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THE
UNIVERSITY OF MISSOURI
BULLETIN

VOLUME 17 NUMBER 16

ENGINEERING EXPERIMENT STATION SERIES 17 ✓

EARTH ROADS AND THE
OILING OF ROADS

BY
H. A. LARUE,
INSTRUCTOR IN CIVIL ENGINEERING



UNIVERSITY OF MISSOURI
COLUMBIA, MISSOURI
JULY, 1916

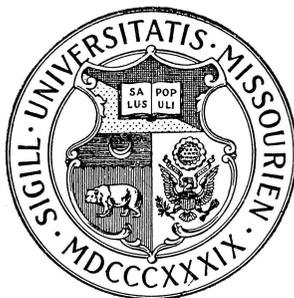
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INTRODUCTION

An extensive mileage of good roads is the most insistent demand of the general public at the present time. To improve any considerable portion of our highway system, the use of some cheap type of improvement is absolutely necessary. The objections to high taxes precludes the possibility of building a great system of hard surfaced roads at present. Cheap roads are needed to reach out and serve the rural districts of the State. In order that any system of improved highways may be provided by the general public, it must serve all who help pay for it. This can be accomplished only by making use of the earth roads as they now exist, and gradually extending the system.

This bulletin seeks to emphasize the advantages to be obtained from the use of inexpensive methods of improving earth roads, which may make it possible for every farmer to have a good road to his very door without burdensome taxation.

Information for this pamphlet has been drawn from all reliable sources available to the writer, and he wishes to acknowledge his indebtedness to these sources. Much has also been drawn from that common fund of knowledge relating to road improvement that is the property of all. Nothing startlingly new is here offered, but attention is directed to some details that are frequently overlooked, even in the use of old methods, which are necessary to obtain good results.

The cuts for the oil distributing machinery were kindly furnished by the Austin-Western Road Machinery Co. of Chicago, to whom the writer extends his thanks.

H. A. LARUE

April 1916.

EARTH ROADS

GENERAL CONSIDERATIONS

Preliminary. In making plans for the improvement of a road, the question of type best suited to the particular need must first be determined. The selection of a proper surfacing material depends primarily on amount and character of traffic, cost of the improvement and the amount of money available. These questions are persistent and precede all forms of improvement, whether of ordinary earth roads or the highest types of pavement. However, most propositions relating to road improvement are assumed to refer to broken stone roads, since attention has been centered on this type for a long time, and other means of improving roads have been seldom considered. In some cases a broken stone road is not the proper road to build, since it may not adequately meet the needs of traffic. A more durable wearing surface, such as bituminous macadam or brick, will often prove more economical in the long run, although the first cost may be much greater.

Need for Earth Roads. Promoters of road improvement often assume that the only good road is that which has some sort of hard surface, requiring an outlay of several thousand dollars per mile. A survey of conditions in the middle west shows this view to be unwarranted. For a long time to come, it will be wise to seek the best results possible from the promotion of earth roads. A majority of the public roads in Missouri do not serve sufficient traffic to justify the expense of broken stone surfaces, nor will funds be available for such work for many years. In fact there are many miles of earth roads that will always remain earth roads. This bulletin offers suggestions for improving these highways with the full realization of the present impracticability of attaining hard surfaces. When it is realized that of more than 120,000 miles of public roads in Missouri, only about 8000 miles have been given a hard surface, the importance of some means of immediate improvement of earth roads can be readily appreciated.

How to obtain Good Roads. Good roads can be obtained by proper methods of construction and maintenance of earth surfaces, and this fact has been proven beyond a doubt by actual results in some localities in the state. The cost of such work is so low that it should appeal to everyone interested in having an extensive mileage of good



Fig. 1. Surface Oiling of Road

roads. The earth road has for so long a time been considered as of little value, an evil to be endured, and at best only temporary, that it may be interesting to note opinions expressed by highway engineers, who have given to the subject considerable study.

The Question of Permanency. In the October—November, 1915, issue of the official publication of the Illinois Highway Department, Mr. H. E. Bilger, Road Engineer, says:

“In the recent revision of the Illinois Tice Road Law, the legislature has seen fit to speak of permanent earth roads, while to the various types of surfacing material for the earth roadbed, there has not been made any mention regarding the probable life of the work. This has been the occasion of provoking some rather humorous comment upon the part of those familiar with the behavior of the Illinois soils when saturated with water. Upon second thought, however, it will be appreciated that the term ‘permanent’ can more properly be applied to an earth road, than to any other type that has yet been devised. With whatever materials we may choose to construct the wearing surface on the earth road, the fact remains that the life of this surface is of but a temporary character as compared with the life of the roadbed formed by old Mother Earth underneath.

“In considering the life of an earth road it would be very superficial, indeed, to consider only the physical condition of the upper few inches of the road surface. With satisfactory original construction, the condition of this surface is dependent upon the faithful maintenance, while the earth road as a type in itself consists more properly of the horizontal and vertical alinement, the width of graded roadway, and the angle of the side slope for cuts and fills. As the improvement in these respects is made to conform to the requirements of both the traffic and the action of the elements, it will be appreciated that in no other character of work does there prevail the inherent permanency as when a volume of earth is taken from where it will never be needed and put where it will always be needed.

* * * *

“The real road maintenance problem in Illinois for many years to come will consist in dealing with the earth road which constitutes more than 90 percent of the entire rural mileage. Without maintenance, it almost ceases to perform the functions of a public highway, but with proper maintenance no other road responds so effectively to the real needs of the traveling public as does the ordinary earth road. Between the present condition of our earth roads and the condition to which they could be brought and maintained by just a little intelligent effort, there exists a gap that is far beyond the realization of the general public. The earth road has never been given even half a chance to make good. With the same opportunity to make good that has been afforded other types of roads, I am satisfied that for a selected 70 percent of total rural mileage the humble earth road would show up for true serviceability far beyond any type of hard road feasible for Illinois.”

CONSTRUCTION

First Principles. The first step in the improvement of an earth road is to construct the road. To speak of "*constructing* an earth road" may seem paradoxical, but it is just as necessary to construct an earth road as it is to construct a hard surfaced road. It is generally understood that to obtain a good hard road, it is necessary to first build a good earth road. Few realize, however, that to have a good earth road, it must be properly constructed. The same fundamental principles are involved in the construction of both types.

Possibilities of Earth Roads. Mr. L. W. Page, Director of the U. S. Office of Public Roads, says:

"We have lived so long with our earth roads at their worst, that we fail to see that vast improvement is possible. This, too, need not jeopardize further improvements and still better roads, such as gravel or macadam. A good earth road is the stepping-stone to a hard road. It is the foundation of all future improvements, and with proper future plans may be constructed at once. A comparatively small annual outlay for maintenance will keep it in shape until funds are available for a hard surface. But to expect a good earth road where none has ever been built, is like expecting a harvest from untilled ground. The earth road must be built just as much as a gravel or macadam road must be built, and as much skill and experience is required to secure the best results for the money expended."

Construction Problems. Earth road improvement involves three operations, viz., establishing the best possible location, providing adequate drainage structures, and completing the necessary grading. These three operations may all be properly termed, permanent improvements.

Location. In most cases the location of a road is approximately fixed by local conditions and is not subject to material change. An extended revision of location is usually impossible, due to permanent buildings along the way, or on account of property or other interests. In some places and for short stretches, a change in location may be accomplished that will be a decided improvement. It is often possible to avoid a steep hill, and a better stream crossing may sometimes be obtained. Occasionally a stream crossing may be eliminated by a slight change in alinement and at an expense much less than the cost of a bridge. Such changes should be made whenever possible, and frequently they are economical in the long run even if accomplished at a considerable initial expense. Do not lose sight of the fact that money expended to improve location will insure a permanent dividend in reduced costs of operation and maintenance.

Drainage Structures. Culverts and bridges should be of a permanent type, such as reinforced concrete, or steel bridges with concrete floor on concrete abutments. The superior economy of permanent bridges over the temporary wooden or timber types is well estab-

lished and quite generally recognized. The importance of accurately designing these structures cannot be too strongly emphasized. The most common fault is not so much lack of attempt at design as it is of incorrect design. Traction engines, which are somewhat heavier than in former years, and the growing use of the automobile are factors in determining the loads a structure must carry. A bridge should be designed to carry the heaviest load that will be likely to come upon it.



Fig. 2. Concrete Culvert in Nodaway County

An adequate waterway is a necessary feature of a well designed bridge or culvert. An inadequate waterway is frequently the cause of much damage to the road, and often becomes more expensive in the long run than a larger culvert would have been. The safest method to determine the capacity of the waterway required for any given site, is to note the highest mark attained by the stream during flood. In some cases it may not be possible to build a bridge to carry the flood waters, but these cases are exceptional. Generally speaking, the size

of the waterway should be sufficient to carry the largest volume of water that may be discharged by the stream.

The location of the bridge is an important consideration. A bridge is sometimes set out of the line of travel in order to fit the stream. This is not good practice and may be avoided by skewing the bridge, making the barrel follow the stream bed, and at the same time, allow the roadway to cross the bridge in a straight line.

The roadway between end rails of the bridge should be wide



Fig. 3. Small Culvert with End Walls

enough to allow vehicles to meet upon it, a distance of at least 16 feet in the clear. It has been truly said that a road is no wider than the bridges on it.

A great many accidents occur at small culverts overgrown with weeds, and the value of headwalls on such culverts cannot be over-emphasized. Holes will wash into the roadway at unprotected ends, and these, unnoticed by travelers, often result in causing serious accidents.

GRADING

What is Involved. The process of grading may be divided into two parts:—Excavation and embankment for the reduction of hills,

and the shaping or crowning of the roadway for surface drainage. These two operations constitute the constructive work of building the roadway. Both operations require considerable skill and experience in order to obtain the best results.

Steep hills on a road should be eliminated wherever possible, and when it can not be done by a change in location of the road, it may be done by cutting them down and filling the low places. The steepest hill on a road limits the weight of load that can be hauled over it.



Fig. 4. Showing Crowned Roadway with Side Ditches Open

Effect of Hills. The effect of gradient or slope has been estimated as follows:—On a smooth hard surface, on the level, the average horse can pull a load of about 6200 pounds; on a five percent grade the same horse can pull only 1800 pounds, and a ten percent grade he can pull but 1000 pounds. Travelers often take a longer route in order to avoid a steep hill. It is an inexcusable waste of energy to pull a load up one side of a hill only to be required to hold it back while going down the other.

However, this waste of energy is not the only disadvantage of a steep grade. Both the cost of construction and of maintenance of a hilly road is much higher than for a level road. If the longitudinal slope of the road is greater than the transverse slope the rains will cut deep gullies in the center of the track before it can reach the

side ditches. Also traffic on a hilly road will break up the surface much faster than like traffic on a level stretch. Therefore, money expended in cutting down the steep hills is a good investment, and will often prove to be a real saving in the long run.

Slopes across the Roadway. The crowning or transverse sloping of a road is one of the first essentials to secure satisfactory surface drainage. The most common and persistent cause of bad roads is the water that remains on the surface of the road after a rain. If it is allowed to remain on the roadway even for a short time, the traffic will work it up into mud and form ruts hub deep. A sufficient crown continuously maintained, and deep wide gutters at the sides to promptly carry off this water, will insure a smooth and solid roadway even if made of earth. In a level country the roadway should be built up well above the general level of the adjacent land, with side ditches deep enough to keep the water at least two feet below the crown of the roadway. If, due to seepage, ground water causes soft spots, it will be necessary to remove it by tiles, properly laid and connected to an outlet. No other phase of earth road construction and maintenance is of such prime importance as drainage, both surface and sub-surface. Without proper drainage no improvement will be certain of any degree of permanency. Concerning this feature a southern editor is quoted as saying:

“A fruitful source of waste is in failing to employ proper methods of drainage when a road is improved or repaired. Expensive surfaces can be put on roads later, but good drainage makes a satisfactory roadbed for any kind of road surface. Formerly there was nowhere any carefully laid plans for road improvement year by year. Nothing was done until certain parts of the road became practically impassable. Then there was a cry that something be done at once, but this is what it was: The road officials set aside money for the purpose, and the contract was given to some jobless man or to a political leader. In either case the result was the same,—waste, heart-breaking waste.

This occasional road builder usually piled a few scraperfuls of dirt in the stretch of road where he was operating, making a rough, tumbled grade; over this he scattered a little gravel, called the job completed, and drew his money. The first rain washed away the gravel; the second let wagon wheels mire to the hubs. Then there was another hue and cry, and the whole process was repeated at more or less regular intervals. Washouts, indeed, both of dirt and dollars.”

MAINTENANCE

Value of Maintenance. When the construction of a road is finished the problem is not completely solved. Some adequate scheme of maintaining the road in good condition is necessary in order to obtain full benefit from the improvement. Even the more expensive types of hard roads require constant maintenance and the cost of repairs is nearly proportional to the cost of construction. The earth road costs less

to construct and also less to maintain, than any other form of improvement, but the work must be done at the right time and in the right way to get satisfactory results.

The King Road Drag. For maintaining the earth road the most effective and economical device is the King Road Drag. The use of the road drag is so generally known that it seems unnecessary to further describe it here. However, the results that may be obtained with this simple implement are so generally under-rated that a repetition of its possibilities may not be out of place. When properly used, and at the right time, this road drag performs four distinct offices.—First, by moving at an angle to the traveled way it tends to produce and preserve a crowned roadway. Second, if when the surface material is not compact and hard, it reduces the ruts and other irregularities in the road by cutting down the bumps and filling the holes. Thirdly, when used after a rain it hastens the drying out of the road by spreading out any accumulated puddles of water, and thus increases the surface exposed to evaporation. Fourthly, if the surface material is in a slightly plastic state, dragging smears over and seals the pores in the earth, and thus helps to make the road surface more or less impervious to water.

If used improperly or at a wrong time the drag may do actual injury to a road surface. Dragging a very dry road for example, serves to increase the amount of dust produced, and may cause additional damage by destroying the seal formed during a previous dragging. If, on the other hand, the road is very wet and muddy, the irregularities of the surface are likely to be increased rather than diminished by dragging.

The drag should be used soon after a rain, but not until the ground has lost its stickiness sufficiently to allow the material to slide easily along the face of the drag; the road however, should not be quite dry in any place. Not much improvement will be noticed after the first trial with the drag; some of the ruts will be filled and some bumps slightly cut down, but after a few additional trials the benefits will become more apparent. It is perfectly true that any one can use the drag, but the skill required to secure the best results will come only after some practice.

Specific Instructions. The following points should be remembered in the construction and the use of the drag:

Build a light drag; one that can be easily lifted is heavy enough. Any drag that requires more than two horses to pull it is too heavy and should be discarded or used only on gravel roads. Hitch the horses so that the drag scrapers will travel at an angle of 45 degrees with the center line of the road, and do not try to cut too much material at one operation. The amount moved depends wholly upon the length of hitch and the position of the driver. A long hitch will move more earth than a short one. When a hard spot must be cut, the driver throws all his weight on the front plank; when a soft spot

must be filled, he move back on the drag. If the crown becomes too high he should reverse the drag and move some of the material toward the ditches, taking care to smooth it down evenly. Until our country roads have been dragged for some time, very few of them are likely to get too much crown.

The team should be driven at a walk and the driver ride the entire distance, going forward on one wheel track and back on the other. Do not try to improve too wide a section at one operation.

Do not build too long a drag; for narrow roads, it should be half the width of the travelled way, and in any case a nine or ten foot drag is long enough. Do not attempt to maintain a section of too great an extent. So much depends on the condition of the material when the machine is used, that there is danger of dragging the road too wet at one end and too dry at the other.

Effects of Dragging. A well dragged road will be free from mud and ruts in winter and comparatively free from dust in summer. The tractive force required to haul a load over it, is as low as over a gravel surface, and in most cases no further improvement will be required until it is desired to cover it with macadam.

Costs. The cost of maintaining earth roads with the use of the drag is nominal. Roads in the middle west have been dragged as cheaply as \$2.50 per mile per year, and the highest cost was under \$10 per mile per year. Even unusual conditions, the maximum cost would probably never be more than \$25 per mile per year.

A comparison between the cost of building and maintaining a macadam and an earth road may be of some interest.

The permanent features such as location, bridges, culverts and grading, are common to both types of road and may be left out of the comparison:

	Broken Stone	Earth
Cost per mile for furnishing and placing stone		
on road, a low estimate	\$4000.00	
Interest on investment @ 5%	200.00	
Maintenance	250.00	
Dragging		\$25.00
Total annual charge per mile	450.00	25.00

For interest on investment and cost of maintaining one mile of macadam road, about fifteen to twenty miles of earth road can be kept in excellent condition the greater part of the year, and in passible condition during the two or three months in winter, when conditions are at the worst for maintaining a good surface.

Not Intended to Discredit Broken Stone Roads. In the foregoing it is not intended to convey the idea that broken stone roads should never be built, but it is desired to emphasize the advantages from intelligent effort applied to the maintenance of the earth road where it is impracticable to have broken stone or gravel roads. Indeed, there are a great many roads where the traffic is too heavy for an earth road

to be kept in good condition, and some type of hard surface is necessary. This by all means, should be constructed to meet the demands of traffic as soon as the financial condition of the community will allow.

OILING ROADS

Historical. The first attempt, in this country, to treat road surfaces with oil was made in Santa Barbara County, California, in 1894, Crude petroleum from the Summerland wells was sprinkled upon an earth road for the purpose of laying the dust. It proved very effective as a dust preventive, and having an asphaltic base, it improved the condition of the road surface to such an extent that popular attention was aroused. As a result, many experiments were commenced with a view not only to lay the dust, but to bond the surface as well. By 1899 the treatment of roads with both crude oils and oils from which the more volatile substances had been removed, the so-called residual oils, had extended to a number of other states, and by 1902 experiments had been reported from Texas, Pennsylvania, New Jersey, Indiana, Colorado, and the District of Columbia. In 1904, the field had still further broadened, but the work had all been of an experimental nature and the most widely varying results were reported. The only important fact that had been generally established as to the relative value of different petroleums, was that the oils with paraffin base had not proved satisfactory for road treatment, but that those with an asphaltic base were to be preferred. Road engineers had begun to realize that in order to produce good results something more was necessary than to pour any kind of oil upon any kind of road surface. Oil sprinklers, or wagons fitted with spreading devices, had become quite common, and the use of the heavier crude and residual oils which required heating before they could be successfully applied was regarded as the best practice. In 1905 the use of oil for road treatment advanced rapidly, and since that time, owing to the very widespread interest in the problems of dust suppression and road preservation, the total mileage of oil treated roads has increased by leaps and bounds. Road oil industries have been developed for the purpose of producing and selling oils suitable for application in a variety of ways and under varying conditions.

GENERAL CONSIDERATIONS

When Oil Should be Used. Under favorable conditions oils may be applied to earth, gravel, and broken stone roads with good results; and, in any case, application may be made either to the surface of an old road or to the body of a road during resurfacing or construction. A number of distributing devices have been invented for the purpose of facilitating application, and special machinery has been designed for convenient handling and transportation of oil as well as for incorporating it with the road-material.

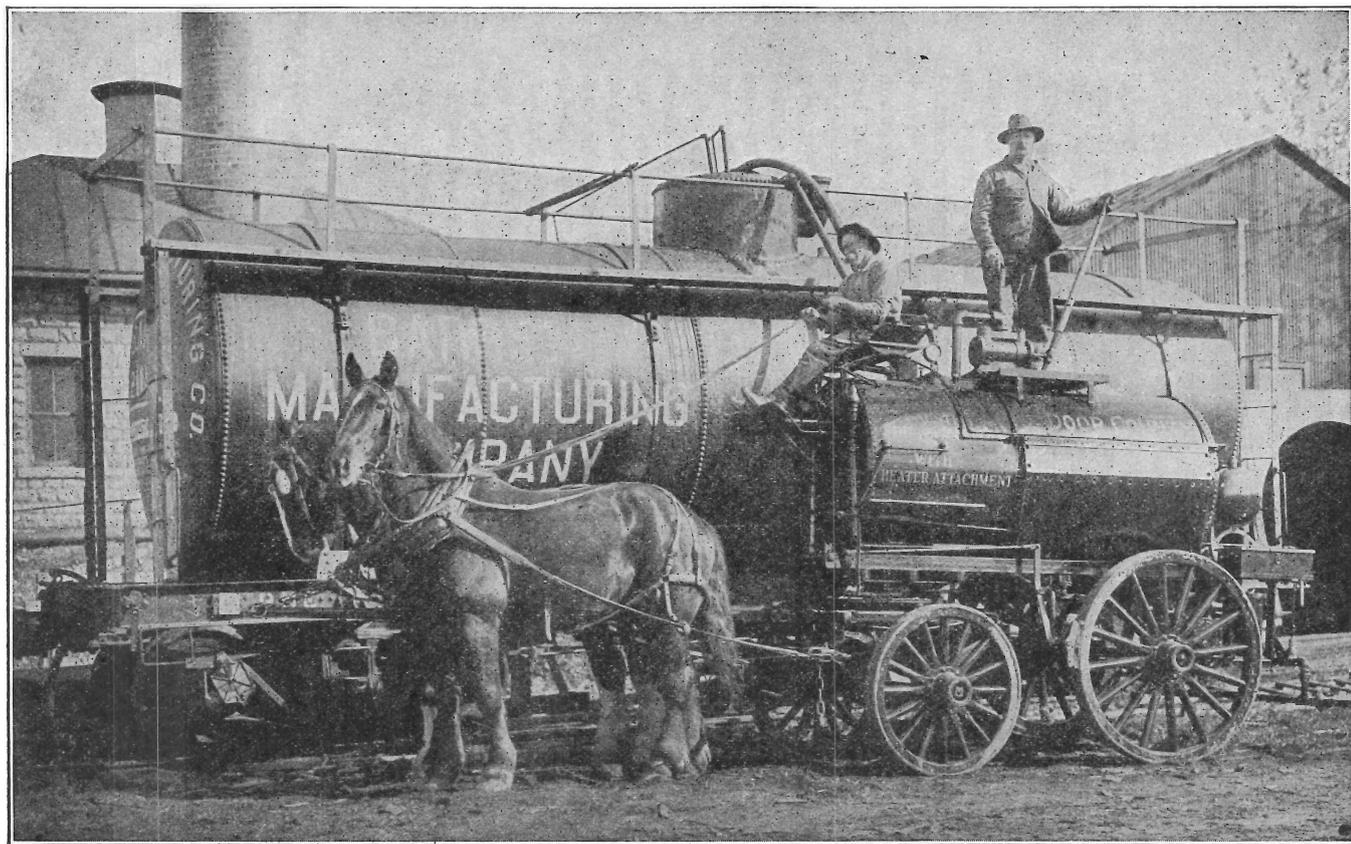


Fig. 5. Loading Distributing Wagon

Light and Heavy Oils. The lighter crude oils, if sufficiently fluid, may be applied cold. When applied cold, they should be spread in only sufficient quantity to saturate the dust on the road. A number of light applications during a dusty season is to be greatly preferred to a single heavy one, for the latter is apt to be incompletely absorbed by the road and will require sanding, in order to take up the excess oil. Even then the surface will become greasy and slippery, unless the oil is very asphaltic in character, and it will cut up badly under traffic in wet weather.

Quantity to be Used. No definite rule can be laid down as to the proper quantity to be applied, because of the variation in the capacity for absorption of different road surfaces. Earth roads will require more than gravel, and gravel roads more than macadam. The consistency of the oil itself may often modify the amount required, as the very fluid oils will be absorbed more readily than those which are of a more viscous nature. The ideal treatment is to use just sufficient oil at one application to lay the dust, and at the same time to prevent the formation of an undesirable surface condition. It is, of course, a difficult matter to estimate this quantity closely, but for macadam roads it will average from one fourth to three fourths gallons per square yard, and for earth roads sometimes as high as one and one half gallons or more per square yard. Gravel roads will require an intermediate amount. If crude asphaltic petroleums, containing relatively large quantities of volatile matter, are used they may develop considerable binding power in the course of time, under ordinary atmospheric conditions. When crude oils are subjected to a partial refining, the lighter ingredients are evaporated off, leaving a heavy residuum, which is used to produce the residual road oils. When the residuums are obtained from oils containing an asphaltic base, they will have greater binding power than will be the case if the base is paraffin.

Effects of Oiling. A road treated with the asphaltic base oils should compact readily under traffic and form a smooth waterproof surface. It was this property of asphaltic base oils that first aroused public attention in California and gave an impetus to the general use of road oils.

Heating Oils. The heavy crude and viscous residual oils require heating before they can be successfully applied to a road surface. Such materials, to be satisfactory, should serve as semi-permanent binders, since the cost and trouble of applying them is too great to allow their use merely as dust preventives. They may be purchased by the barrel or by the tank car, the latter being cheaper, and preferable from the standpoint of heating, if the car is properly equipped with steam coils for that purpose.

For heating the road oil in these tank cars, all that is necessary is to attach a thresher engine or an old boiler and heat with steam until the oil is sufficiently fluid to spread easily. It may then be

pumped into a distributing tank wagon, or run in by gravity and applied to the road by means of an oil sprinkler.

Sprinkling Machinery. There are several types of oil sprinklers on the market; those which distribute the oil by gravity, a type which is used for spreading light crude oils that will flow easily while cold; others which are equipped with compression chambers for the purpose of forcing the oil upon the road in a fine spray. The latter type is recommended for use with oils that are too heavy to run cold, and therefore need to be heated before spreading. By this means, a uniform distribution can be secured and the quantity of oil applied per given area easily controlled.

Machinery manufacturing companies also make an oiling attachment that can be easily fastened to an ordinary sprinkling wagon. Provision is made for bolting the attachment to the rear end of the wagon. These attachments are also of two types, operating by gravity or by pressure. To obtain pressure, a pump is attached, which is run by a chain drive on the rear wheel of the wagon. These attachments give satisfactory results and will prove more economical than spreading by hand pouring cans.

SELECTION OF ROAD OILS

Grades of Oils. There are various grades of road oils on the market, some of excellent quality, but many of no value as road binders. For different classes of road surfaces, different kinds of oils are necessary in order to obtain satisfactory results. This article will discuss some of these kinds of oil and point out the qualities that should determine selection.

Factors Involved. The various factors to be considered in classifying and selecting road oils and which may be determined by laboratory tests, are as follows:

1. Specific gravity.
2. Total bitumen.
3. Naptha insoluble bitumen.
4. Fixed carbon.
5. Viscosity.
6. Loss on evaporation.

An explanation of the meaning and the interpretation of each of these items is here offered.

The specific gravity of road oils varies from 0.93 for the light oils to about 0.98 for the heavier grades. The heavier oils are likely to be better binders than the light ones.

The total bitumen is determined by dissolving the oil in cold carbon bisulphide; any insoluble material is considered as an impurity and is limited to a very small amount by specifications. Most specifications call for 99.5 per cent soluble in carbon bisulphide, an allowance for impurities of 0.5 per cent.

The naptha insoluble bitumen, means the percentage of the bitumen in the oil which is insoluble in 86°B. Paraffine Naptha. This

per cent insoluble. The insoluble portion is the heavy ingredient of the oil and measures its stability under weathering conditions on the road.

The fixed carbon is that part of the oil which remains as a residue after the more volatile parts have been burned off in a gas flame. Paraffine oils run low in fixed carbon, the semi-asphaltic oils contain more, and the asphaltic oils a still greater amount of carbon. These percentages offer an approximate determination of the binding power of the oil, since an asphaltic or high fixed carbon oil will have greater binding force than a paraffine or low fixed carbon oil. The range of the fixed carbon content is from about 2.5 per cent to 13 per cent.

Viscosity measures the tendency of the oil to flow at various temperatures. Some oils are so fluid that they will pour easily at ordinary temperatures and can be applied to the road cold; others are too viscous and require heating to spread well. Tests for viscosity will determine whether it is necessary to heat the oil before application.

Loss on evaporation is generally limited to 25 per cent when the oil is subjected to standard temperature, 163°C., and under standard conditions for five hours. If an oil loses too much by evaporation, there is danger of poor results from the oiling, as this loss will often change the character of the oil. In some cases the evaporation may be so great that the oil will almost entirely disappear from the road in a short time.

Value of Laboratory Tests. Too often, proper consideration is not given to the selection of oils for road work. It is impossible to select good road oils by mere visual inspection, since they differ very little in appearance, although varying widely in physical characteristics. Laboratory tests are necessary to determine these physical characteristics. The final conclusion as to the suitability of an oil for any given road can be reached only after a trial on the road under existing traffic and weather conditions. However, laboratory tests will give material aid in the selection of the oil, and prevent the use of an oil wholly unfit for the particular work contemplated. The tests will prove of especial value in making it possible to duplicate successful work.

Suitability of Oils. For macadam roads that have a raveled surface, or are loosely bonded, the heavier grades of oil are used. For a smooth, hard, well bonded macadam surfaces, a thin oil is recommended. This will penetrate the surface better, and will give greater service than the heavy oils under average conditions. A clean gravel, composed of rounded stream-washed particles, which do not compact well under traffic, will require a heavy oil to furnish a proper binder for the surface. A gravel containing enough clay to cement the particles together will present a hard smooth surface and should be treated with the thinner oils in order to obtain better penetration of such surfaces. On earth roads a sandy soil will absorb oil more readily than a clay soil, and consequently the heavier oils are suitable for sandy soils, while the lighter oils are required for loam or clay.



Fig. 6. Bad effect of spreading oil on top of dust

METHODS OF OILING EARTH ROADS

Purpose of Oiling. The purpose of oiling an earth road is to secure a surface layer of dirt, two to four inches in depth, thoroughly mixed with oil and compacted to form a waterproof crust, which will prevent the rain that falls on the road from sinking into the ground and softening the foundation. This layer of oiled earth will, if properly constructed and maintained, act as a roof and shed the water to the sides. The oil fills the open spaces between the particles of the road surface, and since oil and water do not readily mix, it is almost impossible for the rain to penetrate this outside covering. By using oils of proper consistency, containing an asphaltic base, the road surface should compact under traffic and finally form a hard smooth track. The binding power of the oil will hold the dust on the road, and eliminate the clouds which ordinarily prevail on earth roads in the dry season. Thus the surface will be easier to maintain in a smooth condition, since there will be less wear from travel and less washing from the rains.

To Obtain Best Results. To secure the desired improvement of an earth road by oiling it, careful attention must be given to the proper method of applying the oil. In a great many cases, oiling has been considered a failure, due to improper methods of application; where oil is spread on top of a thick layer of dust, as shown in Fig. 6, or where the road surface is full of ruts and holes, very unsatisfactory results have been obtained. The dust will prevent the oil from penetrating the surface, and it will collect in pools in the holes and ruts or will run off into the gutters at the sides of the road. This greasy dust is injurious to vehicles, ruining the varnish, and rotting rubber tires. It is picked up on shoes and carried into houses, ruining rugs and carpets. These are very serious objections offered by people living near an improperly oiled road. During wet weather conditions are even worse, for a very disagreeable mud is formed, due to the presence of the oil in the dust.

Surface Oiling. The purely surface treatment of earth roads with oils is now almost a thing of the past. It has been found more satisfactory to harrow the oil into the body of the road, and practically construct an oiled earth road. If only a surface application is to be made with an asphaltic oil, the surface may be improved to some extent by the formation of a thin crust of oiled earth, which will, however, break and scale off.

Preparation for Oiling. To make the application of oil to an earth road a success, it is necessary to properly prepare the road bed a season or two in advance of the oil treatment. To do this, the first and most important step is drainage. All culverts should be properly located and constructed, the road graded up and all side ditches and drains cleaned out in order to allow the water to get away from the road as quickly as possible. The best type of pavement will quickly de-

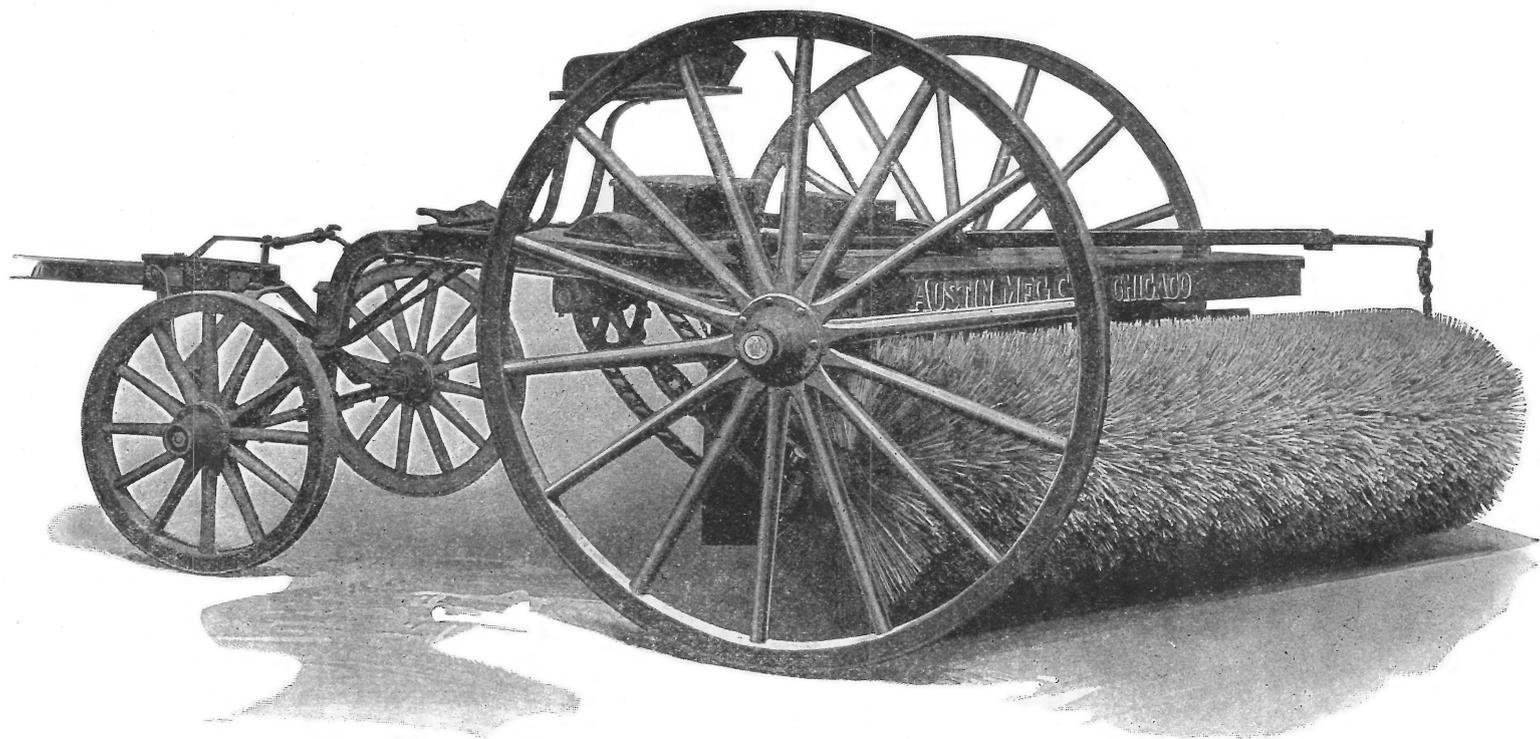


Fig. 7. Mechanical Street Sweeper

teriorate if the water is allowed to remain on its surface and seep into the foundation. It is useless to expect oil alone to make a good road out of a bad one.

Seasoning of Roadway before Oiling. When any heavy grading is done, such as fills of three or four feet or more in depth, it is absolutely necessary to have the work done a year or more in advance of the oiling to allow the embankment to settle and be compacted by travel. Otherwise, ruts and chuck holes will form and the oil will disappear from the surface due to the spongy condition of the road bed. After all grading is done, and while the freshly made fills are settling, it is necessary to keep the road well dragged, in order to smooth out the ruts and holes as fast as they form. This dragging with the travel, will settle and compact the road bed, and form a proper foundation for any kind of surface treatment.

Application of Oil. To apply the oil, which should be done during dry and warm weather, the surface dust is swept to the sides forming a small ridge at each side of the width to be oiled. These ridges of dust will hold the oil on the road and prevent it from running to the gutters while spreading and working it into the surface material. The sweeping may be done by hand with push brooms. If a street sweeper is available, it will serve the purpose much better and greatly lessen the amount of labor. About two trips with this sweeper is sufficient to remove all the dust. After the road is swept clean the surface should be harrowed with a sharp toothed harrow, well weighted down to loosen an inch or two of the surface. This will enable the oil to penetrate readily. Then spread the oil in a thin layer and harrow it in. It is better not to apply all the oil at once, since it will be easier to work it into the earth if applied in small amounts at each trip of the oiler and then harrowed. After sufficient oil has been applied and harrowed until thoroughly mixed with the earth, the ridges of dust which were swept to each side, should be spread evenly over the surface with a road drag. This dust will take up any excess oil on the surface and prevent a sticky condition. Then a light rolling, with an ordinary farm roller, will compact the surface sufficiently to be thrown open to use.

After this, the road should gradually increase in compactness under the ordinary volume of traffic. For the first week or so, the road should be carefully observed and if any tendency develops to form ruts, a light dragging may be necessary. The use of too much oil should be carefully avoided, as it will produce a spongy surface, which will cut up badly under traffic and increase the draft of vehicles.

Excess of Oil. Should any excess of oil appear, all that can be done is to drag in fresh dry earth from the sides of the roadway and cover the oiled section with a thin layer of dirt to take it up. Traffic should not be allowed to go upon the oiled section for a day or two after treatment in order to allow the oil to penetrate into the soil. If open to traffic too soon after applying the oil, there will be a tendency for

the wheels of vehicles to pick up the oiled material and thus break the surface.

Maintenance of Oiled Roads. The method of maintenance of an oiled earth road is the same as that for the ordinary earth road, i. e., the use of the road drag at the proper time. If the surface is kept smooth, the oiled earth will form a roof to shed the water that falls on it, and if the water is not allowed to stand in the ditches until it seeps into the foundation of the road, a hard smooth surface can be maintained for practically the entire year. This simple feature of road maintenance, drainage, can not be given too much emphasis, since it is the most essential element in any scheme of road improvement.

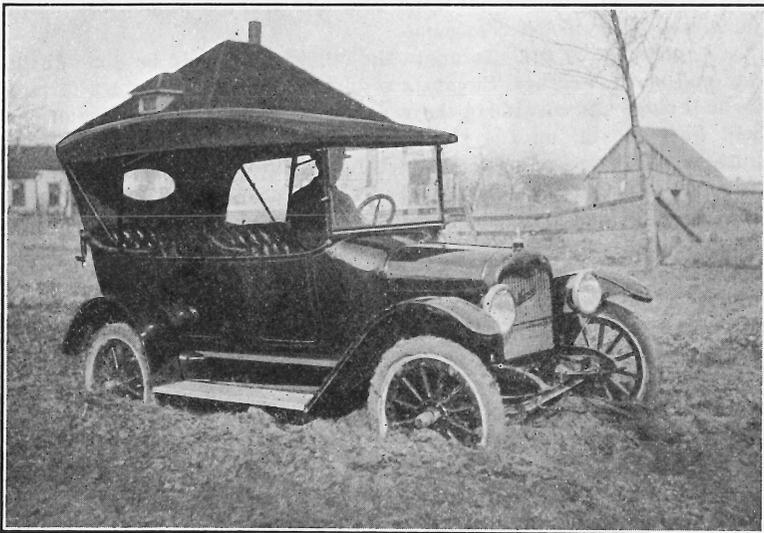


Fig. 8. Early Spring on Road Not Oiled

Figs. 8 and 9 show the effect of proper maintenance. These views are on the same road less than 500 feet apart, and were taken February 22, 1916 just as the winter frosts had left the ground. Fig 9 proves the value of dragging and oiling in preserving a foundation.

The cost of oiling earth roads is variable for different localities and an estimate of the cost of oiling will therefore be in the nature of a guess. The amount of oil needed varies for different soils, its price is variable and the cost of transportation is dependent on the distance it has to be conveyed. However, according to records of work that has been done, some idea of probable cost can be roughly approximated.

Quantities of Oil. For a width of finished surface of twelve feet, the amount of oil required for a mile of road will be about 7000 gallons, assuming that one gallon per square yard is used. With oil at two and

varies with the different grades of oils, being less for the light oils and greater for the heavier oils. The range is from 5 per cent to 25 a half cents per gallon at the refinery, and freight at eighty cents per 100 gallons, the cost of the oil will be about \$235 per mile of road. The cost of applying is ordinarily from \$50 to \$75 per mile. This will make a total cost of about \$285 to \$310 per mile of twelve feet roadway. The first oiling will be the most expensive, since less material will be required for the subsequent oilings.

Summary. Summarizing, the principal items in the proper oiling of earth roads to obtain good results are as follows:—

1. Proper drainage of both surface and subsurface.



Fig. 9. Effect of Oiling. Same Road as Shown in Fig. 8

2. Heavy grading done at least one season in advance of oiling.
3. Proper shaping of roadway to form good crown and gutters.
4. Maintenance of surface with road drag for some time previous to oiling to insure compact and smooth roadway.
5. Careful removal of dust before oiling. This is of the utmost importance.
6. Proper method of applying oil; includes thorough mixing of oil in earth.
7. Use of right kind of oil. Quality of oil can be determined only by proper tests.
8. Proper maintenance after oiling, and renewed oiling as needed.

OILING MACADAM AND GRAVEL ROADS

Production of Dust. The principal source of dust on macadam and gravel roads is the abrading action of the traffic that passes over the surface. Abrasion or wear on a road consists in the breaking up of the surface into fine particles which have no cohesion and which forms the dust. This action takes place under various forces due to traffic,

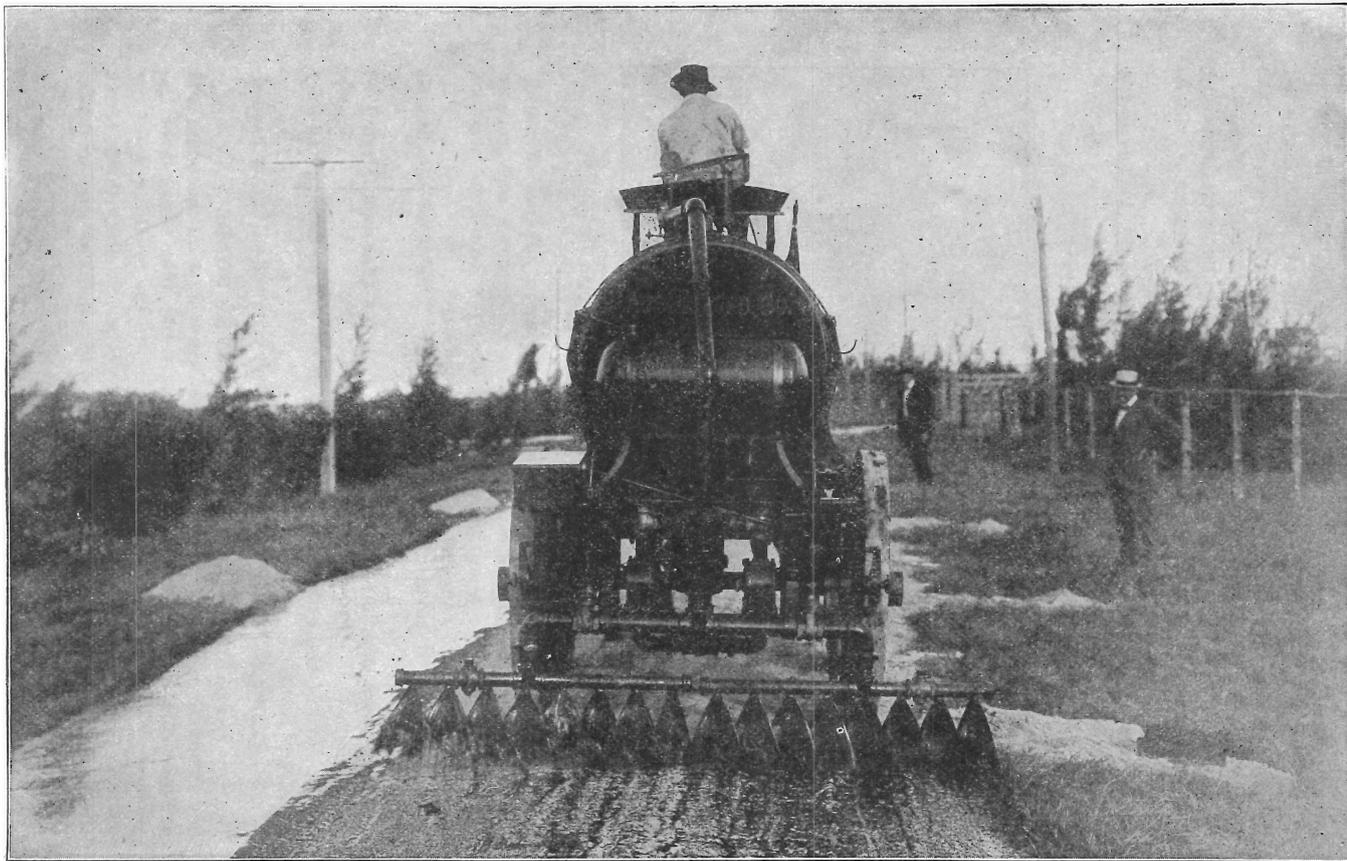


Fig. 10. Spreading oil on macadam road.

such as the grinding of steel tired wheels, the blows from horses' hoofs, the local compression of narrow tires on heavily loaded vehicles, and the frictional effect of motor-driven vehicles. Other factors which tend to produce dust are, frost, rain and wind.

Effect of Dust Layers. The life of broken stone and gravel roads is dependent to some extent on the retention of a layer of dust on the surface. This layer acts as a carpet to protect the body of the road from excessive wear. Wind and traffic both tend to remove this dust from the road and thus hasten the wear. Before the advent of the automobile, the wear from horse drawn vehicles was about sufficient to provide a good covering of dust for the road, and this sort of traffic had little tendency to remove any of it. But the effect of a motor vehicle, traveling at high speed, is to produce a suction behind the body of the car, which raises the dust from the road, and scatters it over the surrounding country. The result is that in a short time the road surface is stripped of the fine material and the body of the road is exposed to the destructive action of traffic. The larger stones will become loosened and work out, producing a roughened surface. This breaking up of the surface is called "raveling" of the road.

Value of Dust Layer. The necessity for finding some means of retaining the dust on macadam and gravel roads is becoming a matter of great importance on account of the great increase in motor traffic.

It has been found that surface oiling of macadam and gravel with crude petroleum or with partially refined road oils, will lay the dust, prevent excessive wear from motor vehicles and prolong the life of the road several years. When the right kind of oil is used and proper methods are employed in its application, this process will prove to be a most economical method of maintaining a hard smooth surface.

Purpose of Oiling. The purpose of oiling the surface of a macadam road is to obtain a uniform coating of oil, and a penetration into the broken stone to form a waterproof crust which will be more resistant to the wear of traffic than a plain macadam surface. Oiling will not make a good road out of a poor one in bad repair. It is intended only as a means of maintenance.

Preparation for Oiling. The road must be put in good condition before oiling, if success is to be expected with this method of treatment. All holes and ruts should be filled with fresh stone and screenings, watered and rolled. If the road is very badly worn and the surface so uneven that patching of the holes will not give a smooth surface, it may be necessary to completely tear up the old roadway, and add enough new material to obtain the proper crown and grade. Then shape up the road, add screenings and water and roll it until solid. This repairing should be done some time in advance of the oiling in order that the road may be compacted by traffic, to a uniformly hard, smooth surface.

Effect of Weather Conditions. The oiling should be done during warm weather. Better results can be secured when the stone is warm,

since it will not cool the oil so quickly, and better penetration can be obtained.

Routine of Operations. After all repairs have been made and the roadway is in good shape the oiling can proceed as follows:

First sweep the surface dust to the sides. This sweeping should expose the larger stones of the road. Then spread the oil at the rate of about one-fourth to one-half gallon per square yard, following the distribution immediately with brooms to sweep the oil into the surface. This brooming will also help to cover all the surface with the oil, and secure an even covering. Next, spread over the oil a thin layer of fresh stone screenings, and roll until solid. If any spots show an excess of oil while rolling, screenings should be added to prevent a sticky condition.

Care should be taken to spread the screenings in a uniformly thin layer. An excess of screenings will produce a poor wearing surface likely to become uneven. Just enough screenings should be used to absorb the excess of oil. One cubic yard of screenings will cover from 100 to 150 square yards of road surface.

Number of Applications. It is better to make two applications of the oil at the rate of one-fourth to one-half gallon per square yard each time. The total amount required to obtain good results will vary from one-half gallon to three-fourths gallon per square yard, depending upon the ability of the surface to absorb oil.

Final Results. The character of the road finally obtained, and its ability to resist wear due to traffic will depend to a great extent upon the bond between the oiled screenings, and the oil road surface. With proper care in applying the oil, a surface may be obtained that will compare favorably with a bituminous macadam. It is essential that a uniform thickness of the oil and screenings be obtained, since the wearing qualities of the surface will be greatly increased by the smoothness of the road. To obtain an even distribution of the oil, mechanical distributors are recommended. Such distributors are on the market, and can be obtained from any road machinery company.

If a heavy oil is used, it will require heating before application, and one oiling should be sufficient to lay the dust for the season. If a thin light oil is used for cold application it may be necessary to oil twice during a season. If the proper quality of oil is used, the best results will be obtained, and it will prove cheaper in the long run, to get a good quality even though the oil may cost more per gallon. The selection of an oil depends on the kind of surface to be oiled, the traffic, the climate and many other conditions, so that each case should be studied carefully in order to assure the best results. For instance, a solid, well bonded road will require a thin oil in order that it may penetrate into the surface, whereas on a loosely bonded road a heavier oil should be used.

Costs. The cost of the oil varies from three to eight cents per gallon, making the cost of oiling about eight to ten cents per square yard.

Method of Oiling Gravel Roads. The method of applying oil to gravel surfaces is practically the same as that for macadam roads. Gravel roads may often require a larger amount of oil, and the actual quantity required is quite variable depending on the condition of the surface. A gravel that contains some clay for bonding material does not absorb much oil, while a road built of stream-washed gravel often requires considerable amounts to obtain a good surface.

Preparation for Oiling. The road should be put in proper condition by filling the holes with fresh gravel, and allowing these to be consolidated by the traffic. It is absolutely necessary that these patches be thoroughly compacted before oiling, otherwise they are apt to become soft, since they absorb more oil than is absorbed by the solid surface of the road. An excess of oil as noted before will produce a spongy condition of the wearing material and this is fatal to permanency.

For Loose Gravel. If a loose gravel surface is to be oiled, it may be economical to distribute a thin layer of limestone screenings over the surface before oiling, and allow this to become compacted by traffic. The screenings will act as a binder for the rounded particles of the gravel, which by themselves will not become solid under traffic. Frequent dragging of a gravel road will eliminate the ruts and maintain the crown until a sufficiently solid surface is formed to receive the oil.

The surface should be swept free from dust, then the oil should be spread at the rate of about one-half gallon to three-fourths gallon per square yard and covered with a thin layer of gravel or screenings and rolled. Some gravel roads may require as much as a gallon or more of oil per square yard. With these amounts the oil should be spread in two layers, each layer covered with gravel or coarse sand and rolled.

General Results. In localities where a good supply of gravel can be obtained, excellent roads can be built and maintained with a proper use of oil. Such roads may compare favorably with high class hard surface roads. The cost will be so much lower than for the hard surface types, that a much more extensive mileage of roads may be built with the available funds. In New Hampshire, practically the entire system of state roads are surfaced with gravel, and are built at a cost of about \$3000 per mile. Oil is used to maintain the surface in proper condition for the traffic. These roads carry an unusually heavy motor tourist traffic, but they have given excellent service and at a very low cost both for construction and for maintenance.

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