SCHOOL OF CIVIL ENGINEERING

INDIANA DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY RESEARCH PROJECT

FHWA/IN/JHRP-87/7 -2

Executive Summary

EFFECTS OF ASPHALT COMPOSITION AND COMPACTION ON THE PERFORMANCE OF ASPHALT PAVEMENT MIXTURES

L. E. Wood
A. G. Altschaeffl

PURDUE UNIVERSITY

JOINT HIGHWAY RESEARCH PROJECT

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Executive Summary

Final Report

"Effects of Asphalt Composition and Compaction on the Performance of Asphalt Pavement Mixtures"

To: Harold L. Michael, Director
Joint Highway Research Project

September 9, 1987
Revised: May 23, 1988
Project: C-36-66G

From: L. E. Wood
Research Engineer

File: 2-4-33

Please find attached the Final Report entitled "Effects of Asphalt Composition and Compaction on the Performance of Asphalt Pavement Mixtures". It was prepared by L. E. Wood and A. G. Altschaeffl, and represents the work of R. Aunan, R. Luna, and N. Garrick of our staff.

This report is presented in two parts. The first part presents the work done to characterize the fabric of this asphalt sand mix surface and to reproduce this fabric in the laboratory. In addition, it examines the field compaction time requirements for these materials. The second part evaluates the use of blended asphalts, as well as the use of high pressure-gel permeation chromatography to characterize the chemical composition of asphalts.

Based upon the comparison of the pore-size distribution of the fabric of both laboratory and field compacted mixtures, the gyratory and kneading compactors created satisfactorily equivalent laboratory fabrics to those of field cores. Very limited performance data suggested that good performance is associated with fabric that has a wide-spread of void sizes, with no major portion being concentrated at any one size.

No major differences in behavior were found for the artificially blended asphalts, in general, although rich asphaltene asphalts show a higher hardening rate at high temperatures. Blended ROSE asphalts do <u>not</u> create differences in performance than straight-run produced asphalts. The asphalt chemical composition does appear associated with individual performance characteristics; this suggests promise for the use of HP-GPC in the continuing effort to produce quality performance of asphalt pavement mixtures.

This report is presented for review and approval as evidence of fulfillment of the objectives of this project.

Respectfully,

L E Wood / wlc

L. E. Wood
Research Engineer

Executive Summary

FINAL REPORT

EFFECTS OF ASPHALT COMPOSITION AND COMPACTION ON THE PERFORMANCE OF ASPHALT PAVEMENT MIXTURES

by

L. E. Wood
A. G. Altschaeffl

Joint Highway Research Project
Project No.: C-36-66G
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16. Abstract

This report is presented in two parts. The first part presents the work done to characterize the fabric of this asphalt sand mix surface and to reproduce this fabric in the laboratory. In addition, it examines the field compaction time requirements for these materials. The second part evaluates the use of blended asphalts, as well as the use of high pressure-gel permeation chromatography to characterize the chemical composition of asphalts.

Based upon the comparison of the pore-size distribution of the fabric of both laboratory and field compacted mixtures, the gyratory and kneading compactors created satisfactorily equivalent laboratory fabrics to those of field cores. Very limited performance data suggested that good performance is associated with fabric that has a wide-spread of void sizes, with no major portion being concentrated at any one size.

No major differences in behavior were found for the artificially blended asphalts, in general, although rich asphaltene asphalts show a higher hardening rate at high temperatures. Blended ROSE asphalts do not create differences in performance than straight-run produced asphalts. The asphalt chemical composition does appear associated with individual performance characteristics; this suggests promise for the use of HP-GPC in the continuing effort to produce quality performance of asphalt pavement mixtures.

17. Key Words

pore size distribution; field mix fabric; field compaction time; surface wearing courses; laboratory compaction fabric; asphalt composition; high pressure-gel permeation chromatography; blended asphalts

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EXECUTIVE SUMMARY

This report is presented in two parts. Part I presents the results of studies to characterize the fabric of thin asphaltic concrete wearing surfaces and to reproduce this fabric in the laboratory using standard compaction methods. An additional objective of these studies was to investigate field compaction time requirements for the mixtures.

Part II presents an evaluation of blended asphalts produced by the Residuum Oil Supercritical Extraction (ROSE) process. Several blends of the asphalts and commercially produced asphalts were compared using High Pressure-Gel Permeation Chromatography (HP-GPC). Evaluation of the HP-GPC technique as a suitable procedure for characterizing the chemical composition of asphaltic materials was an additional objective of this study.

Study Purpose

In recent years surface courses have suffered distress due to heavy traffic loads. These thin surface courses have high voids contents to obtain good skid resistance, and at the same time provide a smooth riding surface. The most common type of distress was delamination in the "post-construction" stage. A difference in densities in the top and the bottom layers caused by compaction from in-service traffic loads produced a horizontal plane of failure at approximately mid-depth of the thin surface

course. This problem provoked attention upon the nature of the problem in relation to the compaction procedures and mix design formula.

It was believed the details of how the material is compacted determines the arrangement of components of the mix, i.e., the material fabric. It is the fabric, or the aggregate framework, that controls subsequent performance. It was believed that field procedures produce different fabrics than do laboratory procedures, but it is not known which of the laboratory procedures best simulates the fabric development of field procedures. This question is one of the major objectives that this study tried to address.

Study Approach

The distribution of the sizes of the voids in the mix were compared for field cores and for laboratory specimens. This comparison consisted of matching proper bulk specific gravities and the best set of descriptors of this pore-size distribution. If it is possible to correlate the fabric to in-service performance, this knowledge could be a valuable contribution to the mix design process. A major portion of this study is an examination of the fabric of sand mixes as it affects our understanding of mix design procedures.

Four compaction methods were used: Gyratory, Kneading, Marshall and Vibratory. Two kinds of binders were used: an asphalt cement (AC-20) and medium setting high float asphalt emulsion (AE-60). Three kinds of aggregate were varied in the two mixes: pit-run gravel-sand, crushed gravel-sand, and 70% sand - 30% crushed limestone. Once the compaction parameters were determined for each compaction method the independent variables in the specimen preparation procedure were varied to see the effect on the behavior of the compacted mix. Pore size distribution studies were performed on field core samples and laboratory samples as well. It was thought that the comparison of the pore size distributions would indicate which compaction method best replicated the field fabric.

Additionally, some of the problems of premature failure of asphalt pavements have been attributed to a belief that refineries are suplying an increasing amount of inferior asphalt. This in turn is blamed on the more widespread use of non-traditional methods of asphalt production. However, there is no documented evidence concerning the adequacy or inadequacy of these asphalts for paving. Consequently, one objective of this project was to evaluate the products of one non-traditional asphalt production process, the residuum oil supercritical extraction (ROSE) process.

In addition to the changes in asphalt, there has been new technology for asphalt mix production and pavement construction. Furthermore, greater demands have also been placed on the pavements by significant increases in vehicle load, tire pressure and traffic volume. It is increasingly apparent that current methods of specifying and characterizing asphalts are inadequate in light of the rapid changes that have recently taken place in the industry. Consequently, an additional objective of this project was to investigate and evaluate a new procedure for characterizing asphaltic materials.

A final objective of this study was to develop a suitable procedure for characterizing the chemical composition of asphaltic material. If this goal was successful an additional objective was to develop relationships between chemical composition of the asphalts and their physical properties. To this end, high pressure-gel permeation chromatography was selected for evaluation as a tool for characterizing the chemical composition of asphalt.

The asphalts tested in this project were from two different ROSE sources and from four other sources. However, a significant proportion of the tests were conducted on asphalts from one ROSE source and one conventional source only. The tests on asphalt mixes were conducted primarily for a sand mix gradation of a local aggregate. However, some tests were also conducted for a base course gradation with aggregate from this same local source. All of the tests were conducted on laboratory samples only.

The tests of physical properties of asphalt cements included the following: specific gravity, viscosity (140°F and 275°F), penetration (39.2^{o}F and 77^{o}F), and thin film oven test (TFOT). The TFOT residues were tested for viscosity (140^{o}F and 275^{o}F) and penetration (39.2^{o}F and 77^{o}F). All of these tests were conducted in accordance with the ASTM procedures.

The amount of heat hardening in the TFOT was determined by calculated viscosity ratios (140^{o}F and 275^{o}F), and penetration retained values (39.2^{o}F and 77^{o}F) from the results for both the original and residual asphalt. Large values of viscosity ratio indicate a significant amount of heat hardening in the thin film oven. While, large values for penetration retained values indicate little or no heat hardening.

High pressure-gel permeation chromatography (HP-GPC) was used in this project to characterize the chemical composition of the asphalt cements. This test was conducted on all asphalts from Plants A, D, E, and F. In addition, HP-GPC parameters were obtained for two of the three ROSE asphalts from Plant B. These results were used in developing regression functions relating HP-GPC data to i) properties of the asphalt cements, and ii) properties of the asphalt mixes.

The following tests were conducted on asphalt mixes: resilient modulus (50^{o}F and 72^{o}F), indirect tensile strength, pulse velocity, stability (Hveem R-value and S-value), water sensitivity test and artificial age hardening. All of these tests were conducted for both sand and number 11 mixes with asphalts from Plant A and C. In addition, resilient modulus and indirect tensile strength determinations were conducted for sand mixes with asphalts from sources B, D, and E.

The physical properties of the asphalts used in this study were compared to those of a representative sample of asphalts from across the United States. The objective of this was to identify any anomalous properties of the asphalts that were produced by the ROSE process.

Conclusions

From the results obtained in Part I, two compaction methods, the Gyratory and the Kneading, created satisfactorily equivalent fabrics to that of the comparable field cores. Due to the lateral confinement of the mold, the thin asphaltic concrete layers require less than standard compactive effort to achieve target densities. The gyratory compactor with a 20 psi vertical ram pressure for 35 revolutions at a one-degree angle of inclination plus five leveling revolutions (at no angle) provides the best duplication of the field fabric of sand mixes. These fabrics exhibit typical Hveem stability values in the range of 15 to 20, which is satisfactory when corrected to standard specimen thickness. From very limited field performance date it is believed that good performance is associated with a fabric that has a wide-spread of void sizes, i.e., there is no concentration of void sizes about some peak frequency diameter.

It was also determined that the temperature of the mix during compaction has a very marked effect on the workability of the mix. The higher the temperature, the easier it is to handle and spread the mix in the field. The effects on the final compacted mix were not significant. The presently used minimum allowable compaction temperatures of 145°F for AE-60 and 180°F for AC-20 samples were confirmed. It was additionally determined that compaction must occur within 4 minutes for the AC-20 mix and 9.5 minutes for an AE-60 mix when ambient air and base temperatures are at 90°F, while these times are reduced to 2.5 and 5 minutes respectively when temperatures drop to 50°F.

It was determined in Part II of this project that it was possible to blend asphalts of different compositions which met the specifications for a given grade. Consequently, three AC-10 and three AC-20 asphalts were blended from the ROSE products from Plant A. The conclusions summarized below are based upon the effects of differences in composition on the physical properties of these asphalts.

1. The results for tests on asphalt cement show that there are only small differences in temperature susceptibility among asphalts of different composition in each viscosity grade.

2. Results from the thin film oven test indicates that at higher temperatures, the high asphaltene content (HAC) asphalt in each grade harden to a greater extent than the

other two asphalts. At lower temperatures, the differences in TFOT results between asphalts of different composition are not significant.

3. It was determined that asphalt chemical composition had a significant effect on the properties of asphalt concrete mix.

Two sets of ROSE asphalts were evaluated in this project. The properties of these asphalt cements were compared to those of a wide cross-section of commercial asphalts produced in the United States. Data on these commercial asphalts were obtained from the literature. The properties of asphalt mixes with one set of ROSE asphalts were also compared to those of asphalt mixes with a commercial asphalt. Based on these comparisons it was concluded that there is no evidence to support the view that the blended, ROSE asphalts are significantly different from commercially produced asphalts.

The conclusions presented below resulted from the evaluation of a number of asphalts by means of high pressure-gel permeation chromatography:

1. It was determined that high pressure-gel permeation chromatography gives reproducible profiles which distinguish among asphalts of different compositions. Thus, it was concluded that HP-GPC is suitable for characterizing the chemical composition of asphalts.

2. Regression functions were developed relating HP-GPC parameters and various physical properties of asphalt cements and of the asphalt concrete mixes. The tentative conclusion from these results is that there is a unique relationship between chemical composition of asphalts, as characterized by HP-GPC, and individual performance characteristics of asphalts of all types. These relationships are interrelated with effects of aggregate composition and gradation and asphalt content.

Recommendations

The findings of these studies offer promise for the more effective and efficient use of bituminous materials by IDOH. In order to realize this potential benefit, it is recommended that the following be considered by IDOH:

1. When reproducing field compaction of thin wearing surfaces in the laboratory, the gyratory compactor with a 20 psi vertical ram pressure for 35 revolutions at a one degree angle of inclination plus five leveling revolutions (at no angle), or the kneading compactor will best duplicate field fabrics.

2. Data suggest that good performance is associated with a fabric that has a wide spread of void sizes, as measured on

pore size distribution (PSD) curves. The FM gradation sand mix overlay used by IDOH is characteristic of this fabric, and should show good field performance.

3. It is recommended that minimum compaction temperatures of 145°F for AE-60 and 160°F for AC-20 be specified. Compaction must be performed within 9.5 minutes for AE-60 and 4 minutes for AC-20 mixes when ambient air and base temperatures are 90°F. The use of three-roller trains will help meet these time requirements. Projects in the early spring or late fall should use only AE-60 to allow sufficient compaction times.

4. When using ROSE produced asphalts, only small differences in temperature susceptibility among asphalts of different composition in each viscosity grade can be expected, and no difference in performance properties than commercially produced asphalts should be expected.

5. High pressure-gel permeation chromatography can be used to characterize the relationship that exists between chemical composition of asphalts and individual performance characteristics of asphalts, and is recommended for future IDOH studies of asphalt composition and performance.

These recommendations can be acted upon directly by IDOH, or be developed further in cooperation with the Joint Highway Research Project of Purdue University in a joint venture.

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