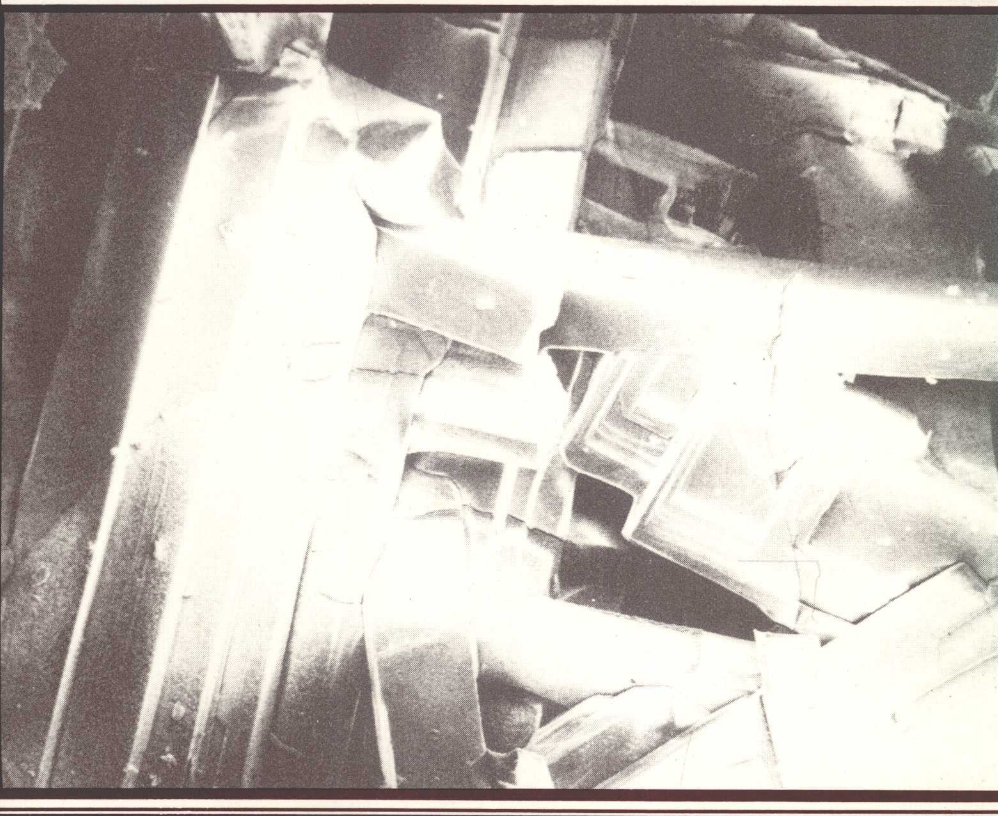
PROPERTIES OF FLEXIBLE PAVEMENT MATERIALS



J. J. Emery
editor

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PROPERTIES OF FLEXIBLE PAVEMENT MATERIALS

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Foreword

This publication, *Properties of Flexible Pavement Materials,* contains papers presented at the symposium on Advances in Pavement Materials Characterization which was held in Houston, Texas, 9 December 1981. The symposium was sponsored by ASTM Committee D-4 on Road and Paving Materials. John J. Emery, Trow Ltd., presided as symposium chairman and editor of this publication.

Related ASTM Publications

Frictional Interaction of Tire and Pavement, STP 793 (1983), 04-793000-37

Pavement Surface Characteristics and Materials, STP 763 (1982) 04-763000-47

Asphalt Pavement Construction: New Materials and Techniques, STP 724 (1981), 04-724000-08

Quality Assurance in Pavement Construction, STP 709 (1980), 04-709000-08

Surface Texture Versus Skidding, STP 583 (1975), 04-583000-37

Fatigue and Dynamic Testing of Bituminous Mixture, STP 561 (1974), 04-561000-08

Viscosity Testing of Asphalt and Experience with Viscosity Graded Specifications, STP 532 (1973), 04-532000-08

A Note of Appreciation to Reviewers

The quality of the papers that appear in this publication reflects not only the obvious efforts of the authors but also the unheralded, though essential, work of the reviewers. On behalf of ASTM we acknowledge with appreciation their dedication to high professional standards and their sacrifice of time and effort.

ASTM Committee on Publications

ASTM Editorial Staff

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Introduction

This publication is dedicated to the memory of Professor Emeritus Herbert E. Schweyer of the University of Florida College of Engineering (Chemical Engineering), whose untimely death prevented planned participation in the symposium. We are fortunate to have the abstract of his contribution with Ruth and Potts, New Approaches for Studying Rheology Properties of Asphalt, as the first paper. New development with Schweyer's rheological approach—"asphalt flow technology"—that enlightened many at meetings of technical societies such as ASTM, TRB, and AAPT were to have been described along with applications to asphalt pavement behavior. Let us hope that both Professor Schweyer's colleagues and newcomers to asphalt materials characterization will carry forward his challenging and important work on asphalt technology.

The ASTM D-4 Road and Paving Materials Subcommittee on Papers has for some time been organizing an annual evening symposium during the December committee week with themes drawn from three general areas of interest to the asphalt paving fraternity: asphalt mix materials; developments in asphaltic concrete pavement construction; and flexible pavement materials characterization and design. Since the two previous symposia were concerned with materials and construction, and there is continuing important flexible pavement materials characterization research and applications activity, it was decided to develop a symposium on advances in pavement materials characterization. The symposium was concerned with the characterization of pavement components (subgrades, subbases, bases, and surfacings), with emphasis to be on the overall characterization (moduli, fatigue performance, and permanent deformation) required for rational flexible pavement designs. Integrated papers were sought that demonstrate how advances in laboratory and field characterization can be implemented through rational design procedures supported by field evaluations. The characterization of newer pavement materials, such as sulfur binder and recycled asphalt mixes was also considered important to symposium participants.

Eleven contributions are included in this publication, drawn from the review of seven presented papers and a further ten submitted for possible publication without presentation. It is impossible to include the detailed and informative discussions that followed the brief presentations. The distribution of an abstract booklet during the symposium certainly fostered the participation of the ninety attending, and it is hoped that such abstract booklets will become a regular feature of D-4 symposia.

Those reading this publication will find many advances in flexible pavement materials characterization to further the use of rational pavement design procedures, including several field evaluations. Unfortunately, none of the contributions focus clearly on the overall integration of characterization and design. Hopefully, a future symposium will provide this integration supported by documented field performance.

The assistance of the symposium co-ordinating committee (W. W. Hotaling, J. E. Huffman, and F. T. Wagner) and ASTM staff is gratefully acknowledged.

John J. Emery
Trow Ltd., Toronto, Ontario, Canada; symposium chairman and editor.

Cover photograph from technical paper by C. R. Gannon et al, "New Concepts and Discoveries Related to the Strength Characteristics of Plasticized Sulfur."

Herbert E. Schweyer,[1] *Byron E. Ruth,*[2] *and Charles F. Potts*[3]

New Approaches for Studying Rheology Properties of Asphalts

REFERENCE: Schweyer, H. E., Ruth, B. E., and Potts, C. F., **"New Approaches for Studying Rheology Properties of Asphalts,"** *Properties of Flexible Pavement Materials, ASTM STP 807,* J. J. Emery, Ed., American Society for Testing and Materials, 1983, pp. 3–4.

ABSTRACT: After 2000 years or more of using asphalts for engineering purposes that involve their rheological properties, we are finally beginning to understand their behavior. It is our opinion that the mystery of deformation of bitumen or its composites or both under stress has to be no different from any other viscoelastic engineering material. The principal differences one would expect should be only in the magnitude of the individual viscoelastic components contributions to affecting the response of a material to which type of stress (shear, compression, etc.) that is applied.

The viscosities of asphalts *are not* a single point measurement as seems to be the general understanding of technologists. This is true only for true Newtonian flow. There is no such material in the real world because all materials have some elasticity (even water). Accordingly, we must consider how the viscosity varies with stress and time to explain its real world behavior. The elasticity at a given stress is an instantaneous effect (Hooke spring, 1678) coincidental with a delayed decaying strain (Kelvin spring and dashpot, *circa* 1875) starting at time zero at which time also creep flow begins as a Burns–Schweyer dashpot.[4] The latter is a variable dashpot resistance that responds to the stress in a manner necessary to account for whatever non-Newtonian flow response function is applicable for the material (pseudoplasticity, thixotropy, etc.). Therein the model differs from the Burger's model (1935) that uses a Maxwell dashpot that does not account for stress or strain susceptibility. Some concepts of a creep curve often include a St. Venant body (*circa* 1840) that is viewed as two parallel bodies held together by friction that is in series with the Burger model to allow for yield stress. The present authors believe yield flow for gelatin (or glass) at any stress (low or high) is only a matter of time, maybe eons. Therefore, there is no such property other than that a very strong spring in either the Hooke element or the Kelvin component that at low stresses is not observed until sufficient time has elapsed. Time is always a parameter in viscoelastic analysis.

Failure in the model is caused by breaking the spring or excessive flow that pulls the pistons out of the dashpots.

The objectives of this paper are to propose some new thoughts on using more recent

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[4] Schweyer, H. E., Baxley, R. L., and Burns, A. M. in *Low-Temperature Properties of Bituminous Materials and Compacted Bituminous Paving Mixtures, ASTM STP 628,* American Society for Testing and Materials, 1977, pp. 5–42.

developments in asphalt flow technology and attempt to demonstrate these concepts in a general way to asphalt pavement behavior over a range of ambient temperatures.

Accordingly the paper consists of three parts: (*a*) a short summary of the basic rheology concepts for viscoelastic flow of asphalts at an elementary level; (*b*) a demonstration of experimental data as to how Part A applies to bitumen and mixes; and (*c*) an illustration of the significance of the application in service.

In Part A the discussion provides a background for a new physical model of the viscous and elastic flow components that are shown to demonstrate good fit to experimental data in Part B. Some of this material is taken from polymer technology since asphalt bitumen is really a thermoplastic material.

Part C will discuss how the application of the rheological data and the physical model can aid in understanding design of better field performance for road paving applications by using rheological data on the bitumen and mixes.

KEY WORDS: pavements, flexibility, asphalts, rheology, flexible pavement

Thomas W. Kennedy,[1] *Thomas D. White,*[2] *and Jon A. Epps*[3]

Use of Material Tests and Pavement Design Procedures to Evaluate New Paving Binders

REFERENCE: Kennedy, T. W., White, T. D., and Epps, J. A., **"Use of Material Tests and Pavement Design Procedures to Evaluate New Paving Binders,"** *Properties of Flexible Pavement Materials, ASTM STP 807,* J. J. Emery, Ed., American Society for Testing and Materials, 1983, pp. 5–45.

ABSTRACT: Experience and a review of practice indicate new paving materials and technology are being evaluated with empirical tests. The evaluations are comparative, usually including a familiar asphalt in binder tests or a favorite aggregate in paving mixture tests. Generally, at least one type of water sensitivity test would be applied in the evaluation. Rational tests such as creep modulus and fatigue tests are being used to some extent but meet resistance because of lack of equipment and experience, both with the tests and meaning of the results.

An attempt is made to supply background on both the empirical and rational tests that are used in evaluating modified asphalts or replacement binders for asphalt. The background discussion is considered timely for long-used empirical tests as well as newer rational tests because of the insight such discussion can offer in considering the potential changes facing the pavement industry today.

Drawing on the background discussion, test results on sulfur-extended asphalt, recycled asphalt, and polymerized asphalt are specifically included in the paper because they are materials currently undergoing evaluation in the United States and around the world.

KEY WORDS: asphalt, asphalt testing, modified asphalt, replacement binders, paving mixtures, sulfur-extended asphalt, recycled asphalt, polymerized asphalt, pavements, flexible pavement

Increasingly, material engineers are evaluating modified and new pavement materials as a result of a changing pavement technology as well as technical and financial problems with conventional pavement systems. Thus, there is a definite need for engineers to better understand laboratory tests used to evaluate paving materials.

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The desirable properties of a conventional bound aggregate system for flexible pavement construction include:

1. Workability.
2. Stability.
3. Durability.
4. Flexible strength and fatigue resistance.
5. Tolerance to thermal changes.
6. Resistance to moisture damage, for example, stripping.
7. Skid resistance.

Pavements built with new or replacement binders should exhibit the same desirable properties.

Many tests that are used to evaluate paving materials are empirical. The fact that a test is empirical means that its worth is based on observation. In the case of asphalt and asphalt mixes, empirical tests are accepted through phenomenological comparisons with field tests and experience. However, empirical tests on new pavement technology can provide meaningful information if their limits and the criteria used in interpreting results are placed in the proper perspective.

New tests have been under development to better understand how paving materials can be characterized as well as to provide basic material properties for rational pavement design systems. Fundamental in these developments is the philosophy that tests and test conditions used for evaluating binders and resulting mixes should reflect how the binder and mixture will perform over the range of temperature and strain conditions that the pavement will experience.

Role of Temperature

The role that temperature plays in material response for pavements built with viscoelastic binders is the most significant variable affecting the choice of test and condition of test, as well as the ultimate performance of the pavement.

The high-temperature regime for pavement performance evaluation should be the highest temperature at which the pavement can be expected to perform without becoming unstable. This temperature regime is generally from 49 to 71°C (120 to 160°F). Tests at 60°C (140°F) are considered significant; however, for nonsurface materials lower temperatures may be more appropriate. In addition, test specimens may be extremely tender at this temperature and difficult to handle. The cold temperature regime for paving material performance should consider the extremely cold, critical cracking temperature. However, the pavement performance may also be critical in a relatively warm temperature regime of from approximately −18 to 21°C (0 to 70°F). In this temperature regime, the binder will be subjected to thermal cycling, including tension and compression. A significant additive condition of tension may also occur from loading because the binder may be in a transitional state from viscoelastic to elastic in which its tolerance to tensile strain is reduced. Thus, the effect that temperature has on pavement materials should not be thought of only in terms of high and low temperature but in terms of the complete temperature range the pavement will experience.

Binder Evaluation

The consistency of an asphalt binder changes with time through exposure to heat, oxygen, and sunlight. A before-and-after evaluation of consistency is important from the standpoint of the rate of change as well as the absolute change. The before condition is essentially the asphalt consistency before being added to a paving mixture. The after condition has two parts. First, the condition after going through a hot mix plant and being subjected to an elevated temperature in a thin film. Second, the condition of the pavement after aging for a period of time. The thin film oven test (TFOT) and the rolling thin film oven test (RTFOT) were adopted to produce changes in asphalt that simulate the changes produced in a hot mix plant. These laboratory tests have been accepted as valid for batch-type asphalt plants and continuous mix-type asphalt plants. Terrel and Holen [*1*][4] reported that the rate of change in asphalt consistency has not been as great in drum plants. In addition, Wilson and Hicks [*2*] raised questions concerning asphalt consistency changes in asphalt plants. These possible differences must be considered in the design and evaluation of the mixtures.

Currently, there does not seem to be an accepted laboratory conditioning procedure for producing changes in asphalt that might take place over a longer term in the pavement. However, a recent CALTRANS [*3*] study correlating results of a modified RTFOT with cores conditioned in various climatic areas of California indicates potential to evaluate longer term changes in asphalt consistency.

In addition, longer term curing of new materials may be also required to ensure that new or even unknown chemical reactions are completed. This is true of modified asphalts and could be true of replacement binders as well.

Primary tests that are being used to determine binder consistency include penetration, viscosity, ductility, and softening point. The history of these tests is summarized in Ref *4*.

[4] The italic numbers in brackets refer to the list of references appended to this paper.

Penetration Test

The common test temperature and condition of testing in the penetration test are 25°C (77°F) with a weight of 100 g on a standard needle for 5 s. Recommendations for testing at other temperatures and under other conditions are given in ASTM Test for Penetration of Bituminous Materials (D 5-73). These standard conditions were most likely adopted in the past because they resulted in differences in consistency with a reasonable scale for rating asphalts that were used for paving. Almost no paving agencies determine penetration at temperatures higher than 25°C (77°F). Several agencies, however, run the standard test at lower temperatures. The practical lower temperature limit of the standard penetration test approaches freezing because most asphalts become so hard in this temperature range that there is little difference in penetration between asphalts. The low temperature most commonly used is 4°C (39.2°F). Other test conditions are used at lower temperatures that include increased load and time to make the differences in penetration larger and improve the scale for rating asphalts. Changing test conditions from one temperature to another precludes direct comparison of the test results without a correlation, such as given by Readshaw [*5*].

The change of penetration with temperature varies from asphalt to asphalt and reflects the nature of a particular asphalt. The penetration index has been used to characterize this relationship. Readshaw [*5*] used the following form of Pfeiffer and Van Doormaal's equation [*6*] to compute the penetration index

$$\frac{20 - \mathrm{PI}}{10 + \mathrm{PI}} = \frac{50(\log P_1 - \log P_2)}{T_1 - T_2}$$

where

PI = penetration index, more positive numbers indicate less temperature susceptibility;
P_1, P_2 = penetration at high and low temperatures, respectively; and
T_1, T_2 = high and low temperatures, °C, respectively.

Penetration index and phenomenological comparison are used as in Fig. 1 to predict asphalt performance. In British Columbia, an asphalt satisfying the experience on Fig. 1 after the TFOT is expected to perform satisfactorily in cold weather. Modified asphalt or replacement binders would not necessarily satisfy this comparison even with similar values of penetration index.

Viscosity

Viscosity of a fluid is such a pertinent term for consistency that the terms are used interchangeably both in and out of the asphalt materials area. In

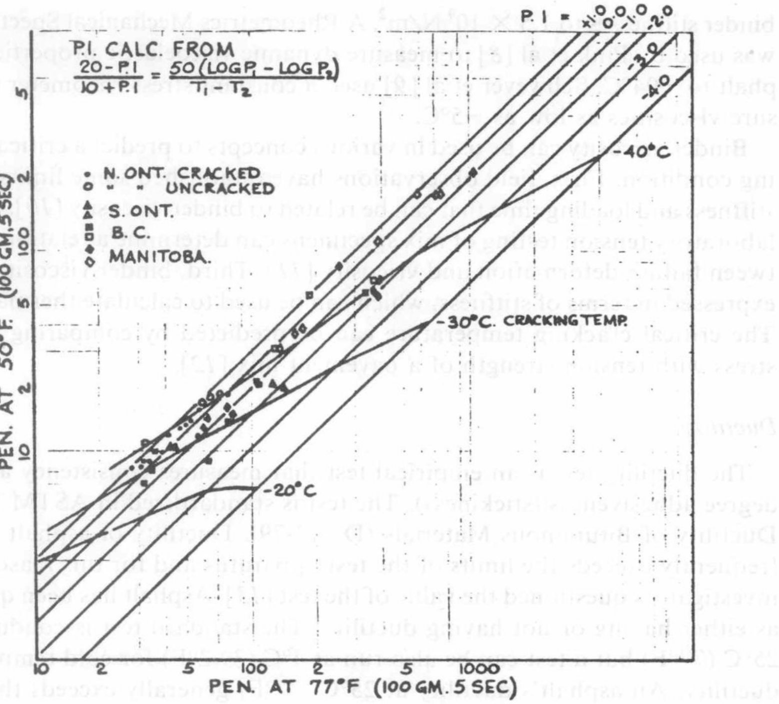

FIG. 1—*Relationship between penetration at 25°C (77°F), penetration at 10°C (50°F) PI, and cracking temperature for bitumens (after Ref 5).*

physical terms, viscosity is a sustained unit rate of shearing or is the ratio of a surface shearing stress divided by the velocity gradient perpendicular to the surface. Because the physical concept of viscosity can be translated into mathematical terms, it is represented as a rational and fundamental property. The physical concept is general enough to apply to many geometric configurations. This includes the penetration test, which can be construed to measure viscosity. Different testing techniques and even different viscosity measuring devices are used for various temperature regimes of interest.

Viscosity is measured most frequently at 135 and 60°C (275 and 140°F) and represents, respectively, the temperature of interest during construction and the average upper pavement temperature. However, a pavement will experience temperatures lower than 60°C (140°F) for a greater portion of its life. For this reason, it is desirable to have viscosity information for all pavement temperatures to better characterize a binder. There are different techniques used for viscosity measurements at 60 and 135°C (140 and 275°F), although basically the same equipment can be used. Generally, special equipment must be used to characterize paving binders near their critical cracking temperature. Gaw [7] used a modified sliding plate rheometer for measuring