Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

Issued December 4, 1907.

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN 311.

SAND-CLAY AND BURNT-CLAY ROADS.

BY

WILLIAM L. SPOON,
Road Expert, Office of Public Roads.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1907.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF PUBLIC ROADS,
Washington, D. C., September 27, 1907.

SIR: I have the honor to transmit for your approval a manuscript containing the results of investigations made by this Office on the mixture of sand and clay for the improvement of roads, and upon the utilization of clay for road construction by burning. Most of the material contained therein has already been published in Bulletin No. 27 of this Office, but the great increase in the demand for reliable information upon the construction of sand-clay and burnt-clay roads makes the publication of a bulletin for wide distribution advisable. I respectfully recommend, therefore, that this manuscript be published as a Farmers' Bulletin.

Respectfully,

LOGAN WALLER PAGE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

SAND-CLAY AND BURNT-CLAY ROADS.

INTRODUCTION.

Natural sand-clay roads may frequently be found in localities where the soil contains the right proportions of sand and clay. In sections of the country where the prevailing subsoil is composed entirely of clay, or, on the other hand, is of an extremely sandy character, these materials may be properly mixed so as to overcome as far as possible the objectionable features of each. The mixing of sand and clay as a form of road construction has received careful study and is of great importance, especially to the Atlantic and Gulf States, where throughout large areas sand and clay are practically the only materials available for road building.

One of the objects of this bulletin is to give some account of the commonly observed physical characteristics of clays and sands as an aid to the use of these materials for constructing roads. It must be remembered, however, that the great variation in the physical properties of clay makes it difficult to give definite rules, which shall be general in their nature, for the mixing and application of this material.

It may safely be said that the construction of sand-clay roads in the Southern States has passed the experimental stage. It has been proved that they are well adapted for light traffic, and are less noisy, less dusty, and more resilient than the average macadam road. Even under heavy traffic they have proved to a great extent satisfactory. There are sand-clay roads in the South Atlantic and Gulf States over which heavy loads of cotton and other farm products are hauled throughout the year, with but little resulting damage. When the cheapness of this kind of construction is considered, it will be seen that for certain localities, at least, it is preferable to macadam. In all cases a mixture of sand and clay is better than either material alone, except perhaps where it is impossible to drain a sandy road, and, in consequence, it is always wet. Very little, if any, clay should be used in this case, for the water acts as a binder and the sand remains firm.

In some sections of the country the only available material from which roads can be constructed is clay. To meet this condition the Office of Public Roads has made experiments in the so-called "gumbo" district of the lower Mississippi Valley, in burning the clay along the entire length of the road. By burning clay, even at a moderate heat, its well-known sticky or plastic quality is destroyed, so that even in the wettest weather it will bear traffic. If the clay is fired along the entire length of the road, the cost of hauling it is avoided, and at the same time the advantage is gained of burning the foundation of the road as well as the material to be placed upon it.

PHYSICAL PROPERTIES OF SAND AND OF CLAY.

The mineral known as quartz, which is composed of silica, is found abundantly in all parts of the earth. When consolidated by heat and pressure into great masses of rock it is known as quartzite, and it also appears as an important constituent of many different kinds of rock. When quartzite is disintegrated by the action of the elements and is found in great loose masses, composed of fine and more or less uniform grains, it is known as sand. It is a well-recognized fact that sand lacks binding power, and on drying out is of a loose and unstable nature.

Clay, on the other hand, is formed by the decomposition of other minerals which go to make up the structure of rocks. The origin of all clay is the mineral feldspar, which, under the action of water, has been gradually leached out and changed into clay. The particles of clay are usually much finer than those of sand and are frequently carried by running water some distance from the point at which they were originally formed, where, having settled as a sediment on the bottom, they form deposits which are known as sedimentary clays. In some cases where huge deposits of feldspathic rock have been disintegrated and changed by the action of water in place, the deposits are known as residual clays.

It will be seen from this that clays must vary both in texture and composition. Some will be found to contain as much as 75 per cent of sand, while others are extremely fine in texture and entirely without grit. As would be expected, the sedimentary clays are usually finer and more sticky and plastic than the so-called residual clays.

The two properties of clays which are of the greatest importance from the standpoint of road building are, first, plasticity, and, second, the property of slaking when they first become wet after having been uncovered. A clay is called plastic which becomes sticky or doughlike when mixed with a certain amount of water, so that it can be molded or pressed into various shapes which it will retain even after it has been dried. The most plastic of these materials are known technically as "ball clays." If a lump of such a clay as this is immersed in water it will usually preserve its form for a long time.

There are other clays, however, which will immediately fall to pieces, as a lump of quicklime will do under similar conditions. This is known to be due to the very rapid absorption of water into the porous structure of the clay. It will easily be seen that this characteristic is an important one from the standpoint of the road builder, for any sort of agitation will cause a large percentage of a slaking clay to pass into suspension in water and form a thick mud. Non-slaking clays, although they are very sticky when wet, do not so readily mix with water. It stands to reason that the slaking clays are usually "deep seated," that is to say, they will be found below the surface of the ground. Slaking clays are more easily mixed with other materials than the more plastic ball clays, and this is, of course, to their advantage for road building. On the other hand, they are often of inferior binding power.

There is still another physical characteristic of clay that is of great importance from the standpoint of road building. Some clays shrink when dried, which leads to the cracking and breaking up of their surfaces. This shrinkage is the measure of their expansion, and expansion renders the sand-clay composition unstable. Shrinkage would do no harm if the clay would stay in this condition, but this it does not do. When water, removed by evaporation, is restored to the sand-clay mixture, its entrance is accompanied by a simultaneous expansion which causes the grains of sand to be separated. This property can not be overcome, for it is inherent in the clay, but we can in some measure modify its effect by using less clay in the composition. This, however, will weaken the road and dispose it to break up in dry weather.

Before attempting to construct a sand-clay road it is best to test the material in the neighborhood in order to secure a clay having the least possible shrinkage. There is no better way than to examine the traveled roadways. In almost every community there are short sections of natural sand-clay road which may be examined.

THE MIXING OF SAND AND CLAY.

The best sand-clay road is one in which the wearing surface is composed of grains of sand in contact in such a way that the voids or angular spaces between the grains are entirely filled with clay, which acts as a binder. Any excess of clay above the amount necessary to fill the voids in the sand is detrimental. If a small section taken from the surface of any well-constructed sand-clay road is examined with a magnifying glass, the condition of contact which exists between the grains of sand and the small proportion of clay which is required to fill the voids may be seen. Wherever this proper condition of contact exists for a few inches in thickness upon the surface of a road, it will bear comparatively heavy traffic for a long time, even when the subsoil is sand or clay. The proper mixture or saturation point of clay and sand can easily be seen by referring to figure 1.

All the experiments that have been made by this Office indicate that the materials should not be mixed in a dry state, but that they should be thoroughly mixed and puddled with water. It makes little difference by what method the stirring or mixing is done, so long as it is thorough and proper proportions of the materials are obtained. If an excess of clay is used in the mixture, as shown in figure 2, the grains of sand which are not in contact are free to move among and upon each other, so that no particle exerts more resistance to pressure than if the entire mass consisted of clay alone. On the other hand, if an insufficient amount of clay is used, the mixture will lack binding power and will soon disintegrate.

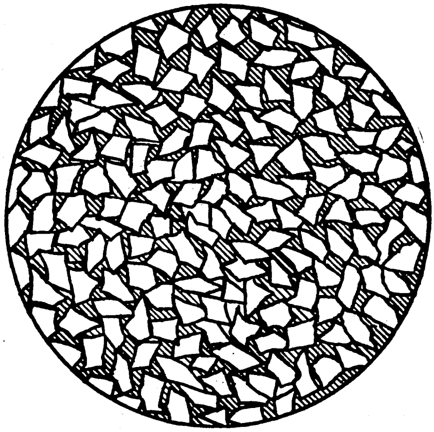

FIG. 1.—Clay mixed with sand to the point of saturation, with the angular sand grains in contact.

We may now outline the methods which have been used to obtain the proper contact mixture, although it will be necessary to discuss separately the methods of treating slaking and nonslaking varieties of clay. It will readily be seen that it is less economical to haul sticky or plastic clay and spread it upon sand than it is to haul sand and spread it upon clay. The clay is difficult to dig and handle and usually comes out in lumps, which, if placed upon the roadbed and covered with sand, are apt to remain unbroken unless great care is taken in the mixing. The bad effects of lumps of clay in a sandy subsoil and the effects of traffic on such a mixture are illustrated in figures 3 and 4.

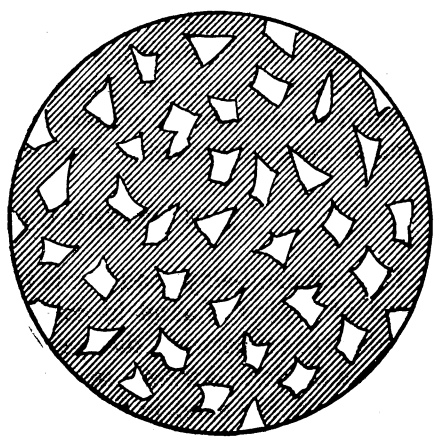

FIG. 2.—Sand-clay mixture with an insufficient amount of sand, the grains not being in contact.

Figure 3 shows a cross section of a road into which lumps of clay have been worked. Figure 4 shows the displacement of these lumps when subjected to the prolonged action of traffic, and the resulting formation of deep ruts and general disintegration of the surface.

It has been pointed out that thorough stirring and puddling are absolutely essential to successful sand-clay construction. This is most easily brought about immediately after a hard or prolonged rain, the clay having been previously spread and the larger lumps broken up as completely as possible. The surface should then be covered with a few inches of sand and plowed and harrowed thoroughly by means of a turning plow and a cutaway or disk harrow. This stage of the work will of course be found somewhat disagreeable, leading, as it does, to the formation of a thick, pasty mud; but it is the only practicable way in which the necessary mixing can be accomplished. Many experiments have been tried with dry mixing of the clay and sand, but all have been more or less unsuccessful. In cases where the plowing and harrowing are considered too expensive the mixing may be left to traffic. This, however, inevitably leads to a muddy road surface for a long time, although finally it is possible, by a proper distribution of the sand upon the clay, to bring about a fairly good result, even by this simple method.

Fig. 3.—Cross section of road, showing lumps of clay placed on a sand subsoil and covered with sand.

In case a slaking clay is used, very much less puddling is required, as there are practically no lumps to be broken up and the mixing can easily be done with a harrow after a rain. Slaking clays do not usually make as effective binders as the more plastic clays; therefore in dry weather the road surface becomes more dusty. It will be seen that the best clay for this kind of construction is one which slakes sufficiently easily to enable the lumps to be readily broken up, and which at the same time, without being too plastic, has sufficient binding power to cement the grains of sand and form a smooth, impervious surface on the road. Clays of this nature which have given excellent results are found in abundance in many of the Southern States and doubtless exist elsewhere. Their color is usually red or mottled red and white. Occasionally clays are found sufficiently sandy to be suitable for use without further mixing. When this is the case it is only necessary to spread the material on the road and allow it to pack under traffic. It is obvious that it is necessary to pay careful attention to the physical

Fig. 4.—Cross section of road, showing displacement of lumps of clay when subjected to travel.

properties of the available clay in the neighborhood of the road, as it will frequently be found economical to haul good material for some distance rather than to use an inferior material which is close at hand. The qualities to be considered, as has been pointed out, are the greatest binding power obtainable, together with the least amount of labor necessary for disintegrating and mixing.

APPROXIMATE METHOD FOR ESTIMATING THE PROPER PROPORTIONS OF SAND AND CLAY.

It has already been shown that the best mixture for sand-clay construction is one in which there is just enough clay to fill the voids in the sand, thus producing the proper cementing bond in the road surface. No exact rules can be laid down for calculating in advance the best mixture. It must be remembered that the relation of weight and volume will vary widely in different clays, according to the amount of water which they contain. Some clays, especially the more plastic varieties, even after they are as thoroughly dried as they can be by the hottest summer sun, will still hold as much as 20 per cent of water. This water is known to chemists as "water of combination," because it seems to be either combined with or held in the structure of the clay particles in such a way that it can only be driven out at a high temperature. It is apparent from this that in handling a clay of this kind, even when it seems quite dry, each ton will contain 400 pounds of water which does not enter into the consideration of volume. The amount of clay necessary to fill the voids in any given sand will therefore be found to vary.

An easy method for making a rough or approximate estimate of the volume of the clay filler required for any unit quantity of a given sand is as follows: Two ordinary glass tumblers of the same size are filled to the brim, one with the dry sand to be tested and the other with water. The water is then poured carefully from the one glass into the sand in the other until it reaches the point of overflowing. The volume of water removed from the glass which was originally full of water can be taken as an approximate measure of the voids in the unit volume of sand contained in the tumbler. A simple calculation will reduce this to percentage volume.

Practical experience has shown that the tendency is to calculate too little rather than too much sand for given amounts of clay, and almost invariably a second and even a third application of sand is necessary over and above the calculated amount. It often happens that clay will work up to the surface under the action of traffic, in which case an extra top dressing of sand should be added when required.

METHODS OF CONSTRUCTING A SAND-CLAY ROAD.

In passing to a detailed description of methods of construction, it must first be stated that there are two distinct conditions which are likely to be met. In the first case the road may have a sandy subsoil, ordinarily spoken of as "deep" sand, the objectionable features of which must be overcome by the addition of clay. On the other hand, the subsoil may be of clay, and in this case sand must be added to it. Since there is a radical difference in the methods of construction in these two cases, each will be treated separately.

DRAINAGE.

In all forms of road construction the most important consideration is that of drainage. If natural drainage does not exist, artificial methods must be used. The best natural drainage is usually found upon a loose gravel or a sandy soil, especially when the grade of the road is somewhat above the surrounding country. If the land is dry and the sand deep enough to absorb quickly even the heaviest rains, no special attention need be given to drainage other than to provide the proper crown to the surface of the finished road to divert the water from it. Frequently, in tide-water regions, the country is so low and level that the surface of the road is likely to be kept continually wet from seepage. If this condition has to be met, it is nec-

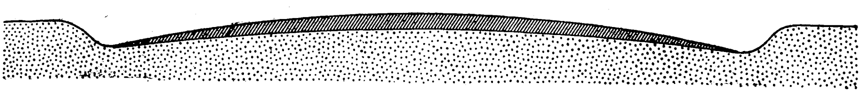

FIG. 5.—Cross section of road, showing clay cover on "deep" sand subsoil.

cessary to dig wide ditches on each side of the roadbed and raise the grade so that the crown of the road will be sufficiently high to shed water thoroughly before hauling any clay upon it.

It is very important that no stumps or branches of trees or other matter subject to decay should be overlooked and left in the roadbed, as at such points weak places are sure to be developed in the course of time. Although natural drainage is much better on sandy subsoils than on clay, in clay districts the conformation of the country is more likely to be of an undulating or rolling character, thus furnishing a natural watershed. Temporary or so-called "wet-weather" springs are not so likely to occur in sandy soils as in clay soils, and therefore need not be so carefully guarded against. Nevertheless, if any indications of these springs are found, precautions should be taken to conduct the water to the side ditches by some form of underdrainage.

SAND-CLAY CONSTRUCTION UPON A SANDY SUBSOIL.

When the drainage has been properly provided, the roadbed should be brought to a crown. It has been found more economical to crown first a section of the road nearest the source of the clay. The first load of clay is dumped on this prepared section at the point nearest the clay bed, each succeeding load thus being hauled over the preceding. Care should be taken to spread each separately and evenly as soon as it has been deposited and before it is driven over. The clay cover spread upon the subsoil is shown in figure 5.

After spreading the clay it should be covered with a layer of clean sand. When the road has been opened to traffic a sufficient amount of sand should be added from time to time to keep the surface smooth and prevent the formation of mud. Both the thickness and the width of the layer of clay to be spread are determined by the volume and character of traffic which the road is to sustain. If a narrow, single-track roadway is to be built, it has been found best to spread the clay to a width of about 12 feet and to a depth of 6 to 8 inches in the center, tapering the layer to a thin edge at the sides. In some cases it may be necessary to modify these directions to accord with the quality of the clay and the amount of sand which it contains. The "leaner" or more sandy the clay, the greater will be the amount required.

After the clay layer is completed and covered with sand, as already stated, if the clay is of a plastic and lumpy character it will probably be necessary to plow and harrow it alternately until the lumps are thoroughly disintegrated. Advantage should be taken of rains in order to puddle the road surface with a harrow. As long as the surface shows a tendency to "ball" and cake, more sand must be added until this trouble is overcome. If, on the other hand, the surface loosens in dry weather, it is due to an insufficient quantity of clay or else because the clay lacks binding power. It must be borne in mind that the construction of a sand-clay road is not a quick operation, but a process of rather slow development. In the course of the work there is time to determine what proportions of the two materials will finally lead to the best results.

If the materials are especially adapted to the purpose it is possible to construct very excellent sand-clay roads without the use of plow, harrow, or roller. The mixing can be left, after the materials have been properly spread, entirely to the action of traffic. In all construction, however, the best results are hastened by the use of plow and harrow. In all cases it is advisable to use a road machine or other similar implement to crown and smooth the surface, after which a light coat of sand may be added.

The quantity of clay required to build a mile of road will vary of course with the width and depth of the clay layer. A roadway 12 feet wide with an average depth of 6 inches of clay will require a cubic yard of clay to cover 4½ feet of road length; that is to say, each cubic yard of clay will make 1½ " running " yards of clay road. Since there are 1,760 yards to the mile, it will be seen that 1,173⅓ cubic yards of clay will be required for 1 mile of construction. From this data the cost may be readily calculated, when the rate of wages and distance of haul are known. The average load has been found to be about two-thirds to three-fourths of a cubic yard, when the hauling is done over sand, and about 1 cubic yard when the hauling is done over a dry clay road. It may be said after rough calculation that a 2-horse load of clay will cover 1 linear yard of 12-foot surface, making 1,760 loads to the mile. The cost of shoveling sand upon the clay is the same, whether the mixing is to be done with a plow and harrow or left to traffic, and should therefore in each case be added to the cost of hauling.

SAND-CLAY CONSTRUCTION UPON A CLAY SUBSOIL.

After proper drainage has been provided the roadbed should first be crowned as nearly as possible to the form desired in the finished road. The road surface should slope from the center to the sides at least one-half inch per foot. It should be noted that it is much more important to form this foundation crown first where the subsoil is of clay than it is with a sandy subsoil.

The foundation having been properly prepared, the surface should be plowed and harrowed to a depth of about 4 inches until it is pulverized as completely as possible. It is then covered with 6 to 8 inches of clean, angular sand. The sand should be spread so that the layer is thickest at the center of the road, following in general the same plan as was outlined for spreading clay upon a sandy foundation. The materials should then be mixed while they are in a comparatively dry state, contrary to the usual practice of doing the entire mixing and puddling when the materials are wet. It has been found that the clay foundation can be more evenly disintegrated when comparatively dry, and it is also a difficult matter to mix the sand evenly with the clay if the latter is soft and cut into ruts by travel. This preliminary mixing should be done if possible, but often conditions do not allow it and the sand has to be mixed on the wet clay road. After this first mixing has been finished the road is finally puddled with a harrow after a rain. In case an excess of clay works to the surface and tends to make the mixture sticky, sand should be applied until this trouble is overcome.

Upon the completion of the mixing and puddling, the road should be shaped while it is still soft enough to be properly finished with a scraper and at the same time stiff enough to pack well under the roller or under the action of traffic. In case it is impossible to obtain the proper consistency of the surface material, it is better to shape the road when somewhat too wet than when it is too dry, even if it is necessary to stop traffic upon it for a few days. The road should be opened to traffic as soon as practicable after completion, as this will be found to have a beneficial effect upon it.

After sand-clay roads are constructed, they should be cared for until the proper condition is established and the road is resistant to traffic. This care is extremely important and is deserving of special mention. No sand-clay road is in proper condition when first constructed, and this attention afterwards is as much a part of the road construction as the hauling of the first load of sand or clay.

COST OF SAND-CLAY CONSTRUCTION.

It is of course impossible to state definitely the cost of this form of construction, as it will be found to vary with the price of labor, the length of haul, the width of roadway, and depth and nature of material. If we assume, however, that the clay can be procured within a mile of the road which is to be improved, and that the cost of labor is about $1 per day and teams $3 per day, the cost of constructing a 12-foot sand-clay road on a sand foundation, covered with clay to an average depth of 6 inches, would be approximately as follows for a distance of 1 mile:

Crowning and shaping road with road machine, using 2 teams at $3 and 1 operator at $1.50 per day for 1 day	$7.50
Loosening 1,173⅓ cubic yards of clay with pick and shoveling into wagons, at 15 cents per cubic yard	176.00
Hauling 1,173⅓ cubic yards of clay, at 23 cents per cubic yard	269.86
Spreading clay with road machine, using 2 teams at $3 and expert operator at $1.50 per day for 3 days	22.50
Shoveling sand on clay, estimated at ½ cent per square yard	35.20
Plowing, using 1 team at $3 per day for 4 days	12.00
Harrowing, using 1 team at $3 per day for 2 days	6.00
Shaping and dressing with road machine, using 2 teams at $3 and expert operator at $1.50 per day for 2 days	15.00
Rolling, estimated at ½ cent per square yard	35.20
Total	579.26

The estimated cost per square yard of road surface, therefore, when computed on the basis of this table, would be about 8 cents, or at the rate of $579.26 per mile.

The cost of building a sand-clay road on a clay foundation would not vary much from the figures given. The latter form of construction would probably be slightly cheaper by reason of the fact that sand can be handled more economically than clay.

According to the experience of this Office, the cost of sand-clay construction in the South has been found to range from $200 to $1,200 per mile, in most cases running from $300 to $800. A sand-clay road constructed under the direction of the Office at Gainesville, Fla., 1 mile in length, 14 feet wide, and having a 9-inch sand-clay surface, cost $881.25 per mile, or 10 cents per square yard. Another sand-clay road built under the direction of the Office at Tallahassee, Fla., 16 feet wide and surfaced with about 7 inches of sand-clay mixture, cost $470 per mile, or about 5 cents per square yard. In case changes of grade have to be made with consequent cuts and fills, the cost would be proportionately greater than the figures given above. There can be no question, however, that under all circumstances this form of construction is cheaper than macadam.

THE USE OF SAND-CLAY ROADS IN THIS COUNTRY.

The possibilities of the sand-clay road may not be fully realized by the public for a long time to come, still the progress being made in this form of road building in nearly every part of the country is encouraging. Such benefits as have come to Richland County, S. C., Pike County, Ala., Dallas County, Ala., Cumberland County, N. C., and many other sections throughout the Atlantic and Gulf States from the use of sand-clay roads should be a sufficient incentive for a general study of the subject in those parts of the country where these materials exist in adequate quantities.

Sand and clay had always been abundant in Pike County, Ala., still a combination of the two for road purposes was not thought of until four years ago. At the present time there are nearly 120 miles of sand-clay road in this county, which for all practical purposes, are as useful as macadam roads, and which have cost about one-sixth of the amount standard macadam of the same or less width would cost in this section. With this system the remotest section of the county may be reached, which would not be the case had fewer and more expensive roads been attempted. At the present rate of improvement every important public road in this county will soon be a serviceable highway, over which a wagon loaded with six bales of cotton may be drawn easily and quickly, whereas, before the improvement began, only small loads were possible. It is important that success like this should be given wide publicity because it carries with it method as well as encouragement. The first thing done in this locality was to find out which of the clays accessible would make a good road. After this important matter had been decided, bonds were issued to raise money to buy equipment. This comprised eight outfits of fourteen to sixteen mules each, wagons, plows, scrapers, and hand tools.

The extent to which this form of road construction can be used in public road improvement throughout the country can hardly be overestimated. In making small repairs to roads, if, instead of filling mudholes with brush, a few loads of sand or gravel from sand bars and gravel beds found along the streams in hilly portions of the country were hauled to the road, permanent improvement would result.

It has been found that this kind of road is admirably suited to the northwestern part of the country as well as to the southern, and it is believed that it will be found worthy of more general study than it has ever received heretofore. Its study should be of interest to the public schools in the rural districts of the country. If school boys were encouraged to make a sand-clay walk to the schoolhouse, the teacher's task of keeping a clean school building would be sufficiently lessened to make up for the time taken to interest the boys. Besides this actual improvement, a lasting benefit would be given to that community from this simple study of a valuable process. For a large part of the country, the sand-clay road is the only road possible or within the reach of the rural districts. It requires less money to build than any other type of road except the earth road and less money to repair. It is simpler in its construction than any other except the earth road, and lasts longer with the same amount of repair.

THE CONSTRUCTION OF BURNT-CLAY ROADS.

In large areas in the South, particularly in the valleys of the Mississippi and its tributaries, sedimentary clays are found very generally. In these areas there is little or no sand, and the clays are of a particularly plastic and sticky variety. These sticky clays are locally known as "gumbo" and "buckshot." In such localities traffic is absolutely impossible during the wet season, as the wheels of heavy vehicles will sink to the hub. In order to overcome this difficulty the Office of Public Roads undertook an investigation of the matter. Special experiments were carried on in the laboratory to see what could be done in the way of burning or clinkering these clays so as not only to destroy their plastic qualities, but also, as far as possible, to form hard, brick-like lumps which should be capable of sustaining traffic. Samples of the material were sent from the Yazoo district in Mississippi to the laboratory, and the clinkering point of the clay was found to be sufficiently low to indicate that simple burning of the lumpy clays upon the road surface by means of open wood fires would accomplish the desired result. Following these laboratory experiments it was decided to make experiments on a road, and it can be stated that this experimental road is proving highly satisfactory.

Gumbo clay is black, owing to the high percentage of organic or vegetable matter it contains. It is particularly sticky in its nature, and is almost wholly free from sand and grit. After it has been burned, however, the plasticity is entirely destroyed, and a light clinker is formed which, though not particularly hard, when pulverized forms a smooth surface and seems to wear well. It should be understood that not all of the clay out of which the road is to be constructed is to be clinkered, but only a sufficient amount should be rendered nonplastic to neutralize the too sticky character of the native clay. Fortunately the gumbo district is plentifully covered with heavy timber, thus affording an abundance of fuel. Work should be done in a dry season of the year.

While the only experimental burnt-clay roads constructed by the Office are in Mississippi, the same methods might be applied with equally good results in the sections of the prairie States that have no other material available for road building and have sufficient timber for this purpose.

FUEL.

Good sound wood, as dry and well seasoned as it is possible to procure, should be provided before beginning the work, and stacked at convenient intervals along the side of the road. About 1 cord of wood has been found necessary for 8 linear feet of roadbed 12 feet wide. The wood may be cut to 4, 8, or 12-foot lengths. Brushwood, if it is dry, or chips, bark, old fence rails and discarded railroad ties, coal slack—in fact any sort of fuel that can be easily and economically obtained—may be used to advantage with the cord wood.

PREPARATION OF THE ROADBED.

After grading the road to an even width between ditches, it is plowed up as deeply as practicable. It will be found necessary to use four horses or mules, as the extremely heavy nature of the clay makes the work of deep plowing difficult. After the plowing has been completed, furrows are dug across the road from ditch to ditch, extending through and beyond the width to be burned. If it is intended to burn 12 feet of roadway, the transverse furrows should be 16 feet long, so as to extend 2 feet on each side beyond the width of the final roadway. Across the ridges formed between these furrows—which should be about 4 feet apart—the first course of cord wood is laid longitudinally so as to form a series of flues in which the firing is started.

The best and soundest cord wood is selected for this first course and should be laid so that the pieces will touch, thus forming a floor. Another layer of wood is thrown irregularly across this floor, in crib formation, with spaces left between in which the lumps of clay are piled. Care should be taken that the clay placed on this cribbed floor is in lumps coarse enough to allow a draft for easy combustion.

After the lumps of clay have been heaped upon this floor, a third course of wood is laid parallel to the first. This third course is laid in exactly the same manner as the first, and each opening and crack should be filled with brush, chips, bark, small sticks, or any other combustible material. The top layer of clay is placed over all and the finer portions of the material are heaped over the whole structure. A careful arrangement of this cord-wood cribbing to separate the clay is important, and the directions should be carefully followed.

The deep covering of clay which is thrown over all should be taken from the side ditches, and may be in lumps of all sizes, including the very finest material. It is spread as evenly as possible over the top in a layer of not less than 6 to 12 inches. Finally the whole is tamped and rounded off so that the heat will be held within the flues as long as possible. When coal slack is available the two top layers of wood may be omitted and the coal slack thoroughly mixed with the mass of clay.

It is necessary to get the fires well under way in the flues before the first layer of wood is burned through. The first action of the fire is to drive out the water contained in the clay before the actual burning and clinkering can begin. In burning the gumbo clays a great advantage is gained from the organic and vegetable matter which is contained in the clay, as that in itself aids combustion.

FIRING.

When the roadbed has been carefully prepared according to the foregoing directions, the firing should begin. In our practice 15 or 20 flues are prepared for firing in one section. If, however, a large force of laborers is available for the work, a greater number of flues can be fired at one time. It is always possible to divide the firing into sections by omitting the charge of wood in one transverse furrow, which may then be covered later and burned in the same way as the rest.

The best results are obtained by firing all the flues of a section simultaneously and maintaining the combustion as evenly as possible. A supply of light, dry, kindling wood, or any easily inflammable material, should be at hand to prevent the fire from dying down in any one place. The firing should invariably be begun on the windward side, in order to obtain the maximum draft. In case the combustion is too rapid in any flue it may be regulated by banking the mouth of the flue with clay.

If the burning is entirely successful, not only the portion of clay which forms the top of the kiln but the ridges between the flues will be burned thoroughly, so as to form a covering of burnt clay 10 to 12 inches in depth, which, when rolled down and compacted, forms a road surface of from 6 to 8 inches in thickness. If properly burned, the material should be entirely changed in character, and when it is wet it should have no tendency to form mud.

When the material is sufficiently cooled the roadbed should be brought to a high crown before rolling, in order to allow for the compacting of the material. This can best be done with a plow or a grader. After this the rolling should be begun and continued until the roadbed is smooth and hard. The finished crown should have a slope of at least one-half inch to the foot.

The main advantages of this method of burning a road over its entire length are, first, that the cost of transporting the clay is avoided; second, that the subgrade of the road is burned as well as the material above.

COST OF BURNT-CLAY CONSTRUCTION.

It is, of course, impossible to give the cost of a burnt-clay road which will apply to the same work in all sections of the country. Although this form of construction in the South up to the present time has been successful, it can not as yet be said to have passed the experimental stage. The items of cost of the experimental road 300 feet long, as constructed at Clarksdale, Miss., are as follows:

30½ cords of wood, at $1.30 per cord	$39.65
20 loads of bark, chips, etc	6.00
Labor, at $1.25 per day, and teams, at $3 per day	38.30
Total cost of 300 feet	83.95
Total cost per mile at this rate	1,478.40

In view of the success of the experiments so far made and the comparative cheapness of this form of construction, it is hoped that the localities which have no hard material available will continue the experiments with burnt clay. Although it can not be denied that the gumbo and buckshot clays of the South are particularly adapted for burning on account of the high percentage of organic matter which they contain, it is none the less probable that many of the surface clays and soils of the States farther north could be treated in the same way, and in fact any soil or clay which bricks or clinkers at a comparatively low temperature should be suitable for the work.

Since the experiment made by this Office at Clarksdale, Miss.,[a] numerous sections of burnt-clay road have been built in that locality, and up to the present time only favorable reports regarding them have been received. Experimental burnt-clay roads are now (1907) being constructed under the supervision of this Office at Indianola, Miss., and at Greenville, Miss., but since the work at these places is still incomplete no report upon it can be given.

[a] For reports concerning this road, see Annual Report, Office of Public Roads, 1905.

FARMERS' BULLETINS.

The following is a list, by number, of the Farmers' Bulletins available for distribution. The bulletins entitled "Experiment Station Work" give in brief the results of experiments performed by the State experiment stations. Titles of other bulletins are self-explanatory. Bulletins in this list will be sent free to any address in the United States on application to a Senator, Representative, or Delegate in Congress, or to the Secretary of Agriculture, Washington, D. C. Numbers omitted have been discontinued, being superseded by later bulletins.

22. The Feeding of Farm Animals. Pp. 40.
24. Hog Cholera and Swine Plague. Pp. 16.
25. Peanuts: Culture and Uses. Pp. 24.
27. Flax for Seed and Fiber. Pp. 16.
28. Weeds: And How to Kill Them. Pp. 30.
29. Souring and Other Changes in Milk. Pp. 22.
30. Grape Diseases on the Pacific Coast. Pp. 15.
32. Silos and Silage. Pp. 30.
33. Peach Growing for Market. Pp. 24.
34. Meats: Composition and Cooking. Pp. 31.
35. Potato Culture. Pp. 24.
36. Cotton Seed and Its Products. Pp. 16.
39. Onion Culture. Pp. 30.
42. Facts About Milk. Pp. 32.
44. Commercial Fertilizers. Pp. 38.
46. Irrigation in Humid Climates. Pp. 27.
47. Insects Affecting the Cotton Plant. Pp. 32.
48. The Manuring of Cotton. Pp. 16.
49. Sheep Feeding. Pp. 24.
51. Standard Varieties of Chickens. Pp. 48.
52. The Sugar Beet. Pp. 48.
54. Some Common Birds. Pp. 48.
55. The Dairy Herd. Pp. 30.
56. Experiment Station Work—I. Pp. 30.
58. The Soy Bean as a Forage Crop. Pp. 24.
59. Bee Keeping. Pp. 48.
60. Methods of Curing Tobacco. Pp. 24.
61. Asparagus Culture. Pp. 40.
62. Marketing Farm Produce. Pp. 31.
63. Care of Milk on the Farm. Pp. 40.
64. Ducks and Geese. Pp. 55.
65. Experiment Station Work—II. Pp. 32.
66. Meadows and Pastures. Pp. 30.
69. Experiment Station Work—III. Pp. 32.
71. Essentials in Beef Production. Pp. 24.
72. Cattle Ranges of the Southwest. Pp. 32.
73. Experiment Station Work—IV. Pp. 32.
74. Milk as Food. Pp. 39.
77. The Liming of Soils. Pp. 24.
78. Experiment Station Work—V. Pp. 32.
79. Experiment Station Work—VI. Pp. 27.
80. The Peach Twig-borer. Pp. 16.
81. Corn Culture in the South. Pp. 24.
82. The Culture of Tobacco. Pp. 22.
83. Tobacco Soils. Pp. 23.
84. Experiment Station Work—VII. Pp. 32.
85. Fish as Food. Pp. 32.
86. Thirty Poisonous Plants. Pp. 32.
87. Experiment Station Work—VIII. Pp. 32.
88. Alkali Lands. Pp. 23.
91. Potato Diseases and Treatment. Pp. 15.
92. Experiment Station Work—IX. Pp. 30.
93. Sugar as Food. Pp. 31.
95. Good Roads for Farmers. Pp. 46.
96. Raising Sheep for Mutton. Pp. 48.
97. Experiment Station Work—X. Pp. 32.
98. Suggestions to Southern Farmers. Pp. 48.
99. Insect Enemies of Shade Trees. Pp. 30.
100. Hog Raising in the South. Pp. 40.
101. Millets. Pp. 30.
102. Southern Forage Plants. Pp. 48.
103. Experiment Station Work—XI. Pp. 30.
104. Notes on Frost. Pp. 24.
105. Experiment Station Work—XII. Pp. 32.
106. Breeds of Dairy Cattle. Pp. 48.
107. Experiment Station Work—XIII. Pp. 32.
108. Saltbushes. Pp. 20.
109. Farmers' Reading Courses. Pp. 20.
110. Rice Culture in the United States. Pp. 28.
111. Farmer's Interest in Good Seed. Pp. 24.
112. Bread and Bread Making. Pp. 40.
113. The Apple and How to Grow It. Pp. 32.
114. Experiment Station Work—XIV. Pp. 28.
115. Hop Culture in California. Pp. 28.
116. Irrigation in Fruit Growing. Pp. 48.
118. Grape Growing in the South. Pp. 32.
119. Experiment Station Work—XV. Pp. 30.
120. Insects Affecting Tobacco. Pp. 32.
121. Beans, Peas, and other Legumes as Food. Pp. 38.
122. Experiment Station Work—XVI. Pp. 32.
124. Experiment Station Work—XVII. Pp. 32.
125. Protection of Food Products from Injurious Temperatures. Pp. 24.
126. Practical Suggestions for Farm Buildings. Pp. 48.
127. Important Insecticides. Pp. 46.
128. Eggs and Their Uses as Food. Pp. 40.
129. Sweet Potatoes. Pp. 40.
131. Household Tests for Detection of Oleomargarine and Renovated Butter. Pp. 10.
132. Insect Enemies of Growing Wheat. Pp. 38.
133. Experiment Station Work—XVIII. Pp. 32.
134. Tree Planting in Rural School Grounds. Pp. 32.
135. Sorghum Sirup Manufacture. Pp. 40.
136. Earth Roads. Pp. 24.
137. The Angora Goat. Pp. 48.
138. Irrigation in Field and Garden. Pp. 40.
139. Emmer: A Grain for the Semiarid Regions. Pp. 16.
140. Pineapple Growing. Pp. 48.
142. Principles of Nutrition and Nutritive Value of Food. Pp. 48.
143. Conformation of Beef and Dairy Cattle. Pp. 44.
144. Experiment Station Work—XIX. Pp. 32.
145. Carbon Bisulphid as an Insecticide. Pp. 28.
146. Insecticides and Fungicides. Pp. 16.
147. Winter Forage Crops for the South. Pp. 40.
149. Experiment Station Work—XX. Pp. 32.
150. Clearing New Land. Pp. 24.
151. Dairying in the South. Pp. 48.
152. Scabies in Cattle. Pp. 32.
153. Orchard Enemies in the Pacific Northwest. Pp. 39.
154. The Home Fruit Garden: Preparation and Care. Pp. 16.
155. How Insects Affect Health in Rural Districts. Pp. 19.
156. The Home Vineyard. Pp. 22.
157. The Propagation of Plants. Pp. 24.
158. How to Build Small Irrigation Ditches. Pp. 28.
159. Scab in Sheep. Pp. 48.
161. Practical Suggestions for Fruit Growers. Pp. 30.
162. Experiment Station Work—XXI. Pp. 32.
164. Rape as a Forage Crop. Pp. 16.
165. Silkworm Culture. Pp. 32.
166. Cheese Making on the Farm. Pp. 16.
167. Cassava. Pp. 32.
168. Pearl Millet. Pp. 16.
169. Experiment Station Work—XXII. Pp. 32.
170. Principles of Horse Feeding. Pp. 44.
172. Scale Insects and Mites on Citrus Trees. Pp. 43.
173. Primer of Forestry. Pp. 48.
174. Broom Corn. Pp. 30.
175. Home Manufacture and Use of Unfermented Grape Juice. Pp. 16.
176. Cranberry Culture. Pp. 20.
177. Squab Raising. Pp. 32.
178. Insects Injurious in Cranberry Culture. Pp. 32.

179. Horseshoeing. Pp. 30.
181. Pruning. Pp. 39.
182. Poultry as Food. Pp. 40.
183. Meat on the Farm: Butchering, Curing, and Keeping. Pp. 37.
184. Marketing Live Stock. Pp. 40.
185. Beautifying the Home Grounds. Pp. 24.
186. Experiment Station Work—XXIII. Pp. 32.
187. Drainage of Farm Lands. Pp. 38.
188. Weeds Used in Medicine. Pp. 45.
190. Experiment Station Work—XXIV. Pp. 32.
192. Barnyard Manure. Pp. 32.
193. Experiment Station Work—XXV. Pp. 32.
194. Alfalfa Seed. Pp. 14.
195. Annual Flowering Plants. Pp. 48.
196. Usefulness of the American Toad. Pp. 16.
197. Importation of Game Birds and Eggs for Propagation. Pp. 30.
198. Strawberries. Pp. 24.
199. Corn Growing. Pp. 32.
200. Turkeys. Pp. 40.
201. Cream Separator on Western Farms. Pp. 23.
202. Experiment Station Work—XXVI. Pp. 32.
203. Canned Fruits, Preserves, and Jellies. Pp. 32.
204. The Cultivation of Mushrooms. Pp. 24.
205. Pig Management. Pp. 40.
206. Milk Fever and Its Treatment. Pp. 16.
208. Varieties of Fruits Recommended for Planting. Pp. 48.
209. Controlling the Boll Weevil in Cotton Seed and at Ginneries. Pp. 32.
210. Experiment Station Work—XXVII. Pp. 32.
211. The Use of Paris Green in Controlling the Cotton Boll Weevil. Pp. 23.
213. Raspberries. Pp. 38.
215. Alfalfa Growing. Pp. 40.
216. The Control of the Boll Weevil. Pp. 32.
217. Essential Steps in Securing an Early Crop of Cotton. Pp. 16.
218. The School Garden. Pp. 40.
219. Lessons from the Grain Rust Epidemic of 1904. Pp. 24.
220. Tomatoes. Pp. 32.
221. Fungous Diseases of the Cranberry. Pp. 16.
222. Experiment Station Work—XXVIII. Pp. 32.
223. Miscellaneous Cotton Insects in Texas. Pp. 24.
224. Canadian Field Peas. Pp. 16.
225. Experiment Station Work—XXIX. Pp. 32.
226. Relation of Coyotes to Stock Raising in the West. Pp. 24.
227. Experiment Station Work—XXX. Pp. 32.
228. Forest Planting and Farm Management. Pp. 22.
229. The Production of Good Seed Corn. Pp. 24.
231. Spraying for Cucumber and Melon Diseases. Pp. 24.
232. Okra: Its Culture and Uses. Pp. 16.
233. Experiment Station Work—XXXI. Pp. 32.
234. The Guinea Fowl. Pp. 24.
235. Preparation of Cement Concrete. Pp. 32.
236. Incubation and Incubators. Pp. 32.
237. Experiment Station Work—XXXII. Pp. 32.
238. Citrus Fruit Growing in the Gulf States. Pp. 48.
239. The Corrosion of Fence Wire. Pp. 32.
240. Inoculation of Legumes. Pp. 8.
241. Butter Making on the Farm. Pp. 32.
242. An Example of Model Farming. Pp. 16.
243. Fungicides and their Use in Preventing Diseases of Fruits. Pp. 32.
244. Experiment Station Work—XXXIII. Pp. 32.
245. Renovation of Worn-out Soils. Pp. 16.
246. Saccharine Sorghums for Forage. Pp. 37.
247. The Control of the Codling Moth and Apple Scab. Pp. 21.
248. The Lawn. Pp. 20.
249. Cereal Breakfast Foods. Pp. 36.
250. The Prevention of Wheat Smut and Loose Smut of Oats. Pp. 16.
251. Experiment Station Work—XXXIV. Pp. 32.
252. Maple Sugar and Sirup. Pp. 36.
253. The Germination of Seed Corn. Pp. 16.
254. Cucumbers. Pp. 30.
255. The Home Vegetable Garden. Pp. 47.
256. Preparation of Vegetables for the Table. Pp. 48.
257. Soil Fertility. Pp. 39.
258. Texas or Tick Fever and Its Prevention. Pp. 45.
259. Experiment Station Work—XXXV. Pp. 32.
260. Seed of Red Clover and Its Impurities. Pp. 24.
261. The Cattle Tick. Pp. 22.
262. Experiment Station Work—XXXVI. Pp. 32.
263. Practical Information for Beginners in Irrigation. Pp. 40.
264. The Brown-tail Moth and How to Control It. Pp. 22.
265. Game Laws for 1906. Pp. 54.
266. Management of Soils to Conserve Moisture. Pp. 30.
267. Experiment Station Work—XXXVII. Pp. 32.
268. Industrial Alcohol: Sources and Manufacture. Pp. 45.
269. Industrial Alcohol: Uses and Statistics. Pp. 29.
270. Modern Conveniences for the Farm Home. Pp. 48.
271. Forage Crop Practices in Western Oregon and Western Washington. Pp. 39.
272. A Successful Hog and Seed-Corn Farm. Pp. 16.
273. Experiment Station Work—XXXVIII. Pp. 32.
274. Flax Culture. Pp. 36.
275. The Gipsy Moth and How to Control It. Pp. 22.
276. Experiment Station Work—XXXIX. Pp. 32.
277. The Use of Alcohol and Gasoline in Farm Engines. Pp. 40.
278. Leguminous Crops for Green Manuring. Pp. 27.
279. A Method of Eradicating Johnson Grass. Pp. 16.
280. A Profitable Tenant Dairy Farm. Pp. 16.
281. Experiment Station Work—XL. Pp. 32.
282. Celery. Pp. 36.
283. Spraying for Apple Diseases and the Codling Moth in the Ozarks. Pp. 42.
284. Insect and Fungous Enemies of the Grape East of the Rocky Mountains. Pp. 48.
285. The Advantage of Planting Heavy Cotton Seed. Pp. 16.
286. Comparative Value of Whole Coottn Seed and Cotton-seed Meal in Fertilizing Cotton. Pp. 14.
287. Poultry Management. (In press.)
288. Nonsaccharine Sorghums. Pp. 28.
289. Beans. Pp. 28.
290. The Cotton Bollworm. Pp. 32.
291. Evaporation of Apples. Pp. 38.
292. Cost of Filling Silos. Pp. 15.
293. Use of Fruit as Fo od. Pp. 38.
294. Farm Practice in the Columbia Basin Uplands. (In press.)
295. Potatoes and Other Root Crops as Food. (In press.)
296. Experiment Station Work—XLI. (In press.)
297. Method of Destroying Rats. (In press.)
298. The Food Value of Indian Corn and Corn Products. (In press.)
299. Diversified Farming under the Plantation System. Pp. 14.
300. Some Important Grasses and Forage Plants for the Gulf Coast Region. Pp. 15.
301. Home-grown Tea. Pp. 16.
302. Sea Island Cotton: Its Culture, Improvement, and Diseases. Pp. 48.
303. Corn-Harvesting Machinery. Pp. 32.
304. Growing and Curing Hops. Pp. 39.
305. Experiment Station Work—XLII. Pp. 32
306. Dodder in Relation to Farm Seeds. Pp. 27
307. Roselle: Its Culture and Uses. Pp. 16.
308. Game Laws for 1907. Pp. 52.
309. Experiment Station Work—XLIII. Pp. 32
310. A Successful Alabama Diversification Farm. Pp. 24.
311. Sand-clay and Burnt-clay Roads. Pp. 19.

O