What is a Quality Asphalt?

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In 1893, Clifford Richardson, one of the first authorities in asphalt paving, issued a "Report on Asphaltum" in which he stated that "The life of an asphalt pavement depends upon three things:

1. The materials of which it is constructed
2. The skill with which it is laid
3. The amount of traffic it sustains."

In 1905 this same author published a book, "The Modern Asphalt Pavement," in which he discussed the quality aspects of asphaltic binders for pavements. Thus the pioneers of asphalt paving in the United States recognized the importance of asphalt quality just as we do in present day construction. A brief historical review of the development of test methods and specifications to assure quality is believed to be of interest.

Prior to 1900 asphalt cements used in the United States were obtained almost entirely from natural deposits such as those found in Trinidad and Bermudez lakes and a few minor deposits found in Cuba, Mexico and the United States. Since these natural asphalts contained varying amounts of organic and inorganic material, one of the earliest criterion of quality was purity. This was measured by the solubility of the materials in solvents.

These natural asphalts usually were too hard to use as binders for pavements and were softened by blending with a flux oil. The fluxes used were products from the refining of the relatively few crude petroleums available at that time. It was established that the quality of the fluxed asphalt was also dependent upon the amount and character of the flux used. Thus, oven heat tests at 325°F. and 400°F. were devised to control the volatility of the flux and the fluxed asphalt. It is of interest to note that for some of these tests the time of heating was five hours, the same as is used today.

To determine the amount of flux necessary to obtain the proper consistency of the fluxed asphalt, the usual test was to chew a small piece of the cement, previously cooled in water. An experienced operator of a fluxing plant could tell whether the material was the consistency desired. Although penetrometers were available around 1890 their use was restricted to the chemist in the laboratory.

The above tests together with such characteristics as color, specific gravity, lustre, fracture, and odor were used to differentiate between or identify the asphalts available in the early days for use in asphalt paving. Even though there were only a few of these materials, questions were frequently asked about their relative quality. There was no system of chemical or physical analysis that would determine for a certainty that a given untried asphalt would make a good pavement and the real and final test of quality could only be determined by its performance in actual service for a proper length of time.

Around 1900, tests were devised to measure softening point, ductility, and flash point of the asphalt cements and these together with tests for penetration, loss on heating, and solubility formed a basis for defining and controlling the properties of asphalt cements. Thus it was through the experience in the use of a few natural asphalts that most of the tests used to control the properties of present-day asphalts were developed.

Since these early days, the development of the petroleum industry in the United States resulted almost entirely in the replacement of these native asphalts with petroleum asphalts. The discovery of widely different crude sources together with the development of numerous methods to refine these crudes for special products has resulted in the production of asphalts with widely divergent properties. However, except for refinements of test procedures and some adjustment of limits of specification requirements, it is only recently that new tests and specification requirements have come into use to more nearly control the quality of our present materials. It is quite evident that the development of quality specifications has not kept pace with the growth of the petroleum industry.

There has been considerable debate among engineers and technologists, representing both consumer and producer interests, as to what purpose our traditional standard specification tests have served. Although the primary use of the penetration test has been to measure consistency to control various grades of asphalt it also is used to evaluate temperature susceptibility.

The penetration test also has been a good tool to evaluate changes in asphalt during laboratory aging tests and during exposure to plant mixing and service in the pavement. While there has been a difference of opinion on the merits of the ductility test, it without doubt has served a useful purpose in restricting the use of some asphalts that would not be satisfactory binders. In the beginning the loss-on-heating test was useful to control the volatility of fluxes for native asphalts, but it has been of little value in differentiating between the hardening characteristics of petroleum asphalts. It is generally agreed that solubility tests have been adequate for controlling purity and the flash point tests are satisfactory to indicate the fire hazard associated with heating the asphaltic materials.

From time to time in the past 30 years, numerous special tests such as susceptibility factors, sulfur determination, solubility in special solvents, etc., have been devised and used for setting specification requirements as an expedient to get better asphalts. Most of these were essentially in the nature of identification tests and the specification requirements were set to obtain an asphalt from a specific source at the exclusion of all or most of the others. Except for the fact that the asphalt wanted had shown good service performance, the special requirements usually had no bearing on quality. Often asphalts of at least equal performance were excluded. Only a few of these special tests are found in specifications in effect today.

Two "new" tests not included among those inherited from the days of natural asphalts are the Oliensis test and the thin film oven test. The Oliensis test was developed nearly 30 years ago and served a useful purpose in identifying and restricting the use of cracked asphalts that were found to have poor weathering properties. The thin film oven test developed by the Bureau of Public Roads, controls the hardening characteristics of asphalts and will be discussed more thoroughly later.

From the foregoing discussion it is evident that almost all of the tests and specification requirements in general use today were developed on a trial and error basis for conditions and materials that no longer exist. Progress in developing new tests that would more nearly define quality requirements has been exceedingly slow.

Perhaps the principal "road block" to the progress has been a failure to clearly understand what these quality requirements are—or as the title of this discussion implies, "What is a Quality Asphalt?"

If this question were given to a number of engineers and asphalt technologists, representing both consumer and producer interest, it is conceivable that the answers would be quite different from the standpoint of what properties constitute a quality asphalt and to what degree the specifications should control any of the properties. From the consumers' point of view, the wide range in properties of present day asphalts meeting the standard specifications together with the differences in the performance of these materials in service shows that problems relative to quality do exist.

We believe at least partial answers to some of these problems have been obtained by research and field performance studies. In some areas this knowledge is adequate to justify revising our specifications to assure better materials. However, there are other problems relative to asphalt quality for which sufficient knowledge has not been developed to provide a firm basis for realistic specification requirements.

Thus the following discussion will be based on three general areas of the problem: (1) the problem associated with the control of the desired engineering properties of the asphalt, (2) how specifications can be improved based on present knowledge, and (3) research needed to develop other quality requirements.

THE PROBLEM OF DURABILITY

The most important property of asphalt that needs to be controlled by specifications is its resistance to change during normal plant mixing with hot aggregates and during exposure in the pavement. It was mentioned earlier that for many years the only standard test used to measure this property was the loss-in-heating test. While this test was of value in determining the volatility of fluxes and fluxed native asphalt it has been generally accepted that it does not measure the hardening characteristics of present day petroleum asphalts. The inadequacy of the loss-on-heating test was shown in two recent reports by the Bureau of Public Roads on the properties of asphalt cements produced in the U. S. for use in highway construction.

The samples of asphalt cement for these studies were collected by the regional offices of the bureau with the cooperation of the state highway departments. In all, 323 samples from 105 refineries or storage terminals were obtained and are believed to be representative of asphalts produced in the U. S. All asphalt cements were tested to show the test characteristics most generally used for specification purposes and those that are being used by some agencies in an effort to obtain better materials. The first report (3) gave the results of tests on only the 85-100 penetration asphalts, and the second report (4) gave the results of tests on the other penetration grades and compared the characteristics of the 60-70 and 120-150 penetration asphalts with those of the 85-100 penetration materials given in the first report. The reports show the range for asphalts on a nationwide basis and point out the significance of the wide differences in properties of materials meeting the same specifications. These reports also stress the importance of more adequate test methods and specifications to control the properties of asphalt cements.

To illustrate the range in the properties of the asphalt cements used in these studies, frequency distribution graphs in the form of frequency polygons were used. When comparisons of the test results for the 60-70, 85-100, and 120-150 penetration asphalts were made, the percent of samples was used for the vertical axis. The percentages of values for a given test falling in each class interval were plotted at the midpoint of each interval and these were connected to form the polygon.

A few of the frequency distribution polygons will be used to illustrate the range in properties of some of the tests discussed here.

To illustrate the inadequacy of the standard loss-on-heating test to control the problem of durability, the results of tests on 119 samples of 85-100 penetration asphalt are used.

In most state specifications for asphalt cement, requirements for the standard loss-on-heating permit up to one per cent loss with the minimum requirements for retained penetration of the residue ranging from 50 to 80 per cent. The maximum loss in weight found for any of the 119 asphalts was 0.58 per cent and only two asphalts had less than 80 per cent retained penetration, the most severe requirement in use.

Some of the asphalts included in this study were known to have relatively low resistance to hardening in plant mixing and had shown poor performance in the road. The standard loss-on-heating test does not furnish the desired restriction against the production of such materials.

The inadequacy of this test was recognized more than 20 years ago and Public Roads started an extensive research program to find a better test. This resulted in the development of the thin film oven test which now has been adopted by many states, the American Association of State Highway Officials, the Corps of Engineers, and the Asphalt Institute. The test is simple and suitable for specification purposes. The procedure is similar to the standard loss-on-heating test except a film of asphalt 1/8 inch thick, in a 5½ inch diameter container, is heated for 5 hours at 325°F. The loss in weight of the sample and the per cent of original penetration and ductility of the residue are determined. It was first established in the laboratory and later confirmed by field studies that the changes in the properties of the asphalt occurring in the thin film test are related to the changes occurring in the mixing plant under normal operation. There is some evidence that the thin film test not only differentiates between the hardening characteristics of asphalts in plant mixing but also is indicative of the rate of hardening of asphalt in the pavement. More research is needed to establish this.

For the 85-100 penetration asphalts the change in weight during the thin film test ranged from a slight gain to a 2.18 per cent loss and the penetration of the residue ranged from 38 to 72 per cent.

A comparison of the range in values for loss in weight of the 85-100 penetration asphalts during the standard and thin film oven tests is shown in Figure 1. The distribution of the results of re-

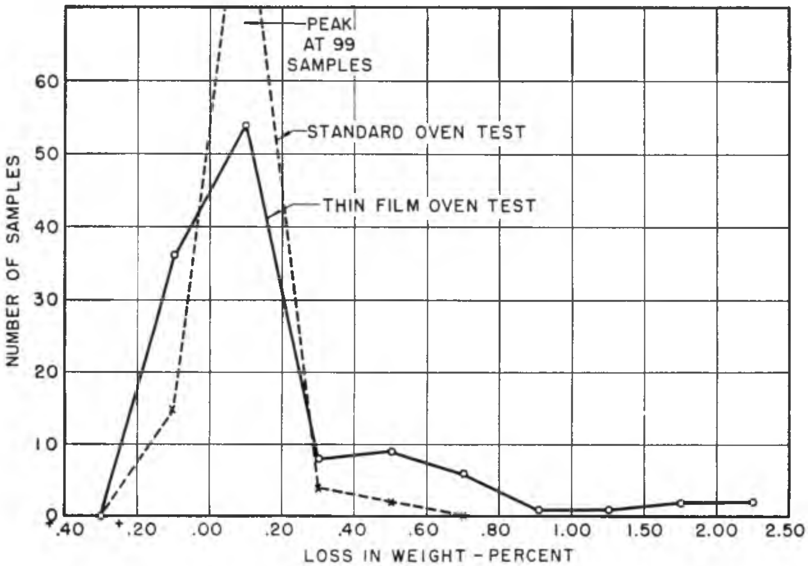

Fig. 1. Distribution of loss in weight for thin-film oven test and comparison with loss in standard test.

tained penetration after these two tests is shown in Figure 2. The appreciable greater spread in loss in weight and in retained penetration for the thin film test provides a much better basis for evaluating the hardening characteristics of asphalt cements.

None of the original asphalts had ductility values less than 100 cm., but after heating 22 asphalts had ductilities less than 100 cm. and of these 9 were less than 50 cm. There has been some criticism of requirements for minimum ductility value on the residue from the thin film test. While it is difficult to establish a numerical value for ductility of the original asphalt or evaluate the amount of change during the thin film test, we believe that the actual ductility of the residue is significant.

In 1959 the American Association of State Highway Officials made the thin film test a part of its specifications. Although requirements are not specified, limits for loss in weight, retained penetration, and ductil-

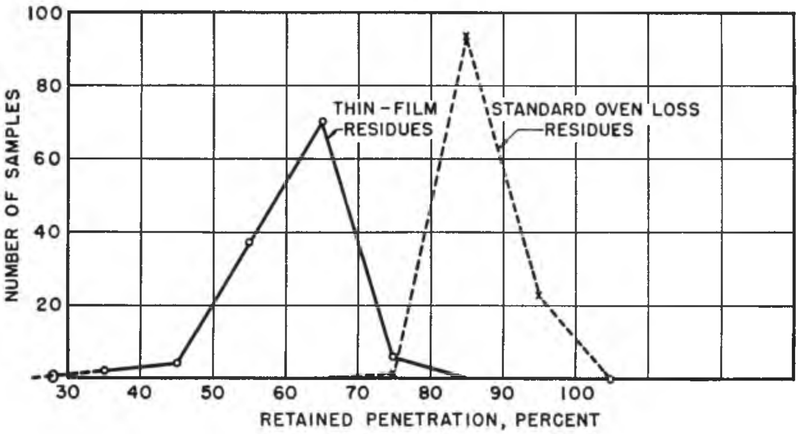

Fig. 2. Comparison of the distribution of the results of retained penetration after standard and thin-film oven tests.

ity are suggested. These were established on the basis of the results of Public Roads' study of asphalts mentioned above. In setting these limits consideration was given to their use on a national basis and the allowance of a certain tolerance for testing precision. In general, they are lenient and we believe more restrictive limits could be used for certain areas of the country without causing undue hardships from the standpoint of asphalt production.

Another development that shows considerable promise for studying asphalt hardening is the sliding plate microviscometer and the aging index. This instrument measures viscosity of the asphalt in poises, and the aging index is a ratio of the viscosity of the asphalt after aging a five-micron film for two hours at 225°F. to the original viscosity. Although our studies show there is a good correlation between the thin film test and the aging index we believe the techniques for making determinations with the microviscometer have not been standardized sufficiently so that specification requirements based on its use would be practical at the present time.

THE PROBLEM OF CONSISTENCY

In the construction of asphaltic concrete pavements the asphalt cement binder is exposed to widely differing temperatures ranging from those required to provide adequate fluidity for mixing with the aggregate to those required for spreading and compacting the mixture and the final normal road temperature. In the pavement the asphalt may be subjected to a range in temperatures from a high of about 140°F. to temperatures well below freezing. Although asphalt cements are required to function over such a wide range of temperature, it has been almost standard practice to control consistency at only one temperature, 77°F., for specification purposes.

It is well established that asphalt cements having the same consistency at 77°F. can have widely different viscosity-temperature relations and that consistency can differ greatly at higher and lower temperatures. Attempts have been made to limit these differences by the use of empirical susceptibility factors based on some relation between penetration tests at two or more temperatures, often using different factors of time and loading. For example, some of the western states use a ratio of the penetration at 39.2°F., 200 g., 60 sec. to the penetration at 77°F., 100 g., 5 sec. as a specification requirement, with a minimum limit of 25. While this requirement may serve to eliminate asphalts of unusually high temperature susceptibility in the western area, it would be of little significance if used on a national basis. The bureau studies of asphalt produced throughout the United States showed that in general the asphalts produced in the western states have to have greater temperature susceptibility (low penetration ratios) than those produced in the eastern states. It was further pointed out that the ratio obtained by different times of penetration and load is not believed to be a realistic measure of susceptibility. Indices of this type are not considered to be satisfactory for specification requirements.

Another approach to controlling the viscosity-temperature characteristics of asphalts is by specification limits for viscosity at high temperatures. Several of the far western states have established minimum and maximum Furol viscosity limits at 275°F. These are 100 to 325, 85 to 260, and 70 to 210 seconds for the 60-70, 85-100, and 120-150 penetration grade asphalts. It was found that thirty per cent of the 60-70, eight per cent of the 85-100 and seven per cent of the 120-150 asphalts represented in our studies had viscosities above the maximum limits. None of the asphalts of any of these grades were below the minimum limits. The asphalts that had viscosities above the maximum requirement were in most cases from eastern sources and it is doubtful whether they would be marketed in the western states. The western specification requirements for high temperature viscosity may be justified from the fact that they tend to control the uniformity of production in that area. However, they cannot be justified on the basis of asphalt quality since asphalts having good performance records in other areas would be excluded.

The bureau studies showed the ranges in viscosity for all asphalts of the 60-70, 85-100, and 120-150 grades were 144-431, 85-318, and 71-250 respectively. The frequency distribution polygons for Furol viscosity at 275°F. for the three grades are shown in Figure 3. The

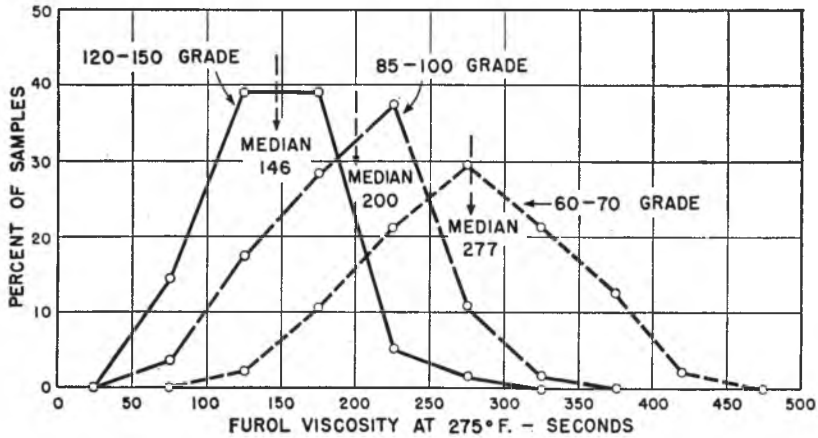

Fig. 3. Distribution of furol viscosity.

median values for these grades are also shown. We believe these wide differences in high temperature viscosity are significant from the standpoint of mixing and compacting asphaltic paving mixtures. In an effort to minimize the effect of this difference, some states have adopted the practice of setting plant mixing temperatures so that the Furol viscosity of the asphalt will be between 75 and 150 seconds.

The Bureau of Public Roads supports this means of control and believes its use will not only reduce excessive damage to the asphalt from overheating mixtures but will also provide more uniform mixture workability. Although these limiting viscosity values are subject to aggregate drying requirements and mixture workability there is some evidence that the maximum limit for viscosity could be higher than 150 seconds. More information is needed to establish the best range.

Another problem that has been associated with asphalt viscosity is the tender mix or as sometimes called "slow setting" property of paving mixtures, reported from a number of areas of the country during the past few years. These conditions are exemplified by the lack of stability of the paving mixture during compaction and/or by a softness of the pavement for one to several days after construction. To date there has been no factual evidence that the asphalt viscosity is the only cause of this condition and other factors such as type and grading of aggregates, amount and effectiveness of mineral fillers, temperatures of mixture and air, as well as other characteristics of asphalts could contribute to the problem.

As a step toward developing further information on the effect of asphalt viscosity on the mixing, laying, and compacting of bituminous mixtures, Public Roads distributed a study proposal to the state highway departments early last year. This was sent out primarily to determine the interest of the states in this problem and if interested, to offer assistance in any way to plan the studies. Several states have indicated they would conduct a study and some of these should be underway this year.

In addition to the work of the states, the Physical Research Division of Public Roads has an active laboratory research program underway to evaluate the effect of viscosity on the properties of paving mixtures over the range of temperatures the asphalt would be subjected to during construction and on the road.

For this study the sliding-plate microviscometer will be used to determine the viscosity of asphalt cements in the temperature range of about 50°F. to 100°F. and the vacuum and Zeitfuchs capillary viscometers will be used for determining viscosity from 100°F. to 300°F. or higher if necessary. With these instruments it will be possible to establish a viscosity-temperature curve covering most of the range in temperature to which asphalt is subjected during construction and in service. Research studies employing these tools should be able to develop fundamental data that should throw more light on the relation of asphalt viscosity to plant mixing and compaction and to the physical properties of mixtures and pavements. If such research indicates that the viscosity of any other property of the asphalt is primarily responsible for the "tenderness" or other undesirable behavior of the mixture, specifications should be written to exclude the use of the unsuitable materials. In the meantime, caution should be used to avoid the indiscriminate selection of viscosity-requirements that would make specifications uduly restrictive.

THE PROBLEM OF ADHESION

In addition to the requirement that an asphalt cement should easily coat and adhere to aggregate, the asphalt also should be of such a nature that it will retain adhesion under the combined effects of moisture and traffic. In the past this problem has been primarily associated with the aggregate. However, since asphalts vary in their wetting ability and adhesion more attention should be directed to the production of asphalt binders that will have proper adhesion characteristics. This is particularly true since the choice of aggregate on the basis of good adhesion properties may not always be possible.

In an attempt to control the adhesion characteristics of asphalts and aggregates, some agencies have included requirements in their specifications based on a coating or stripping test. Tests such as the static immersion or the immersion-compression are useful as a guide for detecting differences in the adhesion characteristics of asphalts, but a better means of evaluation is needed. Research now underway on the fundamental electro-chemical properties of asphalts and aggregates may establish which characteristics of asphalt contribute to differences in adhesion and develop a better test for controlling this property.

THE PROBLEM OF PURITY

As mentioned at the beginning of this discussion, the natural asphalts first used as road binders usually contained relatively large amounts of organic and inorganic solids and purity was of prime importance as a control of quality. In contrast, our present petroleum asphalts as produced by modern refinery methods are almost free of any solids and tests for purity are of considerably less importance. However, as protection against any inadvertent contamination with solids, a solubility requirement should be retained in specifications. A minimum requirement for solubility in carbon tetrachloride of 99.0 or 99.5 is considered adequate. Inadvertent contamination of asphalt cements by other petroleum products or water also is possible. In most cases the contamination by petroleum products will affect other properties and can be readily detected. The presence of any water in the asphalt cement would be evident by foaming during heating.

SAFETY IN HANDLING

Specification requirements for flash points are intended to indicate the temperature to which asphalts may be safely heated. The Cleveland open-cup method has been used for many years and is generally considered adequate. Because it was found that silicone products added to crude petroleum during refining or in storage to reduce foaming gave erroneous results by the Cleveland open-cup method, a few of the western states have adopted specification requirements based on the Pn-sky-Marten closed-cup. The studies of asphalts produced in the U. S. showed that a large number of the asphalts would not meet the flash point requirements set by the western specifications. If the Pensky-Martens method is to be used on a national basis it is important that specification limits should be adjusted so as not to exclude asphalts that are of good quality.

UNIFORMITY OF SUPPLY

Another important element that should be controlled by some specification requirement is the uniformity of the properties of the asphalt supplied to a given contract. While it may not be a direct aspect of asphalt quality, non-uniformity definitely can affect the quality of the pavement. In the past, maximum permissible variations in values for properties such as specific gravity and softening point have been used to control uniformity of supply and these are considered adequate. The use of a tolerance on high temperature viscosity also would provide satisfactory control of uniformity of supply.

SUMMARY

It is apparent from the discussion presented here that even after many years of experience in using asphalt in road construction and the large number of research studies that have been reported, the question *"What is a Quality Asphalt?"* cannot yet be completely answered.

The highway engineer has by trial and error learned to make use of asphaltic materials having wide ranges of properties. Materials used in one set of circumstances may be completely satisfactory yet could fail if used under other conditions. We must recognize also that even the *best* asphalt available does not guarantee a high quality and durable pavement. There are many factors that determine the properties and behavior of the finished road. The use of proper aggregates, the mixture design, the plant mixing, the spreading and compacting of the mixture on the road, all must be considered and properly controlled to obtain good results.

These things, combined with the use of empirical tests that often fail to properly measure the desired properties, have resulted in slow progress in defining and controlling true quality characteristics of the asphalt.

It is not likely that we can throw away all of our old "rules of thumb" or empirical relationships in the very near future, but new techniques now available offer promise of providing a much better basis for establishing specification requirements.

With a coordinated effort of research groups to explore and develop new quality tests, the specification writer to properly use these tests to control materials, the asphalt producer to produce quality products, and the engineer to properly use the materials, steady progress should be possible toward our universal goal of more durable and more economical asphalt pavements.

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