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Dustless & durable Macadam roads

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DUSTLESS AND DURABLE MACADAM ROADS

BY

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THESIS

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This is to certify that the thesis of RAYMOND JOSEPH SHIELDS entitled Dustless and Durable Macadam Roads is approved by me as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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DUSTLESS AND DURABLE MACADAM ROADS

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DUSTLESS AND DURABLE MACADAM ROADS

The ordinary macadam road of today is composed of a surfacing of broken stones of small dimensions, the largest not exceeding 2-1/2 inches in diameter, bound together into a compact mass so as to be substantially a sort of a concrete, but with no matrix other than stone dust or screenings.

This construction is particularly well adapted to main ways connecting centers of population. It is not an economical form of pavement for main streets of cities and large towns, and is usually too expensive for light traveled country roads. Sometimes the macadam surface may be used with economy when a gravel surface would satisfy the demands of traffic, but can not be obtained at a reasonable price.

The more important of the specifications are as follows: 1. The road should have an easy gradient, usually not exceeding five percent. 2. The road should have drainage appliances so perfect that practically no water shall reach the broken stone from below, thus preventing destructive frost action. 3. The road should have a foundation consisting of either natural soil, if suitable, or artificially placed gravel or unbroken stone. This foundation with superimposed broken stone should have sufficient strength to distribute over the underlying soil any load to which the road is likely to be subjected, and should be so crowned that the completed surface will have a cross fall from the center to the sides of from one-quarter to three-quarters of an inch to the foot. 4. The road should have a wearing coat-

ing of two or more layers of broken stone. Those at the bottom usually not more than two and one-half in diameter and those at the top varying in size from one and one-quarter inches to one-half inch in diameter. Each course or layer must be carefully spread, uniform in depth, and rolled thoroughly with a steam roller before the next course is laid. By rolling in thin layers the stones become thoroughly compacted and the void spaces or interstices are largely eliminated. The final process consists in spreading over the surface of the upper layer of broken stone a thin covering of screenings. These screenings contain a considerable amount of fine dust which is worked into the roads between the broken stone. The road is then rolled with a steam roller and the process of grouting* and rolling is repeated until the voids are substantially filled and the roadway refuses to absorb any more of the grout.

A macadam road so built is sufficiently tight to prevent water from penetrating through it to the foundation; the stones are so bound and packed together that they do not shift under horse drawn traffic; and, providing the use of automobiles is not excessive, it may reasonably be expected to last about ten years.

The cost of macadam roads varies from $2500 to $6500 per mile. The locality is an important factor of the cost.

Owing to the rapid increase in the amount of automobile traffic within the last decade, the macadam road described above fails to be an effective and economical construction without

* Grouting as herein used means the working of the fine material into the voids between the larger stones.

some surface treatment. The tires of these rapidly moving vehicles have a disastrous scrubbing effect upon the road surface. They remove the fine stone dust filler which is caught up by the air currents and deposited over the surrounding country causing much annoyance to nearby inhabitants and damaging crops. After the binder is removed the surface begins to ravel and the road is soon in an unserviceable condition unless prompt repairs are made.

In order to stand such traffic the road bed must be hard and dense or a viscuous and elastic binding material must be used. On account of the great expense of a hard and dense surface, such a construction could not be considered, but instead, the remedy seems to lie in the use of a viscuous or elastic binding material. It is quite generally believed that some form of bitumen is best adapted to this purpose.

There are many kinds of dust preventives in use at the present time. They are classified as permanent and temporary according to the nature of the results. The essential requisite of any binding material or dust preventive is its power of holding the fine material produced on the surface of the road. In order to keep down the dust the temporary binders will have to be applied with more or less frequency according as they approach the nature or properties of a permanent binder. The term permanent, as here considered, is only relative and applies to materials which on one application are capable of reducing the formation of dust for at least one season.

The more important of the permanent dust preventives are tars, oils, and sand.

TARS,- Crude tars, as well as prepared tars and tar emulsions, have been used extensively for dust prevention ever since automobiles were first used to any extent. Experiments have been conducted with these materials in France, England, and the United States. The results have, to a large extent, been contradictory, even when experiments have been carried on in the same manner and under like conditions; consequently much confusion has arisen in the minds of road engineers as to the real value of tars.

As a class, tars are heavy liquid bodies obtained from the destructive distillation of such organic substances as wood, bone, and coal. They are of extremely complex composition, being for the most part chemical compounds of the elements carbon, hydrogen, and oxygen, known as hydrocarbons or oxygenated hydrocarbons. In many cases other elements, such as nitrogen and sulphur, are also to be found in varying proportions.

Tar forms part of the volatile products in the manufacture of coke and gas. The coal is charged into long narrow chambers or retorts of about four or five tons capacity and is heated by means of flues set in the retort walls. The volatile matter in the coal passes out through an opening in the top and is conducted through a series of washers and scrubbers in order to remove the tar and ammonia. The tar and ammonia collect in the bottom of this chamber and from there are run into large wells where it is allowed to settle for some time in order to separate it as far as possible from the accompanying ammoniacal liquor. The ammoniacal liquor being lighter than tar rises to the top and can be drawn off. The crude tar which remains is a black viscid fluid of peculiar odor and varying in specific gravity from 1.1 to 1.2.

It always contains a certain amount of ammonia as well as several constituents of gas in solution, and represents about five per-cent of the weight of the coal from which it is produced. The true tarry products are known as artificial bitumens in contra-distinction to the natural bitumens found in various mineral oils and asphalts. The nature of the tar varies with the nature of the coal from which it is produced, and also with the conditions under which it is produced. Its quality as a road builder depends largely upon the temperature at which the tar is produced. In gas plants the attempt is made to produce as much gas as possible from a given quantity of coal, and, therefore, to distill at the highest practicable temperature. As the heat increases the amount of gas produced increases. This is due to the tendency of hydrocarbons to dissociate at high temperatures into their elements, hydrogen and carbon. The hydrogen will be produced as gas and the free carbon will be deposited in the tarry con-densations; also the proportions of such substances as naphthalens and anthracene will be increased in the tar. The temperature maintained in the retort may be as low as 850° to 900° C, but will usually vary between these points and 1100° C, or even higher, according to the quality of gas desired. As the value of coal tar as a dust preventive lies mainly in the binding power of the bitumens contained in it, it is evident that an excess of carbon which has no binding power will prove detrimental. The same may be said of such substances as naphthalene and anthracene, and as these materials are produced in increasing quantities as the temp-erature is raised, it follows that the best results must be obtain-ed by the use of tars produced at a low temperature. Tar pro-

duced in coke ovens is produced at a low temperature and consequently has a large amount of true binding material. When it is considered that the actual bitumen in tar may vary from 60 to 95 percent and the free carbon from 5 to 35 percent according to the temperature employed, the importance of determining the chemical properties of crude tar is evident.

In reviewing the descriptions of the numerous experiments with this material, it is hard to find one in which these properties are taken into account. It is not strange, therefore, that very different results are reported from the use of crude tar.

REFINED COAL TARS,- In refining coal tar for use as a dust preventive most of the valuable products - that is, some of the carbolic and all of the dead oils - are run back into pitch, which is the residue left after the crude tar has been subjected to fractional distillation for the separation of certain constituents used in the arts, until the desired consistency is reached. These oils give life to the tar and, provided the percentage of pitch is not reduced too much, a mixture of this sort has many advantages over crude tar. It is comparatively free from naphthalene and anthracene and contains none of the light volatile oils and ammoniacal liquid found in the latter.

DEHYDRATED TAR,- Dehydrated tar is a prepared crude tar for dust prevention from which all water, ammonious compounds, and some of the light oils have been removed. The absence of water makes it easier to apply when hot, and probably results in better absorption by the road surface. Water in tar also hastens the disentegration of the heavy binding materials. The ammoniacal

liquor tends to saponify some of the oily products. This renders them, the tars, capable of mixing with water and are, therefore, likely to be washed out. Dehydrated tar may be readily prepared by boiling the crude material in open kettles at a temperature of about 110° C.

WATER GAS TAR,- Water gas tar has been used to some extent as a dust layer and road preservative. The principle of making water gas tar is based upon the decomposition of steam by incandescent coke or hard coal. Comparatively few experiments have been made with it as a dust preventive, but from the few made it seems safe to say that the results obtained in any case will not be as lasting in character as from the use of coal tars. It does, however, compare quite favorably with some of the lighter oils and oil and tar emulsions.

APPLICATION OF TARS TO FINISHED ROAD SURFACES,- Most crude tars are too viscous to apply satisfactorily when cold, and must be heated before applying. The addition of a sufficient quantity of oil will serve the same purpose as heating, but a corresponding reduction in the amount of binding material will be produced by this dilution.

Experience has shown that in order to get the best results from tar, the road should be free from dust, perfectly dry, and comparatively warm. If dust and other fine materials are present, the tar will not be properly absorbed by the surface and owing to lack of bond will peal under the traffic. For this reason, it can be supplied successfully to hard surfaces only such as well swept macadam roads. The presence of moisture will prevent the tar from penetrating the road surface, and a cold

surface will chill the tar; therefore, it is necessary that all applications be made in warm dry weather. Before applying the tar, the road should be repaired where necessary, in order to secure as even and smooth a surface as possible. If ruts and hollows are present, the tarred surface will not only present a poor appearence, but water will collect in the hollows and cause rapid disintegration under traffic. It is desirable that repairs be made at a short time previous to the tar application in order to obtain a well bonded and consolidated surface, for it has been found that fresh patches which have been tared are likely to ravle under traffic.

The primitive method of application which has been largely employed in this country up to the present time is as follows· The road surface is first swept to remove all dust· the hot tar, which is usually brought to a boiling point, is then spread on and thoroughly broomed in. The road should then, if possible, be closed to traffic and left untouched for at least twelve hours to allow the tar to soak in.

At the end of this time, a coat of clean sand or stone chips should be applied to absorb the excess of tar, and the surface should be rolled several times to bring it to proper condition quickly. The preliminary sweeping of the road is sometimes done by hand, but an ordinary mechanical sweeper is usually used. The tar is heated in an open kettle usually mounted on wheels and fitted with fire box. These kettles are moved along the side of the road as the work progresses and the hot tar is drawn off into flat-nosed watering pots, hods, or ladles, and spread by hand. The tar should be well broomed and worked into the sur-

face to obtain a smooth and even coat. This spreading is usually done by laborers with stiff, long-handled, brooms, who follow the spreaders and carefully broom and shove the material over every portion of the surface. The excess of tar is thus pushed ahead and can be used for covering fresh surfaces.

Owing to the expense involved and time consumed in applying the tar from kettles, a number of schemes have been devised to apply it by means of special apparatus. In France, a sprinkler has been used with some success. It can be operated by three men, and will cover about three thousand square yards of roadway per day. Tar is pumped into a reservoir, and, after being heated, is sprayed upon the road by means of compressed air stored in an adjoining reservoir. If the road is first thoroughly swept and all remaining dust removed by means of a vacuum cleaner, the tar is expelled with sufficient force to penetrate well into the macadam, and, therefore, does not require brooming. A thin top dressing of sand is usually applied to tarred surfaces.

Some attempts have been made in France to apply the crude tar cold and afterwards set fire to it. It is claimed that by this process the road surface is caused to absorb the tar to a considerable extent and as the lighter oils will be consumed and the water and ammoniacal salts driven off, all of the advantages of applying a refined tar will be obtained.

It is extremely doubtful, however, if this method will ever be employed to any extent, as it seems entirely probable that some of the valuable binding materials will be burned and that the remainder will become brittle and useless on account of the absence of life giving oils.

USE OF TAR IN ROAD CONSTRUCTION,- So far we have dealt only with the methods of applying tars to finished surfaces. Where a new road is under the process of construction or an old road is being resurfaced, it is often desirable to apply the tar in a somewhat different manner. In these cases the road should be shaped and consolidated as well as possible without the use of water. The voids should be well filled with clean fine stone chips free from dust. An excessive amount of rolling should be avoided in obtaining this condition. If the roller is used too freely the larger stones will become rounded and covered with dust which prevents the tar from adhering properly. Hot tar may be applied to all courses if desired, but usually only the top course is so treated. After the tar is applied, a coat of sand or fine stone chips is put on and the whole road is well rolled. A road so treated will have all of the interstices filled with hard material and only sufficient tar to surround each particle. So it is seen that all wear will be taken by the stone aggregate and the tar will act solely as a binder. A road so built approaches very closely the road whose material had been tarred before putting into place.

If the tar is applied by hand, a great deal more will be taken up by the road than is absolutely required. Attempts have been made to devise a method which will give good results with a minimum amount of tar. A tar spreader similar to the one already described has been tried with some success in England and Scotland. The spraying apparatus is mounted on wheels and is so arranged that the tar is forced from the heating tank into an air receiver under a pressure of from 150 to 350 pounds per square inch. The necessary power is obtained by means of a chain drive

from the road wheel of the vehicle.

A properly tarred road after being subjected to traffic for some time closely resembles asphalt. It is smooth and firm, of a more resilient character than asphalt, and is practically noiseless. While in good condition it is to a great extent waterproof and almost dustless; and if the proper amount of tar is applied the resistance to traffic is less than that of an untreated macadam road. If too much tar has been applied, the road is apt to become soft and sticky in warm weather, and thus cause marked increase in the draft of vehicles.

AMOUNT AND COST OF MATERIALS,- The amount of tar required to treat a road will depend upon the fluidity of the material when applied and the absorbing power of the road. According to conditions and methods of application, a surface-treated road will require from .35 to.70 gallon of tar per square year when application is made by hand. When applied by machine, as small an amount as 0.21 gallon has been used with good results. With either method, the application of tar must be repeated from time to time, though less is required at each successive application. If the tar is applied by hand while the road is being built as much as 1.5 gallons is often consumed.

Crude coal tar varies in price according to the locality, but it can ordinarily be purchased from coke or gas companies at from three to five cents per gallon. The price of refined tars runs from six to twelve cents per gallon and higher. On account of the difference in price, the use of a good crude tar is often to be preferred.

The cost of treatment for a surface tarred road will, of

course, depends largely on the number of factors. In France, when done by machine, it will average about three cents, and when done by hand it will cost five cents per square yard. In this country where it is generally applied by hand, it costs from six to twelve cents per square yard. This is largely due to the poor condition of our roads before treatment, which necessitates more tar and surface dressing than if they were in good condition in the first place.

OILS,- Oils are fatty organic substances derived from innumerable sources. They may be classed under three heads; as animal, vegetable, and mineral. While oils of the first two classes have been used to some extent as dust preventives, mineral oils are by far the most important, and have been most generally used for this purpose. Animal and vegetable oils, owing to their lack of true binding base, may be classed as temporary binders.

As in the case of tar, the value of oil as a permanent dust preventive lies in the quantity and quality of its bituminous base. The bases of petroleums vary from those of almost pure paraffin to almost pure asphalt, many being mixtures of the two. While the paraffin oils are of much more value than the asphalt from a commercial point of view, the opposite is true from the standpoint of their use in dust suppression. An oil wholly paraffin is of value only as a temporary binder, while an asphalt oil ranks with coal or tar as a permanent binder. Like coal tar, petroleum is a mixture of a large number of organic bodies known as hydrocarbons, together with small quantities of sulphureted, nitrogenized, and oxygenated compounds.

While crude oil has been used to a large extent in the West

for the purpose of dust prevention, it is often customary in the East to partially distill oils containing asphalt residues before using them in this connection. By this means many of the more valuable constituents are recovered and the residual oils produced have a much better binding quality, owing to the fact that they contain a larger percentage of asphaltic base.

As in the case of tars, many valuable facts have been learned in regard to the application of oils to road surfaces, although, owing to contradictory results, considerable differences of opinion seem to exist as to the actual and relative values of different kinds of oil. This is largely due to the lack of knowledge in regard to the properties of the materials used and to the fact that the character of the surface treated and the climatic conditions have a much more important bearing upon the results than is usually realized.

In applying oil to a macadam surface, the same general methods are employed as in the application of tar. Holes and inequalities should be repaired. It has not been found necessary to remove all dust from the road surface so carefully as in the case of tar, but sticks, leaves, and other detritus of an organic nature should be removed. The crude or refined oil may be applied either hot or cold, according to its viscosity and ability to penetrate the road surface. The application of crude oil is considerably cheaper than tar and is to be preferred on that account. It has, however, been found necessary to heat most of the heavier oils before application.

As a rule, the oil is applied by means of some mechanical device, as in the case of tar, the main object is to maintain an

even coating, which shall be well absorbed by the road surface. The application of a large amount of oil at one time should be avoided as it is sure to make the surface sticky and disagreeable. A covering of one-half inch of sharp sand or stone screenings should be applied after the oil has been allowed to penetrate as much as possible, in order to take up all excess. The surface thus formed should be rolled until well compacted, additional sand or screenings being thrown on whereever the oil shows a tendency to force its way to the surface and produce a sticky condition. Sometimes two or three courses of oil and screenings are applied. If the oil is well absorbed before applying the sand or screenings, it is not always necessary to employ a roller, as ordinary traffic will consolidate it in course of time.

APPLICATION OF OIL TO MACADAM ROAD DURING CONSTRUCTION,- The application of oil during process of construction has been carried on with greatest success in California where the heaviest asphaltic oils are found. The residuums obtained from the partial distillation of these oils have so far given the best results when properly applied. The treatment is essentially the same as that with tar, the object being to build a road containing a low percentage of voids, so that the oil will act as a binder only, and the wear of the traffic be borne by the road stones. Considerable attention should be paid to proper drainage of the road, as it is essential that the foundation be perfectly dry. The hot oil is applied by means of a tank wagon fitted with a distributing device. Any excess of oil is taken up by the application of a sufficient covering of sand and screenings.

A road constructed in this manner will usually require from

three-quarters to one and one-half gallons of oil per square yard, depending upon the quality of oil and kind of road surface treated. In order to keep the road in proper condition, repairs should be made from time to time. By this method rapid integration will be prevented, which would occur if water were allowed to accumulate in worn places.

COST OF MATERIAL,- Texas and some of the Kentucky oils are the best available in this locality, and range in price from about three to seven cents per gallon. The residuums and special preparations vary in price from two to twelve cents per gallon.

SAND,- Where automobile traffic is not excessive, a coating of sand or stone chips can be used to advantage. On an ordinary country road, where automobile traffic is light, a stone road can be preserved in good condition for many years at an average cost of 1.5 to 2.5 cents per square yard per year.

TEMPORARY BINDERS,- The temporary binders as previously defined are materials which have to be applied at more or less frequent intervals, perhaps several times in a season, in order to suppress the dust. They contain little if any true binding base and much volatile matter, and, therefore, are effective only so long as this remains upon the surface. No distinct line can be drawn between the permanent and temporary binders, but in general the latter class may be said to embrace water, salt solutions, the lighter oils, and tars, and various emulsions. Some of these materials, however, approach the former class quite closely and can be considered in either class.

WATER,- Water is undoubtedly the first material ever used for the purpose of laying dust. During hot, dry weather, its use has

never been satisfactory, owing to the rapid evaporation. The cost of frequent sprinklings is a considerable item; and when the fact is taken into account that little permanent benefit has been derived from its use, it will be seen its use is by no means economical.

SALT SOLUTIONS,- Salts have a great affinity for water, and are not only capable of retaining moisture for a long time under conditions which would otherwise produce rapid evaporation, but are capable of absorbing water from the atmosphere.to a great extent. Some of these salts are so hygroscopic that in a humid atmosphere they will often completely dissolve in the water which they have absorbed from the air. Salts of this character are termed diliquescent, and it is these which have been employed as dust preventives. By their use, the road is kept in a semimoist condition for a much longer period than by the application of a corresponding amount of water. Of the salt solutions, sea water and calcium are used most.

The principal advantages of salt solutions as dust layers are that they are odorless and clean. As a rule they are slightly more expensive than water, but the beneficial effect produced upon the road will, in many cases, more than compensate for this difference. The cost of these applications vary in cost from two and one-half to three cents per square yard per year.

TEMPORARY TAR AND OIL BINDERS,- Oils and tars which contain a certain amount of true binding base are desired for the purpose of laying dust. While for the most part they volatilize slowly, they leave behind some binding material which tends to bind together the fine material. Successive applications result in an

accumulation of this binding material which at the end of the season may result in a condition similar to that produced by the single application of a permanent binder containing the same kind of base.

Water gas tar is perhaps one of the best temporary binders that can be applied in its natural state. It can be obtained for about three cents a gallon and when applied at the rate of .3 gallon per square yard on an ordinary macadam road will lay the dust successfully for some time. The number of applications required during a season will depend upon the various conditions, but ordinarily a few will suffice.

EMULSIONS,- Emulsions of oils or fats with water may be made by either chemical or mechanical means.

Chemical emulsions have up to the present time been most generally used for the purpose of dust prevention, but mechanical devices are being used much at present. Chemical emulsions are oily substances made miscible with water through the agency of saponifying materials.

Asphaltic and semi-asphaltic oil emulsions have been used to a greater extent than any other. In Boston a number of the park roads are treated with an emulsion prepared as follows: To every fifty gallons of water eighteen pounds of cotton-seed oil soap, costing four and one-half cents per pound, are added, and the solution is hastened by the application of steam heat. One hundred gallons of crude petroleum is then added to every fifty gallons of soap solution and the mixture is agitated until emulsification is complete. The emulsion thus produced contains about 66% of oil and is considerably diluted before applying.

The number of applications vary with conditions but are usually applied every ten or twenty days. In certain cases the cost of laying dust for a season has been two cents per square yard while the cost of watering in previous seasons at three cents per square yard.

SELECTION OF DUST PREVENTIVES OR BINDING MATERIAL,- It is undoubtedly true that thousands of dollars are wasted annually in a repetition of experiments which have time and again proved costly mistakes. On the other hand, experiments which have given good results in one locality have proven a failure when tried in a different locality. It is necessary, therefore, not only that the experience of others be considered, but that some thought should be given to the probable effect of local conditions upon the results which may be obtained.

In treating macadam it is usually impractical to use anything but a permanent binder. This is due to the fact that macadam road construction is limited mostly to the country where it would be out of the question to treat long stretches of road at comparatively short intervals of time.

Among the permanent dust preventives, coal tar and the asphaltic and semi-asphaltic oils are the only ones which can be used under ordinary conditions on account of expense. Asphalt would undoubtedly make an almost perfect dust preventive and binder, but, as has been stated, it is out of the question on account of expense. A top coating of road stone or sand with good binding quality may be used to advantage on macadam roads exposed to but little motor traffic.

The use of oil and tar on a macadam road will depend largely

on conditions, but in general it can be said, when a permanent binder is desired, good results are obtained more often when refined tar is used. Oils are not reliable.

The introduction of bituminous binders into the voids between the broken stones, while the road is under construction, has proven satisfactory in many places. This is done by mixing the bituminous material with the broken stones before they are placed on the road, or by grouting the bituminous material into the spaces between and around the broken stones after they have been placed and partially rolled.

However, since the application of these add materially to the cost of the ordinary macadam road, and since it seems probable that the roadway will require a protective covering as often as once a year, it would appear to be economical to rely on a protective covering and to omit the bituminous material from the voids between the stones while the traffic remains as at present.

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