BITUMINOUS DUST PREVENTIVES AND ROAD BINDERS.

By PRÉVOST HUBBARD,
Chemist, Office of Public Roads.

USE OF BITUMENS ON ROADS.

At the present time bitumens undoubtedly constitute the most important class of materials employed as dust preventives and road binders. In one form or another they are extensively used for this purpose by all civilized countries where the preservation of roads has become a serious problem because of the destructive action of automobile traffic.

In the broadest sense bitumens may be defined as mixtures of native or pyrogenetic hydrocarbons and their derivatives, which may be gases, liquids, viscous liquids, or solids. If solids, they melt more or less readily upon the application of heat and are soluble in carbon bisulphid, chloroform, and similar solvents. They may be conveniently divided into two main classes: (1) native bitumens and (2) artificial bitumens. Native bitumens, as their name implies, occur in nature, and often contain impurities such as water, clay, silt, sand, and extraneous organic or vegetable matter. Those of interest as road materials are petroleums, malthas, asphalts, and other solid products of an asphaltic nature, such as gilsonite and grahamite. Artificial bitumens are distillates and residues produced by the partial or fractional distillation of bitumens, and hydrocarbon distillates produced by the destructive distillation of bitumens, pyrobitumens, and other organic materials, such as wood or bone. Manufactured petroleum residuums, oil asphalts, asphaltic cements, coal tars, and water-gas tars are the most important members of this class from the standpoint of road treatment and construction.

TREATMENT OF NATIVE BITUMENS.

Comparatively few native bitumens are, in their original condition, suitable for use on roads, but many of them can be made so by proper treatment or modification. Thus a hard, native asphalt may have to be fluxed to suitable consistency with a petroleum residuum, or a fluid asphaltic petroleum may have to be brought to proper

consistency by distilling off a certain percentage of its lighter and more volatile constituents. After undergoing such treatment, these materials are, properly speaking, artificial or manufactured products.

Fluxing and distilling are the two principal processes involved in the preparation of bituminous dust preventives and road binders. The fluxing process consists in mixing or combining a hard or solid bitumen with one that is more or less fluid, called the flux. This combination is usually facilitated by the application of heat and mechanical agitation. Fluxing may serve one of two purposes: A hard bitumen may be softened to the desired consistency by the addition of a relatively small amount of a fluid bitumen, or a heavy viscous oil may be reinforced or hardened by the addition of a relatively small amount of some solid bitumen. In rare instances the proportion of flux to the material fluxed may be equal. In the preparation of fluxed road binders it is not essential that the flux show any binding value unless it constitutes the greater part of the finished product. The material fluxed should, however, invariably possess high binding value or should impart binding value to the finished product. Solid bitumens of asphaltic character possess this property, while those of a paraffin nature do not. The former are, therefore, of value as road materials, while the latter are valueless in this connection. On the other hand, fluxes composed largely of paraffin hydrocarbons may prove very satisfactory, providing they do not constitute the greater part of the finished product.

There are two general methods of distillation in use in the manufacture of bituminous dust preventives and road binders—fractional distillation and destructive distillation. In each, two classes of products are formed—distillates and residues. Fractional distillations cause a mechanical separation of the more volatile from the less volatile constituents of the material distilled, while destructive distillation causes a complete chemical change in which the identity of the material is destroyed.

BITUMINOUS DISTILLATES AND RESIDUES.

Distillates obtained from the fractional distillation of bitumens show no binding value and are unsuitable for use as road materials, except occasionally in the capacity of fluxes. The residues from fractional distillation may or may not possess binding value, according to the character of the material distilled and the extent to which distillation has been carried. If they possess binding value and are of suitable consistency, they may prove satisfactory for the treatment or construction of roads. Residual tars and residual asphaltic petroleums are examples of this type of road material. When distillation is carried so far that the residues are hard and more or less brittle when cold, these residues are called pitches. This term is then pre-

fixed with the name of the material distilled, such as coal-tar pitch or oil pitch. Hard, brittle pitches are unsuitable for road construction, but many of them can be made suitable by fluxing them to the desired consistency with a fluid bitumen. If a distillate is used for fluxing, the resulting product is said to be cut back. Sometimes volatile distillates are used for the purpose of cutting back. When this is done, the material which is cut back usually has the consistency which it is desired will be maintained in the road, and the volatile distillate is employed merely for the purpose of facilitating application by making the material more fluid. After the product has been applied this distillate volatilizes and leaves the original material in place to serve as a binder.

Unlike fractional distillation, destructive distillation often produces distillates having excellent binding value. When these distillates are composed of hydrocarbons and their derivatives, they are known as tars. The residue from destructive distillation is merely coke or carbon and is of no interest as a road material. Hydrocarbon distillates obtained from the destructive distillation of coal and oil are, however, of considerable interest. They are known as coal tars and oil tars. Tars are for the most part by-products of industrial processes and are commonly known by the name of the plant or process in which they are formed; for example, gas-house coal tar, coke-oven tar, oil-gas tar, water-gas tar. Water-gas tar, so called because it is formed in the manufacture of carbureted water gas, is in reality an oil tar. It is produced by a peculiar method of destructively distilling oil for the purpose of enriching water gas. Crude tars, as obtained from the industrial processes above mentioned, are of little value as road materials unless subjected to fractional distillation. If thus treated, only the residues possess binding value as described in the preceding paragraph, while the distillates are of a greasy nature.

CLASSIFICATION OF BITUMINOUS ROAD MATERIALS.

Now that some idea of the types of bitumen in use as road materials has been obtained, it may be well to take up their further classification under the headings "Dust preventives" and "Road binders." No very definite distinction can be made between the two classes, for the function of both is in reality the same. There are certain differences, however, which may be shown by the following definitions. Dust preventives are materials applied to the surface of finished roads for the purpose of laying the dust already present and of retaining dust which may be brought upon the road from outside sources. In bituminous dust preventives it is highly desirable, if not absolutely essential, that the material act as a binder for the loose mineral particles upon the road surface before treatment, and also for any sand, gravel, or stone chips which may afterwards be applied.

Bituminous dust preventives which do not bind are apt to destroy the already existing bond of the road surface and to hasten the ultimate disintegration of the road. Road binders are materials employed in the construction or reconstruction of roads for the purpose of holding together and in place the individual particles of which the road is composed. By so doing they reduce the wear of the road under traffic, and therefore tend to prevent the formation of dust from the road material.

In most instances the same type of bitumen that will give satisfaction as a dust preventive will also give satisfaction as a road binder. The principal difference between the two is only a matter of consistency. This is true in so far as type is concerned. There are, however, various physical and chemical differences to be found among members of a given type, which will, of course, have to be taken into account in connection with the purpose for which the bitumen is used.

With this understanding the more important bituminous dust preventives and road binders now in use may be classified as follows:

Bituminous dust preventives:
- Crude asphaltic petroleums.
- Fluid malthas.
- Fluid semiasphaltic and asphaltic petroleum residuums.
- Emulsions of very viscous semiasphaltic and asphaltic petroleum residuums.
- Dehydrated coal tars.
- Fluid coal tar and water-gas tar residuums.

Bituminous road binders:
- Very viscous malthas.
- Rock asphalts.
- Fluxed native asphalts, gilsonites, and grahamites, known as asphaltic cements.
- Semisolid, semiasphaltic, and asphaltic petroleum residuums or oil asphalts.
- Very viscous cut-back asphaltic cements and oil asphalts.
- Very viscous and semisolid coal tar and water-gas tar residuums.
- Very viscous cut-back coal-tar residuums.

SELECTION OF MATERIAL.

From among such a large and varied assortment of materials it is often a difficult matter for the road engineer to select that product which will give the best results consistent with reasonable economy. The principal factors which he has to consider in making his selection are (1) the character of the road to be treated, including the type of road (earth, gravel, or broken stone) and the physical characteristics of the road material; (2) the desired method of application, i. e., whether the material is to be applied cold or hot and by means of a sprinkler, with or without pressure, by pouring from buckets, or as a prepared mixture with the road material, and in the latter

case it is also desirable to know in advance whether or not the road material itself is to be heated; (3) the quantity and character of traffic; (4) the climatic conditions; (5) the cost of bituminous material; and (6) the probable cost of application.

After a selection has been made, much depends upon applying the material properly if satisfactory results are to be obtained. In regard to the application of dust preventives, it should be said that they may be used either as temporary binders or as semipermanent binders. The temporary binders are applied to road surfaces mainly for the purpose of laying dust. In order to lay the dust brought upon the road from outside sources, they must, therefore, be applied at frequent intervals and for reasons of economy must be capable of easy application. The only economical method of applying them is by means of a sprinkling cart, and they must, therefore, be quite fluid or else capable of emulsifying with water. Their dust-laying effect is of short duration, because they soon become saturated with dust, and are thus rendered incapable of holding down fresh dust which may be formed or brought upon the road. If they possess good binding value, they concentrate upon the road surface after a number of applications and become in effect semipermanent binders. They may often be used to advantage on roads constructed with a bituminous binder. No definite rule can be laid down in regard to the frequency with which they should be applied, as this is not only dependent upon the character of each material, but also upon local conditions to which the road is subjected.

SEMIPERMANENT BINDERS.

Those bituminous dust preventives which may be classed as semipermanent binders are applied to road surfaces mainly for the purpose of preserving the road from wear, although they also serve as dust layers for some time after application. A single application of these materials should preserve the road surface from disintegration and appreciably lessen dust formation for the period of at least one year. They can not, however, be expected to keep a road dustless for this length of time where any considerable quantity of dust from outside sources is encountered.

The semipermanent bituminous binders are rather viscous liquids containing an appreciable amount of true binding base. They are applied cold or hot according to their viscosity at ordinary temperatures. Cold applications may sometimes be made by means of an ordinary sprinkling cart, but hot applications require hand labor or else especially constructed sprinkling contrivances, usually known as oil distributors. Distributors carrying spraying devices and so equipped that the material may be heated in the cart and forced

upon the road surface under pressure of air or steam are extensively employed in England and France, and such machines are gradually being adopted in this country.

The heavier dust preventives seldom prove effective for over a year. They rarely withstand satisfactorily the severities of winter weather and winter traffic, and may therefore best be applied in the early spring at the beginning of the dusty season in order that their beneficial effect may be of longest duration. It is poor policy to apply them to worn out or badly rutted road surfaces, as their function is not to make a bad road good, but to keep a good road in good condition. In most cases it is desirable and in some absolutely necessary to remove all loose dust and detritus from the road surfaces before applying them and any repairs required should of course be made before their application. These materials give best results on broken stone or gravel roads which are not subjected to exceedingly severe traffic conditions, but which require some medium to consolidate or hold down their wearing surface. They are sometimes used in the treatment of earth roads, but it is usually better practice to reconstruct such roads with the addition of a suitable binder during construction.

SURFACING FOR LIGHT TRAFFIC.

While automobile traffic undoubtedly causes more damage to the average untreated road than horse-drawn traffic, the reverse is true of roads the surface of which has been treated with a bituminous dust preventive. Surface treatment proves most satisfactory when employed under conditions similar to those encountered on park and pleasure drives. Such roads are, as a rule, subjected to automobile and light horse-drawn traffic only, and no heavily-loaded teams are allowed to use them. Under these conditions the film or mat of bituminous-bound material is not greatly damaged by iron-shod hoofs and iron-tired wheels, and what damage is done is largely repaired by the passage of rubber-tired automobile wheels which continually iron out the marks made by the other class of traffic. Automobiles themselves cause but little wear of the material of which a road is constructed, but, if the surface is not well bonded, they rapidly wear out the road by displacing first the finer particles in the form of dust and later the larger mineral fragments which require this dust to hold them in place. This action is due to a shearing effect exerted upon the road surface by the wheels connected with the driving mechanism. A good bituminous dust preventive will hold the dust in place and, therefore, prevent such damage. When the road is subjected to any amount of heavy-teaming traffic, however, the heavily loaded steel-tired wheels cut through the surface mat of bituminous-bound material and cause rapid disintegration. This destruction

of the surface is also hastened by the cutting and pulling action of horses' hoofs when heavy loads are being drawn over the road. For such traffic the true road-binders prove more satisfactory than the dust preventives.

USE OF BITUMENS IN ROAD CONSTRUCTION.

As has been stated, bituminous road binders are mainly employed in the construction and reconstruction of roads. They may be used in a variety of ways according to various conditions. They are most commonly applied in the construction of macadam roads according to two methods, known as the penetration method and the mixing method. In either it is sufficient to incorporate the binders with only the upper 2 or 3 inches of broken stone constituting the wearing surface. The foundation course of the road may be constructed as in ordinary macadam work, except that more attention should be paid to filling the voids between the larger fragments with stone screenings. No excess of screenings should, however, be left upon the surface of the foundation to interfere with its interlocking with the wearing course of bitumen-covered stone. Careful attention should be paid to this matter, otherwise a separation of the two courses may occur and lead to a breaking up of the wearing surface under traffic.

THE PENETRATION METHOD.

In the penetration method the wearing course of what is known as No. 2 broken stone is placed upon the foundation before the road binder is applied. The No. 2 stone usually runs from one-half inch to 1¼ inches in diameter, but, when the road stone is soft and easily crushed under the roller, larger sizes may sometimes be employed to advantage. This stone is laid to a depth of from 2½ to 3½ inches, and rolled until the stones interlock. A light coating of clean half-inch stone chips, free from dust, may then be applied and rolled into the surface, which should, however, never be completely filled. Sometimes this application of stone chips is omitted, particularly if the binder is a very heavy one and therefore difficult to incorporate in the wearing surface owing to its tendency to harden rapidly when brought in contact with the stone. The bituminous binder is always heated to a considerable degree of fluidity before being applied, and application is made either by hand directly from portable heating kettles or by means of specially constructed distributors, as in the case of surface treatment with the heavier bituminous dust preventives. Approximately 1½ gallons of binder are thus consumed to every square yard of road surface. Clean stone chips are next applied in sufficient quantity to fill all surface voids and prevent the bitumen from sticking to the wheels of the roller,

and the road is then well rolled. The surface is finished off by applying a flush or seal coat of bitumen at the rate of from 0.3 to 0.5 gallon per square yard. This coat is then covered with a thin layer of stone chips, and the road rolled until firm and smooth.

The object of the penetration method is to produce a bituminous concrete wearing surface without incurring the time, labor, and, therefore, the expense of mixing. While the whole surface may be covered with comparatively little bitumen, a uniform penetration and distribution for a depth of two or more inches can not be secured with less than 1 gallon of bitumen per square yard, and usually 1½ gallons are required. If lasting results are expected, not less than 1 gallon should ever be applied. The seal coat of approximately one-half gallon of bitumen to the square yard is very desirable, as it protects the underlying thinner films from weathering and disintegrating. In some cases attempts have been made to construct a macadam road according to this method with a total of only a little over one-half gallon of bitumen per square yard. This amounts to nothing more than a surface treatment, and the bitumen can therefore be expected only to serve in the capacity of a semipermanent binder. Roads so constructed will usually require additional treatment at the beginning of the next dusty season. The main disadvantage of the penetration method of construction is the uncertainty of obtaining a uniform distribution of bitumen throughout the wearing surface. In spite of this objection, however, many excellent roads have been built by the method when carefully followed in all of its details. It has the advantage of being one of the cheapest forms of bituminous road construction, and should cost but a few cents per square yard plus the price of from 1½ to 2 gallons of bitumen, above that of ordinary macadam construction. In many cases, however, the cost of such work has been excessive because of the makeshift heating apparatus which has been employed.

THE MIXING METHOD.

The mixing method of constructing bituminous macadam is identical with the penetration method up to the completion of the foundation course. The wearing course, which is usually laid to a finished depth of 2 or 2½ inches, is composed of a more or less carefully graded broken-stone aggregate which has been previously mixed and coated with a hot bituminous binder. Sometimes the aggregate itself is heated before mixing, while sometimes it is used cold. In the former case a binder of high original consistency may be employed, while in the latter it should be considerably softer, and preferably a cut-back product containing a volatile flux. The mixture may be made either by manual labor or by machinery.

After the bitumen-coated stone has been laid to the desired depth, it is rolled either with or without the addition of a thin layer of half-inch stone chips, free from dust. When the latter can be done without the stone sticking to the roller wheels, a very satisfactory surface may be secured by the application of a light coating of bitumen-covered sand or stone chips, which is rolled into the surface voids and dusted over with fine stone screenings. In the former case all surplus of screenings should be broomed off and a flush or paint coat of bitumen applied in the same manner as described under the penetration method. Stone screenings are then applied and rolled down in sufficient quantity to take up any excess of bitumens on the surface. Under favorable conditions a macadam road constructed with a 2-inch top course of bitumen-covered stones should not cost over 6 cents per square yard, plus the cost of from 1.3 to 2 gallons of bitumen, above the cost of an ordinary macadam road of the same depth. Mechanical mixing when properly done is much preferable to hand mixing and should prove considerably cheaper under ordinary circumstances.

ROCK ASPHALTS.

Before leaving the subject of bituminous macadam construction, mention should be made of one other type known as the rock-asphalt macadam. Rock asphalts are sandstones or limestones more or less impregnated with maltha. They have been employed to a considerable extent in the surfacing of macadam roads, but all are not suitable for this purpose, as both the character and percentage of bitumen present vary within wide limits. Those which contain from 7 to 10 per cent of a viscous sticky maltha are the best for road construction. The rock should be crushed down until it consists of an aggregate of individual grains, each thoroughly coated with a film of bitumen, which should cause it to adhere firmly to the surrounding grains if subjected to pressure. This aggregate may then be used as a surfacing material in macadam construction.

The foundation of a rock asphalt macadam is prepared in the same manner as described under the penetration method. Upon this foundation should be spread a 2½-inch course of broken stone, preferably ranging from 1 to 2 inches in diameter. This course should be rolled only sufficiently to produce a smooth, even surface, and no attempt should be made to reduce the voids in any other manner. The rock asphalt should then be thrown on and raked over the surface to a uniform depth of one-half inch. This application is rolled into the upper course as thoroughly as possible and a second coat of the rock asphalt applied in the same manner, but to a depth of 1 inch. The road is then finished off by rolling until it is firm and well compacted.

MANUFACTURED BITUMINOUS AGGREGATES.

Besides the three methods of constructing bituminous-bound roads which have been described there are a number of others, but all of less importance. Certain proprietary or patented mixtures of bitumen with a mineral aggregate can now be obtained for use in the construction of the wearing course of roads, and some of them have been quite extensively employed in the eastern part of the United States with excellent results. Most of these mixtures, while prepared with hot materials, can be shipped and laid cold. They are used in place of the No. 2 course in ordinary macadam construction. To prevent the individual particles from cementing together under their own pressure during shipment, damp sand is sometimes incorporated in the mixture. The mineral aggregate is carefully graded, and when laid and rolled, consolidates into a dense, well-bound wearing surface. Fluxed native asphalts, oil asphalts, and residual tars are employed as binders for the aggregates, and sometimes other ingredients, such as lime, are combined with the bitumen. Both crushed rock and crushed slag have been used for the aggregate, the latter principally in England. While these manufactured bituminous aggregates are very convenient for the road engineer to employ, their use is necessarily limited to the locality in which they are manufactured, as freight charges on long shipments raise their cost to a prohibitive figure.

CONCLUSION.

Bituminous road binders may be employed in the construction of earth and gravel roads as well as macadam roads, but it is the latter type which, at the present time, gives promise of the most satisfactory results. The bituminous macadam, if properly constructed, seems well adapted to withstand the combined action of automobile and horse-drawn traffic. It is firm, resilient, and waterproof, and is dustless in the same sense that an ordinary asphalt pavement is dustless. Much depends upon the character of the bituminous binder used, and it is most necessary that this binder be subject to examination and certain specific tests, as in the case of cement, iron, steel, and other structural material.