THE TESTING AND USE OF ROAD TARS

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SYNOPSIS

In order to make needed improvements in specifications for bituminous materials that will assure protection against weathering, more information is needed concerning the mechanics of weathering and its effects on bituminous films

By means of special apparatus the effects of evaporation, oxidation, polymerization, water and light on tar road materials were studied It was found that evaporation is the major factor with oxidation playing a minor rôle Light water and polymerization were found to be relatively unimportant in the weathering of road tar

Further studies were made by subjecting road tars to the combined effects of evaporation and oxidation in a test designed to simulate road conditions which permit water and air to penetrate below the aggregate on the surface

The effects of the treatment were studied by a stability test on a modified Hubbard-Field stability machine and a sand-blast wear test Thus far no case has been found in these tests where a mix containing a pure bitumen has shown a decrease in stability as a result of weathering

The results of the wear tests on samples weathered in a loose condition and on specimens molded under pressure indicate the effect of surface area on speed of weathering and emphasize the necessity for reducing the amount of bituminous surface exposed to weathering to a minimum

Many bituminous roads, constructed during the past few years, have required early and excessive maintenance because they were open roads Any road is an open road which will permit water and air to penetrate below the aggregate on the surface If water and air can enter from the top they, together with light, heat and cold, may cause mechanical destruction, chemical alteration, evaporation or oxidation of part or all of the materials of which the open road is composed Every road building material is affected to some extent by part or all of these weathering influences, the rate and extent depending upon the degree of exposure

The materials in the interior of a dense tightly sealed road are weathered only slightly, if at all, by these same agencies because weathering is confined to the surface and the surface is the top of the road The surface of an open road is not confined to the top but extends all through the road and is the sum of all the individual surfaces of all exposed materials contained therein On this basis the surface of an open road is many times greater than that of a tightly sealed road and, since the extent of weathering varies with the area of the exposed surface, it follows that the rate and extent of weathering in an open road is many times greater than that in a tightly sealed road In fact, an open road may be called an accelerated weathering device

Many engineers have failed to recognize these facts in building bituminous roads, especially by premix and road mix methods The use of improperly graded aggregates, too low viscosity binders, too little binder and little or no seal coat have caused some bituminous roads to be so open that rapid weathering has occurred Usually such weathering could have been prevented by the use of proper seal coats It is just as necessary for a bituminous road to have a weather-tight surface as it is for a house to have a weather-tight roof Both serve the same purpose They protect the contents of the structures against the destructive agencies of nature. It is just as necessary to seal the surface of a road completely as it is to seal the surface of wood or iron, exposed to weathering, with paint or varnish

All too frequently bituminous binders have been blamed for failures caused by open type construction and inadequate or improper seal coats For example, a mixed-in-place road, composed of coarse, improperly graded aggregate and a low viscosity binder with no seal or sealed with the same low viscosity material and course aggregate, starts to ravel or wear excessively and the bituminous material is said to be of inferior quality, but the same material used in another road of the same type, built with properly graded aggregates and properly sealed, gives satisfactory service for many years The reasons should be obvious The thin films of binder surrounding aggregate particles in the open road are directly exposed to weathering, whereas similar films in the road that is tightly sealed are not

Many cases of this kind have demonstrated that the service life of a bituminous road depends to a large extent upon the construction and surface treatment methods used and to a smaller extent upon the bituminous binder On this account every enginer should give careful attention to his construction and surface treatment methods so that, from these standpoints at least, his completed roads are as completely resistant to weathering as possible

On the other hand, absolute protection against weathering is impossible and specifications for bituminous materials should be so written that the engineer is assured of good weather resistance in the bituminous materials which he uses

Present specifications for bituminous materials are not entirely satisfactory in this respect and improvements probably can be effected, but, in order to make such improvements, more information is needed concerning the mechanism of weathering and its effects upon bituminous films

We are endeavoring to obtain such information for road tars and for this purpose have developed certain test methods and procedures which are not intended to be used for routine analytical purposes but rather as research tools to supply the information upon which routine test methods and specifications can be based

At the start of our investigations we assumed that the weathering of tar road materials may involve one, all or any combination of the following weathering agencies evaporation, oxidation, polymerization, water, light

In order to study the effects of these weathering factors individually a special cell was designed This cell consisted of a closed chamber surrounded by an oil bath for maintaining a constant temperature and was equipped with suitable inlets and outlets for the passage of gases or water The chamber contained a large horizontal cylinder of wire screening that rotated at a speed of 5 to 6 revolutions per minute It carried a thin film of tar from a supply in the bottom of the container up into the atmosphere or water above the tar, thereby renewing the bituminous film continuously and exposing a large surface area to the weathering conditions

By recirculating a stream of nitrogen through the chamber (with suitable scrubbers outside the chamber to remove material evaporated from the tar) it was possible to study the effect of evaporation alone By maintaining a static atmosphere of oxygen or air in the chamber the effect of oxidation alone was determined The combined effects of oxidation and evaporation were studied by passing a current of air through the chamber A stream of water was passed through the chamber to determine the effects of water, and for polymerization the tar was subjected to heat alone in an atmosphere of nitrogen, all openings being closed to prevent evaporation The effects of light were not determined in this apparatus

In each of these experiments consistency determinations were made to detect and measure changes in the road tar The consistency test used for this purpose was the float test of the American Society for Testing Materials, D 139–27

The results of these tests are best illustrated by the curves on the following Figure 1 which represent the data from a typical hot application road tar made from high temperature coke oven tar

The tar was maintained at 60°C (140°F) in these tests because this temperature approximates that reached by a road surface in the northern United States in summer Of the factors studied it appears that evaporation has the greatest effect Oxidation is second in importance and its effect is considerably smaller than that of evaporation The effect of water is slight and polymerization appears to have little or no effect The higher initial consistency in the case of polymerization was the result of manipulation in introducing the tar into the exposure chamber While the effect of light was not studied with this apparatus, later work with other equipment indicated that light has but slight effect on a high temperature coke oven tar Heat has some effect in that it accelerates evaporation, heat also accelerates oxidation and polymerization, but the data presented here indicate that at the temperature at which the experiments were carried out (140°F) these processes were not accelerated to any appreciable extent

Recent investigations by a number of European investigators (1, 2, 3, 4, 5, 6)[1] also have led to the conclusion that evaporation is the principal factor in the weathering of tars Sabrou and Renaudie state (6) that evaporation has one hundred times as much effect as oxidation These two workers also investigated the effect of light, subjecting samples of tar spread in thin films to ultra-violet radiation for periods of 150 hours and found no change in the tar under these conditions

Having decided from our investigations that evaporation is the major factor in the weathering of road tar and oxidation a minor factor, with light, water and polymerization relatively unimportant, we proceeded to develop a method which subjects road tars to the combined effects

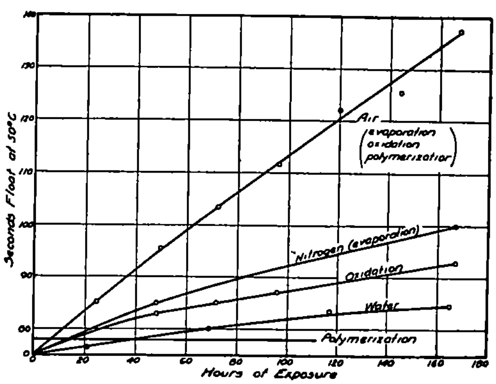

Figure 1. Effects of Various Factors on a Road Tar Prepared from High Temperature Coke Oven Tar

of evaporation and oxidation under conditions simulating the conditions of an open road As explained above, the aggregate in an open road is surrounded by thin films of the bituminous binder and those films, due to the open construction, are exposed to weathering We simulate this condition by mixing approximately three to four percent by weight of the tar to be tested with standard 20–30 mesh Ottawa sand and then weather the mixture in an oven held at 60°C (140°F) with the ports open on the side to permit a natural circulation of air and to permit the escape of products removed by evaporation

[1] See list of references at end

The oven used for this purpose is of the rotating shelf type described by A S T M Specification D 6–33, but the standard shelf is replaced by a circular pan—the bottom of which is 25 mesh screen reinforced by a heavier screen of larger mesh This equipment is illustrated by Figure 2

The mixture of tar and Ottawa sand is placed loosely on this screen in a layer approximately $\frac{3}{8}$ in thick, by which arrangement some circulation of air through the mix is obtained By revolving the pan containing the mixture all portions are subjected uniformly to the conditions of temperature and air circulation which cause the tar films to be evaporated and

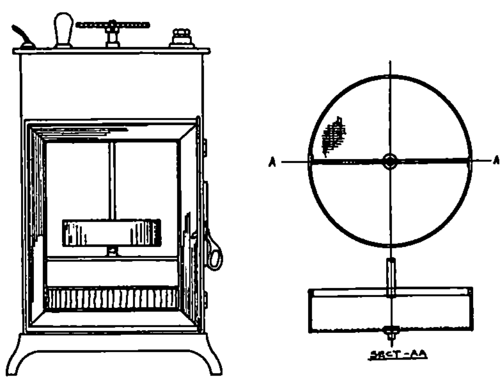

Figure 2 Oven for Weathering Test

oxidized The temperature of the oven is maintained at 60°C (140°F) and the pan is rotated at a speed of 5 to 6 r p m

In order to determine the effects produced by weathering tar-sand mixtures under these conditions, it was necessary to develop a miniature stability device, but that alone was found to be insufficient A mixture can have high stability and yet because of brittleness or for other reasons have poor resistance to wear, so that it was necessary to devise and construct a wear tester Each mixture weathered in the oven described above can now be tested for stability and wear resistance

The stability test is used to follow the course of oven weathering because it is dependent upon the actual binding capacity of the tar and the results have significance from the standpoint of road construction Since there was no stability machine available for small scale work, it was necessary to build a special machine for this purpose The necessity for this construction proved advantageous, however, because it made possible the incorporation of certain desirable modifications The general arrangement used in the Hubbard-Field stability machine was employed because it allows specimens to be tested without removing them from the molds in which they are compressed—an important factor when working with uncured material However, a modification was provided in that the plunger which exerts force on the specimens is slightly smaller than the extrusion orifice, thereby making possible the measurements of an action approaching true shear This modification, coupled with the negligible mechanical stability of the aggregate (composed of very closely graded particles of nearly spherical shape) makes possible the measurement of effects which are almost wholly related to the bituminous material under test

In this stability test, 15 gram portions of the tar-sand mixture are placed in brass cylinders of one inch inside diameter and one and one-half inches high The cylinders are held in a constant temperature oven at 25°C for 30 min (sufficient time to bring the specimens to constant temperature) then molded by a hydraulic press at 3300 pounds per square inch pressure for 1 min The specimens are tested immediately thereafter The testing temperature is so close to that of the room that no testing bath is required

The arrangement used in testing the specimens for stability is shown in Figure 3 The molding form "A" containing the test specimen "B" is placed on the beveled ring "D" which is held in place by the testing ring support "C" The beveled ring "D" has an inside diameter of 0 875 in Into the molding form "A" and on top of the test specimen "B" is placed the steel tube "E" of 0 750 in inside diameter; this steel tube acts as a guide for the plunger "F" which rests on the upper surface of the test specimen The assembled testing unit is then placed on a weighing scale Force is applied to the test specimen by means of a constant speed motor and gear arrangement fastened directly over the scale The gear is connected to a piston which moves downward at a rate of three inches per minute and, pressing against the steel ball "G" (used to insure direct application of force), exerts a constantly increasing force through the plunger "F" on the test specimen The magnitude of the force is given by the indicator on the scale When the force reaches a certain magnitude which is governed by the character of the bitumen a shearing action takes place within the test specimen and the center core is forced through the testing ring "D " When this breakdown in the structure of the specimen takes place the indicator on the scale shows a sudden decrease in force; the maximum reading on the scale is taken as the stability of the test specimen

The range of the instrument is from 0 to 2800 ounces The scale itself has a capacity of 640 ounces and by the use of an auxiliary beam which can be attached to the main beam of the scale the capacity of the scale is increased by more than four times Since the initial stabilities of hot application surface treating tars range from 50 to 100 ounces by this test, it is obvious that the machine will measure the stabilities of extensively weathered materials

The degree of precision obtainable with this method is of a high order considering the factors involved Check specimens of the same material generally vary no more than four or five ounces for stabilities less than 100 ounces and since it has been the practice to express results as the average of three to five readings, stabilities below 100 ounces can be checked within 2 ounces For higher stabilities the precision of the test is within 5 per cent

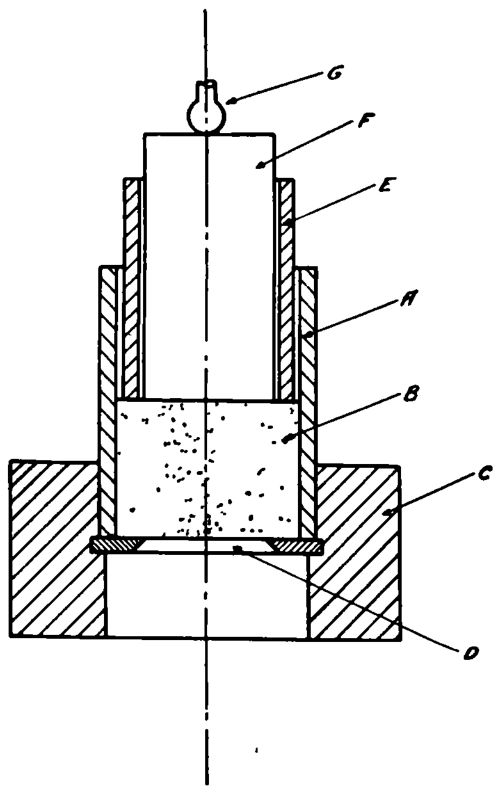

Figure 3 Arrangement Used in Testing for Stability

Information concerning the wear resistance of the weathered tar-sand mixes is needed in order to obtain a more complete picture of weathering over extended periods. While the stability test is used for the entire range of weathering its practical significance is limited to the earlier stages of weathering during which the bituminous material is "setting-up" sufficiently to prevent movement of aggregate particles Thus far we have found no case where a mix containing a pure bitumen has shown a decrease in stability as the result of weathering Accordingly, examination of some other characteristic of the tar-sand mixes is necessary We selected the wear test for this purpose because it simulates the abrasive action of traffic which tends to remove aggregate particles from the road surface when the bituminous films have become too brittle to hold them in place

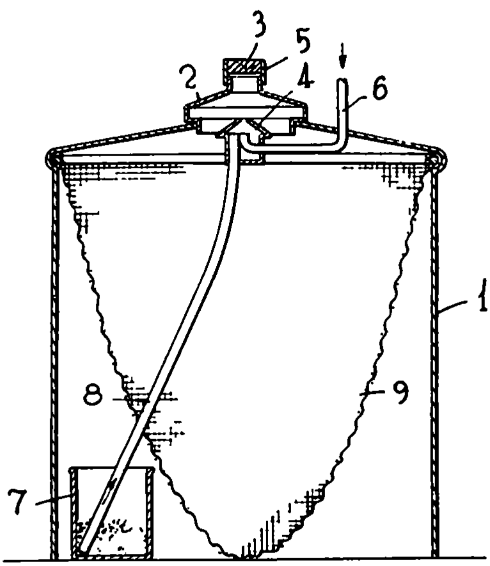

Figure 4. Apparatus for Wear Test

In order to determine the resistance to wear a 15-gram specimen of the tar-sand mix taken from the oven is cooled to 25°C and molded at 3300 pounds pressure per square inch, as described previously for the stability test This specimen is then blasted with Ottawa sand projected by air under 10 pounds pressure The loss in weight is reported as the percentage of wear for the specimen The arrangement of the apparatus used for this test is illustrated in Figure 4 The weighed mold "5" containing the compressed tar-sand mix is placed in position over the collar "2". Fifty grams of 20–30 mesh Ottawa river sand for the sand blast are placed in the vessel "7" The sand is drawn up to the nozzle "4" through the tube "8" by means of air under 10 pounds pressure which is admitted through connection "6" The spent sand, together with dislodged material from the specimen drops into the bag "9" which permits the air to escape but retains all of the sand After the specimen has been blasted with the 50 grams of sand it is removed from the machine, reweighed, and the percentage of wear calculated

In order to determine the exact amount of tar in the mixes to be weathered a representative sample is weighed into a porcelain crucible on an analytical balance, ignited until all traces of tar and carbon have disappeared, cooled and reweighed The Ottawa river sand used as the aggregate is so clean it generally shows no loss when ignited by itself and the loss in weight of the tar-sand mix resulting from ignition can, therefore, be taken as the amount of tar This means of controlling the proportions in the original mix has added considerably to the precision of the weathering test

Accelerated Weathering of a Typical Road Tar·

The following description of a complete weathering test will help to illustrate the way in which such tests are performed A weathering test was made exactly as described in the previous section: 800 g of the 20–30 mesh Ottawa river sand were mixed with 28 44 g of a typical road tar by hand until the sand particles were evenly coated Loss on ignition of three samples taken from different portions of the mix showed 3 37 per cent, 3 38 per cent and 3 37 per cent of tar by weight (only a slight amount of tar was left on the walls of the pan) indicating that the tar was distributed uniformly throughout the mix Fifteen gram portions of the mix, cooled to 25°C, molded for one minute at 330 lb per sq in pressure and tested for stability showed figures of 8, 7 and 8 ounces respectively The remainder of the mix was then spread out evenly in the rotating pan and placed in the weathering oven held at 60°C (140°F) Samples were taken from the oven at the end of 1, 2, 4, 7, 9 5, 12 and 15 hours and tested for stability and resistance to wear The results of these tests are shown as curves 1 and 2 in Figure 5 It should be noted that the stability scale is given on the left side of the graph, the per cent wear on an inverted scale on the right hand side and that the time is plotted on a logarithmic scale

In order to clarify the mechanics of the test another mix of the same tar and sand in the same proportions was prepared, but in this case the mix was divided into 15-g portions and placed into brass molds These portions were pressed at 3300 lb per sq in for one minute and then placed on the rotating pan in the weathering oven At the end of three days the specimen had developed enough stability at 60°C to retain their structure and it was possible to lay the molds on their side, thereby allowing weathering to take place both on the tops and bottoms of the specimens At certain intervals specimens were removed from the oven and tested for stability and resistance to wear, the results of these tests are shown as curves 3 and 4 in Figure 5

The results of the two tests just described are placed side by side in order to show the greater effect that is obtained by weathering the tar-sand mix in a loose state A tar-sand mix that has been weathered for some time and then taken from the oven and cooled to the testing temperature before being molded never develops as much structural strength as it will possess if it is subjected to the same amount of weathering while in a molded state This fact is brought out clearly by Figure 5, while the tar-sand mix in the premolded state was confined and changed somewhat more slowly, it showed a radically different relation between stability and resistance to wear When the premolded specimens reached a stability of 2800 ounces, their wear was only 5 percent, while the mix weathered in the loose state showed 10 percent wear for the same stability figure Furthermore, long after the premolded specimens had developed stabilities exceeding the capacity of the testing machine, the wear showed only a very gradual increase and at the end of 312 hours weathering was less than half the figure reached by the loose mix in 23 5 hours

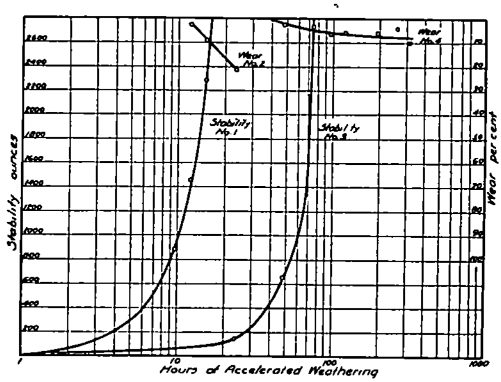

Figure 5

These two tests clearly indicate the effect of surface area on speed of weathering and emphasize the necessity for reducing the amount of bituminous surface exposed to weathering to a minimum That minimum should be the area of the top surface of the road

During the past two years we have been comparing the results obtained by these accelerated weathering tests with actual service results and have found that we can predict the comparative rates at which different road tars will approach the point at which they contribute stability to the road and are said to have "set-up" This pertains both to road tars applied to the surfaces of roads and those used for construction by mixed-in-place, premix or penetration methods As stated previously, we do not expect these tests to be applied, in a routine manner, to every road tar to determine "setting-up" rates, but by comparing such rates for a large number of road tars of known composition we do expect to be able to modify existing road tar specifications or suggest new ones so that they will better control this particular characteristic

We also have found that we can predict the comparative durabilities of different road tars exposed to weathering under service conditions on the surfaces of roads or in the interiors of open roads, and as soon as sufficient data have been collected, we expect to be able to suggest modifications of and additions to existing road tar specifications which will insure maximum durability for any particular set of service conditions

In closing, we wish to point out that the accelerated weathering methods which we have described have already proved to be valuable research tools when applied to road tars They have not been used for the comparison of examination of other varieties of bituminous road materials, and if so used probably would need to be modified, particularly if in the weathering of such bituminous materials, light and water are important factors

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DISCUSSION ON ROAD TARS

MR CALEB DAVIES, JR, *Consulting Engineer* The remarks about the importance of good seal coats and the fact that tight paving mixtures are greatly superior to open ones are certainly well taken In line with this, it might be well also to emphasize the fact that it is easy to waste money by not using enough tar per square yard, or by using tar of too low viscosity, as well as by not properly closing the voids

It should also perhaps be emphasized that the tests described are the result of successful scientific efforts to *accelerate* deterioration Some materials which deteriorated rapidly under these procedures are similar to components of a 20 year bonded roof and identical with tar which is found to be in "live" condition on the under side of the chips in a properly constructed road surface after prolonged use

Caution should be used in comparing different materials according to their *ultimate* deterioration products A very considerable amount of hardening or "curing" is inherent in the normal performance of good bituminous road materials But comparison after too unusual a degree of hardening might be as misleading as to evaluate different kinds of steel according to the kinds of rust they make Only if the road surface is too open and the tar films too thin and with too much contact with air and too little tar contact "stone-to-stone," will the tar be likely to approach ultimate deterioration very soon—but no tar will give satisfactory service under these conditions, anyhow The proper comparison of tars would seem to be that which follows an amount of "accelerated weathering" which is sufficient to cause normal hardening of a normal tar However, two tars may at first approach equilibrium with service conditions at different rates without much difference in ultimate life, since most of the life of a road may be after most of the evaporation changes in the tar have taken place

The sand-blast test may not be as significant as the stability test in cases where the wearing surface of the road is protected against abrasion by a good coating of chips