Thesis
for
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Highway Construction.

In traveling through Rome today there can be seen the remains of old roads, built before and during the Christian era. These roads were built of stone by the Roman Government for the purpose of quick transportation of their armies in time of war. So famous were they, that a common expression at that time was:- "All roads lead to Rome". Here one of the great problems of the present day, "Highway Construction", had its beginning, and although their methods of construction have been greatly improved upon, we may safely say that they layd the foundation upon which our knowledge of today is based. Road building could be traced from Ancient Rome until the present but it would be of no use to us here as the question before us is, "The construction at the present day."

Up until a few years ago roads were built solely to stand the wear and tear of carriages, wagons and heavily loaded drays but now a

new question has arisen. Which road will best stand the automobile, running at a high speed of 60 miles per hour and also at the same time the heavily loaded dray, drawn by mules? This has given rise to much thought by our engineers and has been the means of much experimentation by our Government. The dray has the tendency to make the road more compact and harder, whereas the automobile has the opposite effect of loosening the material in the road. Using mechanical terms, the automobile is a tensile stress and the dray is compression. The steel wheels of the ordinary vehicles grind off sufficient powder from the stone to serve as a binder, replacing the binding material blown away by winds or washed off by rains. It is usually possible when the binder becomes deficient and the stones in the upper course begin to appear, to spread a little course sand in the center of the macadam road. The sand is

soon spread by traffic over the greater portion of the width of the macadam. It relieves the roughness and keeps the stone from raveling. But not so with the swiftly moving motor car which weighs between 1800 and 4000 pounds. The large rubber tires on wheels of small diameter appear to exert a suction on the binder of the road. The vehicle moving rapidly over the road lifts the dust into the air in clouds, and it is blown away into the fields. This in course of time will cause the whole road to be blown away.

There are several different kinds of roads in use, depending upon the locality. The government has also built roads for the purpose of experimentation in order to find out the kind of road which is most durable and which will best stand under the heavy traffic which is imposed upon it. As a result the macadam road has proved itself to be in the front rank and one which is destined to be the typical American road.

A "Dust preventive is used to keep the road from blowing away as dust. Along by the side of the macadam, are other roads which are giving good service today and which may prove equally as valuable as the macadam but this remains yet to be seen.

Taking them up in order they are!— I Macadam road. II Sand-Clay road. III Burnt-Clay road. I shall discuss each one of these roads separately, giving the mode of construction and the details therein.

The first thing to be done before building any road is to make a thorough study of the county through which the road is to be built. The ideal road is one which is perfectly level but of course this in practice is impossible, unless in a country where there are no mountains and this is very seldom the case. A survey should be made as if for a railroad although not near so much care is needed. A maximum grade should be

established and no grade made steeper than this. In selecting a grade, our maximum should not be greater than 5% if the country will possibly permit, because a horse can trot over this with ease and a motor car can cover it on high speed. However no iron clad rule can be laid down for selecting the route but let the surveyor use his judgment. Of course in some counties so small a grade is impossible as the cost would be too great, but in all cases use just as small a grade as possible. The hills are cut down by plows and scoops, and the dirt carried into the valleys until our grade is established. Stakes should be set on either side of the road at intervals of 50' and grade marked upon them. With this determined we are now ready to begin construction on the road bed proper.

The widths of the road bed should be 12' to 18' wide, depending entirely upon the traffic. Shoulders from 3' to 5' in width are made on each side

of the road to prevent shearing off of the road material. No impervious material such as clay and loam should be permitted within at least 18" of the top of the completed road. All stumps and roots should be grubbed out and removed.

I

Macadam Road.

The word "macadam," as herein used, relates to a surfacing composed of stone broken into small fragments, the largest not exceeding 2½" in diameter, suitably bound together into a compact mass so as to be substantially a sort of cement, but with no binder other than stone dust or screenings. A road so surfaced might be more properly called a "broken stone road." These details of construction may require modification to some extent to be suitable for different parts of the country, depending upon rainfall, temperature and topography but this is adaptable to nearly all parts of the United States where suitable stone exists or to which such stone

Tools and machinery.

may be carried without excessive cost.

Before it is possible to begin work a provision must be made for tools and machinery. In addition to the shovels, picks, and other ordinary implements, a considerable outlay for machinery is necessary.

A stone crusher is obtained for about $2000. This is an instrument so made that rock can be crushed to any size from powder up. The crusher will take rocks which measure 7" by 14", larger stones than these must be mauled. A machine when in good condition will turn out about 90 tons of broken stone per day.

In places where the stone is limited to ledges, there is often but little choice as to the location of the crushing plant. It is as easy to haul the broken stone to the road if the crusher is set up at the ledge as it is to haul the unbroken stone from the ledge to the crusher if set up beside the road. But if field stones are to be used or suitable ledges are available along the road to be

constructed, the crusher should be located near the road. Experience has shown that 2 miles is about the economical limit for operating the plant in one place. So the crusher must be moved from time to time, whenever economy demands it. Next to the quality of the material, economy must be strictly observed.

Probably the most important piece of machinery is the steam roller. It is now used to so great an extent that a discussion of its advantages over the horse roller is unnecessary, and without it our road would never be as hard or as compact. It should weigh at least 10 tons and still heavier if finances will permit, although most of the culverts and many of the bridges are too weak to sustain with safety the heavier rollers. A 10-ton roller will cost about $3000.

Since water is always needed in rolling the macadam a watering cart or sprinkler should be provided. A cart with a capacity of 450 to 600 gallons will be sufficient. Most of these carts are provided with extremely broad tires, so that the

cart assists in consolidating the stone, instead of cutting it.

Road machines can be used to advantage in preparing the road for the broken stone, but it should not be used for scraping back from the gutters, womout material which has washed there from the road. Drag and wheel scrapers are used in grading and shaping the roadbed. Automatic spreading carts are often used in spreading the broken stone. They are useful and save time and labor but are not essential.

Labor and Teams.

In macadam roads as in all other construction work, there should be a competent foreman or superintendant in charge. Since the conditions are never the same in any two pieces of road, it is impossible to give any definite statement as to the number of men required in the construction, except with regard to the broken-stone portion of the work. The foreman has an opportunity to use considerable judgment and skill in arranging his men and teams so as to secure

a maximum of effect with a minimum of effort..

Those necessary for operating the broken stone portion of the road are:- A crusher, roller operator, 2 ordinary laborers to feed the crusher with a third to assist them and to haul stone which are too large, two spreaders for spreading the stone on the road, and a driver with a pair of horses for watering cart. The number of teams for hauling the stone depend upon the length of haul.

Earthwork.

The earthwork, such as grading, setting stakes and preparing the roadbed in proper was explained previously, so it is unnecessary to give this in detail further. However, in fixing the grades, care must be taken to adjust the cuts and fills so that there will be little or no waste of material. This requires some judgment and experience, since most materials shrink to a greater or less extent when taken from the cuts and placed in the fills. It is estimated that this shrinkage, together with certain unavoidable waste, averages about 15%.

when the depth of the fill is but a few inches, the use of the steam roller will often cause a much greater shrinkage.

Stone for Macadam

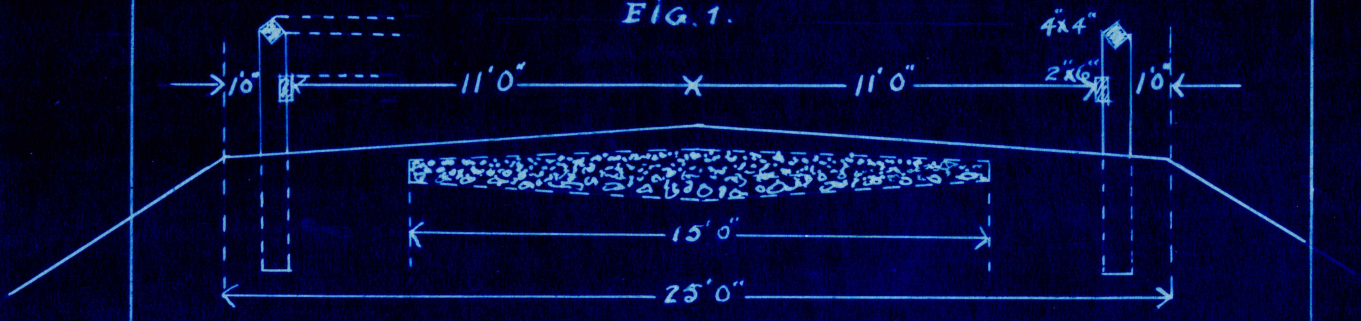
Some stone is more suitable for road building than others. The principal qualities which are necessary are hardness and toughness. The cementing values of the stone dust should not be forgotten, but these are not so important as the qualities first mentioned. Often the choice of stone is very limited and only field stone may be had, or perhaps nothing but interval ledge stone can be found, except at a great cost.

"Trap rock" - meaning by the term the diabases, the diorites, and certain other igneous rock - has long been considered the best material for macadam purposes. Unfortunately, except in certain localities, these stones are not common and some other stone, which many times is not so suitable, must be used. Some of the hornblende granites give good results, as do the felsites and some of the harder limestones,

but slates, schists, most of the sandstones, the micaceous granites, and the quartzites have but little value as road surfacing material. Some of these inferior stones may sometimes be used in the lower course of the macadam, provided the upper stratum is composed of a better grade of stone. Stone from a ledge is more desirable than field stone as it makes a smoother and more durable road.

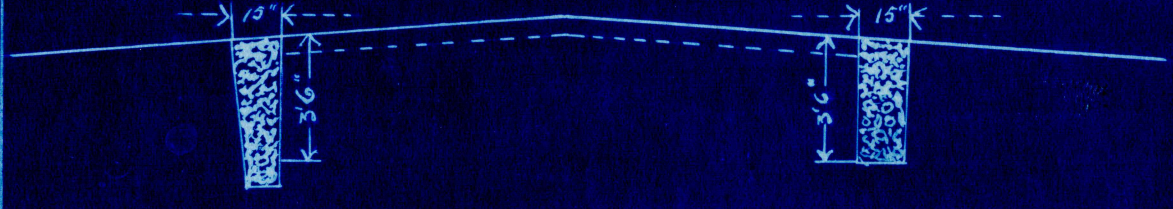
Drainage } Water should never be permitted to remain under a macadam road. It softens the foundation so that the broken stone is forced down into it by the wheels of vehicles, thus causing ruts to develop. In freezing it expands and causes the larger fragments of stone to rise to the surface. As a result the material in the subgrade is forced up into the interstices, and in the spring the macadam will be found to be rough, irregular in shape and weakened. There are several ways of removing the subsurface water, at least in part. Sometimes

FIG. 1.



V UNDERDRAIN.

FIG. 2.



SIDE DRAIN. BLIND DRAIN.

MACADAM ROADS.

J.M. Douglass.

if the grade is raised in wet places the trouble will be lessened, particularly if porous materials are used.

Side Drains

Side drains may be constructed in the cuts on each side of the road, just outside of the limits of the macadam (See Fig 1.) These drains consist of narrow trenches, filled with broken stone or gravel stones, with a pipe 5" or 6" in diameter near the bottom. The pipe is laid with open joints, true to grade, and is carried to a proper outlet. Sometimes the pipe is omitted and the entire trench is filled with stones, in which case it is called a blind drain. Such drains serve to cut off the subsurface water before it can get under the macadam.

V Drains

The subgrade may be excavated to the width of the macadam so as to be 6" to 8" deep at the edges, and 12" to 18" deep at the center. The surface will then have the shape of an extremely flattened letter V (See fig 2.). The bottom should be fairly true to grade so as to permit the water to flow readily. This excavation is filled

with stones varying in size from small pebbles to boulders 8" to 10" in diameter, the latter being placed at the bottom. To dispose of the water collected by a drain of this kind, narrow trenches should be cut to the sides so as to connect with open outlets. These trenches should be filled also with stones.

Telford Foundations

Another way of nullifying in part the effect of the subsurface water is to construct a foundation of telford. Formerly, nearly all macadam roads were built with a telford base, regardless of any consideration of the requirements of traffic but they have been very largely superseded now. When the foundation of the road would otherwise be very bad, and no gravel or other like material is readily obtainable or where an unusually substantial road is required to meet the demands of traffic, this form of construction is recommended. Under ordinary conditions it is very much too expensive.

Surface Drainage

In order to keep the road in good condition the removal of surface water is very necessary and it should be gotten rid of as soon as possible. Culverts,

make of rubber masonry or Portland cement concrete reenforced with steel, should be built at low points where outlets are available, and existing streams should always be utilized for outlets. The water should never be carried in the gutters or in side ditches any further than is necessary. Sometimes when the volume of water is small, it may be carried across the road in tile pipes buried in the ground sufficiently deep not to be broken by vehicles.

In cuts where the grade is in excess of 3% and where the soil is loose and sandy, it is sometimes necessary to pave the gutters with cobblestones or with paving bricks to prevent the formation of gullies in the shoulders and in the macadam. This, however is rarely necessary and should be avoided if possible as it adds considerable to the cost.

Shaping the subgrade.

It is not enough that the roadway shall be graded with reasonable care — the surface upon which the broken stone is to be placed must be hard, smooth, and carefully crowned. If the foundation is

not hard and firm the stones will be pressed into it by the roller and wasted; if not crowned an unnecessary quantity of stone will be used. When the macadam is to be of uniform thickness throughout its cross section, the crown of the subgrade should be the same as that of the finished road, but if the macadam is to be thicker at the center than at the sides, a part of the crown will be in the macadam itself and the center of the subgrade should be raised enough to produce the contemplated surface crown when the stone is in place.

Usually sufficient material is left on the road sides to form the shoulders for the macadam. The shoulders in addition to affording a surface for the occasional passage of wheels, serve to some extent to prevent crowding the broken stone outside the limits of the proposed macadam roadway during the rolling. After the roadbed has been thoughly rolled if there are soft places anywhere to be found, more good material should be put on so that when the subgrade

is ready for the broken stone it shall conform to the proposed cross section as nearly as practicable.

Courses of macadam

The stone crusher is arranged to crush three sizes of stone;- ① fragments not exceeding ½" in diameter; ② stones 1¼" in diameter; ③ stones 2½" in diameter, this being the largest stone that should be used.

It was once thought that the best road was obtained when the material was put on thickest. In fact some roads were built as thick as 2'. This of course make it very expensive. There is now a different theory in vogue and in some instances roads are now built when the macadam is only 3" thick after rolling. The average depth however is 6" after rolling and very often the shoulders are only 4". The course will shrink about 35% under rolling.

As soon as the drainage work is completed and the roadway has been graded, shaped and rolled for a few hundred feet, the spreading of the broken stone should be commenced.

The lower course, which consists

of rock about 2" in diameter, should be spread first. The rock should never be dumped upon the road but they should either be spread with automatic spreaders or with shovels. The depth of the road course should be tested frequently by strings stretched across between the stakes, the top of the course being flush with the top of the string. The stone is sometimes leveled with rakes.

When a hundred feet or so of the first course has been spread the roller should begin. It will be found best to begin the rolling at the outer edge of the macadam, running upon the shoulders a few inches. When this portion of the stone ceases to wave and seems firm under the foot, the roller should be moved to the other side of the roadway and the operation repeated there. After both sides of the roadway are moderately firm, the roller should be moved gradually toward the center until the entire lower course is thoroughly compact. Before the second course is put on, the lower course should be smooth and true

to the cross section.

After about 100' of the first course of stone is rolled, the second course, consisting of the fragments varying in diameter between ¼" and 1½" should be spread and rolled in the same manner as was the lower course. After this course is thoroughly compacted, the binder should be spread. Usually but little more than 1" in depth of the screenings is needed in 6 inches of work. The watering cart should then be put on in advance of the roller and as much as possible of the dust should be flushed into the crevices between the stones. The roadway should be wet and rolled until it "puddles" on the surface, showing that the voids are substantially filled.

No more of the screenings should be used than is necessary to fill the voids and to leave a very thin covering over the larger stones. Depressions in the upper course should not be filled with screenings, but rather with stones of the size used in that course.

The roller operator should be skilled as the appearance of the road depends a great deal upon him.

No matter how much the macadam is rolled, it will not acquire the metallic ring usually noticeable in roads of this kind, for some days. Horses and carriages passing over the road at first roughen the surface, so it is a good plan to keep the roller on the completed road moving back and forth during the progress of the work whenever it is possible. It is not well to allow the first course to be spread too far in advance of the upper as the traveling which may come upon it is injurious.

Roadsides

No matter how smooth and well constructed the traveling road may be, if the roadsides are not cared for, the highway as a whole will not give a good impression. All rubbish should be removed; excavations should be filled and embankments smoothed and planted with grass wherever it will grow. Insightly brush should be cut and

grubbed out while the nice trees should be trimmed and cared for.

Maintenance

There is very little to be done to a macadam road after completion for 2 or 3 years except to keep the weeds down and the gutters clean. A few loose rock may appear on the surface soon after it has been opened; these should be picked up and put into a pile for later use. The wear of the road is very slow and there should be no resurfacing until the upper course has completely been worn through. The present annual practice is to keep the surface always smooth, to fill any small holes or imperfect nuts which may appear and the cost will be small each year.

Cost of macadam road

The cost of a macadam road is governed entirely by existing conditions. Comparison of voucher costs of roads in one locality with those in another is of little value, for the reason that no two localities are ever precisely alike, and but rarely ever approximately so. Particularly is this so with such

details as earthwork and drainage. In some instances the rock must be hauled by railroad for many miles, in others, the quary may be along the roadside and can be obtained at little expense. Also labor in some states is very much cheaper than in others.

Under very favorable circumstances, where practically no grading is necessary and where rock may be obtained at little expense, a macadam road can be constructed for $2000 per mile. On the other hand, where circumstances are unfavorable, where much grading is necessary and where rock must be obtained at a high price, the macadam road may cost as much $8000 per mile.

So we must see that the expense attached to a macadam road is very uncertain. After an engineer has thoroughly looked over the route he can estimate the cost very closely and especially if he is accustomed to road building.

II Sand-Clay Road.

In many parts of the United States and especially in the South Atlantic and Gulf States, the Sand-Clay road is being used to a great advantage. In some localities where sand and clay prevail and rock is scarce, this road is proving itself to be an ideal one. It is cheaper, almost as durable, much more easily constructed, less noisy, less dusty, and more resilient than the average macadam road, this being a great recommendation for its use.

The preliminary work connected with this road is similar to the macadam, except that in most cases it is done on a cheaper scale. Therefore it is useless to repeat this part of the work in this connection but instead we shall take up the road bed proper.

material &c. A derivation of the name shows that the materials which compose this road, are "sand" and "clay". Sand is a material composed of fine and more or less uniform grains, formed by the disintegration of quartzite by the action of the elements and usually found in great loose masses. This substance is loose and unstable and

lacks binding power. 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 clays is the mineral feldspar, which, under the action of water, has been gradually leached ~~out~~ and changed into clay. The particles of clay are much finer than those of sand.

The two properties of clays which are of the greatest importance from the standpoint of roadbuilding are, first, plasticity, and second, the property of slaking when they first become wet after having been uncovered. The most plastic of clays is known technically as "ball clays". A clay of this kind will preserve its form for a long time if immersed in water. On the other hand the slaking clays will fall to pieces as a lump of quicksand when immersed in water, the porous structure of the clay rapidly absorbing the water. So the slaking clays are much more easily mixed with other materials than the plastic ball clays, and this is of course to their advantage for road building, although

they are often of inferior binding power.

Another important physical characteristic from the standpoint of road building is "Shrinkage of clays". Some clays shrink when dried, which leads to the cracking and breaking up of their surfaces. This shrinkage is a measure of their expansion and expansion renders the sand-clay composition unstable. 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 cannot be overcome entirely but it may be modified by using less clay in the composition. This however weakens to some extent and causes it to break up in dry weather.

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 sands 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. If an excess of clay is used in the mixture, 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.

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.

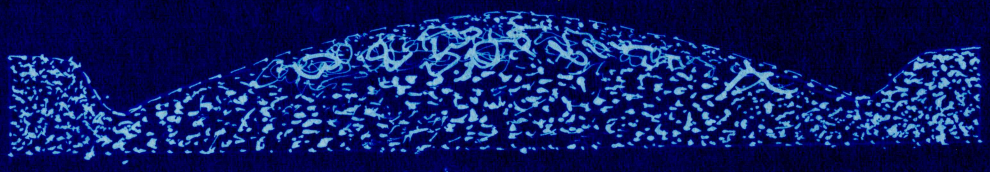


Fig. 4.

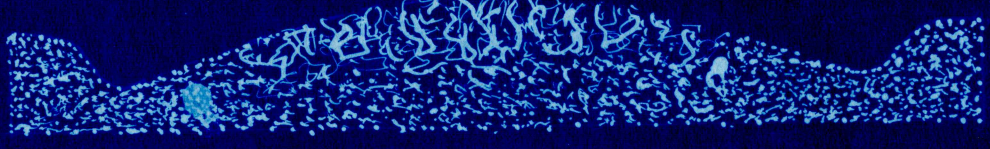


Fig. 5.

SAND-CLAY ROADS.

J. M. Douglass.

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 Figs. 4 and 5. Figure 4 shows a cross section of a road into which lumps of clay have been worked. Figure 5 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.

Thorough stirring and puddling are absolutely essential to successful sand-clay construction. This is most conveniently done after a 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 well by means of a turning plow and a cutaway or disk harrow. This work is sometimes disagreeable on account of the sticky mud but it is necessary as dry mixing has proved itself to be unsuccessful.

When slaking clays are 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 easily 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.

No exact rule can be laid down for the proportions of sand and clay to obtain the best mixture. This depends entirely upon the materials and there is a great variation in them. Some clays, even upon the hottest days, when apparently thoroughly dry, will hold as much as 20% of "water of combination"; others vary. Nevertheless there is an approximate method for mixing the sand and clay, namely: 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.

Construction of Sand-clay road

There are two methods now in use of constructing Sand-clay roads; a Sand-clay road built upon a sandy subsoil, & Sand-clay road built upon a clay subsoil. For either of these, drainage is one of the most essential things for perfection of road.

If natural drainage does not exist, artificial methods must be used. 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 drive the water from it. Frequently in tide water regions, the

county is so low and level that the surface of the road is likely to be kept continually wet. If this condition has to be met it is necessary to dig 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.

Although natural drainage is much better on sandy subsoils than on clays, in clay districts the conformation of the county is more likely to be of a rolling character, thus furnishing a natural watershed. 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.

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 successive 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. When the clay has been spread it should be covered with a layer of clean sand and this should be added from time to time to prevent the formation of mud. Both width and thickness of layer of clay depends upon the character of traffic. If a narrow singletrack road is to be built, it is best to spread the clay to a width of about 12' and to a depth of 6" to 8" in the center, tapering the layer to a thin edge at the sides.

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. Just 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. The construction of this road is not rapid but a process of rather slow development; in this respect it is unlike the macadam road.

Clay Subsoil

After drainage is completed, the roadbed should be crowned to the form desired in the finished road. The road should slope from the center to the sides at least ½" per foot. It is more important to form this foundation crown when the subsoil is clay than when it is sand. The surface should now be plowed about 4" deep and harrowed until pulverized. It is then covered with 6" to 8" of clean, angular sand, the sand being spread thickest at the center and the same plan as before followed. The materials are now mixed in a comparatively dry state as the clay foundation can be more evenly disintegrated when dry. After this first mixing

has been finished the road is finally plowed 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 and 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. Special care should be taken of the road after completion until proper condition for traffic is established.

Cost of Sand-Clay Road

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 the roadbed, and depth and nature of material. If we assume, however that the clay can be procured within one

mile of the road, 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", would be approximately $580 per mile. However all of these conditions can never be realized at once and this of course causes a variation in the cost. Under the most favorable conditions the road can be built for $300 whereas under the most unfavorable it may reach $1200 per mile. The cost of building the road on a clay foundation will not vary but slightly from the above figures.

Use of road in this County

The possibilities of the sand clay road may not be fully realized by the public for a long time to come, but still the progress being made in nearly every part of the country is encouraging. The extent of its use in public road improvement 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 county 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. For a large part of the county, the sand-clay road is the only road possible or within the reach of rural districts. It requires less money to build it 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.

III

Burnt-Clay Road.

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 practically no sand, and the clays are of a plastic and sticky variety, known locally as "gumbo" and "buckshot." In such localities traffic is absolutely

impossible during the wet season, as the wheels of 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, brickbike lumps which should be capable of sustaining traffic. Experimentation showed that the clinkering point of the clay was low enough to indicate that simple burning of the lumpy clay upon the road surface by means of open wood fires would accomplish the desired result. The road is proving highly satisfactory today.

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.

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' wide. The wood must 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 Roadbed

After grading the road to its own 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' of roadway, the transverse furrows should be 12' long, so as to extend 2' on each side beyond the width of the final

roadway. Across the ridges formed between these furrows - which should be about 4' apart - the first course of cord wood is laid longitudinally so as to form a series of flues to 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 the 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 course 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 bark, 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,

le careful arrangement of this cord wood
kibbing to separate the clay is important
and great care should be taken.

The dep 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 8". 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 "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 larger force of laborers is available for the work, a greater number of flues can be fired at one time. The best results are obtained however by firing all the flues of a section simultaneously and maintaining the combustion as evenly as possible. The firing should be begun on the windward side, in order to maintain 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" in depth, which, when rolled down and compacted, forms a road surface 4 from 6" to 8" 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 $\frac{1}{2}$" to the foot.

Cost of Road

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 county, but up to the present time, the average cost has been in the neighborhood of $1500 per mile. It is somewhat more expensive than the Sand-clay road on account of the cost of wood.

Use of Road

Although the burnt-clay road has been very successful up to the present time, it cannot yet be said to have passed the experimental stage. In view of the success of the experiments so far made and the

comparative cheapness of this form of construction, it is likely that the road will live. Its use in the South is increasing every day and in those localities which have no hard material available, it is playing an important factor as a road of great value.

Dust Preventives.

The most important problem which has confronted engineers of recent years is the suppression of dust on roads. Not until the introduction of motor vehicles, however, did this become a factor of sufficient importance to engage the serious consideration of road builders and road users. Fast motor traffic has reached such proportions at the present time as to shorten the life of our most carefully constructed and expensive roads and to keep them in a loose and uneven condition.

When roads are subjected to continuous automobile traffic, peculiar conditions exist. The powerful tractive force exerted by the driving wheels of the automobile soon disintegrate the road surface and the fine dust which

ordinarily acts as a cementing agent is thrown into the air and carried off by wind or is easily washed off by rain. The pneumatic rubber tires wear off little or no dust to replace that removed by natural agencies. The result is that stones composing the road become loose and rounded, giving the greatest resistance to traction, and water is allowed to make its way freely to the foundation of the road.

These conditions have led up to much thought by our roadbuilders of today and many remedies have been suggested and tried for meeting this new condition, but a perfectly satisfactory solution of the problem is still to be found. As a consequence dustpreventives are now being used to the greatest advantage. The two general methods of their use on roads is — those applied in their original condition, and those applied in emulsions or solution through the agency of water. It would be difficult to describe fully all the preparations and

methods of application which have been tried, and so only those which have proved most successful will be considered.

Among the materials which are applied directly to the finished roadspace without the agency of water, the mineral oils and coal tars are the most important.

Oils as Dust Preventives

Among the mineral oils, those which contain the greatest amount of asphaltic base give the best and most lasting results, and chemical analysis will usually indicate those preferable in this respect. Some oils contain a paraffin instead of an asphaltic base, while others contain a mixture of the two. Owing to the greasy nature, paraffin oils are to be avoided as much as possible, and preference should be given to those containing asphalt, which acts as a good binder for the dust particles. The locality from which an oil is obtained is a general guide as to the character of its base.

Oil for dust laying may either be applied in the crude state or be first subjected to fractional distillation at the refineries, when the lighter and more valuable products,

used for illuminating and lubricating, are removed for use in the arts. Oil in this state is realy more preferable than it is before reduction and also much more inexpensive. Oil is used on other kinds of roads as well as the macadam but coal tar is only suitable for macadam roads.

Many of the crude oils may be applied directly to the road surface by means of an ordinary sprinkling wagon but when the oil is too heavy to be used in this way it may be applied with a suitable spraying device by the use of heat and pressure, or it may be run over the road surface through a hose connected to the container. In some instances the oil has been applied directly to the road surface without previously removing the dust; in others the road has been first swept clean of dust in order to allow the oil to penetrate as far as possible into the body of the road. When the latter method is followed the surplus oil which remains on the surface is usually covered with a light coat of gravel, sand or rock screenings, and sometimes the dust which has been

removed by sweeping is replaced. When a soft road is treated with oil the road is often harrowed to the depth of several inches and the oil is worked into the broken surface, which is then compacted by means of a roller. There are several patented oil spreaders which also work the oil into the surface of the road. A tamping roller is now extensively used; it not only compresses and packs the rock, but also mixes the oil with the earth. After this process is completed, the surface is finished with an ordinary roller.

As a general criticism it may be said that the good effects of oils as dust preventives are not usually of a lasting character. They often entirely disappear during the winter season following their use. Then, too, in rainy weather they frequently form a greasy and disagreeable mud, which is easily tracked and is damaging to clothes, varnish of carriages, and probably to rubber tires.

Coal Tar as a Dust Preventive

Coal tar has been used with success only on hard macadam roads from which the dust has been carefully swept. If this dust is not removed before the tar is applied, the road surface will not absorb it, and upon drying, the tar will pick up and put off very rapidly under the action of traffic. The tar is applied in practically the same manner as oil, and a great many experiments have been made both with the crude and refined products. The refined tars have for the most part given the best results, but as they are more expensive than the crude product it is still an open question which is the more economical to use.

The tar is drawn off through a large rubber or iron pipe and spread over the road with brooms such as are commonly used for street sweeping. After the tar has been spread, it should be allowed to dry for a few days before traffic is permitted on the road. The tar should be

spread in warm, dry weather, and when the road is finished and opened to traffic for a few weeks it should produce much the same appearance as an asphalt street.

The objections which have been advanced against the use of tar as a dust preventive are that it lasts only a short time, usually not being effective more than one season; that it produces a slippery and disagreeable surface; and that in reality it does not prevent the formation of dust, but under the action of traffic produces an undesirable, though almost invisible dust. Opposed to this objection, however, stands the fact that no other substance has yet been used which for the same cost and under the same conditions will give a better or more lasting results from one application. A road properly treated and maintained by this method is practically waterproof,

any any dust formed on its surface is frequently washed off by rain. It is only when the tar is breaking up and disintegrating that enough dust is formed to be objectionable.

Solutions as Dust Preventives

Solutions, such as magnesium chloride and calcium chloride are now used to a considerable extent as dust preventives but their use has been found to be suitable only for parks and suburban roads. This is due to the fact that in order to keep the dust down, an application must be made every few days and of course this would be impossible for public highways through the rural districts.

So it is almost useless to discribe them here but only to state that they are applied through a sprinkler in exactly the same manner as water.

Respectfully Submitted,

J. M. Douglass.