Asphalte and Bituminous Roadways.

By A. B. Woolf.

One hundred years ago McAdam successfully demonstrated a scientific method of constructing roadways. The world has benefited to a wonderful extent by his discovery, and the advancement in the art of road construction since that time is a matter of history with which we are all more or less familiar.

The roads built by McAdam and his contemporaries have had their day and the time has come when they must give way to something better, and Road-Engineers in all parts of the world are at present investigating and experimenting in order to ascertain the requirements suitable to modern traffic conditions. The Metropolitan Committee recently appointed by the English Government to consider the effect of motor traffic on the London streets has obtained conclusive evidence that motor traffic—particularly motor bus traffic—is detrimental to macadam-paved roads. Tar spraying seems to diminish the evil somewhat, but it is at the best only a temporary expedient and there seems to be no doubt that as the motor traffic increases, the macadam roadway, as at present constructed, will have to disappear.

Municipal Engineers are often blamed for the bad condition of their roadways, when the fault really lies with the materials available for construction; on the other hand it cannot be denied that many roadways are starved and insufficiently maintained, and in these days of increased traffic with practically no load limit or speed restriction outside of the city area, it calls for the most careful and urgent consideration as to what changes are necessary in the methods of road construction in order to produce the best results.

Macadam as a water-bound surface has been declared unsatisfactory for the modern conditions of traffic, and tar spraying has been shown to be only a temporary expedient in preventing disintegration, whereas tar-macadam—that is, tar used as a binder to hold together the units comprising the macadam—is a subject upon which there exists a great diversity of opinion. If you discard the water bound macadam, the next best thing from a point of cheapness is tar macadam, but although you have advanced several degrees by adopting tar as a binder and by so doing have produced a means of resistance to the disintegrating power of water, the question is whether a more lasting agent would not be more economical in the long run. The value of tar as a binder or for the surface treatment of roads depends upon the method of distillation, but even at its best its life can only be said to be at the mercy of the elements.
It is agreed that a binder of some sort is necessary, and it is desirable that it should be waterproof, and as free as possible from the effect of atmospheric disturbance. Bitumen seems to be the right material to stand up to all the qualifications necessary for a binding agent, and I submit that in the near future bituminous roadways will take the place of tarred macadam, and that bitumen will be used instead of tar as a binding medium for the constructional body and the finished surface—both of which will be waterproof and dustproof.

Bitumen has the advantage over tar inasmuch as it does not disintegrate under the influence of weather, but care must be exercised in its selection if success is to be assured. The comparative cost when compared with tar will show an increase in the initial expenditure, but this will be amply compensated for by the added life of the roadway and reduced cost of maintenance; also by the fact that it is not a dust producer, and any dust brought on to the roadway can be hosed off without fear of the water affecting the surface material.

In European cities bituminous macadam has not met with much success—the compressed rock asphalt has been preferred; but in the United States it is the other way about, due probably to the fact that in Europe the natural asphalt rock is procurable from the European Mines at reasonable rates, whereas in the United States the deposits of crude bitumen are numerous and permit of comparative cheapness as against the natural rock asphalt which has to be imported. Apart from the question of cost, there is no comparison between the two roadways, and it is generally agreed that it will be found necessary to use the Compressed Rock Asphalt for all the principal roadways within the City area; but for all light traffic streets or avenues leading into the city, the bituminous macadam—varying in construction according to the traffic it will be required to carry—will be found suitable for the present day conditions of traffic.

The success of both Rock Asphalt and Bituminous roadways depends upon the proper classification of materials, and to obtain this is not an easy matter—especially in Australia, where the introduction of rock asphalt for roadways is only of modern occurrence, and where bituminous roadways are still unknown. In order to avoid confusion, I will briefly explain the difference between a Mineral Rock Asphalt and a bituminous mixture, so often erroneously called asphalt, and I will then deal with the different methods of construction (of the two materials) for roadway purposes.

MINERAL ROCK ASPHALTE.

The asphalt rock is of a calcareous nature naturally impregnated with bitumen. The mere relation of bitumen to carbonate of lime may prove misleading, as much depends upon the class of limestone and the evenness with which it is impregnated. The bitumen absorbed in the limestone varies.
from 5 per cent. to 17 per cent., and when selecting rock for a compressed asphalté roadway it is necessary to know what are the extreme climatic conditions to be encountered, and the class of traffic it will have to withstand. For a cold climate a rock rich in bitumen can be selected with safety—but in a semi-tropical climate great care must be exercised in the selection of a rock containing sufficient bitumen to bind together all the particles of the carbonate of lime, without fear of any surplus bitumen squeezing out in layers below the surface of that portion which has been compressed by the traffic—as this would create what is known as a "wavey" condition in the asphalté.

Asphalté Mines seem to be confined to Europe, the chief deposits being in France, Germany, Switzerland, Italy and Sicily. The Val de Travers Asphalté Mines in Switzerland are the biggest and their world wide reputation is due to the even distribution of the bitumen contained in the limestone. The rock is found in strata and mined like coal. When the rock is extracted from the mine it is crushed to powder, and in this form it is heated to the proper temperature required according to the class of rock selected, and spread on to the concrete bed which has been prepared for it; it is then raked to the requisite level, allowing for the compression, and rolled with a small roller heated to the necessary temperature, it is then compressed with hot stampers, rolled again, and finally ironed with hot irons. In this manner it becomes compressed back into the rock stage—but with a smooth surface. The thickness of the asphalté varies from \( \frac{1}{2} \) in. to 2 in., according to the condition for which it is required and the thickness of the concrete bed varies from 6 in. to 9 in. As already indicated, there is a tendency to increase the thickness of the concrete to 8 in. or 9 in. on account of the extra load entailed by the advent of motor traffic. The excavations are regulated by the existing levels being reduced to the new levels, and as they follow on the lines of ordinary excavation work, I feel that there is no necessity for me to take up your time in dealing with this part of the construction.

These Compressed Asphalté Roadways are durable and dustless, and being absolutely free from joints, they form the most sanitary roadway known to modern civilisation. It has often been said that a compressed asphalté roadway is slippery—but this is not really the case. If the roadway is kept clean, whether wet or dry, there will be no cause for slipperiness. Any smooth surfaced roadway will become slippery if it is allowed to collect a certain amount of refuse on its surface, which in time becomes converted into slime. Asphalté has the advantage in that it can be hosed down at any time, and it will dry within a few minutes.

On account of the smooth surface of the asphalté and the fact of its being impervious, the camber can be pitched much lower than for wood, stone or macadam. A 2 per cent. fall
from the crown of the roadway to the gutter is the usual camber adopted, subject, of course, to adjustment according to the kerb levels.

For a cross-road where the kerbs of each street are unequal, by drawing a straight line from each rise you will obtain at their intersection the highest point of the cross-road from which the usual fall of $\frac{2}{100}$ should be given, this will allow the water to run freely away.

The longitudinal section if very flat requires careful manipulation towards the catch basins, and these should be of ample proportions and as close as possible together.

I will now pass on to Bituminous Roadways as distinct from Asphalte Roadways—and at the outset it is necessary to remember that bitumen is only a binding material, the same as cement is under certain conditions, and it must not under any circumstances be confounded as Asphalte or Asphaltum, but be regarded strictly as a mineral pitch. The American text books dealing with this subject are responsible for a great deal of confusion in this respect. Just as you would discriminate between tar paving and say Val de Travers Asphalte—both of which are called "Asphalte" by certain sections of people, so you must draw a distinction between a natural mineral rock asphalte and a mixture made up of bitumen and other added ingredients, which unfortunately is too often alluded to as "Asphalte." In the same manner as the Val de Travers Asphalte is so well known because of its uniform character, so is the Trinidad Lake Bitumen regarded, because it is more uniform in composition than any other known deposit of crude bitumen or pitch. Trinidad's pitch lake occupies a bowl like depression of about 114 acres, probably the centre of an extinct mud volcano. It is situated about a mile from the Gulf of Paria—between the island and the mainland of Venezuela. The lake seems to be fed by springs and the centre of the lake stands one foot higher than the edges. There is an overflow from the lake to the sea through a crevice, and this stream is 15 ft. to 18 ft. deep, and beneath the stream is a ravine filled with bitumen and which seems to have no limit to it.

Other deposits of bitumen are widely scattered over the United States from the Atlantic to the Pacific, varying greatly in character, but mainly consisting of petroleum products, including residual petroleum, and what are known in America as "Oil Asphaltes," and which I would like to classify for purposes of distinction as "Oil Bitumens." There are also distillates and residues from coal tar and water gas tar mixed with petroleum, and emulsions of various sorts, all more or less suitable for fluxing purposes; but for roadway constructional purposes it is necessary to classify the Bitumen in order to avoid any possibility of the introduction of artificial bitumen. By artificial bitumens I mean hydrocarbon distillates produced by destructive distillation and manufactured oil bitumens; also petroleum residuums and coal tars. To make this quite
clear I would explain that there are two methods of distillation in use when dealing with bitumens—fractional distillation and destructive distillation; fractional distillation causes a mechanical separation of the more volatile from the less volatile constituents, while destructive distillation causes a complete chemical change in which the identity of the material is destroyed.

All bitumen has a tendency to harden with the effluxion of time, probably due to a gradual indirect oxidation of the surface or to the volatization of the lighter oils, and a good roadway depends upon the consistency of the bitumen selected.

Nearly all bitumens are too hard and brittle to be used for road construction purposes, and it is necessary to flux them with a natural bitumen of a more fluid character or an oil suitable for the purpose and one that will form a perfect chemical combination. If this is not regarded seriously and treated scientifically, it is almost certain to lead to unsatisfactory results.

The space at my disposal would not permit me to go into details connected with the difference of opinion that exists in regard to the relative value of the different fluxing agents, but for the purpose of illustration in order to demonstrate the necessity of care in dealing with this class of material, I will refer to—first—"a petroleum residuum as a fluxing agent," and second—"a natural bituminous flux."

It is essential that the material to be fluxed should possess a high cementitious value and that the flux should only form a comparatively small percentage of the whole. If this principle is once recognised, it will be seen that the effect of the flux is not to bind, but to assist the major ingredient towards the proper consistency to obtain the desired result. In the United States petroleum residuum was used to a very large extent for many years—but it was eventually shown that this form of artificial flux only formed a mechanical mixture inasmuch as it did not dissolve the bitumen sufficiently, and it therefore did not establish a complete chemical affinity with the mixture which depended upon it. The effect of this was a gradual solidification which would eventually adversely affect the wearing qualities of the roadway. The natural bituminous flux constitutes a bitumen of a very fluid nature, of which there are several in the United States, mainly, I believe, in California. The liquid bitumens vary in character, and some of them have a petroleum base, but they possess physical and chemical differences which render them suitable for fluxing purposes if properly treated. They are more expensive in the first instance than the other form of flux, but this is counteracted by the fact that a lesser quantity would be required in order to reduce the mixture to the proper consistency.

The two chief points relating to the flux are that:

1. An asphaltite flux should become volatile at a temperature not exceeding 300 deg. F., because the bitumen forming the
main body is heated up to this temperature before adding the sand or limestone grit, and the flux in order to retain its full effect should not be allowed to volatilize.

2. The fluxing agent should dissolve the asphaltite and not merely form a mechanical mixture.

I will now refer to one other matter which affects both the bitumen and the flux equally, and which from an engineering standpoint should be considered an absolutely essential condition to obtain efficiency: I refer to the analysis of the bitumen and the testing of same by means of a penetration machine.

Taking the refined Trinidad bitumen as a standard—an average analysis would be:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitumen soluble in carbon bisulphide</td>
<td>52.87%</td>
</tr>
<tr>
<td>Earthy matter</td>
<td>36.56%</td>
</tr>
<tr>
<td>Vegetable matter</td>
<td>10.57%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

The amount of bitumen contained in a suitable fluxing material would vary from say 9 to 13 per cent., but it must be understood that in dealing with materials susceptible to atmospheric changes—giving due consideration to sudden changes of climate and the effect of traffic under varying conditions—it is necessary to study the quality of the materials used and to recognise the impossibility of giving stereotyped specifications to suit all the conditions to be encountered.

The penetration machine to which I have referred enables you to test the consistency of the bitumen at a uniform temperature, of say, 70 deg. F. If this temperature is always maintained when making your tests, you will gradually establish a standard which will in course of time become very valuable as a means of ensuring the right consistency of the materials for your roadways, and this means increasing their life and consequently a saving of money. There are various penetration machines, and it is a matter of opinion as to which is the best, but Dow's penetration apparatus is explained thus:

An ordinary No. 2 sewing needle is fastened into the end of a brass rod—which is in turn fastened into the end of a metal tube 1\(\frac{1}{2}\) in. long by 1 centimeter in diameter. Mercury is poured into the tube to give it any desired weight from 30 to 300 grams. The brass rod and the tube with needle end down slide freely up or down through a frame and can be held in any position by a clamp. The motion of the sliding part is communicated by a thread to an index arm moving over a graduated disc. The test samples are kept in a water jacketed copper box to ensure an even temperature being maintained. The unit is the distance in hundredths of a centimeter that a No. 2 needle will sink into the bitumen in five seconds when weighted with 100 grams. The penetration can be measured with accuracy to 1-50th of a millimeter=(0.000.8 inch).
In Washington, in 1900, the average penetration of the Trinidad bitumen used by the two companies doing work there was 36 and 45 respectively.

By taking the penetration results at varying temperatures it is possible to arrive at a result which will safeguard your material from the effect of sudden changes of climate, but this as already indicated, must be taken in conjunction with the physical and chemical conditions of the materials selected.

Having briefly explained the character of the chief binding agent employed in the construction of bituminous roadways, I will pass on to the method of construction which is comparatively simple when once you have mastered the intricacies of the binding medium.

Bituminous roadways have been formed with varying success upon a foundation of broken stone, solid clay, cobblestones and granite blocks, and fairly good results have been obtained where the foundation has been solid, clean and dry, but it stands to reason that to obtain the best result, the foundation must be unyielding, and this is very seldom obtained except upon a bed of cement concrete. For heavy traffic I consider this is indispensable, and a minimum thickness of 6 in. of cement concrete should be constructed. Assuming this to be the base, the concrete must be properly set and absolutely dry before attempting to put on the

**Binder Course.** This is a layer of generally 1½ in. thick, of broken metal bound together with the bituminous cement and rolled whilst still hot. The object of this binder course is to act as a cushion between the foundation and the wearing coat, thus permitting the wearing coat to be harder than it could otherwise be if attached directly on to the foundation. *Bluestone Screenings,* graded from ¾ in. down to ⅛ in., would be suitable; it is not desirable to have too much fine stone surface, as the surface of the binder course should not be smooth—but be rough enough to form a key for the wearing surface to bond on to. The metal is generally conveyed by an elevator, which automatically feeds a revolving cylinder heated up to a temperature of 300 deg. F., and the bitumen heated up to about the same temperature is allowed to pass on to the heated metal from a connecting tank, and when the metal is properly coated, it gravitates into a cart below, and is then taken on to the street, where it is raked uniformly over the area and rolled until cold.

The **wearing coat** consists of sand—crushed limestone and bitumen, varying in proportion according to the voids determined in each of the materials concerned. The sand and limestone are mixed together and poured into a mechanical mixer at the same time as the bitumen, the two being separately heated to 275 to 325 deg. F., when the mixture is ready it drops mechanically into the waggons waiting to convey it to the road. Upon arrival it is dumped on to the binder course and raked over the surface uniformly, then tamped with hot
rammers and rolled with about a one-ton roller, and then gone over with tamping and smoothing irons to eradicate any unevenness on the surface; finally it is dusted over with cement or clean fine sand, and rolled with a 5 to 6 ton steam roller, and sometimes finished off with a roller weighing 10 to 12 tons. The rolling should be continued until all marks are eliminated.

Success or failure depends upon care from start to finish. Each locality provides different conditions of traffic and variations in the quality of materials. Properly qualified supervision is a necessity both on the street and when manufacturing. Temperatures must be watched and quantities regulated, otherwise it is an easy matter to bring into disrepute a form of roadway construction which is badly needed and which has all the elements of success in it, providing that it is not regarded as unworthy of scientific treatment.

The number of asphaltte roadways in Australia must increase in the near future—suitable timber is getting scarce and more costly, and it is admitted by all authorities that asphaltte roadways are scientifically the most perfect known to modern civilisation; the question of cost is not and never was prohibitive, and from the point of hygiene alone—they deserve recognition as the most sanitary form of pavement ever introduced into a municipality.

Engineering students in this part of the world have not the opportunity of studying the wide range of constructional methods prevailing in Europe, and I think I am right in assuming that in this part of the world it is necessary for them to be more adaptable than scientific. Personally I would like to see more chemistry associated with Engineering—particularly in connection with road-construction. The advent of asphaltte and bituminous roadways makes it more desirable than ever that Engineers should possess sufficient knowledge of analytical chemistry to determine the character of the materials which they intend to specify. I have endeavoured to point out how essential it is to understand the effect of chemical changes in the raw material and in the combination of materials, under varying conditions, and it is apparent that if bituminous roadways are to take the place of tarred macadam, and the present waterbound macadam roadways, the Engineer of the future will be at a disadvantage if he lacks the chemical understanding in connection with materials which form such an important branch of his profession. It may be that time will solve the difficulty by producing a specialist whose work will be confined to the analysis of engineering materials, or it may be that a combination covering such points as I refer to will form the future curriculum of municipal engineers; whichever form it takes will be welcomed by all enthusiasts who are earnest in their work and who are endeavouring to establish results which will mark a progressive step in the advance of civilisation.
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