Morrison

Maintenance of Earth, Sand-Clay and Gravel Roads
MAINTENANCE OF EARTH, SAND-CLAY AND GRAVEL ROADS

BY

ROGER LEROY MORRISON

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B. S. University of Illinois, 1912
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ROGER LEROY MORRISON

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Edward C. Schmidt

Head of Department of Railway Engineering

Recommendation concurred in:

Committee

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>I. Maintenance of Earth Roads</td>
<td>4</td>
</tr>
<tr>
<td>II. Maintenance of Sand-clay Roads</td>
<td>21</td>
</tr>
<tr>
<td>III. Maintenance of Gravel Roads</td>
<td>23</td>
</tr>
<tr>
<td>IV. Bituminous Surface Treatments</td>
<td>31</td>
</tr>
<tr>
<td>V. Oiling Earth Roads</td>
<td>35</td>
</tr>
<tr>
<td>VI. Specifications for Bituminous Materials</td>
<td>37</td>
</tr>
</tbody>
</table>
MAINTENANCE OF EARTH, SAND-CLAY, AND GRAVEL ROADS

- INTRODUCTION -

One of the most important problems before the American people today is the proper maintenance of our 2,333,000 miles of public roads. About 263,000 miles have been hard-surfaced at a cost of perhaps $1,000,000,000.00 and our rapidly increasing annual expenditure for road construction and maintenance has already reached the enormous sum of $300,000,000.00. In other words, we are spending each year on our public highways an amount almost equal to the total cost of the Panama Canal. This is a gratifying indication of progress and development, but the appalling fact is that untold millions of our road funds are being absolutely wasted. The amount wasted is estimated at from $50,000,000 to $150,000,000 per year! We are pouring our treasure into a barrel with the bung-hole and spigot wide open.

The waste is caused by wrong methods of financing, improper location, the use of wrong materials and construction methods, incompetentsupervision, and most of all by lack of proper maintenance. This last is due partly to the common use of the absurd term "permanent roads". No such thing as a permanent road was ever built, and probably never will be built, in America. It is true that the Appian Way in Italy has lasted for over 2300 years, but it has never carried modern traffic to any extent, and the estimated cost of reproducing it in this country today is about $245,000 per mile.

Although we cannot build permanent roads, we build expensive roads and then treat them as if they were permanent, often making no provision whatever for maintenance. As a result the roads go to pieces and have to be rebuilt.
History surely repeats itself in-so-far as inefficient highway administration is concerned. America is struggling today with the same problems which engaged the attention of the English Parliament 100 years ago, and which were met and solved by France nearly 150 years ago. It is exactly 200 years since the organization of the famous Corps de Ponts et Chaussees, the corps of engineers in charge of the roads and bridges of France, and about the year 1766 the French engineer, Tresaguet, the real originator of the broken stone road, first proposed a system of continuous maintenance. He fought with energy the old method of intermittent repairs, and the American highway engineers are fighting the same battle today. In 1775 Tresaguet became Inspector General des Ponts et Chaussees and the same year the corvée, which corresponds to our system of working out road taxes, was abolished. At the present time, 141 years after France put road administration on an efficient basis, the old inefficient "corvée" is still used in almost every state in this country. So little have we profited by the experience of others.

France has continued to lead the world in scientific road construction and maintenance. The construction of the modern French road system was begun in 1826, and about 371,000 miles of road were built during the next 25 years. At the present time France has 519,148 miles of roads, about 5 per cent being classified as national roads, 2 per cent as department roads, 30 per cent as vicinal roads, 33 per cent as ordinary vicinal roads, and about 30 per cent as rural roads. These roads cost from $2,470 to $12,400 per mile for construction and from $49 to $285 per mile per year for maintenance.

For comparison, if the same system were adopted in the United States it would give us about 110,000 miles of national roads, 40,000 miles of state roads, 700,000 miles of county roads, 770,000 miles of township roads, and 700,000 miles of neighborhood roads.

The division of roads and navigation of France is under the direct-
ion of a counselor of state, and the section of bridges and roads, of this di-
vision, is in charge of the Inspecteurs General de Ponts et Chaussees. Under
them are chief engineers, ordinary engineers, sub-engineers, foremen, and patrol-
men. Each patrolman has assigned to him a certain section of road, averaging
about three miles in length and he devotes his entire time to the maintenance
of this section. There are nearly 10,000 patrolmen in France. The engin-
eers are trained in L'ecole de Ponts et Chaussees in Paris, and are gradually
advanced from the lower to the higher positions. Every man engaged in high-
way work in France makes it his life work, and his tenure of office is affected
only by his ability.

Compare this with the situation in America where our road work is
in charge of over 150,000 petty officials, most of them entirely untrained
and inefficient in road work, and constantly changing, and where even our
trained highway engineers are constantly put out of office with the changes
of politics. In this way do we administer our $300,000,000 annual road ex-
penditure? Fortunately our methods or road administration and our provisions for
maintenance are improving rapidly.

President Washington, in a letter to Patrick Henry, recommended that
the roads of Virginia be taken away from the control of the county courts and
be given to the state authorities, but Washington's excellent idea of state
control of highways was not adopted anywhere in the country until 1891, when
the New Jersey and Massachusetts Highway Commissions were established. The
system and methods used by some state highway departments at the present time
are practically the same as those of France and the other leading European
nations. Maintenance work is done by the patrol system. This system is
fast being adopted by other states and by many counties. It is similar to
that used by the railroads and wherever tried it has proved to be the most econ-
omical and efficient system for road maintenance.
I. MAINTENANCE OF EARTH ROADS

The proper care of our hard-surfaiced roads, in the construction of which we have placed over a billion dollars, is an immense problem, but a still greater one is the maintenance of our earth roads which still constitute nearly 90 per cent of our entire road mileage. Not all sections of the country have improved roads, but there is no community so small or so large, so poor or so rich, that it is not confronted with the problem of getting the best possible service from the common earth road. Hard surfaced roads can be obtained only by spending more money, but our earth roads can be vastly improved simply by an efficient use of the funds which are now being spent with such poor results.

An earth road is a fairly good road if it is hard and smooth, and this is the object to be attained by proper maintenance. In the case of an earth road, maintenance should be taken into consideration before construction begins, for the difference between good and bad construction is mainly a matter of the resulting effect upon maintenance. A road can never be kept hard and smooth if it is so poorly located that all the surrounding land drains into it, or if the waterways are so small that they do not carry the water properly. In fact, a properly constructed earth road usually means simply a well drained road.

To insure proper drainage, which is essential for proper maintenance, we must provide,

1. Sufficient crown or crossfall so that the water falling on the road surface will run to the sides. The crown of an earth road should be about one inch to the foot; that is, the middle of a roadway 20 feet wide, for instance, should be 10 inches higher than the sides.
2. Side ditches to carry away the water which runs off from the road surface. These ditches should be shallow but should have sufficient fall so that they will be drains, not pounds, and they should have outlets at frequent intervals, so that the water will be carried entirely away from the road as quickly as possible.

3. Bridges and culverts large enough so that they will not wash out or become clogged up easily. The culverts should be protected by headwalls.

4. Where the road passes through a cut on a side-hill a surface ditch should be dug about ten or twelve feet back from the edge of the cut, on the up-hill side of the road. This carries away the water which runs down the hillside and keeps it away from the road.

5. If there are any boggy places in the road, due to ground water near the surface, sub-drains should be put in under the side ditches. Ordinary farm tile can be used for this purpose. Putting a sub-drain in such a place is like boring a hole in the bottom of a tub full of mud and water. When the road has been constructed or re-constructed with these provisions for drainage, then maintenance work can begin. Proper maintenance means practically constant maintenance. Water, weeds, traffic and other agencies of destruction are constantly at work damaging the road, and the battle against them, to be successful must be continuous. The practice of making occasional repairs results in good roads only immediately after the repairs are made, and not always then. A road just after being "worked" is often almost impassable.
Use of Road Grader

The first maintenance operation should usually consist of shaping up the road with a grader and under ordinary conditions this should be done once or twice a year. The road grader is a very effective machine if properly used but should be in charge of a skillful and sensible operator. Cutting should usually begin at the sides, and if the roadside is covered with sod and weeds the blade should be set on the first round in such a way that this material will be scraped into the ditches instead of onto the road. It can then be removed with shovels. Sometimes the entire road surface is covered with worn out material mixed with dead leaves, manure, etc., and in that case this layer of worthless material should first be scraped into the ditches, or else into windrows and then carried away in wagons. Such detritus not only makes a poor road surface, but it washes to the sides and hastens the growth of sod and weeds, which seriously interferes with proper crown drainage. Often this growth on the shoulders can be removed to advantage with a spring-tooth harrow or a hand cultivator. Whatever the means employed, care should be taken to see that this material is entirely removed from the roadway and ditches.

A common mistake is to make the width between ditches too great. A width of from 16 to 24 feet is usually sufficient, and unnecessary width means additional expense for maintenance. If the roadway has been made too wide in the first place, new ditches should be made nearer together. Stakes should be set to guide the workman, and if necessary a plow should be used to loosen the earth at the sides.

In shaping up the road with a grader some operators begin at the sides and use the entire width of the blade, if possible, the blade being set almost at right angles with the center line of the road so that enough material
is carried along to fill up the ruts and holes. Other operators begin just outside of the wheel track and work toward the side instead of beginning at the sides and moving a constantly increasing mass of earth. Instead of using the entire width of the blade they raise the heel, thus allowing the earth to pass under the heel of the blade. This tends to break up clods and puddle the material. Whichever method is used, enough material is moved toward the center at each round to build up a proper crown but it must be remembered that a crown of one inch to the foot is sufficient and it should not be made any steeper. A steep crown forces all traffic to follow in the same tracks, which rapidly forms ruts. Distributing the traffic over the surface helps to save the road.

The road grader should be properly cared for. The blade should be kept sharpened, and worn out blades should be renewed promptly. In many places the use of traction engines or road rollers to pull graders has proved economical, one engine often pulling two graders.

The Road Drag

After the road has been properly shaped up with the grader the most effective tool which can be used to keep it in good condition is the road drag. The first drag was made more than fifty years ago, but it is only during the last few years that they have come into general use. They are easily and cheaply made and operated, and accomplish wonders if properly used.

How to Make a Drag

There are many types of steel drags on the market, and these do good work, but home-made split-log or timber drag is just as effective.

Mr. D. Ward King, in Farmers' Bulletin No. 321, United States Department of Agriculture, give the following directions for the construction of road drags:
"A dry red cedar log is the best material for a drag. Red elm and walnut when thoroughly dried are excellent, and box elder, soft maple, or even willow, are preferable to oak, hickory or ash.

"The log should be seven or eight feet long and from ten to twelve inches in diameter, and carefully split down the middle. The heaviest and best slab should be selected for the front. At a point on this front slab ten inches from the end that is to be at the middle of the road, locate the center of the hole to receive a cross stake, and twenty-two inches from the other end of the front slab locate the center for another cross stake. The hole for the middle stake will lie on a line connecting and half way between the other two. The back slab should now be placed in position behind the other. From the end which is to be at the middle of the road, measure twenty-eight inches for the center of the cross stake, and ten inches from the other end locate the center of the outside stake. Find the center of the middle hole as before. When these holes are brought opposite each other, one end of the back slab will lie eighteen inches nearer the center of the roadway than the front one, giving what is known as "set-back". The holes should be two inches in diameter. Care should be taken to hold the auger plumb in boring these holes in order that the stakes shall fit properly. The hole to receive the forward end of the chain should be bored at the same time.

"The two slabs should be held thirty inches apart by the stakes. Straight grained timber should be selected for the stakes so that each stake shall fit snugly into the two-inch hole when the two slabs are in the proper position. The stakes should taper gradually toward the ends. There should be no shoulder at the point where the stakes enter the slab. The stakes should be fastened in place by wedges only.

"When the stakes have been placed in position and tightly wedged, a brace two inches thick and four inches wide should be placed diagonally to them at the ditch end. The brace should be dropped on the front slab, so that its lower edge shall lie within an inch of the ground, while the other end should rest in the angle between the slab and the end stake.

"A strip of iron about four feet long, three or four inches wide, and one-fourth of an inch thick may be used for the blade. This should be attached to the front slab so that it will be one-half inch below the lower edge of the slab at the ditch end, while the end of the iron toward the middle of the road should be flush with the edge of the slab. The bolts holding the blade in place should have flat heads and the holes to receive them should be countersunk."
"If the face of the log stands plumb, it is well to wedge out the lower edge of the blade with a three-cornered strip of wood to give it a set like the bit of a plane.

A platform of inch boards held together by three cleats should be spaced at least an inch apart to allow any earth that may heap up and fall over the front slab to sift through upon the road again. The end cleats should be placed so that they will not rest upon the cross stakes but drop inside them, while the middle cleat can be shifted to either side of the middle stake. These cleats should extend about an inch beyond the finished width of the platform.

"An ordinary trace chain is strong enough to draw the implement, provided the clevis is not fastened through a link. The chain should be wrapped around the rear stake, then passed over the front slab. Raising the chain at this end of the slab allows the earth to drift past the face of the drag. The other end of the chain should be passed through the hole in the end of the slab and is held by a pin passed through a link. One and one-half trace chains are sufficient.

"In many logs the grain runs around the tree in such a way that when split the slabs will be in a "wind". If this wind is not more than four inches in eight feet the timber can be used to good advantage by setting it so that the blade end of the log shall slant forward when the other end is perpendicular. The construction of the drag in this case is the same as given above, but care must be taken that the holes bored to receive the stakes are plumb. No wedging under the lower edge of the blade is necessary in using such a log.

"Drags are often constructed of planks instead of logs. There is nothing in the construction of a plank drag that calls for particular mention except the strengthening of the planks along their middle line by a 2 x 6-inch strip, as is shown in the figure. A triangular strip may be used under the lower edge of the blade to give it the proper cutting slope"

If one end of each half log or plank is rounded off a little and a chain fastened across the end of the drag it can be pulled end-wise in going to and from work.

Many other types of road drags and road hones are in use. Some have more than two cutting edges, and some have runner attachments. One simple type is made of two short railroad rails. Many road machinery companies make steel drags, the position of the blade of which can be changed by means of levers.
Object of Road Dragging.

If clay is mixed with water and "puddled" and then allowed to dry, a hard, almost water-proof and nearly dustless material is formed. If a smooth, well shaped road could be constructed of this material it would never be very muddy or very dusty, and would be an ideal earth road. Under ordinary conditions this ideal is not realized because after being puddled the earth dries in ruts and holes which are rough while dry and which hold water like dishes when it rains. If the muddy road, after being puddled by the horses' hoofs and wagon wheels, can be smoothed out and properly shaped before drying, then the ideal is attained, and this smoothing and shaping is the work accomplished by the road drag. The water standing in pools and puddles is spread out over a larger surface, so that it dries quickly the minute the holes or pores in the clay are smeared over and closed, making the surface more nearly waterproof; the ruts and holes are gradually filled up and made smooth and just enough earth is moved toward the middle to give the proper crown. The result is a smooth, hard, well shaped road which will shed water and never becomes very muddy in wet weather or very dusty in dry weather.

- When to Use a Drag-

From the above discussion it can readily be seen that dragging should be done when the road is wet, or at least, when it is moist. The exact time to drag any given road will depend upon the character of the road material, and no exact rule can be given which will fit all cases. If traffic can be kept off from the dragged portion for awhile then the road may be dragged when it is very wet and sloppy, but if wagons are going to follow right behind the drag, making deep ruts as soon as the old ones are filled up, the dragging must be deferred until the road has partly dried out.

To keep traffic off from a freshly dragged road surface the New York Bureau of Town Highways uses wooden blocks or "hardheads" about 6 or 8 inches
in size. These are provided at convenient places along the side of the roads and as the road is being dragged they are placed in the ruts at intervals of about 100 or 200 feet, thus forcing the traffic out of the ruts. They are used only where the road is deeply rutted and are removed within 24 hours.

Good judgment and experience on the part of the operator will soon tell him what is the best time to drag any given road. Roads which dry out quickly must be dragged immediately after a rain, while others may be allowed to dry for several days before being dragged. Dragging a dry road simply makes it dusty. Dragging should be done, if possible, after every rain.

In some parts of the West where there is no rain during certain seasons, sprinkling is resorted to before dragging. Utah County, Utah, uses a sprinkling cart followed by a drag and the results are very satisfactory. The cost averages 26 cents per mile per day. Chelan County, Washington, uses the same system during the summer on roads with six miles of trade centers. Horse drawn sprinkling carts were first used at a cost of $1 per mile per day for sprinkling and dragging, but the recent substitution of motor sprinklers has reduced the cost to 30 cents per mile per day.

How to Use a Drag

Whenever the road drag has been tried and pronounced a failure it is safe to say that it was not used often enough or else it was used at the wrong time or in the wrong way. Some operators seem to think that all they have to do is to drive the team and the drag will automatically do the work, but this is a sad mistake.

In the first place the manner of hitching the team to the drag greatly affects its operation. If a short hitch is used the tendency is to raise the front edge of the drag, while a longer hitch makes it cut deeper and move more material. The correct length of hitch to use depends upon the height of the team, arrangement of harness, etc., and must be determined by trial.
The amount of skew or angle which the drag makes with the center line of the road also affects the results. The greater the skew (i.e. the smaller the angle between the drag and the center line of the road) the more the earth will be moved toward the center. Usually this skew angle should be about 45 degrees, but here again the judgment and experience of the operator must be brought into play. The driver can control the operation to a large extent by shifting his position upon the drag. When he approaches a high spot in the road he can step toward the front, thus making the blade cut deeper, while at a depression he can step toward the rear, in this way raising the cutting edge and dumping the earth which is being pushed ahead of the drag. By stepping toward the end of the drag nearest the center of the road he can increase the skew and so move more earth toward the center line, while stepping to the other end of the drag has the opposite effect. In road dragging it is especially true that "practice makes perfect", provided that a little common sense is used along with the practice.

Rules for Dragging

The following rules are given by the Illinois Highway Commission:

"Use a light drag.

Haul it over the road at an angle so that a small amount of earth is pushed to the center of the road.

Drive the team at a walk.

Ride on the drag; do not walk.

Begin at one side of the road, returning up the opposite side.

Drag the road as soon after every rain as possible, but not when the mud is in such a condition as to stick to the drag.

Do not drag a dry road.

Drag whenever possible at all seasons of the year.

The width of traveled way to be maintained by the drag should be from eighteen to twenty feet; first drag a little more than the width of a single
wheel track, then gradually increase until desired width is obtained.

"Always drag a little earth towards the center of the road until it is raised from ten to twelve inches above the edges of the traveled way.

"If the drag cuts too much, shorten the hitch.

"The amount of earth that the drag will carry along can be very considerably controlled by the driver, accordingly as he stands near the cutting end or away from it.

"When the roads are first dragged after a very muddy spell the wagons should drive, if possible, to one side until the roadway has a chance to freeze or partially dry out.

"The best results from dragging are obtained only by repeated application.

"Remember that constant attention is necessary to maintain an earth road in its best condition."

Results and Cost of Dragging

Bulletin No. 48 of the U. S. Office of Public Roads cites, as a typical example of the results of dragging, the case of a road in Arkansas which was systematically dragged for a year:—

"The cost of this work for a year was at the rate of $11 per mile or 50 cents a dragging. The low cost was secured because the only charge was for the driver's time. Before this road was dragged it was possible to haul at most, one bale of cotton with two mules, and sometimes the road was impassible. After the road had been dragged for some months two mules could haul from 10 to 12 bales of cotton at any time. ** After the first year or two, roads can be kept in excellent shape at a cost of from $6 to $12 per mile. The hardest part of road dragging is to make a beginning. The first dragging may not produce much apparent benefit and the operation requires patience and persistence."

Other Maintenance Work

Occasionally it will be necessary to do more or less patching with new material. All chuck-holes should be filled as soon as they begin to form. If an inspection is made on a rainy day these small depressions can be easily located, as water will stand in them. Before such holes are filled the old dust and mud should be cleaned out and only
good material, the same as that forming the road, should be used for filling. If soft material such as road dust, sod, silt from ditches, etc., is used the hole will soon form again, while if stone or other hard material is used the result will be a bump in the road and wagon wheels dropping off from this bump will soon form two holes where there was one before. Even with the proper materials care should be taken that a bump or a hollow is not formed due to the use of too much or too little material. All glass, nails, tin cans, etc., should be removed to avoid injury to horses' feet and automobile tires.

In addition to the proper care of the road surface and shoulders, the ditches should be kept open and cleared of weeds, brush, and other obstruction. Weeds can often be cut advantageously with a mowing machine. All obstructions should be removed from bridge openings and culverts. Loose planks on culverts and bridge floors should be nailed down, and all defective planks should be promptly replaced. The most elaborate provisions for drainage are of little value unless properly cared for and kept open. For the sake of safety, brush and tall weeds should be cut away from the inside of curves and near railroad crossings where they obstruct the view of drivers. A few dollars spent in such work may save human lives.

Maintenance Systems and Costs

The patrol system is probably the most efficient for the maintenance of earth roads, but in may places the law provides for the "working out" of road taxes, and therefore the cash road funds are often limited. In such cases present methods can at least be greatly improved upon, and the statute labor be made much more effective. The work can be carefully planned ahead, the road hands can be called out a few at a time,
and can be worked under the direction of experienced foremen. Mr. W. J.

Keller, State Highway Engineer of Alabama, describes this method as follows:

"Good results have been obtained in several counties in Alabama by putting the work in the hands of a few regularly employed foremen who give all of their time and attention to the work, instead of leaving it to many beat overseers who work when it suits their convenience, or do not work at all when it suits them, as is often the case. These foremen are furnished with two or three teams with regular drivers, wagons, scrapers, and grading machines, split-log drags and necessary small tools and as many beats or districts assigned to each as he can work. A census is taken in each foreman's territory at the first of the year, of all men subject to road duty and he is furnished with a list of names and is required to work every man who has not paid the required amount of cash into the county treasury in lieu of his services. No foreman is allowed, under penalty of dismissal, to receive cash from work hands, but such hands as desire to pay must make their payments to the proper county official at the court house. This method has proven good in most cases, but as a general thing I do not think the best results can be accomplished by permitting men to work out their road tax".

Contracts for road dragging are often made with farmers living along the roads and Mr. Keller describes an experiment made in the use of that system. He says, "The writer, when in charge of road work in a Tennessee county inaugurated a system of dragging that proved very successful. Ten roads were graded a distance of three miles each. The grading was completed in November. With the surface of these roads fresh and loose, it was a foregone conclusion that the winter rains would soften them to the extent that they would become impassible under heavy traffic. Contracts were made with a farmer on each of these roads to keep them dragged during the months of December, January, February and March, and the price paid was 30 cents an hour for a man and team. The county furnished the drags. As an inducement to the men to do good work, the county offered prizes of $25, $15 and $10 for the best kept roads. Specifications for dragging and rules governing the contest were furnished to each contestant. One important rule was that the prizes would be awarded to the men who kept their roads in the best condition at the least cost. In order that the engineer might keep in close touch with the work, postal report cards were furnished each man and they were required to fill them out every Monday, showing the distance dragged, hours consumed and cost for the previous week, and mail them to the office of the engineer. In this way it was practically impossible for a dishonest man to render an account for more time than he really consumed without it being detected, or if he worked more than was necessary, the reports of the other contestants, when compared with his, disclosed it. On the other hand, if one should be neglecting his work by not dragging sufficiently it was likewise
detected. This thirty miles of road was kept in splendid condition despite the fact that two heavy snows fell during the four months. The most interesting fact connected with the contest was the road that was awarded first prize cost the county only $15 or $5 per mile."

 Hale township in Carrol County, Missouri, has a system somewhat similar to that just described. There is an overseer in charge of every eight miles of road and he is held responsible for the dragging of his section. After each rain he uses the telephone to call out farmers with ten drags, and all the roads are dragged at the same time. The work is done during the months of April, May and June, and the cost is from $10 to $15 per mile per year, including $15 to each overseer.

 In Minnesota three different systems are in use for the maintenance of earth roads. They are called the patrol systems, the maintenance section system, and the dragging system. The dragging system is similar to those described above, the work being in charge of a superintendent of maintenance, who is usually one of the county engineer's assistants. The superintendent of maintenance makes contracts for dragging all the roads under his charge.

 The maintenance section system is described by Mr. George W. Cooley, State Highway Engineer of Minnesota, as follows:

 "Under the maintenance section system, one man is given charge of a section of from 20 to 30 miles of road and is employed continuously with his team in the care of his section. He is given authority to employ additional help, both teams and men, and usually has two teams and four or five men at work. Contracts are also entered into by the section foreman with residents along the road for the dragging of same after each rain, or when ordered to do so by him. The section crew takes care of all minor items of construction, such as placing culverts, etc., and we have found that the work, when properly done, is really of a constructive nature. This system is without doubt the most effective and is being adopted generally throughout the state."

 A part time patrol system has been used successfully in Michigan, and was described by Mr. K. I. Sawyer at the 1915 short course at the
University of Michigan. Mr. Sawyer's description of this system is as follows:

"The roads in the jurisdiction were divided into sections or districts and a man was engaged for each district for the season. In practically every instance on the earth road districts, farmers residing on the roads were engaged, though in one instance, a man a little way off one road was hired. The districts after several adjustments were finally fixed at about 3 to 4 miles to a man. Each of these men was supplied with a drag or float, shovels, rakes, axe, pick, wheelbarrow, tamper, brush, scythes and tool box. In our instance the large territory necessitated putting the men under bond for faithful work and correct reporting of expense. Smaller jurisdiction, of course, would not necessitate this. The word continuous was applicable to the system only because there was at all time a resident man responsible for the condition of the road. The traffic on these roads, as on most dirt roads, did not warrant continuous work. The duties of these men were substantially as follows:

"As soon as the frost was about half cut of the roads, they were required to give the roads a good floating, restoring the proper shape over the whole width of the grade. This required three or four round trips as a rule. The road, of course, cut up some immediately. As soon as frost was all cut out the road received additional floating. This usually put it down and the duration of the heavy road condition to be met on all earth roads in spring was cut in two, besides leaving the road in the right shape when it was over, instead of all rutted up. In addition, the road was dragged after every heavy or protracted rain during the season. The dragging being done when the dirt was as near the consistency of unset putty as possible.

"Further, immediately after the road had settled in the spring, the road was patched up, every hole being filled, and on all swamp stretches where the material of the grade had been hauled more than 300 feet, piles were made at that interval, being placed between the road grade and the ditch, i.e. on the ditch berm. Thereafter, except for dragging or for some work, as for instance culvert installation, covered by special order, no payment would be made for team work, the balance of work being entirely hand labor, and I might say that this feature proved one of the big economies.

"These section or district men were required to be on the road and working upon either the road or drainage system two specified days in each month. The first duty of the day being to go over the road taking with them wheelbarrow, shovel, and tamper, and filling every incipient hole. Any obstruction to drainage was also corrected. Time was paid for more than the two days if necessary to complete work, but failure to be on the job in person or by proxy at the specified time and at work was grounds for dismissal. This proved the theory that if you don't allow small holes there will be no big ones."
"In addition, all matters relating to the safe condition of the roads were delegated under restrictions to these section men. They were expected to see to the mowing of weeds and brush on the roadsides, breaking through the snow in winter, and in general, keep the road to the standard of a good dirt road.

"What that means to the traveling public can not be computed. The road was practically at all times a surface which made hauling more easy. The ratio of that being expressed as near as possible in the data on tractive effort obtained experimentally which shows the effort per ton of load at 90-110 for earth road in good condition, as against 150-175 for average condition, or it increased the capacity of road to traffic by 30 per cent, besides making travel more pleasant. The system had also several minor merits derived from its method of operation. It was found that the crown of the road when constantly kept up did not need to be so high as formerly, and in a few places this resulted in getting traffic to travel all over the surface and not make a rut. The floating also had a desirable effect on the clay stretches as it recovered all grit in the material and the clay was gradually leached out, thus hardening the road.

"However, the chief merit came from the administration point of view. I do not want to convey the impression that I succeeded in making all sections work as per schedule, but did on several and approximated it on several more. By holding every good section man I got and changing until I got good ones, in other districts, I believe could ultimately have attained the desired end. By comparing section to section, I found that not only the better maintenance but also greater economy was derived by close following of the system. Also from the administration point of view, it cut down overhead troubles, therefore overhead cost, and actually made a more economic up-keep as is shown in comparison of the following extracts from annual reports of the county:

1909 - Start of maintenance system
Men hired for definite stretches about 6 miles each. Used repair method.
Miles put under system . . . . . . . . . . . . . . . . . 70.5
Average cost per mile (for roadbed) all maintenance . . . . . . . . . . . . . . . . . . . . . 34.73
Average cost of road machine and raking . . . . . . 26.17
Patching, culvert and ditch work . . . . . . . . . . . 8.56

1910 - Section system as before, each section one kind of road. Sections 4 to 6 miles:
Miles put under maintenance system . . . . . . 72.5
Average cost per mile (of road) . . . . . . . . . . . . 28.42
Raking and dragging per mile . . . . . . . . . . . . . 8.65
Raking and dragging per mile, one time . . . . . . 0.925
Hand labor, including cutting brush and weeds, per mile . . . . . . . . . . . . . . . . . 19.77
Repairs on other roads -30 miles repaired up.
Average per mile, &35.29. Ordinary township methods."


Since 1913 Clayton County, Iowa, has used similar patrol systems in the maintenance of earth roads, and Mr. E. B. Tucket, County Engineer, states in Engineering Record, Vol. 73, p. 643, that the condition of the roads has improved 50% in the last three years. There are 1350 miles of road in the county, of which 226 miles comprise what is known as the County System. The patrolmen are under contract to work at such times and places as are designated by the engineer. The average length of each patrol is 10 miles and in some parts of the county 7 miles. The patrolmen sometimes assist one another and they hire such extra help as is necessary. Not all the patrolmen put in their whole time on the roads but they must report whenever ordered to. Several are employed all through the season. All maintenance and repair work is done by the patrolmen, each of whom is supplied by the county with one wheel scraper, slip-drag, one road plow, one Kelly road-drag, one glide, two horse graders, and small tools, such as picks, shovels, etc. Each patrolman furnishes his own team and wagon. The average rate of pay is $27.50 per hour for patrolmen; 475 per hour for man and team, and 105 per hour for each extra horse. Patrolmen's assistants are paid 255 per hour for labor and 455 per hour for man and team. The average cost of dragging is 565 per mile for one round trip. The total cost for maintenance and repairs averages about $56 per mile per year.

The examples given above illustrate several successful systems of earth road maintenance, all of which are much superior to the methods commonly used in most parts of the country. An experiment with the continuous patrol system, in which careful cost records were kept, was made by the United States Office of Public Roads in 1911 and 1912, and is described as follows in Engineering and Contracting for December 25, 1912—

"An experiment to determine the feasibility of the Patrol System in the
maintenance of earth roads was made by the U.S. Office of Public Roads during the fiscal year ending June 30, 1912. The experiment was conducted on eight miles of earth road in the Arlington and Jefferson Road Districts of Alexandria County, Va. The maintenance was commenced on December 17, 1911, and continued during the remainder of the fiscal year. Before the maintenance was undertaken the county repaired the road and put it in good shape. The repairs consisted in shaping parts of the road with a scraping grader, clearing and widening the ditches and clearing culverts, and applying gravel to a section of the road. The cost of the repairs was $700. On the eight miles of road there are 4 bridges, 19 culverts, 54 ditch pipes under driveways, 59 intersecting roads with drainpipes, 42 intersecting roads without pipe drains and 10 small wooden bridges across the gutter. The entire eight miles of road is well travelled and there is considerable heavy teaming over parts of it. A portion of the road is also used by U.S. Cavalry. There is also considerable automobile traffic on some portions. A traffic census for three days in March on one section of the road shows the following: Loaded one-horse wagons, 15; unloaded one-horse wagons, 58; Loaded two-horse wagons, 38; unloaded two-horse wagons, 49; Loaded four-horse wagons, 9; unloaded four-horse wagons, 4; Saddlehorses, 96; and motor runabouts, 1. The patrolman was employed to furnish a horse, cart, and small tools. He was supplied with a plank road drag and required to furnish two horses to drag the road whenever it was in suitable condition for dragging, usually following each rain. He was paid $60 per month and $1 per day extra whenever he used two horses to drag the road. His presence was required on the road from 8 a.m. to 4:30 p.m. with 30 minutes allowed for lunch. The work accomplished by the patrolman on the eight miles of road is indicated in Table I. The average cost of dragging has been $16.11 per mile for 6.5 months, which is at the rate of $29.74 a mile for the first year of 24 complete draggings, or approximately $1.25 per mile for each dragging of three round trips. The item of $159.88 for repairing, clearing and improving ditches and underdrains was large, because it was found necessary as the year progressed to rebuild portions of the gutters and ditches entirely. The following points are clearly demonstrated by the experiment on the eight miles of earth road in question: (a) The use of the road drag has greatly improved the daily condition of the roads and rendered it smooth and comfortable for travel for a greatly increased number of days in bad weather; (b) a width of earth road in excess of 24 ft. is unnecessarily expensive to maintain; (c) the presence of the patrolman during storms and immediately after saves considerable expense for repairs due to the wash of surface water; (d) the existence of poorly drained private driveways and intersecting roads is a constant expense for maintenance; (e) the use of small tiles for ditch drains and the building of wooden bridges over gutters at driveways is a serious obstacle to proper drainage. Small pipe is usually laid at insufficient depth and becomes broken and clogged. It would appear that paved gutters at driveways would not be unduly expensive in the long run and would certainly provide better surface drainage; (f) it will not be economical to employ patrolman during the winter months unless his time can be used to advantage in clearing brush and rubbish from the right of way, but a man should be constantly in charge of every mile of road to inspect it during storms and free the ditches; (g) the presence of old cobblestones and large, poorly consolidated gravel is a serious
impediment to the use of the road drag; stones must be removed from the road before dragging can be successful; and (h) there is ample work for one man continuously during 8 or 9 months of the year, and there is no difficulty in combining road-patrol work with the dragging of earth roads. It is expected to continue this experiment during the fiscal year 1913, and according to the last annual report of the Director of the U.S. Office of Public Roads, the indications are that the entire eight miles of road will show remarkable improvements under the systematic work of the patrolman.

TABLE I. - Work of Road Patrolman on Eight Miles of Earth Road in Alexandria County, Virginia.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Dragging</td>
<td>4</td>
<td>2.5</td>
<td>3</td>
<td>8</td>
<td>11</td>
<td>7</td>
<td>3</td>
<td>38.5</td>
<td>22.7</td>
<td>$128.89</td>
</tr>
<tr>
<td>Repairing, cleaning and improving ditches and under-drains</td>
<td>9</td>
<td>5</td>
<td>14</td>
<td>6.5</td>
<td>11</td>
<td>21</td>
<td>73.0</td>
<td>42.9</td>
<td>169.88</td>
<td></td>
</tr>
<tr>
<td>Picking off stones</td>
<td>2</td>
<td>2</td>
<td>0.5</td>
<td>3.5</td>
<td>2.5</td>
<td>-</td>
<td>10.5</td>
<td>5.2</td>
<td>24.55</td>
<td></td>
</tr>
<tr>
<td>Cutting brush, etc.</td>
<td>2</td>
<td>10</td>
<td>11.5</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>26.5</td>
<td>15.6</td>
<td>61.78</td>
</tr>
<tr>
<td>Census</td>
<td>-</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>5.9</td>
<td>23.36</td>
</tr>
<tr>
<td>Inspection during storms</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>2.5</td>
<td>-</td>
<td>5.5</td>
<td>3.2</td>
<td>12.67</td>
<td></td>
</tr>
<tr>
<td>Misc.- Clearing away fallen trees, building guard rail, etc.</td>
<td>-</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>6</td>
<td>3.5</td>
<td>13.86</td>
</tr>
</tbody>
</table>

II. Maintenance of Sand-Clay Roads

The sand-clay road is really a superior type of earth road and practically everything previously said in regard to the maintenance of earth roads applies equally to sand-clay roads. The only difference is in the method of making repairs to the traveled surface. As in the case of ordinary earth road, economical maintenance depends very largely upon proper original construction. If the sand or clay, or both, are of the wrong kind, or if they are improperly mixed, the cost of maintenance will
be greatly increased. The use of too fine sand, and insufficient mixing of the sand and clay are common causes of failure of this type of road.

If proper maintenance methods are adopted as soon as a sand clay road has been completed, little need be done to the surface except dragging. During the first wet season it is usually necessary to drag after every rain, but after that it is not necessary to drag so often and when the road has become well settled and compacted about ten draggings a year are usually sufficient. Dragging should begin at the side of the roads, going up one side and back on the other side. The second round should be made near the center, and a final trip is often made along the center line of the road, with the drag at right angles to this line. Deep cutting is seldom necessary and light drag should be used. Dragging should always be done after a rain, and it should be done either immediately after the rain while the surface is very soft and plastic, or else after the road has dried out sufficiently so that the mud will not ball up and interfere with the drag. There is a time in between when dragging can not be done to advantage. Ordinary dragging costs about $10 per mile per year. As a rule, dragging will fill all ruts and other depressions and keep the surface in excellent condition, but sometimes holes will be formed which will have to be filled with new material. Such holes are usually due to an excess of clay, so that the filling should consist mainly, or entirely of sand. Sometimes, the fine sand washes to the side of the road leaving an excess of clay in places on the surface and when this occurs the fine sand should be removed from the roadside and ditches, and not used again for filling holes. The bottom of the holes should be loosened up with a pick before the filling is put in, so that the new material will bond with the old.
If the whole surface has a tendency to rut and form holes in wet weather, it usually means that too much clay has been used in the construction of the road, and it may be necessary to cover the entire surface with a layer of sand. This layer may have to be harrowed into the surface. If, on the other hand, the surface is too sandy, clay must be added in the same way. If lack of proper dragging has allowed the road to become badly worn, then it must be scarified, or plowed up with a rooter plow, after which, it should be harrowed, preferably with a disk harrow, reshaped with a grader, and, if possible, rolled. The crown should be the same as that for an earth road; that is, about one inch to the foot.

A well built and properly maintained sand-clay road will give excellent service at a comparatively low cost for maintenance.

III. Maintenance of Gravel Roads.

There are more miles of gravel roads in this country than of any other one type of improved road. It is usually the cheapest type of hard surfaced road which can be built, and if properly built, is satisfactory except under very heavy traffic, so that the proper maintenance of gravel roads will always be one of our most important road problems.

The proper care of side ditches, culverts, shoulders, etc., has been covered in the discussion of earth road maintenance, and all that has been said there applies equally to gravel roads. Rather it is more important in the case of gravel roads because a larger investment is at stake, and a clogged up drainage system may ruin an expensive road.

With this type of road it is extremely important that maintenance work should be started the day the road is completed and should be
practically continuous forever. Only constant attention will enable a community to get full value out of a gravel road. Anything less means money wasted. A small hole if not immediately repaired soon becomes a large hole, and a few large holes mean a ruined road. In no case can it be said with more truth that, "a stick in time saves nine". Many of the best gravel roads ever built have gone to pieces in a few years for lack of proper maintenance, and this short-sighted neglect is costing the people of this country millions of dollars every year.

The Patrol System

It is generally conceded that the patrol system, together with a "flying squadron" or extra gang is the most economical and efficient method of maintaining gravel roads. A patrolman should be placed on each section of from five to ten miles, while the size of the section which can be covered by the extra gang will depend upon various local conditions.

The greatest amount of maintenance work is required during the first few months after the road has been built, before it has become thoroughly compacted and settled by traffic. The surface is likely to become badly cut up in wet weather and to ravel in dry weather. The first condition is most likely to occur if there is too much clay in the gravel, and the second, if there is too little clay. During this time a road grader is usually the best tool to use, as the blade will cut off high spots, fill up hollows, and keep the crown shaped up more effectively than a drag. Opinions differ, however, as to the comparative value of the scraper and the drag for this work. The crown should be about 3/4-inch to the foot, giving for instance, a crown of 6 inches on a 16 foot road. If the crown is made steeper than this, traffic will all
keep to the center of the road and quickly form ruts.

If the gravel contains a great excess of clay it will be necessary to add a thin layer of sand-gravel free from clay. If, on the other hand, the gravel does not contain sufficient clay to properly bind the surface, a layer of clay may be added and harrowed into the gravel. Usually from 10 to 20 per cent of clay makes a satisfactory binder. If the surface does not immediately "set up" it should not be hastily concluded that there is too little binder; in fact, a road which sets up too soon is apt to cut up later on.

Scraping or dragging should be done immediately after a rain, while the road is soft enough to be worked. A scraper has some effect on a dry road, especially where the gravel is displaced through lack of sufficient binder, but a drag should always be used when the road is wet. At first the scraping or dragging should be done after every rain, and scraping may be necessary between rains, but as the road becomes compacted by traffic, this work need not be done so often. After the first few months, a drag will be as effective as a scraper, but the cutting edges of the drag should be protected by iron over their entire length.

Patching.

Although the drag will keep the surface smooth and fill up small depressions, it is usually necessary to do more or less patching. The patrolman can go over his road, during or just after, a rain and locate the depressions by the standing water. If there is any mud in the hole it should be carefully cleaned out and the bottom should be loosened up with a pick. Unless the road is wet the hole should be thoroughly sprinkled before it is filled. This loosening and sprinkling will insure a bond between the old and the new material. Large stones should not be
used in shallow depressions, and the top of the finished patch should be just high enough so that it will be even with the road surface when compacted. If it is left too high, holes will be formed at each end of it where the wagon wheels drop off.

Piles of gravel should be left at intervals of about half a mile along the roadside, to be used for patching, and enough material should be left in each pile so that it will not be scattered before it is used. This gravel should, if possible, be the same material as that used in the original construction.

- Resurfacing -

When the surface becomes so badly worn that patching is no longer sufficient, the road must be entirely resurfaced. This work can best be done in the spring when the road is comparatively soft. All vegetable matter and other refuse should first be removed from the road surface and then the old gravel should be scarified and reshaped before the layer of new material is put on. The scarifying can often be done with a heavy harrow. If the harrow brings large stones to the surface they should be removed. Before the new gravel is put on, the old surface should be well sprinkled to insure a good bond with the new gravel, and if possible, it should also be rolled. The new material, similar to the top layer of a new road is then put on, shaped and if possible rolled. The surface should be kept smooth with a scraper or drag until it is well compacted.

Sometimes a road wears out sooner than it should because it is too narrow. On a narrow road vehicles are forced to follow the same track and ruts are formed much sooner than if there is an opportunity for the traffic to spread out over a wider surface. If the road is too narrow the new surface can be extended out beyond the old one at the sides. There will
be less traffic on the sides than near the middle, so that it will do no harm to have this portion thinner than the rest.

It will add to the life of a gravel road to roll it every spring, whether extensive repairs are made or not, and it is also a good plan to roll it after the first rains in the fall. The rolling should be done when the road is fairly soft, but not while water is standing upon it.

* - Examples of Patrol Maintenance -

"Starting with well-built gravel or dirt and gravel roads, the problem is to maintain them under severe motor-vehicle traffic. The successful method as demonstrated in New Hampshire has two prime essentials - honest, efficient and decently paid patrolmen and a willingness to spend $200 to $300 per mile per year, or even more in exceptional case, on plain gravel-road maintenance. It is in the latter essential that most highway departments fail; for while they show willingness to spend $600 to $1,000 per mile per year to maintain bituminous roads, they generally balk at regularly spending $200 per mile per year on dirt or gravel roads.

"Patrolmen are local men, appointed on the recommendation of the selectmen of their towns. They are intelligent natives, not the ordinary type of laborer. Each patrolman is required to provide himself with the following equipment: Horse, dump cart, chain, shovel, pick, iron-bar, hoe, rake, ax and brush hook. Any other necessary equipment (on exceptional sections tar kettles, etc) is furnished by the state. The patrolman is expected to spend his whole working day of 9 hours, six days a week on the job during the working season. His pay ranges from $3 to $3.50 per day.

"In brief, the patrolman's duties are to frequently patrol his section and see that the road is clear of stones, broken glass or anything of a foreign nature; to see that the ditches and shoulders are cleaned, the culverts clear and bushes cut, and to pay particular attention to the cleaning of the culverts and ditches after each rain. He is to patch any ruts and holes that may appear and drag the road after every rainstorm or shower or whenever the road surface is damp.

"When necessary, a patrolman may hire upon written consent of the division engineer, such assistants as he needs, but for each patrol section only a limited sum is ordinarily available each year - generally $1,000 or $1,200; and it is in the interest of all parties concerned (the state, the town and the patrolman) to make this money go as far as possible. If a patrolman spends a part of his allotment in hiring assistants, he has so much less for his own labor and for materials, which he also purchases out of his allotment - that is to say, his working season will be shorter. By good judgment on the part of the patrolman and division engineer this system works out admirably, and it makes the patrolman's job more than that of a day laborer, and thus it requires and develops a higher grade of intelligence and workmanship.

"The patrolman makes daily postcard reports of his own time, assistants' time, material, work done and weather conditions. As the towns pay part of the maintenance costs, the patrolman must keep a record of his work in each town. Upon the authorization of the division engineer the patrolman makes purchases of such material as is necessary for his work. Where small quantities are purchased at a time, bills are not sent in every week, as otherwise required, but a total bill is rendered at the end of each quarter - May 28, August 28 and November 27. The patrolman pays these bills, sending receipts promptly to the highway office, and at the end of the quarter he is reimbursed by the state.

"There is no hourly allowance for overtime nor docking for short time. The patrolman is left largely to his own devices, but when he takes a day or part of a day off, he records the same and is paid only for the time he actually works. The working time of the patrolman is made up weekly from his daily post-card reports, and an order is sent him for presentation to the selectmen of the town or towns in which his section is, who give him a warrant on the town treasurer to cover his own pay, assistants' pay and material accounts. In cases of emergency, material may be purchased or assistants hired upon telephone order from the division engineer.

"Every patrolman is provided by the state highway department with two cart signs with his number painted on them. He is also provided with a staff having a sign on top, which he carries on his cart; or when he is compelled to leave his section of road to go to a gravel pit, or for any other purpose, he leaves his staff in an upright position beside the road just at the point where he has left it, so that he may be found if necessary.

"Each patrolman is provided with complaint blanks which he is to furnish to all parties wishing to register a "kick" in connection with the highway work. These complaints the patrolman is required to send to the division engineer. The patrolman is also expected to report all accidents. He is also required to report any dangerous place or conditions on the roads or bridges of the town or towns which are not under his supervision, but he is to do this through the division engineer, and is particularly cautioned against criticizing the town authorities, and is urges to assist the town road authorities in every possible way in solving their problems.

"A system of supervising and assisting patrolmen by having three of the most experienced men act as part-time foremen, traveling over the various patrol sections and giving instruction and advice, has been tried, and proved fairly successful in one division, but the scheme of organization for the coming season is somewhat different. It is planned to have one experienced man give his whole time as inspector or foreman of patrolmen. The object is not so much that of checking the work of the patrolmen as to give them the benefit of the advice and experience of the inspector in solving their particular problems."

The dragging and small repairs needed annually cost as a rule from
$20 to $50; though sometimes $100 or more, per mile per year. Resurfacing usually has to be done at intervals of from five to ten years at a cost equal to about two-thirds of the cost of the original gravel surface. Dividing this cost by the number of years between resurfacings and adding the annual cost of dragging and small repairs gives a total annual cost of from $150 to $300 per mile to keep the roads in first-class condition perpetually.

- Use of Motor Trucks -

Motor trucks are successfully used in many localities in the maintenance of gravel roads. Montgomery County, Alabama, has 450 miles of gravel roads, and five trucks are used by that county. Mr. Thomas H. Edwards, County Engineer, described the use of these trucks in Engineering Record for July 15, 1916, as follows:

"Montgomery County, Alabama, has 650 miles of public roads, 450 miles of which are of gravel. In 1914, in order properly to maintain them, the County Board of Revenue decided to motorize the maintenance work. Material economies have been effected. One truck, it has been found, takes the place of from 16 to 20 mules for pulling a scarifier. The five trucks now in use make it possible to scrape practically the entire system after each rain, each truck pulling three road machines and being able to make 30 miles a day. A great saving has been accomplished in the hauling of the gravel. Four trailers are provided for each truck for this purpose.

"The use of the motor truck has made scarifying a comparatively easy matter. As previously stated, where formerly from 16 to 20 mules were required to pull the scarifier, one of the trucks now accomplishes the work with ease.

"Recently there has been completed 6 miles of scarifying and reshaping at a cost of $24 per mile. This includes rebinding. The writer understands that in a neighboring county a contractor bid as much as $400 per mile for similar work. The detailed costs are given in the accompanying table:

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Rate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline for truck</td>
<td>146 gal.</td>
<td>25¢</td>
<td>$36.50</td>
</tr>
<tr>
<td>Oil for truck</td>
<td>35 gal.</td>
<td>56¢</td>
<td>19.60</td>
</tr>
</tbody>
</table>
Laborers' time, 31.5 days @ $1 .......... 31.50
Engineer's wages, 7 days @ $3.00 .......... 21.00
Foreman's wages, 7 days @ $3.00 .......... 21.00
Total cost of scarifying .......... $129.00

Cost per mile .......... 21.60
Cost of shaping 6 miles with truck followed by road machine .......... 14.78
Cost of shaping per mile .......... 2.46
Total cost per mile, of finished road .......... 24.06

"It is very important, in the maintenance of gravel roads, to scrape them after each rain. With the five trucks now in use, it is possible to cover practically the entire system before the roads become too dry to accomplish any good.

"With the truck we are in position to completely scrape 30 miles of road per day. To do this there is hung to each truck a fleet of three road machines. A round trip completes the road.

"The cost per mile of this class of work is about 50 cents. The cost for the 30 miles is: Driver, $3; foreman, $3; 3 laborers $3; gasoline $5; oil $1 - a total of $15.

"The replacing of chains, repairs to trucks, etc., necessary to truck upkeep cost about $400 per year.

"In connection with each truck there are four Troy reversible 3-yd. trailers. While the truck and two of the trailers are at the dump the other two trailers are being loaded. Therefore only about ten minutes are lost per trip, this being consumed in loading the truck.

"By this method of hauling, it has been possible to place gravel on the roads for from 7 to 11 cents per yard-mile, as against from 30 to 40 cents for mule haul, and includes spreading the material on the road.

"With an increase of late in the price of gasoline from 11 to 25 cents per gallon, it has been possible to keep the costs per yard-mile around 10 or 11 cents.

"The accompanying table shows the unit costs of operating one of the trucks for hauling gravel during a week. The table shows a gasoline consumption of about 35 gal. per day. This is from 10 to 12 gal. more than the truck uses on the average haul, due to very long 12-per cent grades on the particular road traveled.

"The first truck, a White 6-cylinder, latest type road truck, was purchased in the latter part of 1914. It proved such an economy to the county that four others were purchased together with trailers and equipment. All of the trucks are of 5-ton capacity."
Some counties have not found the use of motor trucks to be as economical as they have been in the case described above. This economy is affected by various local conditions.

IV. - Bituminous Surface Treatments.

A good gravel road is well adapted to horse-drawn traffic and will stand up under motor traffic better than water-bound macadam. If there are more than about 150 motor cars a day, however, a bituminous surface treatment of some kind will be required to preserve the gravel road.

The materials used for this purpose include various kinds of oils, malthas, asphalts, and tars, and they may be roughly separated into dust layers and road binders. Dust layers consist of light oils and tars which have an effect somewhat similar to that of sprinkling with water. They are applied at the rate of from 1/8 to 1/5 of a gallon per square yard by means of an ordinary sprinkling cart, or special distributor, and are effective for a month or two. The oil prevents the dust from blowing off the road, and to a certain extent prevents the formation of dust. As long as the oiling is effective the dust nuisance is abated, but the oil does not preserve the road to any great extent. A gravel road after being oiled in this way can be maintained with a drag in the same way as a plain gravel road. The oiling must be done so often that it is usually more economical to form a bituminous surface by the use of a road binder.

Road binders consist of heavy asphaltic oils, malthas, asphalts and tars. When applied as carpet coats they protect the road surface from wear and prevent the formation of dust on the road but they do not absorb or hold down the dust which falls on the surface from other
sources. A road which has been treated with a dust layer, then, is similar to a road which has been sprinkled with water, while a road which has been treated with a bituminous binder is more like sheet asphalt in appearance. This difference often causes much confusion in the minds of those who are not familiar with the two processes.

Some of the materials used for bituminous carpet coats are of such a nature that they may be applied cold, while others must be applied hot. The surface treatment of gravel roads is still more or less in the experimental stage but the present tendency seems to be toward the use of hot materials.

Before putting on the carpet coat the gravel surface should be shaped up, patched if necessary, and rolled, if not already well compacted. It should be as free from dust as possible. A horse-drawn rotary broom is often used for removing the dust, but care must be taken not to loosen up the road surface. Sometimes the broom is locked so that it can not revolve and is dragged over the surface.

The bituminous material is usually shipped in 6,000 or 8,000 gallon tank cars, fitted with steam coils for heating. A boiler of any kind, such as that on a traction engine or steamroller, may be used for furnishing steam, or if possible, the cars may be spotted near some manufacturing plant and the steam obtained from the plant. A steam trap should be placed on the outlet end of the coils and a pressure of from 40 to 60 pounds maintained. This will heat the car much more quickly than if the steam is allowed to escape through the outlet. The pressure on the coils is apt to run up very fast unless it is carefully watched and it is often advisable to put a pressure gauge at the outlet. If a steam coil bursts the results are serious. It is important that the coils be constantly drained, because if the condensed steam is not removed the
heating will be greatly retarded. Fire should be carefully kept away from
the inside of tank cars. A fireman once lowered a lantern on the end of
a rope into a partly emptied car of tar which he was heating and an explosion
resulted which nearly killed the inquisitive fireman.

The bituminous material is removed from the tank car through an
outlet in the bottom and this outlet is usually closed by two valves. The
top valve is operated by a handle in the dome of the car, at the top. It
can be opened when the car is received and left open until the car is emptied,
though it is safer to close it every night. The other valve is operated
by means of a wrench from underneath the car. Various kinds of pumps
are used for pumping the bituminous material from the tank car into the
distributor. Some are operated by hand, some by steam, and some by the
engine of a motor truck distributor.

It is beyond the scope of this thesis is to describe the numerous
types of distribution which are on the market, but it is probably safe to
say that a pressure distributor is usually more satisfactory than a gravity
distributor. A more even distribution of the material is obtained and
the force of the spray helps to clean off the dust. Sometimes an auxiliary
air blast is used for this purpose. Theoretically, the rate of application
is controlled by the pressure and the speed of the vehicle, but practically
the temperature of the material has an important effect, so that with a
uniform pressure and speed the rate of flow will vary considerably with
the temperatures. An experienced man can judge the quantity of material
very closely by its appearance on the road and the rate of application
can be checked up after each load by comparing the yardage covered with the
contents of the tank. For checking less than full loads it is convenient
to have a diagram showing the number of gallons contained in the tank at
each inch depth of material. For instance, if there is ten inches of material in the tank the diagram shows how many gallons there are. It is often more convenient to measure the distance from the top of the tank to the surface of the material, and find the depth of material by subtraction from the total depth of the tank.

The proper amount of material to apply depends upon various circumstances, but it is usually from 1/3 to 3/4 of gallon per square yard for the first application. After the bituminous material is applied it is usually best to let it stand, if possible, for several hours and soak into the road surface. It is then covered with stone chips or clean sand. The purpose of the covering is to keep the bituminous material from picking up on the wheels of vehicles, to make the finished surface less slippery, and to add to its wearing qualities. The amount of covering used varies from 7 or 8 pounds per square yard to as much as 35 pounds. When tar is used it is often put on in two coats, the first coat being a lighter material, which will penetrate more readily, while the second coat takes the wear.

A bituminous surface treatment as described above will last from six months to two years, depending upon the amount and kind of traffic carried. Narrow tired horse-drawn vehicles are the most destructive to this type of surface, while automobiles have comparatively little effect upon it.

The kind of material used and the manner of handling it greatly affect the results obtained. To the uninformed, all bituminous materials are "road oil" and often a material which has proved satisfactory under certain conditions has been blindly adopted for use under entirely different conditions with disastrous results. Bituminous surfaces have not been as uniformly successful on gravel roads as they have have on macadam roads,
and the methods of application are not so well standarized, so that before
undertaking such work on a large scale the officials in charge should make
sure that the materials and methods which they intend to use have proved
satisfactory under similar conditions.

There is considerable variation in the cost of such treatments
due to the varying cost of materials, etc. at different locations. In
some of the eastern states the cost has been as low as 3 cents per square
yard, or about $210 per mile of 12-foot roads, while in some placed in
Texas the cost has been as high as 20 cents per square yard, or about
$1400 per mile of 12-foot road.

V. - Oiling Earth Roads -

The economy of oiling earth roads is a subject in regard to which
there is a great difference of opinion among engineers who have done a large
amount of such work. In some places where good results have been obtained
it is strongly recommended, while in other places, where it has not
proved satisfactory, it is condemned as a waste of money. This may be
accounted for by the fact that the kind of soil, the climatic conditions,
and the amount and kind of traffic, the provisions for drainage, the kind
of oil used and the methods of doing the work greatly affect the results.
A sticky clay road, a poorly drained road, a road subjected to heavy
traffic, or heavy loads can not be successfully oiled. A road of sandy
soil, well drained can often be improved by oiling, especially where there
is little freezing and thawing. The oil suppresses the dust and tends
to make the road surface waterproof. If a road is smooth, well drained
and comparatively water-proof, then water will not stand upon it and it
will not cut up under traffic and become muddy. This is the object
of oiling.
Before the oil is applied the road must be carefully graded and shaped up and the dust must be removed as completely as possible. If the road is covered with dust the oil will simply mix with this surface dust and make a disagreeable mess. It is usually best to apply the oil as soon as the road has become dry after a rain and when it has been made smooth with a drag. This reduces to a minimum the problem of dust removal. The road should be dry to a depth of at least two inches. The oil should be applied as described under the treatment of gravel roads, and for the first treatment about 1/2 gallon to the square yard should be used. For subsequent treatments 1/4 to 1/3 of a gallon per square yard is usually sufficient. Care should be taken not to use too much oil, as it makes a disagreeable surface. The oil should be applied as uniformly as possible. After applying the oil it is well to cover it with a light coating of sand, using 20 to 30 pounds per square yard. This gives a better and more durable surface and keeps the oil from "picking up".

During the first year or two it is best to apply the oil both in the spring and in the fall, but after that one treatment a year may be sufficient.

The cost of oiling depends largely upon the amount of preliminary work required in the way of grading and drainage, also upon the cost of oil, the length of haul, etc. After the road has been put in shape the oiling usually costs from $150 to $500 per mile for each treatment.

The oiling of earth roads in Kansas is described in Engineering-Contracting as follows:—

"The oiled earth road has proven generally satisfactory in Kansas, according to W.S. Gearhart, State Engineer of that State. In the construction of these roads, the earth from a strip in the center of the
roadway, from 16 to 18 feet wide is thrown to one side and the sub-grade carefully crowned and rolled. Oil at a temperature of 250° F. is then applied at the rate of from 1½ to 1½ gals. per sq. yd. and enough earth to absorb the oil (usually a layer about 4 ins. deep) is graded back on the road. The roadway is then thoroughly sprinkled and the earth, oil and water mixed by means of a disk harrow and a drag. The roadway is then compacted by a tamping roller, after which a second application of hot oil is made at the rate of about 1½ gals. per sq. yd. Another layer of about 4 ins. of fine earth is graded on to the road and the mixing and tamping repeated. On completion the wearing surface is from 5 to 6 inches thick.

VI. Specifications for Bituminous Materials.

The bituminous treatment of earth and gravel roads is still in a more or less experimental stage, so that it cannot be stated positively that a material conforming to certain definite specifications is the best one to use in any given case. Most of the specifications given below must be considered simply as examples of materials which have given good results under certain conditions.

Petroleums and petroleum products are often referred to as containing a certain "percent of asphalt". This is indefinite, as it means simply that upon heating to a high temperature the material will yield the given percent of residue having certain characteristics. Different bituminous materials can be compared intelligently only when all their properties as shown by the standard tests, are given. The basis of the so-called "asphaltic contents" alone is not sufficient.

Bulletin No. 6 of the Illinois State Highway Department gives the following specifications:

"Light Oils for Surface Treatment of Earth Roads (Cold Application)

1. The oil shall be a fluid product free from water.

2. Specific Gravity. Its specific gravity at 25° C. (77° F.) shall not be less than 0.910.

3. Total Bitumen. It shall be soluble in chemically pure cold carbon disulphide to the extent of at least 99.5 percent."
4. **Naphtha Insoluble Bitumen.** Of the total bitumen not less than 1.5% shall be insoluble in 86° B. paraffin naphtha at air temperature.

5. **Fixed Carbon.** The fixed carbon shall not be less than 2.5 per cent.

6. **Viscosity.** When 240 cc. of oil are heated in an Engler Viscosimeter to 50° C. (122° F.) and maintained at this temperature for five minutes the first 50 cc. which flow through the aperture shall show a specific viscosity of not less than five nor more than fifteen.

7. **Loss on Evaporation.** When 20 grams of the oil (in a tin dish 2 ½ inches in diameter and three-fourths inch deep with vertical sides) are maintained at a temperature of 163° C. (325° F.) for five hours in a N.Y. Testing Laboratory oven, the loss shall not exceed 25 per cent by weight.

**Light Oil for surface treatment of gravel road (cold application):**

1. The oil shall be a fluid product, free from water.

2. **Specific Gravity.** Its specific gravity at 25° C. (77° F.) shall not be less than 0.930.

3. **Total Bitumen.** It shall be soluble in chemically pure cold carbon disulfide to the extent of at least 99.5 per cent.

4. **Naphtha Insoluble Bitumen.** Of the total bitumen, not less than 4.0 nor more than 13.0 per cent shall be insoluble in 86° B. paraffin naphtha, at air temperature.

5. **Fixed Carbon.** The fixed carbon shall not be less than 3.0 per cent.

6. **Viscosity.** When 240 cc. of the oil are heated in an Engler Viscosimeter to 50° (122° F.) and maintained at this temperature for 5 minutes, the first 50 cc. which flow through the aperture shall show a specific viscosity of not less than 15 nor more than 30.

7. **Loss on Evaporation.** When 20 grams of the oil (in a tin dish 2 ½ in. in diameter and 3/4 in. deep with vertical sides) are maintained at a temperature of 163° C. (325° F.) for 5 hours in a N.Y. Testing Laboratory oven, the loss shall not exceed 25 per cent by weight.

**Tar Product for Treatment of Gravel Road (cold application):**

1. The tar shall be free from water.

2. **Specific Gravity.** Its specific gravity at 25° C. (77° F.) shall not be less than 1.12 nor more than 1.22.

3. **Inorganic Matter.** It shall show not more than 0.5 per cent of ash upon ignition.

4. **Free Carbon.** Its free carbon content shall not be more than 20 per cent.
5. Viscosity. When 240 cc. of the tar product are heated in an Engler Viscosimeter to 50° C. (122° F.) and maintained at this temperature for 5 minutes, the first 50 cc. which flow through the aperture shall show a specific viscosity of not less than 20 nor more than 40.

6. Distillation. Fractional distillation by the method described in bulletin No. 38 of the U.S. Office of Public Roads shall give results conforming to the following requirements, all measurements being by weight:

Up to 110° C. the distillate shall not exceed 2 per cent.
Up to 170° C. the distillate shall not exceed 10 per cent.
The total distillate up to 315° shall not be less than 25 per cent.

Professor Agg in "Construction of Roads and Pavements" gives the following specifications for cold application on earth roads:

Specific gravity at 25° C. ........... 0.93
Fixed carbon .................. 6.00
Loss in 5 hr. at 163° C. ........... 25.00
(Residue from above slightly greasy)

Specific viscosity (Engler) 50 cc. at 50° C. 46.00
Solubility in carbon disulphide ........ 100.00 per cent
Bitumen insoluble in 86° naphtha ....... 8.50 per cent.

Dust Layers for Macadam Gravel Roads.

1. Petroled Oil (Specification).
Specific gravity at 25° C. not less than 0.93
Solubility in carbon disulphide, not less than 99.5 per cent and not over 0.3 per cent of organic insoluble matter.
Bitumen insoluble in 86° Be. naphtha not less than 3 per cent nor more than 15 per cent.
Specific viscosity (Engler) 50 cc. at 50° C. between 40 and 80.
Fixed carbon, not less than 3.5 per cent.
Loss on heating at 163° C. for 5 hr., not more than 20 per cent.
(residue must not be greasy)

2. Asphaltic Oil (Soft maltha, analysis).
Specific gravity at 25° C. ........... 0.961
Consistency by float test at 50° C. ........ 10.00 sec.
Loss on heating 5 hr. at 163° C. ........ 26.10 per cent.
(Residue sticky and asphaltic).
Consistency or residue by float test at 50° C. 2 min. 25 sec.
Solubility in carbon disulphide ........ 99.95 per cent
Organic matter insoluble in carbon disulphide .... 0.05 per cent
Bitumen insoluble in 86° Be. naphtha ....... 8.20 per cent
Fixed carbon .................. 3.70 per cent

3. Light Refined Tar (Analysis)
Specific gravity at 25° C. ........... 1.16
Consistency by float test at 50° C. ....... 25 sec.
Free carbon .................. 4.40 per cent
Distillation
Distillate to 110° C. ........... 6.00 per cent.
Distillate from 110° C. to 170° C. ..... 0.00 per cent
Distillate from 170° C. to 270° C. ..... 34.00 per cent
Pitch ..... 66.00 per cent

Messrs. Blanchard & Drowne, in their "Text-Book on Highway Engineering" give the following specifications for dust layers:

**Light Oil**

- Specific gravity at 25° C. ..... 0.92
- Solubility in carbon disulphide ..... 99.9%
- Fixed carbon ..... 5.3%
- Loss at 170° C. for 5 hours ..... 26.8%
- Viscosity Engler 50 cc. at 25° C. ..... 48.
- Insoluble in 88° B. naphtha ..... 9.8%

**Light Coal Tar**

- Specific gravity at 25° C. ..... 1.16
- Free carbon ..... 9.8%
- Distillation 105° C. ..... 6.0%
- Distillation 105° to 170° C. ..... 1.2%
- " 170° " 225° C. ..... 6.9%
- " 225° " 270° C. ..... 8.2%
- " 270° " 300° C. ..... 7.2%
- Pitch ..... 70.5%

The Arizona State Highway Department has successfully treated gravel roads with a California oil asphalt conforming to the following specifications:

1. "It shall be a natural asphaltum that has been refined or one made by the distillation of petroleum having an asphaltum base.

2. It shall be free from carbon and suspended soluble matter.

3. It shall be soluble in carbon bisulphide to the extent of not less than 99%.

4. It shall be soluble in carbon tetrachloride to the extent of not less than 98.5%.

5. It shall be soluble in 86° Baume gasoline.

6. Its penetration shall be from 100° to 125°. The penetration shall be taken according to the District of Columbia standard, with No. 2 needle, 100 grams for 5 seconds at 77° F.

7. Ductility shall be at least 100 cm. This test shall be made
with briquette of cross section of 1 sq. cm. material being elongated at the rate of 5 cm. per minute at 77° F.

8. Loss when 20 grams of the asphaltum shall be heated for 5 hours at a temperature of 325° F. in a tin box 2½" in diameter must not be volatilized more than 5%, nor shall the penetration at 77° F. after such heating, be less than one-half of the original penetration."

Many miles of gravel roads in Texas have been successfully treated by a double application of tar of two different grades, approximately 0.3 gallon per square yard of each grade being used. The specifications for these two grades of tar are as follows:

For First Application:

The specific gravity shall not be less than 1.14 nor more than 1.18 at 60° F. (15.5° C.)

The viscosity tested by the Standard Engler Viscosimeter shall not be more than 250 seconds or less than 100 seconds for 100 cc. at 104° F. (40° C.)

On distilling one hundred grams of the material to 338° F. (170° C.) not more than 7% shall distill over. On continuing the distillation to 572° F. (300° C.) the residue shall not be less than 65 grams. This residue shall be a soft pitch of 60° F. (150.5° C). If the residue appears hard, it shall be tested for melting point and the melting point shall not exceed 140° F. (60° C.) by the one-half inch cube method in water. The specific gravity of the entire distillate shall be not less than 1.01 at 60° F. (15.50° C.)

The free carbon shall be not less than 4% nor more than 12%.

In making the foregoing tests the following methods shall be employed:

**SPECIFIC GRAVITY**

The specific gravity shall be determined by the use of a Hubbard type specific gravity bottle. The bottle shall be filled with the liquid material at a convenient temperature. The bottle shall then be kept in a water bath at 60° F. (15.5° C.) until the level of the liquid, after adjustment to the mark, shows no further contraction. The bottle shall then be weighed. The weight of the material, divided by the weight of the same volume of freshly boiled distilled water at 60° F. (15.5° C.) is the specific gravity.

**DISTILLATION:**

A 250 c.c. Engler flask shall be used and 100 grams of the material taken for distillation. The apparatus shall be set up and the distillation conducted as provided for in the tentative method proposed by the American
The distillate shall be collected in weighed flasks and fractions shall be determined by weight.

Receivers shall be changed when the thermometer records a temperature of 328° F. (170° C.) When the thermometer records a temperature of 572° F. (300° C.) the flame shall be removed.

MELTING POINT:

A clean shaped 1/2" cube of the material shall be formed in the mould, placed on a hook of No. 12 (B & S. Gauge) copper wire and suspended in a 600 c.c. beaker so that the bottom of the cube shall be 1" above the bottom of the beaker (A sheet of paper placed on the beaker, and conveniently weighted, will prevent the pitch from sticking to the beaker when it drops off.) The curve shall remain five minutes in 4<sup>08</sup> c.c. of freshly distilled water kept at a temperature of 40° F. (4.5° C.) before heat is applied. Heat shall be applied in such manner that the temperature of the water shall be raised 9° F. (5° C.) each minute. The temperature recorded by the thermometer at the instant the material touches the bottom of the beaker shall be the melting point.

This test shall be made with apparatus similar to that illustrated on blue print herewith.

FREE CARBON:

The free carbon shall be determined by making a hot extraction of five to ten grams of material with C.P. Toluol followed by C.P. Benzol or C.P. Benzol followed by chloroform as solvents. The extraction shall be made in a Soxhlet, Knorr Underwriters, or some other suitable extraction apparatus. The distillation of the solvent shall be continued until the washings run through practically colorless.

VISCOSITY:

The viscosity shall be determined in a standard Engler Viscosimeter at 104° B. (40° C.) Sufficient material shall be placed in the viscosimeter to bring the surface of the liquid to a level with the tops of the three levelling points. The time required to discharge 100 cc. shall be recorded as the viscosity.

For Second Application:

The specific gravity shall be not less than 1.20 or more than 1.26 at 60° F. (15.5° C.)

The viscosity tested by the standard Engler Viscosimeter shall be not less than 125 seconds nor more than 200 seconds for 100 cc. at 212° F. (100° C.)

On distilling 100 grams of the material, no distillate shall come over below 328° F. (170° C.) On continuing the distillation to
572° F. (300° C.) not more than 25% of distillate shall come over. The specific gravity of the entire distillate shall not be less than 1.03 at 60° F. (15.5° C.) The residue from the foregoing distillation shall have a melting point not greater than 165° F. (74° C.)

The free carbon shall be not less than 12% nor more than 22%.

In making the foregoing tests, the following methods shall be used:

**SPECIFIC GRAVITY:**

The specific gravity shall be determined by the use of a Hubbard type specific gravity bottle. Approximately ten grams of melted material shall be placed in the weighing bottle and the weight taken after cooling. Freshly boiled distilled water shall be added and the bottle kept in a bath at 60° F. (15.5° C.) until no further contraction takes place. The water shall then be adjusted to the mark and the bottle removed from the bath and weighed. The weight of the material divided by the weight of the water displaced is the specific gravity.

**DISTILLATION**

A 250 c.c. Engler Flask shall be used and 100 grams of the material taken for distillation. The apparatus shall be set up and the distillation conducted as provided for in the tentative method proposed by the American Society for Testing Materials, Proceedings Vo. XI, 1911, page 241.

The distillate shall be collected in weighed flasks and fractions shall be determined by weight.

Receivers shall be changed when the thermometer records a temperature of 338° F. (170° C.) and when the thermometer records a temperature of 572° F. (300° C.) the flame shall be removed.

**MELTING POINT:**

A clean shaped ½" cube of the material shall be formed in the mould, placed on a hook of No. 12 (B. & S. gauge) copper wire, and suspended in a 600 c.c. beaker so that the bottom of the cube shall be one inch above the bottom of the beaker (a sheet of paper placed on the bottom of the beaker and conveniently weighed, will prevent the pitch from sticking to the beaker when it drops off.) The cube shall remain five minutes in 400 c.c. of freshly distilled water kept at a temperature of 40° F. (4.5° C.) before heat is applied. Heat shall be applied in such a manner that the temperature of the water shall be raised 9° F. (5° C.) each minute. The temperature recorded by the thermometer at the instant the material touches the bottom of the beaker shall be the melting point.

This test shall be made with apparatus similar to that illustrated on blue print herewith.

**FREE CARBON:**
The free carbon shall be determined by making a hot extraction of five to ten grams of material with C.P. Toluol followed by C.P. Benzol, or C.P. Benzol followed by chloroform as solvents. The extraction shall be made in a Soxhlet, Knorr Underwriters, or some other suitable extraction apparatus. The distillation of the solvent shall be continued until the hings run through practically colorless.

**VISCOSITY:**

The viscosity shall be determined in a standard Engler Viscosimeter at 212°F. (100°C.) Sufficient of the material shall be placed in the viscosimeter to bring the surface of the liquid to a level with the tops of the three levelling points. The time required to discharge 100 cc. shall be recorded as the viscosity.

The materials covered by the following specifications are suggested by the U.S. Office of Public Roads and Rural Engineering for the treatment of gravel roads, but they consider that sufficient information has not been obtained as yet to justify definite recommendations:

**SPECIFICATIONS FOR REFINED TAR TO BE USED FOR THE COLD SURFACE TREATMENT OF MACADAM ROADS.**

1. The tar shall be homogeneous and free from water.

2. The tar shall have a specific gravity of not less than 1.100 nor greater than 1.140 at 25°C.

3. It shall be soluble in cold c.p. carbon disulphide to at least 95 per cent and shall contain not over 5 per cent free carbon.

4. Upon ignition it shall show not over 0.5 per cent inorganic residue.

5. When 240 c.c. of this tar is heated in an Engler viscosimeter to 50°C., and maintained at the temperature for at least 3 minutes, the first 50 c.c. which flows through the aperture shall show a specific viscosity of not less than fifteen (15) nor more than thirty (30).

6. When one hundred (100) cubic centimeters of the tar is distilled according to the method recommended by Committee D-4, of the American Society for Testing Materials in 1916, the several fractions shall fall within the following limits by volume of the original material:

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Volume Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>170°C</td>
<td>2%</td>
</tr>
<tr>
<td>270°C</td>
<td>30%</td>
</tr>
<tr>
<td>300°C</td>
<td>40%</td>
</tr>
</tbody>
</table>
SPECIFICATION FOR REFINED TAR TO BE USED FOR THE HOT TREATMENT OF MACADAM ROADS:

1. The tar shall be homogeneous and free from water.

2. The tar shall have a specific gravity of not less than 1.130 nor greater than 1.220 at 25° C.

3. It shall be soluble in cold c.p. carbon disulphide to at least 85 per cent and upon ignition it shall show not over 0.5 per cent inorganic residue.

4. When a sample of tar is subjected to the float test the float shall sink in water maintained at 32° C. in not less than sixty (60) seconds nor more than one hundred and twenty (120) seconds.

5. When one hundred (100) cubic centimeters of the tar is distilled according to the method recommended by Committee D-4 of the American Society for Testing Materials in 1916, the several fractions shall fall within the following limits by volume of the original material:

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Volume Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>170° C.</td>
<td>not to exceed 1%</td>
</tr>
<tr>
<td>270° C.</td>
<td>20%</td>
</tr>
<tr>
<td>300° C.</td>
<td>30%</td>
</tr>
</tbody>
</table>

SPECIFICATIONS FOR ROAD OIL TO BE USED HOT IN THE SURFACE TREATMENT OF CLEAN, WELL CONSOLIDATED MACADAM ROADS.

1. The oil shall be a viscous fluid product, free from water and showing considerable adhesiveness when rubbed between the fingers.

2. It shall have a specific gravity of not less than 0.980 nor greater than 1.010 at 25° C.

3. It shall be soluble in carbon disulphide at air temperature to at least 99.5 per cent and shall show not over 0.1 per cent inorganic matter insoluble.

4. It shall contain not less than 10.0 per cent of the total bitumen insoluble in 86° B. paraffin naphtha at air temperature.

5. When 240 c.c. of the oil is heated in an Engler viscosimeter to 100° C. and maintained at that temperature for at least three (3) minutes, the first 50 c.c. which flows through the aperture shall show a specific viscosity of not less than fifteen (15) nor more than thirty (30)

6. When twenty (20) grams of the material is heated for five (5) hours in a cylindrical tin dish approximately two and one-half (2½) inches in diameter by one (1) inch high, at a constant temperature of 182° C. the loss in weight by volatilization shall not exceed fifteen
(15) per cent. The residue must be decidedly sticky, and when subjected to the float test on water maintained at $50^\circ$ C. the float shall sink in not less than two (2) minutes.

7. Its fixed carbon shall be not less than 6.0 per cent.

It must be understood that there are probably other materials than those specified above which will give satisfactory results, and all engineers in charge of such work should keep careful records of the materials used and the results obtained, so that others may profit by their experience.