, D. C.

REGIONAL HEADQUARTERS
Mark Sheldon Building, San Francisco, Calif.

DISTRICT OFFICES

DISTRICT No. 1. Oregon, Washington, and Montana.
Box 3900 Portland, Oreg.

DISTRICT No. 2. California, Arizona, and Nevada.
Mark Sheldon Building, San Francisco, Calif.

DISTRICT No. 3. Colorado, New Mexico, and Wyoming.
301 Customhouse Building, Denver, Colo.

DISTRICT No. 4. Minnesota, North Dakota, South Dakota, and Wisconsin.
410 Hamm Building, St. Paul, Minn.

DISTRICT No. 5. Iowa, Kansas, Missouri, and Nebraska.
8th Floor, Saunders-Kennedy Building, Omaha, Nebr.

DISTRICT No. 6. Arkansas, Oklahoma, and Texas.
1912 Fort Worth National Bank Building, Fort Worth, Tex.

DISTRICT No. 7. Illinois, Indiana, Kentucky, and Michigan.
South Chicago Post Office Bldg., Chicago, Ill.

DISTRICT No. 8. Louisiana, Alabama, Georgia, Florida, Mississippi, South Carolina, and Tennessee.
Box J, Montgomery, Ala.

DISTRICT No. 9. Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont.
Federal Building, Troy, N. Y.

DISTRICT No. 10. Delaware, Maryland, North Carolina, Ohio, Pennsylvania, Virginia, and West Virginia.
Willard Building, Washington, D. C.

DISTRICT No. 11. Alaska.
Goldstein Building, Juneau, Alaska.

DISTRICT No. 12. Idaho and Utah.
Fred J. Kiesel Building, Ogden, Utah.

Owing to the necessarily limited edition of this publication it will be impossible to distribute it free to any persons or institutions other than State and county officials actually engaged in planning or constructing public highways, instructors in highway engineering, and periodicals upon an exchange basis. Others desiring to obtain PUBLIC ROADS can do so by sending 10 cents for a single number or $1 per year (foreign subscription $1.50) to the Superintendent of Documents, United States Government Printing Office, Washington, D. C.

BITUMINOUS SURFACE TREATMENT OF SAND-CLAY AND TOPSOIL ROADS

REPORT ON A COOPERATIVE STUDY BY THE BUREAU OF PUBLIC ROADS AND THE ASPHALT INDUSTRY

THIS REPORT on the surface treatment of sand-clay and topsoil roads with bituminous materials represents the first stage of a general investigation of low-cost roads now being conducted by the Bureau of Public Roads and the asphalt industry. This general investigation includes a survey of existing types of low-cost road construction, for the purpose of evaluating work already done and of presenting descriptions of methods and materials which seem to produce the best results as developed from a detailed study of selected sections of highways of each type.

This report is issued for the purpose of supplying immediate information resulting from project surveys of bituminous-treated sand-clay and topsoil roads.

BITUMINOUS SURFACE TREATED SAND-CLAY ROAD. SECTION 1 IN FLORIDA BETWEEN PENSACOLA AND TALLAHASSEE

UNTREATED SAND-CLAY AND TOPSOIL ROADS LIMITED IN TRAFFIC CAPACITY AND OFTEN HIGH IN MAINTENANCE COST

Thousands of miles of sand-clay and topsoil roads have been constructed in the southeastern portion of the United States and lesser mileages in other sections. The wearing course of an untreated road consists of a mixture of sand and clay produced by transporting natural mixtures from near-by deposits or by incorporating sand or clay, as the case may require, with the natural soil. The characteristics of a mixture of sand and clay necessary to produce a satisfactory road surface are well understood by those experienced in their construction. Satisfactory mixtures have been found to consist of from 70 to 85 per cent sand, 5 to 10 per cent clay, and from 10 to 20 per cent silt. Mixing of materials on the road is frequently required to insure intimate admixture in proper proportions of the sand and clay. Topsoil is a natural mixture of sand, including coarser mineral particles, and clay as found in surface deposits and is frequently stripped from the fields. For all practical purposes it may be considered as a natural sand-clay possessing characteristics satisfactory for use without modification.

Data obtained in this survey is largely confirmed by investigations of low-cost improved roads by C. N. Connor [1] and studies of gravel, topsoil, and sand-clay roads by C. M. Strahan,[2] and others indicate that the cost of construction of sand-clay and topsoil surfaces lies between $1,300 and $2,600 per mile, varying largely with length of haul, and with a maintenance cost of between $300 and $600 per year. When untreated, the traffic which they can economically and satisfactorily serve seldom exceeds 400 vehicles per day, including light trucks, Under such traffic the average annual loss in surfacing material may lie between ½ and 1 inch. Under heavier traffic the loss may run substantially higher. Replacement of such material is therefore quite an item of maintenance, in some cases amounting to as much as $500 per mile per year.

While superior to the average graded earth road, the untreated sand-clay and topsoil road becomes softened during prolonged wet spells and is very dusty

[1] Part 2 of the Proceedings of the Seventh Annual Meeting of the Highway Research Board.

[2] The results of a study of construction methods and service value are contained in A Study of Gravel, Topsoil and Sand-clay Roads in Georgia by C. M. Strahan, Public Roads, vol. 10, No. 7.

in dry weather. It is in the best condition when the mixture of sand and clay contains sufficient moisture to prevent it from being dusty but not sufficient to cause it to soften. When in this condition and laid upon a satisfactory subgrade, its traffic-carrying capacity is excellent. These roads are usually made at least 20 feet wide, with a thickness of from 6 to 9 inches in the center and tapering to about 4 inches at the side. Sometimes the feather edge method is used and the materials are spread to cover practically the entire width of the roadway. The crown used varies from ⅛ to ⅜ inches to the foot.

SURFACE TREATMENTS SUCCESSFULLY APPLIED TO SAND-CLAY AND TOPSOIL ROADS

During the past few years there has been considerable interest in the improvement of sand-clay and topsoil roads by surface treatment with bituminous materials, so as to create a better year-round wearing surface and increase their traffic-carrying capacity. An appreciable mileage of road has already been successfully surface treated with bituminous materials and results have been so promising and economical that such work is being extensively prosecuted where funds are available. It is felt that there are great possibilities in surface treatment and it is probable that further study of materials and methods will develop improvement so that the average results will be as good or better than the best work already done. Such study should eliminate the chances of failure that now exist because of lack of information regarding certain important details.

In planning a general survey of existing roads of this type it was decided to make detailed studies in South Carolina and Florida, and representatives of the Bureau of Public Roads, the respective States and the asphalt industry inspected several hundred miles of road before selecting the individual projects described in this report.

Before bituminous surface treatment, the existing sand-clay or topsoil surface generally requires careful preparation, which consists of shaping and compaction where necessary to produce a true, well-bonded surface. A thin stabilizing layer of fine pea gravel is sometimes worked into the surface during such preparation. The treatment itself consists of the following steps:

1. Thorough sweeping to remove all loose particles and dust, in so far as possible, without disturbing the bonded surface.

2. Application of a prime coat of tar or asphaltic oil of sufficiently low viscosity to penetrate the upper portion of the sand-clay surface to which later application of a highly cementitious asphaltic product will adhere.

3. Application of an asphaltic product of relatively high viscosity in sufficient amount to retain the later application of fairly coarse mineral aggregate.

4. Application of mineral aggregate cover, consisting of broken stone or slag passing a 1-inch screen which, after brooming and rolling, combines with the second application of bituminous material to produce a thin wearing course knitted to and overlying the sand-clay or topsoil surface, which thereafter serves as base.

5. Frequently a light application of cut-back asphalt is applied and covered with fine mineral aggregate to throughly seal the surface, if after a few months traffic the bituminous mat previously constructed does not produce the desired degree of waterproofing.

PROJECTS SELECTED FOR DETAILED STUDY DESCRIBED

Five typical sections of highway were selected for detailed study, three in Florida and two in South Carolina. These sections, which will hereafter be referred to by number, are located as follows:

Section 1.—Florida State Road No. 1, in Santa Rosa County, extending northeast from Escambia Bay a distance of 3.177 miles and thence eastward for 1.991 miles; a total of 5.168 miles. This section covered Federal-aid project No. 38 and an extension of State-aid project No. 585.

Section 2.—Florida State Road No. 1, in Santa Rosa County, extending eastward from the end of section 1 for a distance of 4.299 miles and thence northeast to Pond Creek Bridge, a distance of 0.681 mile; a total of 4.980 miles. This section includes State-aid project No. 585.

Section 3.—Florida State Road No. 1, in Walton County, extending almost due east from the Okaloosa County line to Bear Head; a distance of 11.297 miles. This section is known as State-aid project No. 567.

Section 4.—South Carolina State route No. 29, in Anderson and Greenville Counties, beginning at the end of the pavement at Anderson, and extending 28.526 miles in a northeasterly direction to the end of the pavement at Greenville. This section includes the Anderson County section, 20.343 miles; Federal-aid project No. 138, 3.28 miles; Federal-aid project No. 231, 0.776 miles; Federal-aid project No. 183, 3.84 miles; and Greenville city section, 0.287 mile.

Section 5.—South Carolina State route No. 3, in Florence County. This section begins due east of the west city limits of Timmonsville and extends in a northeasterly direction for a distance of 1.894 miles through the town of Timmonsville to the intersection of the paved road to Florence.

Details relative to subgrade and drainage conditions for each section as determined by observation and history records of the State highway departments are given below. Analysis of samples of subgrade taken during the detailed study are discussed in Appendix 1.

Section 1.—The first 3.177 miles of this section, beginning at Escambia Bay Bridge, consists of a 10-foot fill made partly with a dark sandy loam and partly with a natural sand-clay brought in by an industrial railway. The remaining 1.99 miles consists of the natural soil, which is a dark sandy loam with no free clay present. The topography is fairly flat, but natural conditions together with the artificial ditching create good drainage and but two culverts were required. Some eight overflow bridges were constructed on the fill section. A 30-foot graded roadway was completed in June, 1926, and was covered with the sand-clay within a period of 30 days.

Section 2.—The subgrade of the entire section is a dark sandy loam, with no clay strata apparent. The natural drainage is excellent and little artificial drainage other than ditching and the construction of a few culverts has been required. Grading involved one 14-foot cut and one 10-foot fill. The width of the roadway is 30 feet. The grade was completed in April, 1927, and maintained for approximately one year before placing the sand-clay surface.

Section 3.—This entire section has an excellent natural subgrade, consisting of a dark sandy loam with no clay strata in evidence. Grading varied from cuts 2 feet in depth to one 20-foot fill. Natural drainage is

good and no artificial drainage was provided, with the exception of ditching and the construction of a few culverts. About 4 inches of sand-clay had originally been laid in 1925 and this old sand-clay road therefore made up a portion of the new subgrade. The graded roadway, 30 feet in width, was completed in January, 1927, and the sand-clay wearing course was completed in March of the same year.

Section 4.—The subgrade of the first 20.343 miles, namely, the Anderson County section, consists of a natural sandy clay soil. The soil on the remaining sections consists of a stony sand-clay in which there is a considerable amount of disintegrated granite and mica in places and which becomes quite slippery when wet. The grading on the Anderson County section and the Federal-aid project No. 138 was completed in 1922, while Federal-aid project No. 183 and the Greenville city section were graded in 1923. Topsoil surfacing was placed immediately after consolidation of the grade. On Federal-aid project No. 231 which extends across the Saluda River Bridge, the topsoil construction consisted merely of approaches to the bridge. These approaches were graded in September, 1925, about a month before the topsoil surface was laid. Throughout the entire stretch good natural drainage conditions exist and it was found necessary to construct only ditches and culverts as required. The width of road bed varied from 26 to 28 feet.

Section 5.—This section is a relocation of an older road constructed through a natural fine sandy loam over a flat, poorly drained area. The only artificial drainage consists of ditches, which within the city of Timmonsville are not entirely satisfactory. The roadbed was completed in September, 1926, about six months prior to laying the sand-clay surface and is 28 feet wide. The original road, which had an old cinder surface, was covered in some places to a depth of about 18 inches. Prior to laying the sand-clay surface, the grade was maintained under traffic.

SAND-CLAY AND TOPSOIL BASE OF PROJECTS STUDIED CONSTRUCTED BY METHODS IN COMMON USE

Neither Florida nor South Carolina specify the characteristics of sand-clay or topsoil material in detail, but require that the material must be obtained from sources of supply approved by the engineer. Analyses of samples of sand-clay and topsoil mixtures taken from the various sections are discussed in Appendix 1.

The method of construction requires the application of surfacing material upon the prepared subgrade in sufficient quantity so that after compaction it will have the specified thickness. For natural sand-clay mixtures South Carolina requires that the material deposited each day shall, on that day, be twice plowed and harrowed, except when in the judgment of the engineer the material is too dry or too wet to be plowed and harrowed properly. Florida does not specify plowing unless the material sets up to produce a rough surface but requires harrowing with either a spike-toothed or disk harrow. Both States require shaping with a road machine during consolidation under traffic and the use of a drag to finally smooth the surface. Sand-clay readily lends itself to the production of an almost perfect riding surface. It follows, therefore, that the riding qualities of the finished road depend upon the care with which the base is constructed.

PREPARING A SAND-CLAY ROAD FOR SURFACE TREATMENT

Where artificial mixtures are made by adding clay to a sand surface or vice versa the mixing is done by plowing and harrowing until a uniform mixture is produced. The surface is further mixed and shaped with a road machine and is usually finished off with a drag. No roller is used during construction, as traffic is depended upon for compaction. During compaction the mixture must be bladed and dragged as required to produce a uniformly smooth cross section.

Maintenance consists in reblading and shaping the road during its life, adding new material where necessary, and keeping the ditches and culverts open. Detailed information in connection with construction of

the individual sections obtainable from the service history prior to surface treatment is as follows:

Section 1.—Sand-clay road; width, 18 feet; 4½ inches compacted depth, uniform cross section; no side support other than subgrade shoulders; completed July, 1926, and maintained for a period of approximately seven months before surface treatment, during which time it was subjected to a traffic of 960 vehicles per day.

Section 2.—Sand-clay road; width, 20 feet; compacted depth at center, approximately 8 inches and 6 inches at sides; laminated red cypress planks 3 by 8 inches used as permanent curbs, at cost of $950 per mile installed; road maintained for approximately four months by blading, during which time it was subjected to a traffic of 1,030 vehicles per day.

SURFACE TREATED SAND-CLAY ROAD WITH CYPRESS CURBS AND WIDE SLOPING SHOULDERS ON SECTION 1 IN FLORIDA

Section 3.—Sand-clay road; width, 20 feet; average compacted depth, 5 to 5½ inches. No side support other than subgrade shoulders; maintained by blading for a period of approximately two months, during which time the road was subjected to a traffic of about 1,000 vehicles per day.

Section 4.—Topsoil road; width, 20 feet; depth, 5 to 6 inches compacted; no side supports other than subgrade shoulders; constructed in 1922 and 1923 and maintained under traffic without reconstruction; July, 1925, to May, 1926, additional topsoil surfacing added preparatory to surface treatment, cost of maintenance of preparation for surface treatment being $26.72 per mile per month. During this period it was subjected to a traffic of 630 vehicles per day.

Section 5.—Sand-clay road; width, 20 feet; compacted depth, 10 inches at center, 4 inches at sides; no side supports other than natural subgrade shoulders; maintained by blading for a period of nine months prior to surface treatment at a cost of $25 per mile per month, during which period it was subjected to a traffic of 1,170 vehicles per day.

BITUMINOUS SURFACE TREATMENT APPLIED BY DIFFERENT METHODS

In all cases bituminous materials were applied with pressure distributors, material used for the prime coat being slightly warmed before application and the heavier products for second application being heated to temperatures of from 250° to 300° F. All bituminous materials were furnished under the respective State highway specifications but analyses or samples for analysis were seldom found to be available. In most cases duplicates of these materials have been prepared by the respective producers, and the analyses of such materials, together with the specification requirements under which they were furnished, are shown in tabular form in Appendix II. Characteristics of the bituminous mats or surfaces at the time of inspection are shown in Appendix III. Details of the surface treatment of the various sections are described as follows:

Section 1.—During maintenance of the sand-clay base a stabilizing course of fine washed pea gravel, passing a ¾-inch screen and containing about 40 per cent of material retained on a ¼-inch screen, was applied over the 18-foot width at a rate of about 100 tons per mile. The cost of the pea gravel was 50 cents per ton at the pit, plus 80 cents freight, and it was hauled and spread for $2 per ton, making a total cost of $330 per mile plus the cost of dragging and blading over a period of four to six weeks before the bituminous priming material was applied. Just prior to application of the bituminous priming material the road was swept with a mechanical sweeper and all loose material on the surface pushed to one side. Priming material consisted of a light tar product meeting the State highway specification TC–1, and was applied at the rate of 0.25 gallon per square yard. Application was made on half the width of the road at one time, the other half being kept open to traffic. It was allowed to penetrate for two to four hours, after which it was covered with a thin layer of the sweepings previously removed. Immediately after covering, traffic was allowed over the treated surface. After the priming treatment had been down from 48 hours to a period of approximately 3 months, depending somewhat on weather conditions and the delivery of heavy asphaltic material, all hard scabs were scraped off and such potholes as had developed were repaired. The surface was then swept clean of all débris and loose material. Ruts were repaired with broken slag passing a 1-inch screen and treated with the same bituminous material later used for second application.

A fluid asphaltic product or road oil meeting the State specification OH–1 modified was then applied at the rate of 0.4 gallon per square yard and immediately covered with broken slag passing a 1-inch screen and retained on a 20-mesh sieve, from 25 to 75 per cent passing a ½-inch screen. The slag was distributed from piles containing 1 cubic yard previously placed at regular intervals along the side of the road. The rate of application was 40 pounds per square yard. Half of the road width was treated at one time, as in the case of application of priming material. The slag was evened out with a patrol grader or with hand brooms, leaving a 6-inch lap uncovered at the center of the road on the first half treated in order to care for overlapping of the bituminous material upon the treatment of the other half of the road. Immediately after spreading the slag, the road was rolled continuously with a 10-ton 3-wheel roller until a uniformly closed surface was obtained, and traffic was not allowed to pass over the treated surface until it had been thoroughly rolled. The cost of surface treatment, which was completed in April, 1927, was $2,560 per mile; including the stabilizing course of pea gravel.

Prior to inspection 25 months after completion, this surface had been carrying an average daily traffic of 990 vehicles. The cost of maintenance during 1927, the first year, was reported to be $67.92 per mile per month, but as this figure is the average of the cost of maintaining both the surface-treated section and an adjacent untreated section 6 miles in length it is probably too high.

STEPS IN PREPARING A SAND-CLAY SURFACE FOR SURFACE TREATMENT. NOTE THE V-FORMATION OF SWEEPERS

Cost of maintenance during the second year for the surface-treated road was $12 per mile per month and for the first three months of 1929 only $1.78 per mile per month.

Section 2.—The surface treatment of this section was quite similar to that described for section 1, and included the application of a stabilizing layer of pea gravel. Priming material consisted of a light tar product meeting the State highway specification TC–2 and was applied at the rate of 0.3 gallon per square yard. Asphaltic material furnished under specification OH–1 modified was applied at the rate of 0.5 gallon per square yard, covered with broken slag as described under section 1, and rolled with a 5-ton roller.

The road was completed in December, 1928, four months previous to inspection. The cost of the surface treatment only was $1,524.94 per mile. Surface maintenance up to the date of inspection cost approximately $2 per mile per month. Daily traffic on this section averages 1,140 vehicles per day.

Section 3.—The stabilizing layer of pea gravel as described for sections 1 and 2 was omitted on this section. The road was thoroughly swept before applying the priming material, which for a distance of approximately 6 miles, beginning at the Okaloosa County line, consisted of an asphaltic oil meeting State highway specification OC–2. The remaining 5 miles was primed with a tar product meeting specification TC–1. Both priming materials were applied at the rate of 0.25 gallon per square yard, covered with sand, and allowed to cure under traffic for a period of six to eight days, after which the sand was swept off and a heavy asphaltic material meeting specification OH–1 modified was applied at the rate of 0.4 gallon per square yard. This was immediately covered with crushed slag of the same character and in the same quantity described for the preceding sections, and thoroughly rolled.

The total cost of surface treatment, which was completed in May, 1927, was $1,831.34 per mile. Prior to inspection two years after completion, this surface had been carrying an average daily traffic of 990 vehicles. The cost of maintenance of the surface only during 1927 was $60.13 per mile per month and during 1928, $16.66 per mile per month. For the first two months of 1929 the maintenance cost was $2 per mile per month.

Section 4.—The surface treatment of this topsoil section did not involve the use of a stabilizer course as did Florida sections 1 and 2. The reshaped topsoil surface, which had been allowed to compact under traffic for a period of 30 to 90 days, was swept with a rotary power broom in conjunction with hand brooms to remove all loose material. Tar priming material meeting State specification TC–1, grade 1, was then applied at a

SURFACE TREATMENT ON SECTION 3 (FLORIDA ROUTE 1)

temperature of 125° to 150° F. at the rate of 0.26 gallon per square yard, except between stations 159+91 and 161+41 of Federal-aid project 138 and stations 30+62 and 16+12 of Federal-aid project 231, where no priming was used on account of shortage of material. Traffic was not allowed over the priming treatment which after a period of not less than 24 hours was covered directly with heavy asphaltic material applied at 300° F. at the rate of 0.38 gallon per square yard. Over approximately one-sixth of this area material meeting State specification OH–1 was used and on the remainder a heavier product of 150 to 200 penetration, which was a soft grade of asphalt cement.

Immediately after application of the asphaltic products, crushed granite from 1¼ inches to ¼ inch was spread at the rate of about 54 pounds per square yard and rolled longitudinally with a 5-ton 3-wheel roller, and then opened to traffic. The cost of this treatment, which was completed during July, 1926, was $2,324 per mile.

In conformity with regular practice in South Carolina, a seal coat was applied before the first winter. This section was treated with cold application asphaltic road oil, most of which was furnished under State specification LA No. 5, but a portion was according to specification OC–2. These materials were applied at the rate of 0.22 gallon per square yard and covered with local sand applied at the rate of about 20 pounds per square yard. The cost of this seal coat was $526 per mile.

During a period of two years the seal coat bled in warm weather and required the application of 10 pounds of sand per square yard. This produced a rather thick seal mat, which scaled in places and was slippery and dangerous in wet weather. To eliminate this unsatisfactory condition, the road was treated in December, 1928, with quick-drying cut-back asphalt applied cold at the rate of 0.26 gallon per square yard and covered with limestone chats approximately three-eighths inch in diameter at the rate of 26 pounds per square yard. Rolling with a 5-ton roller completed this treatment. Part of the cut-back asphalt contained a 150 to 180 penetration base, and part an 85 to 100 penetration base, meeting State specification AC–2L and AC–2, respectively. The cost of this treatment was $878 per mile. It produced a much more satisfactory surface and eliminated all slipperiness.

Exclusive of the last surface treatment, which was not adopted as a maintenance method, the cost during 1927, which included maintenance of surface, shoulders, and ditches, ranged from $30 to $34.66 per mile per month, and for 1928 was $20.12 per mile per month. The average daily traffic carried by this highway is 800 vehicles.

Section 5.—The surface treatment of this section consisted in preparation of the sand-clay surface and application of 0.3 gallon per square yard of priming material as described for section 4. Owing to rainy weather about one week elapsed between application of the priming coat and the heavy asphaltic material, during which period traffic was not permitted to use the road. The asphaltic product was an asphalt cement of 150 to 200 penetration. It was applied at the rate of 0.4 gallon per square yard and immediately covered with 50 pounds per square yard of the crushed granite and was rolled with a 4-ton 3-wheel roller. This treatment was completed in February, 1928, at a cost of $2,628 per mile.

A seal coat was applied during August, 1928, consisting of cut-back asphalt meeting specification AC–2 and applied at the rate of 0.26 gallon per square yard and covered with ¾-inch to ¼-inch crushed granite at the rate of 25 pounds per square yard and rolled. The cost of the seal coat was $600 per mile and the cost of maintenance during 1928 including shoulder maintenance was $12.50 per mile per month. This highway carries an average traffic of 1,220 vehicles per day.

SHOULDER MATERIAL BLADED OVER WEAK PAVEMENT EDGE IN SOUTH CAROLINA

CHARACTER OF BASE AN IMPORTANT ELEMENT IN SURFACE TREATMENT

All of the sections subjected to detailed study were in good condition when inspected in May, 1929, and differed but little in their generally excellent riding qualities. Variations in materials and methods which have been described were not indicated by the relative

results produced, and the experience of the respective maintenance engineers coupled with deductions drawn from the general survey have been taken into account in the following comments.

It is evident that the bearing power of the subgrade is a most important consideration in this type of work as the sand-clay or topsoil itself is never satisfactory unless well and uniformly supported. In fact the traffic-carrying capacity of the surface treatment is entirely dependent upon the adequacy of support provided by the sand-clay or topsoil base. It was noted that a large proportion of the maintenance of the surface treatments consisted of repairing failures in certain areas, caused by insufficient support afforded by the underlying subgrade or base. In the more recent work, maintenance has been materially reduced by more careful attention to providing uniform support, particularly along the edges, which in earlier work failed to a considerable extent due to the tendency toward thinning or feather edging the original construction. Several methods of preventing or reducing edge failures are now being satisfactorily used, often in combination: 1. Constructing a base which is wider than the area to be surface treated. 2. Installing plank curbs to provide lateral support for the base. 3. Thickening the base at the edges.

Where a surface-treated road has a feather edge, or if for any other reason the edge is weak, traffic should be induced to use the center of the road in preference to the edges. Under such conditions, it is the practice of South Carolina to blade in shoulder material over the weakened edge, as shown in the illustration on page 198.

A good measure of the sufficiency of the supporting value of the sand-clay or topsoil road is its behavior under traffic before surface treatment and it is advisable to delay surface treatment for a sufficient length of time after construction or reshaping of base to develop and correct all weak areas. Thorough admixture of the sand and clay constituents of the base in proper proportions is essential to uniform supporting power, and this detail should receive especial attention during construction.

It is frequently impracticable to specify in advance the exact composition of the sand, clay, or topsoil to be used on any given job, but as previously indicated preference should be given to mixtures which fall within the following limits:

Mechanical analysis

Clay	5 to 10 per cent.
Silt	10 to 20 per cent.
Sand	70 to 85 per cent.

The sand should have 45 to 60 per cent retained on a 60-mesh sieve. Its uniformity coefficient should be above 15 with an effective size approximating 0.01 millimeter.

Mixtures falling within the above limits are frequently found in nature and have been used in many of our best roads. Modifications of the above limits have been found to be useful and are extensively used in road construction. Further description and classification is to be found in Appendix I.

Laboratory tests on available local material serve as a useful guide in original selection and in the correction of mixtures which have proven faulty. Preference should be given to materials having some pebbles retained on the 10-mesh sieve and passing a 1-inch screen.

Cross Section of Surface Treated Sand-Clay Road (Result of Washout) Showing Subsoil and Wooden Curbs. Section 1 in Florida

Careful preparation of the sand-clay or topsoil is essential to the construction of a satisfactory surface treatment wearing course. Any defects or irregularities in the surface of the base will be reflected in the surface treatment and later correction will be more difficult and expensive. The untreated base should have the desired smoothness and shape of the finished road and should be thoroughly compacted and well bonded. To obtain these conditions it is usually necessary to do a considerable amount of machine work shortly before surface treatment which may consist of scarifying, harrowing, blading, and dragging. During dry weather it may be necessary to sprinkle the road with water during these processes. Compaction of this type of road is effected by traffic and some regulating measure for causing traffic to distribute itself uniformly over the road surface is advisable. This may be accomplished by placing obstacles at suitable intervals to force traffic over desired lanes and varying these lanes as seems advisable.

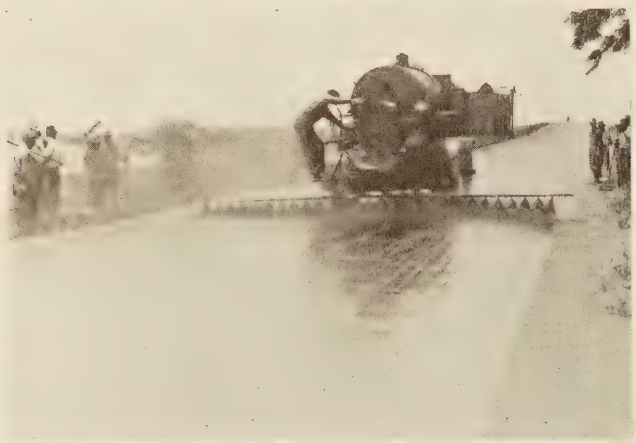
Freshly Bladed Gravel Stabilizer on Sand-Clay Base. Section 1 in Florida

EXPERIENCE SHOWS FACTORS WHICH ARE OF IMPORTANCE IN APPLYING BITUMINOUS MATERIALS

When the sand-clay or topsoil material is deficient in relatively coarse particles it has proven advisable to incorporate a thin course of pea gravel or similar material in the surface before final compaction, as a stabilizing measure in preparing the base for application of the bituminous materials.

Before applying the bituminous priming material it is most important to thoroughly sweep the base so as to obtain a clean, well-bonded surface which will be readily penetrated by the primer, and further stabilized. If the dust is not removed it may prevent the primer from properly penetrating the base and thus produce an unstable mat composed of the primer and the dust.

The purpose of the priming treatment is to harden and moisture proof the upper portion of the base and produce a surface to which the heavier nonpenetrating bituminous material which is later applied will adhere. The primer should therefore be a product of sufficiently low viscosity to be readily absorbed by the sand-clay or topsoil surface and not dry or harden so rapidly as to produce a bituminous mat before it has had an opportunity to penetrate. Light tars of 8 to 13 specific viscosity at 104° F. have been most extensively used as a primer and have in general been found to penetrate and harden more rapidly than the asphaltic products so far used. There appears to be no reason, however, why an entirely satisfactory asphaltic product can not be developed for general use which will have the desired viscosity, penetrating and drying qualities, and such a product, refined from cracking coil residues or produced from an asphalt cement cut back with a light, but not too volatile distillate of the kerosene type, is to be looked for in the near future.

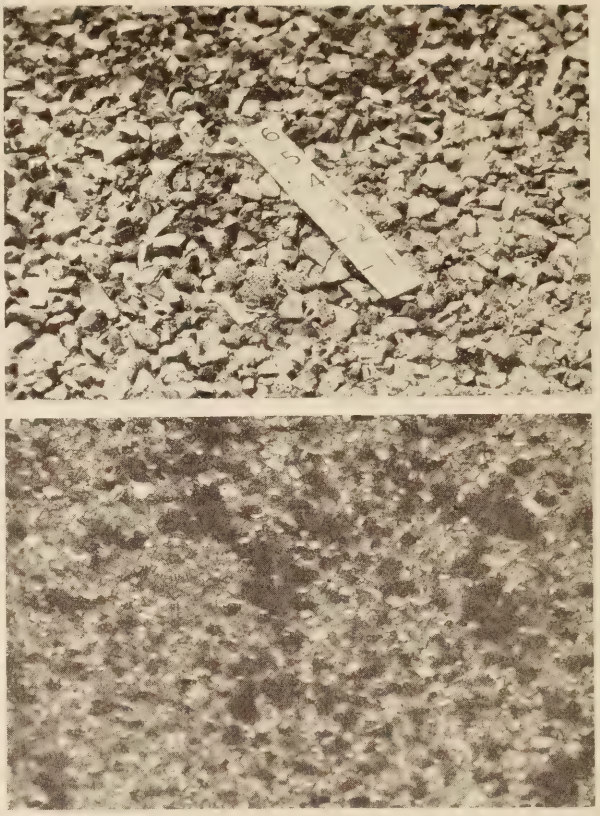


Applying the Prime Coat Immediately After Cleaning

The proper amount of primer to be applied is dependent upon the extent to which it will be readily absorbed within 24 hours by the surface which is treated and it is not advantageous to apply an amount which will require a mineral cover before application of the heavier bituminous material. For the usual surface condition of this type of road the quantity required may vary between 0.2 and 0.35 gallon per square yard.

The next step in the construction of the surface treatment wearing course is application of the heavy asphaltic material, the function of which is to combine with the mineral aggregate cover to produce a thin well-bonded bituminous mat which will adhere to the primed base, protect it from the wear of traffic, and as a waterproofing agent prevent the unsatisfactory conditions produced in the untreated sand clay or topsoil by extremely wet or prolonged dry spells of weather.

To accomplish these results it is evident that the asphaltic product should possess as much body and adhesiveness as possible. The use of a suitable primer makes it practicable to utilize a soft asphalt cement for this purpose while without primer a much more

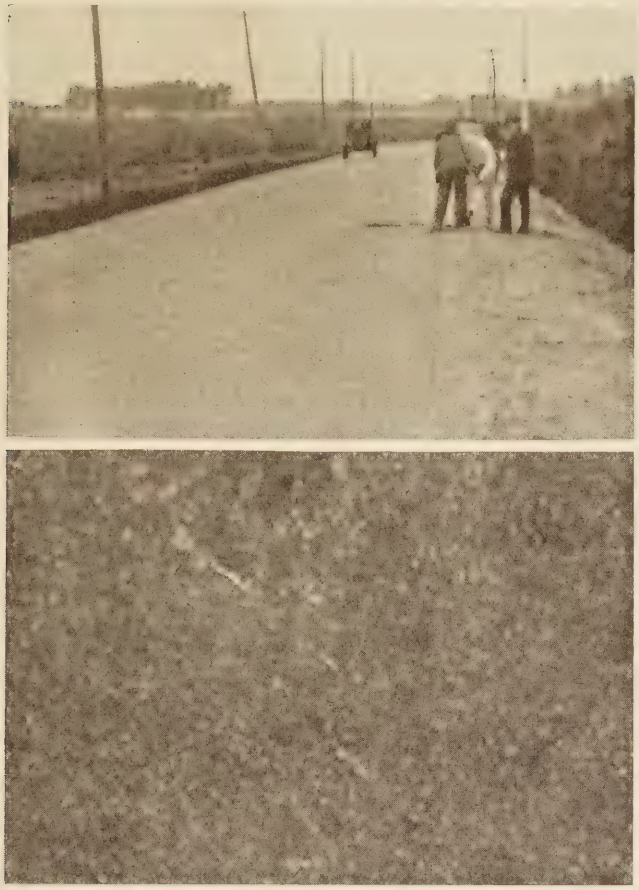


Crushed Slag Cover on Surface Treatment Immediately After Application and After Being Subjected to Traffic

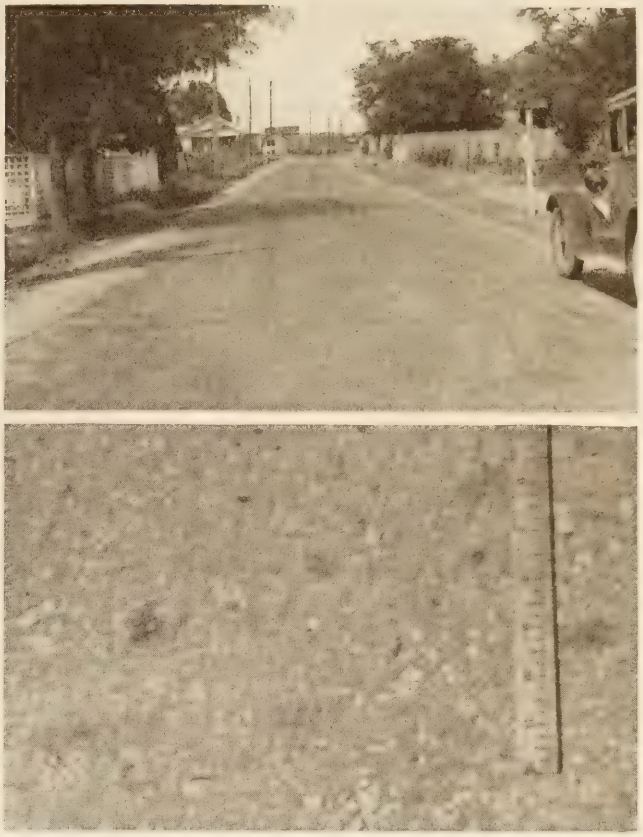
fluid product would be required to obtain any degree of adherence to the untreated surface. While very viscous fluid asphaltic oils have been used with success for second application, there is every reason to prefer the soft asphalt cement of between 100 and 300 penetration, from the standpoint of both durability and stability or resistance to shoving of the mat.

The principal limiting factor with regard to the use of the harder grades of asphalt is difficulty in obtaining retention of the aggregate cover if application is made in relatively cold weather. Between the limits stated, the cooler the weather the softer should be the asphalt cement. On the other hand, the warmer the weather and the heavier the traffic the harder should be the asphalt cement. Tars have been used to some extent for second applications but in general have been found to harden and wear away more rapidly than the asphaltic products.

The quantity of heavy asphaltic product required to produce the wearing mat will range from 0.3 to 0.5 gallon per square yard depending upon the surface texture of the primed base and the size of mineral aggregate used for cover. The temperature of the material when applied should be sufficient to insure the distribution of a continuous fluid sheet over the surface, and will usually lie between 250° and 325° F. It is most important that the applied material be so distributed as to produce a uniform unbroken bituminous film. Failure to secure such uniformity has been responsible for a large proportion of the early maintenance required on some work. Because of the tendency of the mat to fail first near the edges of the road, it has been found beneficial in some cases to apply slightly greater quantities of asphaltic material and



Section 4 Between Greenville and Anderson, S. C. Surface Treated Topsoil Road Resealed and Covered With Limestone Chats



Section 5 in Timmonsville. Surface Treated Sand-Clay With a Seal Coat of Cut-Back Asphalt Covered With Friable Crushed Granite

mineral cover for a width of approximately 2 feet along the sides. This is accomplished by placing nozzles with larger openings on that portion of the spray bar which applies the material along the edges.

The mineral aggregate for cover should preferably consist of hard fragments free from dust, in which case, the size may range from ¾ to ¼ inch. Where a relatively soft and more friable material must be used, a slightly larger size of from 1¼ to ¼ inch will be desirable. Crushed fragments are in all cases preferable to rounded pebbles. As the mineral cover should impart both stability and nonskid qualities to the wearing surface, relatively coarse material is greatly preferable to sand, which generally is considered as unsuitable for cover material.

The amount of cover material required will depend upon the quantity of asphaltic material which has been applied and the size of aggregate. Sufficient cover should be used to prevent bleeding of the mat, but care should be taken not to overload the bituminous material with mineral particles and thus produce a mixture which will wear rapidly under traffic. It is much better practice to apply too little cover material at first and add more as required than to overload the bituminous material on first application. A safe minimum to apply at first is approximately 10 pounds of mineral aggregate for each 0.1 gallon of bituminous material.

Uniform distribution of the mineral cover is extremely important in producing a satisfactory mat. Lack of uniformity makes a rough riding surface and develops fat spots and overloaded areas which induce shoving and disintegration under traffic. At present the accepted practice is to broadcast the aggregate with shovels from the stock piles placed at suitable intervals along the side of the road, throwing the material longitudinally with a sweeping motion of the shovel, and then hand-broom as required to obtain uniform distribution. It is thought that a mechanical spreader attached directly to a dump truck, as used by some of the Western States in surface treatment, might prove to be a considerable improvement over the methods now used. It is quite possible that light blading or dragging of the cover material before rolling, as done by the Western States, would also prove advantageous in improving the riding qualities of the finished road.

Immediately after spreading the cover material, it should be rolled with a 5 to 7½ ton roller until thoroughly compacted and bonded with the bituminous material. A tandem roller is to be preferred to a 3-wheel roller and the amount of rolling should be controlled so as not to produce excessive crushing of the mineral particles. As soon as rolling is completed the road may be opened to traffic. Cover which is forced to the side of the road by traffic may be thrown back to remedy any deficiency which may develop in certain areas.

CHARACTER OF SEAL COAT DEPENDS ON PURPOSE OF TREATMENT

After the treatment has been in service for some time it may require a seal coat. The proper time to apply this coat depends upon the condition of the road surface, but in no case should it be delayed after the surface has assumed a dead or brittle appearance, as

such condition is soon followed by disintegration. In South Carolina a seal treatment is usually applied as a precautionary measure before the winter following construction.

The selection of materials to be used in the seal treatment will depend upon the purpose of treatment. If it is desired to enliven the surface and prevent raveling of an already heavy mat, a light application of a cold cut-back asphalt containing a readily volatile distillate is used with small-sized mineral aggregate. If it is necessary to strengthen the old surface mat by adding appreciable thickness, a heavier bituminous material such as is used in original construction is applied hot with larger mineral cover. Whatever the purpose, it is highly important that the mineral cover be suited to the bituminous material selected.

Surface Treated Topsoil Road Between Greenville and Anderson, S. C., Section 4

For light treatment, an asphalt cement of not over 200 penetration cut to low viscosity with a gasoline type of distillate is satisfactory. Such material is usually applied to the thoroughly swept road at the rate of not more than 0.25 gallon per square yard and covered with clean, crushed mineral aggregate ranging in size from $\frac{5}{8}$ to $\frac{1}{4}$ inch. The principles described for original treatment relative to application of cover material, are applicable to retreatment. The new surface produced is of slightly finer texture, but will possess stability and nonskid characteristics similar to the original treatment.

The serviceability of the bituminous surface treatment is dependent upon careful and intelligent maintenance applied promptly as required. The patrol system is almost essential, as the surface should be under constant observation to detect and correct defects as they develop and prevent deterioration of adjacent areas due to progressive disintegration, which takes place very rapidly if the original trouble is not promptly eliminated. In addition to the regular patrol maintenance, retreatment will be required at intervals of two or three years and may consist of a light seal or enriching treatment or a heavier treatment to thicken or smooth up the original wearing course.

Good judgment is required in the application of maintenance measures and before deciding upon methods to be used, the reason for existing unsatisfactory conditions should be correctly diagnosed. Replacement of a defective wearing course, due primarily to faulty subgrade or base, will correct the trouble only temporarily. In such case the unsatisfactory subgrade or base conditions should be remedied before constructing the new wearing surface.

Patching the wearing course should be skillfully done so as to duplicate as nearly as possible the composition and character of the adjacent satisfactory areas, and may include use of priming material in addition to the heavier bituminous product. Special attention should be given to constructing the patch so as not to interfere with the riding quality of the road, and the use of an excessive amount of bituminous material or an aggregate different from that originally used should be avoided, or otherwise the patch is apt to develop into a rough spot. Properly made patches can hardly be detected a short time after construction, and may be used to correct both disintegrated areas and areas which are intact but not smooth.

CONCLUSIONS SUMMARIZED

1. It is clearly apparent from this investigation that in localities where sand-clay and topsoil roads have been found of value, surface treatment fills a definite need in the economic development of a well-planned highway system by offering a nonskid surface which is exceptionally easy riding, low in first cost, reasonable in maintenance cost, and one that can be constructed with a minimum of inconvenience to traffic. It has the advantage of making maximum use of local material.

2. South Carolina and Florida each have hundreds of miles of this type that have been in service from three months to four years and are successfully carrying traffic which in some instances is in excess of 2,000 vehicles per day. There are a great many miles over 3 years of age on which the traffic has averaged more than 1,000 vehicles per day.

3. Construction and maintenance costs naturally vary with local conditions. The following figures show a normal range of cost for work of this character to date:

(*a*) Construction costs per mile:	
Sand-clay or topsoil base, 20 feet wide and 6 inches uniform thickness, complete	$1,500 to $3,000
Priming material and heavy application with cover, complete	1,800 to 2,500
Seal coat treatment, complete	500 to 1,000
(*b*) Maintenance costs per mile per month:	
First year—	
Surface treatment only	$15 to $60
Shoulders and ditches	15 to 50
Second year—	
Surface treatment only	5 to 20
Shoulders and ditches	0 to 20

4. Important subgrade requirements are as follows:

(*a*) The subgrade should be composed of stable soil, even though to meet this requirement it is necessary to remove from the grade existing unsatisfactory soils and replace them with stable soil.

(*b*) The subgrade should be constructed in layers of not more than 12 inches, thoroughly compacted by contractor's equipment or by hydraulic jetting, and machining and shaping should be continuous under traffic.

(*c*) The grade line should be laid to keep the surface well above the ground level and, in so far as practical, to take full advantage of natural drainage.

5. Details of especial importance with regard to sand-clay and topsoil base are as follows:

(*a*) Base materials should be selected only after examination to determine their suitability for use.

(*b*) The compacted depth of base course should be not less than 6 inches at any point over the areas to be surface treated.

(*c*) The base should be constructed 2 to 3 feet wider than the area to be surface treated or else should be supported at the edge by planks or other curbs.

(*d*) The crown of the sand-clay or topsoil base should not exceed ¼ inch to the foot.

(*e*) After thorough mixing the base should be compacted by traffic for a period of not less than one month accompanied by frequent blading and shaping. This traffic should be so distributed by regulating measures as to obtain uniform compaction over the full width of road.

(*f*) When the sand-clay or topsoil does not contain an appreciable quantity of mineral particles of approximately ¼-inch diameter it is recommended that a stabilizing layer of pea gravel or similar material be worked into the surface of the base when preparing it for surface treatment.

6. Bituminous priming material should be applied only upon a smooth, thoroughly bonded and well-swept base. The priming material should possess high penetrating and fairly rapid hardening properties so as to be absorbed by the base without leaving a sticky mat. Cold application tars and asphalt cements cut back with a kerosene type of distillate appear best adapted for such purpose. Wherever possible traffic should be barred from the road after sweeping preparatory to priming and until compaction of the bituminous wearing course has been effected. The priming material should uniformly cover the surface of the base but there should not be an excess so as to require a mineral cover prior to application of the heavy asphaltic material.

7. The heavy asphaltic material should not be applied within 24 hours after the surface has been treated with priming material. A soft asphalt cement of from 150 to 300 penetration is to be preferred to a softer or less viscous hot oil. It should be uniformly distributed at a temperature of 275° to 325° F. when the air temperature is not lower than 50° F. and immediately covered with coarse mineral aggregate. It is important to exercise extreme care in uniformly distributing the coarse aggregate before and during compaction in order to secure a smooth riding surface. Coarse aggregate should preferably consist of hard, broken fragments of stone or slag from ¾ to ¼ inch in diameter. Uncrushed gravel and sand are not desirable for use as mineral cover. The bituminous mat should be approximately ¾ inch in compacted thickness, and should be rolled with a tandem roller until thoroughly bonded. Cover material should not be applied in excessive amount, as overloading the bituminous mat will greatly reduce its life.

8. Application of a seal coat should be deferred until the condition of the surface treatment indicates its immediate need, except where climatic conditions are such as to create this condition during the winter months, in which case the seal coat should be applied before the first winter of service. Bituminous material for seal coat should be preferably an asphalt cement cut-back with a gasoline type of distillate. The mineral cover should consist of ½ to ¼ inch stone or slag chips.

9. Retreatment with soft asphalt cement and a coarse mineral cover should be made whenever reinforcement or thickening of the bituminous mat is required and when patching becomes so extensive as to make resurfacing more economical.

10. General maintenance should be under the patrol system and patches should be made promptly as required, with care to maintain a smooth riding surface. The material and methods used for constructing patches should duplicate as closely as possible materials and methods used in original construction. Maintenance should include prompt repairs to shoulders and ditches when needed.

APPENDIX I

EXAMINATION AND CLASSIFICATION OF SOIL SAMPLES FROM SUBGRADES AND BASES

Samples were taken of both the subgrades and base courses of the several sections of surface-treated roads covered by this survey. These materials have been classified according to characteristics determined by analyses. General conclusions may be drawn, which explain their behavior up to the time of the survey and the behavior that may be expected in the future. Classification of these soils are independent of the effect of surface treatment which is covered elsewhere.

Analyses were made by methods in use in the laboratory of the Bureau of Public Roads. Clay is defined as material possessing capillarity and cohesion and generally consisting of particles not larger than 0.005 millimeter in diameter. Silt is defined as material possessing capillarity in appreciable amount and little or no cohesion and consisting of particles not larger than 0.05 millimeter nor smaller than 0.005 millimeter in diameter. Sand is defined as material possessing neither capillarity nor cohesion in appreciable amount and consisting of particles larger than 0.05 millimeter in diameter.

The scheme of analyses to which the soil samples were subjected is as follows:

1. Determination of size and percentage of particles to determine—

Percentage of clay.
Percentage of silt.
Percentage of sand.

2. Analysis of sand fraction, on which is based the determination of—

Uniformity coefficient.
Effective size.

3. Physical tests on the soil include the determination of—

Lower liquid limit.
Plasticity index.
Shrinkage limit.
Shrinkage ratio.
Moisture equivalent, centrifuge.
Moisture equivalent, field.
Volume change at centrifuge moisture equivalent.

As a result of these analyses the materials forming the subgrade and base courses of the roads under

discussion were placed in the following soil classifications (basis of classification discussed below):

Section	Group classification	
	Subgrade	Base
(1) Florida Route 1	A-3, A-2	A-3, A-2
(2) Florida Route 1	A-3, A-2	A-3, A-2
(3) Florida Route 1	A-3, A-2	A-3, A-2
(4) South Carolina Route 29	A-7, A-2	A-1, A-2
(5) South Carolina Route 5	A-2	A-2

The group classifications have in general the following properties:

GROUP A–1

Clay, 5 to 10 per cent.
Silt, 10 to 20 per cent.
Sand, 70 to 85 per cent.

Forty-five to sixty per cent of the sand is retained on a 60-mesh sieve. The material has a uniformity coefficient in excess of 15 and an effective size approaching 0.01 millimeter. Group A–1 materials possess high stability, due to both high frictional resistance in the sand and high cohesion of the binder. It is a well-graded product containing coarse and fine particles together with an excellent binder. It is highly stable under wheel loads and compacts well under traffic, functioning satisfactorily when surface treated or when used as a base for relatively thin wearing courses.

GROUP A–2

This group differs from group A–1 in one or more of the following respects:

1. Poor quality of clay-silt binder.
2. Proportion of silt and clay, not conforming to the limits established for group A–1.
3. Less than 45 per cent of the sand is retained on the 60-mesh sieve.

This material softens at high water content caused by rains or by capillary rise from saturated lower strata when surface treatment prevents evaporation.

GROUP A–3

This group differs from groups A–1 and A–2 mainly in a lack of silt and clay or particles less than 0.05 millimeter diameter, being essentially sandy in character and deficient in cohesion. The effective size is usually not less than 0.1 millimeter. This material has no shrinkage or plasticity and no detrimental capillarity. The higher its uniformity coefficient and the sharper the grain the higher will be its stability. Soils of this class are unstable under direct concentrated load and do not compact well under traffic. When moist they possess greater stability than when dry, being similar in this respect to beach sands. These soils furnish excellent support as subgrades for moderately thick pavements without modification. They require the addition of only a small percentage of cohesive material to convert them into very stable bases. Stabilization of this character permits the thickness of the wearing course to be reduced.

GROUP A–7

Soils of this group include clays with elastic and highly expansive properties, differing from groups A–1, A–2, and A–3 in their behavior in the presence of water. Addition of water to the dry soil causes expansion and forms a spongy jellylike mass. The large-sized voids in this soil allow rapid penetration of water to a greater depth with correspondingly rapid softening. They allow rapid evaporation at the surface, dry out uniformly, and quickly lose their spongy character. Because of their elasticity they are less apt to compact well under traffic. The behavior above outlined is largely dependent on field conditions. Where rainfall is light and well distributed, with the ground water level well below the subgrade, this soil may form a fairly stable roadbed. The characteristics of the group on analysis are as follows:

Effective size is greater than 0.002 millimeter (except when coagulated).

Shrinkage limit is less than 30.

The field moisture equivalent may exceed both 35 and the value of the centrifuge moisture equivalent; also under some conditions the field moisture equivalent may be very nearly equal to the lower liquid limit.

Field conditions may produce very detrimental volume change and the elastic properties may tend to prevent the compaction obtainable with other soils.

The clay may be deficient in finer particles, or finer clay may be present in abundance combined with organic matter or coarse-grained mica.

ILLUSTRATIVE ANALYSES PRESENTED

The analyses shown in the following tabulation have been selected from those made on materials forming the subgrade and base courses of the roads surveyed. They do not indicate the group classification limits but are merely illustrative of group differences.

Under A–1, sample South Carolina 31 closely approaches the ideal in grading as well as other properties. Under A–2, Florida No. 34 differs mainly in its 17 per cent of coarse sand as compared with 39 per cent for sample South Carolina 31, as well as its much higher percentage of clay.

Under A–3, Florida No. 2 shows a cohesionless soil with a fair percentage (27 per cent) of coarse sand. It contains only 3 per cent silt and 2 per cent clay.

Under A–7, South Carolina 26 is markedly different in lower liquid limit, plasticity index, both centrifuge and field moisture equivalents, and is high in volume change.

Illustrative analyses of subgrade and base soils

	Group A–1, sample South Carolina 31	Group A–2, sample Florida 34	Group A–3, sample Florida 2	Group A–7, sample South Carolina 26
Mechanical analysis:	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Larger than 0.5 mm	39	17	27	16
0.5 to 0.05 mm	39	55	68	(1)
0.05 to 0.005 mm	14	14	3	(1)
Smaller than 0.005 mm	8	14	2	(1)
Effective size	.009	.0018	.08	
Uniformity coefficient	53	100	5	
Lower liquid limit	17	19	17	64
Plasticity index	4	6	0	32
Shrinkage limit	15	17		28
Shrinkage ratio	1.9	1.8		1.5
Moisture equivalent, centrifuge	13	12	5	48
Moisture equivalent, field	14	15	19	51
Volume change at centrifuge moisture equivalent	0	0	0	30

[1] Unable to make test because of coagulation.

GENERAL DISCUSSION

The effect of either surface or ground water upon soils is of such vital importance that their classification is largely a measure of their behavior in the presence of water in the laboratory and in the field.

Some soils of relatively low susceptibility to water action but deficient in natural binding material may, by treatment with bituminous materials, be made equivalent or superior to natural Group A–1 soils in their stability and load-carrying capacity.

The soil groups highly susceptible to surface water action, which may destroy their stability through softening, are benefited greatly by an impervious surface treatment. Soils susceptible to ground-water action have their resistance increased by the introduction of asphaltic oils in a mixed-in-place treatment, or by the penetration of primer for surface treatment and their classification as natural soil does not necessarily forecast their behavior when thus treated.

Conclusions based on laboratory classifications without fully considering field conditions and the effect of bituminous treatment, may be very misleading and confuse attempts to correlate soil classification with service results. Comparing service results with construction and maintenance costs, it seems reasonable to class the soils of Groups A–1, A–2, A–3, and A–7 as satisfactory under the field conditions existing on the roads covered by this survey. The important part played by field conditions is illustrated by the following examples.

On Florida State Route 1 the extensive fill over Escambia Bay is largely made with Group A–2 soil. The fill has good side drainage and is protected with an impervious asphalt surface treatment. The surface waters are collected in water-tight gutters and carried beyond the sides of the fill by frequent box drains. The fill is standing up well and offers a firm support to the base and surface mat forming the roadway.

On South Carolina State Route 3 within the limits of Timmonsville there is a small section about 10 square yards in area where rutting and cracking of the surface treatment has occurred over Group A–2 soil. Excavation at this point shows that the ground water level approaches the bottom of the base course with resulting softening and instability. Proper ditches have not been built and the slopes on both sides are toward the roadway, this condition probably resulting in pocketing the water beneath the surface.

On South Carolina State Route 29 a portion of the base and subgrade are found to conform to Group A–7 classification, mainly because of the presence of mica coupled with a high clay content. No trouble has been experienced on this road which seems to be directly chargeable to the soil type. In general the natural drainage conditions are ideal and this, together with the waterproofing effect of the bituminous treatment, accounts for the high stability of the roadbed during its several years of service.

APPENDIX II

ANALYSES OF BITUMINOUS MATERIALS

Characteristics of the bituminous materials used for surface treatment have been discussed in the main body of the report and will not be considered in further detail here.

The specification limits and results of analyses of these materials are given in Tables 1 to 3. Wide variations are apparent in both specifications and tests, but it is significant that all these materials have given good service in the treatment of soils with a broad range of characteristics. It seems that considerable latitude in characteristics is allowable and that a general simplification of specification requirements is both possible and desirable.

Specifications for materials for low-cost roads should be as free as possible from requirements which may make it difficult to obtain the desired products in large quantities from as many sources as possible, without recourse to unnecessary methods of refining. Specifications should, of course, cover characteristics essential to ready workability or handling incident to construction and necessary hardening or binding qualities. Most other requirements are believed to be superfluous.

The tables show the results of consistency tests which have almost invariably been included in specifications. The results of a special distillation test for asphaltic products and the consistency of the residue from this test have been included for general information.

TABLE 1.—*Results of tests of tars used for priming*

	Florida							South Carolina				
	TC-1			TC-2				TC-1				
	Specification limits	Sec. 1		Specification limits	Sec. 3			Specification limits	Sec. 4			Sec. 5
Specific gravity at 77° F. (25° C.)	1.100+	1.132	1.127	1.10–1.14	1.134	1.136	1.138		1.124	1.128	1.127	1.131
Specific viscosity, Engler at 104° F. (40° C.)	8–13	12.5	10.3	25–35	28.0	28.5	30.0	8–13	10.4	8.8	10.3	10.4
Bitumen soluble in CS_2, per cent	90+	95.5	95.6	95+	96.0	96.3	96.2	88–97				
Distillation, A. S. T. M., D-20 modified:												
Water, per cent								2.0−	1.0	0.6	2.0	1.8
Percentage, of total distillate to—												
338° F. (170° C.)	5−	1.5	1.6	2.0−	1.0	1.3	1.5	7.0−	1.8	1.6	1.7	0.4
455° F. (235° C.)								20.0−	14.8	14.7	13.6	10.4
518° F. (270° C.)	30−	27.9	27.0−	25.0−	20.4	20.0	19.8	30.0−	27.4	25.3	22.8	21.0
572° F. (300° C.)	40−	38.0	38.2	35.0−	28.8	30.9	28.0	35.0−	34.3	33.5	30.0	30.7
Specific gravity of total distillate at 77° F. (25° C.)								1.01+				
Melting point of residue (R. & B.)								140° F. (60° C.)−				

	Florida, OC-2			Florida, OC-2	
	Specification limits	Sec. 3		Specification limits	Sec. 3
Specific gravity at 77° F	0.925–0.970	0.945	Distillation, A. S. T. M., D-20, modified—Continued		
Flash point (open cup) ° F	122 (50° C.)−	240	Percentage, by volume, of distillation to—Continued.		
Specific viscosity, Engler, at 77° F. (25° C.)	80–120	131.5	554° F. (290° C.)		1.8
Loss at 325° F. (163° C.), 5 hours, per cent	30−	11.02	572° F. (300° C.)		3.0
Float test on residue at 122° F. (50° C.), seconds	90+	15	590° F. (310° C.)		6.5
Bitumen soluble in CS_2, per cent	99.5+	99.76	608° F. (320° C.)		10.5
Bitumen insoluble in 86° B. naphtha, per cent	6.0+	13.50	626° F. (330° C.)		14.5
Distillation, A. S. T. M., D-20, modified: [1]			644° F. (340° C.)		18.0
Initial boiling point, ° F		250	662° F. (350° C.)		21.5
Percentage, by volume, of distillate to—			680° F. (360° C.)		26.5
500° F. (260° C.)		0.2	Float test on residue at 122° F. (50° C.), seconds		36
518° F. (270° C.)		0.5	Residue soluble in CS_2, per cent		99.7
536° F. (280° C.)		1.0			

[1] Test made on 100 c. c. sample measured by weight on basis of specific gravity at 77° F.; bulb of thermometer immersed to a point ¼ inch above bottom of flask; distillation stopped at 680° F., and residue immediately poured in tin box and cooled for consistency tests.

TABLE 2.—*Results of tests of asphaltic products for wearing course construction*

	Florida, OH-1 modified					South Carolina, OH-1		South Carolina, 150–200 penetration asphalt		
	Specification limits	Sections 1 and 3	Section 2	General analyses		Specification limits	Section 4	Specification limits	Section 4	Section 5
Specific gravity at 77° F. (25° C.)	0.99+	0.991	1.030	1.033	1.033	0.98+	1.006	1.00+	1.032	1.032
Flash point (open cup), ° F	212 (100° C.)+	285	435	420	400	176 (80° C.)+	235	347 (175° C.)+	480	465
Specific viscosity, Engler, at 212° F. (100° C.)		63.9	216.4	196.9	332.0	60−	38.2			
Specific viscosity, Engler, at 302° F. (150° C.)	7.5–20.0	8.2	21.3	17.5	28.8					
Float test at 90° F. (32° C.), seconds						60+	183			
Float test at 122° F. (50° C.), seconds	100+	138	410	414	797					
Penetration at 77° F. (25° C.)			217	227				150–200	175	170
Loss at 325° F. (163° C.), 5 hours, per cent	7.5−	6.04	0.22	0.8	0.44	15.0−	6.25	2.0−	0.26	0.24
Float test on residue at 122° F. (50° C.), seconds	110+	455	481	542	1,110	110+	141			
Penetration of residue at 77° F. (25° C.), per cent								60+	95	94.1
Bitumen soluble in CS_2, per cent	99.5+	99.72	99.76	99.82	99.86	99.5+	99.46	99.5+	99.86	99.84
Organic matter insoluble, per cent								0.2−	0.04	0.06
Bitumen insoluble in 86° B. naphtha, per cent						6.0+	20.36			
Distillation, A. S. T. M. method D-20, modified: [1]										
Initial boiling point, ° F		590					536			
Percentage, by volume, of distillation to—										
554° F. (290° C.)							0.2			
572° F. (300° C.)							0.5			
590° F. (310° C.)							0.8			
608° F. (320° C.)		0.2					1.2			
626° F. (330° C.)		1.0					1.6			
644° F. (340° C.)		1.8					2.0			
662° F. (350° C.)		2.5					3.0			
680° F. (360° C.)		5.0	.0	.0	.0		5.0			
Float test on residue at 122° F. (50° C.), seconds		179					122			
Residue soluble in CS_2, per cent		99.7					99.4			

[1] Test made on 100 cc. sample measured by weight on basis of specific gravity at 77° F.; bulb of thermometer immersed to a point ¼ inch above bottom of flask; distillation stopped at 680° F., and residue immediately poured in tin box and cooled for consistency tests.

TABLE 3.—*Results of tests of asphaltic products used for seal coat and resealing in South Carolina*

	LA-5		OC-2	AC-2		AC-2L		AC-2	
	Specification limits	Seal on sec. 4	Seal on sec. 4	Specification limits	Reseal on sec. 4	Specification limits	Reseal on sec. 4	Specification limits	Seal on sec. 5
Specific gravity, 60° F. (15.5° C.)	0.935+	0.960		0.92+	0.949	0.92+	0.944	0.92+	0.95
Specific gravity, 77° F. (25° C.)			0.944						
Flash point (open cup), °F.	200 (93° C.)+	235	140	90 (32° C.)+	100	90 (32° C.)+	95	90 (32° C.)+	95
Specific viscosity, Engler, at 122° F. (50° C.)		27.2	19.3	15–25	35.2	15–25	24.7	15–25	34.9
Specific viscosity, Engler, at 212° F. (100° C.)	2.4–4.4	2.8							
Loss at 325° F. (163° C.), 5 hours, per cent	16.0−	28.66	20.56	23+	22.24	25+	27.72	23+	22.4
Float test on residue, at 122° F. (50° C.) seconds			57						
Asphalt content, 150 penetration, per cent				65–75	76.9	65–75	74.0		76.0
Asphalt content, 100 penetration, per cent	60+	60.4							
Ductility of asphalt, 100 penetration	25+	100+							
Bitumen soluble in CS_2, per cent	99.5+	99.86	99.91						
Bitumen insoluble in 86° B. naphtha, per cent			14.44						
Bitumen soluble in CCl_4				99.8+	99.7	99.8+	99.88	99.8+	99.86
Distillation, A. S. T. M. D-20:									
Percentage, by volume, of total distillation to—									
212° F. (100° C.)				5.0−	0	5.0−	0	5.0−	0
302° F. (150° C.)				17.0−	6.0	15.0−	7.0	17.0−	6.5
401° F. (205° C.)				37.0−	25.0	35.0−	28.0	37.0−	25.0
Initial boiling point, °F.		536	266		302		310		356
Distillation, A. S. T. M. D-20, modified: [1]									
Percentage, by volume, of distillation to—									
284° F. (140° C.)			0.5						
302° F. (150° C.)			0.8						
320° F. (160° C.)			1.2		0.3				
338° F. (170° C.)			1.5		1.6		3.0		
356° F. (180° C.)			1.8		4.0		6.0		
374° F. (190° C.)			2.5		7.5		10.5		3.0
392° F. (200° C.)			3.8		12.0		14.0		7.0
410° F. (210° C.)			6.0		14.5		17.0		11.0
428° F. (220° C.)			8.5		17.0		19.5		13.0
446° F. (230° C.)			10.5		19.0		22.0		15.5
464° F. (240° C.)			13.0		20.5		24.0		17.5
482° F. (250° C.)			15.0		22.0		25.5		19.0
500° F. (260° C.)			17.0		23.0		27.0		20.0
518° F. (270° C.)			18.0		24.0		28.0		21.0
536° F. (280° C.)			19.5		25.0		29.0		22.0
554° F. (290° C.)		0.4	20.5		25.5		30.0		23.0
572° F. (300° C.)		1.0	22.0		26.0		30.5		24.0
590° F. (310° C.)		2.9	23.0		26.6		31.0		24.5
608° F. (320° C.)		5.2	24.0		27.2		31.5		25.0
626° F. (330° C.)		7.6	25.0		27.8		32.0		25.5
644° F. (340° C.)		10.0	26.0		28.2		32.4		26.0
662° F. (350° C.)		13.3	27.0		28.6		32.8		26.5
680° F. (360° C.)		17.5	30.0		30.0		34.0		28.0
Float test on residue at 122° F. (50° C.), seconds		15	77						
Penetration of residue at 77° F. (25° C.)					279		138		280
Ductility of residue at 77° F. (25° C.)					75		100+		
Residue soluble in CS_2, per cent		99.8	99.66		99.82		99.8		99.8
ASPHALT BASE									
Specific gravity, at 60° F.				1.02+		1.02+			
Flash point (open cup) ° F.				450+		410		450+	
Penetration, at 77° F. (25° C.)				85–100		150–180		85–100	
Ductility, at 77° F. (25° C.)				32+		32+		32+	
NAPHTHA FLUX									
Baumé gravity				53°−		53°−		53°−	
Distillation, A. S. T. M., D86-27:									
Percentage, by volume, of total distillation to—									
221° F. (105° C.)				8.0−		8.0−		8.0−	
284° F. (140° C.)				30.0−		30.0−		30.0−	
392° F. (200° C.)				80.0−		80.0−		80.0−	

[1] Test made on 100 c. c. sample measured by weight on basis of specific gravity at 77° F.; bulb of thermometer immersed to a point ¼ inch above bottom of flask distillation stopped at 680° F., and residue immediately poured in tin box and cooled for consistency tests.

APPENDIX III

ANALYSES OF BITUMINOUS MATS

Analyses of samples of the bituminous surface mats from each of the sections surveyed are reported in the accompanying table. These mat surfaces should not be considered as paving mixtures, as no mixing process was involved in their construction. A considerable variation in composition is therefore to be expected, especially in view of the fact that in cutting specimens, more or less of the primed base adheres to the mat proper. In addition, a nonskid surface of the character which it was desired to produce traps more or less surface soil, sand, etc. As no method has been developed for separating the mat proper from these extraneous materials, their presence causes a variation in the analyses in proportion to the amounts adhering to the specimens.

Analyses of the mats are of value in determining the tendency of the aggregate to crush and wear down under traffic, and in measuring the consistency of the bituminnous material at various ages to determine its change in consistency, as well as its power to hold the aggregate required for cover.

The general trend of analyses of samples from sections 2 years or more of age indicates greater hardening of the asphaltic material over the tar prime coats than over the asphaltic oil prime coats. This is seen by comparing samples W–1 and W–7 with W–29, W–30, and W–31, and also with Florida 28, 32, and 36. Sample

W–23 appears to be an exception which may be due to the road having been patched at this particular location. Whether the hardening over a tar prime coat is normal, or accelerated by the presence of tar, remains to be ascertained. The apparent softening in the case of sample W–7 is probably due to the presence of a relatively large amount of the asphaltic oil prime coat which was not thoroughly absorbed by the base. In general, the indicated hardening of the bituminous materials as shown appears to be beneficial rather than detrimental to the stability of the mat.

Although the amount of bitumen recovered from section 1 was not abnormally low, the surface when inspected showed a rather hard brittle mat, indicating a need of further bituminous treatment in the near future. The asphaltic product originally applied had a relatively low viscosity, which would tend to produce very thin films over the particles of a dense mineral aggregate. Use of a more viscous product resulting in thicker films after the very thorough compaction which has taken place on this particular section would probably have been advantageous.

TABLE 1.—*Results of analysis of sections of bituminous surfaces*

FLORIDA

	Section 1			Section 2		Section 3					
	Sample 28	Sample 32	Sample 36	Sample 5	Sample 15	Sample W 1	Sample W 7	Sample W 23	Sample W 29	Sample W 30	Sample W 31
Bitumen, per cent	5.5	6.0	7.4	6.0	6.0	3.0	4.6	3.4	11.4	8.9	7.0
¾-inch to 10 mesh, do	33.1	24.8	34.6	19.1	25.9	21.1	39.8	26.7	51.6	47.7	37.7
10 to 40 mesh, do	20.0	18.7	17.2	24.2	24.2	47.7	37.2	16.6	8.5	14.3	16.2
40 to 80 mesh, do	21.0	22.2	17.7	27.3	24.1	20.3	11.7	41.9	22.6	22.2	29.6
80 to 200 mesh, do	13.2	17.7	16.4	14.5	11.7	4.1	4.3	7.0	3.5	3.5	5.0
Pass 200 mesh, do	7.2	10.6	6.7	8.8	8.1	3.8	3.4	4.4	2.4	3.4	4.5
Extracted bitumen:											
Penetration	138	70	195						102	83	64
Float test at 122° F. (50° C.), seconds				288	198	79	231	175			
Bituminous materials used	TC–1 OH–1, modified			TC–2 OH–1, modified		OC–2 OH–1, modified		TC–1 OH–1, modified			

SOUTH CAROLINA

	Section 4											Section 5		
	Sample 5	Sample 11	Sample 18	Sample 22	Sample 28	Sample 30	Sample 32	Sample 34	Sample 36	Sample 38	Sample 40	Sample 101	Sample 108	Sample 114
Bitumen, per cent	6.3	6.3	4.9	6.3	8.7	5.3	5.1	5.2	5.8	6.6	7.6	5.5	5.4	7.1
¾-inch to 10 mesh, do	22.0	39.1	55.3	26.4	44.8	41.3	32.6	32.8	42.6	42.2	36.7	31.5	54.7	43.8
10 to 40 mesh, do	27.7	21.3	18.4	24.4	18.9	25.8	27.6	26.8	22.4	19.9	23.2	31.5	19.1	25.6
40 to 80 mesh, do	19.6	13.3	9.5	18.5	11.8	13.2	18.5	16.7	14.4	15.2	15.4	12.7	8.4	10.8
80 to 200 mesh, do	13.9	10.9	6.4	14.0	8.4	7.6	9.4	10.6	8.2	9.5	9.2	7.5	5.9	6.3
Pass 200 mesh, do	10.5	9.1	5.5	10.4	7.4	6.8	6.8	7.9	6.6	6.6	7.9	11.3	6.5	6.4
Extracted bitumen:														
Penetration	192	181	178	185	111	70	69			228	145	107	115	97
Float test at 122° F. (50° C.), seconds								273	249					
Bituminous materials used	TC–1 OH–1 LA–5 AC–2L		OH–1 LA–5 AC–2L		(1) LA–5 AC–2L		(1) OC–2 AC–2L	(1) LA–5 AC–2L		(1) LA–5 AC–2		(1) AC–2		

[1] TC–1, 150–200 penetration asphalt.

APPENDIX IV

SPECIFICATIONS TYPICAL OF THOSE IN USE FOR MATERIALS AND METHODS OF CONSTRUCTING TOPSOIL AND SAND-CLAY SURFACES

1 TOPSOIL AND NATURAL SAND-CLAY SURFACES

NATURAL MIXTURES

Description.—This item shall consist of topsoil or of a natural mixture of sand and clay properly proportioned, constructed on the prepared subgrade in conformity with the lines, grades, compacted thickness, and typical cross section shown on the plans and in accordance with these specifications.

MATERIALS

Surfacing material.—The surfacing material shall consist of topsoil or natural sand-clay obtained from fields or pits designated by the engineer. Before any surfacing material is used it shall first be subjected to laboratory test and approved by the engineer. The surfacing material shall be free from foreign matter and shall contain no stones that would fail to pass a 1½ inch ring. * * *

CONSTRUCTION METHODS

Placing and mixing.—The roadbed between the ditches shall be dressed to a true and uniform surface before the soil is applied.

The approved topsoil or natural sand-clay shall be evenly spread on the subgrade to such depth that when compacted it will conform with the finished thickness shown on the plans. After sufficient material has been placed for approximately 100 lineal feet of road surface, and before any part of the material has commenced to pack, it shall be spread to approximately the required cross section. The spreading may be done with shovels or with a road machine, when so required. The surfaced portion of the road shall then be harrowed

with either a spike tooth or disk harrow until it is of uniform texture. Should any portion of the surface of the topsoil or natural sand-clay mixture become uneven and consolidate in that condition, the contractor will be required to thoroughly break same by plowing and harrowing and to reshape the surface at his own expense. Should the surface when finally shaped show a deficiency in thickness, or should depressions occur in the surface, the contractor shall scarify or plow such sections and spread additional material where required.

Maintenance.—For at least 30 days prior to final acceptance the contractor shall maintain the surface under public traffic, true to the cross section specified, by use of a road machine, drag, or other means satisfactory to the engineer. * * *

2. SAND-CLAY SURFACES

ARTIFICIAL MIXTURE

Description.—This item shall consist of an artificial mixture of sand and clay, properly proportioned and mixed, constructed on the prepared subgrade, in conformity with the lines, grades, compacted thickness, and typical cross-section shown on the plans and in accordance with these specifications.

MATERIALS

Surfacing material.—The surfacing material shall consist of an artificial mixture of sand and clay. The materials for such artificial mixture shall be obtained from places designated by the engineer.

Before any surfacing material is used it shall first be subjected to laboratory tests and approved by the engineer. The surfacing material shall be free from foreign matter and shall contain no stones that would fail to pass a 1½-inch ring. * * *

CONSTRUCTION METHODS

Placing and mixing.—The roadbed between the ditches shall be dressed to a true and uniform surface before the sand or clay is applied. The contractor shall haul and uniformly place upon the road, in accordance with the specifications, the sand or clay selected, as hereinbefore provided, in such quantities as may be directed by the engineer. * * *

The contractor shall mix the sand or clay hauled with the sand or clay in the subgrade with plow, disk and spike-tooth harrow, or other satisfactory means, until the surfacing material is of uniform texture.

In any case where the existing roadway is composed of sand and clay which, in the opinion of the engineer, will make a satisfactory surface, the contractor shall mix and shape the existing surfacing material as herein specified, for which work he will be paid the unit price per square yard set forth in the attached proposal for mixing, shaping, and finishing.

Should any depressions appear, they are to be scarified and filled with an approved sand-clay mixture, so that the finished surface will conform to the cross section specified, and on written instruction from the engineer, the contractor shall at any time, during the term of this contract, apply additional sand or clay to the road surface, for which the unit price set forth in the attached proposal, and above referred to, will be paid.

Maintenance.—For at least 30 days prior to final acceptance the contractor shall maintain the sand-clay surface under public traffic, true to the cross-section specified, by use of a road machine, drag, or other means satisfactory to the engineer.

APPENDIX V

SPECIFICATIONS TYPICAL OF THOSE USED IN THE BITUMINOUS SURFACE TREATMENT OF SAND-CLAY AND TOPSOIL ROADS

Description.—This item shall consist of a bituminous surface mat constructed on the prepared road surface in accordance with the specifications and in conformity with the typical cross section shown on the plans and with the lines and grades as staked out by the engineer. The method of construction shall proceed substantially as follows in accordance with the detail requirements of these specifications.

(*a*) Unless the road to be treated has a well-bonded surface, true to the established crown and grade, it shall be scarified, reshaped and consolidated under traffic prior to surface treatment.

(*b*) The prepared road surface shall be thoroughly swept for the entire width of the treatment.

(*c*) A prime coat of light bituminous material shall be applied by means of a pressure distributor.

(*d*) After an interval of about 24 hours, as directed by the engineer, an application of hot bituminous material shall be made by means of a pressure distributor and covered immediately with coarse mineral aggregate and rolled at once with a power roller.

(*e*)[1] After a period of not less than two nor more than six months, as directed by the engineer, the bituminous surface shall be swept for its entire width and a seal coat of bituminous material shall then be applied by means of a pressure distributor. The seal coat shall be covered immediately with fine mineral aggregate and thoroughly rolled.

MATERIALS

Bituminous materials.—The bituminous materials shall meet the following requirements for the purposes indicated.

(A) Tar for first (prime) application. The tar shall conform to the following requirements:

(*a*) Water, not more than 2 per cent.
(*b*) Specific viscosity, Engler, 50 cubic centimeters at 40° C. (104° F.), 8 to 13.
(*c*) Distillation test on water-free material:
Total distillate, by weight, 0 to 170° C. (32 to 338° F.), not more than 7 per cent.
Total distillate, by weight, 0 to 235° C. (32 to 455° F), not more than 20 per cent.
Total distillate, by weight, 0 to 270° C. (32 to 518° F.), not more than 30 per cent.
Total distillate, by weight, 0 to 300° C. (32 to 572° F.), not more than 35 per cent.
(*d*) Specific gravity at 25°/25° C. (77°/77° F.) of total distillate to 300° C. (572° F.), not less than 1.01.
(*e*) Softening point (ring-and-ball method) of residue from distillation test—not more than 60° C. (140° F.)
(*f*) Total bitumen (soluble in carbon disulphide)—88 to 97 per cent.

(B) Asphalt for second (hot) application. The asphalt shall be homogeneous, free from water, and shall not foam when heated to 175° C. (347° F.). It shall meet the following requirements:

1. Specific gravity 25°/25° C. (77°/77° F.), not less than 1.000.
2. Flash point, not less than 175° C. (347° F.).

[1] Applies to South Carolina only, other States apply this treatment under maintenance and only when necessary.

3. Penetration at 25° C. (77° F.), 100 grams, 5 seconds, 150 to 200.
4. Loss at 163° C. (325° F.), 50 grams, 5 hours, not more than 2 per cent.
(*a*) Penetration of residue at 25° C. (77° F.), 100 grams, 5 seconds, as compared to penetration before heating, not less than 60 per cent.
5. Bitumen (soluble in carbon disulphide), not less than 99.5 per cent.
(*a*) Organic matter insoluble, not more than 0.2 per cent.

(C) Cut-back asphalt for third (seal) application. The cut-back asphalt shall conform to the following requirements:

1. Specific gravity (at 25° C.), not less than 0.92.
2. Specific viscosity (Engler), at 50° C., 15 to 25.
3. Flash point (open cup), not less than 90° F.
4. Loss by evaporation, 50 grams, 5 hours at 163° C, not less than 23 per cent.
5. Solubility in CCl_4, not less than 99.8 per cent.
6. Distillation:
Total distillate at 100° C., not more than 5 per cent (by volume).
Total distillate at 150° C., not more than 15 per cent (by volume).
Total distillate at 205° C., not more than 35 per cent (by volume).
Asphalt content at 100 penetration, 63 to 75 per cent

Coarse mineral aggregate.—The coarse mineral aggregate used for cover for the hot asphalt shall consist of approved slag, or broken stone free from dust, thin or elongated pieces, dirt, or other objectionable matter occurring either free or as a coating on the aggregate. Stone from which it is produced shall have a per cent of wear of not more than 6 and a toughness of not less than 5. The coarse aggregate shall meet the following requirements:

Retained on a 1½-inch screen (circular openings)-------	None.
Passing a 1¼-inch screen (circular openings)--per cent--	90–100
Passing a ¾-inch screen (circular openings)------do----	25– 75
Passing a ¼-inch screen (circular openings), not more than----------per cent--	10

Fine mineral aggregate.—The fine mineral aggregate used for cover for seal coat shall conform with either of the following sets of requirements.

(*a*) Crushed limestone: The crushed limestone shall have a per cent of wear of not more than 5 and a toughness of not less than 8. The material shall meet the following grading requirements:

Passing ⅝-inch screen (circular openings)-----per cent--	100
Passing ¼-inch screen (circular openings) not more than----------per cent--	7

(*b*) Crushed granite: The crushed granite shall have a per cent of wear of not more than 5 and a toughness of not less than 8. It shall meet the following grading requirements:

Passing ¾-inch screen (circular openings)-----per cent--	100
Passing ½-inch screen (circular openings)--------do----	25–75
Passing ¼-inch screen (circular openings), not more than----------per cent--	25
Passing 10-mesh sieve, not more than----------do----	3

CONSTRUCTION METHODS

Reshaping existing road surface.—If the road to be surface treated is not well bonded, thoroughly and evenly compacted, and true to established contour and grade it shall be spiked, harrowed, bladed, and maintained by blading or dragging for a period of at least 30 days under traffic and until the desired condition is obtained. Traffic shall be distributed by the use of suitable barricades, moved from time to time so that uniform compaction of the entire surface is obtained.

While the road is being consolidated under traffic a stabilizing layer [1] of bank-run washed gravel which will pass a ¾-inch screen and 40 per cent of which will be retained on a ¼-inch screen, shall be spread over the surface at the rate of 20 pounds per square yard. This stabilizer shall be placed after the surface has been brought to final grade and contour. During maintenance under traffic the blader shall, from time to time, be so operated as to throw back onto the road any loose gravel that has worked onto the shoulder.

Sweeping prepared road surface.—All dust, dirt, caked clay, loose and foreign material shall be removed for the full width to be treated by sweeping with revolving brooms or other approved mechanical sweepers supplemented by hand brooms. Dust or other loose material in depressions or other places not reached by mechanical sweepers shall be swept with hand brooms. Particular care shall be taken to clean thoroughly the outer edges of the strip to be treated, especially adjacent to stock piles of coarse or fine aggregate that may have been placed on the roadway, and, if necessary, such coarse or fine aggregate shall be shoveled back before brooming. Sweeping shall continue until all of the dust or loose dirt is removed and the surfaces of the larger size aggregate in the road surface are exposed.

General requirements for application of bituminous materials.—Bituminous materials shall not be applied on a wet surface nor when the temperature of the air is less than 50° F. in the shade, provided that when the engineer so directs, the asphaltic seal coat only may be applied when such temperature is not less than 40°. F.

All bituminous materials shall be applied uniformly by means of an approved pressure distributor for the full width of the treatment at one application unless, due to the impracticability of detouring highway traffic, the engineer directs that they be applied to only one-half width of the road at one time. If the pressure distributor is mounted on a truck having only four wheels, it shall not be loaded in excess of 600 gallons of bituminous material, and it shall be equipped with tires having a sufficient width of rubber in contact with the prepared road surface to avoid breaking the bond of or forming a rut in such surfacing.

The distance between the centers of openings of the outside nozzles of the manifold shall be 20 feet within an allowed variation of 2 inches. The outside nozzle at each end of the manifold shall have an area of opening not less than 25 per cent, nor more than 75 per cent in excess of the other nozzles, which shall have uniform openings.

If one or more nozzles should become blocked during the application of bituminous materials, the distributor shall be stopped immediately and the nozzle or nozzles cleaned out before it proceeds, unless, during the application of prime and seal coats only, the engineer may direct that application be continued and subsequently be made uniform by the use of hand hose equipped with nozzle, or hand-pouring pots. When the engineer directs that application be made over one-half width of the road at one time, all of the nozzles, except the one toward the outside of the road, shall have the same size opening; and great care shall be taken to see that there is a slight longitudinal overlapping of the two applications along the center line of the road so as to insure complete coverage. In all cases the

[1] This stabilizer is used in Florida when directed by the engineer.

distribution shall be stopped when the application begins to run light, just before the distributor tank is completely empty, and care shall be taken to insure that in beginning the distribution of the next load a proper junction is made with the preceding work. Any excess of bituminous material at the transverse junction between distributor loads shall be removed and corrected in a satisfactory manner, and any parts of the surface to be treated which is not covered with bituminous material directly from the distributor shall be covered by means of a hand hose equipped with nozzle, or hand-pouring pot.

In addition to being applied uniformly, each distributor load of bituminous material must be applied at a rate within 10 per cent of the amount per square yard hereinafter specified. If the contractor should be unable to keep the application of bituminous materials consistently within this allowed variation, he shall discontinue operation until he can provide an operator of greater experience or a better distributor or both, or shall take such other precautions as may be necessary to keep the application within these limits.

Application of prime coat.—The bituminous primer shall not be heated to a temperature greater than 150° F. and shall be applied at a temperature of not less than 125° F. It shall not be applied until the road surface has compacted and bonded under traffic to the satisfaction of the engineer, nor unless the surface conforms to the typical cross section shown on the plans and to the lines and grades staked out by the engineer, and then only when the surface has been properly swept, is firm, compact, and dry, or, if the engineer so directs, when the surface is slightly damp but with no signs of free moisture and is firm enough to show no appreciable deformation under the rear tires of a loaded distributor.

After the prime coat has been applied, and unless it is impracticable to detour highway traffic, the contractor shall keep all traffic off of the road until, in the opinion of the engineer, the bituminous material has penetrated and dried out so as not to pick up under traffic. In cases where traffic is permitted by the engineer, the contractor shall spread the minimum necessary amount of approved cover material over the bituminous primer to avoid its picking up. The primer, whether covered or not, shall be applied at a uniform rate of not less than 0.3 gallon per square yard and, if the engineer so directs, at any increased minimum rate up to 0.35 gallon per square yard, if in his judgment the road surface is sufficiently absorptive to warrant such increase.

The contractor shall maintain the prime coat treatment intact until it shall have been covered by application of the hot asphalt. He shall clean out any spots where the prime coat may have failed, due to disintegration of the underlying surfacing, and the exposed areas so produced shall be lightly scarified, dampened, refilled with selected surfacing material similar to that used in the adjacent portion of the road, and thoroughly tamped while still damp so as to conform with the general crown and surface of the road, after which bituminous primer shall be applied with a hand hose equipped with nozzle or with a hand-pouring pot. If, however, the engineer so directs, the addition of new selected surfacing material shall be omitted in making such repairs, in which case the bituminous primer shall be reapplied after thorough sweeping, and the depression filled with crushed stone so as to bring it true to grade and crown. Should failures in the prime coat occur due to any other reasons, the contractor shall repair them in an adequate and workmanlike manner to the satisfaction of the engineer before the application of hot asphalt. If required by the engineer, the primed surface shall be thoroughly swept prior to application of the hot asphalt.

Application of hot asphalt.—The asphalt shall not be heated to a temperature greater than 350° F. and shall be applied at a temperature of not less than 275° F. It shall be applied at a uniform rate of 0.4 gallon per square yard with an allowable 10 per cent variation and only when the prime coat is firm and intact.

Spreading and rolling coarse mineral aggregate.—Immediately after the hot asphalt has been applied, it shall be uniformly covered with not less than 50 pounds of coarse aggregate per square yard. The aggregate shall be spread by casting it with shovels in a longitudinal direction from piles previously placed along the shoulders of the road or directly from trucks or by approved mechanical spreaders, provided such trucks or spreaders do not drive on the uncovered asphalt. If, due to the impracticability of detouring highway traffic, the engineer may have directed that the hot asphalt be applied to only one-half width of the road at a time, the coarse aggregate shall be spread only to within 8 inches of the edge of the application along the center of the road until the hot asphalt shall have been applied to the remaining half of the road.

The spreading of coarse aggregate shall at all times be kept to within not less than 700 feet from where the hot asphalt is being applied and, immediately after spreading, two men equipped with hand brooms shall broom off all high spots where the coarse aggregate has been spread too thick.

Immediately after spreading and brooming the coarse aggregate shall be rolled with a power roller weighing not less than 5 nor more than 10 tons. Rolling shall proceed in a longitudinal direction beginning at the outer edges of the treatment and working toward the center, each trip overlapping the prior trip by about one-half the width of the front roll. The first rolling of the coarse aggregate must be completed within one-half hour after it has been spread. Rolling shall be continued until a uniformly closed surface has been obtained. Traffic shall be allowed to use the road as soon as the coarse aggregate has been spread, and after several days of such traffic, all loose aggregate shall be broomed evenly over the surface and again rolled as specified above.

Sweeping surface treatment.—Immediately before the application of the asphaltic seal coat the surface treatment shall be thoroughly swept for its entire width until free from loose and extraneous material.

Application of asphaltic seal coat.—The cut-back asphalt used for the seal coat shall not be heated to a temperature above that of its flash point, and shall be applied at a temperature of not less than 20° F. below that of its flash point. It shall be applied only when the surface treatment is clean, firm, and intact, and free from any signs of moisture. It shall be applied at a uniform rate of 0.2 gallon to 0.25 gallon per square yard as directed by the engineer.

Spreading fine aggregate.—As soon as the asphaltic seal coat has been applied, it shall be uniformly covered immediately with 20 pounds per square yard of fine aggregate. The aggregate shall be spread by casting it with shovels in a longitudinal direction from piles previously placed along the shoulders of the road, or directly from trucks or by approved mechanical spreaders, provided such trucks or spreaders do not drive on the uncovered asphaltic seal coat. If, due to the impracticability of detouring highway traffic, the engineer may have directed that the asphaltic seal coat be applied to only one-half the width of the road at a time, the fine aggregate shall be spread only to within 8 inches of the edge of the application along the center of the road until the asphaltic seal coat shall have been applied to the remaining half of the road. Fine aggregate shall be spread as soon after the application of the asphaltic seal coat as may be practicable and within not less than one hour after said application, unless the engineer directs the contractor to delay such spreading to not exceeding six hours when for any reason the cut-back asphalt is absorbed more slowly than usual.

After the fine aggregate has been spread, it shall be dragged with a broom drag which shall be long enough to cover either one-half or the full width of the treatment, and which shall be hinged at points not farther apart than one-fourth of the width of the treatment, so that it will conform to the crown thereof. This dragging shall be repeated from time to time as directed until the seal coat shall, in the opinion of the engineer, have set up sufficiently so that continued dragging would not materially improve the riding qualities of the completed surface treatment. It shall then be rolled with a power roller weighing not less than 5 nor more than 10 tons. Rolling shall proceed in a longitudinal direction beginning at the outer edges of the treatment and working toward the center, each trip overlapping the prior trip by about one-half the width of the front roll. The rolling shall be repeated from time to time while the seal coat is setting up as may be necessary to firmly imbed the fine aggregate in the asphaltic seal coat and produce a uniformly closed surface.

During the period of about two or three days that dragging and rolling may be necessary, the contractor shall respread the fine aggregate that may be whipped to the sides by traffic. Such respreading shall be done with shovels, hand brooms, or revolving broom, as and when directed by the engineer, so as to prevent "bleeding," and to avoid the possibility of the asphaltic seal coat "picking up" under traffic. If the repeated respreading of the fine aggregate is inadequate for this purpose and the engineer so directs, the contractor shall spread additional fine aggregate as may be necessary to prevent such "bleeding" or "picking up."

The contractor shall keep traffic off the road from the time the asphaltic seal coat is applied until in the opinion of the engineer it has set up sufficiently to prevent the displacement of the fine aggregate by traffic.

Maintenance.—The contractor shall maintain the road, including slopes, ditches, and surface treatments, from the time his operations begin until 30 days after final completion of any continuous section of road included in his contract.

APPENDIX VI

CONSTRUCTION AND MAINTENANCE COSTS

TABLE 1.—*Construction and maintenance costs of surface treated roads*

FLORIDA

Section and road	Length	Type of base	Surface treatment construction		Annual maintenance cost per mile, surface only			Average daily traffic
			Date constructed	Cost per mile	1927	1928	1929 [1]	
	Miles							
4-1	12.0	Sand-clay	August, 1927	$2,019	$193	$144	$54	
6-1	14.4	do	July, 1927	2,078	180	148	57	
7-1	17.7	do	June, 1927	2,078	193	157	59	
8-1	20.3	do	May, 1927	2,031	234	214	80	
9-1	20.3	do	December, 1928	1,900	223	200	61	
10-1	19.0	do	April, 1927	2,195	362	315	68	
11-1	20.3	do	March, 1927	2,782	183	175	65	
12-1	19.9	do	October, 1927	2,380	170	158	71	
1-6	18.1	do	November, 1927	2,298		172	86	
2-6	10.2	do	October, 1928	2,436		168	65	
3-6	9.0	do	March, 1929 [2]	2,078			[3] 55	
4-6	8.0	do	do	2,219			[3] 75	
1-33	9.5	do	February, 1929 [2]	1,600			[4] 62	
1-20	11.0	do	April, 1928 [2]	2,207		145	68	
4-10	18.0	do	January, 1928	2,583		135	9	
1-123	6.8	do	October, 1928	2,219		224	24	
6-6	13.5	Topsoil	December, 1928	2,383			114	
2-10	13.5	Lime rock	do	2,230			11	
6-6	7.0	do	November, 1927	2,383		106	9	
3-10	18.0	do	October, 1928	2,583		84	8	
17-1	7.0	do	October, 1927	2,231		58	10	
16-1	6.0	do	do	2,231		58	10	
8-10	19.2	do	August, 1928	2,137		80	24	
9-10	10.4	do	September, 1928	2,759		60	21	

SOUTH CAROLINA

4-F. A. 231	20.3	Topsoil	July, 1926	[5] $2,850	$416 (1925)	$241 (1926)		800
Spartanburg to Inman	7.0	do	May, 1924	2,300	385 (1926)	258 (1927)	[6] (1928)	1,100
5715.2	8.0	do	June, 1925	1,985	284	343	277	834+

[1] Based on first 5 months of 1929 unless otherwise indicated.
[2] Partly constructed.
[3] Based on 2 months of 1929.
[4] Based on 3 months of 1929.
[5] Includes seal-coat treatment.
[6] Not over $300 in 1927.

TABLE 2.—*Maintenance costs of untreated topsoil and sand-clay roads*

SOUTH CAROLINA 1926

Number of projects	Years in service	Total length	Annual maintenance cost per mile						Traffic, weighted daily average
			Topsoil			Sand-clay			
			Maximum	Minimum	Weighted average	Maximum	Minimum	Weighted average	
		Miles							
2	6+	20.17	$890	$690	$773				853
1	6+	12.15						$560	177
11	5	75.36	850	240	429				415
5	5	67.4				$550	$280	449	496
9	4	73.7	420	220	325				308
13	4	144.5				610	150	418	347
2	3	4.8	330	140	243				318
22	3	181.7				730	130	428	332
4	2	28.3	570	110	363				406
12	2	74.5				710	230	464	351
5	1	42.8	480	250	326				332
6	1	73.2				540	230	447	290

GEORGIA

1	4	3.8				$243	$169	[1] $200	355
1	4	8.9				239	169	[1] 200	318

[1] Average for 4 years.

U. S. GOVERNMENT PRINTING OFFICE: 1930

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

ANNUAL REPORTS

Report of the Chief of the Bureau of Public Roads, 1924.
Report of the Chief of the Bureau of Public Roads, 1925.
Report of the Chief of the Bureau of Public Roads, 1927.
Report of the Chief of the Bureau of Public Roads, 1928.
Report of the Chief of the Bureau of Public Roads, 1929.

DEPARTMENT BULLETINS

No. *136D. Highway Bonds. 20c.
257D. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
*314D. Methods for the Examination of Bituminous Road Materials. 10c.
*347D. Methods for the Determination of the Physical Properties of Road-Building Rock. 10c.
*370D. The Results of Physical Tests of Road-Building Rock. 15c.
386D. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387D. Public Road Mileage and Revenues in the Southern States, 1914.
388D. Public Road Mileage and Revenues in the New England States, 1914.
390D. Public Road Mileage and Revenues in the United States, 1914. A Summary.
407D. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
463D. Earth, Sand-Clay, and Gravel Roads.
*532D. The Expansion and Contraction of Concrete and Concrete Roads. 10c.
*583D. Reports on Experimental Convict Road Camp, Fulton County, Ga. 25c.
*660D. Highway Cost Keeping. 10c.
*670D. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
*691D. Typical Specifications for Bituminous Road Materials. 10c.
*724D. Drainage Methods and Foundations for County Roads. 20c.
1216D. Tentative Standard Methods of Sampling and Testing Highway Materials, adopted by the American Association of State Highway Officials and approved by the Secretary of Agriculture for use in connection with Federal-aid road construction.
1259D. Standard Specifications for Steel Highway Bridges, adopted by the American Association of State Highway Officials and approved by the Secretary of Agriculture for use in connection with Federal-aid road work.
1279D. Rural Highway Mileage, Income, and Expenditures 1921 and 1922.
1486D. Highway Bridge Location.

DEPARTMENT CIRCULARS

No. 94C. T. N. T. as a Blasting Explosive.
331C. Standard Specifications for Corrugated Metal Pipe Culverts.

TECHNICAL BULLETIN

No. 55. Highway Bridge Surveys.

MISCELLANEOUS CIRCULARS

No. 62M. Standards Governing Plans, Specifications, Contract Forms, and Estimates for Federal-Aid Highway Projects.
*93M. Direct Production Costs of Broken Stone. 25c.
*109M. Federal Legislation and Regulations Relating to the Improvement of Federal-Aid Roads and National-Forest Roads and Trails. 10c.

SEPARATE REPRINTS FROM THE YEARBOOK

No. 914Y. Highways and Highway Transportation.
937Y. Miscellaneous Agricultural Statistics.
1036Y. Road Work on Farm Outlets Needs Skill and Right Equipment.

TRANSPORTATION SURVEY REPORTS

Report of a Survey of Transportation on the State Highway System of Connecticut.
Report of a Survey of Transportation on the State Highway System of Ohio.
Report of a Survey of Transportation on the State Highways of Vermont.
Report of a Survey of Transportation on the State Highways of New Hampshire.
Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio.
Report of a Survey of Transportation on the State Highways of Pennsylvania.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH

Vol. 5, No. 17, D– 2. Effect of Controllable Variables upon the Penetration Test for Asphalts and Asphalt Cements.
Vol. 5, No. 19, D– 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 24, D– 6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D– 8. Tests of Three Large-Sized Reinforced-Concrete Slabs Under Concentrated Loading.
Vol. 11, No. 10, D–15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.

---

* Department supply exhausted.

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

CURRENT STATUS OF FEDERAL AID ROAD CONSTRUCTION

AS OF

DECEMBER 31, 1929

STATE	COMPLETED MILEAGE	UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FEDERAL-AID FUNDS AVAILABLE FOR NEW PROJECTS	STATE
		Estimated total cost	Federal aid allotted	MILEAGE			Estimated total cost	Federal aid allotted	MILEAGE				
				Initial	Stage[1]	Total			Initial	Stage[1]	Total		
		$	$				$	$				$	
Alabama	2,093.4	2,756,620.03	1,361,094.29	96.9	21.0	117.9						3,381,902.50	Alabama
Arizona	819.5	3,618,100.92	2,957,834.87	162.4	98.7	261.1	100,565.47	75,715.73		14.9	14.9	2,596,174.16	Arizona
Arkansas	1,758.6	3,621,517.19	1,688,676.69	139.5	37.2	176.7	153,524.84	57,472.10	6.2	5.1	11.3	2,640,488.12	Arkansas
California	1,825.4	6,638,343.65	3,134,249.18	178.1	10.4	188.5						2,533,636.81	California
Colorado	1,164.8	4,500,641.68	2,395,655.74	171.8	46.7	218.5	351,936.26	173,531.81	14.8	1.1	15.9	2,419,819.28	Colorado
Connecticut	240.3	1,094,757.41	407,956.09	8.7		8.7	711,624.45	340,811.16	1.4		1.4	893,257.10	Connecticut
Delaware	239.9	841,502.45	342,911.24	26.0		26.0						407,066.28	Delaware
Florida	467.0	3,506,488.15	1,521,213.54	91.5	5.7	97.2	1,453,341.78	726,670.88	10.5		10.5	1,605,141.26	Florida
Georgia	2,664.6	1,842,442.84	888,430.28	93.5	11.4	104.9						3,984,500.25	Georgia
Idaho	1,182.0	1,067,170.55	641,988.33	71.3	24.1	95.4	99,627.73	60,623.92	8.6	3.7	12.3	1,384,961.66	Idaho
Illinois	2,023.8	15,765,014.65	6,960,613.41	448.8		448.8	528,000.00	264,000.00	18.3		18.3	5,600,774.92	Illinois
Indiana	1,344.1	7,509,457.02	3,525,586.95	233.2		233.2	374,724.44	178,170.00	11.8		11.8	1,937,523.87	Indiana
Iowa	3,131.6	830,234.01	349,438.63	15.1	18.5	33.6	962,786.75	417,295.00	9.5	26.4	35.9	1,609,904.56	Iowa
Kansas	2,677.8	5,642,819.60	2,342,462.10	322.9	15.7	338.6	629,925.12	304,019.02	19.0	2.8	21.8	2,103,895.28	Kansas
Kentucky	1,403.9	4,258,135.17	2,022,628.13	235.5	14.1	249.6	46,327.43	23,163.71		6.1	6.1	1,813,978.35	Kentucky
Louisiana	1,357.8	3,419,159.31	1,698,940.83	129.5	4.8	134.3	86,939.89	43,469.94	.1		.1	2,031,260.75	Louisiana
Maine	516.1	1,781,957.66	666,964.62	43.7		43.7	87,912.01	43,956.00	5.6		5.6	1,640,817.21	Maine
Maryland	627.3	1,310,720.60	625,028.85	54.7		54.7	399,114.90	110,344.89	12.6		12.6	549,512.16	Maryland
Massachusetts	648.0	2,095,086.43	642,600.99	25.0		25.0	797,265.03	266,090.99	18.3		18.3	2,294,083.11	Massachusetts
Michigan	1,614.8	8,741,777.77	3,795,506.03	210.4	10.4	220.8	1,030,000.00	390,418.31	20.3	12.4	32.7	2,238,581.43	Michigan
Minnesota	4,085.3	5,127,134.24	1,551,300.00	130.7	91.2	221.9	3,846,017.21	243,000.00	57.5	103.8	161.3	1,382,749.96	Minnesota
Mississippi	1,781.5	2,267,948.87	917,820.56	94.9	7.7	102.6						2,648,953.75	Mississippi
Missouri	2,374.5	7,166,935.27	2,698,123.98	100.5	92.1	192.6						2,622,706.03	Missouri
Montana	1,692.9	7,103,273.32	4,172,212.24	500.2	16.6	516.8	1,246,285.66	664,261.58	99.9	16.2	116.1	3,193,828.56	Montana
Nebraska	3,573.4	6,766,863.43	3,251,061.24	342.2	159.0	501.2	451,377.20	210,985.32	20.9	15.1	36.0	2,390,021.50	Nebraska
Nevada	1,121.8	1,143,105.43	1,006,570.19	121.1	98.5	219.6						1,020,274.79	Nevada
New Hampshire	350.6	414,924.02	111,495.00	5.4	2.1	7.5						449,153.36	New Hampshire
New Jersey	494.7	4,615,658.52	934,830.00	62.3		62.3						1,091,124.08	New Jersey
New Mexico	1,927.4	2,460,423.58	1,563,836.93	128.8		128.8	378,105.81	234,191.86	36.9	2.0	38.9	1,640,420.95	New Mexico
New York	2,458.3	17,239,217.76	3,556,955.00	237.8		237.8	3,986,000.00	642,450.00	42.9		42.9	6,827,080.99	New York
North Carolina	1,757.1	1,036,627.00	517,321.91	65.4	18.2	83.6	908,601.50	444,089.00	57.3	5.2	62.5	2,691,786.09	North Carolina
North Dakota	4,176.8	1,201,978.35	492,106.96	205.4	101.7	307.1	1,616,131.98	826,841.44	306.3	110.8	417.1	1,160,815.98	North Dakota
Ohio	2,152.5	13,125,777.31	3,996,721.02	223.9	18.3	242.2	3,998,564.70	1,050,905.56	49.1	21.2	70.3	3,257,423.03	Ohio
Oklahoma	1,828.4	3,529,871.35	1,613,234.52	94.4	42.8	137.2	523,708.99	224,016.79	19.4	13.2	32.6	1,796,081.01	Oklahoma
Oregon	1,151.3	2,756,685.14	1,613,949.16	141.3	56.2	197.5	1,041,549.02	551,795.23	57.3	19.4	76.7	1,209,476.76	Oregon
Pennsylvania	2,256.9	13,929,757.85	3,374,959.44	207.8	14.1	221.9	1,687,267.65	551,599.26	35.1		35.1	2,866,105.72	Pennsylvania
Rhode Island	184.8	954,695.33	215,017.15	11.5		11.5	321,482.74	144,651.43	4.6		4.6	650,799.90	Rhode Island
South Carolina	1,907.0	2,714,166.09	979,207.62	74.5	24.1	98.6						1,392,889.31	South Carolina
South Dakota	3,460.8	3,505,433.93	1,888,215.21	398.1	108.2	506.3	157,084.95	86,396.71	23.0		23.0	1,185,252.93	South Dakota
Tennessee	1,242.5	1,915,916.03	839,174.54	64.4		64.4						2,535,074.62	Tennessee
Texas	6,372.5	15,599,598.20	7,007,197.90	533.5	226.4	759.9	250,834.39	100,467.99	11.7	9.2	20.9	4,817,766.46	Texas
Utah	974.2	1,045,520.25	588,578.66	40.5		40.5	14,268.52	8,190.81		.3	.3	1,046,530.15	Utah
Vermont	249.6	901,398.87	332,519.96	17.5		17.5						428,497.48	Vermont
Virginia	1,396.0	2,283,599.93	1,111,227.92	121.1	12.0	133.1	457,207.88	188,244.15	5.9		5.9	1,458,707.81	Virginia
Washington	886.3	4,343,763.74	1,561,800.00	93.0	40.2	133.2	37,686.00	20,000.00	.1		.1	1,357,179.87	Washington
West Virginia	707.2	3,249,741.98	1,323,788.34	81.1	12.4	93.5						806,239.69	West Virginia
Wisconsin	2,190.4	6,833,684.84	2,905,463.21	243.6	4.0	247.6						1,875,145.12	Wisconsin
Wyoming	1,735.3	1,534,910.27	991,525.43	150.0	14.8	164.8	41,252.20	27,082.06		9.6	9.6	962,755.92	Wyoming
Hawaii	39.5	402,281.10	137,426.82	5.6		5.6	552,688.38	247,259.61	16.6		16.6	1,438,289.16	Hawaii
TOTALS	82,330.2	217,012,729.09	89,219,421.70	7,256.0	1,479.3	8,735.3	29,339,731.88	9,942,152.26	1,001.5	398.5	1,400.0	99,881,410.04	TOTALS

[1]The term stage construction refers to additional work done on projects previously improved with Federal aid. In general, such additional work consists of the construction of a surface of higher type than was provided in the initial improvement.